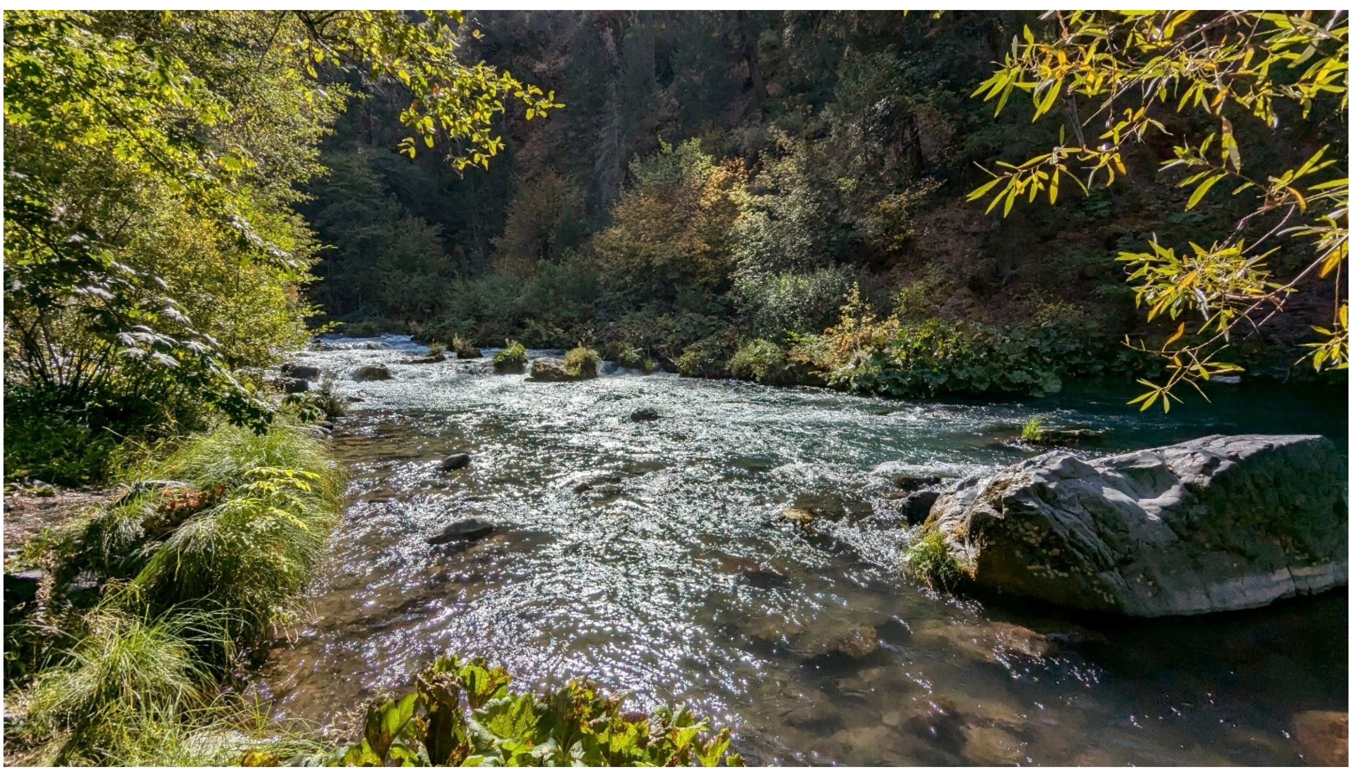
# Winter-Run Chinook Salmon Habitat and Facilities Structured Decision Making

California Great Basin Region

Bay-Delta Office



U.S. Department of the Interior

May 2026

## Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Cover Photo: Winter-Run Chinook Salmon rearing habitat in the McCloud River, in the between AH-DI-NA Campground and The Nature Conservancy Kerry Landreth Preserve, September 2024 (Stantec/Stephen Maurano).

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# Acronyms

| | |
|---|---|
| °F | degrees Fahrenheit |
| cfs | cubic feet per second |
| CNFH | Coleman National Fish Hatchery |
| CRR | cohort replacement rate |

| | |
|---|---|
| CVP | Central Valley Project |
| CVPIA | Central Valley Project Improvement Act |
| Delta | Sacramento-San Joaquin River Delta |
| DOI | United States Department of the Interior |
| DSM | decision support model |
| ESA | Federal Endangered Species Acts |
| ESU | evolutionarily significant unit |
| FERC | Federal Energy Regulatory Commission |
| IOS | Interactive Object-Oriented Simulation Model |
| JPI | Juvenile Production Index |
| LSNFH | Livingston Stone National Fish Hatchery |
| LTO | Long-term Operation |
| M&I | municipal and industrial |
| MAF | million acre-feet |
| NMFS | National Marine Fisheries Service |
| OBAN | Oncorhynchus Bayesian Analysis Model |
| PARTI | Participation, Accountability, Relevancy, Transparency, Innovation |
| pHOS | proportion of hatchery-origin spawners |
| PrOACT | Problem Statement, Objectives, Alternatives, Consequences, Tradeoffs |
| R2R | Reorienting to Recovery |
| RAFT | River Assessment for Forecasting Temperature |
| Reclamation | Bureau of Reclamation |
| ROD | Record of Decision |
| SDM | structured decision making |
| SIT | Science Integration Team |
| SWP | State Water Project |
| TCD | temperature control device |
| USFWS | U.S. Fish and Wildlife Service |
| WRAP | Winter-run Action Plan |
| WRLCM | Winter Run Lifecycle Model |
| WY | water year |

# List of Preparers

| Name | Affiliation |
| --- | --- |
| Adam Witt | Stantec |
| Cat Pien | FlowWest |
| Karen Jenni | Insight Decisions |
| Liz Stebbins | FlowWest |
| Mark Tompkins | FlowWest |
| Mary Beth Day | Kearns and West |
| Sarah Hamilton | Stantec |
| Stephanie Theis | Stantec |
| Stephen Maurano | Stantec |
| Terra Alpaugh | Kearns and West |
| Tom FitzHugh | Stantec |

# Executive Summary

This report documents a rapid Structured Decision Making (SDM) effort initiated by the Bureau of Reclamation (Reclamation) to identify and evaluate habitat, facility, hatchery, and reintroduction actions that could improve outcomes for endangered Sacramento River winter-run Chinook salmon (WRCS) while operating Shasta Dam under existing operational regimes. Reclamation initiated this SDM process as a transparent, repeatable, and science-informed approach to broaden the solution space for improving WRCS outcomes beyond coldwater pool management and identify promising actions that could be explored in future planning and regulatory discussions.

The SDM followed the PrOACT framework (Problem, Objectives, Alternatives, Consequences, Tradeoffs) and was implemented through 14 workshops and meetings over approximately 12 weeks with participation from 26 organizations representing 12 participant groups, including Tribal interests, public water agencies, state and federal resource agencies, non-governmental organizations, and the commercial fishing community. Participants articulated objectives and performance metrics spanning WRCS abundance, productivity, life-history diversity, and tributary support, as well as implementation time and cost and potential impacts to other listed fishes. Individual actions proposed by participants were consolidated into a set of 35 unique actions and combined into 14 portfolios that represent distinct strategic themes (e.g., near-term "low-hanging fruit," drought-focused actions, hatchery-focused actions). Consequences were estimated using a combination of numerical modeling and expert judgment, with modeled metrics derived from an integrated framework linking CalSim 3 (operations and hydrology), HEC-5Q (water temperatures), and a customized winter-run lifecycle model. These tools were applied to a 20-year representative period (1980–2000) under a baseline operated with Reclamation's current objectives-based Shasta management framework. For metrics not amenable to quantitative modeling within the rapid timeline, constructed scoring scales were developed and applied using expert judgment.

Results are intended for comparative screening and learning rather than serving as a final implementation decision. The comparison of weighted portfolio scores (Table ES-1) shows clear differences in relative performance across portfolios. Higher scoring portfolios tend to share common features like expanding access to, and use of habitat above Shasta Dam, while lower scoring portfolios increased supplementation without comparable increases in habitat access or availability. Across portfolios, supplementation benefits were variable (i.e., adding juveniles did not translate uniformly into improvements in adult spawners or other modeled outcomes), and no portfolio produced independent populations meeting all independence thresholds within the evaluation period. Importantly, higher cost or a greater number of actions did not consistently yield higher overall performance, underscoring the need to focus on the type and placement of actions and the tradeoffs among objectives.

These findings provide a structured foundation for deeper engineering, biological, and feasibility evaluation of promising portfolios (including uncertainty/sensitivity analyses and refinement of habitat suitability assumptions), and for transparently communicating why certain strategies may be preferred under differing stakeholder value structures.

**Table ES-1. Combined Portfolio Value (Score) for All Portfolios Considering 11 Different Alternative Weightings**

| Portfolio Number and Name | Portfolio Score by Weight Set | | | | | | | | | | | Average Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | |
| 1. All Actions with Trap and Haul for All Tributaries | 0.492 | 0.521 | **0.338●** | 0.560 | 0.466 | 0.510 | 0.491 | 0.606 | 0.503 | 0.509 | 0.467 | 0.497 |
| 2. All Actions with Trap and Haul for McCloud River | 0.490 | 0.513 | 0.295 | 0.561 | 0.460 | 0.464 | 0.482 | 0.605 | 0.494 | 0.500 | 0.458 | 0.484 |
| 3. All Actions with Shasta Volitional Passage | 0.495 | 0.538 | 0.307 | **0.586●** | 0.477 | **0.515●** | 0.506 | 0.613 | 0.516 | 0.522 | 0.480 | 0.505 |
| 4. Population Enhancement Below Shasta | 0.452 | **0.464○** | 0.202 | 0.522 | 0.417 | 0.399 | 0.439 | 0.578 | **0.451○** | 0.470 | **0.409○** | 0.437 |
| 5. Battle Creek + Hatchery Actions | 0.442 | 0.524 | 0.246 | 0.516 | 0.457 | 0.267 | 0.485 | 0.475 | 0.490 | **0.430○** | 0.484 | 0.438 |
| 6. Mainstem + Hatchery Actions | 0.482 | 0.494 | **0.164○** | 0.514 | **0.417○** | 0.400 | 0.457 | 0.590 | 0.479 | 0.511 | 0.432 | 0.449 |
| 7. Implementable Within 5 years | 0.455 | 0.468 | 0.204 | 0.527 | 0.419 | 0.399 | 0.443 | 0.585 | 0.454 | 0.471 | 0.414 | 0.440 |
| 8. All Actions with Estimated Costs Less Than $10 Million | 0.483 | 0.625 | 0.319 | 0.569 | **0.545●** | 0.336 | 0.569 | 0.517 | 0.574 | 0.485 | 0.588 | 0.510 |
| 9. Near-term Low Hanging Fruit (NTLHF) | 0.510 | 0.634 | 0.297 | 0.559 | 0.534 | 0.328 | 0.568 | 0.523 | 0.584 | 0.514 | 0.588 | 0.513 |
| 10. Battle Creek Actions Only | 0.455 | 0.569 | 0.256 | 0.544 | 0.506 | **0.262○** | 0.520 | 0.498 | 0.526 | 0.456 | 0.530 | 0.466 |
| 11. NTLHF with Enhanced Habitat Access | 0.514 | **0.638●** | 0.301 | 0.566 | 0.541 | 0.332 | **0.572●** | 0.530 | **0.586●** | 0.516 | **0.592●** | 0.517 |
| 12. Drought Mitigation | 0.486 | 0.610 | 0.313 | 0.563 | 0.533 | 0.339 | 0.557 | 0.516 | 0.563 | 0.488 | 0.570 | 0.503 |
| 13. Hatchery Influence/Production | **0.409○** | 0.489 | 0.174 | **0.429○** | 0.444 | 0.271 | **0.437○** | **0.473○** | 0.452 | 0.431 | 0.446 | 0.405 |
| 14. Habitat Enhancement and Restoration | **0.514●** | 0.535 | 0.272 | 0.559 | 0.465 | 0.439 | 0.489 | **0.620●** | 0.512 | **0.533●** | 0.472 | 0.492 |

Notes: Columns represent results based on the 11 sets of participant swing weights using purple (high values) to yellow (low values) to provide a visual cue to the ordering of the portfolios in each column by value. Bold purple cells with "●" indicate the highest ranked portfolio(s) for that set of weights. Bold yellow cells with "○" indicate the lowest ranked portfolios for that weight set.

Key: LSNFH = Livingston Stone National Fish Hatchery, NTLHF = Near-Term Low Hanging Fruit, WRCS = winter-run Chinook salmon

# 1. Introduction

The United States Department of the Interior (DOI), via the Bureau of Reclamation (Reclamation), operates and maintains the Shasta Division of the Central Valley Project (CVP) for flood control and navigation, municipal and industrial and agricultural water supplies, fish and wildlife, hydroelectric power generation, Sacramento River water quality, and Sacramento-San Joaquin River Delta (Delta) water quality. Key facilities include the Shasta Dam and Power Plant, Keswick Dam and Power Plant, and a temperature control device (TCD) on the upstream face of Shasta Dam (Figure 1).

Historically, Sacramento River winter-run Chinook salmon migrated into the cold, spring-fed headwaters of the Sacramento, Pit, and McCloud rivers. In the McCloud River, salmon are believed to have accessed approximately 50 miles of habitat upstream to Lower McCloud Falls, but by the late nineteenth century, anadromous fish access was already constrained by early hatchery-related diversion structures (Yoshiyama and Fisher 2011). Construction of Shasta Dam in the 1940s subsequently eliminated access to nearly all remaining historic winter-run Chinook salmon habitat, confining natural spawning to the mainstem Sacramento River downstream of Keswick Dam (Yoshiyama, Fisher, and Moyle. 1998). Today, one remaining population spawns in the Sacramento River below Keswick Dam, and their survival is largely contingent on cold water released from Shasta Reservoir. A conservation propagation program at Livingston Stone National Fish Hatchery (LSNFH), started in 1997, continues to play an essential role in ensuring against winter-run Chinook salmon extinction. Adequate water quality conditions and hatchery practices are critical to the recovery and resilience of the endangered winter-run Chinook salmon that return to the Sacramento River each summer to spawn.

Reclamation recognizes that managing Shasta Reservoir for cold water releases is increasingly difficult in many water years and will become even more challenging based on the current long-term trajectory of local air temperatures and inflow patterns. To support winter-run Chinook salmon survival and recovery, Reclamation conducted this structured decision making (SDM) study to explore actions – those under the direct control of Reclamation, as well as actions that could be undertaken jointly with other parties – to improve outcomes for winter-run Chinook salmon. Examples actions could include infrastructure modifications, hatchery improvements, habitat restoration, species reintroduction to additional tributaries, and other interventions. Reclamation sought input from cooperating agencies and interest holders to help inform recommendations for strategies for winter-run Chinook salmon that do not rely on constraining the operations of Shasta Reservoir.

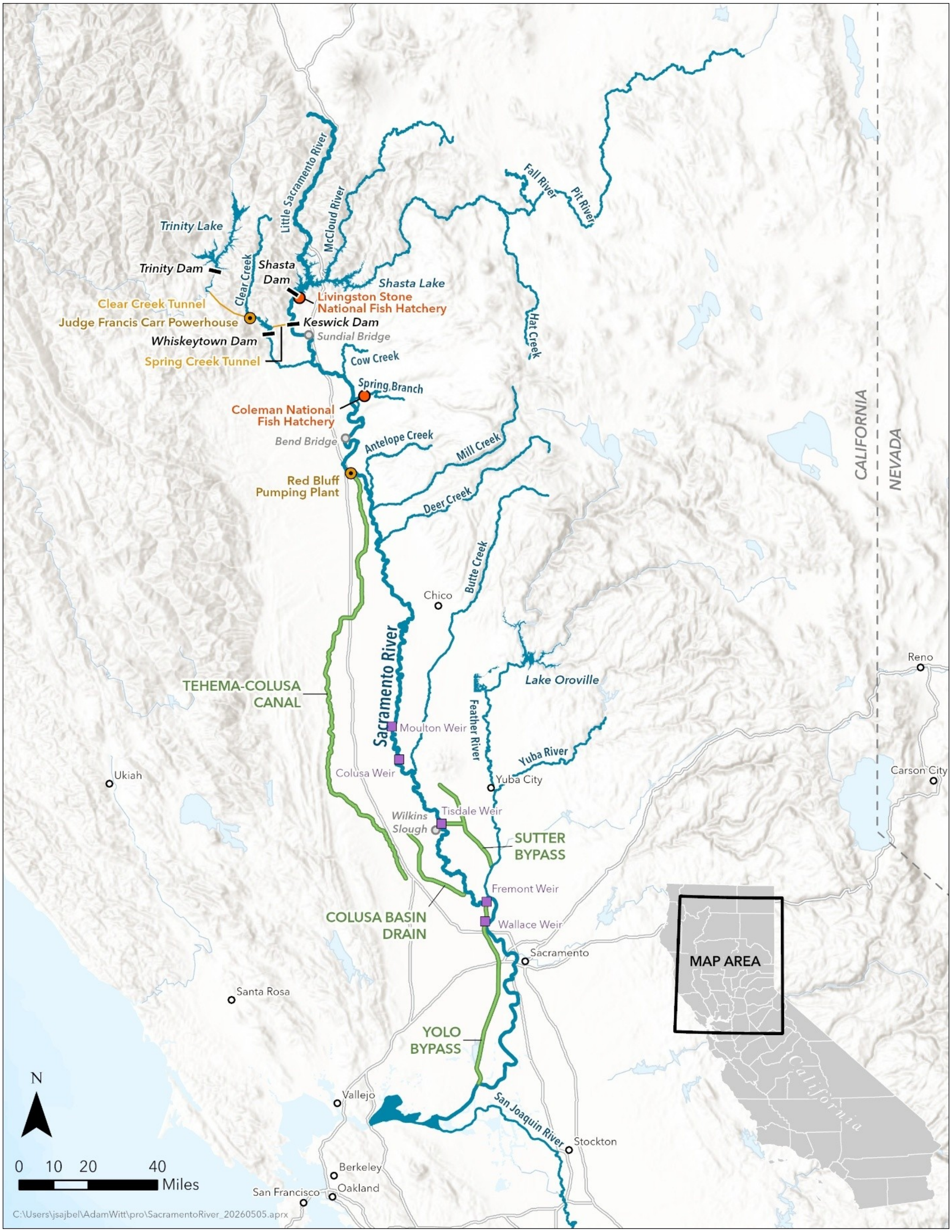



**Figure 1. Sacramento River Facilities in the Shasta and Sacramento Divisions of the Central Valley Project**

## Purpose and Scope

The purposes of this SDM process were to identify conceptual habitat and facility actions that have the potential to improve outcomes for winter-run Chinook salmon in the Sacramento River watershed, and to complete a rapid high-level assessment of the long-term effectiveness of such actions if they were to be implemented. Reclamation sought participation from a broad range of interest groups to increase the breadth, diversity, and innovation of potential actions to be considered and to ensure that the analysis addressed the various types of benefits and costs of actions that are important to those parties.

The SDM approach was chosen for this study to provide a structured, repeatable approach that allows multiple parties to explore a range of possible actions and value tradeoffs through a participatory process. A rapid prototyping approach was implemented, meaning participants moved through the SDM steps on an accelerated timeline to quickly gain insights, clarify key components of new strategies, and identify promising portfolios before committing significant resources to further analysis. Reclamation has applied rapid-prototyping SDM methods in recent studies to support flow and habitat management decision (USGS 2025, Reclamation 2026). Reclamation established the scope of this study to focus on identifying and evaluating non-flow actions that could improve outcomes for winter-run Chinook salmon. They sought actions that focused on ideas generated from participants including infrastructure modifications, hatchery improvements, habitat restoration, fish passage improvements, species reintroduction to additional tributaries, and other fisheries related interventions targeted towards any life stage of winter-run Chinook salmon. This study explicitly excluded actions that would require changes to operations of Shasta Dam.

The study was intended to provide data and analyses that could inform Reclamation's and participant’s strategy as they move forward through other regulatory and planning processes, not to conclude with an implementation decision by Reclamation or any other action agency. It is as a pre-feasibility study providing preliminary technical information, planning-level analysis, and conceptual considerations to support future evaluation, coordination, and decision-making efforts. Further refinement and analysis of actions identified in this rapid prototyping work could be possible as part of future processes.

## Background

### Habitat and Hydrology

The Upper Sacramento River watershed consists of multiple tributaries. The focus of this study is on areas with current or historic habitat for winter-run Chinook salmon, including Battle Creek and the Sacramento River downstream from Shasta and Keswick Dams, and McCloud River and Little Sacramento River, both upstream from Shasta Reservoir. The Pit River, also a historically important tributary for winter-run Chinook salmon, is highly regulated by multiple obstructions to fish passage. The lowest of these block access to historical cold-water habitats resulting in summer water temperatures of approximately 15-18 °C that are too high to support winter-run Chinook salmon egg incubation downstream (FERC 2004).

### *Upper Sacramento River*

The upper Sacramento River flows for approximately 10 miles between Shasta Dam and Keswick Dam and 59 miles between Keswick Dam and the Red Bluff Diversion Dam. The main tributaries to the Sacramento River between Shasta Dam and Red Bluff are Battle, Bear, Clear, Cow, and Cottonwood creeks. Immediately downstream from Keswick Dam, the river is deeply incised in bedrock with very limited riparian vegetation and limited functioning riparian ecosystems. The river below Keswick Dam generally has cool water temperatures because of regulated releases from Shasta and Keswick dams, and a stable, largely confined channel with little meander. Near Redding, the river flows into the valley and the floodplain broadens. The riparian zone in the Anderson/Redding area is affected by urban encroachment, with homes placed directly in or adjacent to the riparian area.

The upper Sacramento River between Keswick Dam and Red Bluff is the bounds for winter-run Chinook salmon spawning. Despite net losses of gravel since construction of Shasta Dam, substrates in much of this reach contain gravel needed for spawning by salmonids through the Central Valley Project Improvement Act (CVPIA) gravel augmentation program. LSNFH is a conservation hatchery for winter-run Chinook salmon located immediately downstream from Shasta Dam. The Sacramento River downstream from Keswick Dam provides spawning and juvenile rearing habitat.

Three water control structures – Keswick Dam, the Anderson-Cottonwood Irrigation District Dam, and Red Bluff Diversion Dam/Pumping Plant – are located along the Sacramento River in this reach. The fish screen allows the Red Bluff Diversion Dam gates to remain open year round to facilitate upstream and downstream passage by adult and juvenile Chinook salmon, steelhead, sturgeon, and other fish. A TCD was installed at Shasta Dam to improve coldwater pool management for salmonids spawning and rearing downstream from Keswick Dam. Instream flow regulation to meet habitat requirements and seasonal water temperatures for salmonids and other fish, flood control, and water supply deliveries are controlled primarily through managed releases of water from Shasta Dam that subsequently pass downstream through Keswick Dam into the mainstem Sacramento River.

Before the construction of Shasta Dam, the Sacramento River typically experienced large fluctuations in flow driven by winter storms, with late-summer flows averaging 3,000 cubic feet per second (cfs) or less. These fluctuations and periodic high flows moved large amounts of sediment and gravel out of the mountainous tributaries and down the Sacramento River. The completion of Shasta Dam in 1945 resulted in general dampening of historic high and low flows, reducing the timing, magnitude, and duration of winter floods while maintaining higher summer flows between 7,000 and 13,000 cfs. The annual volume of flow in the Sacramento River continues to vary significantly from year to year. However, average monthly flows following the construction of Shasta Dam no longer exhibit pronounced seasonal winter highs and summer lows. This is primarily because of winter flood control operations that have reduced peak flood flows, and summer releases made for water supply purposes.

### *Battle Creek*

Battle Creek is a tributary to the Sacramento River, with its confluence near Cottonwood, California, about 30 miles downstream from Keswick Dam. The Battle Creek watershed starts at elevations as high as 10,400 feet, with steep terrain, basalt canyons and foothills, and ends at the confluence with the Sacramento River near Cottonwood, California at an elevation of 335 feet (Terraqua 2004). The

Battle Creek watershed, located on the east side of the Sacramento River, drains roughly 370 square miles. Two forks of Battle Creek form the mainstem approximately 17 miles upstream from the Sacramento River confluence. The North Fork Battle Creek, which has suitable habitat for winter-run Chinook salmon, is about 213 square miles, or about 60 percent of the Battle Creek watershed (McConnaha et al. 2016).

North Fork Battle Creek originates near Mount Lassen and is distinguished by volcanic deposits providing a basalt and porous lava geology. This geology results in flows that are substantially augmented by contributions from springs mostly in Eagle Canyon, and groundwater, giving rise to high summer base flows with moderate year-round water temperatures. Annual precipitation in the North Fork Battle Creek watershed ranges from 43 to 49 inches (DWR 2004).

### *McCloud River*

The McCloud River, located in southern Siskiyou and northern Shasta counties of California, is a major spring-fed tributary to Shasta Reservoir and the Sacramento River that drains a watershed area of approximately 800 square miles (Reclamation 2016). From its origins in Colby Meadow at an elevation of approximately 5,500 feet, in the moderately steep volcanic terrain forming the southeast flank of Mount Shasta, it flows about 50 miles in a southwesterly direction before entering Shasta Reservoir, where its historical confluence with the Pit and Sacramento rivers is inundated by the reservoir. Mean annual precipitation in the McCloud River Basin exceeds 70 inches throughout the watershed with most of the precipitation between December and March (North State Resources 2010, Shasta-Trinity National Forest 2011). The majority of precipitation is in the form of rain and with the rest in form of snow, except at the highest elevations in the uppermost part of the watershed, where snow on Mount Shasta predominates (Blodgett et al. 1985, Shasta-Trinity National Forest 2011, Reclamation 2016).

The McCloud River has a baseflow of about 40 cfs, where it flows from the southeast flank of Mount Shasta onto a volcanic plateau until just downstream from Lower McCloud Falls, where two large springs (Little Muir and Big springs) increase flows, transforming the river into a large, very clear and cold river, with summer temperatures rarely exceeding 46 degrees Fahrenheit (°F) (Rode and Dean 2004). Lower McCloud Falls, about 35 miles upstream from Shasta Reservoir, was historically the upstream limit to migration of anadromous fish before construction of Shasta Dam. McCloud Reservoir, located about 5 miles downstream from Big Springs and about 23 miles upstream from Shasta Reservoir, was formed by construction of McCloud Dam in 1968 and is the current fish migration barrier on the McCloud River above Shasta Reservoir (Reclamation 2016). McCloud Dam partially regulates flow in the McCloud River and is subject to minimum instream flows established under the McCloud-Pit Federal Energy Regulatory Commission (FERC) project (FERC Project No. 2106) operating license. The flow regime of the McCloud River is lowest and relatively stable during the summer and fall and has more flow variability and peak flows in response to precipitation events and snowmelt runoff from the winter through the spring (Reclamation 2014).

### *Little Sacramento River*

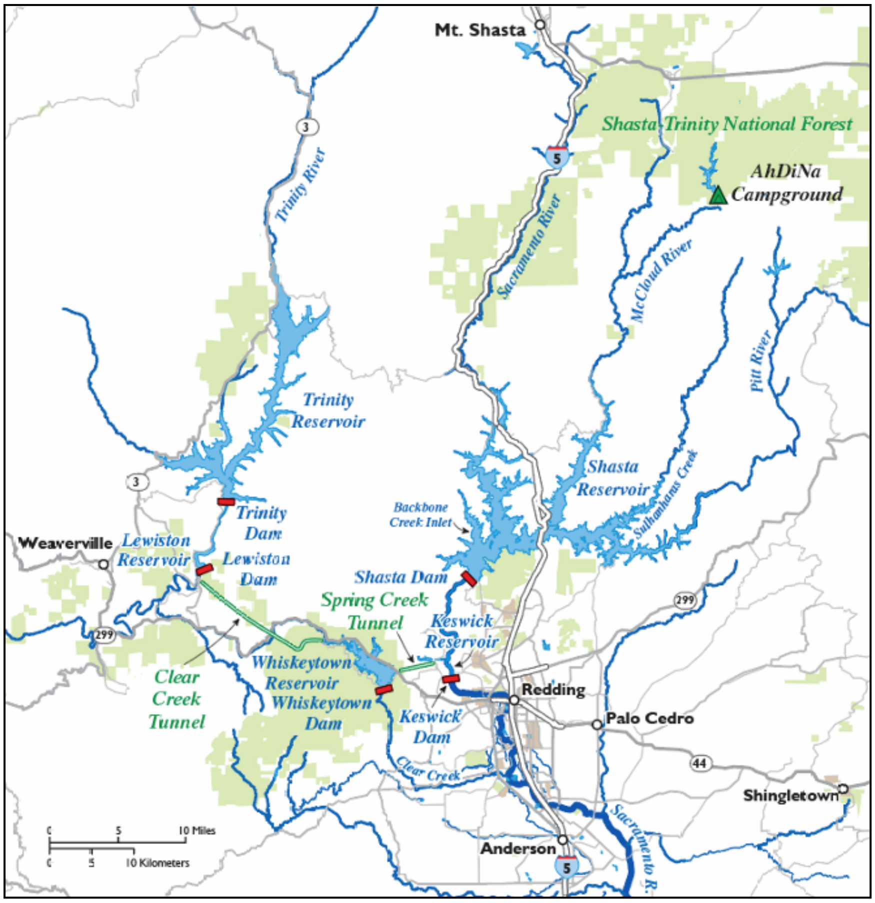
The Little Sacramento River consists of a 37-mile segment of river running from Box Canyon Dam, in Siskiyou County, to where it enters Shasta Reservoir, near Campbell Creek in Shasta County. The watershed boundaries are formed partly by the steep Klamath Mountains, which direct precipitation and stream channels down mountain faces into the Sacramento River for several miles before the river empties into Shasta Reservoir.

The Box Canyon Dam, located 37 miles upstream from Shasta Reservoir, on the Little Sacramento River is a migration barrier. Streamflow in the Little Sacramento River is partially regulated by releases from Box Canyon Dam, however, daily stream flow records show that the operation of Box Canyon Dam has not measurably changed the baseflow discharge of the upper watershed (North State Resources 2010). The FERC license currently requires a minimum dam release of 40 cfs or the full natural inflow, whichever is greater, be released to the river channel below the dam, but releases are typically set to 47.5 cfs to avoid releasing less than the minimum flow (Reclamation 2014). Additionally, water temperature and dissolved oxygen levels of dam discharges are to comply with Basin Plan water quality objectives (North State Resources 2010). Annual flows along the Little Sacramento River are generally about 5 times greater at the confluence with Shasta Reservoir than at the gaging station below Box Canyon Dam (North State Resources 2010).

The average annual precipitation is 40 to 60 inches along the length of the Upper Sacramento River watershed. Approximately 80 percent of this precipitation occurs between October and May, mostly in the form of rain below 5,000 feet and in the form of snow above this elevation (Reclamation 2016).

## Facilities and Operations

Shasta Dam and Shasta Reservoir are located about nine miles northwest of Redding, California on the Sacramento River (Figure 2). Built between 1938 and 1945, the concrete gravity dam is 602 feet high, and the storage capacity of 4.5 million acre-feet (MAF) makes it the largest reservoir in California. Roughly 90 percent of the water stored in the Shasta Reservoir is from rainfall-driven runoff that occurs between December and May. Shasta Dam and Shasta Reservoir are key facilities in the CVP; the water stored in Shasta Reservoir represents about 41 percent of the stored water in the CVP (Reclamation 2025a). Keswick Dam and Keswick Reservoir sit just below Shasta Dam and serve a re-regulating function, smoothing the fluctuating water releases from Shasta Dam before they flow into the Sacramento River. The Shasta Dam TCD, constructed in 1997, blends warmer and colder layers from within Shasta Reservoir and allows Reclamation to manage the water temperature of releases and preserve until late in the season the coldest water in the reservoir to release into Keswick Reservoir and the Sacramento River.




Source: National Academies of Sciences, Engineering, and Medicine (in press)

**Figure 2. Map of the Upper Sacramento River Basin Relevant to Shasta Coldwater Pool Management**

A key principle of Shasta Reservoir long-term management is that drought protection and fish protections are linked. As part of the 2024 Record of Decision (ROD) on the Long-term Operation (LTO) of the CVP and SWP, Reclamation developed an objectives-based management framework that establishes different Shasta water temperature and storage management objectives depending on hydrologic conditions and identifies actions that can be taken for fishery management and drought protection (Reclamation 2024a). This same Shasta framework was maintained in the 2025 ROD (Reclamation 2025a).

Reclamation has historically managed Shasta Dam for multiple objectives that vary by season:

- In the winter, Reclamation's objective is to rebuild storage. The dam is operated primarily for flood control, minimum flow requirements in the Sacramento River, and water quality objectives in the Delta.
- In the spring, Reclamation's objective is to maintain storage. When Shasta Dam is not operated for flood control, Reclamation seeks to maximize storage of inflow in the reservoir by the end of the flood control season (end of May). Higher storage improves the ability to

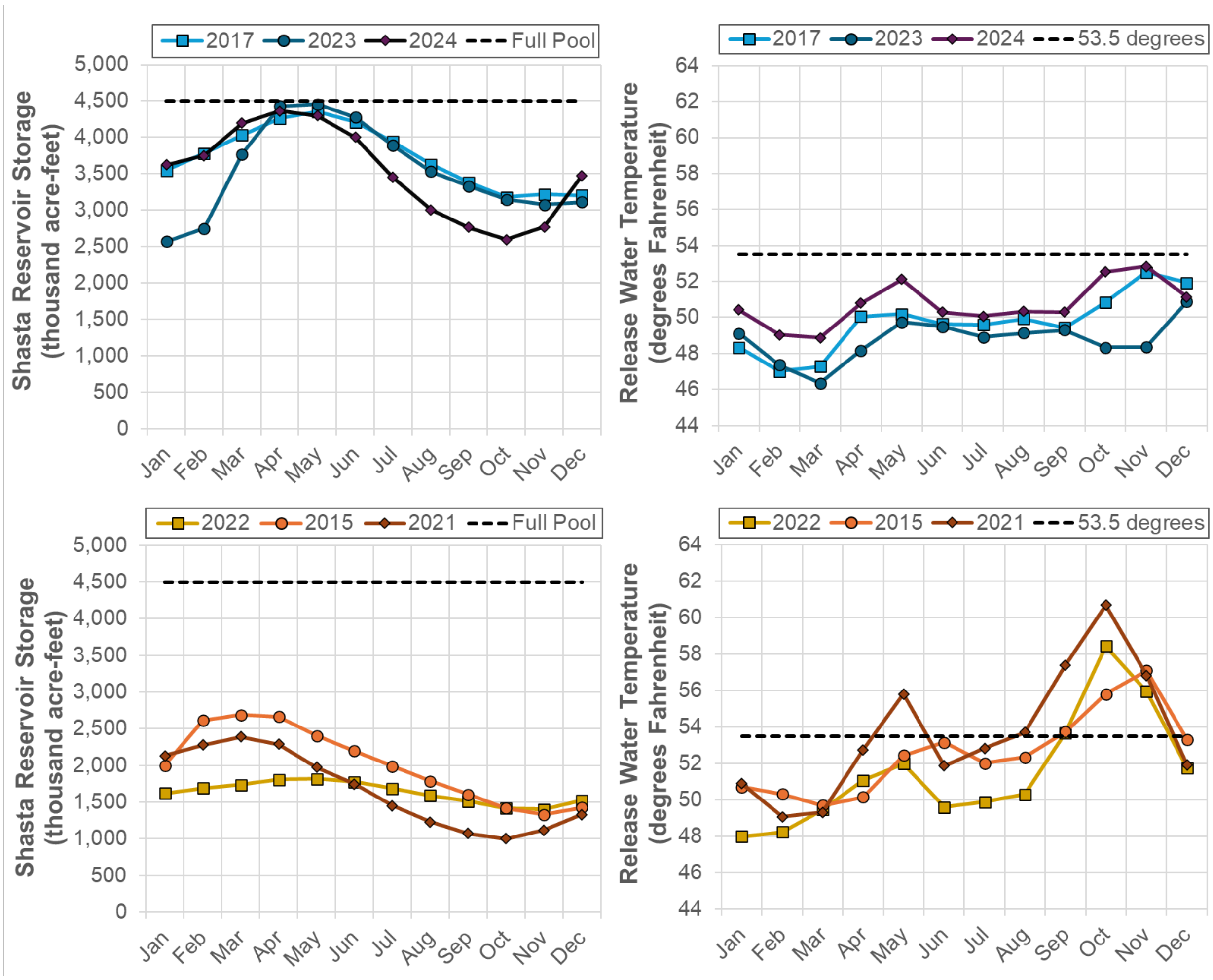
meet downstream water temperature objectives and increases the ability to make releases later in the year for water supply needs.

- Peak releases from Shasta Reservoir typically occur between June and August. Summer operational considerations include releases for in-river temperature control, senior water rights and water service and repayment contract diversions on the Sacramento River, diversions in the Delta, exports from the Delta, and Delta salinity and outflow objectives.

- In the fall, Reclamation's objective is to start rebuilding storage in Shasta Reservoir. Reclamation balances fall operations based on highly variable conditions, including water temperature control (dependent on winter-run Chinook salmon emergence timing), maintenance of winter-run Chinook salmon redds (dependent on spawning depths), instream diversion demands on the mainstem of the Sacramento River, fall-run Chinook salmon redd dewatering minimization (dependent on late-summer flows and fall spawning timing), and release stabilization through the fall-run Chinook salmon egg and alevin incubation.

Cold water releases into the Sacramento River are essential to supporting multiple fish species, including winter-run, spring-run, and fall-run Chinook. In drier years when the reservoir does not reach full pool, there is a limited supply of cold water available, and downstream water temperature control becomes a challenge. An example of Shasta Reservoir storage and Shasta Reservoir release temperatures during wetter and drier water years is shown in Figure 3. During wetter years when Shasta Reservoir storage reaches full pool, release temperatures are below 53.5°F year-round. Maintaining water temperature of 53.5°F downstream of Shasta Dam is a management target and a critical temperature to achieve successful spawning, egg incubation, and fry emergence during summer months. During drier years, Shasta Reservoir storage is low, the volume of cold water behind the dam is smaller, and release water temperatures can exceed 53.5°F for several months in the late summer and fall.

Salmon hatcheries were built in the upper Sacramento River watershed as mitigation to partially offset habitat and fish losses resulting from the construction of Shasta and Keswick dams. The LSNFH, an integrated-recovery supplementation program and a captive broodstock program, sits just below Shasta Dam. The LSNFH, together with the Coleman National Fish Hatchery (CNFH) on Battle Creek, comprise the CNFH Complex. Both facilities are operated by the U.S. Fish and Wildlife Service (USFWS) and funded by Reclamation. LSNFH typically produces around 250,000 to over 500,000 winter-run Chinook salmon juveniles annually, and in most years a portion of these fish are transferred to CNFH for release into Battle Creek.




Source: Data from California Data Exchange Center: storage data from station SHA, temperature data from station SHD.
Note: 53.5 degrees Fahrenheit is the temperature identified as protective of spawning Chinook salmon.

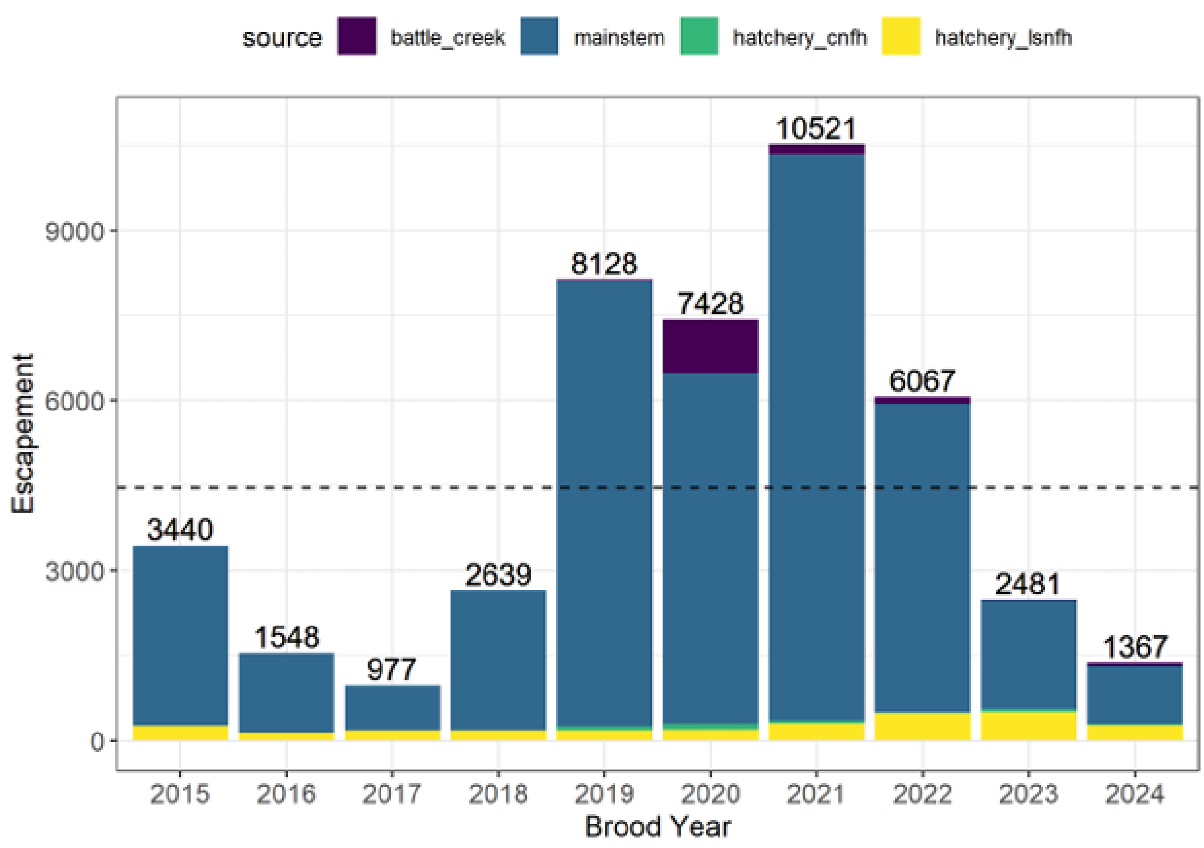
**Figure 3. Shasta Reservoir Storage (left) and Shasta Reservoir Release Temperature (right) During Relatively Wetter (top) and Drier (Bottom) Years**

## Winter-Run Chinook Salmon

Winter-run Chinook salmon are unique among Chinook salmon evolutionarily significant units (ESU) in exhibiting an adult winter migration, extended spring adult holding period, and summer spawning, when river temperatures are typically warming. Historically, winter-run spawned in high-elevation, spring-fed tributaries of the upper Sacramento River Basin, including the McCloud, Little Sacramento, and Pit Rivers, and Battle Creek, where cold summer water was consistently available.

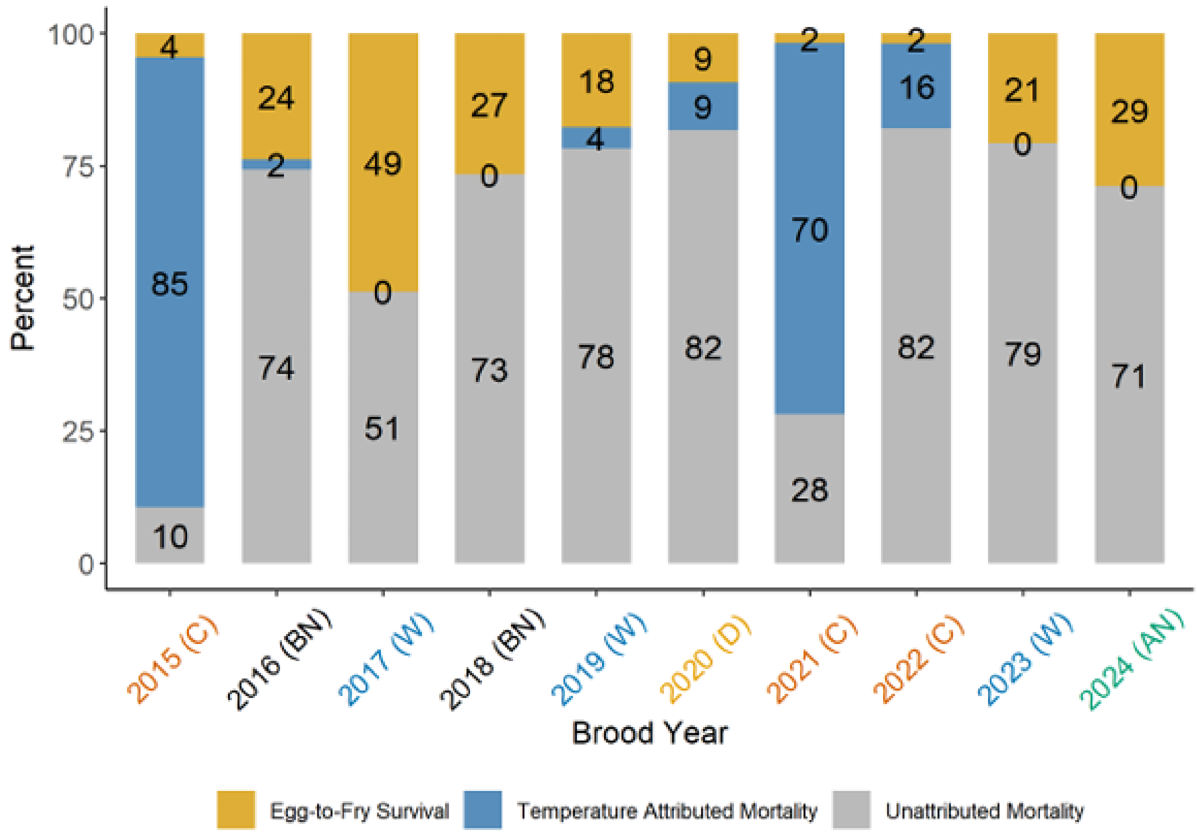
Starting in the 1850s, the construction of dams and diversions in the Sacramento Valley began blocking winter-run Chinook salmon passage into Sacramento Valley tributaries, resulting in declines in salmon abundance (Yoshiyama et al. 1998). Construction of Shasta Dam in the 1940s eliminated access to historic habitat in the McCloud River, Pit River, and Little Sacramento River, confining natural spawning to the mainstem Sacramento River and other tributaries below Keswick Dam. The population experienced a severe bottleneck, declining from an estimated 50,000 adult escapement in the 1970s to only hundreds of adults by the 1990s. The ESU was listed as threatened under the Endangered Species Act in 1989 and reclassified as endangered in 1994. At present, a single remaining population of winter-run Chinook salmon is entirely dependent on cold-water releases from Shasta Reservoir to survive.

Research indicates that elevated temperatures reduce salmon egg survival by increasing metabolic demand beyond what embryos can support prior to hatch (Martin et al., 2017, 2020, Anderson et. al., 2022). Cold-water management is therefore central to Shasta Reservoir operations for winter-run Chinook salmon conservation, but is increasingly challenged by drought, warming due to changes in weather patterns, and competing water demands. Shasta Dam operations rely on temperature monitoring and modeling, selective withdrawal through the TCD, and storage targets to balance seasonal temperature objectives with carryover cold-water needs, a challenge expected to intensify under increasing climate variability. Winter-run Chinook salmon populations have varied substantially in recent years (Figure 4 and Figure 5).




Note: Escapement numbers separated into Mainstem Sacramento River individuals upstream of Red Bluff Diversion Dam in blue, Battle Creek individuals upstream of Coleman National Fish Hatchery (CNFH) in purple, Hatchery transfers from CNFH in green, and Hatchery transfers from Livingston Stone National Fish Hatchery (LSNFH) in yellow. Horizontal line indicates the 10-year average total escapement (Reclamation 2025b).

**Figure 4. Winter-Run Chinook Salmon Escapement Estimates for Brood Years 2015-2024**




Note: Temperature-dependent egg mortality (% blue), unattributed mortality (% gray), and egg-to-fry survival (% yellow) are shown for brood years 2015-2024 (Reclamation 2025b).

**Figure 5. Winter-Run Chinook Salmon Temperature Attributed Mortality**

Battle Creek remains a critical component of the regional Chinook salmon recovery strategy, particularly for hatchery-based production. While its current role emphasizes controlled smolt rearing and returns to CNFH, restoration efforts aim to expand its ecological function and reconnect cold-water habitats. Integrating Battle Creek into broader recovery planning supports diversification of spawning and rearing areas, reduces reliance on single systems, and aligns with federal mandates to restore anadromous fish populations across the Central Valley.

Reclamation identified key stressors for winter-run Chinook salmon in the 2024 Biological Assessment for the LTO of the CVP (EIS Appendix AB, Chapter 5). For holding and spawning adults, the primary stressors include spawning habitat limitations, water temperature, and the presence of pathogens and disease. During the egg incubation and fry stages, stressors such as redd stranding and dewatering, substrate quality, and water temperature were identified as substantial concerns. For juvenile rearing and outmigration, the stressors include stranding risk, outmigration cues, entrainment risk, refuge habitat, food availability and quality, and water temperature. In addition to these life-stage-specific stressors, winter-run Chinook salmon are also affected by thiamine deficiency caused by their marine diets, which can impact survival and development across multiple stages of their life cycle (Mantua et al. 2025).

## Legal and Regulatory Context

Operation of the CVP is needed to meet multiple authorized purposes including flood control and navigation; water supply and fish and wildlife mitigation, restoration and protection; and fish and wildlife enhancement and power generation. Operation of the CVP also provides recreation and water quality benefits. CVP operations are governed by a legal framework that includes water supply contracts and settlement agreements; Federal Endangered Species Act (ESA); CVPIA; Clean Water Act as implemented through California State Water Resources Control Board water quality objectives and water right orders; Federal trust obligations to Tribal Nations; Biological Opinions on the LTO of the CVP and State Water Project (SWP), and associated environmental review requirements such as National Environmental Policy Act compliance.

The CVPIA (Public Law 102-575, Title 34) further requires Reclamation to operate the CVP to protect, restore, and mitigate impacts on fish and wildlife in a manner co-equal with project water supply purposes. To work towards achieving these goals, Reclamation and USFWS established the Science Integration Team (SIT), which uses SDM to develop decision support models (DSM) for multiple sensitive fish species, and works with stakeholders to prioritize recovery actions. The recovery of Sacramento River winter-run Chinook salmon is also supported by a Winter-run Action Plan (WRAP), a multi-agency, science-driven framework led by Reclamation to coordinate monitoring, habitat and fisheries actions, infrastructure improvements, and water operations. Governance of the WRAP is embedded within the CVP/SWP framework, bringing together dedicated technical teams, a brood-year assessment process, and voluntary Sacramento River Settlement Contractors actions to coordinate water management decisions with winter-run Chinook salmon biological objectives.

Winter-run Chinook salmon are listed as endangered under the ESA. To avoid jeopardizing the species, the National Marine Fisheries Service (NMFS) requires specific operational measures particularly for Shasta Reservoir coldwater pool management as identified in the 2024 LTO Biological Opinion (NMFS 2024). In December 2025, Reclamation issued a Record of Decision that adopted the Action 5 Operations Plan for the Long Term Operations of the CVP and SWP (Reclamation 2025a) that changed real-time governance and operational flexibility.

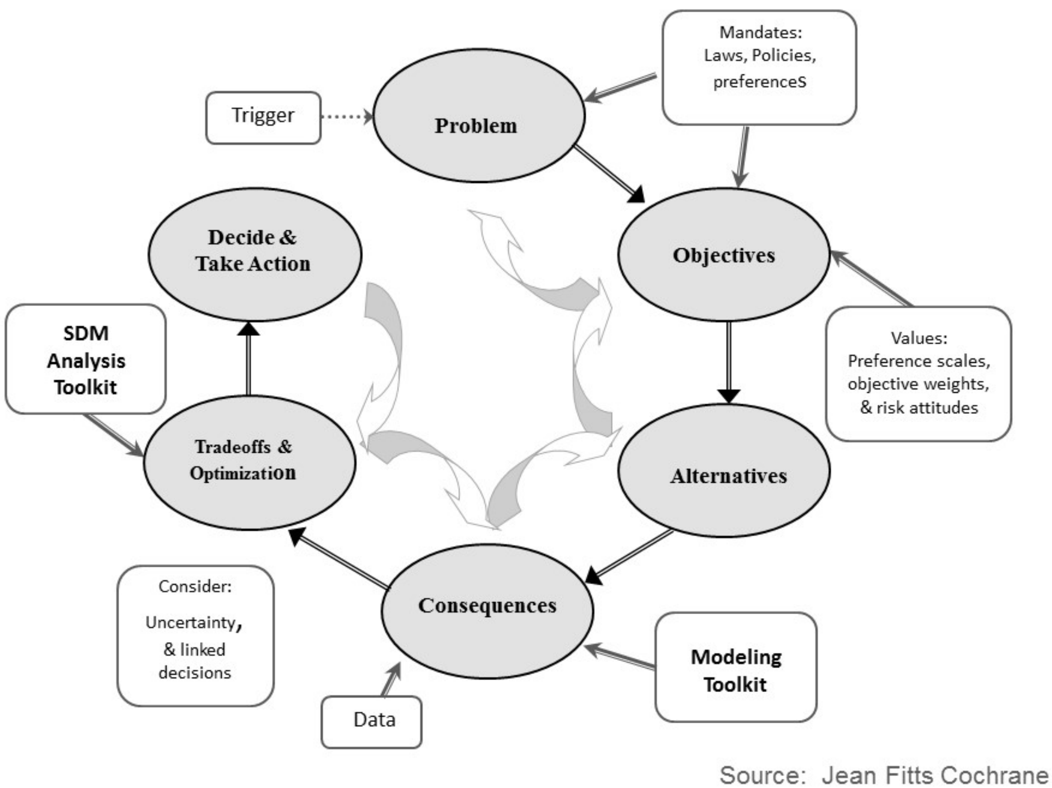
Current executive orders also guide CVP planning and operations. Executive Order 14181 directs the Secretary of the Interior, through Reclamation, to utilize all available discretion to operate the CVP to deliver more water, produce additional hydropower, and increase storage and conveyance capacity. Executive Order 14303 establishes Gold Standard Science to ensure federal research is transparent, reproducible, and guided by credible, unbiased scientific evidence. The SDM study focuses on additive actions that could improve outcomes for winter-run Chinook salmon under current Shasta operations. This SDM was not intended to directly support decision-making, but rather to provide insights into potential actions that might be considered in other decision-making processes. This provided flexibility to consider a broad range of actions, while recognizing that actions ultimately implemented will be done so within these legal and regulatory constraints.

# 2. Methods and Approach

The project team used a structured and sequenced project approach that included formulation of an SDM plan and implementation of SDM steps supported by numerical modeling and expert judgments.

## Structured Decision Making and PrOACT

SDM is a formal approach and a set of tools that facilitates consistent evaluation and comparison of alternative solutions, with the goal of identifying those that best balance the competing needs from the perspectives of various participants in the process. The Winter-Run Chinook Salmon Habitat and Facilities SDM process followed the first five steps of the PrOACT Process: Problem, Objectives, Alternatives, Consequences, Tradeoffs (Figure 6) (Hammond et al. 1999).




Source: USGS 2018

**Figure 6. Steps of the PrOACT Process**

### Problem Statement: Clarify the Decision Context

The first step in the SDM process is to clearly define and describe the decision problem to be addressed. The Problem Statement establishes the scope of the analyses to be conducted, identifies the decision-makers and their decision-making authorities, and describes the types of analytical results that are expected and how those results will be used.

## Objectives: Define Objectives and Performance Metrics

The second step requires decision-makers and participants to clarify the types of outcomes they value and seek by developing a clear set of objectives. The objectives are the key element of an SDM process: when objectives are clearly defined, alternatives can be identified that address those objectives, tradeoffs can be evaluated across those objectives, and decision-makers can more readily assess how each alternative action balances potentially competing goals.

While objectives are high-level statements of valued outcomes within the decision context, they are made operational by identifying quantifiable performance metrics that accurately reflect those high-level values. Identifying quantifiable metrics for each objective is essential for the consequences and tradeoff steps described below.

## Alternatives: Develop Creative Alternatives

In the SDM process, alternatives describe the action or set of actions to be considered and evaluated. Alternatives are identified by participants after the problem statement is developed and objectives are specified, helping to ensure that they fit within the scope of the problem being studied and promoting creativity though explicit consideration of what each alternative is intended to achieve (the objectives). In this process, participants first proposed individual actions, which were then combined into comprehensive groups of actions, termed portfolios. These portfolios of actions were the fundamental alternatives evaluated in the analysis.

## Consequences: Estimate Consequences

The key analytical step in SDM involves estimating the consequences of each alternative in terms of how well it achieves defined objectives. In this SDM process, consequence estimates relied on a combination of models results and expert judgements.

After estimating the consequences, a consequence matrix is often developed, summarizing the estimated consequences of each alternative against each of the objectives and performance metrics in quantitative and qualitative terms. A consequences table provides the first comparison of alternatives, may be sufficient to identify and eliminate dominated alternatives, and can highlight ways that alternatives could be modified to better meet more of the stated objectives.

## Tradeoffs: Evaluate and Value Potential Tradeoffs Among Objectives

It is rare for a single alternative to outperform all others across all of the objectives. The final step in SDM is to consider the tradeoffs among objectives that allow an overall combined comparison of alternatives. This step requires development of one or more sets of “weights” for the objectives. Decision-makers and participants assign weights through a structured approach where they consider their preferences and values as they relate to achieving each objective, relative to the others, within the problem context.

The consequences from the previous step are combined with the weights describing the importance of different levels of achievement on each objective to yield a composite value for each alternative. Different participants may have different value structures and preferences, and those differences lead to different sets of weights and ultimately can lead to different values and different rankings for the alternatives. The key goal in a participatory SDM process is that participating parties develop an understanding of which alternatives they prefer and why, and also an understanding of what other parties prefer and why. A uniformly agreed-on ranking is not expected.

## Implementation of PrOACT

Reclamation endeavors to apply the "PARTI" principles to its work and actively considered their application throughout this process:

- **P**articipation: Communities impacted by Reclamation decisions should have a meaningful voice informing those decisions.
- **A**ccountability: There is a commitment to the group with ownership and timely follow-through
- **R**elevancy: The work Reclamation engages in improves the environmental, water, and power project purposes of the CVP.
- **T**ransparency: Reclamation decisions should be replicable, using open-source data, models, and processes.
- **I**nnovation: Reclamation processes and leadership should foster a culture of continuous advancement.

Reclamation designed this project with these principles in mind and wherever possible, integrated process feedback in real-time to improve participant experience and outcomes. Some of these adjustments are identified below.

Thirty organizations were invited to participate in this process along with Reclamation; 26 accepted the invitation. Reclamation received recommendations of additional interested parties from early participating entities and included them as invitees to broaden the interests and perspectives represented. Appendix A provides a list of the participating parties. Participants represented a Tribe, public water agencies, state and federal resource agencies, environmental non-governmental organizations, and the commercial fishing community. Each participating party was able to identify a primary and alternate representative, as well as an observer.

Participants convened to work through the PrOACT process over the course of 14 workshops in a 12-week period (Table 1). In response to participant feedback and in an effort to increase participation, all meetings were held virtually except for the final meeting, which was a hybrid format with in-person attendance encouraged and remote attendance supported. Parties shared objectives and identified metrics to quantify them, generated actions and, as needed, provided input on how those actions could be modeled, identified portfolios of actions to be evaluated, and weighted objectives based on their organization's values and priorities. Participants were given instructions during workshops and asked to develop and submit these inputs independently between workshops. Participants provided input through an additive process that did not seek consensus, that is, any party could introduce a concept (e.g., objective, metric, action) and if that concept was within the scope of the study, only the party that originated an idea could remove it from consideration. The project team hosted optional office hours for participants to ask questions as they were developing their input. The duration and turn-around times were short, which drove both the participants and project team to develop ideas and analysis amidst significant uncertainty, but successfully produced a rapid high-level assessment of a wide group of potential actions.

**Table 1. Workshop Dates and Discussion Topics**

| Workshop Date | Topics Discussed |
|---|---|
| January 23, 2026 | SDM orientation, project overview, role of modeling in the process, potential modeling approaches and tools, next steps |
| February 4, 2026 | Problem statement, introduction to objectives and metrics in SDM, request to identify objectives and metrics |
| February 11, 2026 | Objectives, metrics, introduction to alternatives in SDM, request to identify actions |
| February 13, 2026 | Revised objectives and metrics |
| February 20, 2026 | Actions and action groups, modeling tools, request to review actions |
| February 25, 2026 | Actions and action groups, actions to evaluate together, finalizing proposed actions |
| March 4, 2026 (morning) | Modeling parameters for Sacramento River and Hatcheries action groups |
| March 4, 2026 (afternoon) | Modeling parameters for Other and Facilities action groups |
| March 6, 2026 (morning) | Modeling parameters for Above Shasta Dam action group |
| March 6, 2026 (afternoon) | Modeling parameters for Battle Creek action group |
| March 11, 2026 | Intersection between this SDM process and other processes, recap of work to date, preview of results reporting |
| March 18, 2026 | Preliminary modeling results, draft portfolio variants, request for input on non-modeled parameters |
| March 25, 2026 | Update on portfolios, overview of tradeoffs and weighting |
| April 8, 2026 | Share and discuss results of analysis, final report outline, additional considerations |

Key:
SDM = structured decision making

Participation in this SDM process did not constitute agreement with or endorsement of any of the alternatives analyzed as part of the process, or any future decisions that reference this process or its results by the participants. This diverse group of participants identified a broader group of potential actions for analysis than Reclamation might have considered alone. Input from participants also ensured that the analysis of those actions reflected the values of each participant. Emphasizing that participants were not committing to an agreement or the end goal of a consensus outcome may have encouraged out-of-the-box thinking and sharing of divergent perspectives. This information could be used to inform future decision-making, including additional analysis.

# Numerical Modeling

Quantitative modeling provides a framework to simplify complexity, reduce bias, and guide choices by incorporating data and science into the SDM process. The modeling approach developed to quantify performance metrics and evaluate portfolios as part of this SDM prioritized use of the best available models that could represent the coupled hydrologic, operational, water temperature, and winter-run Chinook salmon lifecycle processes in the Upper Sacramento River watershed and be applied within the schedule of the rapid SDM. The selected models, described in more detail below, were CalSim 3 for hydrology and water operations, HEC-5Q for water temperature, and a derivative of the CVPIA SIT winter-run Chinook Salmon DSM for assessing the effects of portfolios on winter-run Chinook salmon. This suite of tools was applied to support development and evaluation of the Action 5 Operations Plan adopted by Reclamation in December 2025 (Reclamation 2025a).

The modeling approach used the Action 5 Operations Plan as a baseline to reflect a current snapshot of facilities and regulatory conditions within the upper Sacramento system. Modeling tools simulated historical hydrologic conditions, perturbed by future potential changes in weather patterns, during a simulation period of 1980 – 2000. Even though the CalSim 3 and HEC-5Q models have a simulation period of 1922 – 2021, the winter-run lifecycle model established under this SDM process is only developed for the period of 1980 – 2000, so this period was used for all analyses. Projected changes in future weather patterns corresponding to a 30-year period centered around 2022, referred to as 2022±15 median climate conditions, were used to perturb the historical hydrology and air temperature conditions (e.g., increase or decrease values relative to historical conditions). Sea level rise was assumed to be 15 centimeters above baseline conditions. Additional details on future potential weather patterns and sea level rise assumptions are described in detail in Reclamation (2024b).

A schematic of the numerical modeling workflow is shown in Figure 7. The CalSim 3 model was used to establish monthly average Shasta Dam storage and releases, along with storage and releases from all other reservoirs in the system. CalSim 3 also accounts for monthly average flow diversions and simulates monthly average flow values in major waterways. These CalSim 3 outputs are used as inputs to the HEC-5Q model, which simulates reservoir release temperatures and instream flow temperatures on a daily time step. HEC-5Q outputs are averaged to monthly values and provided as inputs to the winter-run lifecycle model, along with CalSim 3 outputs. A single baseline CalSim 3 and HEC-5Q model run were developed for this SDM analysis. Individual unique actions were identified by SDM participants and grouped into portfolios of actions by both the SDM team and the SDM participants. Portfolios were designed with a thematic focus that sought to explore different combinations of potential habitat, hatchery, facility, and reintroduction actions at varying spatial scales and levels of investment. The winter-run lifecycle model was modified to reflect the collective actions of each portfolio, and lifecycle model outputs, or performance metrics, were analyzed for each portfolio.

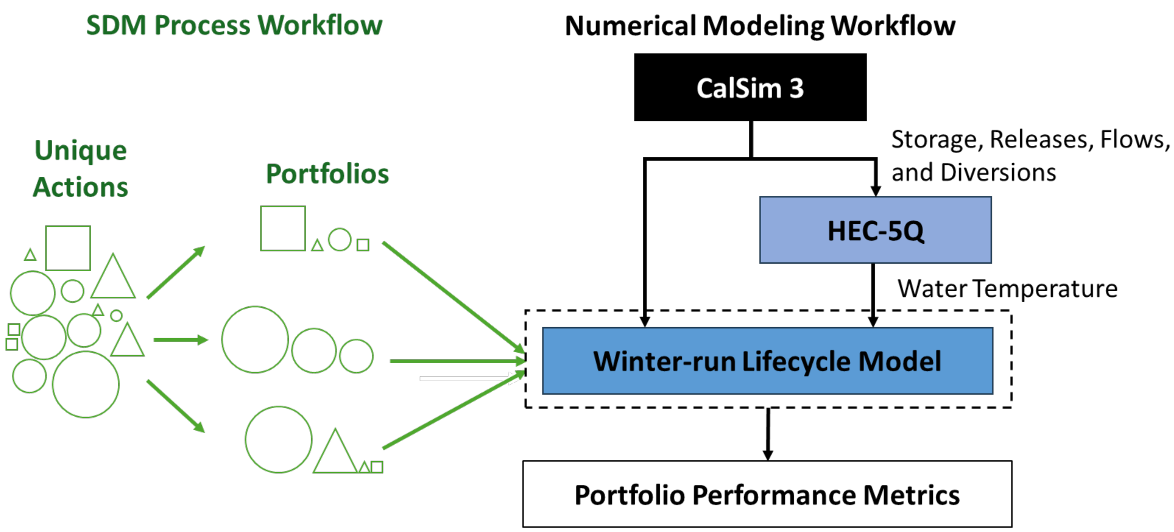



**Figure 7. Schematic of Modeling Framework Used to Evaluate Portfolios.**

The numerical modeling tools used in this SDM process are simplified representations of complex systems. They are not predictive models of project operations and their results should not be interpreted as absolute or associated with a quantifiable confidence interval. Model outputs are most appropriately used for comparative purposes (e.g., comparing results between portfolios, or comparing a portfolio result to the baseline) and serve only as indicators of potential system behavior.

## CalSim 3

CalSim 3 is a water operations model jointly developed by Reclamation and California Department of Water Resources for performing planning studies related to CVP and SWP operations. CalSim 3 simulates system operations for a 100-year period of historical-based hydrology using a monthly time step. The model assumes that facilities, land use, water supply contracts, and regulatory requirements are constant over this period, representing a fixed set of conditions (existing or future). Inputs to CalSim 3 include inflows, rainfall runoff, and agricultural, urban, wetland water demands, and wildlife refuge water demands. CalSim 3 outputs include river and stream flows, water diversions and return flows, surface-groundwater interactions, reservoir storage, Delta channel flows, Delta diversions and exports, Delta outflow, deliveries to project and non-project users, and controlling factors on project operations. These can be used to assess effects resulting from project alternatives.

Assumptions for baseline CVP operations are the same as was modeled for Action 5 and adopted in the December 2025 ROD for the LTO of the CVP and SWP (Reclamation 2025a). The simulated baseline monthly average Shasta Reservoir storage time series is shown in Figure 8. Seasonal operations are apparent, with peak annual storage values occurring around April or May, and minimum storage values present in September and October. The baseline simulation period includes a significant drought from 1987 – 1992 that results in relatively low Shasta Reservoir storage and overall CVP system storage coupled with relatively low streamflow conditions. The baseline simulated monthly average Shasta Reservoir release time series is shown in Figure 9. Relatively wet years show peak releases of above 40,000 cfs, while the historic drought of 1987 – 1992 results in multiple years of relatively low magnitude releases with no substantial high flow releases. As discussed in later sections, reduced flow and relatively high water temperatures during the historic drought period of 1987 through 1992 have a notably detrimental effect on winter-run Chinook salmon abundance, productivity, and survival.

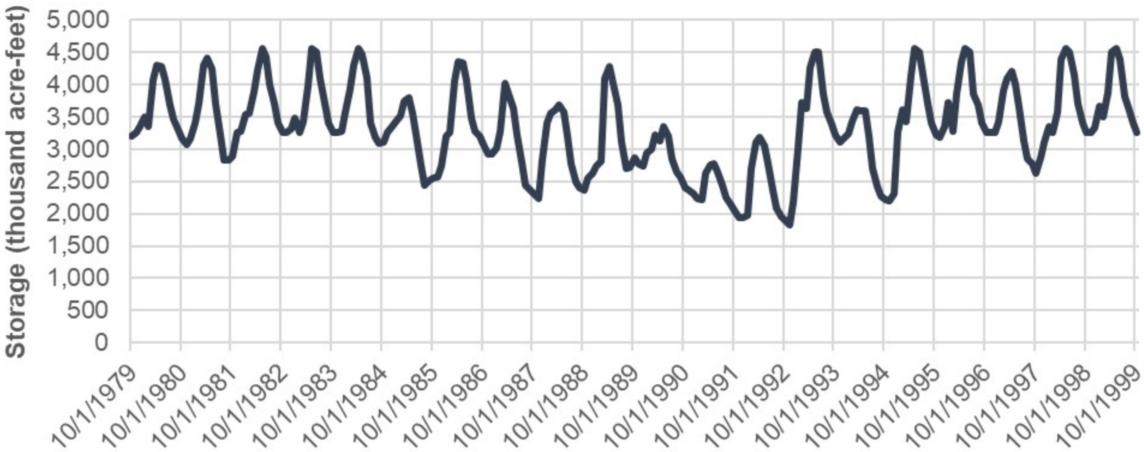



**Figure 8. Simulated Monthly Shasta Reservoir Storage from 1980 – 2000**

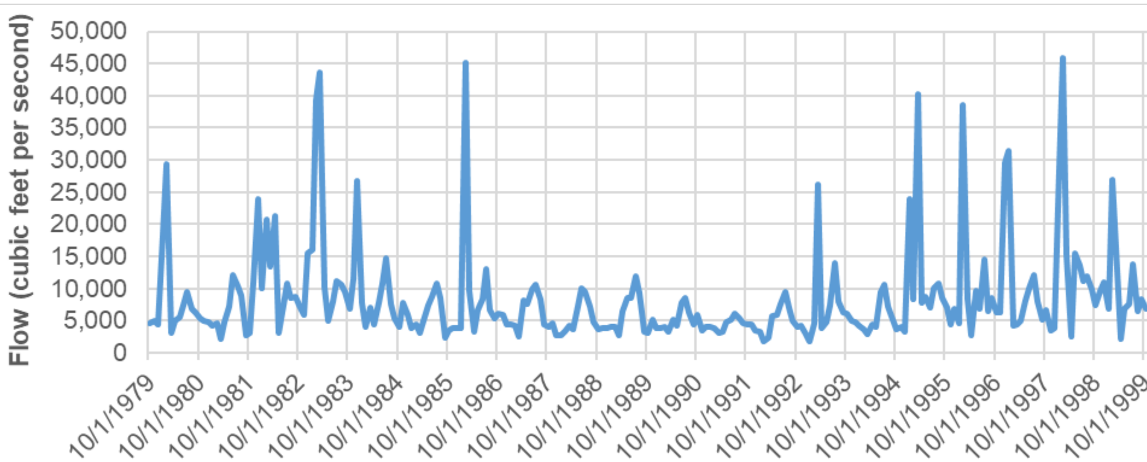



**Figure 9. Simulated Monthly Shasta Reservoir Releases from 1980 – 2000**

## HEC-5Q

The HEC-5Q modeling tool simulates reservoir and river water temperatures based on input storage, flow, and meteorological data. The Trinity-Sacramento River HEC-5Q model simulates water temperatures for major reservoirs and sections of the Trinity River, Clear Creek, the Upper Sacramento River, Stony Creek, and the Sutter Bypass. The same HEC-5Q model version used in the Action 5 ROD (Reclamation 2025a) was applied in this SDM process.

The CalSim 3 baseline model outputs, including initial storage levels, reservoir and tributary inflows, reservoir outflows, diversions, and reservoir evaporation, were downscaled to daily timeseries and used as inputs to the HEC-5Q model. Output parameters of the HEC-5Q model include daily flow and temperature results along the Sacramento River and at select tributary inflow points. For use in the winter-run lifecycle model, daily HEC-5Q model results were averaged into monthly values at

Sacramento River below Keswick, Clear Creek at Igo, Sacramento River below Clear Creek, Sacramento River at Cottonwood Creek, and Sacramento River at Red Bluff Diversion Dam. The baseline simulated monthly average temperature time series at Sacramento River below Clear Creek and at Sacramento River at Red Bluff Diversion Dam are shown in Figure 10 and Figure 11.

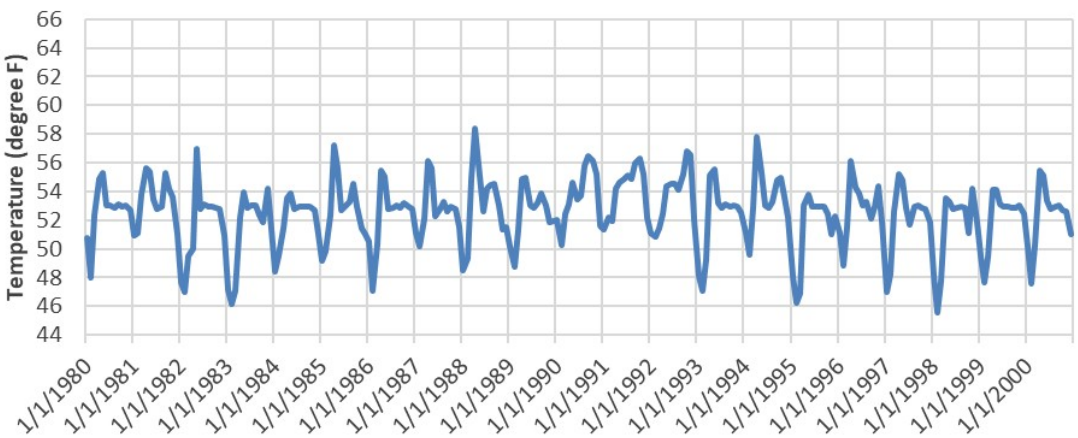



**Figure 10. Simulated Monthly Temperatures at Sacramento River Below Clear Creek from 1980 – 2000**

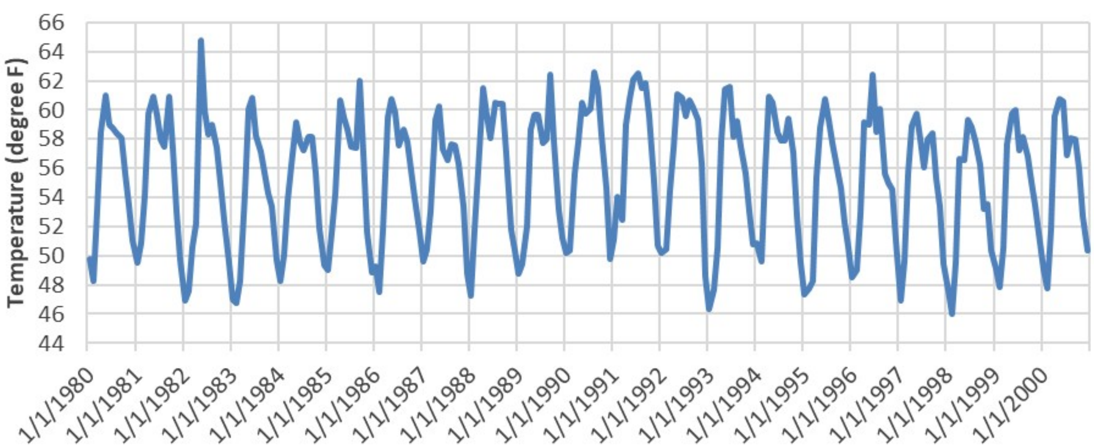



**Figure 11. Simulated Monthly Temperatures at Sacramento River Red Bluff Dam from 1980 – 2000**

## Winter-run Chinook Salmon Model

A winter-run Chinook salmon lifecycle model ("winter-run model") derived from the CVPIA SIT Salmonid lifecycle DSMs and the Reorienting to Recovery (R2R) project was used to evaluate effects of proposed actions and portfolios. The original SIT and R2R efforts included modeling multiple runs of Chinook Salmon, thus the winter-run model includes the ability to simulate population dynamics across 31 watersheds in the Central Valley (see list and map: CVPIA SIT FAQs). For this rapid SDM, modeling changes were implemented in winter-run Chinook salmon watershed units (Appendix B Figure B-3), specifically the Sacramento River reaches and Battle Creek, over a 20-year period representing the hydrology of 1980 to 2000. Tributaries that were not previously represented by the model (e.g., McCloud and Little Sacramento Rivers) were represented within the Upper Sacramento watershed unit. See Appendix B for more details about model assumptions regarding tributaries.

The winter-run model is a stage-based model that includes several submodels to represent the various stages of the winter-run lifecycle, including spawning adults, hatching eggs, growing fry and smolts, routing fish through the system to the ocean, and returning them to spawn (CVPIA FAQs; Appendix B Figure B-1). The model uses inputs of modeled flow (CalSim 3) and temperature (HEC-5Q) as described in previous sections, as well as specific parameter values that determine dynamics of submodels (e.g., stage-specific survival, growth) at each life stage. Inputs were processed in R packages DSMflow and DSMtemperature, and parameter values were taken from literature, expert judgments, or calibrated. In its various iterations, different versions of this model have been used to simulate the effects of habitat actions (CVPIA-SIT), flow actions, hatchery actions, and harvest actions (R2R). For more information on the original model structure, key assumptions, and uncertainties, please see Peterson and Duarte (2020) or the SIT DSM FAQs (CVPIA SIT 2023).

The winter-run model developed for this effort relied on the codebase developed for R2R, which built upon the CVPIA SIT DSM codebase and added capabilities for simulating harvest and hatchery actions. Specific adjustments for the winter-run version were referenced against the 2024 LTOs consultation version of the model (Reclamation 2024c). Modifications to the code were implemented and hosted on the Winter Run GitHub repository to allow the model to simulate the specific actions proposed throughout the process, as well as track metrics identified for use in the modeling results. Actions were modeled as habitat additions, hatchery values, or as modifications to submodels at the relevant life stage and in the relevant watershed. Additional details on the winter-run model and its implementation for this effort can be found in Appendix B.

# 3. Structured Decision-Making Outcomes

The following sections summarize outcomes of the 14-week SDM process, organized by each step of the PrOACT process.

## Problem Statement

This problem statement was developed by Reclamation, considering and incorporating changes suggested by the participants. See the Additional Considerations section for a discussion of participant concerns about the scope of this problem statement. The final problem statement is:

> *Operation of the Central Valley Project (CVP) is needed to meet multiple authorized purposes including flood control and navigation; water supply and fish and wildlife mitigation, restoration and protection; and fish and wildlife enhancement and power generation. Operation of the CVP also provides recreation and water quality benefits.*
>
> *Current Shasta Dam operations use a coldwater pool and selective reservoir withdrawal through a Temperature Control Device to help manage downstream water temperatures for winter-run Chinook salmon egg incubation. Winter-run Chinook salmon are currently prevented from accessing their historic cold-water spawning habitat upstream of Shasta Reservoir, and thus coldwater pool management is a key part of conservation efforts for this species. In past dry and hot years, the reliability of the coldwater pool is reduced and it is difficult to meet the life-stage requirements. Coldwater pool management can constrain the operations of the integrated CVP including Trinity, Folsom and Delta facilities that are operated in coordination with state and local parties. This constraint may limit the ability of Reclamation and the coordinating parties to meet other CVP purposes.*
>
> *Reclamation is exploring actions to improve outcomes for winter-run Chinook salmon. This may include actions that are under the direct control of Reclamation, as well as actions that could be undertaken jointly with other parties. Examples could include infrastructure modifications, hatchery improvements, habitat restoration, species reintroduction to additional tributaries, and other interventions.*
>
> *Reclamation seeks input from cooperating agencies and interest holders to help inform recommendations for strategies for winter-run Chinook salmon that do not rely on constraining the operations of Shasta Reservoir.*

## Objectives and Performance Metrics

Participants were asked to identify objectives they felt were important to consider when evaluating alternatives within this problem context. The SDM team considered all objectives provided (53 in total), identified commonalities, and clarified them by putting objectives into the standard SDM language where every objective has both an object and a direction of preference (increase/maximize or decrease/minimize). Participants reviewed the set of consolidated objectives and made additional recommendations. Consistent with the additive nature of this study and participatory principles laid out at the beginning of the study, objectives that were important to any one participant and that were within the scope of the problem were retained for evaluation.

Table 2 shows the objectives considered in this analysis. Participants identified three overarching goals: make progress towards recovery, reduce extinction risk, and increase the probability of downlisting. These three overarching goals are tightly linked and it was recognized as challenging to estimate or model progress against them directly. Through discussion, participants identified four more specific objectives that, considered together, would support progress on all three goals. These four objectives (shown at the top of Table 2), along with additional objectives, were used to evaluate and compare alternatives.

In response to participant feedback, for several of the objectives, multiple metrics were identified as necessary to provide insight into performance. These performance metrics are more detailed than the objectives, and identify what consequences ultimately need to be evaluated. Performance against these metrics was either modeled or evaluated with expert judgement, as indicated.

## Table 2. Objectives and Performance Metrics

| Objective | Performance Metric | Preferred Direction | Estimation |
|---|---|---|---|
| **Objectives directly related to winter-run Chinook salmon** | | | |
| Increase abundance | Average annual returns | More | Modeled[1] |
| | Average annual proportion of hatchery-origin spawners (pHOS) | Lower | Modeled |
| | Incidents of declining population[2] | Fewer | Modeled |
| | Catastrophic decline[3] | Fewer | Modeled |
| Increase productivity | Average annual out-migration from the upper Sacramento | More | Modeled |
| | Average annual number of smolts reaching ocean | More | Modeled |
| | Average annual cohort replacement rate (CRR) | Higher | Modeled |
| Increase life history diversity | Average annual proportion of hatchery-origin spawners (pHOS)[4] | Lower | Modeled |
| | Average annual size diversity of smolts at ocean entry | Higher | Modeled |
| Increase tributary support | Average annual number of adults spawning in tributaries[5] | More | Modeled |
| | Average annual proportion of total suitable rearing habitat that is in tributaries | More | Modeled |
| | Number of tributaries above Shasta Dam with accessible spawning and rearing habitat | More | Modeled |
| | Number of independent WRCS populations[6] | More | Modeled |
| Increase the ability of WRCS to live their natural life cycle | Constructed scale: change to the amount of human intervention in the life cycle | Less/lower | Expert judgment[7] |
| **Objectives related to other impacts of actions** | | | |
| Avoid or minimize adverse impacts on fall-run Chinook salmon | Change in the amount of habitat or in survival for fall-run Chinook salmon | Less habitat loss | Expert judgment |
| Avoid or minimize adverse impacts on other listed fish species | Change in the amount of habitat or in survival for other listed fish species | Less habitat loss | Expert judgment |
| **Objectives directly related to the alternatives themselves** | | | |
| Minimize time to implementation | Constructed scale: Estimated time (years) to implementation or completion of construction | Less/ Sooner | Expert judgment |

| Objective | Performance Metric | Preferred Direction | Estimation |
|---|---|---|---|
| Minimize time to achieve benefits | Constructed scale: Estimated time (years) from implementation to realization of local-scale benefits | Less/ Sooner | Expert judgment |
| Minimize total cost of actions | Constructed scale: Approximate total cost, including construction costs and 20 years of operations and maintenance. | Lower | Expert judgment |

Notes.

[1] All modeled metrics were calculated using a customized model of the life cycle for winter-run salmon in the Sacramento River. The model was run a 20-year simulation based on the historic hydrologic conditions from 1980 to 2000, updated to reflect current flow and operations practice. All "average" metrics were calculated as the arithmetic average of the relevant model outputs. Refer to Appendix B for discussion of how each of the modeled metrics were estimated.

[2] Calculated as the maximum number of consecutive years in the 20-year modeling period where year-over-year returns declined by 10% or more.

[3] Calculated as the number of years in the modeling period where the population decline over the preceding 3-year period was a factor of 10 or greater.

[4] The pHOS metric was judged to be relevant both to the "increase abundance" and "increase life history diversity" objectives.

[5] In this analysis, three "tributaries" were defined and modeled: Battle Creek (below Shasta Dam), the McCloud River (above Shasta Dam), and the Little Sacramento River (above Shasta Dam).

[6] Independent populations were defined as those meeting all of four criteria: More than 500 return spawners, population growth rate greater than 1, CRR greater than 1, and pHOS less than 5%.

[7] For all metrics estimated using expert judgement, the SDM team developed a constructed scale describing different levels of performance. See Table 4 for discussion of how each of these metrics were estimated.

Key: CRR = cohort replacement rate, pHOS = proportion of hatchery-origin spawners, WRCS = winter-run Chinook Salmon

## Modeled Metrics

The winter-run model produced numerical outputs that were used to estimate values for multiple performance metrics. Table 3 shows the performance metrics that were informed by modeling results, and the specific model outputs used for each metric; Appendix B describes the details of how the performance metrics were estimated from those modeled results. The raw values for the performance metrics were used as consequences for each portfolio (see next section).

### Table 3. Modeled Performance Metrics

| Performance metric(s) | Model output |
|---|---|
| Average annual returns<br>Incidents of declining population<br>Catastrophic decline | Annual spawners by watershed |
| Average annual proportion of hatchery-origin spawners | Annual proportion of hatchery-origin spawners by watershed |
| Average annual outmigration from the upper Sacramento | Annual number of juveniles in the Upper Sacramento River watershed unit, divided into four size classes |
| Average number of smolts reaching the ocean<br>Average size diversity of smolts at ocean entry | Number of juveniles at Chipps, monthly and annually by watershed, divided into four size classes |
| Average number of adults spawning in tributaries | Number of annual spawners above dam |
| Proportion of suitable rearing habitat that is in tributaries | Rearing habitat in square meters, converted to acres (instream and floodplain), monthly and annually by watershed |
| Number of tributaries above Shasta Dam with accessible spawning and rearing habitat | Spawning habitat, monthly and annually by watershed; Rearing habitat in square meters, converted to acres (instream and floodplain), monthly and annually by watershed |

## Constructed Scales and Expert Judgment

Several of the objectives and performance metrics identified for this study were not amenable to quantitative modeling in the timeframe of this study, using the modeling tools discussed above. For those metrics, expert judgment was required to estimate consequences. The use of expert judgment for the non-modeled metrics ensured that the full suite of within-scope objectives identified as important by the participants were considered in the evaluation and comparison of alternatives. For the metrics that were not applicable to modeling, the SDM team developed constructed scales to be used to estimate the consequences of each alternative, and SDM participants were given an opportunity to review the scales and provide recommendations. Table 4 and Table 5 show those constructed scales.

### Table 4. Constructed Scales for Metrics Requiring Expert Judgment: Fisheries Metrics

| Objective | Best Performance | Good Performance | Neutral Performance | Lowest Performance |
|---|---|---|---|---|
| **Ability of WRCS to live their natural life cycle** | **Decreases** human interventions (e.g., hatchery, transport, handling, or infrastructure operations) **by ≥50%** and successfully reestablishes migration, spawning, and rearing processes in historic habitat. | **Decreases** human interventions (e.g., hatchery, transport, handling, or infrastructure operations) **by ≥10%** OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | **No change** in human interventions (e.g., hatchery, transport, handling, or infrastructure operations) **within ±10%** | **Increases** human interventions (e.g., hatchery, transport, handling, or infrastructure operations) **by ≥10%** |
| **Avoid or minimize adverse impacts to fall-run Chinook salmon** | **Increases** suitable spawning/rearing habitat or survival for fall-run Chinook by **≥5%** | N/A | **No change** in suitable spawning/rearing habitat or survival for fall-run Chinook **within ±5%** | **Decreases** suitable spawning/rearing habitat or survival for fall-run Chinook by **≥5%** |
| **Minimize adverse impacts on other listed fish species** | **Increases** habitat or survival for one or more listed fish species by **≥5%** | N/A | **No change** in habitat or survival for other listed fish species by within **±5%** | **Decreases** habitat or survival for one or more listed fish species by **≥5%** |

Key: N/A = not applicable

### Table 5. Constructed Scales for Metrics Requiring Expert Judgment: Time and Cost Metrics

| Objective | Best Performance | 2nd Best Performance | 3rd Best Performance | 4th Best Performance | 5th Best Performance | 2nd Lowest Performance | Lowest Performance |
|---|---|---|---|---|---|---|---|
| **Minimize Time to Implement** | Less than 1 year | 1 to 5 years | N/A | N/A | N/A | 5 to 10 years | More than 10 years |
| **Minimize Time to Benefits** | Less than 1 year | 1 to 5 years | N/A | N/A | N/A | 5 to 10 years | More than 10 years |
| **Minimize Cost** | Less than $1 million | $1 million to $10 million | $10 million to $50 million | $50 million to $100 million | $100 million to $500 million | $500 million to $1 billion | More than $1 billion |

Key: N/A = not applicable

### Objectives Not Considered in this SDM Process

There are two types of objectives that are not represented in the consequences assessment described below: non-differentiating objectives and objectives relevant to different problem scopes.

Participants identified "Avoid or minimize adverse impacts on water quality in the Delta" as an important objective to consider when evaluating facilities and habitat actions aimed at improving outcomes for winter-run Chinook salmon. This objective was carried forward in the analysis until it was determined that none of the proposed actions or portfolios would have any effect, adverse or positive, on water quality in the Delta. At that point it was removed from the analysis and the summary, to reduce the dimensionality of the results. It remains important to at least one participant and could be added back into a future analysis if actions were proposed that did have the potential to affect water quality.

Participants also identified objectives that the SDM team determined to be potentially relevant to different problem framings, but not applicable to the kinds of alternatives that could be proposed given the problem statement. Any of these objectives might be useful in future studies. They include:

- Objectives related to changing flows, which were out of scope because they imply a change in Shasta Dam operations. Examples included: increase water deliveries to users, increase instream flows for salmon, increase hydropower generation, increase natural water flows, maximize benefits to coastal communities.

- Objectives related to information collection and reducing scientific uncertainties. Reducing uncertainty is a valuable activity that improves understanding and enables better and more informed future analyses. Actions to reduce uncertainty, however, were not the focus of this study. Examples included: Reduce uncertainty related to early life history survival, and to pathogen-related mortality.

- Objectives related to how the evaluation is conducted or to how actions would be implemented. Examples included: maximize the measurability of benefits, leverage collaborative science, implement adaptive management principles.

## Alternatives

The alternatives evaluated and compared in this study are portfolios of actions rather than single actions, which allowed for explicit consideration of how individual actions might interact and incorporated judgments from the SDM team and participants about actions that should or should not be considered complementary. As described below, portfolios ranged in size and estimated costs, with the smallest portfolio including only eight unique actions, and the largest portfolios including 35 unique actions.

These portfolios were created through several steps. First, participants were asked to provide their ideas for actions that could be taken to improve outcomes for winter-run Chinook salmon that were within the scope of the study. Each participant developed their ideas independently, and over 150 individual actions were provided. The SDM team took all of those ideas that were consistent with the scope of the problem statement, identified and set aside for future consideration actions that were pure study or uncertainty reduction activities, organized the remaining actions into action groups based on location or type of action, and then combined individual actions that were similar or mutually dependent into a set of 40 unique actions. A few unique actions were ultimately excluded from the evaluation because they could not be defined with enough clarity to allow modeling within the SDM schedule (e.g., purchase water in dry years to supplement in-stream flows). Table 7 provides a short description of each of the unique actions, organized by the following action groups:

- Above Shasta Dam (ASD). Actions that directly affect or enable restored habitat, access to habitat, and species reintroduction above Shasta Dam, including to the McCloud River.
- Facilities (F). New facilities or modifications to existing water management facilities, excluding hatchery actions.
- Hatcheries (H). Actions related to hatchery practices or upgrades that are not directly linked to McCloud River or Battle Creek reintroductions.
- Sacramento River (SR). Actions on the Sacramento River that directly affect or enable restored habitat, reduced predation, or other improved outcomes.
- Battle Creek (BC). Actions that directly affect or enable restored habitat, access to habitat, cold water conservation, and species reintroduction in Battle Creek.
- Other (O). Actions not directly related to the other action groups.

Unique actions were grouped into portfolios for detailed evaluation and comparison. The portfolios are described in Table 7, and the details of which unique actions are part of each portfolio are shown in Table 8. The SDM team initially proposed eight portfolios for consideration by the participants (1 through 8 in Table 7), and each participant was encouraged to submit additional portfolios for consideration. In response to participant submission, six additional portfolios were included(9 through 14 in Table 7). Those 14 portfolios were evaluated in the consequence assessment step of this SDM study.

**Table 6. Description of Unique Actions**

| Identifier | Unique Action | Short Description |
|---|---|---|
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | Reintroduce excess WRCS eggs in optimal habitats and nature-based incubation systems in McCloud River and other tributaries to allow juvenile salmon to better imprint on habitat waters and grow larger and stronger before outmigration. |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | Fund an increased level of effort for agencies to reduce the potential for illegal harvest and poaching |
| ASD-3 | Release hatchery fry into upper McCloud | Unfed fry provided by LSNFH spawning excess adult winter-run Chinook salmon will be released in the Upper McCloud River basin. The UM provides a variety of accessible, high quality rearing habitat. After rearing in the upper McCloud River (for several months or longer) emigrating juvenile winter-run will be captured with traps operated where the upper McCloud River enters Lake McCloud. Captured juveniles would be held temporarily and then transferred as needed for release into the Sacramento River near Redding. The project will begin with 80,000 unfed fry, but could be expanded (up to 500,000) once successful juvenile rearing and relatively high outmigrant capture efficiency is demonstrated (>25%). Locations for fry release upstream of Lake McCloud will depend on hydrologic conditions. In most years, fry can be released at a variety of locations upstream of McCloud falls. In severe drought years, fry may need to be released downstream of the upper McCloud Falls. |
| ASD-4 | Release hatchery fry into lower McCloud | Release unfed fry provided by LSNFH spawning excess adult WRCS in the Lower McCloud River basin (downstream of McCloud Dam). Juveniles would be collected just upstream of where the McCloud River flows into Lake Shasta. Captured juveniles would be held temporarily and then transferred as needed for release into the Sacramento River near Redding. The project will begin with 80,000 unfed fry, but could be expanded (up to 500,000) once successful juvenile rearing and relatively high outmigrant capture efficiency is demonstrated (>25%). |
| ASD-5a | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Capture adult WRCS from the Sacramento River (January through March), collect tissue samples and then transport these fish for release into the lower McCloud River. Collect juveniles in the McCloud River just upstream of Lake Shasta, transport these fish to Sacramento River at Redding for release. |

| Identifier | Unique Action | Short Description |
|---|---|---|
| ASD-5b | Two-way trap and haul into Little Sacramento River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Capture adult WRCS from the Sacramento River (January through March), collect tissue samples and then transport these fish for release into the Little Sacramento River. Collect juveniles in the McCloud River just upstream of Lake Shasta, transport these fish to Sacramento River at Redding for release. |
| ASD-5c | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Capture adult WRCS from the Sacramento River (January through March), collect tissue samples and then transport these fish for release into the lower McCloud River and the Little Sacramento River. Collect juveniles in the McCloud River just upstream of Lake Shasta, transport these fish to Sacramento River at Redding for release. |
| ASD-6 | Volitional passage above Shasta Dam into McCloud River | Construct volitional passage around Shasta Dam to allow salmon to migrate to historic spawning grounds in colder water. All routes will be considered as one option, including a Stillwater Creek Path and Cow Creek - Dry Creek path. Refer to Anchor QEA report on volitional passage structural/operational details. |
| ASD-7 | Remove McCloud Dam | Remove McCloud Dam |
| ASD-8 | Return historic salmon strain from New Zealand | Salmon eggs from the McCloud River and Battle Creek were sent to New Zealand in the late 1800s and early 1900s to establish a salmon fishery where there formerly was none. These salmon hold the genetic profile of historic salmon prior to the construction of Shasta Dam. Must be included in all variants including volitional passage above Shasta. Would require additional costs and time to establish biosecure import facilities. Current approach: modeling tools cannot evaluate integration this salmon strain into broader population, so this unique action will not include any model adjustments. |
| F-1 | Shasta TCD Upgrade/Cold water outlet to access colder water | The TCD Upgrade/Cold Water Outlet project focuses on improving the TCD at Shasta Reservoir to enhance the delivery of cold water downstream, which is critical for the survival of winter-run Chinook salmon during spawning and incubation. The upgrade includes structural modifications to increase efficiency and ensure access to deeper, colder water layers during low reservoir conditions. |
| H-1 | LSNFH modified release practices | Release hatchery-reared salmon in locations or at times that differ from traditional practices to improve survival and support population recovery. This may include releasing fish at different life stages, in alternative river reaches, or under specific environmental conditions to reduce predation, improve imprinting, and enhance ocean survival. |

| Identifier | Unique Action | Short Description |
|---|---|---|
| H-2a | LSNFH facility upgrades | Combines all proposed hatchery upgrades and production improvements, and will be reflected by bookend estimates (high and low) of changes. Major upgrades and improvements reflected include a pathogenic filtration system to allow reintroduction of adult WRCS above Shasta Dam; installation of permanent water chiller to provide the hatchery with cold water during drought years; and electrical and plumbing upgrades. |
| H-2b | Upgrades to Keswick Dam adult collection system | Upgrade Keswick collection facility to facilitate improved ability to collect natural origin brood fish and help to maintain fitness within the integrated (hatchery-natural) winter-run population |
| H-2c | New broodfish collection facility in Upper Sacramento River | Develop expanded capability to collect adult winter-run Chinook salmon for use in conservation hatcheries and for reintroduction efforts. |
| H-3 | CNFH trapping and sorting improvements | Construction of an automated fish sorting and trapping facility to allow for daily real-time sorting that can reduce excess holding/handling and migration delays for WRCS and passage blockage. |
| SR-1 | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | Increase availability of suitable rearing habitat in the upper Sacramento River through levee setbacks and natural process restoration. |
| SR-2a | Physically build and maintain new instream perennial juvenile rearing habitat | Create juvenile rearing habitat to support 10,000 fish to rear from fry to smolts upstream of Red Bluff |
| SR-2b | Artificially enhance existing instream juvenile rearing habitat | This action proposes placing anchored clusters of small diameter deciduous tree limbs (with leaves intact) into portions of the river where comparable natural habitat appears to be limiting. These leafed tree branch clusters will provide cover from predators (birds and fish), but will also provide invertebrate prey that will aggregate to feed on biofilms and leaf shredding organisms. It is expected that each cluster would support growth and survival of several hundred juvenile WRCS (beginning with the fry life stage). |

| Identifier | Unique Action | Short Description |
|---|---|---|
| SR-2c | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | Otolith studies have concluded that WRCS juveniles that rear part of their life in the tributaries return at higher rates as adults than those that do not. Many of the tributaries that they had access to historically have been blocked by impediments such as small irrigation dams, road crossing culverts etc. Many of these impediments have been well documented, and a few even have partial plans and permitting for remediation. The specific actions could include, "complete the fish passage project at Cook and Butcher ditch on Cow Creek", which currently sits at 65% design and permitting. This project would reconnect approximately 7 miles of rearing habitat. This is just one of many tributary reconnection projects that could potentially restore juvenile WRCS access to around 50 miles of important rearing habitat. |
| SR-3 | Build or enhance in-channel spawning habitat | Provide new or enhanced spawning habitat for 200 female adults between Keswick and Clear Creek that increases egg-to-fry survival by 10% relative to background. |
| SR-4a | Reduce predation contact points on Sacramento River | Implement projects to minimize predation at weirs, diversions, and related structures in the Sacramento River. |
| SR-4b | Develop regulations to support a striped bass trophy fishery | Modify existing angling regulations to increase harvest opportunities for smaller striped bass (around 12 to 24 inches) and restrict harvest of larger (greater than 24 inches) and trophy sized bass. This action would benefit juvenile WRCS by reducing the abundance of striped bass within the size range which is most likely to significantly impact survival of juvenile WRCS. |
| SR-5 | Reduce entrainment at Sacramento River diversions | Develop and apply alternative diversion technologies that reduce entrainment. |
| SR-6 | Georgiana Slough bubble curtain | Make permanent the juvenile fish deterrents preventing entrainment in Georgiana Slough |
| SR-8 | Nighttime light reduction on Sundial Bridge and other sources | Negotiate with the City of Redding to reduce the bridge lights over the river to less than 1 lux, between September 1st until February 28 when juvenile winter-run could be present, or whenever they are present in the future. This would decrease predation issues, especially since they let hatchery fish go near by to the Sundial Bridge. Identify the largest 20 light sources between Keswick Dam and Los Molinos and contact each of the light owners (likely cities, Caltrans, and irrigation districts and have them reduce their lights to less than 1 lux. |
| SR-9 | Provide volitional upstream and downstream fish passage at Keswick Dam | Allow WRCS to spawn and rear closer to Shasta Dam where habitat has cooler water temperatures. |

| Identifier | Unique Action | Short Description |
|---|---|---|
| SR-10 | Construct Anderson Cottonwood Irrigation District Water Supply and Fisheries Resiliency Project | The Anderson-Cottonwood Irrigation District Dam impedes movement of WRCS and degrades the quality of spawning habitat in an area of the Sacramento River where more than half of WRCS attempt to spawn. This project would replace the dam with a modern pump station to improve water delivery efficiency, remove a major migratory obstacle, and also enhance upstream spawning and rearing habitat for WRCS. |
| SR-11 | Captive rearing and assisted migration of juveniles in drought years | Provide a temporary refuge for a portion of natural-origin juveniles in years when conditions are predicted to be poor and release them back into the wild. From September to November, capture 10,000 juvenile WRCS (expandable to 100,000 fish over time) at USFWS's Red Bluff Diversion Dam rotary screw traps, transport fish to a contained, protected (from predators) and productive off-channel rearing environment (e.g., artificial floodplain, or net pen). When mean fish size is 90mm or by March (whichever comes first), collect fish from the rearing environment. Apply fin clips and coded wire tags to all fish (parentage-based tagging will not work because parents are unknown). Transfer fish into a boat equipped with continuously recirculating river water. Over 5-7 days, transport fish from Red Bluff to Horseshoe Bay (near Golden Gate Bridge). Fish will be fed natural prey while in transport (cultured dipterans, cladocerans or similar). Fish will be continuously bathed in ambient waters with a clear view of the sky (for imprinting and orientation). Upon arrival at Horseshoe Bay, fish will be transferred into a net pen for approximately 24 hours prior to release. Release will occur on a strong outgoing tide at night.<br>NOTE: When migratory conditions are favorable, some or all of refuge rearing WRCS could be released into the Sacramento River rather than being transported (with imprinting) for downstream release. |
| BC-1 | Control illegal harvest and/or poaching in Battle Creek | Fund an increased level of effort for agencies to reduce the potential for illegal harvest and poaching |
| BC-2 | Battle Creek habitat improvements | Design and implement habitat improvement projects in lower Battle Creek watershed (e.g., levee removal, juvenile rearing habitat, address stranding, riparian restoration, etc.) and upper meadows |
| BC-3 | CNFH water supply intake improvements on Battle Creek | Rehabilitate Intake #2 and #3, add new intake on Battle Creek (would need to be completed before PG&E decommissioning occurs otherwise flows after decommissioning are not suitable for withdrawal into CNFH) |
| BC-5 | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | Barrier removal will add 8 miles of habitat for naturally spawning winter-run and restore fish passage at all flow rates |

| Identifier | Unique Action | Short Description |
|---|---|---|
| BC-6 | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | Change MOU flows on North Fork Battle Creek to unimpaired hydrology, remove hydropower releases coming from South Fork that are artificially attracting fish |
| BC-7 | Limit cold water diversions | Use adaptive management to assess actions either in the Battle Creek Restoration Project or developed by CalTrout and Reclamation to optimize the length of reaches that have suitable temperatures for WRCS. That means conserving cold-water emanating from springs, limiting diversions of cold-water, and even moving cold-water around reaches, using existing PG&E infrastructure or adding new infrastructure, where diversions occur. |
| BC-8 | Battle Creek egg incubation | Place fertilized eggs directly into natural streambed habitats within Battle Creek. This method allows eggs to develop in a more natural environment, improving imprinting and potentially increasing survival rates compared to traditional hatchery rearing. |
| BC-9 | Implement Battle Creek Reintroduction Plan | Build a facility or upgrade CNFH to produce 200,000 smolts per year for release in North Fork Battle Creek. As the adults return over time, only take adults from Battle Creek for producing smolts. |
| O-1 | Improve WRCS Salvage at Tracy and State Fish Collection Facilities | Reduce loss completely at the facility, meaning no fish would be lost and all fish would be salvaged and put back into the Delta. Could potentially be accomplished through different means, including reduced predation within the state and federal facilities, reduced predation within the Clifton Court Forebay, improved transportation of salvaged fishes thus reducing associated mortality in the trucks, additional release sites utilized on a random schedule to frustrate predators that gather near the release sites, or improved screen efficiencies at both facilities through next-generation fish screen research |
| O-2 | Increase distance from shoreline to "International" designation | If the distance from shoreline of the International designation is increased, there could be less fish extracted from the ocean. |
| O-3 | Modify ocean harvest | Modify ocean harvest such that annual impacts (harvest +bycatch mortality) to WRCS (of any age class) do not exceed 15%. |

Key: ACID = Anderson Cottonwood Irrigation District, ASD = Above Shasta Dam, BC = Battle Creek, CNFH = Coleman National Fish Hatchery, F = Facilities, H = Hatcheries, LM = Lower McCloud, LSNFH = Livingston Stone National Fish Hatchery, MOU = memorandum of understanding, O = Other, PG&E = Pacific Gas and Electric Company, SR = Sacramento River, TCD = temperature control device, UM = Upper McCloud, USFWS = United States Fish and Wildlife Service, WRCS = winter-run Chinook salmon

**Table 7. Description of Portfolios**

| Number | Portfolio Name | Short Description |
|---|---|---|
| 1 | All Actions with Trap and Haul for All Tributaries | A comprehensive, high-intervention portfolio that implements trap-and-haul approaches across all targeted tributaries while combining them with habitat, hatchery, and facilities improvements. This portfolio maximizes geographic redundancy and rapid reintroduction. |
| 2 | All Actions with Trap and Haul for McCloud River | Focuses on above-Shasta recovery by prioritizing trap-and-haul exclusively for the McCloud River while retaining a broad suite of hatchery, habitat, and mainstem actions. Represents a more geographically focused version of Portfolio 1. |
| 3 | All Actions with Shasta Volitional Passage | Centers on constructing volitional passage around Shasta Dam and fully enabling upstream migration. Other actions complement this new migratory pathway. Reflects the highest long-term structural investment and emphasizes natural life-cycle restoration. |
| 4 | Population Enhancement Below Shasta | Invests heavily in mainstem Sacramento River actions - habitat, temperature management, predation reduction, and rearing improvements - while deprioritizing above-Shasta interventions. Aims to strengthen the existing population without major structural changes. |
| 5 | Battle Creek + Hatchery Actions | Pairs Battle Creek restoration, reintroduction actions, and CNFS and LSNFH upgrades. Maximizes production stability and spatial redundancy via Battle Creek while improving hatchery reliability and genetic management. |
| 6 | Mainstem + Hatchery Actions | Emphasizes actions in the mainstem Sacramento River and hatchery system without pursuing above-Shasta reintroduction. A moderate-cost, operations-adjacent portfolio that addresses limiting factors downstream of Keswick. |
| 7 | Implementable Within 5 years | A near-term portfolio composed only of actions that can be deployed within the next 5 years. Reduces reliance on long-term infrastructure and focuses on feasibility, permitting readiness, and rapid biological benefit. |
| 8 | All Actions with estimated costs greater than $10 million | Low-cost portfolio prioritizing financially accessible actions. Designed to be implementable under constrained budgets while still supporting rearing, passage, and hatchery functions. |
| 9 | NTLHF | Selects actions with high feasibility, low controversy, and quick implementation timelines. A pragmatic entry point for early SDM wins with clear biological upside and low risk. A “no-regrets” portfolio that emphasizes actions with lowest risk for future delays |

| Number | Portfolio Name | Short Description |
|---|---|---|
| 10 | Battle Creek Actions Only | Focuses exclusively on Battle Creek as a secondary population stronghold, leveraging existing infrastructure, restoration momentum, and cold-water reliability. Enhances resilience through spatial structure. |
| 11 | NTLHF with Enhanced Habitat Access | Builds off Portfolio 9 (NTLHF) but adds targeted access-focused habitat actions (e.g., removing barriers, light reduction, small-scale habitat enhancements) to compound early-action gains. |
| 12 | Drought Mitigation | Targets actions that directly buffer WRCS during drought years, including captive rearing, cold-water management, hatchery upgrades, and high-impact survival interventions. Focuses on resilience to extreme hydrology. |
| 13 | Hatchery Influence and Production | Concentrates on hatchery modernization, broodstock management, genetic health, trap upgrades, and release strategies. Designed to stabilize production and reduce risk during low in river survival periods. |
| 14 | Habitat Enhancement and Restoration | A habitat-focused portfolio spanning floodplains, in-channel improvements, tributaries, and rearing habitat expansion. Minimizes structural actions and emphasizes ecological processes and habitat quantity/quality. |

Key: CNFH = Coleman National Fish Hatchery, LSNFH = Livingston Stone National Fish Hatchery, NTLHF = Near-Term Low Hanging Fruit, WRCS = winter-run Chinook salmon

**Table 8. Crosswalk of Unique Actions to Portfolios**

| Unique Action Identifier | Unique Action Short Description | Portfolio Identifier Number and Description | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1. All Actions with Trap and Haul for All Tributaries | 2. All Actions with Trap and Haul for McCloud River | 3. All Actions with Shasta Volitional Passage | 4. Population Enhancement Below Shasta | 5. Battle Creek + Hatchery Actions | 6. Mainstem + Hatchery Actions | 7. Implementable Within 5 years | 8. All Actions with estimated costs < $10M | 9. NTLHF | 10. Battle Creek Actions Only | 11. NTLHF with Enhanced Habitat Access | 12. Drought Mitigation | 13. Hatchery Influence and Production | 14. Habitat Enhancement and Restoration |
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | X | X | -- | -- | -- | -- | X | X | -- | -- | -- | X | X | -- |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | X | X | X | -- | -- | -- | X | X | -- | -- | -- | -- | -- | -- |
| ASD-3 | Release hatchery fry into upper McCloud | X | X | -- | -- | -- | -- | -- | X | X | -- | X | X | -- | -- |
| ASD-4 | Release hatchery fry into lower McCloud | X | X | -- | -- | -- | -- | -- | X | X | -- | X | X | -- | -- |
| ASD-5a | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | -- | X | -- | -- | -- | -- | -- | -- | -- | -- | X | X | -- | X |
| ASD-5b | Two-way trap and haul into Little Sacramento River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| ASD-5c | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| ASD-6 | Volitional passage above Shasta Dam into McCloud River | -- | -- | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| ASD-7 | Remove McCloud Dam | -- | -- | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| ASD-8 | Return historic salmon strain from New Zealand | -- | -- | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| F-1 | Shasta TCD Upgrade/Cold water outlet to access colder water | X | X | X | X | -- | X | -- | -- | -- | -- | -- | -- | -- | -- |
| H-1 | LSNFH modified release practices | X | X | X | X | X | X | X | X | -- | -- | -- | -- | X | -- |
| H-2a | LSNFH facility upgrades | X | X | X | X | X | X | X | -- | X | -- | X | -- | X | -- |
| H-2b | Upgrades to Keswick Dam adult collection system | X | X | X | X | X | X | X | -- | -- | -- | -- | -- | X | -- |

| Unique Action Identifier | Unique Action Short Description | Portfolio Identifier Number and Description | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1. All Actions with Trap and Haul for All Tributaries | 2. All Actions with Trap and Haul for McCloud River | 3. All Actions with Shasta Volitional Passage | 4. Population Enhancement Below Shasta | 5. Battle Creek + Hatchery Actions | 6. Mainstem + Hatchery Actions | 7. Implementable Within 5 years | 8. All Actions with estimated costs < $10M | 9. NTLHF | 10. Battle Creek Actions Only | 11. NTLHF with Enhanced Habitat Access | 12. Drought Mitigation | 13. Hatchery Influence and Production | 14. Habitat Enhancement and Restoration |
| H-2c | New broodfish collection facility in Upper Sacramento River | X | X | X | X | X | X | X | X | X | -- | X | -- | X | -- |
| H-3 | CNFH trapping and sorting improvements | X | X | X | X | X | X | X | -- | -- | X | -- | -- | X | -- |
| SR-1 | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | X | X | X | X | -- | X | X | -- | -- | -- | -- | -- | -- | X |
| SR-2a | Physically build and maintain new instream perennial juvenile rearing habitat | X | X | X | X | -- | X | X | -- | -- | -- | -- | -- | -- | X |
| SR-2b | Artificially enhance existing instream juvenile rearing habitat | X | X | X | X | -- | X | X | X | X | -- | X | -- | -- | X |
| SR-2c | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | X | X | X | X | -- | X | X | -- | -- | -- | -- | -- | -- | X |
| SR-3 | Build or enhance in-channel spawning habitat | X | X | X | X | -- | X | X | -- | -- | -- | -- | X | -- | X |
| SR-4a | Reduce predation contact points on Sacramento River | X | X | X | X | -- | X | -- | -- | -- | -- | -- | X | -- | -- |
| SR-4b | Develop regulations to support a striped bass trophy fishery | X | X | X | X | -- | X | X | X | X | -- | X | -- | -- | -- |
| SR-5 | Reduce entrainment at Sacramento River diversions | X | X | X | X | -- | X | X | -- | -- | -- | -- | -- | -- | -- |
| SR-6 | Georgiana Slough bubble curtain | X | X | X | X | -- | X | X | -- | -- | -- | -- | -- | -- | -- |
| SR-8 | Night time light reduction on Sundial Bridge and other sources | X | X | X | X | -- | X | X | X | -- | -- | -- | -- | -- | -- |
| SR-9 | Provide volitional upstream and downstream fish passage at Keswick Dam | X | X | X | X | -- | X | -- | -- | -- | -- | -- | -- | -- | -- |
| SR-10 | Construct Anderson Cottonwood Irrigation District Water Supply & Fisheries Resiliency Project | X | X | X | X | -- | X | X | -- | -- | -- | X | X | -- | X |

| Unique Action Identifier | Unique Action Short Description | Portfolio Identifier Number and Description | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1. All Actions with Trap and Haul for All Tributaries | 2. All Actions with Trap and Haul for McCloud River | 3. All Actions with Shasta Volitional Passage | 4. Population Enhancement Below Shasta | 5. Battle Creek + Hatchery Actions | 6. Mainstem + Hatchery Actions | 7. Implementable Within 5 years | 8. All Actions with estimated costs < $10M | 9. NTLHF | 10. Battle Creek Actions Only | 11. NTLHF with Enhanced Habitat Access | 12. Drought Mitigation | 13. Hatchery Influence and Production | 14. Habitat Enhancement and Restoration |
| SR-11 | Captive rearing and assisted migration of juveniles in drought years | X | X | X | X | -- | X | X | X | X | -- | X | X | X | -- |
| BC-1 | Control illegal harvest and/or poaching in Battle Creek | X | X | X | X | X | -- | X | X | -- | X | -- | -- | -- | -- |
| BC-2 | Battle Creek habitat improvements | X | X | X | X | X | -- | X | -- | -- | X | -- | -- | -- | X |
| BC-3 | CNFH water supply intake improvements on Battle Creek | X | X | X | X | X | -- | X | X | -- | X | -- | -- | -- | -- |
| BC-5 | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | X | X | X | X | X | -- | X | X | -- | X | -- | -- | -- | X |
| BC-6 | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | X | X | X | X | X | -- | -- | -- | -- | X | -- | -- | -- | X |
| BC-7 | Limit cold water diversions | X | X | X | X | X | -- | X | -- | -- | X | -- | X | -- | X |
| BC-8 | Battle Creek egg incubation | X | X | X | X | X | -- | X | X | -- | X | -- | X | X | -- |
| BC-9 | Implement Battle Creek Reintroduction Plan | X | X | X | X | X | -- | X | -- | -- | X | -- | -- | -- | -- |
| O-1 | Improve WRCS Salvage at Tracy & State Fish Collection Facilities | X | X | X | X | -- | X | -- | -- | -- | -- | -- | -- | -- | -- |
| O-2 | Increase distance from shoreline to "International" designation | X | X | X | X | -- | X | X | X | -- | -- | -- | -- | -- | -- |
| O-3 | Modify ocean harvest | X | X | X | X | -- | X | X | X | X | -- | X | -- | -- | -- |
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | X | X | -- | -- | -- | -- | X | X | -- | -- | -- | X | X | -- |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | X | X | X | -- | -- | -- | X | X | -- | -- | -- | -- | -- | -- |

Key:
-- = unique action is not included in the listed portfolio
LSNFH = Livingston Stone National Fish Hatchery
NTLHF = Near-Term Low Hanging Fruit
TCD = temperature control device
X = unique action is included in the listed portfolio
CNFH = Coleman National Fish Hatchery
M = million
PG&E = Pacific Gas and Electric Company
WRCS = winter-run Chinook salmon

# Consequence Assessment

In response to participant feedback, different approaches were taken to estimate the consequences of each portfolio using metrics that could be modeled by the Winter-run model, and using metrics requiring expert judgment (Table 2). The following sections detail the consequences of these two approaches.

## Consequence Estimates Developed Using the Winter-run Model

The modeling team evaluated both the unique actions and the portfolios with the Winter-run model. Unique actions were modeled first, enabling the team to incrementally adjust the model and model parameters to ensure that the model could reflect the benefits of actions. The approach and the specific parameter changes used to capture the effects of each unique action were discussed with interested participants, and suggestions from those participants improved the modeling of the unique actions. Portfolio level consequences were then calculated by considering the combined effects of all of the actions within each portfolio. Appendix B describes how actions were modeled, as well as modifications made when actions were grouped within portfolios. Appendix C describes post-processing completed of the HEC-5Q model results to represent one unique action.

Table 9 provides the estimated consequences for the baseline and portfolios on each of the metrics derived from the winter-run modeling results, in raw form. Insights directly from this table include:

- All portfolios have the same consequence for decline, for catastrophic decline, and for number of independent populations. Thus, these metrics do not discriminate among the portfolios.

- Almost all portfolios perform better than the baseline on average annual returns; average annual number of outmigrating juveniles leaving the upper Sacramento; annual average number of smolts reaching the ocean; average number of adults spawning in tributaries; and proportion of total suitable rearing habitat that is in tributaries.

- All portfolios that include population enhancement perform worse than the baseline on the proportion of hatchery-origin spawners (pHOS) and on cohort replacement rate (CRR).

These results are described in more detail in the Discussion section.

**Table 9. Consequences of Each Portfolio on Modeled Metrics**

| Portfolio | Average annual returns of WRCS | Average pHOS | Decline[1] | Catastrophic decline[2] | Average annual number of outmigrating juveniles leaving the Upper Sacramento | Average annual number of smolts reaching the ocean | Average annual CRR | Average annual juvenile size diversity at ocean entry | Average annual number of adults spawning in tributaries (Battle Creek and Above Shasta Dam) | Proportion of total suitable rearing habitat that is in tributaries | Number of tributaries above Shasta Dam with accessible spawning and rearing habitat | Number of independent populations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline | 1,235 | 0.25 | 3 | 0 | 1,318,611 | 15233 | 0.917 | 0.52 | 0 | 0.082 | 0 | 0 |
| 1. All Actions with Trap and Haul for All Tributaries | 2,961 | 0.53 | 3 | 0 | 2,139,303 | 49,596 | 0.557 | 0.49 | 1,344 | 0.868 | 2 | 0 |
| 2. All Actions with Trap and Haul for McCloud River | 2,995 | 0.52 | 3 | 0 | 2,464,142 | 49,535 | 0.575 | 0.5 | 1,350 | 0.541 | 1 | 0 |
| 3. All Actions with Shasta Volitional Passage | 4,457 | 0.52 | 3 | 0 | 4,202,855 | 72,972 | 0.574 | 0.55 | 1,399 | 0.541 | 1 | 0 |
| 4. Population Enhancement Below Shasta | 2,431 | 0.54 | 3 | 0 | 2,179,901 | 43,320 | 0.557 | 0.46 | 968 | 0.209 | 0 | 0 |
| 5. Battle Creek + Hatchery Actions | 1,798 | 0.55 | 3 | 0 | 1,490,030 | 24,396 | 0.53 | 0.3 | 724 | 0.478 | 0 | 0 |
| 6. Mainstem + Hatchery Actions | 1,436 | 0.24 | 3 | 0 | 2,146,970 | 33,057 | 0.928 | 0.41 | 0 | 0.024 | 0 | 0 |
| 7. Implementable Within 5 years | 2,429 | 0.54 | 3 | 0 | 2,182,701 | 43,835 | 0.559 | 0.47 | 926 | 0.209 | 0 | 0 |
| 8. All Actions with estimated costs < $10 million | 2,462 | 0.55 | 3 | 0 | 1,900,287 | 42,252 | 0.555 | 0.46 | 920 | 0.669 | 1 | 0 |
| 9. NTLHF | 1,257 | 0.26 | 3 | 0 | 1,567,060 | 29,496 | 0.897 | 0.43 | 0 | 0.656 | 1 | 0 |
| 10. Battle Creek Actions Only | 1,951 | 0.53 | 3 | 0 | 1,308,776 | 23,283 | 0.566 | 0.52 | 729 | 0.478 | 0 | 0 |
| 11. NTLHF with Enhanced Habitat Access | 1,543 | 0.27 | 3 | 0 | 1,681,463 | 32,183 | 0.867 | 0.48 | 286 | 0.543 | 1 | 0 |
| 12. Drought Mitigation | 2,681 | 0.48 | 3 | 0 | 1,971,181 | 42,468 | 0.601 | 0.49 | 1,116 | 0.62 | 1 | 0 |
| 13. Hatchery Influence and Production | 1,922 | 0.55 | 3 | 0 | 1,600,308 | 38,093 | 0.517 | 0.44 | 773 | 0.082 | 0 | 0 |
| 14. Habitat Enhancement and Restoration | 1,568 | 0.24 | 3 | 0 | 1,607,813 | 18,696 | 0.896 | 0.58 | 290 | 0.475 | 1 | 0 |

Notes:
[1] Calculated as the maximum number of consecutive years in the 20-year modeling period where year-over-year returns declined by 10% or more.
[2] Calculated as the number of years in the modeling period where the population decline over the preceding 3-year period was a factor of 10 or greater.
Key:
CRR = cohort replacement rate
LSNFH = Livingston Stone National Fish Hatchery
NTLHF = near-term low hanging fruit
pHOS = proportion of hatchery origin spawner
WRCS = winter-run Chinook salmon

### Consequence Estimates Developed Using Expert Judgment

Developing consequence estimates for the metrics where expert judgment was required followed the same steps as for the modeled consequences. The SDM team used the constructed scales shown in Table 4 to evaluate the consequences for each individual action, and participants were asked to provide review and comment on those estimates. Detailed ratings for each individual action along with supporting rationale are provided in Appendix D. Portfolio-level consequences were estimated by considering the individual actions within each portfolio and the consequences of those individual actions.

Table 10 shows the estimated consequences of each portfolio on each of the metrics requiring expert judgement. Insights directly from this table include:

- All portfolios decrease human intervention in the winter-run Chinook salmon lifecycle, to varying degrees.
- All but one portfolio have positive effects on fall-run Chinook salmon and on other listed fish species.
- All portfolios have a basic estimate of 1 to 5 years for implementation and 1 to 5 years from implementation to realization of local scale benefits.

These results are described in more detail in the Discussion.

**Table 10. Consequences of Each Portfolio on Metrics Requiring Expert Judgment**

| Portfolio | Ability of WRCS to live their natural lifecycle | Avoid or minimize adverse impacts to fall-run Chinook salmon | Minimize adverse impacts on other listed fish species | Time to implementation | Time to benefits | Total costs |
|---|---|---|---|---|---|---|
| 1. All Actions with Trap and Haul for All Tributaries | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | >$1B |
| 2. All Actions with Trap and Haul for McCloud River | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | >$1B |
| 3. All Actions with Shasta Volitional Passage | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | >$1B |
| 4. Population Enhancement Below Shasta | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | >$1B |
| 5. Battle Creek + Hatchery Actions | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | $500M - $1B |
| 6. Mainstem + Hatchery Actions | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | >$1B |
| 7. Implementable Within 5 years | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | >$1B |
| 8. All Actions with estimated costs < $10M | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | $50M - $100M |
| 9. NTLHF | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | $100M - $500M |
| 10. Battle Creek Actions Only | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | $100M - $500M |
| 11. NTLHF with Enhanced Habitat Access | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | $100M - $500M |
| 12. Drought Mitigation | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | $100M - $500M |
| 13. Hatchery Influence and Production | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | No change in habitat or survival for other listed fish species by within ±5% | 1–5 years | 1–5 years | $100M - $500M |
| 14. Habitat Enhancement and Restoration | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Increases habitat or survival for one or more listed fish species by ≥5% | 1–5 years | 1–5 years | >$1B |

Key: B = billion, LSNFH = Livingston Stone National Fish Hatchery, M = million, NTLHF = Near-Term Low Hanging Fruit, WRCS = winter-run Chinook salmon

## Tradeoffs

As illustrated by the consequence estimates shown above, portfolios have a range of consequences and no portfolio is better than all others on all metrics. Therefore, to compare the portfolios it was necessary to consider the tradeoffs among the metrics.

### Swing Weighting of Objectives and Metrics

Participants were given the opportunity to provide a set of weights on the objectives and metrics by answering a series of questions about the relative value to them and their organization of specific changes in performance on each metric. This process is known as "swing weighting" (Borcherding et al. 1991). Answers to those questions were translated into a normalized weight for each metric. Participants provided input via a spreadsheet in which they first ranked (from high to low) the different objectives, and then assigned relative value to those objectives (from 0 to 100) based on their preferences.

Because of the large number of metrics, the SDM team exploited the hierarchical nature of the objectives and metrics to simplify the questions that participants needed to answer to provide a full set of weights. Specifically, changes in metrics associated with each individual objective (see Table 2) were first considered relative to each other, and then changes in performance across all the metrics associated with an objective were considered jointly.

Swing weights were provided by 11 out of 12 participant groups, and are shown in Table 11. Participants are lettered A – K.

### Similarities and Differences in Participant Weights

To gain further insight into participant weighting, weight sets were organized and plotted for metrics directly related to objectives describing outcomes for winter-run Chinook salmon (Figure 12) and improvements in objectives related to other impacts of actions and characteristics of the actions themselves (Figure 13). Across all participants, most weight was assigned to the metrics directly related to outcomes for winter-run Chinook salmon. As shown in Figure 12, the cumulative weight on those five objectives was between 0.68 and 1. The figure also highlights several similarities and a few significant differences in perspectives:

- Maximizing the ability of winter-run Chinook salmon to live their natural life cycle was highly weighted by a few participants (up to a weight of 0.33), but weighted low for most others.

- All participants had some weight on the objective of tributaries supporting winter-run Chinook salmon, but for one participant it was by far the most highly weighted objective.

- One participant put all weight on only three objectives.

- Across the objectives that were calculated based on modeling results, there are two common patterns:

- Improvements on all four objectives are about equally important (Participants B, D, K).
- Improvement in abundance is most important, followed by improvements in tributaries supporting winter-run Chinook salmon (E, G, I, A).

Figure 13 compares the weights on improvements in objectives related to other impacts of actions and characteristics of the actions themselves. There is less commonality among participants on these objectives, although some patterns are found:

- Several participants have almost equal weight on these three objectives (participants K, B, I, G).
- Two participants (A, H) put much higher weight on timeliness than on the other two objectives.
- There are two perspectives on the weight for minimizing costs: about half the participants gave it a weight above 0.1, and half weighted it much less.

**Table 11. Swing Weighting Results: Calculated Weight on Each Metric and Objective for Different Participants**

| Objective | Performance Metric | Swing: Poor to High Performing Values | Individual Weight Sets | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | H | I | J | K |
| **Increase abundance** | Average annual adult returns of WRCS | 100 to 25,000 | 0.11 | 0.04 | 0.08 | 0.05 | 0.06 | 0 | 0.09 | 0.03 | 0.06 | 0.05 | 0.08 |
| | Average percent of adult returns that are hatchery origin | 100% to 5% | 0.09 | 0.04 | 0 | 0.01 | 0.02 | 0 | 0.02 | 0.01 | 0.05 | 0.05 | 0.04 |
| | Decline: Number of consecutive years with ≥ 10% annual population decline, over 20-year modeling period | 20 yrs to 0 yrs | 0.03 | 0.04 | 0.01 | 0.05 | 0.06 | 0 | 0.05 | 0.01 | 0.05 | 0.06 | 0.02 |
| | Catastrophic decline: number of years with a 3-year population decline of an order of magnitude or more, over 20-year modeling period | 10 to 0 | 0.03 | 0.04 | 0.03 | 0.05 | 0.08 | 0 | 0.05 | 0.02 | 0.05 | 0.08 | 0.02 |
| | | **Subtotal:** | **0.26** | **0.16** | **0.12** | **0.16** | **0.22** | **0** | **0.21** | **0.07** | **0.21** | **0.24** | **0.16** |
| **Increase productivity** | Average annual number of outmigrating juveniles leaving the Upper Sacramento | 30,000 to 4 million | 0.01 | 0.06 | 0.02 | 0.05 | 0.03 | 0.11 | 0.05 | 0.02 | 0.05 | 0.04 | 0.05 |
| | Average annual number of smolts reaching the ocean | 15,000 to 1.2 million | 0.05 | 0.06 | 0.02 | 0.06 | 0.05 | 0.15 | 0.06 | 0.05 | 0.06 | 0.06 | 0.07 |
| | Average annual CRR | 0.3 to 5 | 0.04 | 0.03 | 0.02 | 0.04 | 0.07 | 0.07 | 0.04 | 0.03 | 0.04 | 0.11 | 0.03 |
| | | **Subtotal** | **0.1** | **0.15** | **0.06** | **0.15** | **0.15** | **0.33** | **0.15** | **0.1** | **0.15** | **0.21** | **0.15** |
| **Increase life history diversity** | Average percent of returns that are hatchery origin | 100% to 5% | 0.06 | 0.11 | 0 | 0.03 | 0.03 | 0 | 0.08 | 0.07 | 0.08 | 0.08 | 0.09 |
| | Diversity of size of WRCS leaving the Upper Sacramento Watershed (Average annual Shannon diversity index, see note below) | 0 to 1.4 | 0.02 | 0.03 | 0.01 | 0.12 | 0.11 | 0 | 0.02 | 0.14 | 0.02 | 0.04 | 0.02 |
| | | **Subtotal: Life history diversity** | **0.08** | **0.14** | **0.01** | **0.15** | **0.14** | **0** | **0.1** | **0.21** | **0.1** | **0.12** | **0.11** |
| **Increase tributary support** | Average annual number of adults spawning in tributaries (Battle Creek and Above Shasta Dam) | 0 to 50,000 | 0.08 | 0.03 | 0.47 | 0.05 | 0.05 | 0.11 | 0.06 | 0.05 | 0.06 | 0.04 | 0.03 |
| | Proportion of total suitable rearing habitat that is in tributaries | 0 to greater than 0.5 | 0.04 | 0.04 | 0.07 | 0.04 | 0.04 | 0 | 0.03 | 0.02 | 0.03 | 0.01 | 0.04 |
| | Number of tributaries above Shasta Dam with accessible spawning and rearing habitat for WRCS | 0 to 2 | 0.01 | 0.03 | 0.09 | 0.01 | 0.02 | 0.11 | 0.03 | 0.01 | 0.03 | 0.03 | 0.03 |
| | Number of independent WRCS populations (meeting the criteria listed below) | 0 to 4 | 0.1 | 0.04 | 0 | 0.05 | 0.06 | 0.11 | 0.05 | 0.04 | 0.05 | 0.06 | 0.04 |
| | | **Subtotal: Tributaries supporting WRCS** | **0.23** | **0.14** | **0.63** | **0.15** | **0.17** | **0.33** | **0.17** | **0.12** | **0.17** | **0.14** | **0.14** |
| **Increase the ability of WRCS to live their natural life cycle** | Constructed scale: change to the amount of human intervention in the life cycle | Increase human intervention by >10% to Decrease human intervention by > 50% | **0.1** | **0.04** | **0** | **0.07** | **0.04** | **0.33** | **0.03** | **0.29** | **0.05** | **0.18** | **0.02** |
| **Avoid or minimize adverse impacts on fall-run Chinook salmon and Avoid or minimize adverse impacts on other listed fish species** | Change in the amount of habitat or in survival for fall-run Chinook salmon | Decrease habitat or survival by >5% to Increase habitat or survival by >5% | 0.02 | 0.05 | 0.03 | 0.11 | 0.02 | 0 | 0.07 | 0.01 | 0.06 | 0.01 | 0.05 |
| | Change in the amount of habitat or in survival for other listed fish species | Decrease habitat or survival by >5% to Increase habitat or survival by >5% | 0.02 | 0.06 | 0.03 | 0.06 | 0.04 | 0 | 0.06 | 0.01 | 0.05 | 0.02 | 0.07 |
| | | **Subtotal: Avoid/minimize adverse impacts on other species** | **0.04** | **0.11** | **0.06** | **0.17** | **0.06** | **0** | **0.13** | **0.02** | **0.11** | **0.03** | **0.12** |
| **Minimize time to implementation and Minimize time to achieve benefits** | Constructed scale: Estimated time (years) to implementation or completion of construction | < 1 year to > 10 years | 0.02 | 0.05 | 0.04 | 0.06 | 0.01 | 0 | 0.04 | 0.07 | 0.04 | 0.01 | 0.06 |
| | Constructed scale: Estimated time (years) from implementation to realization of local-scale benefits | < 1 year to > 10 years | 0.17 | 0.09 | 0.02 | 0.05 | 0.1 | 0 | 0.07 | 0.11 | 0.07 | 0.01 | 0.09 |
| | | **Subtotal: Timeliness** | **0.19** | **0.14** | **0.06** | **0.11** | **0.11** | **0** | **0.11** | **0.18** | **0.11** | **0.02** | **0.15** |
| **Minimize total cost of actions** | **Constructed scale: Approximate total cost, including construction costs and 20 years of operations and maintenance.** | <$1 million to >$1 billion | **0.03** | **0.14** | **0.03** | **0.04** | **0.11** | **0** | **0.11** | **0.01** | **0.11** | **0.06** | **0.15** |

Key: CRR = cohort replacement rate, WRCS = winter-run Chinook salmon

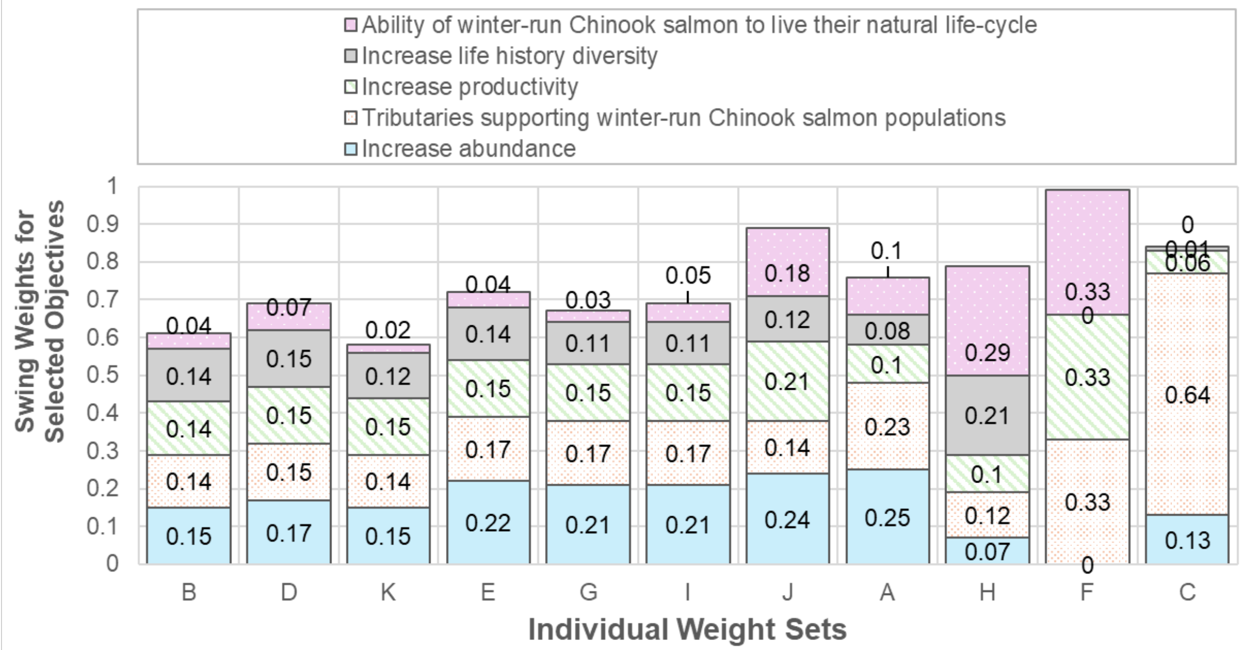



Figure 12. Swing Weights from Eleven Participants for Objectives Directly Related Winter-Run Chinook Salmon

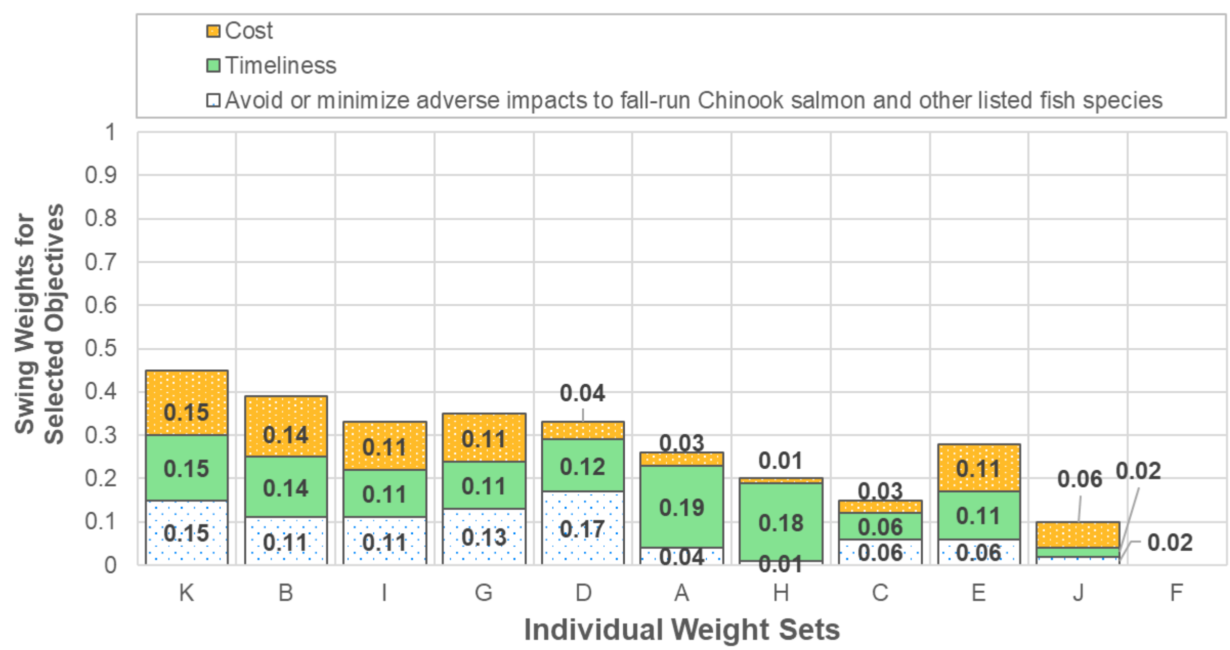



Figure 13. Swing Weights from Eleven Participants for Objectives Related to Other Impacts of Actions and Characteristics of the Actions

## Total Combined Portfolio Values: Combining Consequence Estimates with Swing Weights

A combined value for each portfolio was calculated by: (1) normalizing the raw consequences (Table 9 and Table 10) over the range of the performance for the metric that was used for swing weighting (second column of Table 11), (2) multiplying those normalized consequence estimates by the swing weight assigned to that metric, and (3) summing those weighted, normalized values. The result is a combined value for each portfolio ("portfolio score"), for each different weight set, shown in Table 12.

**Table 12. Combined Portfolio Value (Score) for All Portfolios Considering 11 Different Alternative Weightings**

| Portfolio Number and Name | Portfolio Score by Weight Set | | | | | | | | | | | Average Score | Frequency of Ranking First | Frequency of Ranking Last |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | | | |
| 1. All Actions with Trap and Haul for All Tributaries | 0.492 | 0.521 | **0.338●** | 0.560 | 0.466 | 0.510 | 0.491 | 0.606 | 0.503 | 0.509 | 0.467 | 0.497 | 1 | 0 |
| 2. All Actions with Trap and Haul for McCloud River | 0.490 | 0.513 | 0.295 | 0.561 | 0.460 | 0.464 | 0.482 | 0.605 | 0.494 | 0.500 | 0.458 | 0.484 | 0 | 0 |
| 3. All Actions with Shasta Volitional Passage | 0.495 | 0.538 | 0.307 | **0.586●** | 0.477 | **0.515●** | 0.506 | 0.613 | 0.516 | 0.522 | 0.480 | 0.505 | 2 | 0 |
| 4. Population Enhancement Below Shasta | 0.452 | **0.464○** | 0.202 | 0.522 | 0.417 | 0.399 | 0.439 | 0.578 | **0.451○** | 0.470 | **0.409○** | 0.437 | 0 | 3 |
| 5. Battle Creek + Hatchery Actions | 0.442 | 0.524 | 0.246 | 0.516 | 0.457 | 0.267 | 0.485 | 0.475 | 0.490 | **0.430○** | 0.484 | 0.438 | 0 | 1 |
| 6. Mainstem + Hatchery Actions | 0.482 | 0.494 | **0.164○** | 0.514 | **0.417○** | 0.400 | 0.457 | 0.590 | 0.479 | 0.511 | 0.432 | 0.449 | 0 | 2 |
| 7. Implementable Within 5 years | 0.455 | 0.468 | 0.204 | 0.527 | 0.419 | 0.399 | 0.443 | 0.585 | 0.454 | 0.471 | 0.414 | 0.440 | 0 | 0 |
| 8. All Actions with Estimated Costs Less Than $10 Million | 0.483 | 0.625 | 0.319 | 0.569 | **0.545●** | 0.336 | 0.569 | 0.517 | 0.574 | 0.485 | 0.588 | 0.510 | 1 | 0 |
| 9. Near-term Low Hanging Fruit (NTLHF) | 0.510 | 0.634 | 0.297 | 0.559 | 0.534 | 0.328 | 0.568 | 0.523 | 0.584 | 0.514 | 0.588 | 0.513 | 0 | 0 |
| 10. Battle Creek Actions Only | 0.455 | 0.569 | 0.256 | 0.544 | 0.506 | **0.262○** | 0.520 | 0.498 | 0.526 | 0.456 | 0.530 | 0.466 | 0 | 1 |
| 11. NTLHF with Enhanced Habitat Access | 0.514 | **0.638●** | 0.301 | 0.566 | 0.541 | 0.332 | **0.572●** | 0.530 | **0.586●** | 0.516 | **0.592●** | 0.517 | 4 | 0 |
| 12. Drought Mitigation | 0.486 | 0.610 | 0.313 | 0.563 | 0.533 | 0.339 | 0.557 | 0.516 | 0.563 | 0.488 | 0.570 | 0.503 | 0 | 0 |
| 13. Hatchery Influence/Production | **0.409○** | 0.489 | 0.174 | **0.429○** | 0.444 | 0.271 | **0.437○** | **0.473○** | 0.452 | 0.431 | 0.446 | 0.405 | 0 | 4 |
| 14. Habitat Enhancement and Restoration | **0.514●** | 0.535 | 0.272 | 0.559 | 0.465 | 0.439 | 0.489 | **0.620●** | 0.512 | **0.533●** | 0.472 | 0.492 | 3 | 0 |

Notes: Columns represent results based on the 11 sets of participant swing weights using purple (high values) to yellow (low values) to provide a visual cue to the ordering of the portfolios in each column by value. Bold purple cells with "●" indicate the highest ranked portfolio(s) for that set of weights. Bold yellow cells with "○" indicate the lowest ranked portfolios for that weight set.

Key: LSNFH = Livingston Stone National Fish Hatchery, NTLHF = Near-Term Low Hanging Fruit, WRCS = winter-run Chinook salmon

# 4. Discussion

The SDM team reviewed the consequence assessment and tradeoffs for themes and insights within individual portfolios and across all portfolios. In this section, several individual portfolio scores are highlighted to elaborate on differences across high and low scoring portfolios. Additional observations are provided regarding model assumptions, consequences, and portfolio scores that became apparent when reviewing final results. For reference, refer to Table 6, Table 7, and Table 8 for a description of unique actions, portfolios, and which unique actions were included in each portfolio, respectively.

## Individual Portfolio Differences

Portfolio scores across all weight sets were used to determine the relative performance of each portfolio. The SDM team looked at two criteria for identifying relative performance: how many times a portfolio was the first or last preference of an SDM participant, and the average portfolio score across all weight sets.

### Highest and Lowest Performing Portfolios

The highest performing portfolio was Portfolio 11: NTLHF with Enhanced Habitat Access. Four SDM participant weight sets rated this as the highest scoring portfolio, and it was in the top three highest scoring portfolios for three other SDM participants. This portfolio was comprised of 10 unique actions, which primarily included modest habitat improvements on the Sacramento River coupled with supplementation of the winter-run Chinook salmon population above Shasta. The portfolio did not have any actions in Battle Creek.

The lowest performing portfolio was Portfolio 13: Hatchery influence and production. All weight sets rated this portfolio in the bottom five, and four weight sets had this as the lowest scoring portfolio. This portfolio was focused on supplementation above Shasta Dam, in Battle Creek, and along the Sacramento River, but did not include any habitat-focused actions.

A comparison of the normalized consequences for all metrics across all portfolios is shown in Figure 14 (see Table 3, Table 4, and Table 5 for description of metrics). A comparison of the modeled performance metrics relative to the baseline are shown in Figure 15. Both figures omit metrics that did not contain any variation across portfolios (e.g., incidents of declining population), and Figure 15 also omits metrics that did not have a baseline value (e.g., number of tributaries above Shasta Dam with accessible spawning and rearing habitat). The highest scoring portfolio had higher normalized consequences for nearly every performance metric, and scored higher than all other portfolios for the proportion of total suitable rearing habitat in tributaries. The lowest scoring portfolio had the lowest normalized consequences in six of the fourteen metrics, and was the only portfolio with lower scores on avoiding impacts to other fish species.

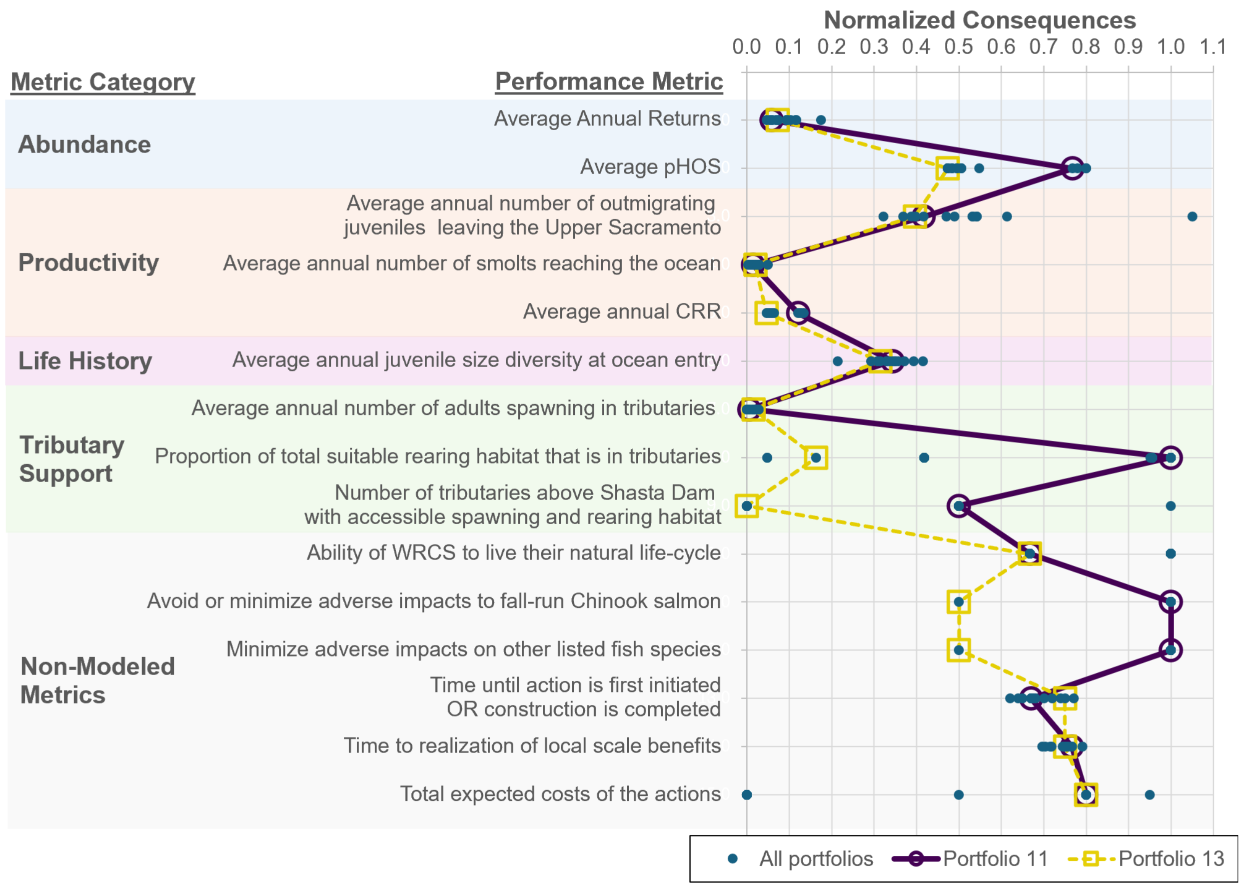



**Figure 14. Normalized Consequences Highlighting the Highest and Lowest Rated Portfolio**

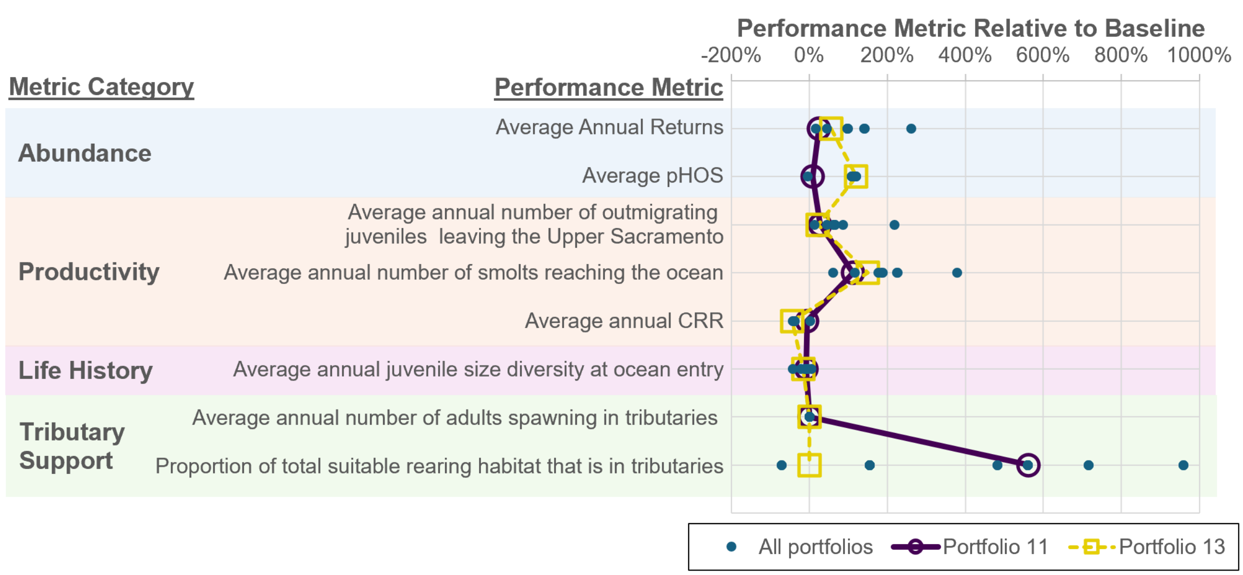



**Figure 15. Portfolio Performance Metrics Relative to the Baseline Highlighting the Highest and Lowest Rated Portfolio**

Considering performance metrics relative to the baseline, the lowest performing portfolio was better than the highest performing portfolio for average annual returns and average annual number of smolts reaching the ocean. The lowest performing portfolio had a higher pHOS and much lower proportion of total suitable rearing habitat in tributaries. For other metrics, both portfolios scored similar relative to the baseline.

The primary differences between the lowest and highest performing portfolios are the highest performing portfolio significantly increased tributary support at the lowest relative increase in pHOS, and the underlying unique actions also improved outcomes for fall-run and other species. They had similar overall estimated costs and time to realize benefits, but the time to construct or implement the actions was relatively longer for the lowest performing portfolio. Based on most SDM participants' weight sets, this resulted in the highest portfolio score.

## Characteristics of Higher Performing Portfolios

An assessment of the highest performing portfolio and third highest portfolio provides some additional insights into the tradeoffs between habitat and reintroduction. The third highest performing portfolio was P3: All Actions with Shasta Volitional Passage, which was comprised of 35 unique actions covering all action groups and tributaries.

A comparison of all normalized consequences across all portfolios is shown in Figure 16, and a comparison of the modeled performance metrics relative to the baseline are shown in Figure 17. Portfolio 3 and Portfolio 11 are highlighted in both plots. Normalized consequences for Portfolio 3, and consequences relative to the baseline, are highest across all portfolios for average annual spawner returns, average annual number of juveniles leaving the upper Sacramento, average annual number of smolts reaching the ocean, and proportion of total suitable rearing habitat in tributaries. Portfolio 3 also had the highest normalized consequences for several non-modeled metrics, including the ability of winter-run Chinook salmon to live their natural life cycle, avoiding impacts to fall-run Chinook salmon, and minimizing adverse impacts to other listed species. However, Portfolio 3 also resulted in relatively low normalized pHOS consequences (i.e., high absolute pHOS values) and CRR consequences, and it had the highest total expected cost of all portfolios. For participants that weighted tributary support and ability of winter-run Chinook salmon to live their natural life cycle highly, but did not weight abundance, life history diversity, or cost metrics relatively highly, Portfolio 3 scored relatively well. In comparison to Portfolio 11, this outcome highlights that some participants value higher fish returns and more juveniles and smolts in the system even if it requires increases in supplementation with hatchery fish in multiple tributaries and has higher cost.

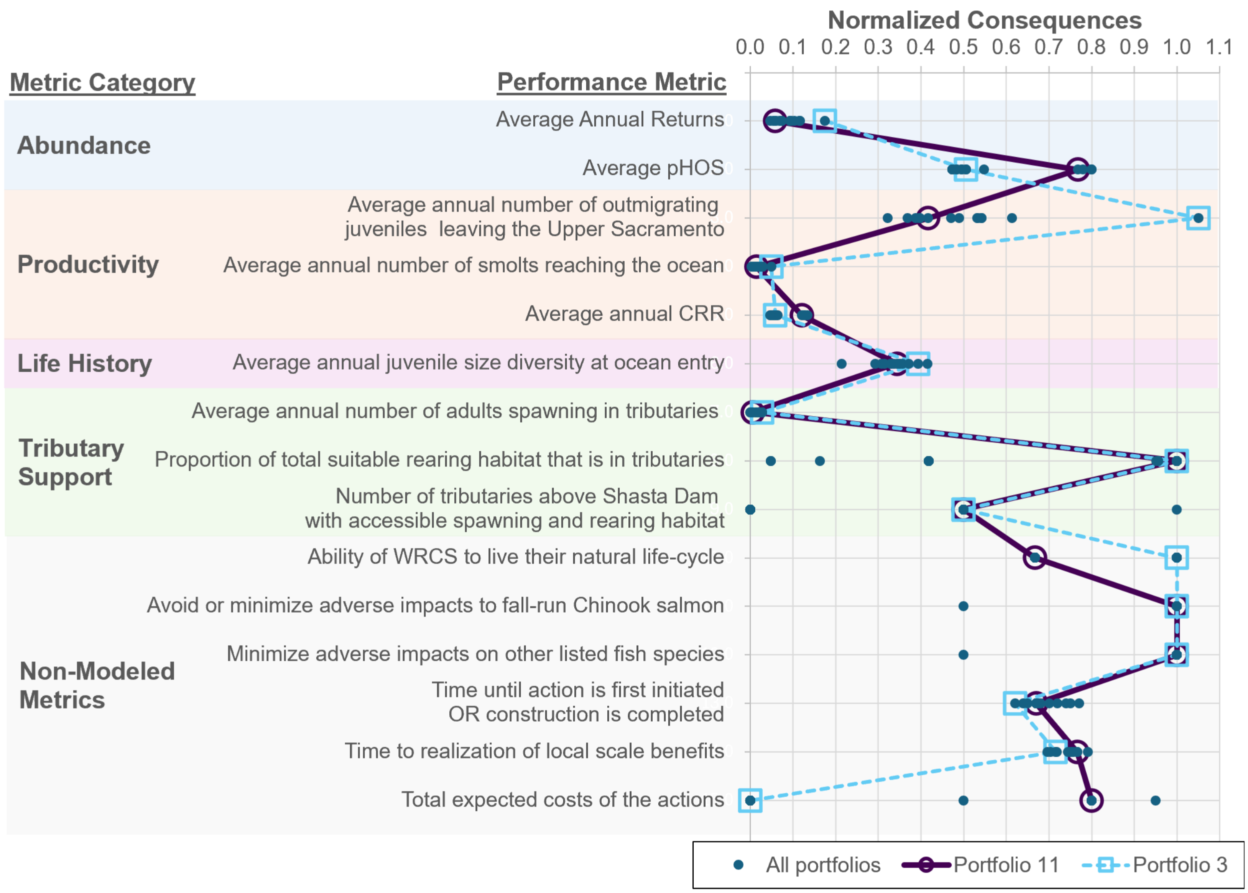



**Figure 16. Normalized Consequences Highlighting the Highest and Thid Highest Rated Portfolio**

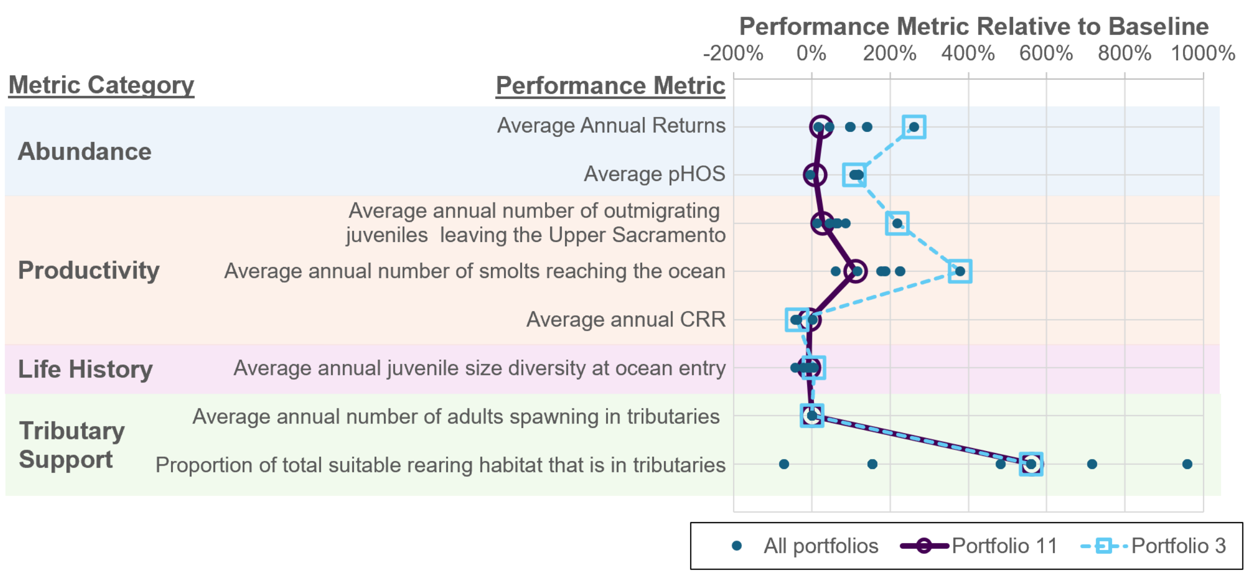



**Figure 17. Portfolio Performance Metrics Relative to the Baseline Highlighting the Highest and Third Highest Rated Portfolio**

# Observations Across Portfolios

The following observations highlight findings and considerations that are relevant across multiple portfolios.

## Modeled Tributary Habitat Suitability Limited Viability of Some Portfolios

Several portfolios included actions that represented the addition of, or access to, new habitat for winter-run Chinook salmon in tributaries above Shasta Dam (Little Sacramento River and/or McCloud River) or Battle Creek. For all tributaries, participants emphasized that modeling should account for both the new suitable area created by an action and the suitability of water temperatures in the parts of each watershed where habitat additions would occur. While rearing habitat was not temperature limited, spawning habitat enhancements in the Little Sacramento River and in lower Battle Creek were significantly constrained by temperature exceedances of salmonid survival thresholds. The temperature effects were modeled by scaling down habitat additions in proposed actions. This approach was developed using relatively limited historical temperature data, which was then applied uniformly to habitat additions in each watershed. The lack of a finer-scaled resolution of temperature changes in different parts of each watershed likely underestimates the effects of these actions, especially on Battle Creek where only 1.5 to 3 acres of new spawning habitat is added by any action.

For more information on data needs, see "Considerations for Future: Data and Information Gaps." For more details on methodology, refer to Appendix B.

## Influence/Effect of Supplementing Population was Variable

Many portfolios included supplementation of additional fish (Table 13). The effects of additional hatchery fish in the system interact positively with some performance metrics (e.g., they increase abundance and productivity) and negatively with others (e.g., they increase pHOS, rather than decreasing it, and they reduce the calculated CRR). In addition, portfolios with habitat improvements, especially above Shasta Dam or in Battle Creek, perform better when supplementation is also included.

**Table 13. Average Number of Juvenile Fish Added to the Baseline Model per Year for Each Portfolio by Origin (hatchery or natural) and Size Class (medium or large)**

| Portfolio Number | Number of Hatchery Fish Supplemented per Year by Size Class | | Number of Natural Fish Supplemented per Year by Size Class | Total Number of Fish Supplemented per Year by Portfolio |
|---|---|---|---|---|
| | Medium | Large | Large | |
| P1 | 75,750 | 530,000 | 0 | 605,750 |
| P2 | 75,750 | 530,000 | 0 | 605,750 |
| P3 | 0 | 500,000 | 500,000 | 1,000,000 |
| P4 | 0 | 500,000 | 0 | 500,000 |
| P5 | 0 | 500,000 | 0 | 500,000 |
| P6 | 0 | 300,000 | 0 | 300,000 |
| P7 | 20,000 | 530,000 | 0 | 550,000 |
| P8 | 75,750 | 530,000 | 0 | 605,750 |

| Portfolio Number | Number of Hatchery Fish Supplemented per Year by Size Class | | Number of Natural Fish Supplemented per Year by Size Class | Total Number of Fish Supplemented per Year by Portfolio |
|---|---|---|---|---|
| | Medium | Large | Large | |
| P9 | 55,750 | 0 | 0 | 55,750 |
| P10 | 0 | 200,000 | 0 | 200,000 |
| P11 | 55,750 | 0 | 0 | 55,750 |
| P12 | 75,750 | 230,000 | 0 | 305,750 |
| P13 | 20,000 | 530,000 | 0 | 550,000 |
| P14 | 0 | 0 | 0 | 0 |

The hydrology represented by the 20-year simulation period includes five consecutive dry years in the middle of the simulation. This dynamic, combined with low initial natural spawning populations, causes abundance to decrease across all portfolios during and after this series of dry years. Additional fish in the system through supplementation can counteract this decline somewhat and can lead to improved abundance and production metrics (i.e., spawner or juvenile counts) but result in increased pHOS. This dynamic is seen in a comparison of the average annual number of supplemented fish added in the model to the change in average annual adult winter-run Chinook salmon returns relative to baseline (Figure 18, top) and to the change in average annual number of outmigrating juveniles leaving the Upper Sacramento River relative to baseline (Figure 18, bottom). There is a positive correlation between the addition of fish, adult returns, and outmigrating juveniles. Some portfolios added the same number of fish, but showed differing levels of performance for adult returns and outmigrating juveniles. For example, Portfolios 5 and 13 added generally similar numbers of fish as Portfolios 1 and 2, but Portfolios 1 and 2 saw three times the increase in adult returns. As described below, portfolios that included many Above Shasta Dam actions (e.g., Portfolios 1, 2, and 3) generally produced greater adult returns and outmigrating juveniles than other portfolios.

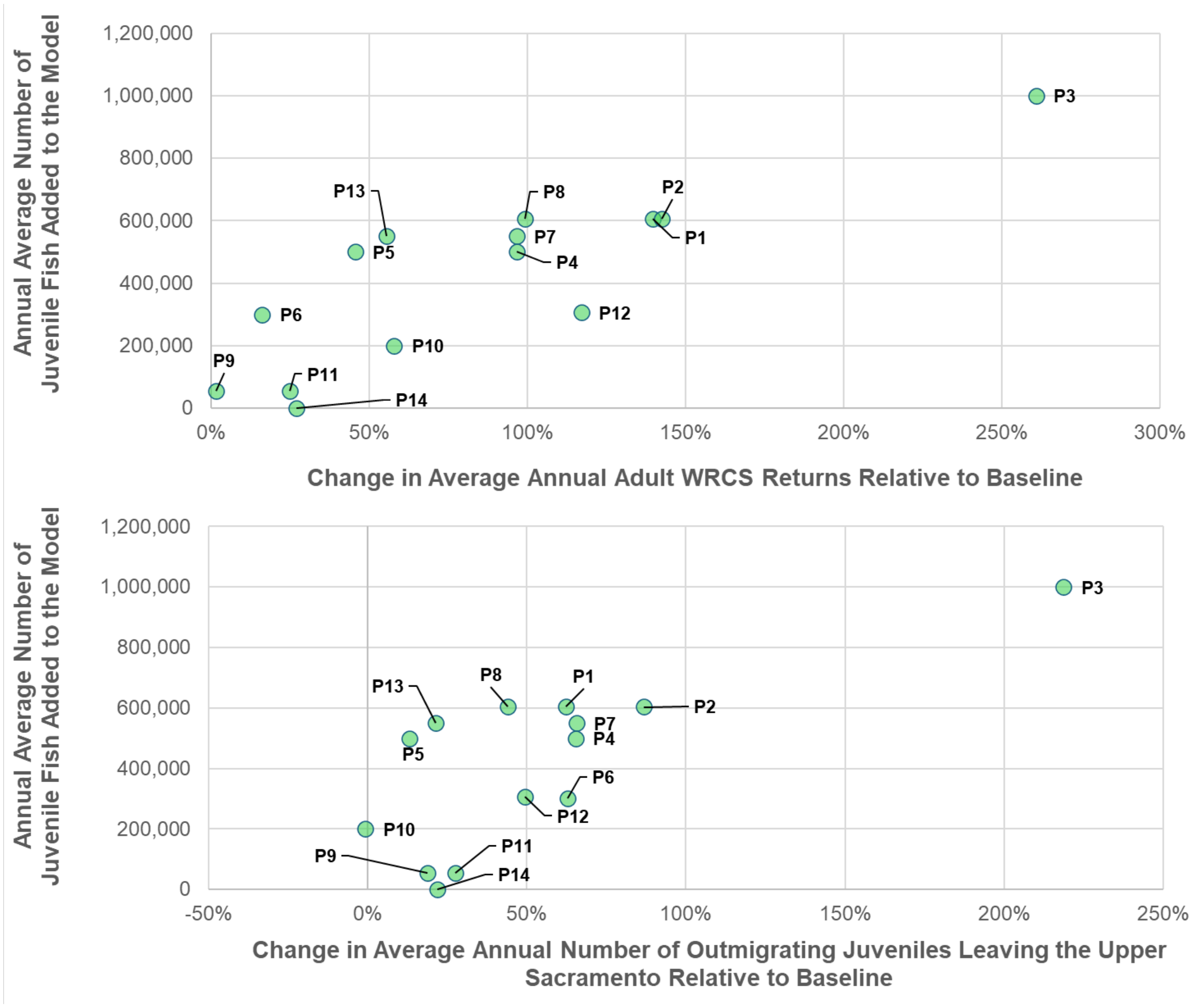



**Figure 18. Comparison of Total Fish Added in the Model to Change in Adult Spawners Relative to Baseline (top) and Change in Outmigrating Juveniles Relative to Baseline (bottom)**

## No Portfolio Leads to any Population Meeting Independence Thresholds

Previous studies on winter-run Chinook salmon recovery highlight the necessity of increasing the number of independent viable populations of the species to achieve population representation and redundancy (Compass 2022, NMFS 2014). The NMFS Recovery Plan for winter-run Chinook salmon specifies that three populations within the Basalt and Porous Lava Diversity Group at low risk of extinction must exist in order to achieve winter-run Chinook salmon recovery (NMFS 2014). The R2R effort defined independent populations based on recovery criteria described in Lindley et al. 2007, and NMFS 2014, using the same criteria to evaluate whether populations are independent. The criteria are:

- positive population growth rate,
- CRR greater than 1,

- minimum of 500 spawners in a population, and
- pHOS less than 5% (0.05).

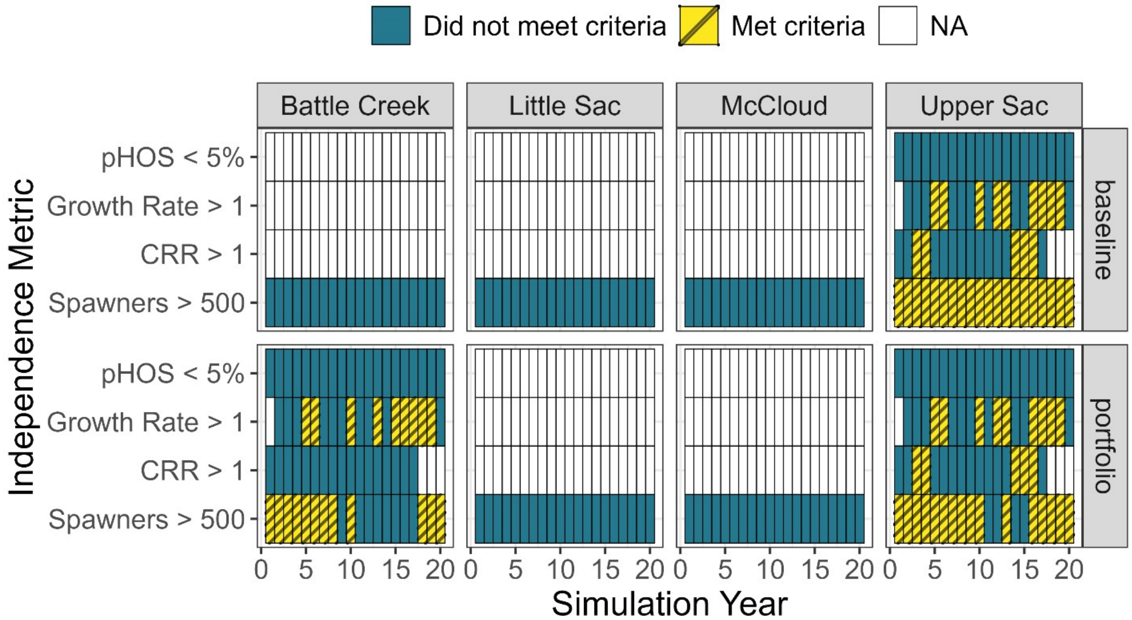
In order to summarize results, the criteria were evaluated in the final 3 years of the simulation for each tributary (years 15 to 17 since CRR calculations rely on spawner estimates for the cohort 3 years later).

For this effort, populations in the Upper Sacramento River below Shasta Dam (the single existing spawning population), Battle Creek, the McCloud River, and the Little Sacramento River were assessed for independence. The Pit River was deemed by participants to be low priority, based on the high temperatures and thus low habitat suitability in the tributary, and was not included in this analysis.

Results indicated that across portfolios, no watershed achieved an independent population, with the pHOS threshold being most limiting for achieving independence. The portfolio with the lowest pHOS (Portfolio 14: Habitat Enhancement and Restoration) had a mean pHOS of 0.24, which was still significantly higher than the 0.05 threshold specified for independent populations. The high and relatively static pHOS values are largely due to the inclusion of numerous hatchery additions in most portfolios, and the proportion of natural spawning adults calculated as the proportion natural at time of juvenile release. These are explained above in the section “Influence/Effect of Supplementing Populations was Variable” and below in the section “Refinements to Lifecycle Model.”

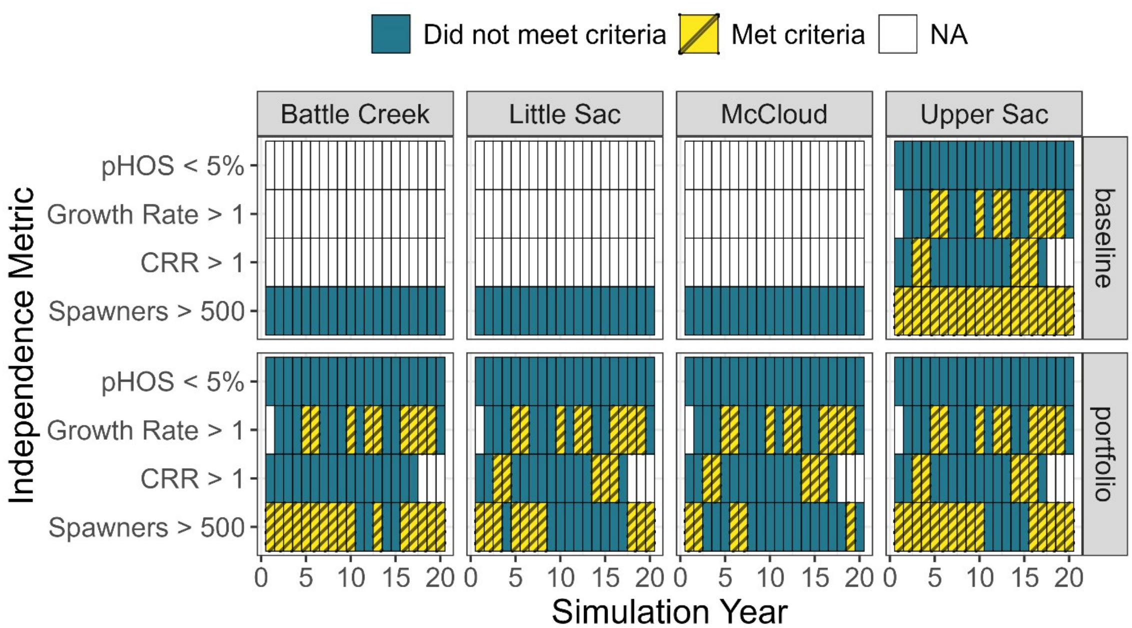
Other metrics for evaluating independence were achieved in various portfolios in several years for relevant tributaries (Figure 19 and Figure 20). High hatchery releases and the nature of the time series, with a large drought in the middle of the simulation period, led to several years of fish experiencing low CRR (below 1), and negative population growth. In Battle Creek, the dependence on hatchery fish led to the inability to achieve CRR > 1 and pHOS < 5% in all years.

The lack of achieving recovery criteria in the rapid SDM reflects results from other modeling efforts that have evaluated strategies to recover winter-run Chinook Salmon (Osterback et al. 2026). In order to achieve independence, the renaturing logic for Battle Creek and other tributaries could be further examined. See “Refinements to Lifecycle Model” for additional details on suggested changes that might lead to more variable and lower pHOS values. It is also possible that a longer simulation period, and/or a different simulation period (with a less severe drought in the middle of the time series) is needed to allow the population to achieve recovery goals. Additional actions and combinations of actions could also be more extensively explored, as other studies have found that strategically combining actions targeting complementary life stages and varying environmental conditions can help fish come closer to achieving viability targets (Osterback et al. 2026).




Key: CRR = cohort replacement rate, pHOS = proportion of hatchery origin spawners

**Figure 19. Portfolio 5 (Battle Creek and Habitat Actions) Independence Criteria by Simulation Year**




Key: CRR = cohort replacement rate, pHOS = proportion of hatchery origin spawners

**Figure 20. Portfolio 1 (All Actions with Trap and Haul for All Tributaries) Independence Criteria by Simulation Year**

## Higher Relative Scoring of Portfolios that Include Actions Above Shasta Dam

Portfolios that incorporated actions Above Shasta Dam scored consistently higher than those that did not. The three highest average score portfolios included at least two unique actions above Shasta Dam, while four of the six lowest average score portfolios did not include any actions above Shasta Dam.

A comparison of the average value of performance metrics of portfolios with and without Above Shasta Dam actions shows that portfolios with actions Above Shasta Dam have a greater increase in nearly every modeled winter-run metric relative to the baseline (Figure 21). Providing access to suitable habitat in the McCloud River generally improves modeled outcomes for winter-run. These results are consistent with feedback from some SDM participants that moving winter-run spawning off of the valley floor and into tributaries is essential for recovery of the species. These results also align with literature indicating that restoring access to colder, higher-elevation habitat is one of the most effective and scientifically defensible strategies for winter-run Chinook salmon persistence under warming air temperatures and changing weather patterns (Herbold et al. 2018, Crozier et al. 2019, Lipscomb et al. 2025).

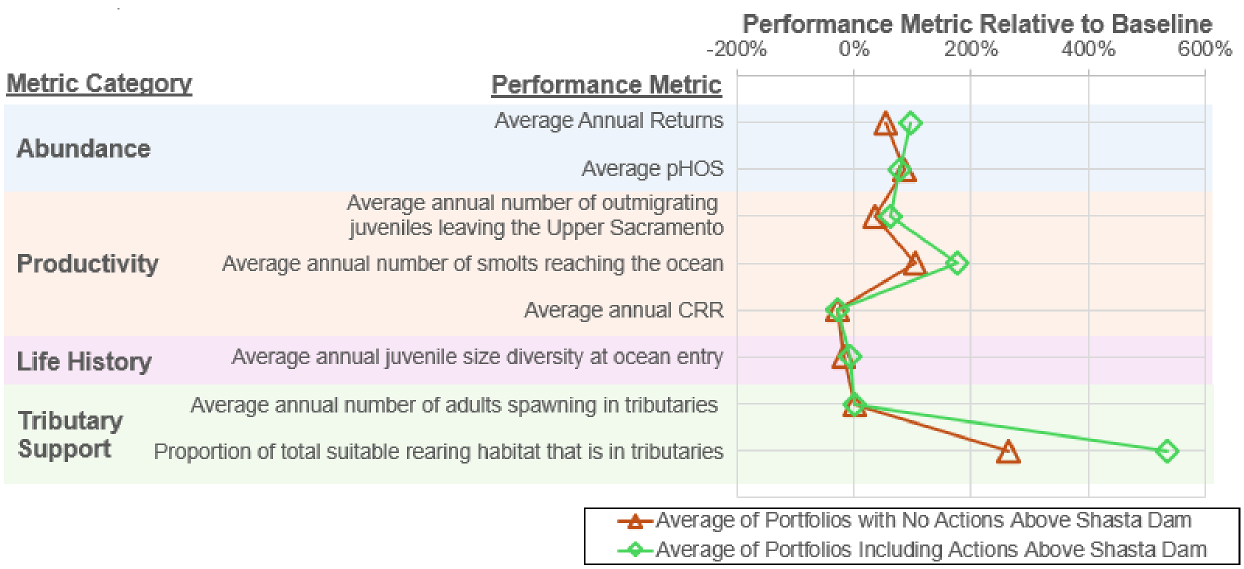



**Figure 21. Comparison of Average Performance Metrics for Portfolios With and Without Actions Above Shasta Dam**

Three portfolios include many Above Shasta Dam actions: Portfolio 1 (including trap and haul into the McCloud River and Little Sacramento River), Portfolio 2 (including trap and haul into the McCloud River), and Portfolio 3 (including volitional passage into the McCloud River instead of trap and haul). The modeled winter-run metrics of these three portfolios relative to the baseline are shown in Figure 22. Model results show that Portfolio 3 produced better performance metrics for abundance and productivity. Two factors are likely contributing to these results:

- First, total habitat in the Little Sacramento River is limited by negative water temperature effects. The estimated total additional habitat in the Little Sacramento River is relatively high, with more total habitat acres than the McCloud River. However, spawning habitat in the Little Sacramento River gets scaled down substantially due to unsuitable temperatures during spawning season. Temperature effects do not significantly scale down rearing habitat. Overall, the negative temperature effects on spawning in the Little Sacramento River likely counteract the beneficial effects of access to additional rearing habitat.

- Second, the modeled trap efficiency of outmigrating juveniles for trap and haul (Portfolios 1 and 2) is 90% (i.e., 90% of outmigrating juveniles in the system are captured). Volitional passage outmigration efficiency was assumed to be 100%. Upstream and downstream trap and haul survival was assumed to be 80%, while volitional passage survival estimates were estimated to be 80% upstream and 40% downstream. The volitional passage downstream survival estimate also accounts for other factors that could contribute to mortality, for example, juveniles getting lost in Lake Shasta or otherwise unable to locate the volitional passageway.

Overall, Portfolio 3 scores higher for abundance and productivity modeled performance metrics, likely because more juveniles are assumed to move downstream annually around Shasta Dam under volitional passage actions than trap and haul actions, and this benefit compounds over time to produce more adult returns.

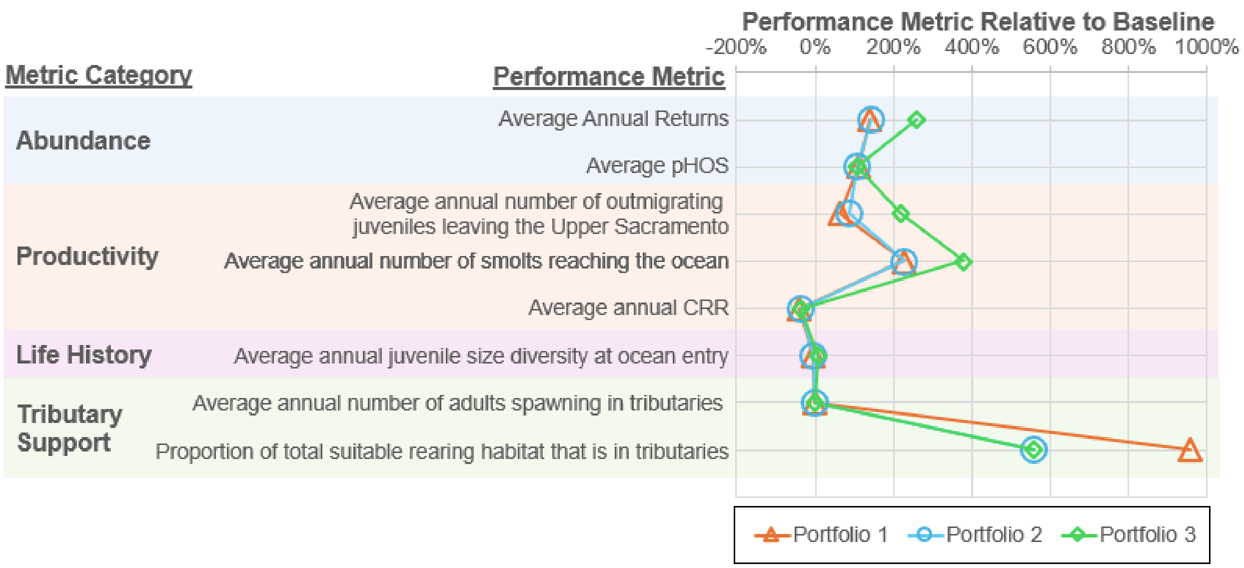



**Figure 22. Comparison of Average Performance Metrics for Portfolios with Many Above Shasta Dam Actions**

### Nuanced Effect of Cost on Portfolio Scores

The effect of monetary investment associated with portfolios is included in the total portfolio value, because total portfolio cost is one of the metrics. For participant weight sets where the minimize cost objective had greater than zero weight, the weighted portfolio value is in part a function of cost. This makes a comparison of cost versus value complicated. To examine this relationship, the weighted portfolio values were recalculated removing the effect of costs from the value, and the adjusted portfolio values were plotted against the costs of each portfolio (Figure 23). For this exercise, the total portfolio cost was estimated by summing the midpoint of the cost range for every unique action in the portfolio.

There is a clear positive relationship, meaning higher estimated portfolio costs do produce higher average portfolio weighted scores if cost is removed from the value calculations and treated as an independent variable.

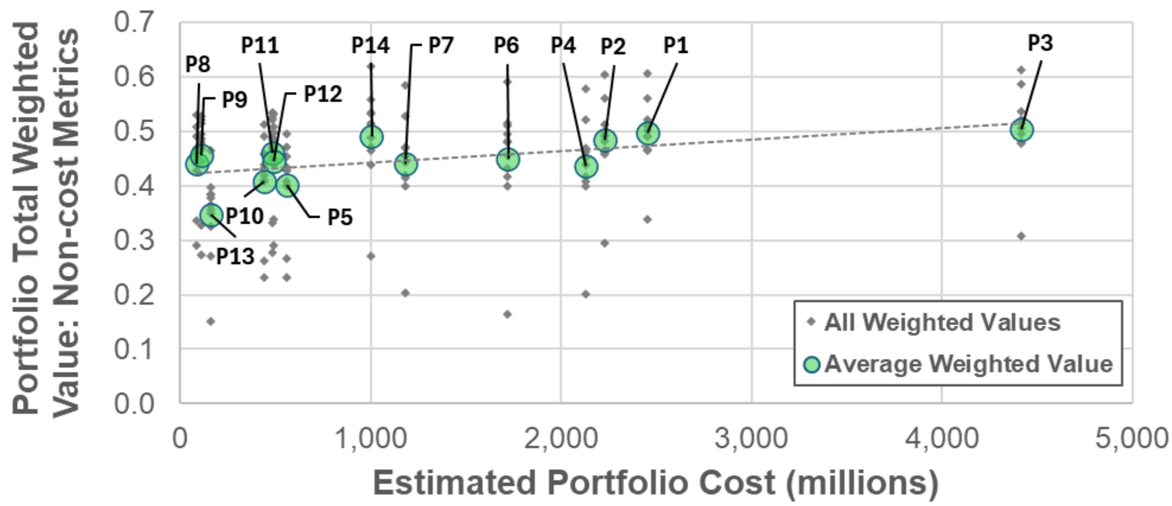



**Figure 23. Comparison of Raw Estimated Costs and Weigthed Portfolio Values Without Cost Metrics for All Weight Sets**

## Number of Actions Within a Portfolio was not Correlated with Performance

The number of actions within a portfolio ranged from 8 to 35, with an average value of 19. The portfolios with the three highest average weighted scores across weight sets were Portfolio 11, Portfolio 9 and Portfolio 8. These portfolios contained 10, 8, and 16 unique actions, respectively, lower than the average number of actions in a portfolio. Additionally, only two total actions were common across these three portfolios, meaning high scoring portfolios could be achieved multiple ways by using different combinations of a small number of unique actions. The lowest scoring portfolio was Portfolio 13, which was comprised of eight unique actions, the lowest number of actions across all portfolios. Weighted portfolio scores were more correlated to the scale and location of the actions than to the number of actions included.

# 5. Consideration for Future Analyses

SDM participants provided substantive feedback throughout development and implementation of the SDM process. This section categorizes and describes these additional considerations.

## Further Refine PrOACT Input and Outcomes

Participants provided feedback at each step of the PrOACT process. The primary concern expressed by many of the participants was the speed of the rapid prototyping approach. Many would have preferred a slower approach with more time for back-and-forth discussion and more time to review draft inputs to the process as they were developed.

Feedback was incorporated into the SDM outcomes to the extent the schedule allowed, but many considerations were raised that may be relevant to any use of the results of this analysis and for future analyses that also address winter-run Chinook salmon. These are listed below.

### Problem Statement Constraint

The problem statement excluded consideration of actions that would change Shasta Dam operations. Three main considerations about this scope were expressed several times by multiple participants:

- Concern that not considering flow modifications in this study was a statement that Reclamation and CVP would not consider flow modifications to better support winter-run Chinook salmon under any circumstances.
- Concern that evaluating the potential effects of portfolios under only one flow regime could lead to under- or over-estimation of the benefits of those portfolios if actually implemented, because actual flows will differ from modeled flows.
- Multi-species approaches to conservation should be evaluated, not single species.

### Additional Objectives and Metrics

Participants proposed several objectives that were not carried forward in this SDM process because they fell outside the scope of the problem statement. However, participants considered them to be very important statements of objectives that matter to them and did not want the relatively narrower scope of objectives included here to suggest they do not care about other issues. There is disagreement between participants on the direction of preference for some of these objectives, but the topics that might be considered in future studies include the impact of actions on: water deliveries; in-stream flows; hydropower generation; and water quality.

### Evaluate Other Actions

SDM participants initially suggested evaluating many actions that were later determined to be outside the scope of the SDM process. These actions were generally aligned into three categories: develop a new study or plan (eight actions), evaluate flow-based actions (five actions), or improve data acquisition, monitoring, and modeling (12 actions). An additional 18 actions did not include sufficient detail to be incorporated into the analysis framework, two actions did not address the problem statement and were outside the scope of the SDM, and seven actions were already incorporated in the baseline tools and were not new unique actions that could be incorporated into the SDM process. A summary of all actions to consider in future efforts is shown in Table 14.

**Table 14. Other Actions to Consider in Future Efforts**

| Category | Action Description |
|---|---|
| Develop a plan/study | Develop Fish Passage Above Shasta Implementation Plan |
| Develop a plan/study | Create a cost benefit analysis comparing building a new conservation hatchery vs using a privately owned facility |
| Develop a plan/study | Collaboratively develop and implement a peer-reviewed reintroduction plan for winter-run Chinook salmon to historic habitats upstream of Shasta Dam |
| Develop a plan/study | Study to evaluate Shasta Dam raise to determine how coldwater pools could affect downstream water temperatures |
| Develop a plan/study | Upper McCloud River Water Temperature and Habitat Evaluation project to estimate the carrying capacity for WRCS |
| Develop a plan/study | Battle Creek Water Temperature and Habitat Evaluation project to estimate the carrying capacity for WRCS |
| Develop a plan/study | Middle Sacramento River eDNA Predation Study |
| Develop a plan/study | Evaluate different critical temperature criteria being used below Shasta Dam versus for McCloud River and Battle Creek reintroduction efforts and spawning success |
| Flow-based actions | Enforce laws regarding illegal diverters of water from both the Sacramento River and its tributaries |
| Flow-based actions | Water right purchases and/or leases to keep water instream in the lower watershed |
| Flow-based actions | Raise Shasta Dam |
| Flow-based actions | Augment existing operational flows |
| Flow-based actions | Add environmental water allocation from Sites Reservoir on top of baseline operational conditions |
| New data, monitoring, or model | Development and utilization of a pathogen mortality model, similar the S3 model used for the Klamath and Trinity Rivers |
| New data, monitoring, or model | Enhance winter-run Chinook salmon monitoring to reduce uncertainty in life-stage impacts and assist in management. |
| New data, monitoring, or model | Support parentage-based tagging (PBT) and related monitoring |
| New data, monitoring, or model | Improve monitoring of ocean recreational salmon fishing |

| Category | Action Description |
|---|---|
| New data, monitoring, or model | Winter-run Chinook salmon brood year assessments and genetics PBT testing (hatchery and natural-origin) |
| New data, monitoring, or model | Improve salmon ocean harvest estimates (Video/computer vision-based monitoring of recreational salmon fishing) |
| New data, monitoring, or model | Real time temperature monitoring in winter-run Chinook salmon habitat to support adaptive management decisions |
| New data, monitoring, or model | New Monitoring Station below the WR spawning area for a better Egg-to-fry survival estimate - juvenile trapping station |
| New data, monitoring, or model | Fall-run Chinook salmon Floodplain fry rearing project (identify habitat, modify flows, monitor) |
| New data, monitoring, or model | Improve model representation of TCD structure leakage |
| New data, monitoring, or model | Support PBT for Chinook (sampling broodstock and adults) |
| New data, monitoring, or model | Explore (model) optimal water year sequence + population size specific approaches to hatchery intervention |
| Insufficient detail | Enforce laws regarding illegal diverters of water from both the Sacramento River and its tributaries |
| Insufficient detail | Make sure the habitat restoration projects are done in areas that still have water when flow levels are low. |
| Insufficient detail | When water rights are curtailed, adequately police the curtailments |
| Insufficient detail | Incorporate recommendations of the (Park Fire) Fish Restoration Plan for Antelope, Mill and Deer Creek relative to fire recovery and/or preventative measures |
| Insufficient detail | Implement landscape management actions to reduce potential impact of catastrophic fire on aquatic habitats |
| Insufficient detail | Implement recommendations of the CalTrout spring study |
| Insufficient detail | Address outlying significant road/culvert improvement projects |
| Insufficient detail | Restore tributary habitats in fire-impacted streams. |
| Insufficient detail | Improved adult WRCS holding facility, identification, and transportation decisions |
| Insufficient detail | Reduce habitat in the Upper-Mid, Lower-Mid, and Lower Sacramento River combined with actions that speed transit through this migratory corridor to increase the number of fry and smolts surviving to the Delta. |
| Insufficient detail | Support integration of landlocked fish originating from Shasta Reservoir |
| Insufficient detail | Evaluate spawning and rearing habitat needs and update existing project lists |
| Insufficient detail | Fall-run Chinook salmon Sacramento River Imprinting Project |
| Insufficient detail | Implement the recommendations from the National Academies of Science review of the Long-term Operations of the Central Valley Project |

| Category | Action Description |
|---|---|
| Insufficient detail | Use GSAs to curtail groundwater pumping in the Sacramento Valley to a particular GSA's water balance amounts only |
| Insufficient detail | Implement actions in the middle and lower river and the Delta that are identified in other plans |
| Insufficient detail | Sacramento River new diversion/pipeline to CNFH (this action was later removed from consideration by the SDM proponent) |
| Insufficient detail | Prevent entrainment by physically closing fish access to Georgiana Slough |
| Outside of scope | Sacramento River new diversion/pipeline to Coleman National Fish Hatchery |
| Outside of scope | Use a Fall-run Chinook Life Cycle Model to evaluate portfolios |
| Included in baseline | Maintain existing spawning habitat below Keswick Dam. |
| Included in baseline | Maintain and monitor constructed juvenile rearing habitats. |
| Included in baseline | Continue to implement a long-term gravel augmentation plan consistent with CVPIA to increase and maintain spawning habitat for winter-run Chinook salmon, spring-run Chinook salmon, and steelhead downstream of Keswick Dam. |
| Included in baseline | Real-time management of DCC gates |
| Included in baseline | SIT Priority Action 6: Continue maintenance of existing salmonid spawning habitat Clear Creek, Stanislaus, American, and upper Sacramento rivers. |
| Included in baseline | SIT Priority Action 7: Maintenance of perennial constructed juvenile rearing habitats with at least 1 tier 2-3 monitoring |
| Included in baseline | Return Sacramento River WRCS LSNFH releases to conservation levels |

Key: CNFH = Coleman National Fish Hatchery, DCC = Delta Cross Channel, eDNA = environmental DNA, GSA = Groundwater Sustainability Agency, LSNFH = Livingston Stone National Fish Hatchery, PBT = parentage-based tagging, SDM = Structured Decision Making, TCD = temperature control device, WRCS = winter-run Chinook salmon

## Address Data and Information Gaps

The rapid schedule of the SDM process required use of available models and readily accessible data to represent actions. During modeling, key data and information gaps were identified that contributed to uncertainty; those gaps are outlined here and expanded upon in Appendix B: Model Assumptions.

- Temperature data
  - Temperature data were particularly lacking for reaches not previously included in the winter-run model, such as the McCloud River, Little Sacramento River, and North Fork Battle Creek. While some data were provided at particular gages (Deas and Wood 2026) this was limited in temporal scale (roughly 1 year of data) and to specific locations, rather than being modeled on a tributary scale (as in watersheds available in HEC-5Q).

- Habitat estimation
    - In certain cases, participants provided acreage estimates, but not how these estimates varied by flow.
    - Additional modeling, including surveys and hydraulic modeling, can refine habitat estimates and was not available at the time of modeling for habitats above Shasta Dam.
- Because reintroduction of winter-run Chinook salmon above Shasta has not been implemented, there was high uncertainty in survival rates for volitional passage actions, and survival rates and trap efficiency associated with trap and haul actions.
- Reported capture efficiencies above Shasta were used to inform estimates but spanned a wide range of values (Anchor QEA and HDR Engineering, Inc. 2026). More information about potential trap locations with additional efficiency trials would reduce uncertainty around this parameter.
- Several actions included a reduction of incidental and illegal harvest. Illegal harvest is by nature unreported, thus the current level of illegal and incidental harvest for each tributary represents an information gap.
- Field data/estimates for winter-run egg-to-fry survival above Shasta were not identified, and required an alternative approach described in Appendix B.

## Consider Alternative Modeling Tools and Approaches

Participants suggested additional modeling tools should be considered for lifecycle modeling and temperature modeling.

Criteria were developed for the selection of a winter-run model based on the timeline and needs of the SDM process: a model would ideally be in the public domain, transparent, and well documented. It would be highly adaptable on a short timeline to suit a range of potential actions, spanning habitat additions to hatchery practices. Finally, it would be scientifically vetted and familiar to users in the system. Participants identified several models that fit some or all of these criteria: the NMFS Winter Run Lifecycle Model (NMFS WRLCM; methods described in Hendrix et al. 2024); the Oncorhynchus Bayesian Analysis Model (OBAN; methods described in ICF International 2016); the Juvenile Production Index (JPI; methods described in O'Farrell et al. 2018); Interactive Object-Oriented Simulation Model (IOS; methods described in ICF International 2016); and a derivation of the CVPIA SIT model developed for Reorienting to Recovery (Reorienting to Recovery Project Planning Team 2024). Of these models, only the derivations of the CVPIA-SIT model had a publicly accessible codebase. Use of the R2R lifecycle model in this process does not preclude the use of another, or additional, lifecycle modeling tool in the future.

One participant recommended the SDM consider using the River Assessment for Forecasting Temperatures (RAFT) water temperature model for simulating Sacramento River water temperatures. RAFT is a one-dimensional model consisting of three modules that include thermal hydrodynamics, heat fluxes, and data-assimilation techniques (Pike et al. 2013). Recent applications of the model have evaluated a simulation period of 1990 – 2017 to quantify the relative contributions of the various physical drivers of river temperature (Daniels and Danner 2023), and the model is also used to support Sacramento River temperature management decisions. The SDM modeling team did not select the RAFT model because it does not have a publicly accessible codebase, and the model has not been developed to align with the simulation period of 1980 – 2000 used in the SDM study.

Several participants recommended alternative approaches to the modeling framework that could not be implemented under the scope and schedule of the SDM study, including:

- Modeling should consider how the operational effects of future facilities, including Sites Reservoir, might influence the set of actions developed in this SDM.

- Some actions would see greater benefits from or would be complemented by modified flow releases out of Lake Shasta. Consideration should be made during this process of which actions should be assessed with alternative flow regimes to determine if additional flow drives additional habitat benefits.

- Modeling results will be influenced heavily by the simulation period of 1980 – 2000, and by the specific hydrologic sequence of wet and dry years within that simulation period. Winter-run Chinook salmon outcomes might vary substantially under different conditions, and the modeling team might consider testing the sensitivity of outcomes by simulating alternative sequencing of hydrologic conditions.

## Refinements to Lifecycle Model

Aspects of the winter-run model were identified as limitations or improvements that could be made in future assessments. Several of these emerged through the process of modeling full portfolios and in initial examination of results.

- Consideration of extending the simulation period of the winter-run model to a more recent time period. The 1980-2000 simulation period was selected for the original CVPIA-SIT modeling for many reasons, including its incorporation of a variable hydrology that allows for contrast of hydrological conditions. The time series includes several dry years in the middle of the simulation period, which results in a population decline that in most or all portfolios remains depressed through the end of the period. Extending the time series might allow for the benefits of the final wet years to be better represented in results, and also to account for more variable and representative hydrology that has been seen in the 21st century.

- Refinement of renaturing logic for hatchery fish. The winter-run model logic for renaturing hatchery fish relied on two consecutive years of pHOS decline in a watershed. That assumption was problematic for Battle Creek in the process because no natural spawning population was modeled in the baseline condition, based on participant input. Thus, pHOS was 1 (100%) for all fish in Battle Creek and the population never experienced renaturing.

Future iterations can more accurately represent renaturing, allowing 2nd generation or older generation hatchery fish to renature, which would result in a variable pHOS value for Battle Creek.

- The egg-to-fry submodel is not a function of modeled temperature inputs and instead relies on a constant calibrated parameter to account for temperature effects. This led to difficulties in producing benefits that could be achieved from providing access to cooler habitat. Future versions of the model could adapt the egg-to-fry survival submodel by drawing from existing models that explicitly represent temperature-dependent mortality, allowing outputs to vary directly based on HEC 5Q model temperature inputs. Temperature benefits of scenarios would then directly improve egg-to-fry survival.

- The original CVPIA-SIT models represent 31 watersheds across the Central Valley used by different runs of Chinook Salmon. This process modeled the introduction of winter-run Chinook into tributaries above Shasta, which were represented here as additional habitat for the Upper Sacramento River model watershed unit. Adding new model watershed units for the Little Sacramento River and McCloud Rivers would let the model more accurately represent and track actions and metrics for fish experiencing the conditions in these watersheds. Submodels could operate at a higher resolution, including straying logic, habitat modeling, and temperature modeling.

- The model pools natural and hatchery juveniles and treats them as equal for the rearing and outmigration submodels. This complicates actions and metrics targeting hatchery or natural fish. The model calculates proportions of hatchery and natural fish at the juvenile stage (before rearing and outmigration) and uses this proportion to split up adult returns, assuming that there is no differential in hatchery and natural survival between those two points in the life cycle. Adapting submodels for the rearing and outmigration phases of the winter-run model to treat hatchery and natural juveniles differently and track them separately would provide a more accurate accounting of their differences in the system, and a more precise estimate of the proportion of adult returns that came from hatchery stock. This would also improve the precision of pHOS and other hatchery-related estimates.

Many of these changes have already been identified through the course of the original model development and may be underway for other versions of the model. We outline the considerations here to provide context for the complications they presented in the specific context of this SDM process.

## Conduct Sensitivity and Uncertainty Analyses

Due to the short time frame and the novel actions included in the rapid SDM, estimation of several parameters in the winter run model was necessary based on available information and analyst and participant expertise. Some parameters in the model, especially those that were inputs to submodels, had a disproportionate effect on model outcomes, so some originally proposed input values were scaled up or down to reflect reasonable model outcomes reflecting the action intent. Given additional time, sensitivity analyses could be conducted on additional parameters (especially those with high uncertainty, as noted in Address Data and Information Gaps, such as volitional passage survival, trap and haul survival, capture efficiencies, and egg-to-fry survival) to account for the range of uncertainty in parameters and the effect that changes to these parameters would have on results.

# 6. Data Availability

Modeling results from CalSim3 and HEC-5Q available via Shiny app at: winterRunDSM Shiny App.

Winter-run Model code available at: Winter Run DSM GitHub. See README on the main page to orient to where code is located for different stages of modeling.

Plotted model outputs and SDM results available via Shiny app at: winterRunDSM Shiny App.

# 7. References


Anchor QEA and HDR Engineering, Inc. 2026. Background Compendium and Design Criteria Report for the Feasibility of Volitional Fish Passage above Keswick and Shasta Dams. Prepared for California Department of Fish and Wildlife. January 2026.

Anderson, J.J., W.N. Beer, J.A. Israel, and S. Greene. (2022). Targeting river operations to the critical thermal window of fish incubation: Model and case study on Sacramento River winter-run Chinook Salmon. *River Research and Applications*, *38*(5), 895-905.

Blodgett, J.C., K.R. Poeschel, and J.L. Thomton. 1985. A water-resources appraisal of the Mount Shasta area in northern California. United States Geological Survey. Water Resources Investigation Report Number 87-4239.

Borcherding, K., Eppel, T. and Von Winterfeldt, D. 1991. Comparison of weighting judgments in multi-attribute utility measurement. Management Science. 37:1603–1619.

CVPIA Science Integration Team. (2023). DSM FAQ. *CVPIA SIT.* https://cvpia.scienceintegrationteam.com/cvpia-sit/resources/dsm-faq. Accessed April 15, 2026.

California Department of Water Resources (DWR). 2004. California's Groundwater Bulletin 118: Hydrologic Region Sacramento River, North Fork Battle Creek Valley Groundwater Basin. Available at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Bulletin-118/Files/2003-Basin-Descriptions/5_050_NorthForkBattleCreekValley.pdf. Accessed April 15, 2026.

Compass Resource Management. (2022). Defining Broad-Sense Recovery for Central Valley Salmonids, Reorienting to Recovery Project – Phase 1 Report. Available at: https://csamp.baydeltalive.com/assets/eec462358f80cc8d9910bfda974fa6f4/application/pdf/Salmon_Recovery_Phase_1_Report_FINAL.pdf

Crozier, L.G., M.M. McClure, T. Beechie, S.J. Bograd, D.A. Boughton, M. Carr, T.D. Cooney, J.B. Dunham, C.M. Greene, M.A. Haltuch, E.L. and Hazen. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PloS one, 14(7), e0217711.

Daniels, M., and E. Danner. 2023. The drivers of river temperatures below a large dam. *Water Resources Research* 56.5 (2020): e2019WR026751.

Deas, M., and M. Wood. 2026. Water Temperature Assessments for Winter Run Habitat – SDM Support. Technical Memorandum. Watercourse Engineering, Inc. March 16, 2026.

Federal Energy Regulatory Commission (FERC). 2004. Final Environmental Impact Statement for the Pit 3, 4, 5 Hydroelectric Project (FERC No. 233-081), California. Office of Energy Projects, FERC/FEIS-0158F. Federal Energy Regulatory Commission, Washington, DC. June 2004. Available at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/docs/pit345_ferc233081/feis_p233081_part1.pdf

Hammond, J.S., R.L. Keeney, and H. Raiffa. 1999. Smart Choices: A Practical Guide to Making Better Decisions. Harvard Business School Press, Boston MA.

Hendrix, N., A.K. Osterback, S. John, M. Daniels, E. Dusek Jennings, E. Danner, and S. Lindley. 2024. Life Cycle Modeling Framework for Chinook Salmon Spawning in the Sacramento River. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-696. Available: https://repository.library.noaa.gov/view/noaa/60717

Herbold, B., S.M. Carlson, R. Henery, R.C. Johnson, N. Mantua, M. McClure, P.B. Moyle, and T. Sommer. (2018). Managing for salmon resilience in California's variable and changing climate. *San Francisco Estuary and Watershed Science*, *16*(2).

ICF International. 2016. Biological Assessment for the California WaterFix. July. Sacramento, CA. Prepared for U.S. Department of the Interior, Bureau of Reclamation, Sacramento, CA. Available: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/petitioners_exhibit/dwr/part2/dwr1142/App_5.D_Methods_update_.pdf Accessed: April 15, 2026.

Lindley, S.T., R.S. Schick, E. Mora, P.B. Adams, J.J. Anderson, S. Greene, C. Hanson, B.P. May, D. McEwan, B.R. MacFarlane, C. Swanson, and J.G. Williams. 2007. Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin. SFEWS 5(1). Available at: https://doi.org/10.15447/sfews.2007v5iss1art4

Lipscomb, T.N., Z. Siders, S. Austing, J. Von Bargen, and L.A. Earley. 2025. Accelerating the reintroduction of endangered Sacramento River winter-run Chinook Salmon to Battle Creek, California using captive broodstock. *North American Journal of Fisheries Management*, 45(2):236-250.

Mantua, N.J., H. Bell, A.E. Todgham, M.E. Daniels, J. Rinchard, J.M. Ludwig, J.C. Field, S.T. Lindley, F.E. Rowland, C.A. Richter, D. Walters, B. Finney, H.A.R. Distajo, D. Tillitt, D.C. Honeyfield, T. Lipscomb, K. Kwak, J. Kindopp, D. Cocherell, A. Ward, T.H. Williams, J. Harding, N.A. Fangue, C. Jeffres, R.I. Ruiz-Cooley, S.Y. Litvin, S. Foott, M. Adkison, B. Kormos, P. Harte, F. Colwell, C.P. Suffridge, K.C. Shannon, A. Cranford, C. Ambrose, A. Reed, and R.C. Johnson. (2025). Widespread thiamine deficiency in California salmon linked to an anchovy-dominated marine prey base. *Proceedings of the National Academy of Sciences*, *122*(26), e2426011122.

Martin, B.T., A. Pike, S.N. John, N. Hamda, J. Roberts, S.T. Lindley, and E.M. Danner. (2017). Phenomenological vs. biophysical models of thermal stress in aquatic eggs. *Ecology Letters*, *20*(1), 50-59.

Martin, B.T., P.N. Dudley, N.S. Kashef, D.M. Stafford, W.J. Reeder, D. Tonina, D., A.M. Del Rio, J.S. Foott, and E.M. Danner. (2020). The biophysical basis of thermal tolerance in fish eggs. Proceedings of the Royal Society B: Biological Sciences, 287(1937).

McConnaha, W.E., G. Blair, and J. Lecky. 2016. Battle Creek winter-run Chinook salmon reintroduction plan. Prepared for the California Department of Fish and Wildlife. Sacramento, CA. 155 pp.

National Academies of Sciences, Engineering, and Medicine. (in press). Review of the Long-Term Operations of the Central Valley Project and the State Water Project. Available at: https://www.nationalacademies.org/read/29130/

National Marine Fisheries Service (NMFS). 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead. California Central Valley Area Office. July 2014. Available at: https://s3.amazonaws.com/media.fisheries.noaa.gov/dam-migration/central_valley_salmonids_recovery_plan-accessible.pdf

National Marine Fisheries Service. West Coast Region (2024). Endangered Species Act Section 7(a)(2) Programmatic Biological Opinion for the Reinitiation of Consultation on the Long-Term Operation of the Central Valley Project and State Water Project. Available: https://doi.org/10.25923/70mc-st96

North State Resources. 2010. Upper Sacramento River watershed assessment and management strategy. Prepared for The River Exchange. Dunsmuir, California. June 2010. 421 pp.

O'Farrell, M.R., W.H. Satterthwaite, A.N. Hendrix, and M.S. Mohr. 2018. Alternative Juvenile Production Estimate (JPE) Forecast Approaches for Sacramento River Winter-Run Chinook Salmon. San Francisco Estuary and Watershed Science 16(4). Available at: https://doi.org/10.15447/sfews.2018v16iss4art4

Osterback, A.K., A.N. Hendrix, M. Daniels, E. Danner, R. Henery, and S.T. Lindley. 2026. Coupling habitat, hydrological and population models to evaluate strategies to recover an endangered salmonid population. Frontiers in Ecology and Evolution. Available at: https://doi.org/10.3389/fevo.2026.1778333

Peterson, J.T., and A. Duarte. 2020. Decision analysis for greater insights into the development and evaluation of Chinook salmon restoration strategies in California's Central Valley. Restoration Ecology, 28: 1596-1609. Available at: https://doi.org/10.1111/rec.13244

Pike, A., E. Danner, D. Boughton, F. Melton, R. Nemani, B. Rajagopalan, and S. Lindley. (2013). Forecasting river temperatures in real time using a stochastic dynamics approach. *Water Resources Research*, 49(9), 5168-5182.

Reorienting to Recovery Project Planning Team. 2024. Reorienting to Recovery: Identifying a Broad-sense Recovery Scenario for Central Valley Salmonids. Prepared for the Delta Stewardship Council. November 2024.

Rode, M., and M. Dean. 2004. Lower McCloud River Wild Trout Area Fishery Management Plan: 2004 through 2009. Prepared for the California Department of Fish and Game, Northern California – North Coast Region. 62 pp. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=60019&inline

Shasta-Trinity National Forest. 2011. Lower McCloud Watershed Analysis. Shasta-McCloud Management Unit. McCloud, California. December. 212 pp. Available at: https://www.fs.usda.gov/sites/nfs/files/legacy-media/shasta-trinity/Lower%20McCloud%20WA%20update%20of%20existing%20WA.pdf

Terraqua Inc. 2004. Battle Creek Watershed Assessment: Characterization of stream conditions and an investigation of sediment source factors in 2001 and 2002. Prepared for the Battle Creek Watershed Conservancy. Manton, CA. 78 pp.

U.S. Bureau of Reclamation (Reclamation). 2014. Shasta Dam Fish Passage Evaluation – Habitat Assessment Final Report. Mid-Pacific Region. 89 pp. Available at: https://www.usbr.gov/mp/bdo/docs/final_sdfpe_habitat_assessment.pdf

U.S. Bureau of Reclamation (Reclamation). 2016. Shasta Dam Fish Passage Evaluation: Draft Pilot Implementation Plan. Mid-Pacific Region. December. 139 pp. Available at: https://www.usbr.gov/mp/bdo/docs/shasta-fp-pilot-plan.pdf

U.S. Bureau of Reclamation (Reclamation). 2024a. Final Environmental Impact Statement. Long-Term Operation of the Central Valley Project and State Water Project.

U.S. Bureau of Reclamation (Reclamation). 2024b. Final Environmental Impact Statement. Long-Term Operation of the Central Valley Project and State Water Project. Appendix F, Attachment F.1-1.

U.S. Bureau of Reclamation (Reclamation). 2024c. Final Environmental Impact Statement. Long-Term Operation of the Central Valley Project and State Water Project. Appendix F, Attachment F.1-2, CVPIA SIT Winter-run LCM.

U.S. Bureau of Reclamation (Reclamation). 2025a. Record of Decision. Long-Term Operation of the Central Valley Project and State Water Project. December 2025.

U.S. Bureau of Reclamation (Reclamation). 2025b. Appendix C: Winter-Run Chinook Salmon Cohort Report (Brood Year 2024). U.S. Department of the Interior, Bureau of Reclamation. Appendix C: Winter-Run Chinook Salmon Cohort Report (Brood Year 2024)

U.S. Bureau of Reclamation (Reclamation). 2026. Structured decision-making for Folsom Dam power bypass operations. U.S. Department of the Interior, Bureau of Reclamation, Bay-Delta Office. Structured Decision-Making for Folsom Dam Power Bypass Operations

U.S. Geological Survey (USGS). 2018. Structured Decision Making. Eastern Ecological Science Center. Available at: [Structured Decision Making | U.S. Geological Survey](). Accessed: April 14, 2026.

U.S. Geological Survey (USGS). 2025. Rapid structured decision making for *Hypomesus transpacificus* (Delta Smelt) summer–fall freshwater outflow management. U.S. Geological Survey Open-File Report 2025–1055. https://doi.org/10.3133/ofr20251055

Yoshiyama, R., F. Fisher, and P. Moyle. 1998. Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California. North American Journal of Fisheries Management, 18(3), pp.487-521.

Yoshiyama, R. M., & Fisher, F. W. (2001). Long time past: Baird station and the McCloud Wintu. Fisheries, 26(3), 6-22.

# Appendix A

# Participating Parties

# Appendix A: Participating Parties

- Winnemem Wintu Tribe
- Anderson-Cottonwood Irrigation District
- California Department of Fish & Wildlife
- Contra Costa Water District
- Defenders of Wildlife
- Friant Water Authority
- Friends of the River
- Glenn-Colusa Irrigation District
- Institute for Fisheries Resources
- National Marine Fisheries Service
- Nor-Cal Guides & Sportsmen's Association
- Northern California Water Association
- Pacific Coast Federation of Fishermen's Associations
- Princeton-Codora-Glenn Irrigation District
- Reclamation District 108
- Regional Water Authority
- River Partners
- Sacramento River Settlement Contractors
- San Francisco Baykeeper
- San Luis & Delta-Mendota Water Authority
- Save California Salmon

- Sutter Mutual Water Co. / Reclamation District 1500
- Tehama-Colusa Canal Authority
- Trout Unlimited
- U.S. Bureau of Reclamation
- U.S. Fish & Wildlife Service
- Westlands Water District

# Appendix B

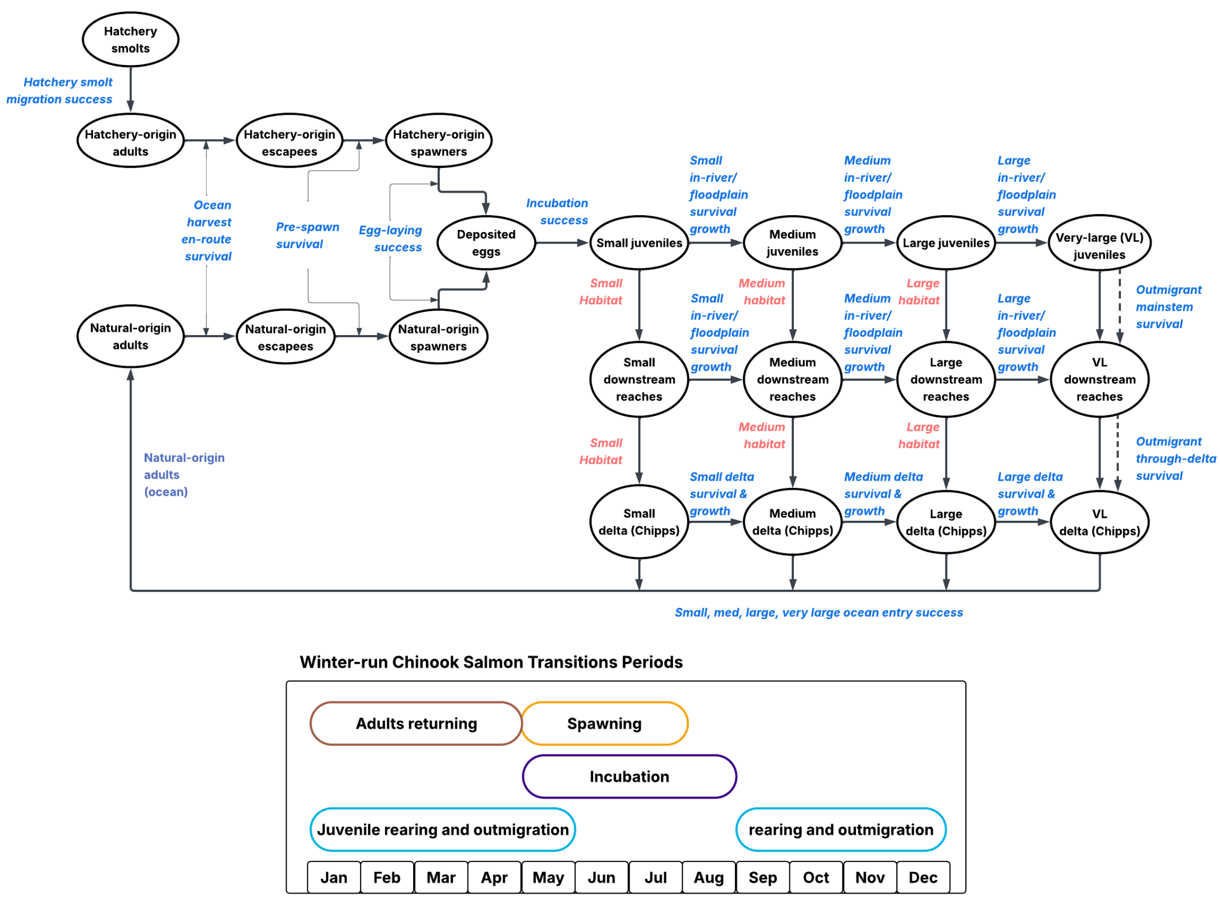
# Lifecycle Modeling

# Appendix B: Lifecycle Modeling

## Winter-Run Model Background

### Model Structure

The winter-run model used in this rapid structured decision making (SDM) process is a derivative of salmonid lifecycle decision support models (DSM) developed and maintained by the Central Valley Project Improvement Act (CVPIA) Science Integration Team (SIT). The original suite of lifecycle models includes a model for each Chinook salmon run (fall, winter, spring, and late-fall), simulating the salmonid life cycle across 31 watersheds ("watershed unit") at a monthly time step (CVPIA Science Integration Team 2023; [CVPIA FAQs]). The simulation model differs for each run by the watersheds utilized, the timing of life history events, the routing and straying logic, and the model inputs. Figure B-1 outlines the stages of the lifecycle model, with ovals representing life stages and arrows representing state transitions like growth, movement, and survival.

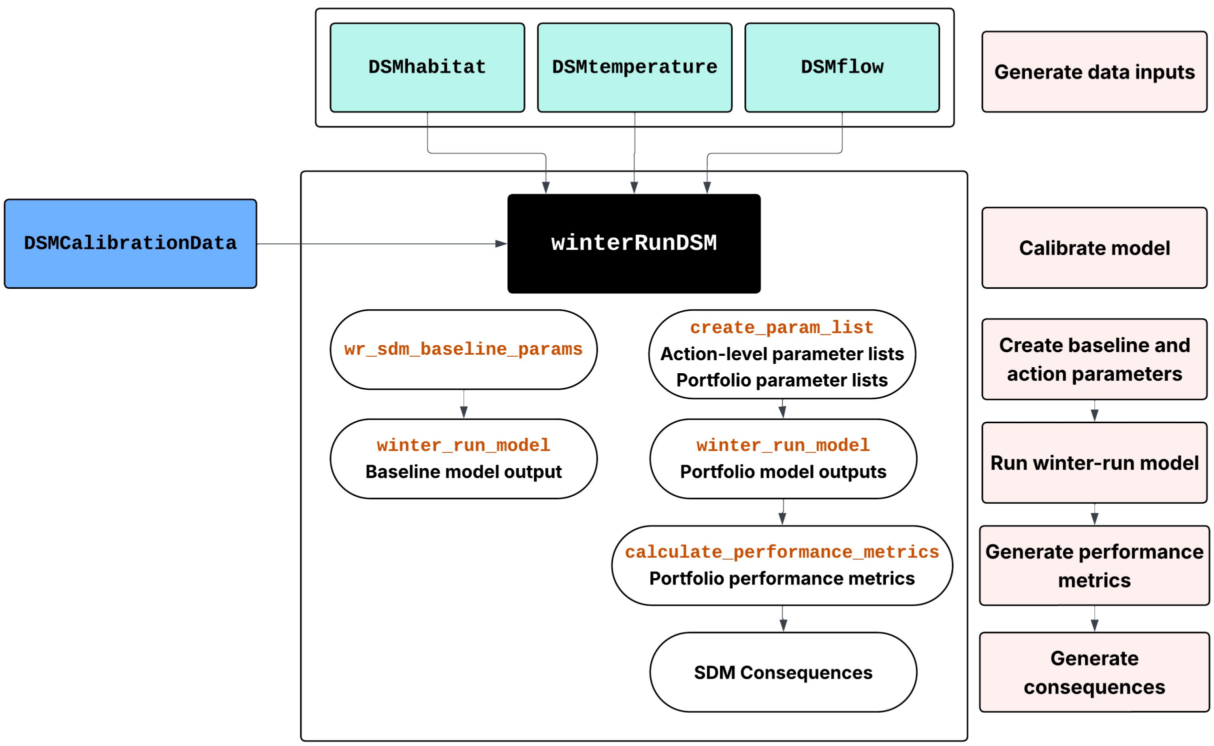



Source: Adapted from Peterson and Duarte (2020), Figure 2.

**Figure B-1. Conceptual Chinook Salmon Population Dynamics and Life Stage Transitions Used for Winter-run Model**

The model used and described herein is an adaptation of a derivative of the CVPIA-SIT winter-run DSM produced for the Reorienting to Recovery (R2R) project (Reorienting to Recovery Project Planning Team 2024). Specific adjustments for the winter-run version were referenced against the 2024 Long Term Operations (LTO) consultation version of the model (Reclamation 2024). Through the R2R and this rapid SDM process, the model was adjusted in its logic, submodels, inputs, and outputs; these changes are not endorsed by the CVPIA-SIT and would need to be formally proposed through the formal CVPIA-SIT process in order to be incorporated into that process.

Development of the model used in this process included: generating inputs in R packages specific to each input, specifying additional action-specific inputs, running the winter-run model, and generating performance metrics that were subsequently weighted for SDM analyses (Figure B-2). All model code used for this process is publicly available on the winter Run SDM GitHub repository. Summary of locations for each step of the process is included in the readme.



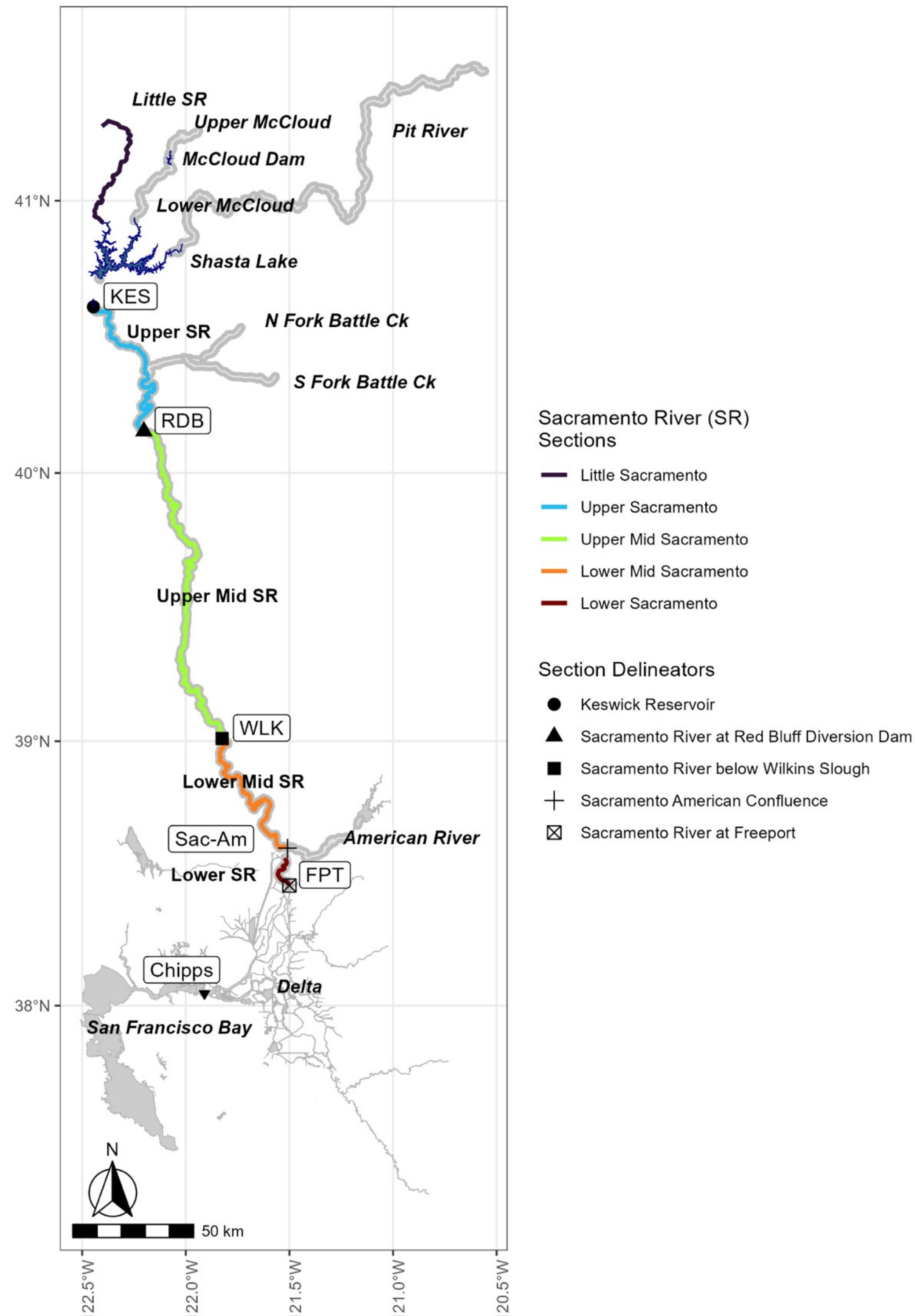

Note: Boxes on the right summarize the steps of the process, while ovals represent relevant functions and objects created during the process. Other colored boxes represent key packages used to run the winter-run model.

**Figure B-2. Simplified Winter-run Lifecycle Modeling Workflow**

## Geographic Scope

The spatial scope of the original SIT-CVPIA model includes 31 watershed units (see list and map: CVPIA SIT FAQs) used by various Chinook salmon runs that were applicable for other modeling efforts. For the rapid SDM process, only winter-run Chinook salmon habitat was included, with modeling actions occurring in Battle Creek (spawning and rearing life stages), the Upper Sacramento River (spawning and rearing life stages), the Upper-mid Sacramento River (rearing and outmigration life stages), Lower-mid Sacramento River (rearing and outmigration life stages), and Lower

Sacramento River (rearing and outmigration life stages). Winter-run Chinook salmon outmigrate through the Delta and San Francisco Bay in the model, then return to the Sacramento River. Some actions also included the McCloud River and the Little Sacramento River (Figure B-3), which were historically accessible to winter-run Chinook salmon. Habitat additions were calculated specifically for these tributaries and represented in the model along with other tributary actions within the Upper Sacramento River model watershed unit.




Note: Colored segments represent delineations of the Sacramento River watershed units in the model. Other locations of interest are noted as well.

**Figure B-3. Geographic Scope of Winter-run Lifecycle Model**

## Model Calibration

The calibration from the R2R effort was used for this process, which was conducted using the GA package in R (Table B-1). The fitness function was used to minimize the sum of squared errors of simulated natural adults and Grandtab escapement values from brood years 1998-2017, scaled using simulated proportion of natural adults. Optimization parameters used were: popSize = 150, maxiter = 10000, run = 50, pmutation = 0.4. See DSM Calibration Summary for more details about the calibration process and see Calibration script for the calibration script.

The calibrated model underpredicts population peaks seen in the California Department of Fish and Wildlife GrandTab escapement values used in calibration, which contributes to average modeled populations being lower than in actual observed data. While other analyses based on model derivatives of the CVPIA SIT DSMs have shown underprediction from calibrated models, this indicates that the winter-run model may not be capturing processes in the life cycle (e.g., ocean conditions) driving large peaks seen in the GrandTab values (Reclamation 2024). Table B-1 shows the calibrated parameter values used in the analysis with additional notes for use in the winter-run model.

**Table B-1: List of Calibrated Parameters Values with Associated Descriptions and Aliases (Parameter code) in the Codebase**

| Parameter Description | Parameter code | Calibrated value | Notes |
|---|---|---|---|
| Adult en-route survival intercept | surv_adult_enroute_int | 1.46507095 | -- |
| Juvenile instream and floodplain rearing survival intercept | surv_juv_rear_int | -0.965162 | -- |
| Effect of contact points on juvenile rearing survival | surv_juv_rear_contact_points | -0.2224633 | -- |
| Effect of proportion flow diverted on juvenile rearing/migratory survival | surv_juv_rear_prop_diversions | 0.48583725 | -- |
| Effect of total diversions on juvenile rearing/migratory survival | surv_juv_rear_total_diversions | 1.93046179 | -- |
| Juvenile bypass rearing survival intercept | surv_juv_bypass_int | -1.8205386 | -- |
| Juvenile Delta rearing survival intercept | surv_juv_delta_int | -0.8502327 | -- |

| Parameter Description | Parameter code | Calibrated value | Notes |
|---|---|---|---|
| Effect of contact points on Delta juvenile rearing survival | surv_juv_delta_contact_points | 1.21916702 | -- |
| Effect of Delta diversions on juvenile rearing survival | surv_juv_delta_total_diverted | -0.869897 | -- |
| Juvenile San Joaquin migratory survival intercept | surv_juv_outmigration_sj_int | -3.1105559 | Not relevant for winter-run model |
| Ocean entry success intercept | ocean_entry_success_int | 3.31032391 | -- |
| Egg-to-fry survival intercept | surv_egg_to_fry_mean_egg_temp_effect | 0.646623 | This value is a constant for other runs |

Note: The Notes column provides context for use in the winter-run version of the model.

For future winter-run modeling analyses, new hydrology and habitat inputs should be paired with a re-calibration effort to produce results that more accurately capture the peaks observed in the actual population. A recalibration effort was initiated for this rapid SDM process that produced new parameters, but two elements precluded the team from using re-calibrated parameters in the time frame available for this process: simulated spawner counts did not produce a match with observed (which is not uncommon for this model and its derivatives, but requires more in-depth analyses of algorithm performance and metrics before inclusion), and the implementation and testing of modeled actions was concurrent with the calibration process.

## Model Inputs

### *Temperature*

Temperature inputs are described in the HEC-5Q section. Temperature-related parameters in the model are used in the pre-spawn survival, growth, rearing, and migratory survival submodels. More details and code available at: DSMtemperature Github.

### *Flow*

Flow inputs are described in the CalSim 3 section. Further processing of the flow inputs included: monthly flow in cubic feet per second (cfs) at nodes for each watershed unit in the model, diversions, bypass flows, and conditions of the Delta Cross Channel gates. More details and code available at: DSMflow Github.

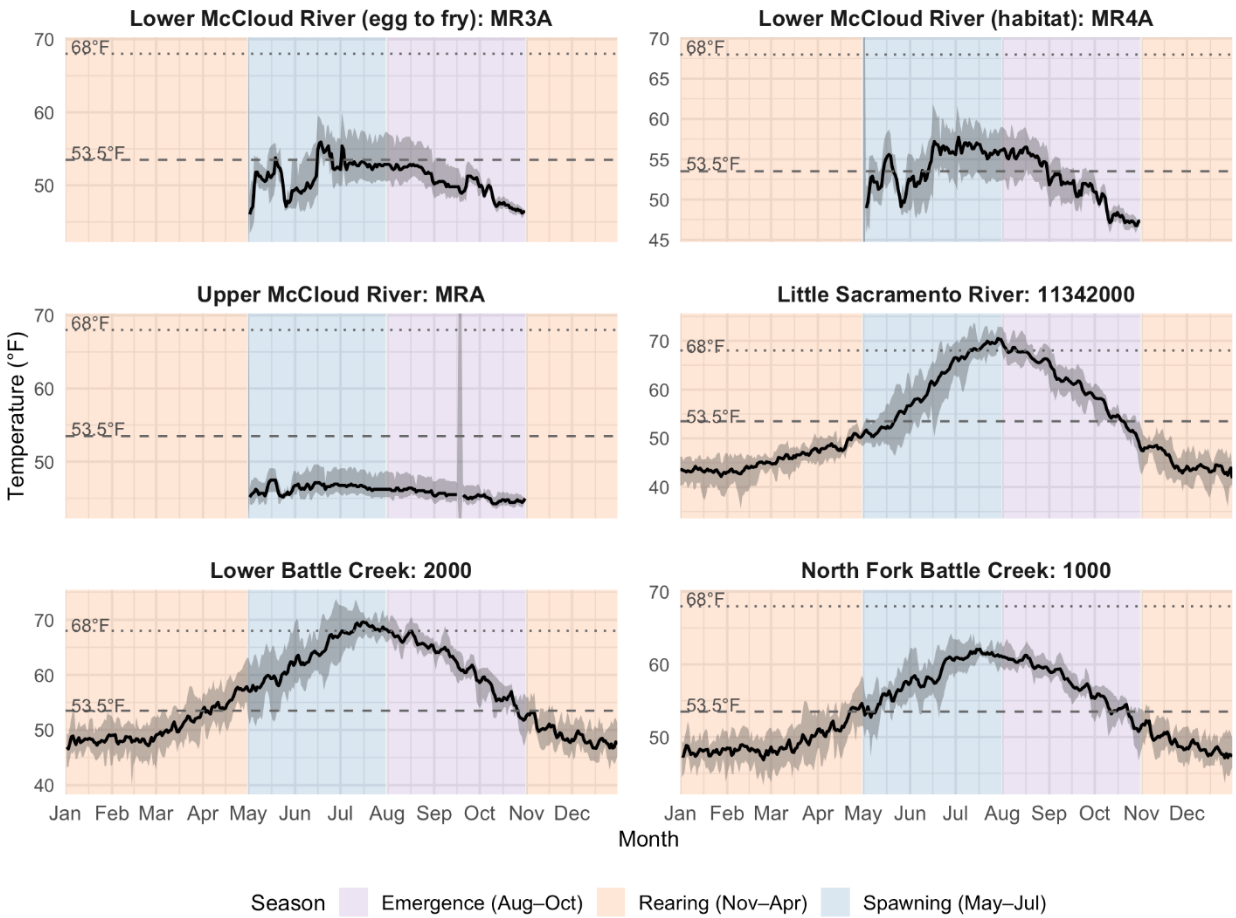
### *Habitat*

Habitat inputs in the model are produced for each watershed unit, at a monthly time step and for spawning, instream rearing, and floodplain rearing. These inputs are calculated through a variety of methods based on the watershed unit and level of available data, but most commonly via applying a flow-to-suitable habitat relationship to the CalSim 3 modeled flows. Each habitat input value represents the suitable area at the modeled flow for that same month and year, tailored to the specific life stage (spawning or rearing). Additional detail, including the underlying methodology and sources for each watershed unit as well as code, is available at: DSMhabitat Github.

### *Temperature Analysis for Scaling Habitat and Egg-to-Fry Survival*

The method developed used temperature time series data for the Upper McCloud River, Lower McCloud River, Little Sacramento River, Lower Battle Creek, and North Fork of Battle Creek. A report was provided to the modeling team containing these data (Deas and Wood 2026).

Proposed habitat in the Upper and Lower McCloud Rivers, the Little Sacramento River, and two reaches of Battle Creek were scaled according to temperature suitability. A rearing temperature threshold value of 68 degrees Fahrenheit (°F) was used to represent a point beyond which temperatures would have a significant negative effect on rearing survival. This value was based on the threshold value used for degree days affecting rearing survival per the original CVPIA-SIT model. 53.5°F was used as the spawning threshold per participant input and usage as a management target, and served as a value beyond which negative effects on egg survival compound. Additional nuance in the spawning temperature threshold was included to account for cumulative effects of temperature exposure (Reclamation and SWRCB 2003). Gages were selected based on the maps included in Deas and Wood 2026 and temperature time series were analyzed for exceedance of the spawning temperature thresholds for the appropriate months. For habitat scaling, May-August was used for spawning habitat and September-April was used for rearing according to the months in the model code (Figure B-1). For egg-to-fry survival, May-October was used to account for emergence (Figure B-4).




Note: Maps of gage locations and additional details about data origin can be found in Deas and Wood 2026. Battle Creek and Little Sacramento River data are from 2020 McCloud data are from 2008. Orange shading represents the rearing time frame, blue blocks represent the spawning time frame, and purple shading represents a time frame that is considered for rearing in habitat calculations and emergence for the egg-to-fry survival calculations. The upper dotted line represents the rearing temperature threshold and the dashed line represents the spawning temperature threshold. The grey ribbon around the data represents daily minimum and maximum temperatures.

**Figure B-4. Historical Mean Daily Temperatures in Fahrenheit from Selected Tributaries Where Habitat or Egg-to-Fry Survival Scaling was Applied**

### Habitat Addition Scaling

Proposed habitat in the Upper and Lower McCloud Rivers, the Little Sacramento River, and two reaches of Battle Creek were scaled according to temperature suitability. The scale factor was calculated as the proportion of daily temperatures in the time frame that was below the threshold.

Estimates of additional suitable habitat area were obtained for Battle Creek from weighted usable area (WUA) estimates developed for an Instream Flow Incremental Methodology (IFIM) study (Thomas R. Payne & Associates 1998); for the Little Sacramento and McCloud rivers, an estimate of habitat was calculated using river length, channel width, and habitat suitability using methods developed for R2R (Reorienting to Recovery Project Planning Team 2025). These produced time series of spawning and rearing habitat (instream and floodplain) as a function of modeled flows. Rearing habitat was generally not constrained by temperature suitability across all tributaries due to the cooler temperatures present during rearing months. Spawning habitat was limited across all tributaries except the Upper McCloud River, but the effect of high temperatures was most significant for the Little Sacramento River, for which a scale factor of 0.30 (only 0.30 of existing habitat was suitable) was estimated, and Lower Battle Creek, which had an estimated scale factor of 0.25 (Table B-2).

This approach was an attempt to account for multiple factors affecting spawning and rearing habitat suitability in reaches not previously represented in the winter-run model and which represent a source of uncertainty. It is likely that in some cases the negative effect of temperature is overestimated via this method, as the approach is highly sensitive to the location of a selected gage. The temperature data were limited in availability and in most cases spanned a single year, which, if representing a poor year for temperatures, could bias results. Finally, the proposed habitats in many cases represent spring-fed streams where additional cold water is supplying the habitats with better temperature conditions than were captured in this analysis. Future efforts to model habitat additions to the winter-run model will benefit from identifying longer historical datasets, further engagement with watershed experts on gage selection, and an analysis comparing across the existing studies on the habitats proposed.

### Egg-to-fry Survival Scaling

The intent of many of the actions was to provide more suitable conditions for winter-run Chinook salmon spawning, thus the modeling team also accounted for temperatures when modeling egg-to-fry survival above Shasta. A similar methodology was used to develop these scale factors with three modifications: Station MR3A was used for the Lower McCloud River to more closely represent conditions for existing streamside egg incubators, a time frame of May-October was used for temperature analysis to include fry emergence, and scale factors were calculated as a ratio to the HEC-5Q modeled temperatures to represent baseline conditions below Shasta Dam. Calculated scale factors were then multiplied by egg-to-fry survival to modify baseline values.

Like results for the spawning habitat scale factors, the Little Sacramento River time series showed few mean daily temperatures in the selected time period that were below the threshold in comparison to the Upper Sacramento River below Shasta, resulting in a scale factor of 0.3. Conditions in the McCloud River were generally better than those in the Sacramento River below Shasta, resulting in scale factors of 1.67, 1.56, and 1.61 for different reaches of the McCloud River (Table B-2).

Table B-2 shows the results of these analyses and the values used to scale new habitat or egg-to-fry survival ("scale factors") to account for temperature suitability.

**Table B-2: List of Station IDs Used in the Temperature Scaling Analysis for Each Tributary in the Winter-run Model and Associated Scale Factor.**

| Station ID | Tributary | Spawning Habitat Scale Factor | Rearing Habitat Scale Factor | Egg-to-Fry Survival Scale Factor |
|---|---|---|---|---|
| 11342000 | Little Sacramento River | 0.15 | 0.9 | 0.3 |
| MRA | Upper McCloud River | 1 | 1 | 1.67 |

| Station ID | Tributary | Spawning Habitat Scale Factor | Rearing Habitat Scale Factor | Egg-to-Fry Survival Scale Factor |
|---|---|---|---|---|
| MR3A | Lower McCloud River | N/A | N/A | 1.56 |
| MR4A | Lower McCloud River | 0.7 | 1 | N/A |
| N/A | Full McCloud River | 0.85 | 1 | 1.61 |
| 1000 | North Fork Battle Creek | 0.5 | 1 | N/A |
| 2000 | Lower Battle Creek | 0.25 | 0.9 | N/A |

Note: Values for the "Full McCloud" were calculated as the average across the "Lower" and "Upper" reaches of the river.

## Model Assumptions

### *Seeding*

All model runs include a 6 year "spin-up" period using the same hydrology as the first 6 years of the 20-year simulation, including any actions in the portfolio. This allows winter-run Chinook salmon to complete 2 full life cycles to reflect a realistic starting point for the population and assess more fully the effects of the actions during the 20-year simulation period.

The Upper Sacramento is seeded with 2,787 spawners (17.6% hatchery) per the original CVPIA-SIT DSM methodology, and Battle Creek is seeded with 500 spawners (100% hatchery). Battle Creek was a unique situation that required an initial population to seed the model, but where participant input indicated there was no naturally spawning population. The modeling team accounted for this dynamic by seeding a low value (500 spawners) composed of 100% hatchery fish.

### *Model Structure and Parameterization*

- Straying rate was reduced to 0 based on participant input that winter-run Chinook salmon do not tend to stray to other tributaries.

- The egg-to-fry survival submodel does not vary based on temperature. However, temperature effects on the egg-to-fry survival estimate were accounted for by scaling temperature using a multiplier as described in Egg-to-fry survival scaling.

- Spawners are renatured (switch from hatchery to natural origin upon return) if proportion of hatchery-origin spawners (pHOS) decreases for 2 years in a row. The number of fish renatured is based on the percent difference between pHOS in the simulation year and the pHOS 2 years prior and the number of spawners in the simulation year. See "Refinements to Lifecycle Model" for considerations related to renaturing.

- Hatchery

    - Upper Sacramento River hatchery release baseline values were modified (see Table B-3) based on elicited feedback.

- Egg incubation actions were modeled by adding hatchery fry to the relevant watershed unit.
- Egg-to-fry survival was scaled up in instances of increasing natural broodstock, since this submodel includes a negative relationship between hatchery fish and survival.
- Hatchery and natural-original juveniles are not tracked distinctly in the model; juveniles experience the same rearing, growth, and migratory conditions once they leave their natal watershed unit.
- Battle Creek reintroduction Broodstock was modeled based on phase-specific thresholds delineated in the Battle Creek Reintroduction Plan (ICF 2016).

- Above Shasta actions
  - Tributaries above Shasta are represented within the Upper Sacramento River watershed unit. See specific parameters created to track action specifics above Shasta in Table B-3. See Reorienting to Recovery Project Planning Team (2025) for information on how habitat above Shasta is calculated.
  - For volitional passage, spawners were assumed to populate tributaries based on the proportion of habitat available in each of the tributaries.
  - Survival estimate of 0.8 was selected based on information that "the levels of passage and survival for adults below Keswick Dam to juvenile below Keswick Dam would need to be approximately 0.80 to match historical abundance levels of winter-run spawners in the Nomtipom Waywaket" (Section 4.2.5.4 of Anchor QEA and HDR 2026). While this is not a survival estimate based on releasing fish in the field, this provides a target value for reintroduction.
  - Juvenile Trap efficiency estimate of 0.25 was based on 2022-2024 results from in-river collection of juvenile Chinook Salmon outmigrating from the Winnemem Waywaket incubation site (Tables 15 and 16, Anchor QEA and HDR 2026). Different trap configurations and sites were evaluated, averaging at 22.3% (range of 0.3 to 43%) efficiency in 2023 and 1.42% (range of 0-6%) efficiency in 2024/2025. 25% was selected as an optimistic value, assuming optimization of sites and configuration in the future.

- Harvest
  - The R2R model included an incidental and illegal harvest estimate for the ocean of 0.1. Based on participant input, this estimate was modified to vary by age class, with harvest rate set to 0 for Age 2, 0.2 for Age 3, 0.5 for Age 4, and 0 for Age 5. Maturity by age was also set by age class, with 0 for Age 2, 0.95 for Age 3, 0.05 for Age 4, and 1 for Age 5.
  - Several actions also recommended reducing harvest in the Sacramento River and tributaries. Thus, parameters were created for watershed-specific baseline harvest estimates. These values are highly uncertain. The Sacramento River watershed units were

assigned values of 0.10, Battle Creek was assigned 0.05, and Above Shasta tributaries were assigned 0.025 to reflect the differing level of access for each watershed.

## Modeling Actions

The winter-run model was adapted to model actions proposed by participants. Modelers identified existing model parameters that could be altered to represent actions and consulted with the analyst team and participant team to arrive at suitable values for parameter value changes. In some cases, after observing either diminished or exaggerated effects that certain parameter changes had on the results, values were adjusted to meet the intent of the action.

Changes to existing model parameter values included: addition of habitat (spawning, instream rearing, floodplain rearing), addition of hatchery releases in different watershed units for different life stages, addition of natural juveniles, and changes to the number of spawners collected for Broodstock. New "multiplier" parameters also allowed scaling of survival (e.g., egg-to-fry, enroute survival, delta survival) estimates.

In certain cases, the model required larger updates to accommodate actions. The most significant changes to the model involved Above Shasta actions. Because the tributaries above Shasta are not included as distinct watershed units in the model with their own parameters and accounting, they are, for the most part, combined with the Upper Sacramento watershed unit. Thus, model changes were necessary to track different components of the proposed actions, and several new parameters were added:

- Juvenile trap efficiency
- Juvenile survival during volitional passage or trap and haul transport
- Adult survival during volitional passage or trap and haul transport
- Proportion of spawners returning from the Upper Sacramento that were "sent" above the dam (Shasta)
- Proportion of Upper Sacramento habitat available to spawners above the dam
- Pre-spawn survival above the dam
- Egg-to-fry survival above the dam (Little Sacramento, Lower McCloud, Upper McCloud)
- Incidental and illegal harvest above dam

Table B-3 summarizes the changes that were made for each action, and values that were included in the baseline (representing existing conditions from the simulated time period). In some cases, actions combined in a portfolio had interactive effects, thus parameters were modified accordingly based on modeled portfolios to meet the intent of the action. Specific details and code used to generate baseline and action parameters are available at: https://github.com/WinterRunSDM/winterRunDSM.

- Action development: Script to develop action parameters.
- Baseline parameters: Script to develop baseline parameters.

**Table B-3. List of Actions, Baseline Characteristics of the Winter-Run Model, and Implementation of Actions Within Model**

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| H-1 | Hatchery | LSNFH modified release practices | Adds large hatchery fish (smolts) into all mainstem Sacramento River reaches for every year of the simulation. Values are on top of baseline hatchery releases: 30,000 additional fish in Upper Sacramento, 90,000 additional fish in Upper-mid, Lower-mid, and Lower Sacramento River). | Upper Sacramento releases: 50,000 large hatchery fish in dry years and 25,000 large hatchery fish in normal and wet years. |
| H-2a | Hatchery | LSNFH facility upgrades | No changes | N/A |
| H-2b | Hatchery | Upgrades to Keswick Dam adult collection system | 15% of naturally spawning adults in the Upper Sacramento are collected for hatchery broodstock. | 8.7% of naturally spawning adults in the Upper Sacramento are collected for hatchery broodstock |
| H-2b | Hatchery | Upgrades to Keswick Dam adult collection system | Upper Sacramento egg-to-fry survival is increased by 10% (1.1 x egg-to-fry survival) to balance the reduction of natural spawners through removal, and the benefits of more natural-origin broodstock. | Upper Sacramento egg-to-fry survival varies annually, ranging 0.37-0.38 |
| H-2c | Hatchery | New broodfish collection facility in Upper Sacramento River | 25% of naturally spawning adults in the Upper Sacramento are collected for hatchery broodstock. This action overrides H-2b if both selected. | 8.7% of naturally spawning adults in the Upper Sacramento are collected for hatchery broodstock |
| H-2c | Hatchery | New broodfish collection facility in Upper Sacramento River | Upper Sacramento egg-to-fry survival is increased by 20% (1.2 x egg-to-fry survival) to balance the reduction of natural spawners through removal, and the benefits of more natural-origin broodstock. | Upper Sacramento egg-to-fry survival varies annually, ranging 0.37-0.38 |
| H-3 | Hatchery | CNFH trapping and sorting improvements | Increases survival of adults migrating to Battle Creek (enroute survival) by 10% (1.1 x enroute survival) | Battle Creek enroute survival varies annually, mean of 0.81 |
| SR-1 | Sacramento River | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | Triples the amount of floodplain rearing habitat available in the Upper-mid Sacramento River. | Range of 0.1 to 5090.5 acres |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| SR-2a | Sacramento River | Physically build and maintain new instream perennial juvenile rearing habitat | Doubles instream habitat for both fry and juveniles in the Upper and Upper-mid Sacramento River. | Upper-mid Sacramento: Range of 6.0 to 130.0 acres Upper Sacramento: Range of 5.2 to 73.2 acres |
| SR-2b | Sacramento River | Artificially enhance existing instream juvenile rearing habitat | Doubles instream habitat for both fry and juveniles in the Upper and Upper-mid Sacramento River. Has a lower cost compared with SR-2a. | Upper-mid Sacramento: Range of 6.0 to 130.0 acres Upper Sacramento: Range of 5.2 to 73.2 acres |
| SR-2c | Sacramento River | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | Shifts 60% of fry to a larger size class to represent benefits of rearing in non-natal tributaries | N/A |
| SR-3 | Sacramento River | Build or enhance instream spawning habitat | Increases egg-to-fry survival in the Upper Sacramento by 10% (1.1 x egg-to-fry survival), representing improvements to spawning habitat. | Upper Sacramento egg-to-fry survival varies annually, ranging 0.37-0.38 |
| SR-4a | Sacramento River | Reduce predation contact points on Sacramento River | Decreases predator contact points by 7% in mainstem Sacramento River reaches, representing decrease in predation risk | 33 in Upper Sacramento, 121 in Upper-mid Sacramento, 352 in Lower-mid Sacramento, 101 in Lower Sacramento |
| SR-4b | Sacramento River | Develop regulations to support a striped bass trophy fishery | Decreases the proportion of habitat under high predation pressure in mainstem Sacramento River reaches by 7% | 0.30 in Upper Sacramento, Upper-mid Sacramento. 1.00 in Lower-mid Sacramento and Lower Sacramento. |
| SR-5 | Sacramento River | Reduce entrainment at Sacramento River diversions | Reduces the effect of water diversions on juvenile rearing survival by 25%, e.g., via improved screens or operational changes. | Baseline value not interpretable without submodel context |
| SR-6 | Sacramento River | Georgiana Slough bubble curtain | Reduces the probability of juveniles routing into Georgiana Slough by 20%. | Baseline ranges 0.15 to 0.3 |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| SR-8 | Sacramento River | Nighttime light reduction on Sundial Bridge and other sources | Decreases the proportion of habitat under high predation pressure in mainstem Sacramento River reaches by 3% if paired with SR-4a and SR-4b. Otherwise, decreases high predation pressure habitat by 5%. | 0.30 in Upper Sacramento, Upper-mid Sacramento. 1.00 in Lower-mid Sacramento and Lower Sacramento. |
| SR-9 | Sacramento River | Provide volitional upstream and downstream fish passage at Keswick Dam | Adds ~1.8 acres of spawning habitat to the Upper Sacramento. | Range of 10.8 to 63.2 acres spawning habitat |
| SR-9 | Sacramento River | Provide volitional upstream and downstream fish passage at Keswick Dam | The proportion of fish spawning above the dam is the proportion of spawning habitat above Keswick that is in the total Upper Sacramento watershed unit. | No fish spawning above the dam |
| SR-9 | Sacramento River | Provide volitional upstream and downstream fish passage at Keswick Dam | Includes a multiplier for adult (99% survival) and juvenile (97%) volitional passage survival at Keswick Dam. If combined with ASD-6, survival reduces to 0.8 for adults and 0.6 for juveniles to represent passage through both Shasta and Keswick reservoirs | Baseline does not include a multiplier |
| SR-10 | Sacramento River | Construct Anderson Cottonwood Irrigation District Water Supply & Fisheries Resiliency Project | Increases spawning habitat (approximately 7 additional acres), floodplain habitat (approximately 1 acre), and instream habitat (approximately 2 acres), with acreages based on the 0.75 quantile of each baseline habitat type. | Range of 10.8 to 63.2 acres spawning habitat, 0.03 to 527.1 acres for floodplain habitat, 5.2 to 73.2 acres instream habitat |
| SR-10 | Sacramento River | Construct Anderson Cottonwood Irrigation District Water Supply & Fisheries Resiliency Project | Increases pre-spawn survival by 4% | Pre-spawn survival of 0.92 |
| SR-10 | Sacramento River | Construct Anderson Cottonwood Irrigation District Water Supply & Fisheries Resiliency Project | Increases spawning habitat (approximately 7 additional acres), floodplain habitat (approximately 1 acre), and instream habitat (approximately 2 acres) Increases pre-spawn survival by 4% | Range of 10.8 to 63.2 acres spawning habitat, 0.03 to Pre-spawn survival of 0.92 |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| SR-11 | Sacramento River | Captive rearing and assisted migration of juveniles in drought years | In drought years (years 9-13), transfers 50,000 fry from the base of the Upper Sacramento River and adds them as the largest size class of smolts at Chipps Island | No additional fish added |
| BC-1 | Battle Creek | Control illegal harvest and/or poaching in Battle Creek | Cuts incidental and illegal harvest of winter-run in Battle Creek by 50%. | 5% incidental and illegal harvest in Battle Creek |
| BC-2 | Battle Creek | Battle Creek habitat improvements | Restores floodplain, fry, and juvenile instream habitat in lower Battle Creek using temperature-adjusted habitat values tied to proponent-informed data | Ranges 0 to 20 acres floodplain habitat in Battle Creek, 5.1 to 7.1 acres instream habitat |
| BC-3 | Battle Creek | CNFH water supply intake improvements on Battle Creek | No changes | N/A |
| BC-5 | Battle Creek | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | Adds temperature-adjusted spawning habitat and instream fry and juvenile rearing habitat on the North Fork of Battle Creek tied to proponent-informed data | Ranges 0.08 to 0.14 acres spawning habitat in Battle Creek, 5.1 to 7.1 acres instream habitat |
| BC-6 | Battle Creek | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | Represents additional habitat and better survival due to cooler temperatures from unimpaired North Fork flows:<br>Increases spawning habitat by 3% | Ranges 0.08 to 0.14 acres spawning habitat in Battle Creek |
| BC-6 | Battle Creek | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | Represents additional habitat and better survival due to cooler temperatures from unimpaired North Fork flows:<br>Increases egg-to-fry survival by 3% | Varies annually, approximately 0.33 |
| BC-7 | Battle Creek | Limit cold water diversions | Represents additional habitat and better survival due to cooler temperatures:<br>Increases spawning habitat by 3% | Ranges 0.08 to 0.14 acres spawning habitat in Battle Creek |
| BC-7 | Battle Creek | Limit cold water diversions | Represents additional habitat and better survival due to cooler temperatures:<br>Increases egg-to-fry survival by 3% | Varies annually, approximately 0.33 |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| BC-8 | Battle Creek | Battle Creek egg incubation | Establishes hatchery releases of 200,000 smolts across all years on Battle Creek. If paired with BC-9, increases releases by 10%. | No hatchery releases |
| BC-9 | Battle Creek | Implement Battle Creek Reintroduction Plan | Establishes hatchery releases of 200,000 smolts across all years on Battle Creek. | No hatchery releases |
| BC-9 | Battle Creek | Implement Battle Creek Reintroduction Plan | Establishes thresholds based on the geometric mean of spawners in Battle Creek, with natural adult removal rate starting at 0, increasing to 0.15 at 100+ spawners, to 0.5 at 500+ spawners, and decreasing to 0 at 850+ spawners | Natural adult removal rate of 0 |
| O-1 | Other | Improve WR Salvage at Tracy & State Fish Collection Facilities | Increases overall delta survival by 1%, representing operational improvements to water management. | No change in delta survival |
| O-2 | Other | Increase distance from shoreline to "International" designation | Reduces ocean harvest rates by 1% across all age classes. | 0 for Age-2, 0.2 for Age-3, 0.5 for Age-4 and 0 for Age-5 |
| O-3 | Other | Modify ocean harvest | Reduces ocean harvest: age-2 fish reduced by 25%, age-3 fish reduced by 70%. | 0 for Age-2, 0.2 for Age-3, 0.5 for Age-4 and 0 for Age-5 |
| F-1 | Facilities | Shasta TCD Upgrade/Cold water outlet to access colder water | Increases egg-to-fry survival in the Upper Sacramento by 8.1%, representing better survival due to lower temperatures. | Upper Sacramento egg-to-fry survival varies annually, ranging 0.37-0.38 |
| ASD-1 | Above Shasta Dam | Excess hatchery eggs placed in-river or in streamside egg incubators | Adds 20,000 additional medium and 30,000 additional large hatchery fish into the Upper Sacramento in all years. | Upper Sacramento releases: 50,000 large hatchery fish in dry years and 25,000 large hatchery fish in normal and wet years. |
| ASD-2 | Above Shasta Dam | Control illegal harvest and/or poaching in McCloud River | Reduces incidental and illegal harvest of adults above Shasta Dam by 50%. | Incidental and illegal harvest of 0.10 in Upper Sacramento |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| ASD-3 | Above Shasta Dam | Release hatchery fry into upper McCloud | Releases hatchery fry (medium juveniles) into the Upper Sacramento River: 80,000 fry for the first 8 years, 115,000 fry for the next 6 years, and 150,000 fry for the final 6 years. 25% juvenile capture efficiency is incorporated into the estimate of hatchery fish exiting above Shasta habitat and entering the Upper Sacramento River. | Upper Sacramento releases: 50,000 large hatchery fish in dry years and 25,000 large hatchery fish in normal and wet years. |
| ASD-3 | Above Shasta Dam | Release hatchery fry into upper McCloud | Adds upper McCloud River fry and juvenile rearing and floodplain habitat, adjusted for temperature suitability. Assumes no natural spawning above the dam. | Just Upper Sacramento below dam habitat |
| ASD-3 | Above Shasta Dam | Release hatchery fry into upper McCloud | Transport survival for juvenile fish from McCloud Dam is set at 80%. | No transport survival |
| ASD-4 | Above Shasta Dam | Release hatchery fry into lower McCloud | Releases hatchery fry (medium juveniles) into the Upper Sacramento River: 80,000 fry for the first 8 years, 115,000 fry for the next 6 years, and 150,000 fry for the final 6 years. 25% juvenile capture efficiency is incorporated into the estimate of hatchery fish exiting above Shasta habitat and entering the Upper Sacramento River. | Upper Sacramento releases: 50,000 large hatchery fish in dry years and 25,000 large hatchery fish in normal and wet years. |
| ASD-4 | Above Shasta Dam | Release hatchery fry into lower McCloud | Adds lower McCloud River fry and juvenile rearing and floodplain habitat, adjusted for temperature suitability. Assumes no natural spawning above the dam. | Just Upper Sacramento below dam habitat |
| ASD-4 | Above Shasta Dam | Release hatchery fry into lower McCloud | Transport survival for juvenile fish from the Lower McCloud is set at 80%. | No transport survival value |
| ASD-5a | Above Shasta Dam | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | 50% of returning Upper Sacramento River adults are trapped and hauled above Shasta Dam to spawn in the lower McCloud River | No fish spawning above dam |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| ASD-5a | Above Shasta Dam | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Addition of temperature-adjusted spawning, floodplain, instream habitat in the Upper Sacramento, representing the Lower McCloud. If paired with ASD-3 and ASD-4, temperature-adjusted Upper McCloud juvenile habitat is also added. | Just Upper Sacramento below dam habitat |
| ASD-5a | Above Shasta Dam | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Pre-spawn survival above dam is set to 95% | Upper Sacramento River pre-spawn survival varies annually, ranging 91%-93% |
| ASD-5a | Above Shasta Dam | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Egg-to-fry survival is multiplied by Lower McCloud scale factor. | Upper Sacramento egg-to-fry survival varies annually, ranging 0.37-0.38 |
| ASD-5a | Above Shasta Dam | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Juveniles are trapped and hauled below Shasta Dam, with 90% efficiency. This value was scaled up from suggested values since model structure can compound reduction of fry. | No juvenile efficiency |
| ASD-5a | Above Shasta Dam | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Transport survival is 80% for both adults and juveniles. | No juvenile efficiency |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| ASD-5c | Above Shasta Dam | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | 50% of returning Upper Sacramento River adults are trapped and hauled above Shasta Dam to spawn in the lower McCloud and Little Sacramento | No fish spawning above dam |
| ASD-5c | Above Shasta Dam | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Addition of temperature-adjusted spawning, floodplain, instream habitat in the Upper Sacramento, representing the Lower McCloud and Little Sacramento. If paired with ASD-3 and ASD-4, temperature-adjusted Upper McCloud juvenile habitat is also added. | Just Upper Sacramento below dam habitat |
| ASD-5c | Above Shasta Dam | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Pre-spawn survival above dam is set to 95% | Upper Sacramento River pre-spawn survival varies annually, ranging 91%-93% |
| ASD-5c | Above Shasta Dam | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Egg-to-fry survival is multiplied by mean of the Lower McCloud and Little Sacramento scale factor. | Upper Sacramento egg-to-fry survival varies annually, ranging 0.37-0.38 |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| ASD-5c | Above Shasta Dam | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Juveniles are trapped and hauled below Shasta Dam, with 90% efficiency. This value was scaled up from suggested values since model structure can compound reduction of fry. | No juvenile efficiency |
| ASD-5c | Above Shasta Dam | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Transport survival from trap and haul is 80% for both adults and juveniles. | No juvenile efficiency |
| ASD-6 | Above Shasta Dam | Volitional passage above Shasta Dam into McCloud River | The proportion of fish spawning above dam is equal to the proportion of spawning habitat available in the Lower McCloud. | No fish spawning above dam |
| ASD-6 | Above Shasta Dam | Volitional passage above Shasta Dam into McCloud River | The proportion of spawning habitat available above dam is also equal to the proportion of spawning habitat available in the Lower McCloud. | No spawning habitat above dam |
| ASD-6 | Above Shasta Dam | Volitional passage above Shasta Dam into McCloud River | Addition of temperature-adjusted spawning, floodplain, instream habitat in the Upper Sacramento, representing the Lower McCloud. | Just Upper Sacramento below dam habitat |
| ASD-6 | Above Shasta Dam | Volitional passage above Shasta Dam into McCloud River | Pre-spawn survival above dam is set to 95% | Upper Sacramento River pre-spawn survival varies annually, ranging 91%-93% |
| ASD-6 | Above Shasta Dam | Volitional passage above Shasta Dam into McCloud River | Egg-to-fry survival is multiplied by the Lower McCloud scale factor. | Upper Sacramento egg-to-fry survival varies annually, ranging 0.37-0.38 |
| ASD-6 | Above Shasta Dam | Volitional passage above Shasta Dam into McCloud River | Adult survival due to volitional passage is set to 80% and juvenile survival is set to 40%. | No volitional passage |

| Action | Category | Description | Model Changes | Baseline |
|---|---|---|---|---|
| ASD-6 | Above Shasta Dam | Volitional passage above Shasta Dam into McCloud River | Adult survival due to volitional passage is set to 80% and juvenile survival is set to 40%. | No volitional passage |
| ASD-7 | Above Shasta Dam | Remove McCloud Dam | The action itself does not send any fish above Shasta but is paired with other actions to increase the habitat available to fish. | N/A |
| ASD-7 | Above Shasta Dam | Remove McCloud Dam | The proportion of spawning habitat available above dam is equal to the proportion of spawning habitat available in the Full McCloud. | No spawning habitat above dam |
| ASD-7 | Above Shasta Dam | Remove McCloud Dam | Addition of temperature-adjusted spawning, floodplain, instream habitat in the Upper Sacramento, representing the Full McCloud. | Just Upper Sacramento below dam habitat |
| ASD-7 | Above Shasta Dam | Remove McCloud Dam | Pre-spawn survival above dam is set to 95% | Upper Sacramento River pre-spawn survival varies annually, ranging 91%-93% |
| ASD-7 | Above Shasta Dam | Remove McCloud Dam | Egg-to-fry survival is multiplied by the Full McCloud scale factor. | Upper Sacramento egg-to-fry survival varies annually, ranging 0.37-0.38 |
| ASD-8 | Above Shasta Dam | Return historic salmon strain from New Zealand | Add 500,000 smolts (large fish) to Full McCloud River | N/A |

Notes:

Watersheds described represent the watershed unit represented in the model.

Key: CNFH = Coleman National Fish Hatchery, N/A = not applicable, PG&E = Pacific Gas and Electric Company, TCD = Temperature Control Device, WRCS = winter-run Chinook salmon

## Changes to Model Functions

Spawn success

- Pre-spawn survival multiplier
- Egg-to-fry survival multiplier (temperature-informed)
- Applies unique pre-spawn survival, habitat capacity calculation, and egg-to-fry survival for fish above the dam (either through volitional passage or trap-and-haul).

Multipliers: Given the rapid timeframe of this SDM process, modelers scaled several life stage-specific survival and routing estimates rather than modify the mechanics of survival submodels. Multipliers were used for:

- Egg-to-fry survival: scaled for different tributaries and actions. Temperature-related scaling for above Shasta actions described in detail in "Egg-to-fry survival scaling."
- Adult enroute survival: scaled to increase adult enroute survival related to hatchery improvements
- Delta survival: scaled to increase outmigration survival related to salvage improvements
- Routing into Georgiana Slough: scaled to decrease routing into Georgiana Slough due to bubble curtain, based on participant input

## Modeling Portfolios

To model portfolios, actions were combined to create an updated list of parameter inputs. Because portfolios often contained actions that modified similar parameters, the modeling team added qualifiers to appropriately adjust parameter values, where needed. Details are provided in Table B-3.

## Construction of Performance Metrics

Performance metrics were determined by the analyst team based on input from participants. The winter-run model generally generates results by watershed unit at an annual time-step, and depending on the metric, may also generate results at a monthly time-step, and at size or age class scales. In order to simplify consequence weighting, the analyst team decided to summarize each metric with one value averaged across the output scales. Table B-4 describes how these metrics were generated and summarized.

**Table B-4. Description of Performance Metrics**

| Objective | Performance Metric | Metric Calculation Methods |
|---|---|---|
| Increase abundance | Average annual returns of WRCS | Model estimates the number of adult spawning salmonids in each tributary, for each year of the 20-year simulation. Spawners for each watershed unit were summed annually, then those totals were averaged across the 20 years to yield the average value of total spawners. |
| Increase abundance | Average pHOS (abundance) | pHOS was estimated by dividing total hatchery-origin spawners (considering all watersheds units) by total spawners, for each year of the 20-year simulation. Those pHOS values were then averaged across the 20 years to yield the average pHOS. |
| Increase abundance | Decline | Year over year decline in number of total spawners is calculated for each year of the modeling period (20 years). The longest run of consecutive years with greater than or equal to 10% decline is identified and reported. |
| Increase abundance | Catastrophic decline | Estimated as the number of years with a 3-year population decline (based on total spawners across watershed units) of an order of magnitude or more. The number of such 3-year catastrophic decline "events" over the 20-year modeling period is identified and reported. |
| Increase productivity | Average annual number of outmigrating juveniles leaving the Upper Sacramento | Estimated with models as the annual number of juveniles exiting the Upper Sacramento at Red Bluff prior to undergoing rearing, outmigration, and growth. Model results were summarized with one 20-year average value of number of juveniles. |
| Increase productivity | Average annual number of smolts reaching the ocean | Estimated with models as the annual number of smolts (larger juveniles) reaching Chipps Island. Model results were summarized with the 20-year average value of number of smolts. |
| Increase productivity | Average annual CRR | CRR is estimated with models as the adult natural origin return ratio in each tributary, tracked for 20 years. CRR is calculated annually as the total number of natural-origin adult returns in year X+3 divided by the number of total spawners in year X. Natural-origin and total spawners were each summed across watershed units annually and the 20-year average value is reported. |

| Objective | Performance Metric | Metric Calculation Methods |
|---|---|---|
| Increase life history diversity | Average annual juvenile size diversity at ocean entry | Salmonid models can be used to estimate the annual variation of size (small, medium, large, very large) in juveniles at ocean entry. Size distribution of juveniles is summarized in a single metric by using a Shannon diversity index, calculated for each year. The 20-year average of the annual value is reported. |
| Increase life history diversity | Average pHOS (diversity) | pHOS was estimated by dividing total hatchery-origin spawners (considering all watersheds units) by total spawners, for each year of the 20-year simulation. Those pHOS values were then averaged across the 20 years to yield the average pHOS. |
| Increase number of tributaries supporting WRCS | Average annual number of adults spawning in tributaries (Battle Creek and Above Shasta Dam) | Spawners above dam model outputs were summed annually with Battle Creek returns, then summarized by the 20-year average value of total tributary spawners. |
| Increase number of tributaries supporting WRCS | Proportion of total suitable rearing habitat that is in tributaries | Available annual rearing habitat in tributaries was calculated for each portfolio by summing instream and floodplain habitat in each tributary (McCloud, Little Sacramento, Battle Creek) for each year and dividing by the total rearing habitat across tributaries and the Upper Sacramento mainstem. Results were then summarized to show the 20-year average value of proportion of suitable rearing habitat found in tributaries. |
| Increase number of tributaries supporting WRCS | Number of tributaries above Shasta Dam with accessible spawning and rearing habitat | Actions including trap and haul and removal of barriers to above Shasta habitat increase habitat available to WRCS above Shasta in the WRCS model. Based on the method described above, if both rearing habitat and spawning habitat proportions were greater than 0, the tributary was considered to be accessible. Tributaries considered were the McCloud River and Little Sacramento River. This value is reported as a count: 0 (no tributaries accessible), 1 (either McCloud or Little Sacramento accessible), or 2 (both McCloud and Little Sacramento accessible). |

| Objective | Performance Metric | Metric Calculation Methods |
|---|---|---|
| Increase number of tributaries supporting WRCS | Number of independent populations | Watershed-specific estimates from models can be used to calculate the number of independent viable populations of WRCS. Independent populations were defined as those meeting the following criteria: greater than 500 spawners, pHOS less than 5%, CRR > 1, spawner increase > 1. If a population met the thresholds for the last 3 years of the modeling period that have values for those metrics, this was considered an independent population. Watersheds considered were the McCloud River, Little Sacramento River, Battle Creek, and the Upper Sacramento River below Shasta. Spawners for the Upper Sacramento River watershed unit were estimated by using the proportion of habitat available in each of the watersheds (Upper Sacramento mainstem, McCloud, Little Sacramento) for each portfolio multiplied by the total returns in the Upper Sacramento watershed. |

Key:
CRR = Cohort Replacement Rate
pHOS = proportion of hatchery-origin spawner
WRCS = winter-run Chinook salmon

Additional Notes on Spawner Metrics:

- Average annual returns of winter-run Chinook salmon: The model's spawner output reflects returns prior to consideration of pre-spawning survival.

- Average annual number of adults spawning in tributaries: The spawner above dam output used to estimate this metric takes into account pre-spawning survival, thus reflecting lower spawner outputs compared with annual returns.

- Independent populations: because spawners were tracked above dam rather than by tributary above Shasta, and above Shasta tributary and mainstem Upper Sacramento River spawners were combined into the Upper Sacramento River watershed unit, a method was needed to obtain independent estimates for each tributary. For consistency with the available output for Battle Creek and Upper Sacramento River below Shasta, spawners were calculated by multiplying annual returns prior to pre-spawning survival by proportion of spawning habitat in each watershed for each portfolio (see Table B-4).

- While outputs used for these different metrics may not fully be consistent with each other due to the combination of watersheds within the Upper Sacramento, the values of the different metrics are not being compared against each other, and are only compared within metric for relative differences.

# Appendix B References

Anchor QEA and HDR Engineering, Inc. 2026. Background Compendium and Design Criteria Report for the Feasibility of Volitional Fish Passage above Keswick and Shasta Dams. Prepared for California Department of Fish and Wildlife. January 2026.

CVPIA Science Integration Team. (2023). DSM FAQ. *CVPIA SIT.* https://cvpia.scienceintegrationteam.com/cvpia-sit/resources/dsm-faq. Accessed: April 15, 2026.

Deas, M., and M. Wood. 2026. Water Temperature Assessments for Winter Run Habitat – SDM Support. Technical Memorandum. Watercourse Engineering, Inc. March 16, 2026.

ICF International. 2016. Battle Creek Winter-Run Chinook Salmon Reintroduction Plan. (ICF00148.15.) August. Sacramento, CA. Prepared for California Department of Fish and Wildlife. Sacramento CA. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=129504&inline

Peterson, J.T., and A. Duarte. 2020. Decision analysis for greater insights into the development and evaluation of Chinook salmon restoration strategies in California's Central Valley. Restoration Ecology 28:1596–1609. https://doi.org/10.1111/rec.13244

Reorienting to Recovery Project Planning Team. 2024. Reorienting to Recovery: Identifying a Broad-sense Recovery Scenario for Central Valley Salmonids. Prepared for the Delta Stewardship Council. November 2024.

Reorienting to Recovery Project Planning Team. 2025. Calculating Theoretical Maximum Habitat. Reorienting to Recovery Documentation Site. Available: https://reorienting-to-recovery.gitbook.io/documentation-site/zCZ2Z2yqFYMUQrtZdTlg/modeling-documentation/scenarios/bookend-scenario-overview/theoretical-maximum-habitat-overview/calculating-theoretical-maximum-habitat. Accessed: April 15, 2026.

Thomas R. Payne & Associates. 1998. Battle Creek Fisheries Studies Task 1: Instream Flow Study. Prepared for California Department of Fish and Game, Redding, CA. April 1998.

U.S. Bureau of Reclamation (Reclamation) and California State Water Resources Control Board (SWRCB). 2003. Appendix M: Instream Flow Effects on Water Temperatures in the Battle Creek Restoration Area. Battle Creek Salmon and Steelhead Restoration Project Draft Environmental Impact Statement/Environmental Impact Report. July 2003.

U.S. Bureau of Reclamation (Reclamation). 2024. Appendix F, Attachment F.2: CVPIA SIT Winter-run LCM. Final Environmental Impact Statement, Long-Term Operation of the Central Valley Project and State Water Project. U.S. Department of the Interior. November 2024.

# Appendix C

# Development of Unique Action F-1 Timeseries

# Appendix C: Development of Unique Action F-1 Timeseries

## Background on Action

The unique action F-1 focuses on structural (not operational) modifications to Shasta to increase access to coldwater pool. This action focuses on enhancing delivery of cold water downstream, which is critical for survival of winter-run Chinook salmon during spawning and incubation. The action includes structural modifications to increase access to deeper, colder water layers during low reservoir conditions. Improving the accessibility of cold water supports more reliable temperature management in the Sacramento River, complements real-time monitoring efforts, and strengthens broader salmon recovery strategies tied to hatchery operations, in-river incubation, and habitat restoration.

## Background on Temperature Model

HEC5Q is a modeling tool that simulates reservoir and river water temperatures based on input storage, flow, and meteorological data. HEC5Q is often used for long-term planning analyses and was previously used in the Action 5 Record of Decision (ROD). The same HEC5Q model version used in the Action 5 ROD process was applied in this structured decision making (SDM) process. The HEC5Q model input was from the CalSim 3 operations simulated under the SDM process.

The Trinity-Sacramento River HEC5Q model simulates water temperatures for major reservoirs and sections of the Trinity River, Clear Creek, the Upper Sacramento River, Stony Creek, and the Sutter Bypass. Model inputs to the Trinity-Sacramento River HEC5Q model include initial storage levels, reservoir and tributary inflows, reservoir outflows, diversions, and reservoir evaporation derived from CalSim 3 outputs. Monthly CalSim 3 outputs, with a period of record of October 1921 to September 2021, were downscaled to daily timeseries and then used to prescribe storage and flow data for use in the HEC5Q model. Output parameters of the HEC5Q include daily flow and temperature results at select locations in the model. Various fisheries models utilize the outputs from HEC5Q for their inputs. These include models which incorporate the daily flow and temperature outputs from the HEC5Q model to calculate production and mortality of different species and life-stages of Chinook salmon in the upper Sacramento River. For the SDM analysis, the simulation period of interest was a 20-year period from January 1980 to December 2000 which is the same simulation period of the Lifecycle Model.

# Background on Water Temperature Management Through TCD

Reclamation operates Shasta Dam and Lake for specific environmental objectives related to downstream temperature management. The temperature control device (TCD) was constructed in 1997 to provide flexibility and improve efficiency in managing cold water resources in Shasta Lake. The TCD enables selective withdrawal of water from varying lake depths for release through the hydropower plant, while maintaining adequate water temperatures to support environmental objectives in the Sacramento River downstream of Keswick Dam.

In a given year, Sacramento River water temperatures are managed to a prescribed temperature at a downstream control point. This control point defines how far downstream protective water temperature will be maintained throughout the temperature management season (typically May through October) using all available cold-water resources. Control point designation varies according to the initial cold-water storage in Shasta Lake. High initial cold-water volumes translate to a control point that is farther downstream, and low cold-water volumes result in a control point closer to Keswick Dam.

## Physical Configurations

The TCD is located on the upstream face of Shasta Dam and includes four sets of gates: the upper, middle, lower, and side gates. Respective elevations of the gates: upper (1,000 feet mean sea level (msl) to 1,042 feet msl, 42 feet), middle (900 feet msl to 942 feet msl, 42 feet), lower (802 feet msl to 830 feet msl, 28 feet), and side (718 feet msl). The TCD is also open at the top, allowing releases through this ungraded section when reservoir storage levels are high. The side gates, located adjacent to middle and lower gates access the Low-Level Intake. Reservoir water enters the Low-Level Intake vertically through the bottom of the structure. The TCD was not designed to be watertight; hence, there are areas where leakage can be considerable and may affect overall performance of the TCD. Reservoir storage and stratification; the timing and order of gate opening and closing, both laterally (left to right within a gate level) and vertically (among the four gate levels); flow rate; and leakage can all play a role in TCD performance. In addition to the TCD structure, Shasta Dam has three river outlets: upper (950 feet msl), middle (850 ft msl), and lower (750 feet msl). When these river outlets are used they also impact release temperatures and effect downstream temperatures.

## Hydraulic Constraints of TCD Gate Use

Hydraulic constrains include minimum head requirements for hydropower production and gate access. Minimum head requirements for each set of gates are 35 feet. Access to the upper gates early in the temperature management season is critical for overall coldwater pool conservation and downstream temperature management throughout the season. If the upper gates are limited by hydraulic constraints and are inaccessible in the spring period, temperature management challenges can be significant. Water entering gates is mixed in the TCD. At the same time, not all gates on the same level perform exactly the same. The outcome is a complex hydrodynamic and thermal mixing regime that can present challenges to accurately use gate combinations to meet tail bay temperatures.

## Hydraulic Constraints of TCD Side Gate and Low-Level Intake

The TCD is used to respond to the seasonal progression of thermal conditions in Shasta Lake, which in turn are the result of seasonal thermal loading and releases from the dam to meet downstream objectives. Critical to annual temperature management and efficient use of cold-water resources is the progression of TCD gate settings throughout the temperature management season, particularly the timing of side gate operations. The Low-Level Intake is the lowest elevation that water can be drawn from the lake, and once transition to the side gate commences, the Low-Level Intake is used throughout the remainder of the temperature management season. Thus, timing of transition to the side gate (i.e., schedule) is an important aspect of a temperature management strategy because this gate accesses the last manageable cold-water volume in the lake. Transitioning the side gate too early can lead to over-utilization of the coldwater pool, resulting in further challenges later in the temperature management season.

In drier hydrology years, the progression of thermal conditions in the lake can present operational challenges for temperature management using the lower gates and side gate operations. Under these conditions, mid- to late-summer temperature profiles can exhibit locally high temperature gradients. A high temperature gradient translates to a large change in temperature within a small vertical elevation change. A high temperature gradient yields a high density gradient, which can result in complex hydrodynamics and thermal conditions.

When these high temperature gradients occur in the vicinity of the lower gates, small changes in the seasonal thermal structure progression in the reservoir can lead to rapid and considerable changes in tail bay temperatures. Side gate operations are particularly sensitive to these conditions, as waters enter the structure vertically, pulling water upwards to access the last remaining cold-water supplies. TCD performance characteristics are sensitive to late season high temperature gradients, and associated water density differential in the vicinity of the lower gates in the later season. The high temperature gradient condition in the vicinity of the lower gates often occurs in years where initial storage is low and access to the upper gates is limited. It can diminish the effectiveness of the TCD for remainder of the temperature management season.

### Summary of Shasta TCD

The TCD is a pivotal facility to manage water temperature in downstream reaches of the Sacramento River. TCD selective withdrawal strategies and the associated gate progression throughout the temperature management season consider multiple factors and temperature related elements as well as natural system variability.

Alternative TCD selective withdrawal strategies, as well as response to natural variability, result in different temperature management outcomes. TCD operations (i.e., gate progression, water blending) that are made early in the temperature management season have direct ramifications on tail bay temperatures late in the season. Similarly, TCD operations made in response to natural variations have a cumulative direct effect on tail bay temperatures as the season progresses. TCD flexibility in the late summer and fall may be limited due to a seasonal low cold-water storage (limited available supply) and reduced access (limited number of gates) to the remaining cold-water volume.

## Approach to Evaluating this Action

The unique action F-1 focuses on structural (not operational) modifications to Shasta to increase access to deeper, colder water layers during low reservoir conditions. Accessing the Shasta coldwater pool is limited based on the location of the TCD gates and river outlets. Additional blending with another gate lower than the side gates (718 feet msl) could extend the period of coldwater pool availability. This action will evaluate if structural modifications were made to the TCD that would allow access to coldwater pool at 700 feet msl could result in improved blending for temperature management.

The effects of this structural modification will be evaluated in a post-processing analysis of the HEC5Q model results. This analysis included evaluating coldwater pool storage remaining in mid-November of each year and assume that the coldwater pool volume above 700 feet could have been accessed and available for releases in earlier periods. The HEC5Q model generates an output file that shows the daily TCD operations summary and includes total releases and temperature by TCD gates, river outlets, and TCD leakage by elevation. The HEC5Q model also generates output files showing the Shasta storage by temperature. The analysis evaluated if additional blending with coldwater pool volume at 700 feet could have been utilized to reduce Shasta release temperatures to achieve higher compliance with temperature targets at control points downstream.

## Available Coldwater Pool

Table C-1 summarizes the mid-November Shasta Storage by Temperature above 700 feet msl. For this analysis coldwater pool is assumed to be 54 degrees Fahrenheit (°F) and cooler. The values in italics with an asterisk indicate the portion of Shasta storage above 700 feet for that temperature range. For example, in 1980 the total volume of Shasta storage at 48°F is 118,722 acre-feet but only 67,620 acre-feet of that volume is above 700 feet. (Note: The total Shasta storage at 700 feet is 51,102 acre-feet). In the post-processing analysis, these Shasta storages by temperature are compared to the baseline TCD operations to see if there were opportunities during earlier parts of the year where the coldwater pool could have been utilized in the blending for the Shasta releases to attain temperature compliance at downstream control points.

**Table C-1. Available Coldwater Pool**

| Year | Mid-November Shasta Storage Volume (acre-feet) by Temperature (degrees Fahrenheit) Above 700 Feet Elevation | | | | | | | | | | Total Shasta Storage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | Total Cold-water Pool | |
| 1980 | 0 | 0 | *67,620** | 128,237 | 89,134 | 56,959 | 73,389 | 110,577 | 99,600 | 625,516 | 3,120,437 |
| 1981 | 0 | 0 | 0 | 0 | 0 | 0 | *7,414** | 3,972 | 45,604 | 56,991 | 2,983,850 |
| 1982 | 0 | *130,502** | 99,133 | 69,062 | 48,712 | 64,385 | 83,457 | 71,318 | 86,463 | 653,033 | 3,244,310 |
| 1983 | 0 | 0 | 0 | *1,671** | 3,464 | 2,361 | 1,176 | 1,176 | 1,176 | 11,024 | 3,146,776 |
| 1984 | 0 | *3,778** | 121,320 | 93,871 | 62,403 | 39,113 | 26,792 | 70,506 | 474,057 | 891,840 | 3,175,880 |
| 1985 | 0 | 0 | 0 | *7,082** | 9,425 | 82,073 | 78,663 | 70,320 | 139,368 | 386,931 | 2,557,391 |
| 1986 | 0 | *59,178** | 116,826 | 70,999 | 47,820 | 31,763 | 25,933 | 48,520 | 73,099 | 474,138 | 3,005,829 |
| 1987 | 0 | 0 | 0 | 0 | *7,262** | 5,379 | 44,094 | 61,204 | 52,106 | 170,045 | 2,276,849 |
| 1988 | 0 | 0 | 0 | *10,551** | 26,030 | 63,421 | 58,637 | 55,448 | 60,730 | 274,816 | 2,446,906 |
| 1989 | 0 | 0 | 0 | *8,594** | 26,633 | 117,869 | 87,611 | 72,181 | 65,850 | 378,737 | 2,840,531 |
| 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *1,026** | 5,301 | 6,327 | 2,390,987 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 0 | *258** | 3,090 | 8,469 | 11,817 | 2,005,147 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | *1,255** | 2,148 | 3,403 | 1,872,762 |
| 1993 | 0 | *62,331** | 101,682 | 58,947 | 47,453 | 36,274 | 27,998 | 32,113 | 72,247 | 439,045 | 3,170,697 |
| 1994 | 0 | 0 | 0 | 0 | 0 | 0 | *4,000** | 6,237 | 8,359 | 18,597 | 2,205,010 |
| 1995 | 0 | *3,006** | 8,350 | 14,455 | 41,130 | 37,095 | 36,536 | 39,241 | 48,741 | 228,554 | 3,203,278 |
| 1996 | 0 | 0 | 0 | 0 | 0 | *4,889** | 3,598 | 2,548 | 7,682 | 18,717 | 3,193,488 |
| 1997 | *56,191** | 116,024 | 75,866 | 47,878 | 34,256 | 28,292 | 32,514 | 41,795 | 77,608 | 510,423 | 2,747,978 |
| 1998 | 0 | 0 | 0 | 0 | *893** | 989 | 1,083 | 1,669 | 1,669 | 6,302 | 3,232,693 |
| 1999 | 0 | *73,306** | 127,837 | 88,028 | 52,824 | 60,740 | 88,975 | 77,698 | 77,125 | 646,533 | 3,265,627 |
| 2000 | 0 | 0 | *87,478** | 104,700 | 65,675 | 46,641 | 32,470 | 30,819 | 59,280 | 427,064 | 3,228,036 |

## Temperature Control Points

Shasta Dam has a TCD that allows water to come from different elevations of the reservoir pool to produce a specified tailwater temperature target that is intended to meet a downstream temperature objective, particularly during the summer months. Annual schedules of monthly tailwater temperature targets are specified in the Trinity-Sacramento River HEC5Q model based on end-of-month April Storage in Shasta Lake, an indicator of the available coldwater pool, for each year of the simulation period. The annual schedules were developed for different tiers of end-of-April Shasta Storage, with each tier corresponding to meeting temperature targets at a downstream compliance location, see Table C-2. Using the tailwater target temperature schedule timeseries, the model determines which configuration of the TCD gates will provide a release temperature that best meets the monthly temperature target. These temperature targets were compared to the baseline HEC5Q results to see which months and years the temperatures were above the target temperature. These months and years were identified as opportunities in the post-processing and the TCD operations were evaluated to see if blending with cold-water could have helped to achieve or get closer to the downstream temperature target.

**Table C-2. Temperature Targeting Schedule for Shasta Dam**

| Compliance Location | Tier | End of April Shasta Storage (thousand acre-feet) | Shasta Release Temperature Targets (degrees Fahrenheit) | |
|---|---|---|---|---|
| | | | Jan – May 15 | May 16 - Dec |
| Airport Road | Tier 1 | <3,200 | 58 | 53.5 |
| Clear Creek | Tier 2 | >3,200 &<4,000 | 58 | 53.5 |
| Highway 44 | Tier 3 | >4,000 | 58 | 53.5 |

## HEC5Q Modeled Temperature by Control Point

Table C-3 summarizes the average monthly temperature for the temperature compliance point per year from the baseline HEC5Q. The values in bolded italics indicate the months when the modeled temperature exceeded the target temperature. In the 20-year simulation period, 43 out of 252 months (17 percent) showed an exceedance of the average monthly temperature target at the control point. These occurred between April and November.

**Table C-3. Baseline HEC5Q Modeled Average Monthly Temperature by Control Point**

| Year | Compliance Location | Average Monthly Temperature (degrees Fahrenheit) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1980 | Airport Road | 50.7 | 48.0 | 52.5 | 55.2 | ***55.9*** | 53.5 | 53.4 | 53.3 | 53.5 | 53.2 | 53.1 | 52.6 |
| 1981 | Airport Road | 50.9 | 51.2 | 53.9 | 56.1 | ***55.9*** | ***54.0*** | 53.2 | 53.3 | ***55.7*** | ***54.5*** | ***53.6*** | 50.9 |
| 1982 | Airport Road | 47.6 | 47.0 | 49.6 | 50.2 | ***58.0*** | 53.3 | 53.5 | 53.4 | 53.3 | 53.1 | 52.8 | 50.9 |
| 1983 | Clear Creek | 47.2 | 46.1 | 47.1 | 52.2 | 53.9 | 52.8 | 53.0 | 53.0 | 52.3 | 51.8 | ***54.2*** | 51.4 |
| 1984 | Airport Road | 48.5 | 49.6 | 51.7 | 53.9 | 54.4 | 53.2 | 53.2 | 53.4 | 53.3 | 53.2 | 52.7 | 50.9 |
| 1985 | Clear Creek | 49.1 | 49.8 | 52.3 | 57.2 | 55.7 | 52.7 | 53.0 | 53.3 | ***54.5*** | 52.9 | 51.4 | 51.0 |
| 1986 | Airport Road | 50.4 | 47.1 | 50.5 | 56.0 | 55.6 | 53.4 | 53.2 | 53.5 | 53.3 | 53.4 | 53.1 | 52.7 |
| 1987 | Clear Creek | 51.1 | 50.2 | 52.1 | 56.1 | 55.6 | 52.3 | 52.8 | 53.2 | 52.6 | 52.9 | 52.8 | 51.5 |
| 1988 | Clear Creek | 48.5 | 49.4 | 54.9 | ***58.4*** | ***55.9*** | 52.6 | ***54.2*** | ***54.5*** | ***54.6*** | 53.1 | 51.4 | 51.5 |
| 1989 | Airport Road | 50.0 | 48.9 | 51.4 | 55.3 | 55.4 | ***53.5*** | 53.3 | ***53.5*** | ***54.5*** | 53.4 | 52.0 | 51.9 |
| 1990 | HWY 44 | 52.4 | 50.3 | 51.4 | 52.1 | 53.3 | 52.3 | 52.4 | ***54.4*** | ***55.4*** | ***55.7*** | ***55.3*** | 52.0 |
| 1991 | HWY 44 | 51.3 | 51.7 | 51.3 | 52.9 | 53.3 | 53.4 | ***53.6*** | ***53.5*** | ***54.8*** | ***55.5*** | ***55.1*** | 52.4 |
| 1992 | HWY 44 | 51.2 | 50.2 | 50.5 | 51.3 | 53.0 | 53.3 | ***53.5*** | 52.8 | ***54.1*** | ***56.3*** | ***56.5*** | 52.5 |
| 1993 | Airport Road | 47.7 | 47.2 | 49.4 | 55.5 | ***56.2*** | ***54.0*** | 53.3 | ***53.6*** | 53.3 | 53.3 | 53.0 | 52.3 |
| 1994 | Clear Creek | 51.1 | 49.6 | 52.9 | 57.8 | 55.3 | 53.0 | 52.9 | 53.3 | ***54.8*** | ***55.0*** | ***53.6*** | 52.1 |
| 1995 | Airport Road | 48.1 | 46.4 | 47.0 | 53.3 | 54.3 | ***53.7*** | 53.5 | 53.3 | 53.2 | 52.6 | 51.1 | 52.1 |
| 1996 | Airport Road | 50.9 | 48.9 | 51.7 | 56.6 | 54.8 | ***54.6*** | 53.5 | ***53.8*** | 52.4 | 53.1 | ***54.4*** | 51.8 |
| 1997 | Airport Road | 47.0 | 48.5 | 52.9 | 55.6 | 55.3 | 53.3 | 52.0 | 53.3 | 53.4 | 53.1 | 52.8 | 51.6 |
| 1998 | Airport Road | 48.1 | 45.6 | 47.9 | 53.9 | 53.6 | 53.4 | 53.3 | 53.3 | 53.1 | 51.3 | ***54.2*** | 51.7 |
| 1999 | Airport Road | 49.5 | 47.7 | 49.5 | 54.7 | 54.6 | ***53.7*** | 53.2 | 53.4 | 53.2 | 53.1 | 53.1 | 52.4 |
| 2000 | Airport Road | 50.0 | 47.6 | 50.5 | 55.9 | 55.6 | ***53.9*** | 53.1 | 53.3 | 53.4 | 52.9 | 52.6 | 51.0 |
| Number of Months Baseline Temperature Exceeds Target Temperature | | 0 | 0 | 0 | ***1*** | ***5*** | ***7*** | ***3*** | ***6*** | ***8*** | ***5*** | ***8*** | 0 |

The TCD operations were evaluated for each of these 43 months and compared to the available mid-November coldwater pool above 700 feet. The post-processing approach used the available coldwater pool to substitute warmer water in the Shasta blending to try to meet or get closer to the target temperature at the downstream control point. The mass balance of Shasta storage and Shasta releases is maintained in the post-processing, just the blending of water at different temperatures was adjusted.

## Post-Processed Available Coldwater Pool

Table C-4 summarizes the remaining post-processed mid-November Shasta Storage by Temperature above 700 feet msl. The values in bolded italics indicate a change in the volume of Shasta wstorage for that temperature, compared to Table 14. For example, in 1980 the total volume of Shasta storage at 48°F above 700 feet was 67,620 acre-feet. In the post-processing analysis, the model was able to use 22,558 acre-feet and blend in the total releases to decrease the Shasta release temperature in order to reach or get closer to the temperature compliance at the downstream control point. The remaining Shasta storage at 48°F above 700 feet is 45,062 acre-feet (67,620 acre-feet – 22,558 acre-feet). The 22,558 acre-feet of storage substituted warmer water in the blending.

**Table C-4. Post-Processed Available Coldwater Pool**

| Year | Mid-November Shasta Storage Volume (Acre-Feet) by Temperature (degrees Fahenheit) above 700 Feet Elevation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | Adjusted Total Cold-water Pool | Baseline Total Cold-water Pool | Change in Cold-water Pool |
| 1980 | 0 | 0 | ***45,062*** | 128,237 | 89,134 | 56,959 | 73,389 | 110,577 | 99,600 | 602,958 | 625,516 | 22,558 |
| 1981 | 0 | 0 | 0 | 0 | 0 | 0 | ***0*** | ***0*** | ***0*** | 0 | 56,991 | 56,991 |
| 1982 | 0 | ***62,055*** | 99,133 | 69,062 | 48,712 | 64,385 | 83,457 | 71,318 | 86,463 | 584,586 | 653,033 | 68,447 |
| 1983 | 0 | 0 | 0 | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** | 0 | 11,024 | 11,024 |
| 1984 | 0 | 3,778 | 121,320 | 93,871 | 62,403 | 39,113 | 26,792 | 70,506 | 474,057 | 891,840 | 891,840 | 0 |
| 1985 | 0 | 0 | 0 | ***1,916*** | 9,425 | 82,073 | 78,663 | 70,320 | 139,368 | 381,765 | 386,931 | 5,166 |
| 1986 | 0 | 59,178 | 116,826 | 70,999 | 47,820 | 31,763 | 25,933 | 48,520 | 73,099 | 474,138 | 474,138 | 0 |
| 1987 | 0 | 0 | 0 | 0 | 7,262 | 5,379 | 44,094 | 61,204 | 52,106 | 170,045 | 170,045 | 0 |
| 1988 | 0 | 0 | 0 | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** | ***42,511*** | 42,511 | 274,816 | 232,305 |
| 1989 | 0 | 0 | 0 | ***0*** | ***16,789*** | 117,869 | 87,611 | 72,181 | 65,850 | 360,299 | 378,737 | 18,438 |
| 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ***0*** | ***0*** | 0 | 6,327 | 6,327 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 0 | ***0*** | ***0*** | ***4,921*** | 4,921 | 11,817 | 6,896 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ***0*** | ***0*** | 0 | 3,403 | 3,403 |
| 1993 | 0 | 62,331 | 101,682 | 58,947 | ***0*** | ***0*** | ***0*** | ***0*** | 72,247 | 295,208 | 439,045 | 143,837 |
| 1994 | 0 | 0 | 0 | 0 | 0 | 0 | ***0*** | ***0*** | 8,359 | 8,359 | 18,597 | 10,238 |
| 1995 | 0 | ***0*** | ***2,087*** | 14,455 | 41,130 | 37,095 | 36,536 | 39,241 | 48,741 | 219,285 | 228,554 | 9,269 |
| 1996 | 0 | 0 | 0 | 0 | 0 | ***0*** | ***0*** | ***0*** | ***0*** | 0 | 18,717 | 18,717 |
| 1997 | 56,191 | 116,024 | 75,866 | 47,878 | 34,256 | 28,292 | 32,514 | 41,795 | 77,608 | 510,423 | 510,423 | 0 |
| 1998 | 0 | 0 | 0 | 0 | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** | 0 | 6,302 | 6,302 |
| 1999 | 0 | ***0*** | ***119,263*** | 88,028 | 52,824 | 60,740 | 88,975 | 77,698 | 77,125 | 564,653 | 646,533 | 81,880 |
| 2000 | 0 | 0 | ***59,648*** | 104,700 | 65,675 | 46,641 | 32,470 | 30,819 | 59,280 | 399,234 | 427,064 | 27,830 |

## Post-Processed Temperature of Shasta Releases

Table C-5 summarizes the differences in the Shasta release temperature between the post-processing analysis and the baseline HEC5Q modeled results. The values represent the decrease in Shasta release temperatures. There were 30 months when Shasta release temperature could be adjusted, these occurred between April and November. These differences range from less than 0.01°F to 2.64°F, with an average difference of 0.35°F.

### Table C-5. Difference in Average Monthly Shasta Release Temperature (Baseline – Post-Processed)

| Year | Average Monthly Temperature (degrees Fahrenheit) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1980 | 0 | 0 | 0 | 0 | **0.50** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1981 | 0 | 0 | 0 | 0 | **0.38** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1982 | 0 | 0 | 0 | 0 | **2.64** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1983 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0.05** | 0 |
| 1984 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1985 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0.03** | 0 | 0 | 0 |
| 1986 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1988 | 0 | 0 | 0 | **0.43** | **1.14** | 0 | **0.11** | **1.11** | **0.49** | 0 | 0 | 0 |
| 1989 | 0 | 0 | 0 | 0 | 0 | **0.36** | 0 | **0.12** | **0.03** | 0 | 0 | 0 |
| 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **<0.01** | **0.02** | 0 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 0 | **0.07** | 0 | 0 | **<0.01** | 0 | 0 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 0 | **0.03** | 0 | 0 | 0 | 0 | 0 |
| 1993 | 0 | 0 | 0 | 0 | **0.85** | **0.53** | 0 | **0.12** | 0 | 0 | 0 | 0 |
| 1994 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **<0.01** | **0.01** | 0 |
| 1995 | 0 | 0 | 0 | 0 | 0 | **0.24** | 0 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 0 | 0 | 0 | 0 | 0 | **0.03** | 0 | **0.04** | 0 | 0 | **0.15** | 0 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0.02** | 0 |
| 1999 | 0 | 0 | 0 | 0 | 0 | **0.23** | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 0 | 0 | 0 | 0 | 0 | **0.72** | 0 | 0 | 0 | 0 | 0 | 0 |
| Number of Months | 0 | 0 | 0 | **1** | **5** | **6** | **3** | **4** | **3** | **3** | **5** | 0 |

Note: he values in italics with an asterisk indicate the portion of Shasta storage above 700 feet for that temperature range. For example, in 1980 the total volume of Shasta storage at 48°F is 118,722 acre-feet but only 67,620 acre-feet of that volume is above 700 feet.

## Post-Processed Temperature by Control Point and Locations of Interest

The post-processing results show changes in the Shasta release temperatures. To apply these changes to downstream locations, a longitudinal temperature relationship between the Shasta and downstream locations was calculated based on the baseline HEC5Q modeled results. Developed relationships for the following locations: Sacramento River below Keswick, Sacramento River at Highway 44, Sacramento River below Clear Creek, Sacramento River at Cottonwood Creek, Sacramento River at Red Bluff Dam, and Sacramento River at Airport Road. These were selected based on these being locations for temperature control points and locations of interest in the Lifecycle modeling. From the baseline the difference in monthly average temperature for each year was calculated between Shasta and these locations. Using the same baseline longitudinal relationship, the post-processed downstream temperature locations from the post-processed Shasta release temperatures for each month and year were calculated. As an example, Table C-6 shows the longitudinal relationship between Shasta and downstream locations for 1993. Positive values indicate the downstream location is warmer than the Shasta release temperature. Negative values indicate the downstream location is cooler than the Shasta release temperature. The greatest increase in downstream temperatures occurs in the May, June, and August periods.

**Table C-6. Baseline HEC5Q Longitudinal Temperature Relationship**

| Location | Average Monthly Temperature for 1993 (degrees Fahrenheit) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Below Shasta | 48.0 | 46.0 | 48.8 | 51.8 | 50.3 | 47.8 | 49.9 | 49.0 | 50.1 | 51.4 | 53.1 | 53.0 |
| **Location** | **Difference in Average Monthly Temperature from Below Shasta for 1993 (degrees Fahrenheit)** | | | | | | | | | | | |
| Below Keswick | -0.2 | 0.6 | 0.2 | 2.0 | 3.4 | 3.2 | 1.6 | 2.4 | 1.7 | 0.9 | -0.1 | -0.2 |
| Highway 44 | -0.1 | 0.8 | 0.3 | 2.6 | 4.1 | 3.9 | 2.1 | 3.0 | 2.1 | 1.2 | -0.1 | -0.2 |
| Clear Creek | 0.1 | 1.1 | 0.5 | 3.3 | 5.2 | 5.4 | 3.0 | 4.1 | 2.9 | 1.6 | -0.1 | -0.6 |
| Airport Road | -0.3 | 1.2 | 0.6 | 3.7 | 5.9 | 6.2 | 3.4 | 4.6 | 3.2 | 1.8 | -0.1 | -0.7 |
| Cottonwood Creek | -2.0 | 1.1 | 1.0 | 4.5 | 8.3 | 10.0 | 4.8 | 6.0 | 4.3 | 2.6 | -0.1 | -1.8 |
| Red Bluff Dam | -1.7 | 1.7 | 1.7 | 6.0 | 11.1 | 13.8 | 8.2 | 10.2 | 7.4 | 4.2 | -0.1 | -2.3 |

After developing these longitudinal temperature relationships, the downstream location temperatures from the post-processed Shasta release temperatures were calculated. Table C-7 summarizes the post-processed average monthly temperature at the temperature compliance point per year. Utilizing the coldwater pool volume, as summarized in Table C-4, resulted in an additional 17 months of temperatures meeting target temperatures, reducing the number of months temperature exceeded the targets from 43 to 26 months out of 252 months (from 17 percent to 10 percent). The temperature improvements primarily occurred between April and August. The values in the bolded italics with asterisks indicate the months where the temperature does meet the target temperature at the compliance point. The values in bold indicate the months when the compliance point does not meet the target temperature.

**Table C-7. Post-Processed HEC5Q Modeled Average Monthly Temperature by Control Point**

| Year | Compliance Location | Average Monthly Temperature (degrees Fahrenheit) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1980 | Airport Road | 50.7 | 48.0 | 52.5 | 55.2 | **_55.4*_** | 53.5 | 53.4 | 53.3 | 53.5 | 53.2 | 53.1 | 52.6 |
| 1981 | Airport Road | 50.9 | 51.2 | 53.9 | 56.1 | **_55.4*_** | **54.0** | 53.2 | 53.3 | **55.7** | **54.5** | **53.6** | 50.9 |
| 1982 | Airport Road | 47.6 | 47.0 | 49.6 | 50.2 | **_55.4*_** | 53.3 | 53.5 | 53.4 | 53.3 | 53.1 | 52.8 | 50.9 |
| 1983 | Clear Creek | 47.2 | 46.1 | 47.1 | 52.2 | 53.9 | 52.8 | 53.0 | 53.0 | 52.3 | 51.8 | **54.2** | 51.4 |
| 1984 | Airport Road | 48.5 | 49.6 | 51.7 | 53.9 | 54.4 | 53.2 | 53.2 | 53.4 | 53.3 | 53.2 | 52.7 | 50.9 |
| 1985 | Clear Creek | 49.1 | 49.8 | 52.3 | 57.2 | 55.7 | 52.7 | 53.0 | 53.3 | **54.5** | 52.9 | 51.4 | 51.0 |
| 1986 | Airport Road | 50.4 | 47.1 | 50.5 | 56.0 | 55.6 | 53.4 | 53.2 | 53.5 | 53.3 | 53.4 | 53.1 | 52.7 |
| 1987 | Clear Creek | 51.1 | 50.2 | 52.1 | 56.1 | 55.6 | 52.3 | 52.8 | 53.2 | 52.6 | 52.9 | 52.8 | 51.5 |
| 1988 | Clear Creek | 48.5 | 49.4 | 54.9 | **_58.0*_** | **_54.8*_** | 52.6 | **54.1** | **_53.4*_** | **54.1** | 53.1 | 51.4 | 51.5 |
| 1989 | Airport Road | 50.0 | 48.9 | 51.4 | 55.3 | 55.4 | **_53.2*_** | 53.3 | **_53.4*_** | **54.4** | 53.4 | 52.0 | 51.9 |
| 1990 | Highway 44 | 52.4 | 50.3 | 51.4 | 52.1 | 53.3 | 52.3 | 52.4 | **54.4** | **55.4** | **55.7** | **55.3** | 52.0 |
| 1991 | Highway 44 | 51.3 | 51.7 | 51.3 | 52.9 | 53.3 | 53.4 | **_53.5*_** | **_53.5*_** | **54.8** | **55.5** | **55.1** | 52.4 |
| 1992 | Highway 44 | 51.2 | 50.2 | 50.5 | 51.3 | 53.0 | 53.3 | **_53.5*_** | 52.8 | **54.1** | **56.3** | **56.5** | 52.5 |
| 1993 | Airport Road | 47.7 | 47.2 | 49.4 | 55.5 | **_55.4*_** | **_53.5*_** | 53.3 | **_53.4*_** | 53.3 | 53.3 | 53.0 | 52.3 |
| 1994 | Clear Creek | 51.1 | 49.6 | 52.9 | 57.8 | 55.3 | 53.0 | 52.9 | 53.3 | **54.8** | **55.0** | **53.6** | 52.1 |
| 1995 | Airport Road | 48.1 | 46.4 | 47.0 | 53.3 | 54.3 | **_53.4*_** | 53.5 | 53.3 | 53.2 | 52.6 | 51.1 | 52.1 |
| 1996 | Airport Road | 50.9 | 48.9 | 51.7 | 56.6 | 54.8 | **54.6** | 53.5 | **53.8** | 52.4 | 53.1 | **54.4** | 51.8 |
| 1997 | Airport Road | 47.0 | 48.5 | 52.9 | 55.6 | 55.3 | 53.3 | 52.0 | 53.3 | 53.4 | 53.1 | 52.8 | 51.6 |
| 1998 | Airport Road | 48.1 | 45.6 | 47.9 | 53.9 | 53.6 | 53.4 | 53.3 | 53.3 | 53.1 | 51.3 | **54.2** | 51.7 |
| 1999 | Airport Road | 49.5 | 47.7 | 49.5 | 54.7 | 54.6 | **_53.5*_** | 53.2 | 53.4 | 53.2 | 53.1 | 53.1 | 52.4 |
| 2000 | Airport Road | 50.0 | 47.6 | 50.5 | 55.9 | 55.6 | **_53.2*_** | 53.1 | 53.3 | 53.4 | 52.9 | 52.6 | 51.0 |
| Number of Months Temperature Exceeded Target (Post-Processed) | | 0 | 0 | 0 | **0** | **0** | **2** | **1** | **2** | **8** | **5** | **8** | 0 |
| Number of Months Temperature Exceeded Target (Baseline) | | 0 | 0 | 0 | **1** | **5** | **7** | **3** | **6** | **8** | **5** | **8** | 0 |
| Difference | | 0 | 0 | 0 | **1** | **5** | **5** | **2** | **4** | **0** | **0** | **0** | 0 |

Note: The values in the bolded italics with asterisks indicate the months where the temperature does meet the target temperature at the compliance point. This was to highlight the difference between values in Table C-3 (baseline) and Table C-7 (post-processed)

## Summary

This unique action F-1 focused on assessing a potential structural modification to Shasta to evaluate the opportunity to increase access to the coldwater pool and reduce Shasta release temperature. Baseline HEC5Q results were used in this post-processing analysis. The potential available coldwater pool volume was defined as the remaining coldwater pool in mid-November at an elevation above 700 feet. The baseline temperature results for the control points were evaluated to determine which months and years the temperature target was not achieved. These were identified as the potential months where an increased access to coldwater pool could provide a benefit to Shasta releases and downstream temperatures. A longitudinal temperature relationship between Shasta releases and downstream locations was developed for the baseline HEC5Q results and applied in the post-processing analysis to calculate downstream temperatures. The baseline TCD operations summary was evaluated to understand the blending that results in the final Shasta release temperatures. The post-processing analysis evaluated the opportunities of increased access to the coldwater pool volumes and the resulting change in Shasta release temperature and downstream temperatures. Below summarizes baseline and post-processing results:

- In the baseline HEC5Q results, the available mid-November Shasta Coldwater Pool Storage (below 54°F) and at an elevation above 700 feet msl ranged from 3,403 acre-feet to 891,840 acre-feet, with an average of 297,137 acre-feet.

- In the baseline HEC5Q results, there were 43 out of 252 months (20-year simulation period from 1980 to 2000) where the monthly average control point temperature exceeded the target temperature. The control point varies by year, and the target temperature changes by month.

- In the post-processing results, increased access to coldwater pool volume could result in between 3,403 acre-feet to 232,305 acre-feet of cold-water being used in the blending for Shasta release temperatures. The average use of coldwater pool is 42,919 acre-feet.

- In the post-processing results, decreased Shasta releases resulted in an additional 17 months where control point temperatures could meet their target temperatures, reducing the number of months where control point temperatures exceeded the target temperature from 43 to 26 months of the 252-month simulation period.

- In the post-processing results, the average monthly Shasta release temperatures could be reduced from less than 0.01°F to 2.64°F, with an average of 0.35°F.

# Appendix D

# Non-Modeled Metric Scores for Individual Actions

# Appendix D: Non-Modeled Metric Scores for Individual Actions

The project team developed initial non-modeled metric scores for each individual action based on a literature review and expert judgment. The initial scores were provided to participants for review and comment, and their feedback was incorporated into a final non-modeled metric scores, which are shown in Table D-1 through Table D-6.

**Table D-1. Scores for Ability of WRCS to Live Their Natural Lifecycle**

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Placing fertilized eggs into natural substrate or streamside incubators increases exposure to natural thermal regimes, flows, sediment dynamics, and chemical cues. Although technicians place the eggs, the majority of development occurs under fully natural conditions. This enhances imprinting, increases expression of natural fry emergence timing, and reduces dependence on artificial raceway incubation. Over time, this method can support a more naturally structured WRCS population with stronger homing fidelity to restoration areas. |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Enforcing anti-poaching laws increases adult WRCS escapement without altering natural migratory behavior or increasing reliance on hatchery production. The action protects adults during migration and spawning, preserving natural life-stage transitions and supporting long-term population resilience. |
| ASD-3 | Release hatchery fry into upper McCloud | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Releasing unfed fry upstream of Lake McCloud enables juvenile development under natural flow, temperature, and food-web conditions. This increases imprinting and growth variability, enhancing natural life-history diversity. Although fry releases represent human intervention, they facilitate natural rearing pathways unavailable due to blocked historical habitat above Shasta Dam. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-4 | Release hatchery fry into lower McCloud | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | This action increases natural rearing opportunities below McCloud Dam but requires very active human handling, particularl the need for downstream juvenile collection to bypass Lake Shasta. |
| ASD-5a | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Two-way trap-and-haul increases WRCS access to historical habitats but relies heavily on human handling for both adult transfer upstream and juvenile transport downstream. While necessary before volitional passage is feasible, it represents a high-intervention approach. Still, the action enables natural spawning and rearing in high-quality upstream reaches. |
| ASD-5b | Two-way trap and haul into Little Sacramento River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Two-way trap-and-haul increases WRCS access to historical habitats but relies heavily on human handling for both adult transfer upstream and juvenile transport downstream. While necessary before volitional passage is feasible, it represents a high-intervention approach. Still, the action enables natural spawning and rearing in high-quality upstream reaches. |
| ASD-5c | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Two-way trap-and-haul increases WRCS access to historical habitats but relies heavily on human handling for both adult transfer upstream and juvenile transport downstream. While necessary before volitional passage is feasible, it represents a high-intervention approach. Still, the action enables natural spawning and rearing in high-quality upstream reaches. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-6 | Volitional passage above Shasta Dam into McCloud River | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Volitional passage is the most natural reintroduction strategy, restoring unassisted upstream and downstream movement. This action dramatically reduces human intervention long-term by eliminating trap-and-haul dependency. Once operational, WRCS can reoccupy cold, spring-fed McCloud habitats, restoring historical migration timing and life-stage expression. |
| ASD-7 | Remove McCloud Dam | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Dam removal restores unimpeded upstream movement, natural flow regimes, bedload transport, and cold-water continuity. This action enables full expression of WRCS life stages with minimal long-term intervention, although implementation is technically complex. |
| ASD-8 | Return historic salmon strain from New Zealand | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Reintroducing a historic McCloud lineage may enhance genetic diversity and restore traits underrepresented in the current population following population bottlenecks. Although involving human-mediated broodstock importation and biosecure quarantine, the long-term goal supports more naturally adapted fish once established. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| F-1 | Shasta TCD Upgrade/Cold water outlet to access colder water | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Upgrading the TCD improves access to deeper, colder reservoir layers, stabilizing downstream temperatures during critical incubation and juvenile rearing periods. While the action does not reduce human intervention, it allows WRCS eggs and fry to experience thermal conditions closer to their historical regime. This supports more natural emergence timing and reduces temperature-induced mortality, improving life-cycle expression even though flows remain operationally controlled. Ultimately, the level of intervention would be comparable to current TCD operations. |
| H-1 | LSNFH modified release practices | No change in human interventions (e.g., hatchery, transport, handling, or infrastructure operations) within ±10% | Modified release strategies - such as altering release timing, adjusting fish size, or releasing at varied locations - represent a higher level of human intervention. These actions intentionally alter juvenile distribution, migration cues, and exposure to environmental conditions. While these strategies can improve survival, they reduce reliance on volitional, natural migratory behavior. Thus, although beneficial operationally, they increase human influence on early life-stage processes. |
| H-2a | LSNFH facility upgrades | Increases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% | Facility upgrades - pathogen filtration, new trapping options, water chillers, and electrical/plumbing improvements - enhance hatchery reliability but do not reduce human intervention. These improvements stabilize hatchery production and reduce emergency responses that could disrupt broodstock management. However, they maintain or increase reliance on human-mediated propagation. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| H-2b | Upgrades to Keswick Dam adult collection system | No change in human interventions (e.g., hatchery, transport, handling, or infrastructure operations) within ±10% | Improving adult collection systems increases human handling but supports more effective broodstock selection and reduces stress or delay for migrating WRCS adults. This strengthens hatchery integration goals but does not reduce human intervention in the life cycle. |
| H-2c | New broodfish collection facility in Upper Sacramento River | No change in human interventions (e.g., hatchery, transport, handling, or infrastructure operations) within ±10% | Establishing an additional broodstock collection point increases human involvement in WRCS reproduction. While necessary to meet genetic management goals (e.g., higher natural-origin broodstock proportions), it does not reduce intervention and relies on controlled adult capture. |
| H-3 | CNFH trapping and sorting improvements | No change in human interventions (e.g., hatchery, transport, handling, or infrastructure operations) within ±10% | Reduces holding/handling and migration delays of WRCS. |
| SR-1 | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Restoring floodplain access reestablishes natural hydrologic function and seasonal inundation, enabling WRCS juveniles to utilize productive off-channel habitats. This increases growth opportunities, improves survival, and reduces dependence on artificial rearing or temperature management actions. Floodplains support natural life-history diversity by expanding rearing pathways. |
| SR-2a | Physically build and maintain new instream perennial juvenile rearing habitat | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Constructing perennial side channels and rearing alcoves expands access to natural habitats essential for WRCS development. The action strengthens natural rearing pathways without increasing direct handling, enabling fry and parr to rear in hydraulically diverse environments. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-2b | Artificially enhance existing instream juvenile rearing habitat | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Adding anchored woody material and leafed branch bundles increases cover and invertebrate production, mimicking natural structural complexity. This improves juvenile survival and growth, supporting more natural rearing outcomes with minimal ongoing human intervention. |
| SR-2c | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Removing small dams, culverts, and diversions restores access to up to 50 miles of rearing habitat. This supports natural juvenile movement into cooler, food-rich tributaries, enhancing growth and life-history diversity. |
| SR-3 | Build or enhance in-channel spawning habitat | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥50% and successfully reestablishes of migration, spawning, and rearing processes in historic habitat. | Improving gravel quality and substrate distribution enhances natural WRCS spawning success and embryo survival. This reduces density pressures and supports natural reproduction without increasing hatchery reliance. |
| SR-4a | Reduce predation contact points on Sacramento River | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Reducing predator hotspots at structures lowers unnatural mortality rates on WRCS juveniles. This helps restore more natural survival rates without manipulating WRCS directly. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-4b | Develop regulations to support a striped bass trophy fishery | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Reducing predators lowers unnatural mortality rates on WRCS juveniles. This helps restore more natural survival rates without manipulating WRCS directly. |
| SR-5 | Reduce entrainment at Sacramento River diversions | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Improved diversion screening and fish-friendly technologies reduce juvenile entrainment, enabling more natural migratory survival. |
| SR-6 | Georgiana Slough bubble curtain | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | A permanent bubble curtain can reduce juvenile fish misrouting into the interior Delta, increasing survival along natural migratory pathways. Although this approach requires additional human intervention, it helps counteract the impacts of other anthropogenic stressors - such as the Delta Cross Channel and state and federal pumping facilities - that otherwise entrain fish into high-mortality areas of the interior Delta. |
| SR-8 | Nighttime light reduction on Sundial Bridge and other sources | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Reducing artificial nighttime illumination lowers predation risk and restores natural diel migration cues for juvenile WRCS. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-9 | Provide volitional upstream and downstream fish passage at Keswick Dam | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Volitional passage restores upstream access to cooler spawning areas, supporting natural migration timing and reducing hatchery intervention. |
| SR-10 | Construct Anderson Cottonwood Irrigation District Water Supply and Fisheries Resiliency Project | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Removing ACID Dam and replacing it with a pump station restores unrestricted migration and improves access to high-quality spawning habitat. The backwater effects of ACID do help keep some later emerging SWRC redds inundated, a benefit that would be forgone under this action. |
| SR-11 | Captive rearing and assisted migration of juveniles in drought years | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Action increases human intervention by removing juveniles from the river and rearing them artificially. However, it protects cohorts during lethal drought conditions and ensures survival through extreme years. |
| BC-1 | Control illegal harvest and/or poaching in Battle Creek | Increases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% | Enforcing anti-poaching laws increases adult WRCS escapement without altering natural migratory behavior or increasing reliance on hatchery production. The action protects adults during migration and spawning, preserving natural life-stage transitions and supporting long-term population resilience. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| BC-2 | Battle Creek habitat improvements | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Habitat projects - levee removal, improved side channels, meadow restoration - restore natural geomorphic and hydrologic processes. These actions expand accessible spawning and rearing habitats, allowing WRCS to complete all life stages in a more natural, self-sustaining environment with less dependence on human intervention. The habitat could potentially support an additional WRCS population in Battle Creek. |
| BC-3 | CNFH water supply intake improvements on Battle Creek | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Improving water supply reliability at CNFH supports consistent hatchery operations that complement WRCS recovery but does not increase direct handling or restrict natural behaviors. Reliable intake capacity prevents hatchery actions that might otherwise disrupt natural population dynamics. |
| BC-5 | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Removing this barrier opens 8 miles of high-quality upstream habitat, enabling natural migration, spawning, and rearing. Increased habitat area supports life-cycle diversity. |
| BC-6 | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Restoring unimpaired hydrology reduces the very complex and artificial flow routing that curently exists on Battle Creek. More natural temperature and flow regimes could improve future juvenile rearing conditions, and potentially egg incubation, substantially supporting self-sustaining WRCS life cycles. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| BC-7 | Limit cold water diversions | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Reducing cold-water diversions helps maintain naturally cool reaches essential for WRCS spawning and juvenile survival. However, this scenario requires human intervention for hydrologic regulation and operations (and potentially additional infrastructure). It is uncertain whether it will ultimately require more or less intervention than the current condition. |
| BC-8 | Battle Creek egg incubation | No change in human interventions (e.g., hatchery, transport, handling, or infrastructure operations) within ±10% | Placing fertilized eggs directly into natural substrates increases imprinting and exposure to natural environmental cues, reducing reliance on hatchery raceways. Although humans still place eggs, the rearing environment becomes more natural. |
| BC-9 | Implement Battle Creek Reintroduction Plan | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Initially increases human intervention due to hatchery-based production, but long-term goal is establishing a naturally returning, self-sustaining population. Over successive generations, reliance on hatchery support decreases as imprinting strengthens. |
| O-1 | Improve WRCS Salvage at Tracy and State Fish Collection Facilities | No change in human interventions (e.g., hatchery, transport, handling, or infrastructure operations) within ±10% | Improved salvage reduces anthropogenic mortality during export operations, allowing a larger portion of outmigrating juveniles to survive the Delta. Although, complicated by the fact that salvage itself is a human intervention. The action does potentially reduce the need for compensatory hatchery production. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| O-2 | Increase distance from shoreline to "International" designation | No change in human interventions (e.g., hatchery, transport, handling, or infrastructure operations) within ±10% | Extending offshore harvest boundaries reduces WRCS exposure to mixed-stock fisheries. This reduces anthropogenic mortality on adults before freshwater entry but does not alter natural freshwater behavior. The action does indirectly support the life cycle by increasing escapement and reducing harvest pressure without increasing direct human handling. |
| O-3 | Modify ocean harvest | Decreases human interventions (e.g., hatchery, transport, handling, or infrastructure operations) by ≥10% OR allows successful reestablishment of migration, spawning, and rearing processes in historic habitat. | Harvest restrictions reduce adult WRCS mortality at sea, increasing the number of spawners returning to the river. This supports natural reproduction and stabilizes population age structure. Although harvest regulation is a human intervention, it strengthens natural life-cycle continuity by protecting adults before freshwater entry. |

Key: ACID = Anderson Cottonwood Irrigation District, ASD = Above Shasta Dam, BC = Battle Creek, CNFH = Coleman National Fish Hatchery, F = Facilities, H = Hatcheries, LSNFH = Livingston Stone National Fish Hatchery, O = Other, PG&E = Pacific Gas and Electric Company, SR = Sacramento River, TCD = temperature control device, WRCS = winter-run Chinook salmon

**Table D-2. Scores for Avoid or Minimize Adverse Impacts to Fall-run Chinook Salmon**

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Fall-run impacts remain negligible because incubation occurs in upstream WRCS restoration reaches. Monitoring of release numbers and spawning distributions ensures hatchery-origin fry do not enter fall-run territories or compete with fall-run juveniles. |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Fall-run are not present in this upper basin, so the action is neutral. Enforcement may provide ancillary protection to species passing through lower reaches. |
| ASD-3 | Release hatchery fry into upper McCloud | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Fall-run do not occupy the upper McCloud. Effects remain neutral. |
| ASD-4 | Release hatchery fry into lower McCloud | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; fall-run are not present in these reaches. |
| ASD-5a | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; the action is focused on upper basin tributaries outside fall-run use areas. |
| ASD-5b | Two-way trap and haul into Little Sacramento River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; the action is focused on upper basin tributaries outside fall-run use areas. |
| ASD-5c | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; the action is focused on upper basin tributaries outside fall-run use areas. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-6 | Volitional passage above Shasta Dam into McCloud River | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; fall-run do not utilize these upstream reaches. |
| ASD-7 | Remove McCloud Dam | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; fall-run do not inhabit upper McCloud reaches. |
| ASD-8 | Return historic salmon strain from New Zealand | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; action targets WRCS lineage restoration. |
| F-1 | Shasta TCD Upgrade/Cold water outlet to access colder water | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run benefit substantially from cooler late-summer and fall temperatures, which improve spawning success and embryo viability. |
| H-1 | LSNFH modified release practices | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Fall-run effects are minimal because LSNFH focuses on WRCS propagation. Release timing adjustments may indirectly reduce competition or predation overlap, but no substantial shift in habitat or survival conditions for fall-run occurs. |
| H-2a | LSNFH facility upgrades | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral. Upgrades benefit WRCS operations without altering fall-run spawning or rearing areas. Operational safeguards prevent interference with fall-run release schedules. |
| H-2b | Upgrades to Keswick Dam adult collection system | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral. Keswick collection improvements target WRCS broodstock collection and do not alter fall-run operations. |
| H-2c | New broodfish collection facility in Upper Sacramento River | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral. The facility focuses solely on WRCS adults. Spatial overlap with fall-run is limited and manageable through timing and selective trap design. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
| --- | --- | --- | --- |
| H-3 | CNFH trapping and sorting improvements | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral. The facility focuses solely on WRCS adults. Spatial overlap with fall-run is limited and manageable through timing and selective trap design. |
| SR-1 | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run benefit similarly, as expanded floodplain habitat reduces density stress and improves early growth conditions for multiple Chinook runs. These habitats buffer extreme temperatures and provide high invertebrate prey densities that improve smolt fitness. |
| SR-2a | Physically build and maintain new instream perennial juvenile rearing habitat | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run benefit from increased capacity and reduced competition. Improved habitat reduces predation pressure and better supports overwinter growth. |
| SR-2b | Artificially enhance existing instream juvenile rearing habitat | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run juveniles experience similar benefits through increased refuge and greater food availability. |
| SR-2c | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run benefit from similar non-natal rearing strategies in many systems; expanded habitat reduces competition and improves survival. |
| SR-3 | Build or enhance in-channel spawning habitat | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run also experience improved spawning conditions, benefiting adult escapement and smolt output. |
| SR-4a | Reduce predation contact points on Sacramento River | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run juveniles benefit similarly from reduced concentration of predators at weirs and diversions. |
| SR-4b | Develop regulations to support a striped bass trophy fishery | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run juveniles benefit similarly from reduced concentration of predators. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-5 | Reduce entrainment at Sacramento River diversions | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run show improved outmigration survival due to reduced losses at diversions. |
| SR-6 | Georgiana Slough bubble curtain | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run outmigrants benefit similarly from lower entrainment risk, increasing smolt survival. |
| SR-8 | Nighttime light reduction on Sundial Bridge and other sources | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run juveniles benefit from reduced predator aggregation and more natural movement patterns. |
| SR-9 | Provide volitional upstream and downstream fish passage at Keswick Dam | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run benefit from reduced density in downstream spawning areas and improved habitat segregation. |
| SR-10 | Construct Anderson Cottonwood Irrigation District Water Supply and Fisheries Resiliency Project | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run experience improved passage and reduced stress during upstream migration. |
| SR-11 | Captive rearing and assisted migration of juveniles in drought years | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; WRCS-targeted action does not alter fall-run habitat. |
| BC-1 | Control illegal harvest and/or poaching in Battle Creek | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Enhanced enforcement is largely neutral (estimate <5% impact) but may slightly benefit fall-run by reducing incidental take. Since both runs share migration corridors, reducing illegal gear and non-compliant fishing activity helps maintain adult abundance. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| BC-2 | Battle Creek habitat improvements | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Habitat enhancements boost rearing capacity and reduce predation risk for fall-run juveniles. Increased channel complexity and improved temperature refugia can lead to higher survival during critical growth periods. This generally increases habitat suitability and survival for fall-run alongside WRCS in the reach below Coleman. |
| BC-3 | CNFH water supply intake improvements on Battle Creek | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Positive for fall-run Chinook because the action directly supports Battle Creek Hatchery operations, which play a critical role in sustaining and stabilizing fall-run production. By providing a cooler and/or more stable water supply, the action enhances adult broodstock health, incubation success, and juvenile rearing conditions, all of which contribute to higher survival during early life stages. |
| BC-5 | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Fall-run do not typically access this reach, so impacts are neutral. |
| BC-6 | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral for fall-run since they occupy reaches below Coleman; upstream hydrologic changes do not reduce available habitat or flows in fall-run areas. |
| BC-7 | Limit cold water diversions | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral, as the action affects upstream Battle Creek temperatures rather than shared fall-run habitat. |
| BC-8 | Battle Creek egg incubation | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Any effect on fall-run is indirect and likely minimal. Monitor for straying/competition and adjust practices (PNI, release timing/locations) to avoid adverse effects. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| BC-9 | Implement Battle Creek Reintroduction Plan | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Neutral; plan focuses on WRCS in North Fork Battle Creek without affecting downstream fall-run habitat. |
| O-1 | Improve WRCS Salvage at Tracy and State Fish Collection Facilities | Increases suitable spawning/rearing habitat or survival for fall-run Chinook by ≥5% | Fall-run juveniles benefit similarly through reduced entrainment, as both species are vulnerable to losses at export facilities. |
| O-2 | Increase distance from shoreline to "International" designation | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Uncertain. Offshore boundary shifts target WRCS harvest reduction, which could impact fall-run harvest regimes when the commercial fishery reopens. |
| O-3 | Modify ocean harvest | No change in suitable spawning/rearing habitat or survival for fall-run Chinook within ±5% | Fall-run impacts remain neutral because this action is specifically tailored to WRCS harvest control. Mixed-stock fisheries may require monitoring to prevent unintended changes to fall-run harvest opportunity. |

Key: ACID = Anderson Cottonwood Irrigation District, ASD = Above Shasta Dam, BC = Battle Creek, CNFH = Coleman National Fish Hatchery, F = Facilities, H = Hatcheries, LSNFH = Livingston Stone National Fish Hatchery, O = Other, PG&E = Pacific Gas and Electric Company, SR = Sacramento River, TCD = temperature control device, WRCS = winter-run Chinook salmon

**Table D-3. Scores for Minimize Adverse Impacts on Other Listed Fish Species**

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | No change in habitat or survival for other listed fish species by within ±5% | No major impacts are anticipated. Egg incubation systems are small-scale, passive, and do not alter hydrology or substrate beyond small placements. With proper site choice, no adverse displacement of other salmonids or native fishes is expected. |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | No change in habitat or survival for other listed fish species by within ±5% | Other listed salmonids benefit indirectly from reduced illegal gear use and unregulated take. No habitat or flow alterations occur. |
| ASD-3 | Release hatchery fry into upper McCloud | No change in habitat or survival for other listed fish species by within ±5% | Careful fry release planning minimizes density pressure and disease transmission risk for other species. |
| ASD-4 | Release hatchery fry into lower McCloud | No change in habitat or survival for other listed fish species by within ±5% | Neutral with proper monitoring. Operations are localized and should not affect other fish species if biosecurity protocols are maintained. |
| ASD-5a | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | No change in habitat or survival for other listed fish species by within ±5% | Minimal if appropriately targeted. Passive trapping methods and careful handling reduce risk to non-target species. |
| ASD-5b | Two-way trap and haul into Little Sacramento River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | No change in habitat or survival for other listed fish species by within ±5% | Minimal if appropriately targeted. Passive trapping methods and careful handling reduce risk to non-target species. |
| ASD-5c | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | No change in habitat or survival for other listed fish species by within ±5% | Minimal if appropriately targeted. Passive trapping methods and careful handling reduce risk to non-target species. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-6 | Volitional passage above Shasta Dam into McCloud River | No change in habitat or survival for other listed fish species by within ±5% | Improved connectivity benefits steelhead and possibly spring-run where distributions overlap. |
| ASD-7 | Remove McCloud Dam | Increases habitat or survival for one or more listed fish species by ≥5% | Connectivity improvements benefit cold-water specialists and broaden native fish access. The removal could allow non-native rainbow trout (already present in the basin) to move upstream into currently protected McCloud River Redband Trout habitats, or restoration of natural flow regimes could allow redband trout to re-expand into portions of their historical range. |
| ASD-8 | Return historic salmon strain from New Zealand | No change in habitat or survival for other listed fish species by within ±5% | Neutral, assuming strict biosecurity prevents pathogen risks. |
| F-1 | Shasta TCD Upgrade/Cold water outlet to access colder water | No change in habitat or survival for other listed fish species by within ±5% | Neutral: cooler water temperatures can aid steelhead but can also sometime fall below sturgeon preferences. No direct habitat modifications occur. |
| H-1 | LSNFH modified release practices | No change in habitat or survival for other listed fish species by within ±5% | Careful release planning required to avoid negative effects on native predators or other salmonids. However, some strategies - like large-scale coordinated releases - may briefly alter local food-web dynamics or predator distributions. |
| H-2a | LSNFH facility upgrades | No change in habitat or survival for other listed fish species by within ±5% | Neutral. Biosecure hatchery systems reduce pathogen risks and help ensure hatchery outplants do not negatively affect native species. |
| H-2b | Upgrades to Keswick Dam adult collection system | No change in habitat or survival for other listed fish species by within ±5% | Neutral to slightly beneficial if improved sorting reduces bycatch or handling of non-target species. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| H-2c | New broodfish collection facility in Upper Sacramento River | No change in habitat or survival for other listed fish species by within ±5% | Minimal. A well-designed facility with selective trapping reduces incidental capture of other species. |
| H-3 | CNFH trapping and sorting improvements | No change in habitat or survival for other listed fish species by within ±5% | Minimal. A well-designed facility with selective trapping reduces incidental capture of other species. |
| SR-1 | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | Increases habitat or survival for one or more listed fish species by ≥5% | Other listed species benefit from increased shallow-water habitat, improved connectivity, and higher productivity. |
| SR-2a | Physically build and maintain new instream perennial juvenile rearing habitat | Increases habitat or survival for one or more listed fish species by ≥5% | Steelhead and other native species benefit from expanded complex habitat and cold-water refugia. |
| SR-2b | Artificially enhance existing instream juvenile rearing habitat | Increases habitat or survival for one or more listed fish species by ≥5% | Must avoid unintended effects on native predators; properly designed placements minimize such risks and improve habitat for other salmonids. |
| SR-2c | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | Increases habitat or survival for one or more listed fish species by ≥5% | Steelhead and other native fishes benefit from new upstream access and improved summer thermal refugia. |
| SR-3 | Build or enhance in-channel spawning habitat | Increases habitat or survival for one or more listed fish species by ≥5% | Better substrate supports steelhead spawning and macroinvertebrate productivity, improving food webs. |
| SR-4a | Reduce predation contact points on Sacramento River | Increases habitat or survival for one or more listed fish species by ≥5% | Effectiveness depends on method; carefully designed approaches avoid harming native predators. |
| SR-4b | Develop regulations to support a striped bass trophy fishery | Increases habitat or survival for one or more listed fish species by ≥5% | Effectiveness depends on method; carefully designed approaches avoid harming native predators. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-5 | Reduce entrainment at Sacramento River diversions | Increases habitat or survival for one or more listed fish species by ≥5% | Steelhead, sturgeon, and other migrants benefit from decreased entrainment risk. |
| SR-6 | Georgiana Slough bubble curtain | Increases habitat or survival for one or more listed fish species by ≥5% | Bubble curtain is also explicitly designed to benefit spring-run |
| SR-8 | Nighttime light reduction on Sundial Bridge and other sources | Increases habitat or survival for one or more listed fish species by ≥5% | Native predators may respond to changed light conditions; careful shielding minimizes unintended habitat disruption. |
| SR-9 | Provide volitional upstream and downstream fish passage at Keswick Dam | Increases habitat or survival for one or more listed fish species by ≥5% | Steelhead and other anadromous species gain expanded upstream access. |
| SR-10 | Construct Anderson Cottonwood Irrigation District Water Supply and Fisheries Resiliency Project | Increases habitat or survival for one or more listed fish species by ≥5% | Steelhead, lamprey, and other migratory fishes benefit from improved connectivity. |
| SR-11 | Captive rearing and assisted migration of juveniles in drought years | No change in habitat or survival for other listed fish species by within ±5% | Neutral, assuming secure enclosures and transport procedures. |
| BC-1 | Control illegal harvest and/or poaching in Battle Creek | No change in habitat or survival for other listed fish species by within ±5% | Other listed species benefit indirectly because poaching often uses harmful gear types affecting multiple species, but not expected to result in a >5% impact to their respective populations. Enforcement reduces unregulated mortality without modifying flows or habitat |
| BC-2 | Battle Creek habitat improvements | No change in habitat or survival for other listed fish species by within ±5% | Habitat restoration/reconnection and screening tend to benefit multiple native species via improved migration, temperature refugia, and rearing conditions, without direct negative interventions on other species. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| BC-3 | CNFH water supply intake improvements on Battle Creek | No change in habitat or survival for other listed fish species by within ±5% | Neutral to beneficial (<5%) because improved screening and water delivery reduce inadvertent entrainment and promote cold, stable hatchery water without affecting downstream species. |
| BC-5 | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | Increases habitat or survival for one or more listed fish species by ≥5% | Steelhead and other native fishes gain new passage opportunities, improving genetic exchange and habitat connectivity. |
| BC-6 | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | No change in habitat or survival for other listed fish species by within ±5% | Steelhead and spring-run benefit from more natural flows and increased access to cold-water reaches. |
| BC-7 | Limit cold water diversions | No change in habitat or survival for other listed fish species by within ±5% | Temperature benefits extend to steelhead and spring-run in affected reaches. |
| BC-8 | Battle Creek egg incubation | No change in habitat or survival for other listed fish species by within ±5% | Neutral for other species; egg boxes do not modify habitat or flows. |
| BC-9 | Implement Battle Creek Reintroduction Plan | No change in habitat or survival for other listed fish species by within ±5% | Neutral; due to the extremely low population size of WRCS, their current and foreseeable presence in North Fork Battle Creek is not expected to create substantial ecological interactions or competitive pressure on other salmonid species. |
| O-1 | Improve WRCS Salvage at Tracy and State Fish Collection Facilities | Increases habitat or survival for one or more listed fish species by ≥5% | Sturgeon, steelhead, and other migrants experience lower entrainment-related mortality when salvage efficiency improves. |
| O-2 | Increase distance from shoreline to "International" designation | No change in habitat or survival for other listed fish species by within ±5% | Minimal: action changes regulatory boundaries rather than habitat conditions. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| O-3 | Modify ocean harvest | No change in habitat or survival for other listed fish species by within ±5% | Neutral. Ocean regulatory changes do not alter freshwater habitat or flows affecting other species. |

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**Table D-4. Scores for Time Until Action is First Initiated or Construction is Completed**

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | 1–5 years | Minimal infrastructure allows initiation within 1–5 years depending on placement sites. |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | <1 year | Assuming enforcement expansions can begin within a year. |
| ASD-3 | Release hatchery fry into upper McCloud | 1–5 years | Site planning and trap-and-transport logistics allow initiation within 1–5 years. |
| ASD-4 | Release hatchery fry into lower McCloud | 1–5 years | Moderate planning and site selection allow start within 1–5 years. |
| ASD-5a | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | 1–5 years | Permitting and facility preparation enable implementation within 1–5 years. |
| ASD-5b | Two-way trap and haul into Little Sacramento River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | 1–5 years | Permitting and facility preparation enable implementation within 1–5 years. |
| ASD-5c | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | 1–5 years | Permitting and facility preparation enable implementation within 1–5 years. |
| ASD-6 | Volitional passage above Shasta Dam into McCloud River | >10 years | Major capital project with complex engineering, rights-of-way, and environmental compliance. Large, technically complex fish passage structures require >10 years to initiate. |
| ASD-7 | Remove McCloud Dam | >10 years | Dam removal planning and compliance typically exceed 10 years. |
| ASD-8 | Return historic salmon strain from New Zealand | >10 years | Complex international import and facility requirements require >10 years. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| F-1 | Shasta TCD Upgrade/Cold water outlet to access colder water | 5-10 years | Large multi-agency permitting and construction effort. |
| H-1 | LSNFH modified release practices | <1 year | High readiness: requires only operational adjustments and can be implemented within a season. |
| H-2a | LSNFH facility upgrades | 1–5 years | Design, engineering, and permitting typically require 1–5 years. |
| H-2b | Upgrades to Keswick Dam adult collection system | 1–5 years | 1–5 years for design, construction, and installation. |
| H-2c | New broodfish collection facility in Upper Sacramento River | 1–5 years | Likely 1–5 years due to permitting, site development, and engineering. |
| H-3 | CNFH trapping and sorting improvements | 1–5 years | Likely 1–5 years due to permitting, site development, and engineering. |
| SR-1 | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | 1–5 years | Requires environmental review, hydrologic modeling, design, and permitting—typically 1–5 years. |
| SR-2a | Physically build and maintain new instream perennial juvenile rearing habitat | 1–5 years | Construction planning and permitting require 1–5 years. |
| SR-2b | Artificially enhance existing instream juvenile rearing habitat | 1–5 years | Low infrastructure needs allow initiation within 1–5 years. |
| SR-2c | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | 1–5 years | Dependent on project backlog; typically 1–5 years for design and permitting. |
| SR-3 | Build or enhance in-channel spawning habitat | 1–5 years | Feasible within 1–5 years with proper design and spawning gravel sourcing. |
| SR-4a | Reduce predation contact points on Sacramento River | 5-10 years | Requires design, permits, and construction but is tractable within a single planning cycle. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-4b | Develop regulations to support a striped bass trophy fishery | 1–5 years | Could be implemented through administrative process, requires no construction |
| SR-5 | Reduce entrainment at Sacramento River diversions | 1–5 years | Moderate planning and engineering: 1–5 years. |
| SR-6 | Georgiana Slough bubble curtain | <1 year | Can be implemented quickly (<1 year) with limited permitting. |
| SR-8 | Nighttime light reduction on Sundial Bridge and other sources | <1 year | <1 year with cooperative agreements. Permitting is minimal and infrastructure either exists or is small-scale; can start within a season. |
| SR-9 | Provide volitional upstream and downstream fish passage at Keswick Dam | 5-10 years | Moderate capital project requiring consideration of effects to existing federal infrastructure, 5-10 years for design and regulatory processes. |
| SR-10 | Construct Anderson Cottonwood Irrigation District Water Supply and Fisheries Resiliency Project | 1–5 years | 1–5 years given engineering and permitting needs. |
| SR-11 | Captive rearing and assisted migration of juveniles in drought years | 1–5 years | Requires design, permits, and construction but is tractable within a single planning cycle. |
| BC-1 | Control illegal harvest and/or poaching in Battle Creek | <1 year | Some immediate actions could be funded to increase outreach and enforcement. Any changes to fishing regulations would likely be a longer process. |
| BC-2 | Battle Creek habitat improvements | 1–5 years | Requires design, permits, and construction, would require series of projects on ~8 year time frame, difficult area to construct. |
| BC-3 | CNFH water supply intake improvements on Battle Creek | 1–5 years | Engineering, permitting, and contracting lead to a 1–5-year initiation period. |
| BC-5 | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | 1–5 years | Requires design, permits, and construction but is tractable within a single planning cycle. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| BC-6 | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | 5-10 years | Large, multi-agency decommissioning requires lengthy coordination, often 5–10 years. |
| BC-7 | Limit cold water diversions | 1–5 years | Moderate planning and coordination enable a 1–5-year initiation window. |
| BC-8 | Battle Creek egg incubation | <1 year | Permitting is minimal and infrastructure either exists or is small-scale; can start within a season. |
| BC-9 | Implement Battle Creek Reintroduction Plan | 1–5 years | Moderate planning and facility preparation require 1–5 years. |
| O-1 | Improve WRCS Salvage at Tracy and State Fish Collection Facilities | 5-10 years | Would require significnat investments to existing facility |
| O-2 | Increase distance from shoreline to "International" designation | 1–5 years | Primarily regulatory; changes could be implemented within 1–5 years. |
| O-3 | Modify ocean harvest | 1–5 years | Regulatory changes generally require 1–5 years, coordinated through fisheries management agencies. |

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**Table D-5. Scores for Time from When Action is First Initiated or Construction is Completed to Realization of Local Scale Benefits**

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | 1–5 years | Biological benefits - improved imprinting and early survival - occur in the first emergence cycle, typically within 1–3 years. |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | <1 year | Benefits - improved adult survival - begin in the same migration season. |
| ASD-3 | Release hatchery fry into upper McCloud | 1–5 years | Juvenile survival and imprinting benefits manifest within the first generation. |
| ASD-4 | Release hatchery fry into lower McCloud | 1–5 years | Benefits occur as soon as juveniles complete the first freshwater growth season. |
| ASD-5a | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | <1 year | Benefits accrue quickly as transported adults spawn and juveniles rear upstream. |
| ASD-5b | Two-way trap and haul into Little Sacramento River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | <1 year | Benefits accrue quickly as transported adults spawn and juveniles rear upstream. |
| ASD-5c | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | <1 year | Benefits accrue quickly as transported adults spawn and juveniles rear upstream. |
| ASD-6 | Volitional passage above Shasta Dam into McCloud River | 5-10 years | Full benefits require multiple generations (5–10 years) as populations reestablish. |
| ASD-7 | Remove McCloud Dam | 5-10 years | Ecological improvements build over 5–10 years as channel and sediment regimes stabilize. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-8 | Return historic salmon strain from New Zealand | 5-10 years | Several generations are needed to evaluate fitness and integration. |
| F-1 | Shasta TCD Upgrade/Cold water outlet to access colder water | 1–5 years | Temperature benefits appear soon after commissioning but require tuning over multiple operational seasons. |
| H-1 | LSNFH modified release practices | <1 year | Modified release strategies produce benefits immediately, particularly in early juvenile survival and routing. |
| H-2a | LSNFH facility upgrades | 1–5 years | Benefits appear once new systems are operational, improving water quality and hatchery reliability. |
| H-2b | Upgrades to Keswick Dam adult collection system | 1–5 years | Benefits begin after commissioning, with improved broodstock capture efficiency and reduced migration delay. |
| H-2c | New broodfish collection facility in Upper Sacramento River | 1–5 years | Benefits—for broodstock quality and genetic integrity—appear within the first spawning cycles. |
| H-3 | CNFH trapping and sorting improvements | 1–5 years | Benefits of reduced handling and migration delays appear within the first spawning cycles. |
| SR-1 | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | 1–5 years | Benefits begin post-construction but improve over several seasonal inundation cycles. |
| SR-2a | Physically build and maintain new instream perennial juvenile rearing habitat | 1–5 years | Benefits appear once features are constructed and connected to the river. |
| SR-2b | Artificially enhance existing instream juvenile rearing habitat | 1–5 years | Habitat benefits begin almost immediately after installation. |
| SR-2c | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | 1–5 years | Physical habitat/connectivity benefits begin after construction and vegetation establishment. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-3 | Build or enhance in-channel spawning habitat | 1–5 years | Physical habitat/connectivity benefits begin after construction and vegetation establishment. |
| SR-4a | Reduce predation contact points on Sacramento River | <1 year | Predation reductions can produce rapid benefits (<1 year), although rebounds in predator populations are possible |
| SR-4b | Develop regulations to support a striped bass trophy fishery | <1 year | Predation reductions can produce rapid benefits (<1 year), although rebounds in predator populations are possible |
| SR-5 | Reduce entrainment at Sacramento River diversions | 1–5 years | Benefits begin as screens are installed and functional. |
| SR-6 | Georgiana Slough bubble curtain | <1 year | Immediate improvements for outmigrating fish once operational. |
| SR-8 | Nighttime light reduction on Sundial Bridge and other sources | <1 year | Rapid - benefits appear in the same outmigration season. |
| SR-9 | Provide volitional upstream and downstream fish passage at Keswick Dam | 1–5 years | Benefits begin after first upstream migration cohort succeeds. |
| SR-10 | Construct Anderson Cottonwood Irrigation District Water Supply and Fisheries Resiliency Project | 1–5 years | Benefits appear within the first migration cycle post-removal. |
| SR-11 | Captive rearing and assisted migration of juveniles in drought years | <1 year | Immediate - juvenile survival improves that same season. |
| BC-1 | Control illegal harvest and/or poaching in Battle Creek | <1 year | Adult survival increases immediately once enforcement is active, reflected in same-year escapement. |
| BC-2 | Battle Creek habitat improvements | 1–5 years | Physical habitat/connectivity benefits begin after construction and vegetation establishment. |
| BC-3 | CNFH water supply intake improvements on Battle Creek | 1–5 years | Thermal/flow regime benefits follow commissioning of new infrastructure but may require adaptive tuning. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| BC-5 | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | 1–5 years | Physical habitat/connectivity benefits begin after construction and vegetation establishment. |
| BC-6 | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | 1–5 years | Flow and habitat improvements begin soon after completion but population-level gains develop over several cohorts. |
| BC-7 | Limit cold water diversions | 1–5 years | Temperature improvements appear quickly upon implementation, but benefits depend on hydrology/meterology. |
| BC-8 | Battle Creek egg incubation | 1–5 years | Physical habitat/connectivity benefits begin after construction and vegetation establishment. |
| BC-9 | Implement Battle Creek Reintroduction Plan | 1–5 years | Benefits accrue as returning adults establish a stable run over multiple brood cycles. |
| O-1 | Improve WRCS Salvage at Tracy and State Fish Collection Facilities | 1–5 years | Benefits accrue once upgraded salvage systems operate consistently. |
| O-2 | Increase distance from shoreline to "International" designation | 1–5 years | Benefits occur immediately in the subsequent fishing season through higher adult escapement. |
| O-3 | Modify ocean harvest | 1–5 years | Benefits occur immediately in the next harvest season as more adults escape fisheries |

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**Table D-6. Scores for Total Expected Costs of the Actions.**

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-1 | Excess hatchery eggs placed in-river or in streamside egg incubators | $1M - $10M | Low-tech systems keep costs in the $1M–$10M range. |
| ASD-2 | Control illegal harvest and/or poaching in McCloud River | $1M - $10M | Enforcement/ops changes or small deterrents are relatively low-cost to implement. |
| ASD-3 | Release hatchery fry into upper McCloud | $1M - $10M | Releasing unfed fry into the Upper McCloud requires substantial field logistics, including multi-site fry distribution, operation of downstream juvenile capture traps, and safe transport of outmigrants to the Sacramento River. Ensuring successful rearing and evaluating release locations across variable hydrologic conditions also demands multi-year monitoring, staff time, and equipment. As the program scales the infrastructure, personnel, and operational costs increase accordingly. |
| ASD-4 | Release hatchery fry into lower McCloud | $1M - $10M | Moderate operational costs: $1M–$10M. |
| ASD-5a | Two-way trap and haul into McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | $50M - $100M | High operational and logistics costs: $50M–$100M. Facilities, vessels, and multi-year operations typically require mid eight-figure investment. |
| ASD-5b | Two-way trap and haul into Little Sacramento River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | $50M - $100M | High operational and logistics costs: $50M–$100M. Facilities, vessels, and multi-year operations typically require mid eight-figure investment. |
| ASD-5c | Two-way trap and haul into Little Sacramento River and McCloud River (adult spawners above Shasta Dam, juveniles downstream of Shasta Dam) | $100M - $500M | High operational and logistics costs: $50M–$100M per tributary, some efficiencies when combined but likely requires greater effort than individual tributaries. Facilities, vessels, and multi-year operations typically require mid eight-figure investment. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| ASD-6 | Volitional passage above Shasta Dam into McCloud River | >$1B | Major dam passage or removal concepts have capital needs in the hundreds of millions to billions. |
| ASD-7 | Remove McCloud Dam | $500M - $1B | Major dam passage or removal concepts have capital needs in the hundreds of millions to billions. |
| ASD-8 | Return historic salmon strain from New Zealand | $10M - $50M | Genetic importation, quarantine, and facility upgrades fall within $10M–$50M. |
| F-1 | Shasta TCD Upgrade/Cold water outlet to access colder water | $100M - $500M | Large civil works (dam removal/replacement, TCD upgrades) typically fall into high nine figures. |
| H-1 | LSNFH modified release practices | $1M - $10M | Low to moderate ($1M–$10M), mainly for additional staff hours, transport logistics, and monitoring. |
| H-2a | LSNFH facility upgrades | $50M - $100M | Higher cost ($50M–$100M) due to major structural improvements, equipment, and electrical upgrades. |
| H-2b | Upgrades to Keswick Dam adult collection system | $10M - $50M | $10M–$50M depending on structural modifications and mechanical systems. |
| H-2c | New broodfish collection facility in Upper Sacramento River | $1M - $10M | Lower than major hatchery upgrades ($1M–$10M), given simplified infrastructure needs. The collection facility would likely employ low-technology design elements, minimizing the need for extensive infrastructure development. |
| H-3 | CNFH trapping and sorting improvements | $10M - $50M | Hatchery upgrades programs are usually one to several million in capital and operations/maintenance costs. |
| SR-1 | Restore floodplain access for rearing habitat in upper and upper-mid Sacramento | $50M - $100M | Large-scale earthwork and levee modifications place costs in the $50M–$100M range. |
| SR-2a | Physically build and maintain new instream perennial juvenile rearing habitat | $50M - $100M | High due to earthmoving and multi-year maintenance: $50M–$100M. Both construction of habitat and action specifically mentions ongoing maintenance |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-2b | Artificially enhance existing instream juvenile rearing habitat | $1M - $10M | Relatively low ($1M–$10M), driven by installation logistics, monitoring, and maintenance. Although the structural materials used in this action are inherently low-technology and low-cost, large-river habitat projects require extensive planning, permitting, installation logistics, and long-term monitoring and maintenance. These factors collectively justify cost range for full implementation. |
| SR-2c | Restore access to instream rearing habitat in ephemeral non-natal tributaries of the Sacramento River | $50M - $100M | Categorizing as similar to other restoration actions like SR-1 |
| SR-3 | Build or enhance in-channel spawning habitat | $10M - $50M | Constructing or enhancing in-channel spawning habitat for 200 females between Keswick and Clear Creek requires major river engineering, high-quality gravel placement, flow manipulation, and long-term geomorphic maintenance to ensure durability over multiple decades. Achieving a 10% increase in egg-to-fry survival demands robust monitoring, adaptive management, and repeated maintenance cycles across the 20-year timeframe. These capital-intensive activities, combined with annualized monitoring and upkeep, place the total cost well within the upper multi-million-dollar range. |
| SR-4a | Reduce predation contact points on Sacramento River | $10M - $50M | Requires mutliple structural modifications at different locations, in-water construction work and associated permits. |
| SR-4b | Develop regulations to support a striped bass trophy fishery | <$1M | Administrative action that would require minimal investment and no construction costs |
| SR-5 | Reduce entrainment at Sacramento River diversions | $100M - $500M | High ($100M–$500M) due to large numbers of diversions and, in some locations, engineering complexity. Programmatic habitat or screening portfolios commonly span eight figures. |
| SR-6 | Georgiana Slough bubble curtain | $10M - $50M | Conceptual level cost esimate for facility similar to existing facility at Georgiana Slough was ~$12M. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| SR-8 | Nighttime light reduction on Sundial Bridge and other sources | $1M - $10M | While individual lighting fixtures are inexpensive, objective is in the $1M–$10M considering fixture modifications and coordination. |
| SR-9 | Provide volitional upstream and downstream fish passage at Keswick Dam | $10M - $50M | Moderate ($10M–$50M). |
| SR-10 | Construct Anderson Cottonwood Irrigation District Water Supply and Fisheries Resiliency Project | $100M - $500M | High ($100M–$500M) due to major infrastructure replacement. |
| SR-11 | Captive rearing and assisted migration of juveniles in drought years | $1M - $10M | $1M–$10M depending on rearing system complexity. |
| BC-1 | Control illegal harvest and/or poaching in Battle Creek | $1M - $10M | Primarily personnel (e.g., game wardens) and equipment costs; scalable within a $1M–$10M program. |
| BC-2 | Battle Creek habitat improvements | $10M - $50M | Moderate-High cost based on difficult area to construct. |
| BC-3 | CNFH water supply intake improvements on Battle Creek | $1M - $10M | Infrastructure upgrades require construction and equipment investment, typically $1M–$10M each. |
| BC-5 | Remove boulder barrier on North Fork Battle Creek downstream of Eagle Canyon Dam | $1M - $10M | Barrier removal is a moderate-scale construction project. Designs, permits, and funding already in place. Current status is the grant is pending DOI approval process. |
| BC-6 | Complete PG&E decommissioning and restore unimpaired flows on North Fork Battle Creek | $100M - $500M | Major civil works, sediment management, and infrastructure removal cost $100M–$500M. |
| BC-7 | Limit cold water diversions | $10M - $50M | $10M–$50M depending on infrastructure modifications. |

| Unique Action Identifier | Unique Action | Metric Score | Metric Score Rationale |
|---|---|---|---|
| BC-8 | Battle Creek egg incubation | $1M - $10M | Creating and maintaining naturalized incubation sites requires engineered substrates, field infrastructure, environmental monitoring systems, and multi-year staffing. Even though humans only place the eggs, ensuring survival, biosecurity, and regulatory compliance in an uncontrolled river environment demands heavy logistics and long-term investment. |
| BC-9 | Implement Battle Creek Reintroduction Plan | $10M - $50M | Producing 200,000 smolts annually requires major hatchery expansion or construction, including water treatment, high-capacity incubation, rearing infrastructure, and long-term operational staffing. Ensuring that only naturally returning Battle Creek adults are used for broodstock adds additional monitoring, trapping, genetic management, and facility modifications to support a sustainable closed brood cycle. |
| O-1 | Improve WRCS Salvage at Tracy and State Fish Collection Facilities | $100M - $500M | Potentially high: $100M–$500M, especially if new facilities or major retrofits are required. Due to facility age, may require new facility versus refurbishments in order to be cost-effective. |
| O-2 | Increase distance from shoreline to "International" designation | $1M - $10M | Low to moderate ($1M–$10M), tied to regulatory processes and stakeholder coordination. |
| O-3 | Modify ocean harvest | $1M - $10M | Low to moderate ($1M–$10M), primarily administrative and monitoring-related. |

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