Fisheries Framework: Spring-run and Fall-run Chinook Salmon

SAN JOAQUIN RIVER
RESTORATION PROGRAM

July 2018

Mission Statements

The mission of the Department of the Interior is to protect and Provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

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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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List of Abbreviations and Acronyms

AHA model	All-H Analyzer model (habitat, harvest, hatcheries, hydro)
BDCP	Bay Delta Conservation Plan
BY	Brood Year
CDFW	California Department of Fish and Wildlife
CDWR	California Department of Water Resources
CFS	Cubic Feet per Second
CV	Central Valley
CWT	Coded Wire Tag
DO	Dissolved Oxygen
FMP	Fisheries Management Plan
FRH	Feather River Hatchery
HGMP	Hatchery and Genetic Management Plan
HOR	Hatchery Origin Return
HOS	Hatchery Origin Spawner
HIS	Habitat Suitability Index
HSRG	Hatchery Scientific Review Group
M2	Square meters
MAP	Mitigation Action Plan
M&E	Monitoring and Evaluation
MSY	Maximum Sustainable Yield
N	Population census size
NFH	National Fish Hatchery
NMFS	National Marine Fisheries Service
NOB	Natural Origin Broodstock
NOR	Natural Origin Return
NRDC	Natural Resources Defense Council
PBT	Parentage Based Tagging
PDO	Pacific Decadal Oscillation
pHOS	Proportion of the natural spawning population composed of hatchery fish
PNI	Proportionate Natural Influence
pNOB	Proportion of natural origin fish incorporated into hatchery broodstock
Program	San Joaquin River Restoration Program
PVA	Population Viability Analysis
RA	Restoration Administrator
RM&E	Research, Monitoring and Evaluation

RMIS	Regional Mark Information System
SAR	Smolt to Adult Return rate
SCARF	Salmon Conservation and Research Facility
Settlement	Agreement reached to resolve NRDC, et al. v. Kirk Rodgers, et al.
SIRF	Satellite Incubation and Rearing Facility
SJRRP	San Joaquin River Restoration Program
TAC	Technical Advisory Committee
USFWS	US Fish and Wildlife Service
VSP	Viable Salmonid Population

Executive Summary

This Fisheries Framework establishes a realistic schedule for implementation of the fisheries management actions in the San Joaquin River Restoration Program (SJRRP or Program) based upon the best available science and information. Specifically, this Fisheries Framework provides guidance to the SJRRP Implementing Agencies, which include the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Bureau of Reclamation (Reclamation), California Department of Fish and Wildlife (CDFW), and California Department of Water Resources (CDWR), to implement the fisheries components of the Stipulation of Settlement in NRDC, et al. v. Kirk Rodgers, et al. (Settlement) and the San Joaquin River Restoration Settlement Act, Title X, Subtitle A, Part I of Public Law 111-11 (Settlement Act).

This Framework contains a description of: (1) goals and objectives for establishing spring-run and fall-run Chinook salmon populations in the Restoration Area; (2) habitat and ecosystem conditions that will support naturally reproducing, self-sustaining salmon populations; (3) the scientific foundation for the planned management actions; and (4) a proposed Adaptive Management process and implementation plan.

The Settlement's foundational fishery goal, stated in the Restoration Goal, is to restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence of the Merced River (the Restoration Area), including naturally reproducing and self-sustaining populations of Chinook salmon and other fish. The Settlement provides direction on certain reintroduction actions in Paragraph 15, including incorporating recommendations from the Restoration Administrator on the reintroduction of spring-run and fall-run Chinook salmon. However, the Settlement does not establish a process for achieving naturally reproducing and self-sustaining populations, nor does it establish specific, sequential objectives that lead toward this goal, such as biological and habitat objectives necessary to achieve a naturally reproducing and self-sustaining population.

As these more specific objectives are important to guide, measure and monitor the process of fish reintroduction and to guide the development of the physical projects in Paragraph 11 and the release of Restoration Flows in Paragraph 13 of the Settlement, this Fisheries Framework establishes specific fisheries and habitat objectives. These objectives are specific, measurable steps that lead toward achieving the Settlement's Restoration Goal.

This Framework describes the fisheries and habitat goals and objectives established for the SJRRP (see Section 2). Goals for both spring-run and fall-run Chinook salmon and other native fish focus on restoring self-sustaining and naturally reproducing populations in the Restoration Area. Habitat objectives for the Restoration Area are focused on establishing habitat conditions that produce self-sustaining populations of Chinook salmon and other native fish. Program actions are designed to reduce physical, biological and ecological stressors (also referred to as limiting factors) within the system that limit the development of healthy fish populations.

This Framework also describes the scientific foundation for the Program's fisheries actions (see Section 3). Specifically, it describes how management activities related to habitat, hatcheries, and harvest have been designed to achieve Program goals. This scientific foundation is intended to ensure the benefits and risks of the proposed management actions have been considered. A scientifically defensible program weighs such benefits and risks against the Program's goals and objectives and the most up-to-date science. Management actions must be consistent with current scientific knowledge of the target species and their habitat needs.

The Program's implementation plan is described in Section 3. The Program will be implemented using the Adaptive Management Approach outlined in the Fisheries Management Plan (FMP) (SJRRP 2010a) and described in detail in this Framework.

Program implementation includes two components:

(1) Implementation of the physical projects outlined in the Settlement Agreement.

(2) Restoration of spring-run and fall-run Chinook salmon populations.

The initial focus of the Program will be to reduce the high priority stressors (also known as limiting factors). The Program's implementation plan is designed to reduce these stressors and produce self-sustaining populations of spring-run and fall-run Chinook salmon.

The Revised Framework for Implementation (SJRRP 2015a) established five-year Vision Periods to provide clear, realistic and accomplishable steps toward achievement of the structural and environmental goals outlined in the Settlement Agreement. These Vision Periods correspond to the following timeline:

- 5-Year Vision (2015–2019)
- 10-Year Vision (2020–2024)
- 15-Year Vision (2025–2029)
- Beyond 15-Year Vision (2030+)

The Framework for Implementation uses these time periods to describe the activities needed to plan, permit, design, construct and operate the major elements of the Program. These activities and their completion dates define the environment within which fish reintroduction will take place.

Restoration of spring-run and fall-run Chinook salmon populations will be implemented in three phases, each of which has specific biological and population objectives. These phases are:

- Reintroduction (i.e., recolonization)
- Local Adaptation
- Full Restoration

The phases are not associated with specific timelines because it is not possible to predict with confidence when the shift from one restoration phase to the next will occur. Salmon populations are subject to substantial annual and decadal variability due to changes in environmental conditions. Therefore, movement between phases will be based on biological criteria (triggers) rather than the timeline used for implementation of physical projects.

1 Introduction

This Fisheries Framework establishes a realistic schedule for implementation of the fisheries management actions in the San Joaquin River Restoration Program (SJRRP or Program) based upon the best available science and information. Specifically, this Fisheries Framework does the following:

- Establishes a framework for the SJRRP Implementing Agencies, which include the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Bureau of Reclamation (Reclamation), California Department of Fish and Wildlife (CDFW), and California Department of Water Resources (CDWR), to implement the fisheries components of the Stipulation of Settlement in NRDC, et al. v. Kirk Rodgers, et al. (Settlement) and the San Joaquin River Restoration Settlement Act, Title X, Subtitle A, Part I of Public Law 111-11 (Settlement Act).
- Establishes specific fisheries and habitat goals and objectives that lead toward achieving the Settlement's Restoration Goal.
- Establishes an implementation plan for actions that reduce physical, biological and ecological stressors, primarily within the Restoration Area, that limit fish production.

This Fisheries Framework builds on the SJRRP's Revised Framework for Implementation (Implementation Framework) completed in July 2015 (SJRRP 2015a). The Implementation Framework established a realistic schedule and future funding needs for the SJRRP Implementing Agencies to implement the Settlement, Settlement Act, and "Friant Division Improvements" in Title X, Subtitle A, Part III of Public Law 111-11. The Implementation Framework primarily focused on activities necessary to plan, permit, design, and construct major physical project elements of the SJRRP. It established the major physical project elements that the SJRRP intends to undertake in five-year increments or Vision Periods (Table 1a). In addition, this Fisheries Framework identifies the biological management actions that the SJRRP intends to undertake as construction actions move forward. Specifically, this Framework links the various physical projects identified in the Implementation Framework and their proposed schedules with management actions planned to establish Chinook salmon populations (Table 1b).

This Framework contains a description of: (1) goals and objectives for establishing spring-run and fall-run Chinook salmon populations in the Restoration Area (Section 2.1); (2) habitat and ecosystem conditions that will support naturally reproducing, self-sustaining Chinook salmon populations (Section 2.2); (3) the scientific foundation for the planned management actions (Section 3); and (4) a proposed Adaptive Management process and implementation plan (Section 3).

For context, the Restoration Area encompasses the San Joaquin River from Friant Dam to the confluence with the Merced River, shown in Figure 1.

Table 1a. Schedule of key construction actions during each Vision Period (SJRRP 2015a)

2015-2019	2020-2024	2025-2029	2030+
Goal: At least 1,300 cfs Capacity in all Reaches	**Goal: Increased Capacity**	**Goal: Phase 1 Projects Complete**	**Goal: All Remaining Projects**
Friant-Kern Capacity Restoration Madera Canal Capacity Restoration Mendota Pool Bypass Temporary Arroyo Canal Screen and Sack Dam Passage Conservation Facility Seepage Projects to at least 1,300 cfs	Financial Assistance for Groundwater Banks Reach 2B Arroyo Canal and Sack Dam Reach 4B Land Acquisition Seepage Projects to 2,500 cfs Levee Stability to 2,500 cfs	Reach 4B Salt and Mud Sloughs Chowchilla Bifurcation Structure Modifications Highest Priority Gravel Pits Seepage Projects to 4,500 cfs Levee Stability to 4,500 cfs	Ongoing Operations and Maintenance

Table 1b. Schedule of key fisheries actions during each Vision Period that align to construction activities

2015-2019	2020-2024	2025-2029	2030+
Goal: Reintroduction (i.e. recolonization)	**Goal: Volitional Passage**	**Goal: Local Adaptation**	**Goal: Full Restoration**
Temporary Juvenile Trap and Haul Adult Trap and Haul Conservation Hatchery Volitional Juvenile Out-Migration Possible in High Flow Years Volitional Adult Escapement Possible	Completion of Mendota Pool Bypass, Arroyo Canal Fish Screen and Improved Sack Dam Fish Passage Volitional Juvenile Out-Migration Possible in Most Flow Years Increased Juvenile Survival Due to Increased Channel Capacity	Completion of Seasonal Barriers at Mud and Salt Slough Sufficient Quality and Quantity of Habitat to Support Self-Sustaining Populations of Chinook salmon.	Ongoing Fisheries Monitoring

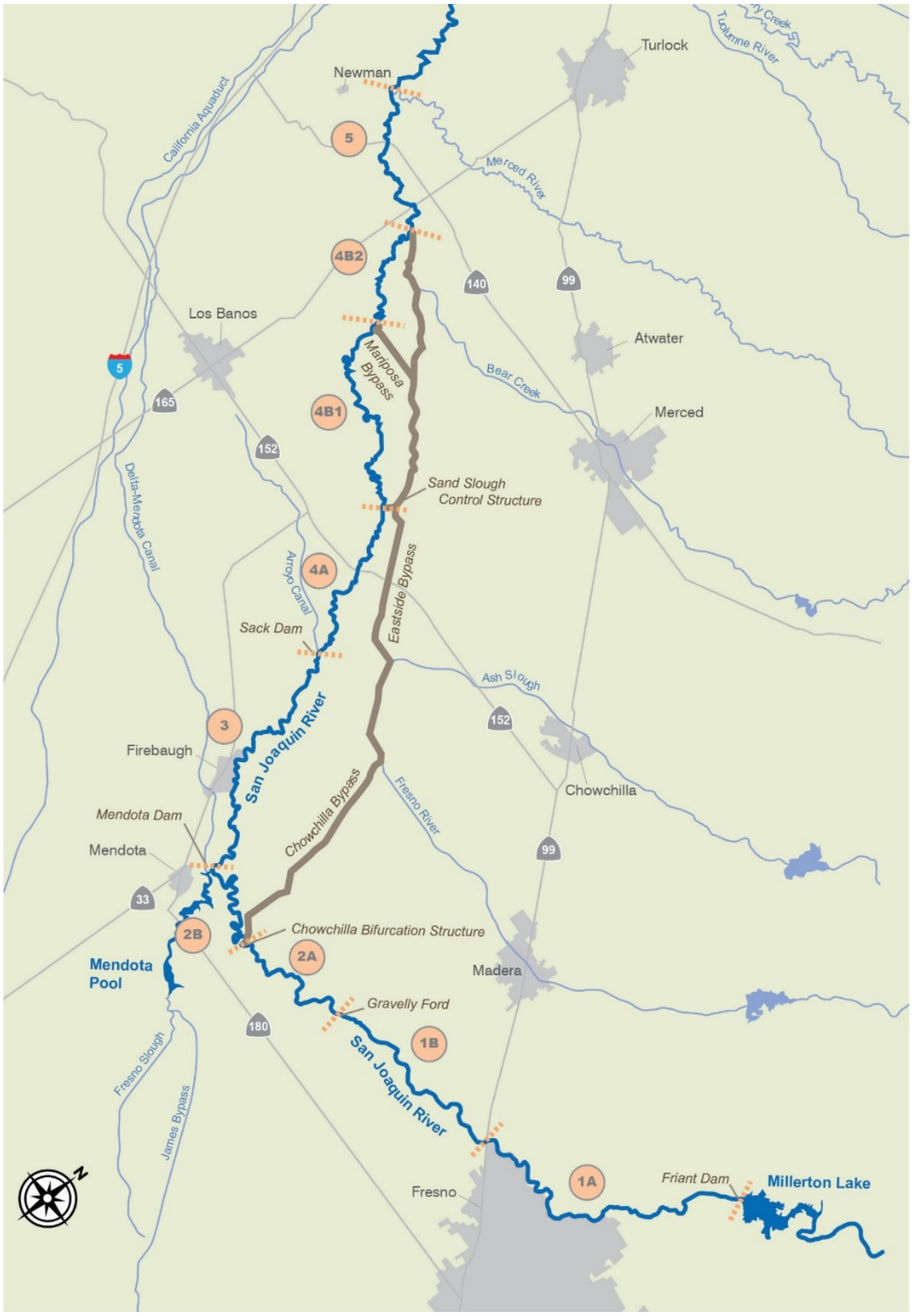


Figure 1. Restoration Area

1.1 Background

1.1.1 Settlement and Settlement Act

In 1988, a coalition of environmental groups led by the Natural Resources Defense Council (NRDC) filed a lawsuit challenging the renewal of the long-term water service contracts between the United States and the Central Valley Project Friant Division Contractors. After more than 18 years of litigation, the parties to the litigation reached agreement on the terms and conditions of the Settlement. The court approved the Settlement in 2006 and the Settlement Act, passed in 2009, authorizes the Secretary of the Interior to implement the Settlement.

The Settlement includes two parallel goals:

- Restoration - To restore and maintain fish populations in "good condition" in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish; and
- Water Management - To reduce or avoid adverse water supply impacts to all of the Friant Division long-term Contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

To achieve the Restoration Goal, the Settlement calls for the release of water from Friant Dam to the confluence of the Merced River (referred to as Interim and Restoration Flows), a combination of channel and structural modifications along the San Joaquin River below Friant Dam, and reintroduction of Chinook salmon.

This document is focused on achieving the fish reintroduction component of the Restoration Goal that is largely contained in Paragraph 14 of the Settlement and which also plays a critical role in how actions in Paragraphs 11 (physical improvements) and 13 (Restoration Flows) of the Settlement are implemented. The fisheries reintroduction components of the Restoration Goal also played a role in how Paragraph 15, Interim Flows, were implemented. However, the Interim Flows program was completed on December 31, 2013.

1.1.2 Fisheries Documents that Form the Basis of this Framework

The SJRRP Implementing Agencies have prepared a series of documents that outline components of the Program's fisheries actions. These documents, along with the best available science and information, form the basis of this Fisheries Framework. The partial list of the SJRRP documents is provided below, and many of these documents can be found on the SJRRP website at www.restoresjr.net. See the reference section for a listing of additional scientific and other information used in the development of this Fisheries Framework.

Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program (SJRRP 2010a)

- Hatchery and Genetic Management Plan (SJRRP 2010b and 2016)
- Minimum Floodplain Habitat Area for Spring and Fall-Run Chinook Salmon (SJRRP 2012a)
- Revised Framework for Implementation (SJRRP 2015a)
- Stock Selection Strategy for Spring-run Chinook (SJRRP 2010c)
- Reintroduction Strategy for Spring-run Chinook Salmon (SJRRP 2011)
- Permit 14868 in accordance with section 10(a)(1)(A) of the Endangered Species Act: San Joaquin River Restoration Program Central Valley Spring-run Chinook Salmon Reintroduction (77 FR 67796) (2012)

- Permit 17781 in accordance with section 10(a)(1)(A) of the Endangered Species Act: Release of Central Valley Spring-Run Chinook Salmon and Eggs from the Feather River Fish Hatchery and the Interim/Conservation Facility into the San Joaquin River (79 FR 26944) (2014)

In addition, the following documents prepared by the SJRRP Restoration Administrator also form the basis of this Fisheries Framework. These can also be found on the SJRRP website.

- Recommendations on Restoring Spring-run Chinook Salmon to the Upper San Joaquin River (Hanson et al. 2007)
- Recommendations on Restoring Fall-run Chinook Salmon to the Upper San Joaquin River (Hanson et al. 2008)

1.2 Accomplishments and Remaining Actions

The original schedule for implementation envisioned in the Settlement was ambitious by design and reflected the Parties' intent that improvements be completed in an expeditious manner. Many assumptions were made in developing the schedule, and while the Parties have exercised due diligence, some actions are unavoidably behind schedule. However, many initial actions that establish the foundation for reintroduction of spring-run and fall-run Chinook salmon have been accomplished. These include the following:

- Restored flow connectivity in the San Joaquin River throughout the Restoration Area from Friant Dam to the confluence with the Merced River.
    - Petitioned for and obtained water rights for Program purposes
    - Obtained the necessary flowage and seepage easements to restore flow up to approximately 300 cfs
- Completed the rules and permits necessary to implement the SJRRP's spring-run Chinook salmon broodstock and direct release efforts.
    - 10(j) designation of a Non Essential Experimental Spring-run Chinook Salmon Population within the Restoration Area (78 FR 79622)
    - Permit 14868 in accordance with section 10(a)(1)(A) of the Endangered Species Act: San Joaquin River Restoration Program Central Valley Spring-run Chinook Salmon Reintroduction (77 FR 67796)
    - Permit 17781 in accordance with section 10(a)(1)(A) of the Endangered Species Act: Release of Central Valley Spring-Run Chinook Salmon and Eggs from the Feather River Fish Hatchery and the Interim/Conservation Facility into the San Joaquin River (79 FR 26944)
- Completed the Programmatic Biological Opinions for NMFS and USFWS for Endangered Species Act under the purview for all Program actions.
- Awarded a contract to construct a full-scale Salmon Conservation and Research Facility (SCARF).

- Developed a spring-run Chinook salmon broodstock program at the SCARF.
- Constructed genomic databases using Parentage Based Tags (PBTs) to identify returning Program fish.
- Released spring-run Chinook salmon broodstock into Reach 1 of the Restoration Area for holding over summer.
    - Documented the first spring-run Chinook salmon redds in over 50 years.
- Performed four consecutive years of juvenile spring-run Chinook salmon releases in the Restoration Area.
- Performed five consecutive years of adult fall-run Chinook salmon trap and haul to move salmon into the spawning area of Reach 1 for research purposes.
    - Monitored multiple years of successful spawning within Reach 1, allowing biologists to examine fish movements, behavior, and spawning conditions.
- Completed juvenile Chinook salmon trap and haul analysis report and performed three years of field studies under low-flow conditions with fall-run Chinook salmon.
- Held two Program Science Meetings to share with the public and Program staff findings from research projects.
- Established a segregation protocol for returning spring-run and fall-run Chinook salmon.
- Completed a Programmatic Biological Opinion outlining passage and habitat concerns and solutions related to Mendota Pool, Reach 2B, and associated control structures.

Tables 2 and 3 provide a summary of the accomplishments and remaining actions to implement the fish reintroduction component of the Restoration Goal in the Settlement and Settlement Act, respectively.

Table 2. Accomplishments and remaining actions to implement the fish reintroduction component of the Restoration Goal in the Settlement

Paragraph [1]	Project [2]	Accomplishments	Action(s) Remaining
11 (generally)	Various	• Programmatic Biological Opinion outlining passage and habitat concerns and solutions related to Mendota Pool, Reach 2B, and associated control structures. • NMFS annual Technical Memorandum for potential take of spring-run at the Delta pumps	• Design, construct and operate projects in a way that works to achieve the Restoration Goal

Table 2. Accomplishments and remaining actions to implement the fish reintroduction component of the Restoration Goal in the Settlement

Paragraph [1]	Project [2]	Accomplishments	Action(s) Remaining
14	Reintroduce spring-run and fall-run Chinook salmon	• Fisheries Management Plan, Hatchery and Genetics Management Plan, Strategy for Spring-run Chinook Salmon Reintroduction, and permit applications • Trapped and transported fall-run salmon starting in 2012 and continuing to present • Natural spawning of fall-run in fall 2012 and naturally produced fall-run in spring 2013, continues yearly • Generated a rule under Section 10(j) of the Federal Endangered Species Act that designated a nonessential experimental population of spring-run in the Restoration Area that allowed the release of spring-run Chinook salmon • Initiated spring-run broodstock collection and propagation efforts in 2013 • Constructed and began operations of the Interim Conservation Facility • Commenced direct releases of spring-run into the San Joaquin River in 2014 • Began release of spring-run from the Interim Conservation Facility into the San Joaquin River in 2016 • Summer of 2016 began spring-run adult broodstock release in upper reaches, to hold over summer, create redds, and produce wild offspring	• Continue spring-run broodstock efforts and direct releases of spring-run into the river • Begin using wild spring-run stock for broodstock efforts • Construct permanent Salmon Conservation and Research Facility, including water supply for the facility • Remove Hills Ferry Barrier and allow fall-run to recolonize the San Joaquin River • Continue study and adaptive management efforts • Create floodplain habitat for juvenile rearing • Increase quality and quantity of spawning habitat in Reach 1 • Mitigate for introgression on or imposition of fall-run on spring-run • Establish volitional passage of adults migrating upstream • Coordinate on routing, timing, and volume of restoration flows to benefit various life stages of spring-run and fall-run Chinook salmon

Table 2. Accomplishments and remaining actions to implement the fish reintroduction component of the Restoration Goal in the Settlement

Paragraph [1]	Project [2]	Accomplishments	Action(s) Remaining
14(a)	USFWS to submit a permit application to NMFS for the reintroduction of spring-run Chinook salmon	• USFWS submitted two permit applications, one for broodstock and one for direct release of spring-run. Both applications requested 5 year terms • NMFS issued Section 10(a)(1)(A) Permit 14868 on October 11, 2012 • NMFS issued Section 10(a)(1)(A) Permit 17781, in March 2014, for direct release of spring-run into the San Joaquin River • About 50,000 spring-run juveniles released beginning in 2014 and continuing to present • Began release of spring-run from the Interim Conservation Facility into the San Joaquin River in 2016, including release of adult ancillary broodstock	• Existing permits are limited to 5 years, expiring in 2017 for broodstock and 2019 for direct release. Extension of the existing permits or new permits will be needed in the future • Permit for future take of wild spring-run
14(b)	Include Restoration Administrator's recommendations in planning and decision-making for reintroduction actions	• Recommendations for spring-run and fall-run included to date	• Ongoing for the duration of the SJRRP

[1] Only those Settlement paragraphs that include actions to implement the fisheries reintroduction actions of the Settlement Act are included.

[2] Short summaries are not intended to be all inclusive. Refer to the Settlement paragraph for more information and detail.

Table 3. Accomplishments and Remaining Actions to Implement the Fish Reintroduction Component of the Restoration Goal in the Settlement Act

Section 1	Project 2	Accomplishments	Action(s) Remaining
10004(h)(4)	Evaluate the effectiveness of the Hills Ferry Barrier in preventing the unintended upstream migration of anadromous fish	Evaluations were completed in 2010 and 2011 and reports were prepared as part of the SJRRP's Annual Technical Report process	Complete, no further action anticipated
10011(c)(2)	Rule pursuant to section 4(d) of the Endangered Species Act governing the incidental take of reintroduced spring-run salmon	Rule issued on December 31, 2013	Implement technical memorandum actions for the duration of the rule
10011(d)	Secretary of Commerce report to Congress on the progress made on the reintroduction, no later than December 31, 2024	None	Complete monitoring actions that may be necessary for the Secretary of Commerce to complete the report and complete the report

[1] Only those Settlement paragraphs that include actions to implement the fisheries reintroduction actions of the Settlement Act are included.
[2] Short summaries are not intended to be all inclusive. Refer to the Settlement Act paragraph for more information and detail.

1.3 Development of this Fisheries Framework

This Draft Fisheries Framework was developed in an inclusive process by the SJRRP Implementing Agencies and representatives of the SJRRP Settling Parties. The San Joaquin River Exchange Contractors were invited to participate in this process and did so periodically.

This Draft Fisheries Framework is being provided for a 30-day public review period to solicit comments and suggestions from agencies, organization, and members of the public on how best to implement the SJRRP's fisheries actions. Comments can be submitted to dportz@usbr.gov by close of business July 30, 2017. The Implementing Agencies will respond to comments that are relevant to the scope and content of this Fisheries Framework and will provide responses in the Final Fisheries Framework, anticipated in late spring 2017.

2 Program Fisheries and Habitat Goals and Objectives

The Settlement's foundational fishery goal, stated in the Restoration Goal, is to restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence of the Merced River (the Restoration Area), including naturally reproducing and self-sustaining populations of Chinook salmon and other fish. The Settlement provides direction on certain reintroduction actions in Paragraph 15, including incorporating recommendations from the Restoration Administrator on the reintroduction of spring-run and fall-run Chinook salmon. However, the Settlement does not establish a process for achieving naturally reproducing and self-sustaining populations, nor does it establish specific, sequential objectives that lead toward this goal, such as biological and habitat objectives necessary to achieve a naturally reproducing and self-sustaining population.

As these more specific objectives are important to guide, measure and monitor the process of fish reintroduction and to guide the development of the physical projects in Paragraph 11 and the release of Restoration Flows in Paragraph 13, this Draft Fisheries Framework establishes specific fisheries and habitat objectives. These objectives are specific, measurable steps that lead toward achieving the Settlement's Restoration Goal.

This section describes the fisheries and habitat goals and objectives established for the SJRRP. These goals and objectives will be achieved through implementation of actions that reduce physical, biological and ecological stressors, primarily within the Restoration Area, that limit fish production.

2.1 Fisheries Goals and Objectives

The Settlement established goals for spring-run and fall-run Chinook salmon and other fish. Although not specified in the Settlement, at this time fisheries goals are limited to native fish. Goals for both spring-run and fall-run Chinook salmon and other native fish focus on restoring self-sustaining and naturally reproducing populations in the Restoration Area.

2.1.1 Reintroduction Strategies for Chinook Salmon

The general strategy for establishing spring-run and fall-run Chinook salmon populations in the Restoration Area includes two types of actions: (1) reintroduce salmon into the system, and (2) create conditions that allow salmon to complete their life history and populations to grow.

The Program has adopted two different approaches for reintroducing salmon into the system: 1) volitional strategy for fall-run Chinook, and 2) artificial propagation for spring-run Chinook.

Extant populations of fall-run Chinook salmon within the larger San Joaquin Basin regularly try to enter the lower Restoration Area. Once passage and flows are established, fall-run Chinook salmon will be able to enter the system, migrate to the spawning grounds and reproduce. Over the last four years, the Program has captured adult fall-run Chinook salmon in the Restoration Area above Hills Ferry Barrier and transported them to Reach 1, where they have successfully spawned and produced juveniles. Hills Ferry Barrier is a fish migration barrier located approximately 150 yards upstream of the mouth of the Merced River within the Restoration Area. The barrier's main purpose is to redirect upstream migrating adult fall-run Chinook salmon away from the Restoration Area, where spawning habitat is currently inaccessible without actively aiding adult Chinook salmon migration. On an annual basis, it is operated from September–December. The barrier is funded by the CDWR as mitigation for Chinook salmon lost in the Central Valley and State Water Project Delta pumps and has been managed by the CDFW at this location since the fall of 1992.

Once suitable conditions exist within the system (i.e., volitional passage), fall-run Chinook salmon populations can begin to establish without the need for direct reintroduction activities. The Program may, however, manage fall-run Chinook salmon access to the system by transporting fish to overcome temporary passage barriers, or control access if there is concern that fall-run Chinook salmon may interfere with spawning spring-run Chinook salmon, or if hatchery fish from other basins stray into the Restoration Area at a high rate.

A volitional spring-run Chinook salmon strategy is unlikely to succeed in the Restoration Area because there are no recognized spring-run Chinook salmon populations in the Basin to contribute to population reestablishment. Therefore, the Program is using artificial propagation to reintroduce spring-run Chinook salmon to the system. The majority of the fish for this purpose will come from the Salmon Conservation and Research Facility (SCARF) below Friant Dam and the Interim SCARF prior to SCARF being constructed. The SCARF was designed as a conservation hatchery that will produce up to one million smolts through a captive broodstock program. The captive broodstock program anticipates, subject to permit approval, taking a small number of fish from extant stocks to produce large numbers of juveniles for release in the system. This limits impacts to the sensitive stocks of spring-run Chinook salmon extant in the Central Valley. The numbers of fish released from the SCARF will increase over time until the production target of one million juveniles is reached (Table 4). The hatchery program will be managed to complement progress toward the goal of producing a self-sustaining population of spring-run Chinook salmon.

Table 4. The number and potential source of hatchery juvenile spring-run Chinook salmon released by year from the San Joaquin River Conservation Facility (SCARF)

Brood Year Collection Year	Offspring Release Year	Juveniles Released[1]	Broodstock Source Population(s)[3]
2012	2016	48,350	Feather River
2013	2017	51,044	Feather River
2014	2018	148,800[2]	Feather River
2015	2019	249,600[2]	Feather River
2016	2020	428,750[2]	Feather River
2017	2021	735,000[2]	Feather River, San Joaquin River
2018	2022	1,000,000[2]	Feather River, Butte Creek[4], San Joaquin River
2019+	2022	1,000,000[2]	Feather River, Butte Creek[4], Deer Creek[4], Mill Creek4, San Joaquin River

Source: P. Adelizi

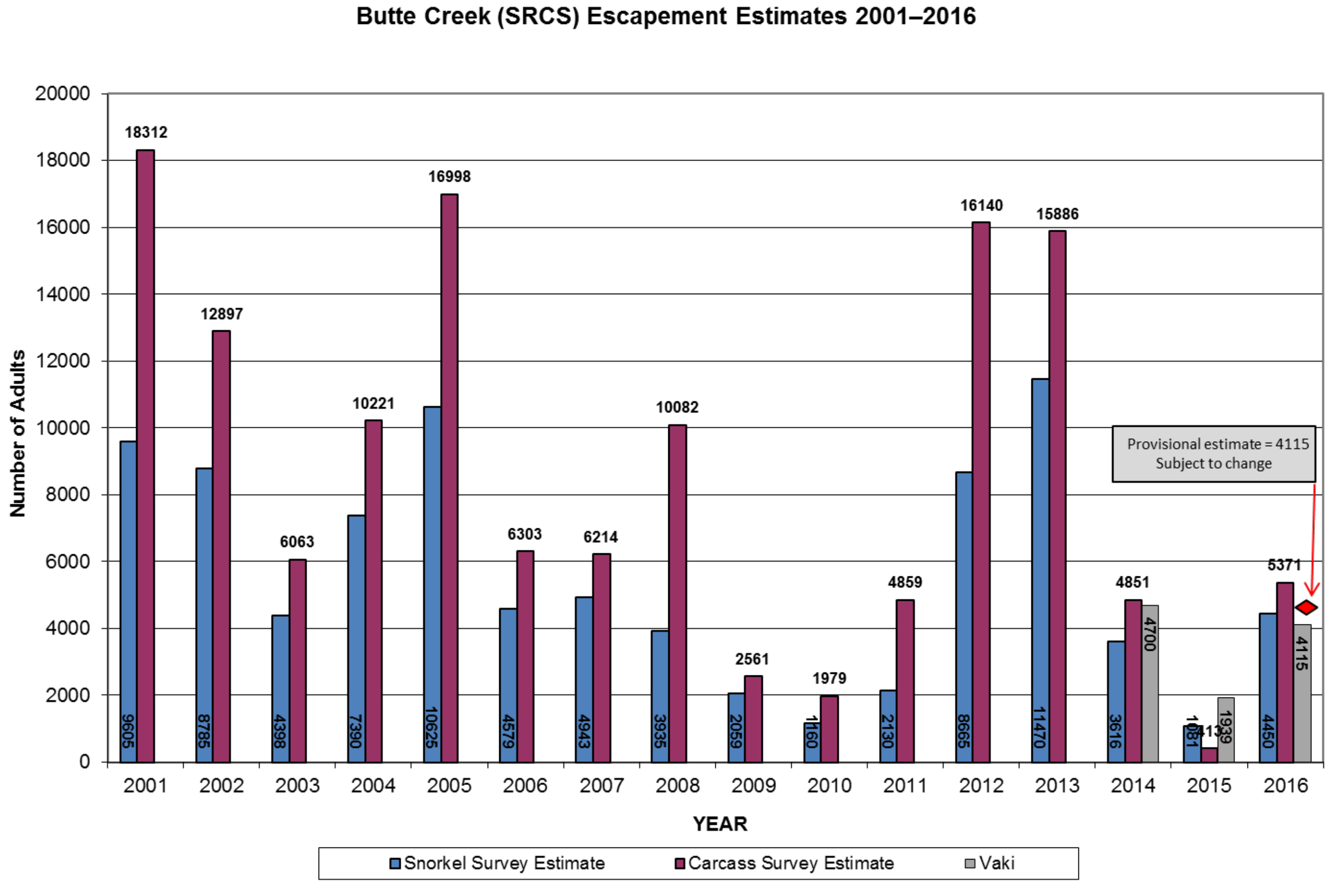
[1] These figures only include releases from the captive broodstock program and do not include releases from the translocation program.

[2] Target for release.

[3] Future broodstock source populations are still to be determined.

[4] Butte Creek, Mill Creek, and Deer Creek stocks are subject to approved permits.

Spring-run and fall-run Chinook salmon adult abundance is expected to increase over time as habitat, hatchery and fish passage actions are completed. However, the rate and magnitude of increase in adult abundance is difficult to predict because natural environmental variability greatly affects adult production year-to-year, as evidenced by wild spring-run Chinook salmon returns to Butte Creek (Figure 2). Adult population size is also highly influenced by factors outside the Restoration Area that the Program has little or no control over, such as juvenile Chinook salmon migratory survival through the Delta and ocean survival.



Note: This figure was adapted from personal communication with Clint Garman, CDFW, and the 2016 Butte Creek Spring-run Escapement Survey by CDFW (Garman 2016).

Figure 2. Butte Creek spring-run Chinook salmon spawning escapement 2001–2016

2.1.2 Chinook Salmon Goals and Objectives

The Settlement calls for establishing self-sustaining populations of both spring-run and fall-run Chinook salmon. Both populations were historically present in the Restoration Area prior to construction of Friant Dam and the reduction of flows through water diversions (CDFG 1990).

Spring-run Chinook salmon are believed to have been the more abundant run and once spawned as high in the watershed as Mammoth Pool (P. Bartholomew, pers. comm., based on information from Native American informants, as cited in Yoshiyama et al. 1996). The spring-run Chinook salmon population in the San Joaquin River represents the southernmost extent of the spring-run Chinook salmon geographic range and was once the largest such population in California (CDFG 1990). Construction of Kerkhoff Dam blocked migration to the historical spawning grounds, although substantial spawning habitat existed lower in the system including what is now Millerton Lake (Yoshiyama et al. 1996). Construction of Friant Dam in the 1940s removed about one-third of the remaining spawning habitat for spring-run Chinook salmon. Spring-run Chinook salmon runs continued up to 1948 at lower than historical levels following the completion of water diversions and the cessation of consistent flows through the Restoration Area. By 1950, the population (adults and juveniles) were extirpated from the Restoration Area (Hallock and Van Woert 1959, Fry 1961).

Fall-run Chinook salmon were also once abundant in the Restoration Area, but in smaller numbers than spring-run Chinook salmon (Moyle 2002). Fall-run Chinook salmon spawned lower in the system and declined earlier than spring-run Chinook salmon following the reduction of fall flows by diversions in the 1920s (Clark 1929). The Settlement explicitly calls for the reintroduction of both runs (Paragraph 14) but acknowledges the potential for negative interactions between runs that may require management intervention. In the event of negative interactions between the two Chinook salmon runs, the Settlement provides guidance to favor spring-run Chinook salmon (Paragraph 14a). The Program's strategy is to proceed with the reintroduction of both runs, but to monitor any impacts fall-run Chinook salmon may have on spring-run Chinook salmon and adjust accordingly.

The Restoration Goal of the Settlement is to restore and maintain fish populations in "good condition" in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish. A self-sustaining population is one that perpetuates without continual augmentation with hatchery origin juvenile or adult salmon. To meet the self-sustainability goal, the Hatchery and Genetic Management Plan (HGMP) states both the spring-run and fall-run Chinook salmon populations should possess the following characteristics (SJRRP 2010b, SJRRP 2016):

- Locally adapted to the environmental conditions in the upper San Joaquin River.
- Have sufficient productivity, abundance and life-history diversity to be self-sustaining.
- Be genetically and phenotypically diverse.
- Show no substantial signs of hybridizing with each other or genetically mixing with non-target hatchery stocks.

The Fisheries Management Plan (FMP; SJRRP 2010a) used a recent tenet of salmonid conservation biology known as the Viable Salmonid Population (VSP) concept (McElhany et al. 2000) along with Moyle's definition of "good condition" (Moyle 2005) to guide the development of salmon population objectives. "Good condition" and the VSP concept are similar. McElhany et al. (2000) defines a "viable population" of Pacific salmon as:

> *…an independent population of any Pacific salmonid (genus Oncorhynchus) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame.*

Viability is determined by examining the population parameters of abundance, productivity and spatial structure/life history diversity. Habitat quality and quantity define system carrying capacity (i.e., the number of fish by life stage the habitat can support). The VSP is used here to define objectives for Chinook salmon because it includes quantitative guidelines. In contrast, "good condition" is a general term used to describe goals for all native fishes. A comparison between the VSP and Moyle's definition of "good condition" is outlined in Table 5.

Table 5. Comparison of NMFS VSP parameters to "good condition" as defined in the FMP

Viable Salmon Population (VSP) Parameters	"Good Condition"
Genetic Diversity	Genetically fit and diverse Does not show ill effects of inbreeding, outbreeding No reliance on artificial propagation Resilience to catastrophic events Self-sustaining
Population Abundance	Persistent membership over time Self-sustaining
Population Growth	Productivity Viability of all life history stages and biological processes
Spatial Structure	Replicated geographically Resilience to catastrophic events

Source: McElhany et al. 2000 and SJRRP 2010a.

In addition to the Program goal of restoring self-sustaining populations of spring-run and fall-run Chinook salmon in "good condition", specific quantitative adult population abundance targets have been identified to minimize the extinction risks for spring-run and fall-run Chinook salmon. The criteria used to assess the extinction risk for Pacific salmon populations are provided in Table 6 (Lindley et al. 2007). The population size associated with a low risk of extinction is defined as an effective natural spawner population size (Ne) of > 500 fish or a census size (N) of > 2,500. The overall risk of extinction is determined by the highest score for any of the categories (i.e., High, Moderate, or Low; Lindley et al. 2007).

The Program's FMP (SJRRP 2010a) adopted these criteria as numerical targets for establishing self-sustaining populations of salmon as required in the Settlement. Progress toward meeting and maintaining these criteria will be measured in terms of five-year observed running averages. The Program will be considered a success upon achievement of the self-sustaining adult abundance levels. However, these abundance targets do not represent expectations for the ultimate population the system could sustain or the long-term population objectives for the Restoration Area as recommended by the Restoration Administrator.

The Settlement charges the Restoration Administrator with recommending long-term population targets for both spring-run and fall-run Chinook salmon in Exhibit D. The spawning escapement targets are based, in part, on estimates of adult run size just after the construction of Friant Dam but prior to completion of all water diversions and the extirpation of Chinook salmon. The long-term adult spawning escapement targets for naturally produced spring-run and fall-run Chinook salmon are 30,000 and 10,000 adults, respectively, on average[1] (Hanson et al. 2007 and 2008).

Table 6. Criteria for assessing the risk of extinction for populations of Pacific salmon. In Lindley's analysis, the population size associated with a low risk of extinction is defined as an effective natural spawner population size (Ne) of > 500 fish or a census size (N) of > 2,500

Criterion	Risk of Extinction		
	High	Moderate	Low
Extinction risk from PVA	> 20% within 20 years - or any ONE of -	> 5% within 100 years - or any ONE of -	< 5% within 100 years - or ALL of -
Population size[a]	Ne ≤ 50 -or- N ≤ 250	50 < Ne ≤ 500 -or- 250 < N ≤ 2500	Ne > 500 -or- N > 2500
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	Not apparent
Hatchery influence[f]	High	Moderate	Low

Source: Lindley et al. 2007

[a] Census size N can be used if direct estimates of effective size Ne are not available, assuming Ne / N =0.2.

[b] Decline within last two generations to annual run size ≤ 500 spawners, or run size > 500 but declining at ≥ 10% per year. Historically small but stable population not included.

[c] Run size has declined to ≤ 500, but now stable.

[d] Catastrophes occurring within the last 10 years.

[e] Decline < 90% but biologically significant.

[f] See Figure 1 in Lindley et al. 2007 for an assessment of hatchery impacts.

The Restoration Administrator's population targets and recommendations were structured to achieve the long-term spawning escapement targets by 2040 (SJRRP 2010a). This was the expected length of time for all habitat actions to reach full effectiveness and to develop Chinook salmon populations adapted to the San Joaquin River. The current project schedule described in the Framework for Implementation is prolonged well beyond the Settlement timeframe used to develop the Restoration Administrator's targets, so the specific dates in these recommendations

[1] Given current harvest exploitation rates (~50 percent) for both runs, total adult production is expected to be 60,000 spring-run and 20,000 fall-run Chinook salmon.

are no longer valid. These population targets are still valid, however, to guide Program planning and assess progress toward establishing populations as physical projects and fish reintroduction actions are implemented. Long-term population growth targets help Program managers make meaningful decisions, such as determining how much juvenile rearing habitat to create or assessing whether existing spawning habitat is sufficient.

The Program has established a series of biological objectives for salmonids to help managers assess progress toward meeting the Restoration Goal without relying solely on adult abundance objectives. As shown in Table 7, biological objectives include survival rates for each life stage that are considered to be achievable and sufficient to establish self-sustaining Chinook salmon populations within the Restoration Area. Other objectives include targets for hatchery operations and maintaining genetic integrity. The majority of the biological objectives are from the Fisheries Management Plan (SJRRP 2010a) and HGMP (SJRRP 2010b, SJRRP 2016) where they are described in more detail. Monitoring these biological objectives will allow Program managers to assess progress towards meeting the Restoration Goal and evaluate the effectiveness of restoration actions.

Table 7. Biological objectives for salmonids in the Restoration Area

Objective	Spring-run Chinook salmon	Fall-run Chinook salmon	Measured	Source	Overall Strategy
Adult Objectives					
Adult growth population target (naturally produced)	30,000	10,000	Spawning grounds	FMP, Hanson et al. 2007 and 2008	Achieve all environmental objectives for Restoration Area and survival rate objectives for Delta.
Adult self-sustaining abundance	Effective natural spawner population size of Ne > 500 fish or a census size of N > 2,500.	Effective natural spawner population size of Ne > 500 fish or a census size of N > 2,500.	Spawning grounds	FMP	Achieve all environmental objectives for Restoration Area and survival rate objectives for Delta. Monitor as outlined in the HGMP.
Pre-spawn adult survival	>85%	>85%	Spawning grounds	FMP	Maintain appropriate water temperature (<15˚C) and reduce to extent possible stress/injury associated with adult passage facilities.
Adult passage survival rate - Restoration Area	≥90%	≥90%	Sack Dam to spawning grounds	FMP	Begin with trap and haul and progress to full volitional passage as fish passage structures are built in Restoration Area. Design facilities to meet NMFS criteria.
Female egg fecundity	4,200	6,000	At hatchery or spawning grounds	FMP	For hatchery fish, ensure that broodstock represent all age classes.
Degree of spring-run/fall-run Chinook salmon introgression and superimposition	<2%, <10%	<2%, no objective	Spawning grounds	Introgression Protocol	Investigate the use of weirs, passage control at structures, redd grating and fish-run timing to achieve objectives.
Degree of fall-run Chinook salmon introgression with hatchery fall-run Chinook salmon from other rivers	N/A	<2%	Lowest Adult Passage Structure or Spawning Grounds	CA HSRG (2012)	Develop protocols for reducing the number of hatchery origin fish from spawning in the Restoration Area – applies only to the Local Adaptation and Full Restoration phases
Eggs					

Objective	Spring-run Chinook salmon	Fall-run Chinook salmon	Measured	Source	Overall Strategy
Egg survival to fry emergence	50%	50%	Spawning grounds	FMP	Maintain appropriate water temperate (< 13˚C) and low fine sediment levels in gravel.
Juvenile Objectives					
Total natural origin juvenile production	1,575,000; minimum of 44,000. Minimum value based on low adult extinction risk of 833.	750,000; minimum of 63,000. Minimum value based on low adult extinction risk of 833.	Confluence Merced River	FMP	Achieve all environmental objectives for Restoration Area and survival rate objectives for Delta.
Minimum Juvenile survival rate (measured as fry-to-smolt)	5%, juvenile length > 70 mm	5%, juvenile length > 70 mm	Restoration Area to Merced River	FMP	Provide adequate flows and juvenile rearing habitat of sufficient quality and quantity.
Juvenile growth rate-spring	0.4 grams per day	0.4 grams per day	Restoration Area	FMP	Provide adequate flows, temperature (< 18˚C) and juvenile rearing habitat of sufficient quality and quantity to meet objective. Create floodplain habitat at appropriate time of year.
Juvenile growth rate-summer	0.07 grams per day	0.07 grams per day	Restoration Area	FMP	Provide adequate flows, temperature (< 18˚C) and juvenile rearing habitat of sufficient quality and quantity to meet objective.
Diversity of juveniles exiting system	Minimum 20% fry, 20% parr, 10% smolt, 10% yearling	Minimum 20% fry, 20% parr, 10% smolt	Restoration Area	Fry, parr, and smolt from Stanislaus River data, yearling from FMP	Provide Restoration Flows, appropriate temperature and juvenile rearing habitat of sufficient quality and quantity to meet objective.
Juvenile passage survival rate -Restoration Area	>70%, juvenile length > 70 mm	>70%, juvenile length > 70 mm	Sack Dam to spawning grounds	SJRRP 2010a	Begin with trap and haul and progress to full volitional passage as fish passage structures are built in Restoration Area. Design facilities to meet NMFS criteria.

Objective	Spring-run Chinook salmon	Fall-run Chinook salmon	Measured	Source	Overall Strategy
Juvenile migration survival rate Confluence of Merced River to Delta	To Be Determined	To Be Determined	To Be Determined	To Be Determined	Work with other fisheries managers to create flow, temperature (< 18˚C) and habitat conditions that protect juvenile migrants when present.
Screen efficiency at each facility	NMFS Design Criteria	NMFS Design Criteria	Facility Specific	NMFS 1997, 2011	Design fish screening systems to achieve physical parameters that meet NMFS salmonid screening criteria (NMFS 1997, 2011). Screening efficiency is the percentage of juvenile salmonids that can be deterred from a diversion with minimum delay, loss, or injury.
Juvenile to adult survival rate (after harvest) - All juvenile life stages combined	1.90%	1.33%	Confluence Merced River	FMP-Technical Team Review March 8, 2016	Achieve all environmental objectives for Restoration Area and survival rate objectives for Delta.
Hatchery Production					
Hatchery juvenile production	1.0 million; phased out starting in ~2025	Not Applicable	Release from hatchery	FMP	Build and operate a conservation hatchery. Production to be decreased as natural production abundance increases. All hatchery fish will be marked to distinguish from naturally produced fish.
Hatchery composition of total natural spawning population (pHOS)	<15 percent – 10-years after reintroduction begins (exception for drought conditions)	Not applicable	Restoration Area	FMP	Reduce spring-run Chinook salmon hatchery production as naturally produced spring-run Chinook salmon adult abundance increases. Maintain pHOS < 15 percent. By 2025 hatchery proportion of total natural spawning population will be declining based on a four-year moving average expressed as pHOS (pHOS to be less than 15% in 2032).
Percent of natural spring-run Chinook salmon adult production used as broodstock (pNOB)	< 10%	Not Applicable	Confluence of Merced River	HGMP	All hatchery fish will be marked to distinguish them from naturally produced spring-run Chinook salmon. Hatchery staff will collect only 1 of 10 NOR fish observed at collection sites.
Proportionate Natural Influence (PNI)	> 0.67 4-year average in 2029	Not Applicable	Spawning grounds and hatchery	HGMP	Control hatchery origin fish spawning naturally and incorporate natural origin adults into broodstock.

Objective	Spring-run Chinook salmon	Fall-run Chinook salmon	Measured	Source	Overall Strategy
Age of return – hatchery	3 or more year classes, minimum 10% 2, 3, 4 year-olds	Not Applicable	Spawning grounds/ hatchery	Technical Team Review March 8, 2016	Collect broodstock throughout the entire migration period. No selection for physical traits (e.g., size) or behavior.

In addition to conditions within the Restoration Area, a major factor that will affect Program success is the survival rate of fish leaving the Restoration Area. Currently, San Joaquin River juvenile Chinook salmon survival rates through the Sacramento-San Joaquin Delta are estimated to be 5–7 percent (BDCP 2013, NMFS 2017). Although the Bay Delta Conservation Plan process has been superseded, there are other processes and activities in the Delta that are anticipated to create improved Delta survival rates in the future[2]. Attainment of the long-term Delta survival objectives is highly influenced by factors outside of the Restoration Area over which the Program has little or no control, such as total river flow, amount and timing of pumping operations for irrigation, predator abundance, and habitat restoration. It has been observed that juvenile survival can also be strongly influenced by water year types, where years with more water in the river generally have higher survival rates and years tending to have less water have lower survival rates (Perry et al. 2016). Although these effects will be monitored by the Program they cannot be controlled by the Program.

2.1.3 Goals for Other Fish

There are no plans to establish quantitative population objectives for other fish. Work that is being performed for salmon (e.g., improvements to fish passage and habitat) will create a functional system that supports other native fishes. The intent of the Program is to establish a balanced, integrated, adaptive community of salmon and other fish having a species composition and functional organization similar to what would be expected in the Sacramento-San Joaquin Province (SJRRP 2010a).

A major assumption of this Fisheries Framework is that achieving the Program's habitat objectives will not only support self-sustaining populations of Chinook salmon but will also support populations of other fish. Baseline data on species composition in the Restoration Area has been collected as part of the SJRRP's monitoring efforts and is expected to continue to be collected at appropriate intervals to monitor community composition over time to ensure that the Program supports healthy populations of other native fishes.

2.2 Habitat Objectives

Habitat objectives for the Restoration Area are focused on establishing habitat conditions that produce self-sustaining populations of Chinook salmon and other native fish (Figure 9, Tables 10 and 11). To implement the Settlement and achieve the fisheries goals described above the Program will need to:

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[2] California Eco Restore: http://resources.ca.gov/ecorestore/

- Use Restoration Flows to: (1) maximize the duration and downstream extent of suitable rearing and outmigration temperatures for Chinook salmon and other native fishes, and (2) provide year-round river habitat connectivity throughout the Restoration Area.
- Use Restoration Flows and make necessary structural modifications to ensure adult and juvenile passage during the migration periods of both spring-run and fall-run Chinook salmon.
- Use Restoration Flows to provide suitable habitat for Chinook salmon holding, spawning, rearing, and outmigration during a variety of water year types.
- Use Restoration Flows to provide water quality conditions suitable for Chinook salmon and other native fishes to complete their life cycles.
- Provide a balanced, integrated, native vegetation community in the riparian corridor that supports channel stability and buttressing, reduces bank erosion, filters sediment and contaminants, buffers stream temperatures, supports nutrient cycling, and provides food resources and unique microclimates for the fishery.
- Reduce predation losses in all reaches to levels that allow for self-sustaining salmon populations.
- Provide habitat complexity, functional floodplains, and diverse riparian vegetation that provide habitat for spawning and rearing by native species, including salmon.

Program actions designed to produce these conditions are described in Section 3. In short, the actions will reduce stressors (also referred to as limiting factors) within the system that limit the development of self-sustaining fish populations.

The Chinook salmon habitat objectives and associated metrics the Program will strive to achieve in the Restoration Area are provided in Figure 9 and Tables 9, 10, and 11. These are the habitat objectives that need to be met to achieve Program fisheries goals. If these objectives are not met, the Program is less likely to be successful in meeting self-sustaining and long-term adult Chinook salmon population targets. In some water year types (e.g., critical-low), it is likely that these habitat objectives will not be met.

2.3 Scientific Foundation

This section describes the scientific foundation for the Program's fisheries actions. Specifically, it describes how management activities related to habitat, hatcheries, and harvest have been designed to achieve Program goals. This scientific foundation is intended to ensure the benefits and risks of the proposed management actions have been considered. A scientifically defensible program weighs such benefits and risks against the Program's goals and objectives and the most up-to-date science. Management actions must be consistent with current scientific knowledge of the target species and their habitat needs.

In addition, the Program should have a working hypothesis, a clearly stated set of assumptions, and an implementation plan. The Program's working hypothesis is stated in Section 3.1. The initial focus of the Program will be to reduce the high priority stressors (also known as limiting factors) described in Section 3.2. Following the description of the high priority stressors, this section outlines the rationale for the Program's planned habitat (Section 3.3), hatchery (Section 3.4), and harvest activities (Section 3.5) to reduce these stressors and produce self-sustaining populations of spring-run and fall-run Chinook salmon. The Program's assumptions and implementation plan are described in Section 3.

2.4 Working Hypothesis

The working hypothesis for the Program is as follows:

> Program actions, flows and operations designed to reduce physical, biological and ecological stressors will create conditions within the Restoration Area to achieve the Restoration Goal and to produce self-sustaining populations of spring-run and fall-run Chinook salmon and other fish.

The efficacy of SJRRP actions will be assessed based on the extent to which the measures advance or achieve the Program's biological objectives (Table 7) and habitat objectives (Figure 9 and Tables 9, 10, and 11) and will initially focus on reducing the high priority stressors described below. The Program recognizes long-term fish population goals cannot be achieved until habitat objectives are met.

2.5 Stressors (Limiting Factors)

Stressors (also known as Limiting Factors) are conditions (physical, biological or ecological) within the system that limit or inhibit the attainment, existence, maintenance, or potential for desired conditions, as characterized by the biological and environmental objectives. Because specific objectives are already being achieved to different degrees under existing conditions, identification of stressors is critical in order to:

a) Highlight components of desired conditions that are not being achieved, and

b) Identify the specific obstacles (i.e. stressor(s)) inhibiting desired conditions.

As a complement to this, ranking stressors further:

c) Enables the development of specific actions to achieve desired conditions by resolving stressors, and

d) Facilitates the prioritization and sequencing of those actions to maximize benefits by addressing the most significant stressors first.

The collective current knowledge and experience of the SJRRP was used to develop a comprehensive list of stressors (Table 8). These stressors are described as limiting factors in Exhibit A of the Fisheries Management Plan (SJRRP 2010a). They were first developed based on the expert opinion of the SJRRP fisheries biologists and Technical Advisory Committee (TAC) during development of the FMP conceptual models (SJRRP 2010a).

Table 8. Stressors by life stage for spring-run and fall-run Chinook salmon

Adult Migration	Adult Holding	Spawning
Inadequate flows	Habitat quantity	Low spawning gravel-quality
High water temperatures	High water temperatures	Insufficient spawning site quantity
Physical barriers	Disease	High water temperatures
False pathways	Predation	Hybridization between runs
In-river harvest	Harvest	Instream flows
Egg Incubation/Emergence	**Juvenile Rearing/Migration**	**Ocean Phase**
Excessive sedimentation	Inadequate food resources	Inadequate food availability
High water temperatures	Disease	Marine predation
Redd superimposition	Predation	Harvest
	Water quality	
	Entrainment	
	Lack of cover	
	High water temperatures	
	Harvest of yearling juveniles	
	Delta survival	

The stressor derivation and ranking is based on current knowledge and modeled or anticipated outcomes for the San Joaquin River system. Clearly, many future outcomes may differ from projections. Additionally, knowledge gained during implementation of early phases of the Program should result in changes to stressors and the need for Program response.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP), the first of four regional plans intended to implement the CALFED Ecosystem Restoration Program (ERP), developed specific guidance to evaluate restoration actions, stressors, and program performance, and to guide adaptive management (DRERIP 2006).

Using this guidance, SJRRP biologists used expert opinion to assign scores to stressors based on the potential to achieve biological objectives under current conditions and at the end of each 5 year Vision Period, as defined in the Program's Revised Framework for Implementation (July 2015). Stressors were scored and ranked according to their potential to affect attainment of environmental and biological objectives in the Restoration Area (Appendix B). The process of stressor scoring and ranking was informed and supported by the quality and quantity of existing information (data and literature). Scoring and ranking stressors within a life stage identifies the most limiting factors within each life stage, indicates how these factors will change over time as restoration is implemented, and provides guidance on where the Program should focus its research and monitoring dollars. Combining the scores across life stages identifies some trends in concerns and provides overall guidance on setting priorities.

The value of stressor prioritization is to determine:

a) Which stressors are of greatest biological impact to the species;

b) How actions should be optimally sequenced for greatest biological benefit and

c) What expectations for biological response are appropriate given the state of project implementation, associated stressor resolution and environmental objective attainment.

In cases where other prioritization considerations (e.g., financial, political, etc.) prevent stressors from being addressed in order of anticipated biological impact, stressor ranking also helps to correctly set expectations about the extent of progress toward desired conditions that a given action may achieve, and/or the suite and scale of actions necessary to achieve or make progress toward desired conditions.

A comprehensive description of the process and results is provided in Appendix B. Not surprisingly, the highest scoring stressors are directly addressed by the projects defined in the Settlement and prioritized in the Program's Framework for Implementation. Essentially, removing passage barriers, protecting juveniles from entrainment, creating floodplain habitat and providing flow to the river will go a long way toward creating conditions suitable for both spring-run and fall-run Chinook salmon. Figure 3 summarizes the relative severity of the stressors as a function of the magnitude score (Appendix B - Table 1) anticipated as the Program progresses through its implementation phase. Program actions designed to reduce the highest-ranking stressors (and others) are presented starting in section 3.2. A description of the time frame for implementing known Program actions is provided in section 3.3.

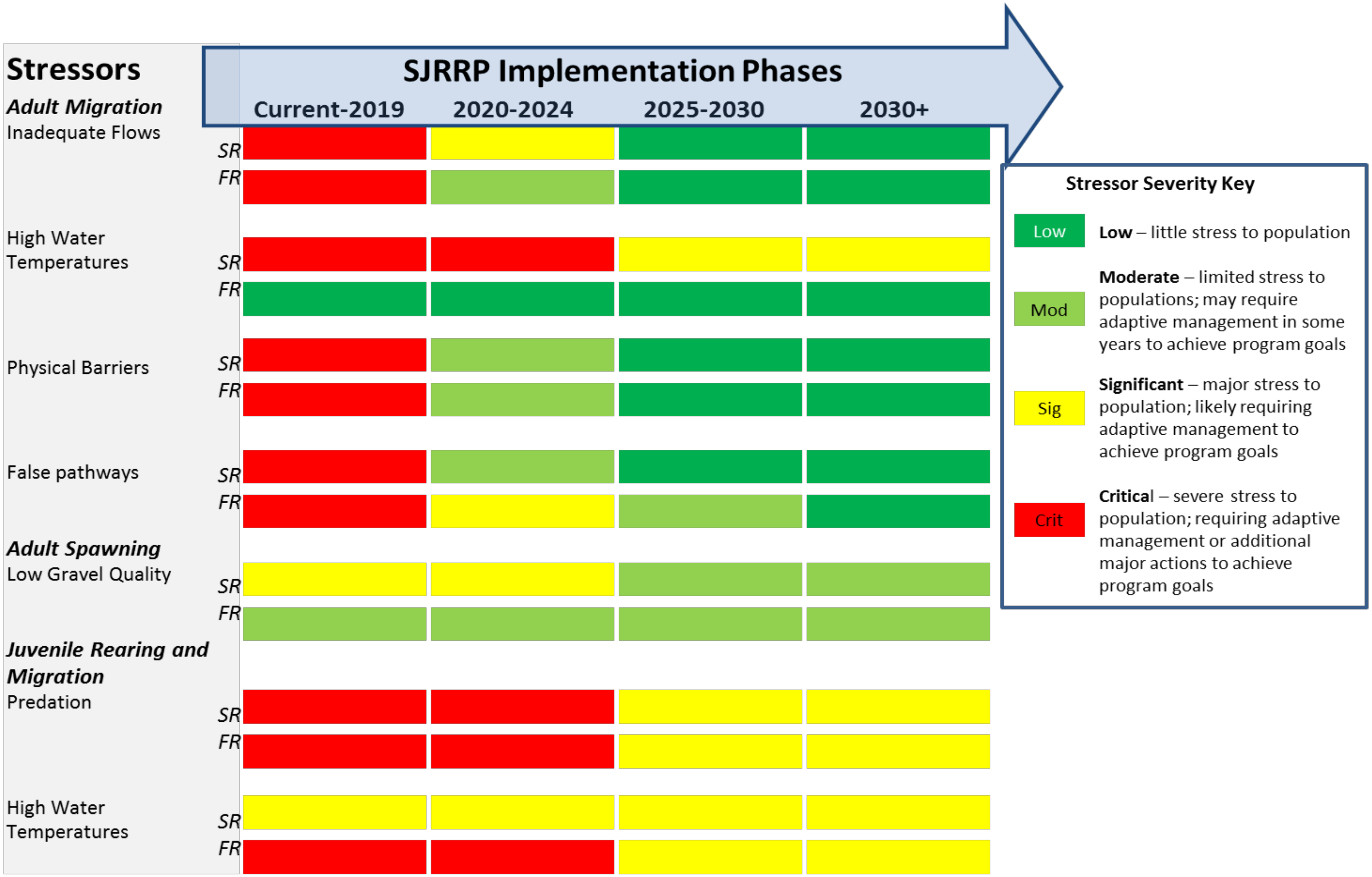


Figure 3. Depiction of the anticipated severity of major stressors for fall-run (FR) and spring-run (SR) Chinook salmon, respectively, and associated need for Program actions or adaptive management during SJRRP implementation phases through 2030. Stressor severity, assigned based on magnitude score, is represented on a green to red scale with green representing the least stress (see key)

2.6 Habitat

Program actions such as providing Restoration Flows and developing floodplain habitat are being used to produce the quantity and quality of stream and riparian habitat needed to achieve long-term adult abundance targets for spring-run and fall-run Chinook salmon. It is assumed the resulting habitat will also achieve goals for other native fish species.

Details on river flows and the amount of adult holding/spawning and juvenile rearing habitat required to achieve long-term adult abundance targets are presented below.

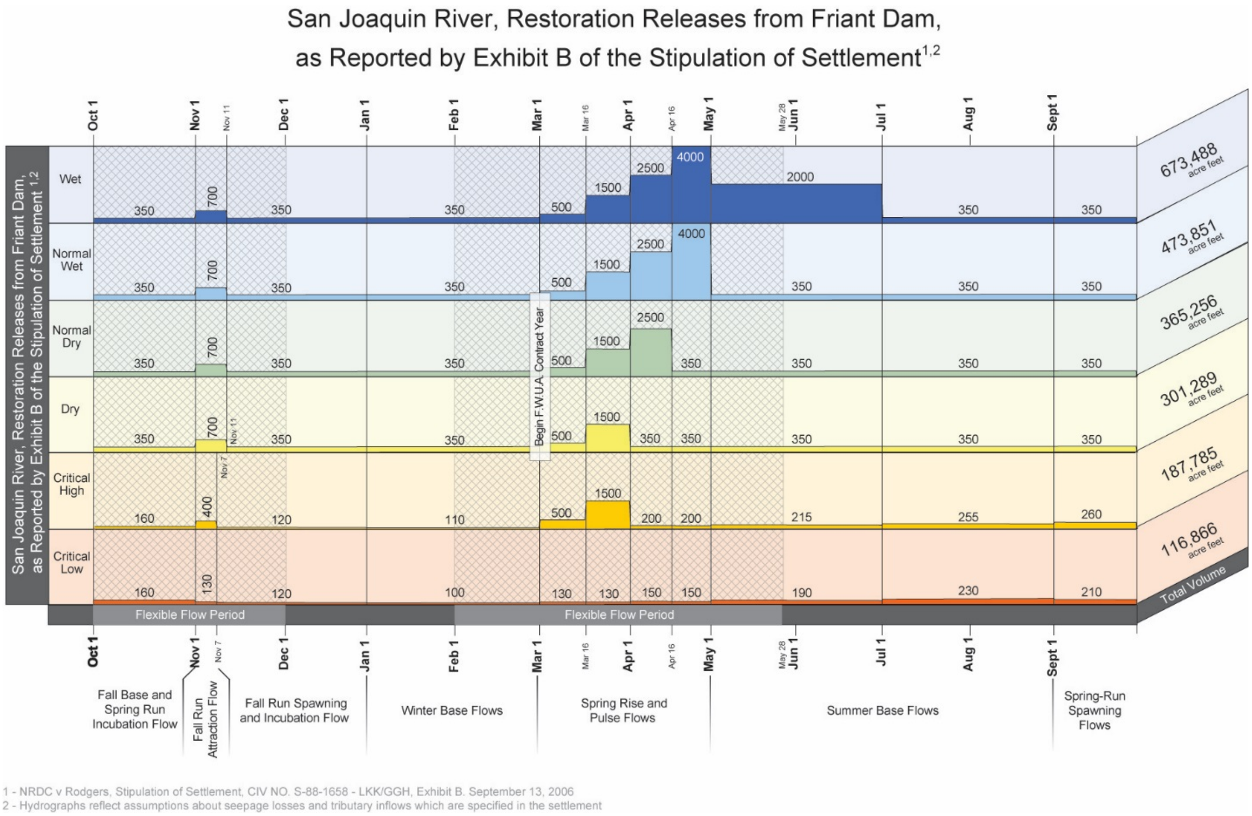
2.6.1 Restoration Flows

Restoration Flows are based on those outlined by Reaches 1–5 in Exhibit B of the Settlement and are shown graphically in Figures 4–8. Flow hydrographs defined in Exhibit B of the Settlement are the default hydrographs to be followed if the RA does not provide a flow recommendation.

The hydrographs represent the allocation of water based on water year type and river reach. The RA will make recommendations based on needs while within the flexible flow periods (grey crosshatched section of Figures 4–8). The flexible flow periods are designed to help facilitate suitable temperatures and habitat conditions during critical fish life stages.

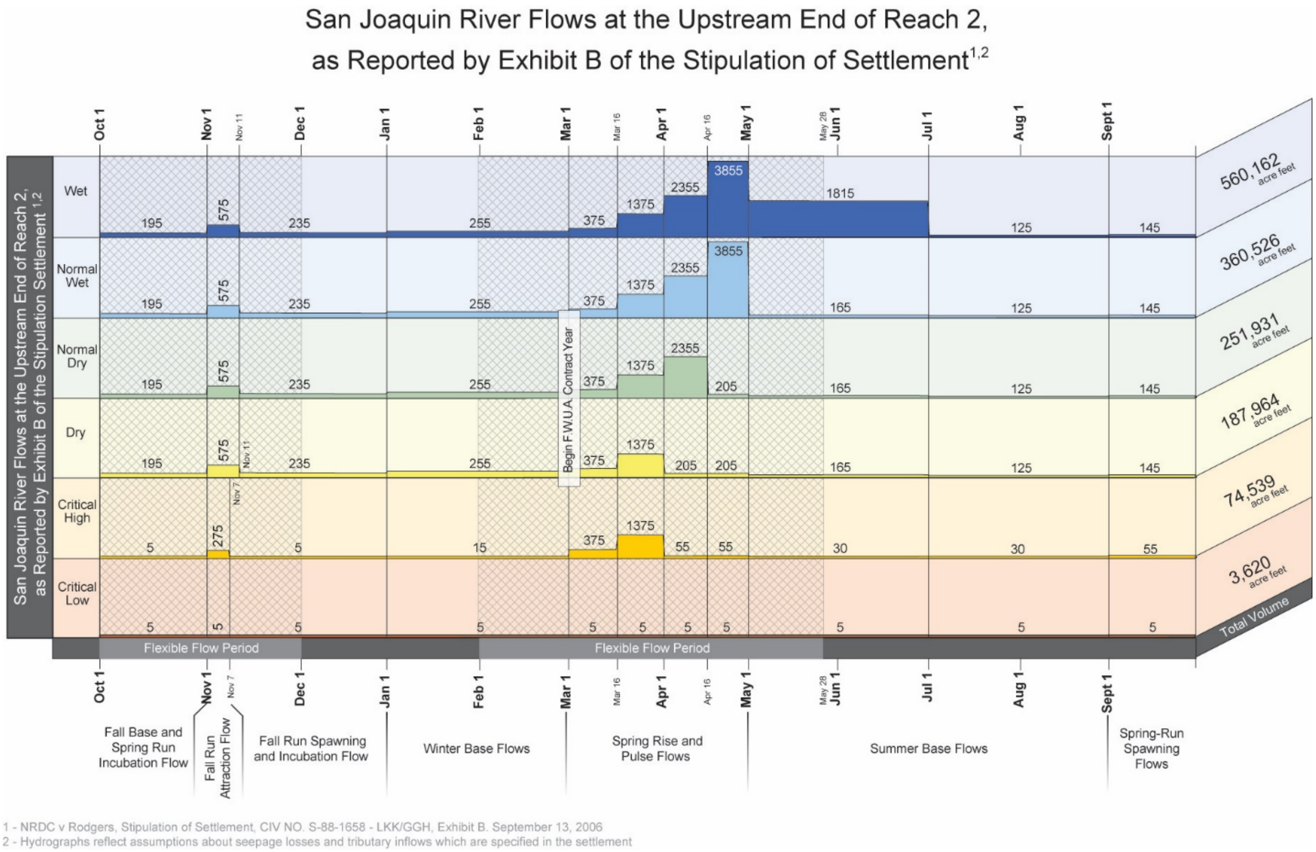
Optimal, critical, and lethal temperature objectives for spring-run and fall-run Chinook salmon corresponding to each life stage are shown in Figure 9. Optimal temperatures are defined using ecological and physiological optimum criteria. These criteria are threshold levels for long-term population sustainability and signify optimum growth and survival under natural ecological conditions including the existence of predation pressure, competition, and variability in food availability (EPA 2003). Because optimal temperatures represent a range, they are defined as less than or equal to the upper limit of the optimal range. Critical and lethal temperatures are cited from a number of independent studies (e.g., EPA 2003, Rich 2007, Pagliughi 2008, Gordus 2009) evaluating thermal stress to salmonids in both laboratory and natural settings. Critical temperatures are expressed as a range of stress-inducing temperatures.

The Program will strive to achieve the optimal water temperatures identified for adult and juvenile life stages in Figure 9 without exceeding the critical water temperatures. In addition, an objective of the Program is to produce these temperatures over the full geographic range of the Restoration Area to the extent possible given the Restoration Flows allocated under the Settlement as shown in Figures 4–8.



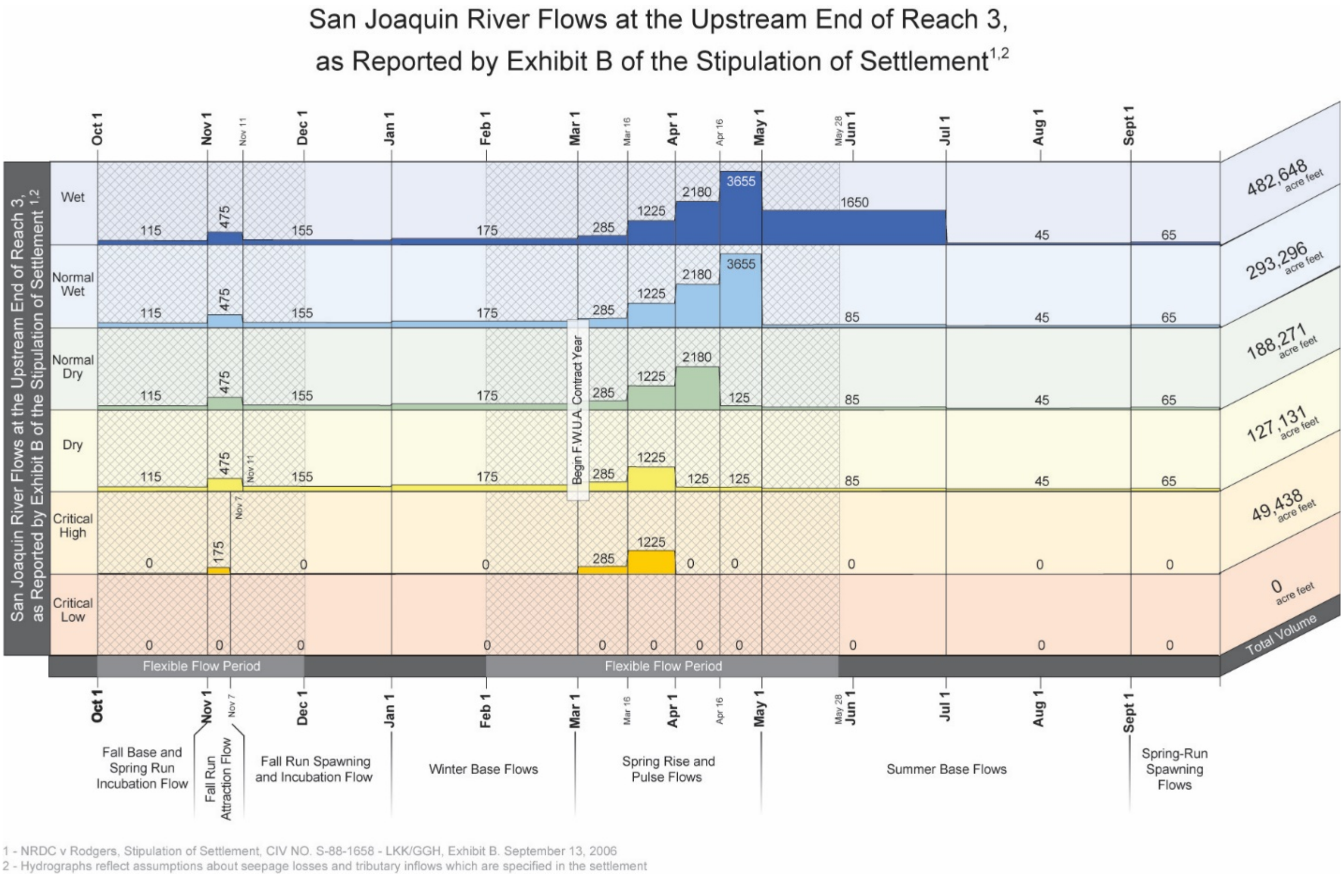
Source: NRDC et al. 2006

Figure 4. San Joaquin River flows at Friant Dam (Exhibit B, of the Stipulation Agreement)



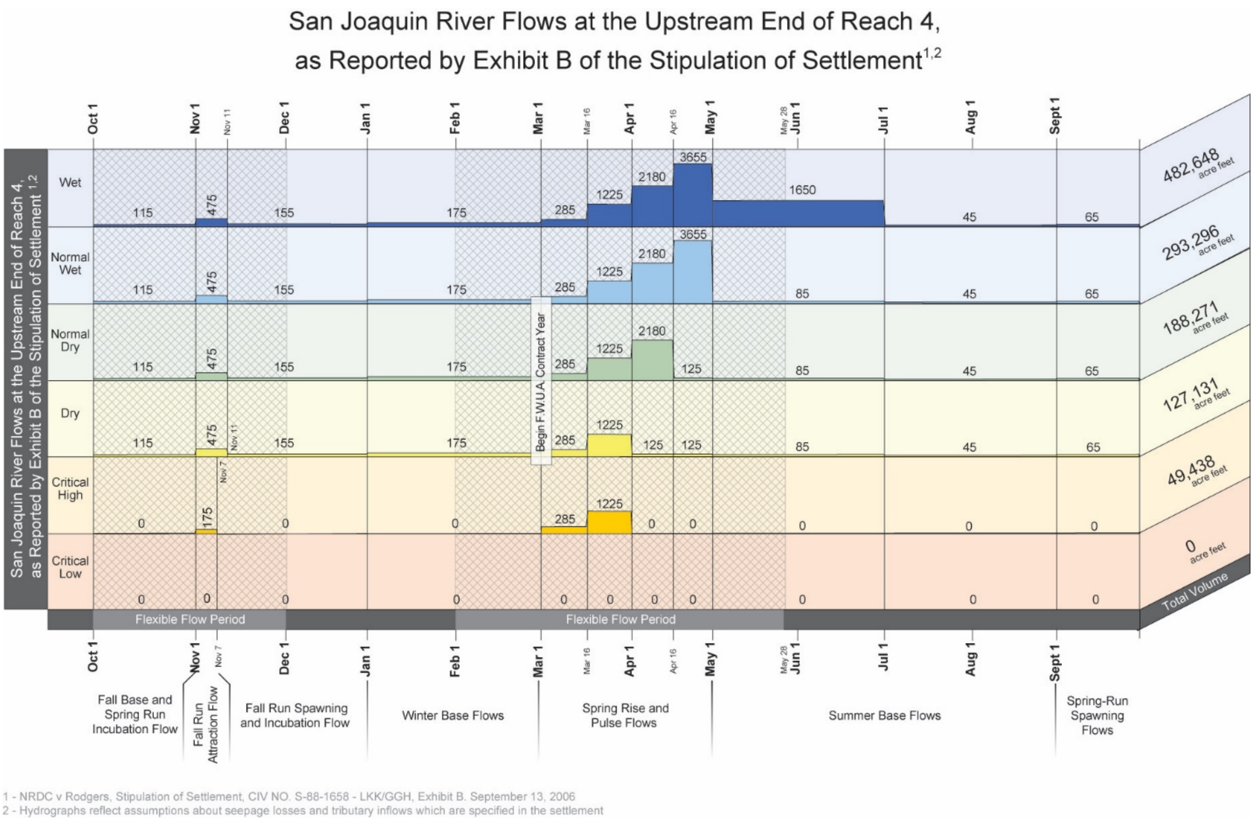
Source: NRDC et al. 2006

Figure 5. San Joaquin River flows at the upstream end of Reach 2 (Exhibit B, of the Stipulation Agreement)



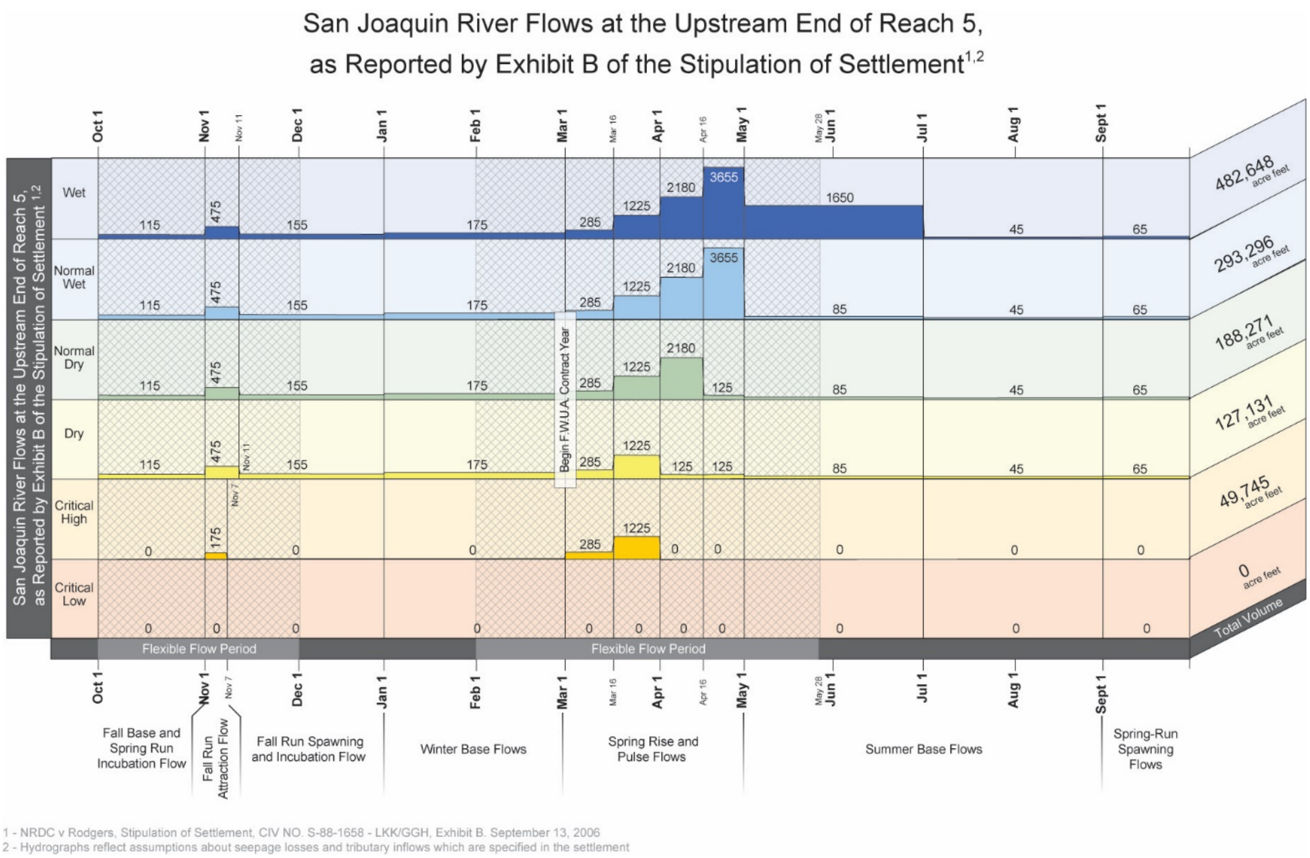
Source: NRDC et al. 2006

Figure 6. San Joaquin River flows at the upstream end of Reach 3 (Exhibit B, of the Stipulation Agreement)



Source: NRDC et al. 2006

Figure 7. San Joaquin River flows at the upstream end of Reach 4 (Exhibit B, of the Stipulation Agreement)



Source: NRDC et al. 2006

Figure 8. San Joaquin River flows at the upstream end of Reach 5 (Exhibit B, of the Stipulation Agreement)

<table>
<tr><th colspan="13">Water Temperature Objectives for the Restoration of Central Valley Chinook Salmon</th></tr>
<tr><th colspan="13">Spring-Run and Fall-Run Chinook Salmon</th></tr>
<tr><th>Life Stage</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>June</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>Adult Migration[1]</td><td></td><td></td><td colspan="4">Optimal: < 59°F (15°C)
Critical: 62.6 – 68°F (17 – 20°C)
Lethal: >68°F (20°C)</td><td></td><td></td><td colspan="4"></td></tr>
<tr><td>Adult Holding
(Spring-Run</td><td></td><td></td><td colspan="7">Optimal: <55°F (13°C)
Critical: 62.6 – 68°F (17 – 20°C)</td><td></td><td></td><td></td></tr>
<tr><td>Spawning</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">Optimal: < 57°F (13.9°C)
Critical: 60 – 62.6°F (15.5 – 17°C)</td></tr>
<tr><td>Incubation
and
Emergence[2]</td><td colspan="5">Optimal: <55°F (13°C)
Critical: 58 – 60°F (14.4 – 15.6°C)
Lethal: >60°F (15.6°C)</td><td></td><td></td><td colspan="5"></td></tr>
<tr><td>In-River
Fry/Juvenile</td><td colspan="12">Optimal: <60°F (15.6°C), young of year rearing; <62.6°F (18°C), late season rearing (yearling; primarily spring-run)
Critical: 64.4 – 70°F (18 – 21.1°C)
Lethal: >75 °F (23.9°C), prolonged exposure</td></tr>
<tr><td>Floodplain
Rearing[3]</td><td colspan="12">Optimal: 55 – 68°F (13 – 20°C), unlimited food supply</td></tr>
<tr><td>Outmigration[4]</td><td colspan="6">Optimal: <60°F (15.6°C)
Critical: 64.4 – 70°F (18 – 21.1°C)
Lethal: >75°F (23.9°C), prolonged exposure</td><td></td><td></td><td></td><td colspan="3"></td></tr>
</table>

*Source: Modified from SJRRP 2010a; EPA 2003, Rich 2007, Pagliughi 2008, Gordus 2009***.**

*Shaded box indicates life stage is present. Temperatures are provided in degrees Fahrenheit (°F) and degrees Celsius (°C).

[1] SJR5Q temperature modeling using a 7-day average daily maximum exceedance of 68°F determined modeled water temperatures remain <68°F through May for a Wet water year type but exceed 68°F in mid-May for Normal Wet water year types and the end of April for Dry and Normal Dry water year types.

[2] Emergence can extend into May from January fall-run Chinook salmon spawning under colder water temperatures in a Wet water year type.

[3] Floodplain rearing temperatures represent growth maximizing temperatures based on floodplain condition. No critical or lethal temperatures are cited assuming salmon have volitional access and egress from floodplain habitat to avoid unsuitable conditions.

[4] SJR5Q temperature modeling using a 7-day average daily maximum exceedance of 75°F determined that modeled water temperatures remain <75°F through June for a Wet water year type but only into May for Dry, Normal Dry, and Normal Wet water year types.

Figure 9. Optimal, critical, and lethal temperature values for Central Valley spring-run and fall-run Chinook salmon

2.6.2 Adult Spring-run and Fall-run Chinook Salmon Habitat

Achieving adult population targets will require sufficient adult holding (spring-run Chinook salmon only) and spawning habitat in the Restoration Area to support the biological objectives for survival (Table 7).

The adult holding and spawning habitat objectives for spring-run and fall-run Chinook salmon are shown in Table 9. The analysis used to determine these habitat objectives is based on the upper range of the "long-term" adult population targets for spring-run and fall-run Chinook salmon:

- 5-year running average of 30,000 spring-run Chinook salmon spawners (range: 15,000–45,000)
    - Average of 15,000 females (range: 7,500–22,500; Hanson et al. 2007)
- 5-year running average of 10,000 fall-run Chinook salmon spawners (range: 5,000–15,000)
    - Average of 5,000 females (range: 2,500–7,500; Hanson et al. 2008)

To meet the average spawning population size, habitat capacity must allow for natural variability. Providing sufficient habitat capacity to sustain the upper range of the population size offsets years with lower adult returns, which allows the population to meet the average objective over time. This is why recent analyses of adult holding and spawning habitat are based on the upper range of the population objective.

Table 9. Adult holding and spawning habitat objectives for spring-run and fall-run Chinook salmon

Chinook Salmon Race	Adult Holding Habitat	Adult Spawning Habitat
Spring-run	45,000 m^2	270,000 m^2
Fall-run	No objective[1]	90,000 m^2

Source: SJRRP Spawning and Incubation Small Interdisciplinary Group.

[1] Assumes that adult holding habitat for fall-run Chinook salmon is not needed as this race enters the river and spawns relatively quickly.

2.6.2.1 Adult Holding Habitat

The FMP (SJRRP 2010a) includes an objective of 30,000 square meters (m2) of high-quality spring-run Chinook salmon holding pool habitat, which is based on the average "growth" target of 30,000 spawners (Hanson et al. 2007). However, the SJRRP has shifted to using the upper range of the "long-term" target of 45,000 spawners (Hanson et al. 2007) for habitat planning, which requires 45,000 m^2 of holding habitat (Table 9). As outlined in the Revised Framework for Implementation (SJRRP 2015a), existing holding habitat in the first 10 miles below Friant Dam, where temperatures are typically suitable during the holding period, is more than 240,000 m^2 at 350 cfs. Flows of 350 cfs during the holding period (summer) are expected in 95 percent of years. Therefore, assuming temperature objectives are met in this habitat, the quantity of holding habitat is not expected to limit the size of the San Joaquin River spring-run Chinook salmon population in the foreseeable future.

2.6.2.2 Adult Spawning Habitat

A preliminary assessment of existing Chinook salmon spawning habitat in the Restoration Area is under development and is expected to be complete in 2017, (SJJRP Spawning and Incubation Small Interdisciplinary Group, pers. comm.). Hydraulic modeling and observed average redd size are being used to assess spawning habitat objectives. These parameters suggest that the upper extent of the long-term fall-run Chinook salmon target (15,000 adults, 7,500 females) is likely met in the 24 miles downstream of Friant Dam. However, instream temperatures during the spring-run Chinook salmon spawning period typically are only suitable in the first 5–7 miles below Friant Dam. Currently available spawning habitat in these 5–7 miles can only support approximately 7,500 spring-run Chinook female spawners, which is the lower range of the long-term population target (average 15,000 females, range 7,500–22,500). Therefore, assuming spring-run Chinook salmon spawning is limited to the first 5–7 miles below Friant Dam, additional spawning habitat may need to be created within the appropriate temperature range in Reach 1 to support a population that exceeds the lower range of the long-term adult population target.

In-situ egg survival studies within the Restoration Area estimated survival to emergence as highly variable and, on average, below the SJRRP target of 50 percent (Castle et al. 2016a, SJRRP 2012b). SJRRP (2012c) found that the egg survival environment was affected by sedimentation, gravel embeddedness, and water temperature. These results indicate that even at low population sizes, improvement of existing habitat conditions may increase the population growth rate. The egg survival results were all conducted under low flows, and it is unknown if survival would be different with higher flows, or if consistent Restoration Flows could improve gravel permeability. Further, we do not know which specific locations spring-run Chinook salmon will use as spawning sites, so additional evaluation is necessary to understand the potential for improving spawning success. The upcoming report will synthesize the results of the analyses and make recommendations on future studies to fill data gaps or identify habitat improvement actions.

The FMP (SJRRP 2010a) includes an objective of 78,000 m2 of functioning spawning habitat (i.e., habitat with suitable substrate and hydraulics for spawning) for spring-run Chinook salmon but does not identify a spawning habitat objective for fall-run Chinook salmon. The spring-run spawning habitat objective was based on the Restoration Administrator's "growth" population objective of 30,000 spawners (Hanson et al. 2007) and assumes a 50:50 sex ratio and 5.2 m2 per redd. Since the FMP was released, additional work has highlighted the need to revise both the redd size and population assumptions used to develop those targets (e.g., SJRRP 2012a, Castle et al. 2016a, Castle et al. 2016b). For example, measurements of 314 fall-run Chinook salmon redds in Reach 1 of the Restoration Area averaged 12 m^2 (Castle et al. 2016a, Castle et al. 2016b).

As with estimating adult holding habitat objectives, using the upper range of the Restoration Administrator's "long-term" target of 45,000 returning spring-run adults to estimate required spawning habitat will prevent spawning habitat from being limiting during years when the population exceeds the average objective of 30,000 spawners (Hanson et al. 2007). This is consistent with the methodology used to derive habitat requirements for other life stages (e.g., juvenile rearing habitat as derived in SJRRP 2012a). For these reasons, the spawning habitat objective for spring-run Chinook salmon was revised to 270,000 m^2 of suitable spawning habitat, calculated as 22,500 females * 12 m^2/redd (Table 9)3. Similarly, a spawning habitat objective of 90,000 m^2 was derived for fall-run Chinook salmon based on the upper range of the "long-term" target of 15,000 returning fall-run adults (Table 9). An underlying assumption of these habitat objectives is that the quality of hydraulically suitable spawning habitat can support the biological objectives for egg incubation and fry emergence (Table 7).

In establishing these objectives, it is important to note that several studies in natural rivers have shown redd density at carrying capacity can be much lower than would be predicted by using average redd size, in part due to territorial defense behaviors (e.g., Burner 1951) and variation in substrate composition (e.g., Riebe et al. 2014). For example, Burner (1951) and EA Engineering (1992) estimated the area required per Chinook salmon redd to be 20.4 m^2 and 16.8 m^2, respectively. While at this point it is unknown how these factors may influence the requirements of the San Joaquin River Chinook salmon populations, ongoing monitoring should inform the necessity to revise these objectives. In this respect, the habitat objectives presented here should be considered preliminary estimates of the required area of suitable spawning habitat. These will be updated with more robust estimates in the preliminary assessment of existing Chinook salmon spawning habitat in the Restoration Area, expected to be completed in 2017.

2.6.3 Juvenile Habitat

The minimum amount of juvenile rearing and migration habitat necessary to meet spring-run and fall-run Chinook salmon population targets was evaluated in the Minimum Floodplain Habitat Area report (SJRRP 2012a). Juvenile habitat requirements were developed based on the juvenile abundance objectives for both spring-run and fall-run Chinook salmon described in the FMP (SJRRP 2010a), the Restoration Administrator recommendations (Hanson et al. 2007, Hanson et al. 2008), and assumptions about juvenile survival, growth, territory size, and migration timing and speed. The amount of existing suitable habitat for each water year type in each reach of the Restoration Area was estimated using 2-dimensional hydraulic and GIS modeling and habitat suitability indices (HSI). Suitable habitat was defined as meeting inundation duration, timing, depth, water velocity, and vegetative cover requirements for juvenile Chinook salmon (SJRRP 2012a). Based on the available suitable habitat calculated throughout the Restoration Area, approximately 10–25 percent of the total inundated area is expected to be suitable habitat depending on the reach (SJRRP 2012a).

The area of suitable juvenile rearing habitat that currently exists in the Restoration Area and the amount required to meet juvenile abundance objectives are presented in Table 10. Achieving targets during any year is largely a function of water year type. While the weighted average of suitable habitat for all water year types is used for comparison, the ability to meet targets each year will depend on hydrologic conditions experienced by juveniles rearing in the system. An underlying assumption is that habitat quality in these areas meets the water quality and survival objectives established by the Program. The total amount of rearing habitat in the Restoration

[3] This is a preliminary estimate. The work group is expected to complete the analysis in 2017.

Area is expected to increase with implementation of the Mendota Pool Bypass and Reach 2B Improvements Project (Reach 2B Project) and the Reach 4B, Eastside Bypass and Mariposa Bypass Channel and Structural Improvements Project (Reach 4B Project), along with implementation of full Restoration Flows. The specific amount of increase in rearing habitat will depend on the 2B and 4B alternatives selected. As the program moves forward, additional habitat may be created through program actions or through partnerships with regional landowners or conservation organizations.

Table 10 shows existing suitable habitat by reach and water year type and compares it to the calculated juvenile suitable habitat needed to estimate the suitable habitat deficit. The fraction of suitable habitat in Reaches 2B and 4B will depend upon the actual revegetation, floodplain grading, and channel restoration activities implemented. Likely spring pulse flows were modeled in different water year types to determine existing suitable habitat. Under Exhibit B of the Settlement, between 1,000–1,500 cfs is expected in Dry water year types (20 percent of years), 2,180–2,500 cfs in Normal water year types (60 percent of years), and 3,600–4,500 cfs in Wet water year types (20 percent of years). Existing suitable habitat was calculated for each water year type and weighted based on the percentage of years that are of each type to obtain the weighted average of existing suitable habitat. The second to the last column of Table 10 shows required suitable habitat to meet population targets based on juvenile Chinook salmon population, survival, growth, territory size, migration timing, and speed (SJRRP 2012a). The last column of the table shows the suitable habitat deficit after existing habitat is subtracted from required habitat. The minimum amount of inundated area required to meet juvenile rearing needs is estimated to range from 3,244–8,110 acres (Table 11). This is calculated by taking the total suitable habitat needed (811 acres; Table 10) and dividing by the percent of total inundated area that is expected to be suitable habitat (10–25 percent; SJRRP 2012a).

Table 10. Suitable juvenile rearing habitat (acres) under existing conditions, for each water year type, compared to that needed to achieve juvenile abundance objectives

Reach	Existing Suitable Habitat				Suitable Habitat Needed	Suitable Habitat Deficit
	Dry Water Years (acres)	Normal Water Years (acres)	Wet Water Years (acres)	Weighted Average Suitable Habitat (acres)	Required Suitable Habitat to Meet Population Targets (acres)	Required Suitable Habitat minus Existing Habitat (acres)
1B[1]	67	56	59	59	109	50
2A	94	104	114	104	183	79
2B[2]	56 – 140	75 – 188	–[4]	71 – 178	144	0 – 73
3	45	62	71	60	203	143
4A	50	56	68	57	76	19
4B1[2, 3]	0	0	0	0	54[5]	54
Middle Eastside Bypass	78	89	96	88	54[5]	0
4B2	200	281	344	277	19[6]	0
Lower Eastside Bypass	16	17	21	18	19[6]	1
5	230	371	526	374	23	0
Total	836 – 920	1111 – 1224	1299	1108 – 1215	811	346 – 419

[1] Suitable rearing habitat is calculated, in part, as a factor of water depth and velocity. As a result, depths and velocities do not exceed habitat requirements.

[2] Habitat computations are approximate for Reaches 2B and 4B1 as modeling depth, velocity, and cover were not analyzed in these reaches as they will be restored.

[3] Currently there is no flow in 4B1, so existing suitable habitat values are zero (SJRRP 2012a).

[4] Existing suitable habitat was not estimated as 3,665 cfs in a Wet water year type exceeds the 1,120 cfs Reach 2B current channel capacity. Under these conditions, Wet water year type suitable habitat could be assumed from the Normal water year type.

[5] Value is dependent upon Reach 4 flow routing decision. Either a required suitable habitat value of 0 or 54 is used for 4B1 or Middle Eastside Bypass as only one alternative will maintain Restoration Flows.

[6] Value is dependent upon Reach 4 flow routing decision. Either a required suitable habitat value of 0 or 19 is used for 4B2 or Lower Eastside Bypass as only one alternative will maintain Restoration Flows.

Table 11. Rearing habitat objectives for spring-run and fall-run Chinook salmon

Objective	Juvenile Chinook Salmon Area
Minimum Inundated Area for Rearing Habitat[1]	3,244 – 8,110 acres
Suitable Juvenile Rearing Habitat	811 acres

Source: SJRRP 2012a.
[1] Based on approximately 10–25 percent of the total inundated area expected to be suitable habitat depending on the reach (SJRRP 2012a).

As shown in Table 12, there are suitable juvenile habitat deficits in the upper reaches of the San Joaquin River (Reach 1B through Reach 4B1). The total suitable habitat deficit is estimated to be 365–419 acres. Two projects in the SJRRP will create large amounts of suitable habitat. These are the Mendota Pool Bypass and Reach 2B project, which will construct floodplain habitat during approximately 2020–2025 as discussed in the Framework for Implementation, and the Reach 4B project, which will construct floodplain habitat during approximately 2025–2030.

Table 12. Suitable habitat needs met by projects

Reach	Required Suitable Habitat to Meet Population Targets (acres)	Suitable Habitat Deficit (acres)	SJRRP Project Suitable Habitat Creation (acres)
1B	109	50	
2A	183	79	
2B	144	0 – 73	234
3	203	143	
4A	76	19	
Middle Eastside Bypass / 4B1	54	54	245+
Lower Eastside Bypass / 4B2	19	0 – 1	
5	23	0	
Total	811	365 – 419	479

The SJRRP will meet juvenile suitable habitat needs after implementation of the Mendota Pool Bypass and Reach 2B Project and the Reach 4B, Eastside and Mariposa Bypasses Project. These projects will create a total of 479 additional acres of suitable habitat (Table 12), and are the only projects identified in the Settlement that provide floodplain habitat. The Mendota Pool Bypass and Reach 2B project will meet all of the Reach 1B, 2A, 2B, and part of the Reach 3 juvenile suitable habitat needs. A preferred alternative has not yet been selected for the Reach 4B project. However, with the narrowest levee alignment A, the Reach 4B, Eastside and Mariposa Bypass

Improvement Projects will meet the remaining Reach 3 juvenile suitable habitat need, as well as the Reach 4A, Reach 4B / Eastside Bypass, and Reach 5 suitable habitat needs where they exist.

2.7 Hatchery Operations

The Program has adopted two different approaches for reintroducing spring-run and fall-run Chinook salmon into the system. Extant populations of hatchery fall-run Chinook salmon within the larger San Joaquin River Basin regularly try to enter the lower Restoration Area. Once suitable passage and flow conditions exist within the system, fall-run Chinook salmon populations can begin to establish volitionally without the need for direct reintroduction activities. A volitional spring-run Chinook salmon strategy is unlikely to succeed in the Restoration Area because there are no large spring-run populations in the San Joaquin River Basin to volitionally contribute to population reestablishment. Therefore, in addition to establishing suitable habitat conditions, the Program has decided to rely on artificial propagation to reintroduce spring-run Chinook salmon to the system. The majority of the fish for this purpose will come from the Salmon Conservation and Research Facility (SCARF) below Friant Dam and the Interim SCARF prior to SCARF being constructed.

The Chinook salmon conservation program will be operated as an integrated recovery program pursuant to the HGMP (SJRRP 2010b, SJRRP 2016) developed by CDFW in collaboration with SJRRP partners and consistent with standards and guidelines established by the California Hatchery Scientific Review Group (CA HSRG 2012). The work completed by this independent scientific group represents the most up-to-date science for the operation of hatchery facilities consistent with salmon restoration and conservation objectives. SCARF design and operation will implement the following conservation measures:

- Ensure broodstock collection does not significantly reduce potential juvenile production in the source populations.
- Ensure broodstock collection does not adversely impact the genetic diversity of the naturally spawning source population.
- Manage hatchery broodstock to achieve proper genetic integration with the natural population, minimize domestication selection and maximize effective population size.
- Promote local adaptation.
- Minimize adverse ecological interactions between naturally produced fish (NOR) and hatchery produced fish (HOR).
- Minimize the effects of hatchery and monitoring facilities on the ecosystem in which they operate.
- Operate consistent with CDFW fish health policies and guidelines.
- Ensure annual release numbers do not exceed estimated habitat carrying capacity, including the spawning areas, freshwater rearing areas and migration corridor in the Restoration Area.

- Phase out hatchery operations when so indicated by an adaptive management approach and achievement of salmon restoration goals and objectives.
- Manage the program in a scientifically defensible manner.

An integrated program consists of a composite population of fish that spawn both in the hatchery and in the wild (i.e., naturally). A primary goal of an integrated program is to increase adult abundance while minimizing genetic divergence of the hatchery component from the naturally spawning population component. Hatchery program integration is achieved by incorporating NOR fish into the broodstock (NOB) and limiting gene flow by monitoring and controlling the proportion of naturally spawning fish which are hatchery origin (HOS). The proportion of NOR fish incorporated into the hatchery broodstock (pNOB) should exceed the proportion of the natural spawning population composed of hatchery origin fish (pHOS) so that the natural environment has a greater influence on the population than the hatchery environment. Fish adapted to the natural environment in the Restoration Area are expected to have higher productivity and abundance than non-locally adapted fish. The so-called Proportionate Natural Influence (PNI) index[4] is approximated by the ratio pNOB/(pNOB + pHOS). The SCARF will be operated to achieve a PNI > 0.67 after the Reintroduction Phase, as described in the spring-run Chinook salmon HGMP (SJRRP 2016).

The working hypothesis for introgression is that the higher the introgression rate between spring-run and fall-run Chinook salmon, the greater the loss in Chinook salmon population fitness and resulting adult abundance (see Appendix D, Table 3; HSRG 2014). In addition, high rates of introgression may lead to the loss of distinct spring-run and fall-run Chinook salmon phenotypes and/or genotypes (Tomalty et al. 2014).

The Program's biological objective is to maintain introgression rates between spring-run and fall-run Chinook salmon below 2 percent (see Appendix E; SJRRP 2015b), which is consistent with the NMFS viability criteria (NOAA 2014).

Hatchery facilities will be operated to minimize introgression between San Joaquin River spring-run and fall-run Chinook salmon. This will be accomplished through run segregation and genetic analysis of all broodstock. Only after results of genetic analysis confirm a spring-run Chinook salmon lineage will those adults be incorporated into the SCARF as broodstock.

Introgression and its consequences for spring-run Chinook salmon population genetics are further described in Appendix D.

2.8 Harvest: Ocean and Freshwater

This section summarizes available information on ocean and freshwater harvest impacts to spring-run and fall-run Chinook salmon produced by the Program based on NMFS 2016. While

[4] The PNI concept is attributed to Craig Busack, NMFS (presentation at a Columbia River HSRG workshop, 2004).

adult Chinook salmon exploitation rates can reach 70 percent for some stocks (CA HSRG 2012, PFMC 2014)[5], there is substantial uncertainty related to the magnitude and annual variability of the effect of ocean and freshwater harvest on spring-run and fall-run Chinook salmon to be produced by the Program. The fall-run Chinook salmon ocean harvest rate index[6] peaked in the late 1980s and early 1990s, ranging from 60–80 percent, but then declined. With the closure of nearly all Chinook salmon ocean fisheries south of Cape Falcon, Oregon in 2008 and 2009, the index dropped to six percent and one percent in these years, respectively. Although ocean fisheries resumed in 2010, commercial fishing opportunity was severely constrained, particularly off California, resulting in a harvest rate index of 16 percent. Since 2011, ocean salmon fisheries in California and Oregon have had more typical levels of fishing opportunity. The average fall-run Chinook salmon ocean harvest rate index from 2011–2014 was 45 percent.

Attempts have been made to estimate Central Valley (CV) spring-run Chinook salmon ocean fishery exploitation rates using coded wire tag (CWT) recoveries from natural origin Butte Creek fish (Grover et al. 2004), but due to the low number of tag recoveries, the uncertainty of these estimates is too high to accurately determine actual harvest rates (NMFS 2016). However, the HSRG was concerned exploitation rates of naturally produced CV Chinook salmon were too high given the likely low productivity of these populations. Importantly, it is possible CV spring-run Chinook salmon experience lower overall fishing mortality than do fall-run Chinook salmon. The CV spring-run Chinook salmon spawning migration largely concludes before the mid- to late-summer opening of freshwater salmon fisheries, suggesting in-river fishery impacts on CV spring-run Chinook salmon are relatively minor (NMFS 2016). Overall, it is highly unlikely harvest resulted in overutilization of CV spring-run Chinook salmon, but actual harvest rates on fish produced from the Restoration Area will not be known for many years. Therefore, harvest level is a risk that will be evaluated over time through Program monitoring and evaluation.

For planning purposes, it is assumed exploitation rates for spring-run and fall-run Chinook salmon will average 50 percent. The current assumption is based on exploitation rates observed for tagged naturally produced Butte Creek spring-run Chinook salmon fry (~48 percent) and Feather River hatchery fish which are being used in reintroducing spring-run Chinook salmon[7]. Harvest exploitation rates for Program fish will be refined over time based on the results of updated CWT analyses.

The Program assumption is spring-run, and fall-run Chinook salmon populations can be restored at the current exploitation rate of 50 percent (i.e., the assumption is harvest rates will not be

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[5] The spring-run Chinook salmon HGMP indicated that harvest rates may range from 17–60 percent (SJRRP 2010b).

[6] Annual ocean harvest rate of fall-run Chinook salmon south of Cape Falcon from Sept. 1 through August 31. See PFMC (2016) Appendix B, Table B-7 for a time series of the fall-run Chinook salmon ocean harvest rate index from 1983-2014.

[7] This estimate is based on a query of the Regional Mark Information System (RMIS) coded wire tag database [www.rmis.org) reported by the CA HSRG (2012) for multiple hatchery programs.

reduced in the future). Monitoring will determine whether harvest is preventing the Program from meeting adult abundance targets.

3 Program Implementation

The Program will be implemented using the Adaptive Management Approach outlined in the FMP (SJRRP 2010a) and described in detail in this Framework (Section 3.1). Program implementation includes two components:

1) Implementation of the physical projects outlined in the Settlement Agreement.

2) Restoration of spring-run and fall-run Chinook salmon populations.

According to the FMP, Conceptual Models are used to develop restoration actions that have a high likelihood of achieving Program goals and objectives, while providing information to increase understanding of ecosystem function and resolve conflicts among alternative hypotheses about the ecosystem (SJRRP 2010a). The Conceptual Model for how the system will function over time is formed by the selection of restoration projects, their effectiveness in reducing stressors, and their effect on Chinook salmon production (Section 3.2).

The Revised Framework for Implementation (SJRRP 2015a) established five-year Vision Periods to provide clear, realistic and accomplishable steps toward achievement of the structural and environmental goals outlined in the Settlement Agreement. These Vision Periods correspond to the following timeline[8]:

- 5-Year Vision (2015–2019)
- 10-Year Vision (2020–2024)
- 15-Year Vision (2025–2029)
- Beyond 15-Year Vision (2030+)

The Framework for Implementation uses these time periods to describe the activities needed to plan, permit, design, construct and operated the major elements of the Program (Section 3.3 through 3.9). These activities and their completion dates define the environment within which fish reintroduction will take place.

Restoration of spring-run and fall-run Chinook salmon populations will be implemented in three phases, each of which has specific biological and population objectives (Section 3.10 and 3.11). These phases are:

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[8] The time periods are similar to those described in the FMP: Reintroduction (2010-2019), Interim (2020-2024), Growth (2025-2040), and Long Term (2040+).

- Reintroduction (i.e., recolonization)[9]
- Local Adaptation
- Full Restoration

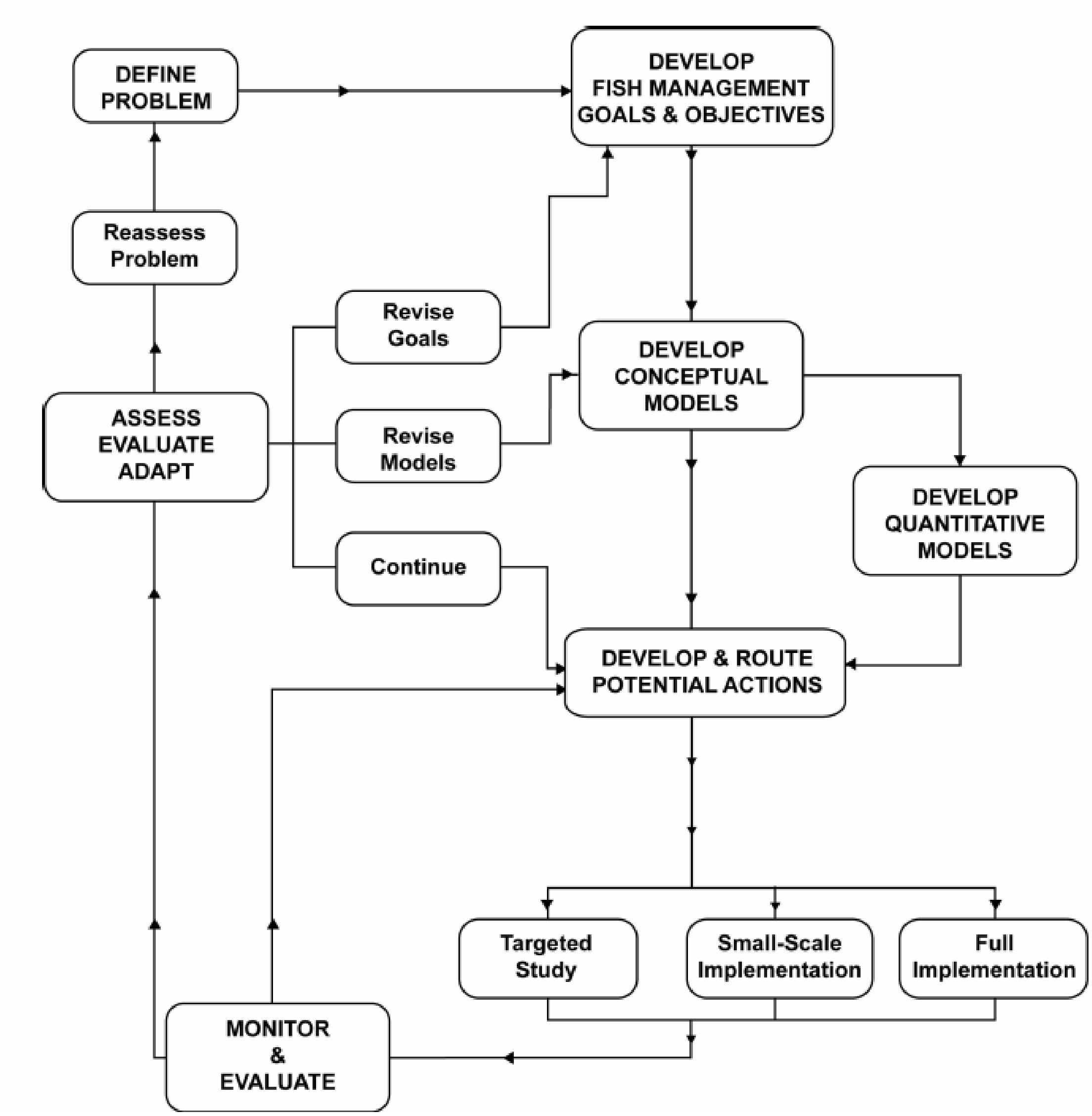
The phases are not associated with specific timelines because it is not possible to predict with confidence when the shift from one restoration phase to the next will occur. Salmon populations are subject to substantial annual and decadal variability due to changes in environmental conditions. Therefore, movement between phases will be based on biological criteria (triggers) rather than the timeline used for implementation of physical projects. These biological triggers are described in detail in Sections3.10 and 3.11.

3.1 Program Management and Decision Making

Because of the large amount of uncertainty and variability inherent in salmon populations and their habitat, the Program developed an Adaptive Management Approach as part of the FMP (SJRRP 2010a; Figure 10). The adaptive management process is designed to ensure the Program adjusts the implementation strategy as new knowledge is gained. An adaptive management process will allow the Program to:

- Clearly articulate and communicate Program goals and objectives and adjust them as necessary.
- Identify data gaps and uncertainties.
- Prioritize management actions and ensure actions are scientifically defensible.
- Ensure research, monitoring and evaluation (RM&E) are effectively incorporated into the decision-making process and are used to revise or update program management actions and projects.
- Maximize the likelihood Program actions are successful.

[9] While spring-run Chinook salmon will be actively reintroduced to the Restoration Area, fall-run Chinook salmon are expected to recolonize the area volitionally over the long term.



Source: SJRRP 2010a.

Figure 10. Adaptive Management Approach flow chart

As part of the Adaptive Management Approach, Program managers and staff will review Program goals and objectives, the working hypothesis and key assumptions, status and trends data, progress toward biological and habitat goals and objectives, and RM&E priorities. Managers will also review the Program's Decision Rules (see Sections 3.10 and 3.11), which determine how the Program will be managed given expected adult run sizes, environmental conditions (e.g., water year type), the status of physical projects, and results from RM&E.

In addition, the FMP recommends a formal peer review process be initiated every 5 years (SJRRP 2010a). External review of the Program will benefit the SJRRP by providing mechanisms for obtaining: (1) peer review of draft reports, (2) technical oversight of Restoration Area and reach-specific actions, (3) independent scientific advice, recommendations and evaluations of models, monitoring plans, experimental designs and other elements of SJRRP planning, implementing, and reporting, and (4) independent assessment of progress toward meeting Restoration Goals.

The peer review process may include staff from other programs that might affect or be affected by the SJRRP. Coordination with other programs will help eliminate unnecessary duplication of effort, reduce potential conflicts, and promote cooperation and information exchange (SJRRP 2010a).

3.2 Conceptual Model for Restoring Spring-run and Fall-run Chinook Salmon

The purpose of developing a Conceptual Model for the Program is to link specific management actions to Program goals for spring-run and fall-run Chinook salmon (SJRRP 2010a; Figure 11). It builds on the working hypothesis wherein Program projects and actions are designed to reduce stressors and create habitat of sufficient quality and quantity to support self-sustaining runs of spring-run and fall-run Chinook salmon. Specifically, the Conceptual Model links the key assumptions about life stage survival to the Program's adult abundance objectives for spring-run and fall-run Chinook salmon.

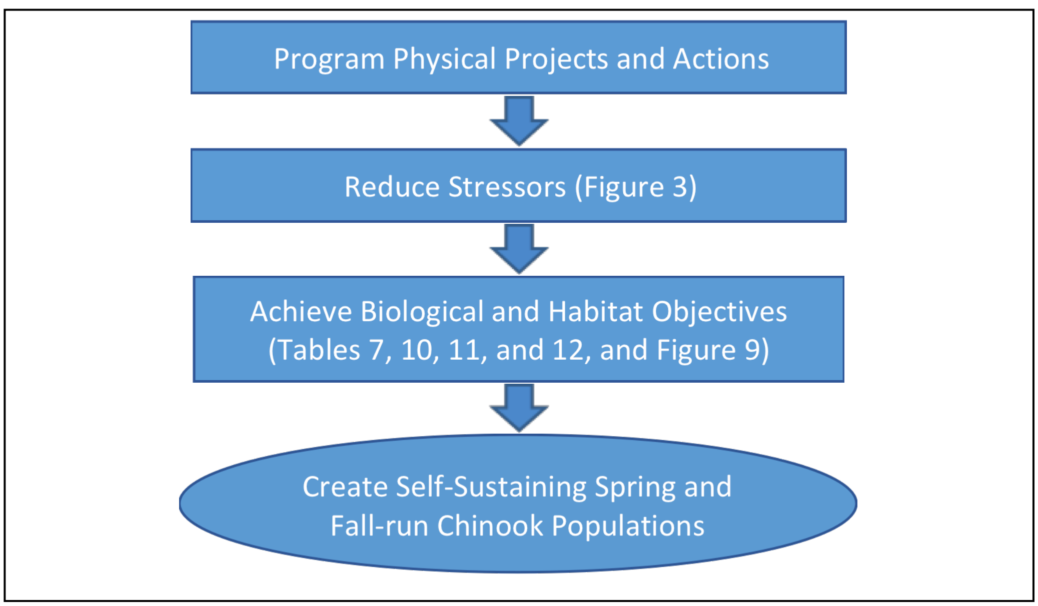


Figure 11. Conceptual Model linking actions to Program goals for spring-run and fall-run Chinook salmon

3.2.1 Spring-run Chinook Salmon

The Beverton-Holt model is commonly used by fisheries managers to predict population level relationships between the annual abundance of adult spawners and the number of juveniles that population can produce. It accounts for density dependent survival from one life stage or time period to the next. This relationship was traditionally used to set harvest rates and is a key component of most stock assessments. In this Framework document, the Beverton-Holt model was used to develop the Conceptual Model of how long-term adult abundance objectives for naturally produced spring-run Chinook salmon will be achieved.

The key assumptions applied to develop the Conceptual Model for spring-run Chinook salmon are provided in Table 13[10]. These values were used to estimate the Beverton-Holt production function parameters (productivity and capacity) needed to meet the long-term adult abundance target for spring-run Chinook salmon (average of 30,000 spawners; Table 14)[11].

Productivity is defined as the number of adult recruits per spawner at low population abundance (i.e., density independent survival). It is affected by habitat quality and fitness of each life stage and is therefore population and life stage specific.

Capacity is a measure of the quantity and quality of habitat available for a specific life stage. Capacity determines the effects of population density on survival. Here, adult capacity is defined as the maximum number of adult spawners that can be supported by the available spawning habitat. The Beverton-Holt parameters assume a fully fit population, defined as being adapted to the Restoration Area and able to take full advantage of the survival potential of the available habitat.

The productivity value estimated using the assumptions in Table 13 (5.2; see Table 14), falls within the range (4–6) NMFS researchers have used for natural origin stream-type and ocean-type Chinook salmon populations in the U.S. and Canada when spawner-recruit data are unavailable (Liermann et al. 2010).

[10] See Table 7 for all life stage survival assumptions.

[11] These numbers were developed by running a population model that included varying ocean survival rates based on the Pacific Decadal Oscillation (PDO) over a 100-year period. Results are reflective of a population that is locally adapted to the San Joaquin River Restoration Area.

Table 13. Key assumptions used to develop the Conceptual Model for naturally produced spring-run Chinook salmon

Parameter	Value	Data Source
Average number of spawners (measured at spawning grounds)	30,000	SJRRP (2010a)
Percent females	≥50%	
Fecundity (number of eggs)	4,200	
Egg survival rate	50%	
Juvenile passage survival rate	70%	
Minimum fry-to-smolt survival rate (includes juvenile fish passage losses)	5%	
Total juvenile production (measured at downstream end of Restoration Area)	1.575 million (90% subyearlings, 10% yearlings)	
Harvest exploitation rate (average)	50%[1]	CA HSRG (2012), RMIS database
Adult passage survival	90%	SJRRP (2010a)
Smolt-to-adult survival rate (after harvest)	1.90%	30,000/1.575 million
Smolt-to-adult survival rate (pre-harvest)	3.80%	(30,000/0.5)/1.575 million

[1] The HGMP assumed harvest rates of 17–60 percent (SJRRP 2010b, 2016); see Section 3.5 of this document for a discussion of the 50 percent harvest rate assumption.

Table 14. Spring-run Chinook salmon population parameters needed to meet long-term population objectives. Productivity and capacity values are for a Beverton-Holt production function based on the assumptions in Table 13

Parameter	Value
Adult Productivity	5.2
Adult Capacity	146,701
Modeled Juvenile and Adult Population Estimates	
Adult Spawners (After Harvest)	~30,000
Total Number Fry	~39 million
Total No. Juveniles (measured at downstream end of Restoration Area)	~1.7 million

The expected long-term (Vision Period 2030+) range of adult spring-run Chinook salmon spawners and juvenile production given the attainment of all environmental and biological objectives is shown in Table 15.

Table 15. Percentile values for spring-run Chinook salmon adult spawners and juvenile production based on population modeling results from a 100-year simulation

Metric	Adult Spawners	Juvenile Production
5th Percentile	12,281	1,025,188
10th Percentile	15,326	1,183,428
20th Percentile	18,884	1,341,678
30th Percentile	22,414	1,468,449
40th Percentile	25,790	1,612,745
50th Percentile (median)	30,873	1,736,495
60th Percentile	34,918	1,854,624
70th Percentile	39,296	1,947,236
80th Percentile	43,459	2,040,282
90th Percentile	50,173	2,156,538
95th Percentile	55,950	2,243,433

3.2.2 Fall-run Chinook Salmon

The assumptions used to develop the working hypothesis for naturally produced fall-run Chinook salmon are provided in Table 16. These values were used to estimate the Beverton-Holt production function parameters (productivity and capacity) needed to meet the adult abundance target for fall-run Chinook salmon (average of 10,000 spawners; Table 17)[12]. Please see the explanation of these parameters in section 3.2.1.

[12] These numbers were developed by running a population model that included varying ocean survival rates based on the Pacific Decadal Oscillation (PDO) over a 100-year period. Results are reflective of a population that is locally adapted to the San Joaquin River Restoration Area.

Table 16. Key assumptions used to develop the Conceptual Model for naturally produced fall-run Chinook salmon

Parameter	Value	Data Source
Number of Spawners	10,000	SJRRP (2010a)
Percent Females	50%	
Fecundity	6,000	
Egg Survival Rate	50%	
Juvenile Passage Survival Rate	70%	
Minimum Fry-to-Smolt (subyearling) Survival Rate (after passage)	5%	
Total Juvenile Production (measured at downstream end of Restoration Area)	750,000	
Harvest Exploitation Rate	50%[1]	CA HSRG (2012), RMIS Database
Adult Passage Survival	90%	SJRRP (2010a)
Smolt-to-Adult Survival Rate (after harvest)	1.33%	10,000/750,000
Smolt-to-Adult Survival Rate (pre-harvest)	2.66%	(10,000/0.5)/750,000

[1] The HGMP assumed harvest rates of 17–60 percent (SJRRP 2010b, 2016); see Section 3.5 of this document for a discussion of the 50 percent harvest rate assumption.

Table 17. Fall-run Chinook salmon population parameters needed to meet long-term population objectives. Productivity and capacity values are for a Beverton-Holt production function based on the assumptions in Table 16

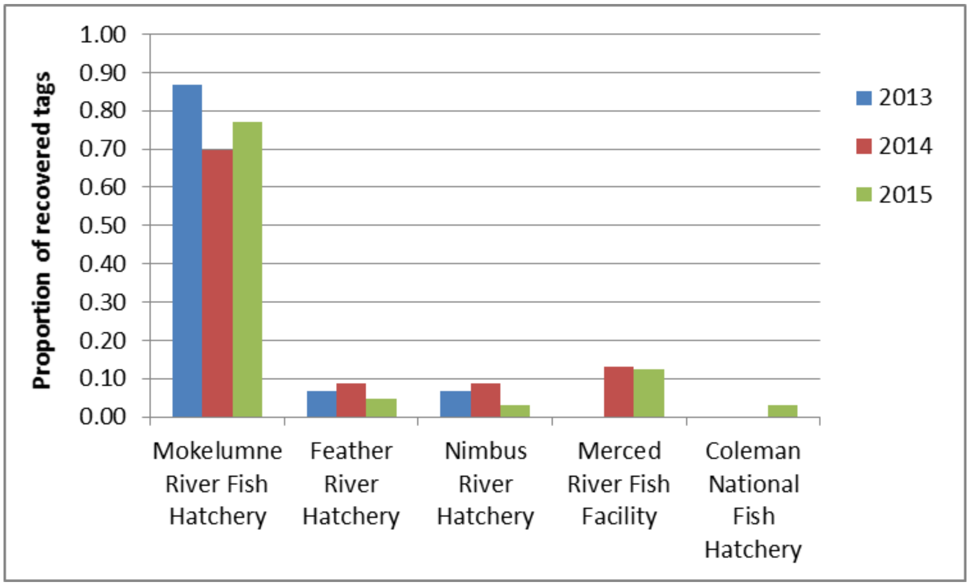
Parameter	Value
Adult Productivity	5.7
Adult Capacity	50,560
Modeled Juvenile and Adult Population Estimates	
Adult Spawners (After Harvest)	~10,000
Total Number Fry	~18 million
Total No. Juveniles (measured at downstream end of Restoration Area)	~960,000

The expected long-term (Vision Period 2030+) range of adult fall-run Chinook salmon returns to the basin after harvest is shown in Table 18.

Table 18. Percentile values for fall-run Chinook salmon adult spawners and juvenile production based on population modeling results from a 100-year simulation

Metric	Adult Spawners	Juvenile Production
5th Percentile	4,170	526,333
10th Percentile	5,028	625,157
20th Percentile	6,691	736,129
30th Percentile	7,812	806,244
40th Percentile	9,036	888,510
50th Percentile (median)	10,367	962,365
60th Percentile	12,114	1,049,230
70th Percentile	13,835	1,114,702
80th Percentile	15,445	1,185,998
90th Percentile	18,123	1,270,607
95th Percentile	19,716	1,319,596

Adults collected upstream of the Hills Ferry Barrier (or other sites if developed) will first be used to restore fall-run Chinook salmon to the Restoration Area. Adult data from carcass surveys indicate almost all (>95 percent) of the fall-run Chinook salmon collected upstream of Hills Ferry Barrier in the Restoration Area are of hatchery origin with the majority of these originating from the Mokelumne River Hatchery (Figure 12). Key assumptions of the fall-run Chinook salmon working hypothesis are: (1) hatchery fish will continue to stray into the Restoration Area in numbers large enough to successfully re-colonize the area, 2) fall-run Chinook salmon can be segregated from spring-run Chinook salmon to attain introgression objective (<2 percent), and (3) the origin and number of hatchery strays from outside of the Restoration Area has minimal effect on achievement of fall-run Chinook salmon goals in the year 2030+.



Source: Pers. comm. J. Netto, USFWS

Figure 12. Origin of coded wire tags (fall-run Chinook salmon) recovered in the Restoration Area during the period 2013–2015. The y-axis shows the percentage of recovered tags originating at each hatchery facility

3.2.3 Challenging the Spring-run and Fall-run Chinook Salmon Conceptual Models

The Conceptual Models for the spring-run and fall-run Chinook salmon populations are based on the abundance objectives and key assumptions described in previous Restoration Administrator Reports, the FMP and HGMPs (Hanson et al. 2007, 2008; SJRRP 2010a, 2010b, 2016). The Program's Adaptive Management approach will be used to revise goals, objectives and management actions as new knowledge is acquired and scientific understanding of the system improves (SJRRP 2010a).

New information collected by the Program and elsewhere may require updating the assumptions used in the Conceptual Models, particularly those associated with a great deal of uncertainty. The assumptions that need to be challenged are presented below.

3.2.3.1 Stressor Reduction

Both spring-run and fall-run Chinook salmon performance ultimately will be determined by habitat quality and quantity, both within and outside of the Restoration Area, and the ability of introduced spring-run and fall-run Chinook salmon to adapt to environmental conditions. The results of the limiting stressor analysis presented in Section 3.2 indicated that, even with the completion of major actions and projects, Program biologists believe high water temperatures during adult and juvenile migration, juvenile survival through the Delta and juvenile predation stressors will continue to have large impacts on Chinook salmon survival and total adult production. If the magnitude of these impacts is large, the assumptions about life stage survival and fish production used in the Conceptual Models may not be achieved.

3.2.3.2 Egg-to-Smolt Survival Rate

The Program assumes an egg-to-smolt (subyearling > 70 mm) survival rate for both Chinook salmon runs of 2.5 percent[13] measured at the downstream end of the Restoration Area. The 2.5 percent survival rate was estimated based on rotary screw trap data on the Stanislaus River (SJRRP 2010a). This survival value is considerably smaller than the 10 percent value reported by Quinn (2011) for Chinook salmon in his review of the ecology of salmon. In addition, biologists working on the Stanislaus River are using survival values ranging from 5–15 percent (short term) and 15–35 percent (long term) depending on the water year (SEP 2016). The Program will monitor egg-to-smolt survival rates and make adjustments in the future as appropriate. Because of the high degree of uncertainty and annual variability associated with this value, this is the best available information on egg-to-smolt survival.

3.2.3.3 Smolt-to-Adult Survival Rate (SAR)

The Program assumes the SARs for spring-run and fall-run Chinook salmon are 2 to 4 percent (Table 13 and Table 16). These values are back-calculated based on assumptions about harvest and the number of adults required to meet the Program's long-term adult abundance targets. Recent analyses and queries of the CWT database (www.rmis.org) show total smolt-to-adult survival rates for Central Valley hatchery Chinook salmon are highly variable. SARs for hatchery Chinook salmon that migrate in-river are generally less than 0.5 percent and are near zero in some years (Kormos et al. 2012, Palmer-Zwahlen and Kormos 2013)[14]. The total survival rate (before harvest) of Butte Creek natural origin spring-run Chinook salmon fry averaged about 0.15 percent from 2000–2004 (query of RMIS database, K. Malone, DJWA, pers. comm.).

The Program needs additional information to diagnose where in the system survival rates need to be improved. For example, additional information is needed on juvenile survival rates in the reach extending from the Merced River to the Delta. In addition, juvenile survival rates in the Delta impact the ability of the Program to achieve adult abundance objectives. Currently, San Joaquin River juvenile spring-run and fall-run Chinook salmon survival estimates through the Sacramento-San Joaquin River Delta are estimated at 7 percent and 5 percent, respectively (BDCP 2013, NMFS 2017). Survival rates are expected to increase in the future, but the methods and specific projects for these improvements are uncertain.

3.2.3.4 Spring-run Chinook Salmon Juvenile Life History

Assumptions regarding juvenile life-history affect the amount of rearing habitat required and its geographic distribution (SJRRP 2012a), fish passage design, timing of flows, and the fry-to-juvenile survival rate needed to achieve abundance objectives. The current assumption for spring-run Chinook salmon juveniles is that the migration will consist of approximately 90 percent subyearlings (fish length > 70 mm) and 10 percent yearlings (SJRRP 2010a).

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[13] Assumes an egg-to-fry survival rate of 0.5 and fry-to-smolt survival rate of 0.05 (0.5*0.05 = 0.025).

[14] Total SARs are based on recoveries of CWTs in fisheries and escapement to spawning grounds and hatcheries. This is a composite rate for spring-run and fall-run Chinook salmon.

3.2.3.5 Fall-run Chinook Salmon Population Performance

The fall-run Chinook salmon adult spawner abundance objectives were established in the 2008 RA report (Hanson et al. 2008). The population abundance targets were based on a review of historical population estimates, adult run-size after the construction of Friant Dam, recent fish abundance in San Joaquin River tributaries, adult abundance for recovering populations, habitat carrying capacity and modeling.

Hanson et al. (2008) provided data on fall-run Chinook salmon production from San Joaquin River tributaries showing average natural escapement (from 1992–2006) to the Stanislaus, Tuolumne and Merced Rivers averaged 3,700, 4,600 and 3,800 salmon, respectively. The analysis also showed maximum fall-run Chinook salmon adult production from these tributaries ranged from 10,000–20,000 fish. These numbers were used to support conclusions regarding short-term and long-term abundance targets.

3.2.3.6 Habitat Quantity and Quality

It is assumed stream temperatures in all or a portion of the Restoration Area will support all Chinook salmon freshwater life stages and that total habitat will be sufficient to achieve adult and juvenile abundance targets.

There is some uncertainty surrounding the attainment of temperature and habitat needs because factors such as final stream channel width and depths, channel configuration, and amount of floodplain and riparian habitat to be developed are still a work in progress.

Major issues are:

- Water temperature modeling suggests all adult spring-run Chinook salmon, and spring-run and fall-run juvenile Chinook salmon emigrants, will encounter water temperatures in the Restoration Area that will be near or exceed the upper threshold for migration in some water year types, dependent on adult run-timing. With limited flow allocation, water may need to be prioritized to increase survival of one run or life stage over the others.
- In some water year types, water temperature may limit spring-run Chinook salmon spawning to the first 5–10 miles below Friant Dam, and the first 5 miles can only support from 5,099–10,198 spawners (Gordon 2015, Science Symposium Presentation).

However, to improve temperature models to better address these questions, flows must first be restored to the river, which will happen in steps in the future.

3.3 Implementation of Physical and Fisheries Projects

The major physical and fisheries projects to be undertaken in the Restoration Area for the 5, 10, and 15-year Vision Periods are provided in Table 1a and 1b. A more detailed description of each of the projects can be found in the Revised Framework for Implementation (SJRRP 2015a). These projects are designed to reduce the biological, environmental and ecological stressors preventing the attainment of Program goals. The timing and effectiveness of each of these projects has a direct bearing on fish performance and establishment of spring-run and fall-run Chinook salmon in the Restoration Area.

The key milestones that will affect how the system will be operated over time are as follows:

- 2017[15] – Volitional juvenile out-migration possible year-round (connected river)
- 2018 – Conservation hatchery fully operational.
- 2019 – Volitional adult upstream migration possible.
- 2022 – Completion of Mendota Pool Bypass, Arroyo Canal Fish Screen, and Improved Sack Dam Fish Passage
- 2024 – Expected increase in juvenile migration survival rate due to increase in channel capacity resulting in higher spring pulse flows and lower temperatures.
- 2029 – Sufficient habitat available to achieve self-sustaining populations of spring-run and fall-run Chinook salmon.

3.4 Stream Flow

Stream flow in the Restoration Area is limited by multiple factors (SJRRP 2015a). Channel capacity constraints of the SJRRP will gradually be reduced over time, allowing more flow through the river (Table 19). There are no flow constraints in Reach 1.

Table 19. Channel capacity schedule 2015–2030+

Vision Period	Year	Reach 2B Capacity (cfs)	Levee Capacity Maximum (cfs)	Ground-water Seepage Maximum (cfs)	Maximum Friant Dam Release (cfs)	Maximum Flow in Reach 4 (cfs)	Constraint on Maximum Flow (project)
5-year	2015–2019	1,120	580	900	1,490	580	Groundwater seepage, Levees
10-year	2020–2024	1,120	1,300	2,500	1,490	1,120	Reach 2B
15-year	2025–2029	4,500	2,500	2,500	2,725	2,500	Levees

[15] The target date for this milestone was updated to 2017. The original target date in the Revised Framework for Implementation (SJRRP 2015a) was 2016.

Vision Period	Year	Reach 2B Capacity (cfs)	Levee Capacity Maximum (cfs)	Ground-water Seepage Maximum (cfs)	Maximum Friant Dam Release (cfs)	Maximum Flow in Reach 4 (cfs)	Constraint on Maximum Flow (project)
Beyond 15-year	2030+	4,500	4,500	4,500	4,500	4,500	Levees

3.5 River Temperature

River temperature objectives are theorized to be met upon completion of all habitat projects and full implementation of Restoration Flows (Figures 4–8). The Program has conducted temperature modeling for future conditions in the system with the HEC 5Q river temperature model; however, this model has not been extensively calibrated for temperatures in the lower reaches of the river due to lack of flow in the system. Modeling shows that temperatures in the lower reaches are likely to remain cool during high spring pulse releases of several thousand cfs. After April, or if flows are lower, water temperatures in the lower river are likely to remain above Chinook salmon temperature thresholds.

Upon completion of all projects, several factors will affect whether river temperatures are sufficient to support spring-run and fall-run Chinook salmon, including adult and juvenile run-timing, water year type, environmental variability, and effectiveness of projects designed to maintain temperatures at biologically acceptable levels (Figure 9).

One issue of concern is the adult run-timing of spring-run Chinook salmon. Currently, it is theorized that spring-run Chinook salmon adults will return from late February–May and will have to hold all summer in the river before spawning in late August–early October when temperatures can be quite high. There is also concern that San Joaquin River adult spring-run Chinook salmon run-timing may be more reflective of Sacramento River spring-run Chinook salmon, which occur in May and June when stream temperatures are even higher (USFWS 2012). If this occurs, flows may have to be managed to better protect adult spring-run Chinook salmon.

3.6 Juvenile Rearing Habitat

The estimated amount of suitable juvenile rearing habitat presents in each reach during three time periods is shown in Table 20.

In addition to the estimates in Table 20, it is expected that seepage projects may result in some land acquisition and habitat measures. The extent of these projects is unknown at this point and is not included in Table 20. In addition, vegetation will become reestablished in all of the reaches of the river as a result of Restoration Flows. This will also increase the amount of suitable habitat primarily in Reaches 1B, 2A, 3, and 4A, but these increases are not included in

Table 20. A more detailed explanation of the assumptions used to develop Table 20 is provided in Appendix F.

Table 20. Estimated suitable juvenile habitat (acres) in the San Joaquin River over three time periods with implementation of the SJRRP

Year	1B	2A	2B	3	4A	4B1/ME SB	4B2 / LESB	5	Total
Current	56	104	71–178	62	56	0 / 88	281 / 18	371	930
2025	56	183	234	62	56	0 / 88	281 / 18	371	1,243
2030	56	183	234	62	56	245	281	371	1,488
Goal	109	183	144	203	76	54	19	23	811

Note: The routing decision for the Reach 4B1/East Side Bypass has not been finalized yet. This reach of the river will need to meet the juvenile habitat goal regardless of the routing decision. Suitable habitat acreages were not calculated for alternative in the Eastside Bypass but it is possible there will be considerable juvenile habitat available if this is the final flow routing decision.

3.7 Juvenile and Adult Passage Survival

The Program has identified adult and juvenile fish passage survival as a limiting factor in establishing and sustaining Chinook salmon populations within the system. Prior to completing physical projects and increasing flow capacity, passage for adults and juveniles will be compromised. After completion of physical projects and increased flow capacity, passage will still be compromised in low water years. In critical low water years, no flows are expected below Gravelly Ford, and in critical high and dry years low juvenile survival is expected and adult passage success is uncertain. Given these short-term and long-term concerns, the Program has been pursuing options to alleviate the passage stressor for adult and juvenile Chinook salmon.

3.7.1 Adult Trap and Haul

Currently, the Restoration Area has a number of structures that serve as passage barriers and others that have been identified as possible passage impediments. These barriers are expected to be alleviated by 2022 through completion of physical projects (SJRRP 2015a) and adequate flow levels. In 2012, the Program initiated an effort to capture adult fall-run Chinook salmon above Hills Ferry Barrier (near confluence with Merced River) and transport the fish above all passage barriers in the system to allow access to the spawning areas. Field crews installed fyke nets at locations above Hills Ferry Barrier and at the entrance to false migration barriers, and roaming crews looked for adult salmon in sloughs and canals.

The purpose of this effort was multi-fold: (1) to serve as a proof of concept to evaluate the future feasibility of adult trapping and transport; (2) to further the process of reintroduction by alleviating the adult passage stressor; and (3) to provide fish in the system to allow further studies on habitat use and spawning success, and to provide juveniles for additional studies during the spring.

Each year starting in 2012, the adult trapping effort has captured between 119 and 933 fall-run Chinook salmon. These fish were either released in Reach 1or spawned to produce juveniles to use in field studies the following spring. The mortality rate of captured fish was extremely low, and the released adults were able to build redds, spawn, and produce juveniles. Those spawning efforts concluded that the incubation survival rate was at a level comparable with other hatchery systems except for a few individual fish that were identified as being in poor shape or over ripe at the time of capture. Based on the results of the effort and review of efforts in other systems, adult trap and haul should be an effective tool to alleviate poor adult passage conditions.

The fall-run adults were able to successfully build redds, spawn, and produce juveniles in the system indicating that adult transport could be effective for furthering population establishment if other stressors can be alleviated.

In addition, the effort successfully supported several studies evaluating spawning site selection, spawning success of females, egg incubation success, and monitored juveniles. The specific results for each year are described in the annual reports that can be accessed through the Program's website (http://www.restoresjr.net/).

The Program plans to expand the trap and haul effort for returning spring-run adults in conjunction with a monitoring effort. In essence, the Program will conduct monitoring to identify any returning spring-run Chinook salmon. Once spring-run Chinook salmon adults are identified, the capture and transport effort will be initiated following similar protocols to those followed for fall-run Chinook salmon.

Trap and haul may be used to transport adults to the spawning grounds until volitional passage is established. During the initial years of volitional passage, the Program will implement a monitoring effort to ensure adults are able to successfully migrate to the spawning grounds and will be prepared to implement the trap and haul program as necessary.

The Program plans to keep this tool in place to alleviate passage concerns in low water years for both spring-run and fall-run Chinook salmon. In critical water years, the Restoration Area will not be able to support passage, and the Program will implement the trap and haul program to avoid complete year class failures. The Program may also use trap and haul in non-critical years if results from monitoring indicate that volitional passage is not likely to be successful.

3.7.2 Juvenile Trap and Haul

Juvenile migration success has been identified as a potential limiting factor for establishing and sustaining spring-run and fall-run Chinook salmon populations in the San Joaquin River (SJRRP 2012d). Based on the review of efforts in other systems and evaluation of the conditions in the Restoration Area, the Program recognized that the potential for implementing a successful juvenile trap and haul program was less certain than the prospects for developing an adult program. Therefore, the juvenile trap and haul program was implemented as an experimental effort to develop methods and evaluate the feasibility of using trap and haul as a tool for overcoming poor juvenile migration conditions. The evaluation and development effort has not been completed and is ongoing.

Similar to the adult effort, the need for juvenile migration assistance serves a short-term and long-term purpose. In the short term, volitional juvenile passage success is expected to be zero until flow connectivity is established and screening projects are completed. In the long-term, juvenile migration success is expected to be minimal in critical low water years and low in other dry water years.

In 2014, the Program initiated a 3-year pilot effort to determine the feasibility of developing a juvenile trap and haul system. In addition, the Program identified a number of questions to evaluate the utility of such a system:

- Where is the best location for a trapping system?
- What type of trapping methods should be used? Is a permanent structure necessary, or can a temporary system be successful?
- Under what conditions would a trap and haul effort be implemented?
- Can flow management be used to increase the success of a trap and haul effort?

Determining the best location to trap juveniles to be transported out of the system requires consideration of many factors. The trap location should be high enough in the system that river flow is maintained in low water years. Under the Settlement hydrographs, no flow is expected below Gravelly Ford in critical low years, so the trapping location would need to be above this location to be successful in critical low years. Further, the trapping location must be close enough to the spawning grounds that enough juveniles will survive to the trapping site. Ideally the trapping site would also be low enough in the system that only migrating fish would be captured and transported. This factor is especially important for spring-run Chinook salmon, which may spend a year in freshwater before beginning their migration to the ocean. Moving fish out of the rearing area in Reach 1 before they are prepared to migrate may cause additional mortality due to poor rearing conditions in the lower river.

The Program conducted a literature review of juvenile trapping efforts used in other systems (see Appendix G). This analysis generally indicated that trapping efficiency increases with the level of infrastructure and cost. There are no planned construction projects in Reach 1 of the Restoration Area, so any trapping effort high enough in the system to be effective in critical water years would be an additional construction project. Implementing a high infrastructure project might serve the Program's long-term purpose but would not be useful in the short term because Restoration Flows and some physical projects would need to be completed prior to the trapping structure being constructed. In implementing the pilot effort, the Program tested a few rapidly deployed mobile systems and determined that a weir type system was the most effective.

Finally, the Program will need to determine when to implement a trap and haul system. Conceptually, trap and haul would be used when it substantially increases the survival of juveniles migrating through the system. When flows are extremely low, the decision would be easy, but the Program would conduct paired survival studies during intermediate years to help determine the appropriateness of implementing the trap and haul system. The objective of the Program is to limit human intervention and allow fish to migrate volitionally and would only implement a trapping effort when it is deemed beneficial to sustaining or establishing a population.

During the pilot implementation phase, trapping efficiencies were not high enough to successfully support a population level benefit. Low capture numbers may have been exacerbated by low production and survival, leading to fewer individuals available to be captured. Trapping efficiency tests and juvenile survival studies indicate survival and migration rates are as important as trap efficiency. The Program implemented a series of flow pulses to increase movement and survival of juvenile salmon and found catch rates increased substantially with flows. Survival rates may increase in a restored system that has consistent flows even during low water years, due to the disruption of predator populations. Also, the trapping system itself may affect the movement rates and survival of juvenile salmon by changing the flow pattern and creating conditions that increase predation rates. The prospect of developing a juvenile trap and haul system will require further research into the factors that affect survival as well as improving capture efficiency at the structure.

3.8 Hatchery Operations

As described in Section 3.4, the Program has adopted two different approaches for reintroducing spring-run and fall-run Chinook salmon into the system: (1) volitional strategy for fall-run Chinook salmon, and (2) artificial propagation for spring-run Chinook salmon. The majority of artificially propagated spring-run Chinook salmon will come from the SCARF below Friant Dam and the Interim SCARF prior to SCARF being constructed.

3.8.1 Salmon Conservation and Research Facility (SCARF) Operations

The SCARF will be a conservation-style hatchery used to help establish spring-run Chinook salmon in the Restoration Area. It is expected to be completed and operational in the spring of 2018. In the interim, the CDFW is operating a temporary, small-scale conservation facility (Interim SCARF) capable of raising four different cohorts of spring-run broodstock, at approximately one tenth of the capacity of the full-scale SCARF. The SJRRP also operates a satellite incubation and rearing facility (SIRF), located just below Friant Dam, 1.5 km upstream of the SCARF/Interim SCARF location.

The SCARF will be constructed adjacent to the San Joaquin River, just south of the existing San Joaquin (trout) Hatchery in Friant, CA, adjacent to the current Interim SCARF. When complete, the SCARF will consist of a main hatchery building and outdoor broodstock and juvenile rearing tanks with volitional release channels. Once the SCARF is operational, it will be capable of producing up to one million smolts annually for release to the Restoration Area.

Initial broodstock for captive breeding is being collected from Feather River Hatchery (FRH), and donor stocks could eventually be expanded to include Butte Creek and other extant spring-run Chinook salmon populations in the Central Valley (SJRRP 2010b). The objective of the multi-stock strategy at the SCARF is to develop a genetically diverse source of broodstock for the Program without increasing the extinction risk of the donor populations. When there are returning adults in the Restoration Area, broodstock will also be collected from the San Joaquin River population.

Hatchery facilities will be operated as an integrated program consisting of a composite population of fish that spawn both in the hatchery and in the wild (i.e., naturally). A primary goal of an integrated program is to increase adult abundance while minimizing genetic divergence of the hatchery component from the naturally spawning population component (see Section 3.4).

Hatchery operations are described in detail in the Program's HGMP (SJRRP 2016). Key milestones for hatchery operations are provided in Table 21.

Table 21. Major Conservation Program Milestones by Vision Period

Five-year Vision 2015-2019	Ten-year Vision 2020-2024	Fifteen-year Vision 2025-2029	Beyond Fifteen-year Vision 2030+
2015- SCARF spawning of spring-run Chinook salmon begins 2016- Potential first adult returns of releases (Permit 17781) 2016- Ancillary adult spring-run Chinook salmon broodstock reintroduced to Restoration Area 2017- Full scale SCARF construction begins 2018- Full scale SCARF construction complete; full scale operations begin 2018- Interim SCARF repurposed 2018- Import wild fish from other spring-run Chinook salmon populations	2022- First full-scale hatchery production release 2023- Possible collection of broodstock from Deer and Mill creeks 2023- First unaided returns of spring-run Chinook salmon 2024- Possible end of wild fish import from other populations 2024- First significant number of adult spring-run Chinook salmon HOR returns	2025-2029- Full-scale hatchery production continues 2028- Evaluate continuing need for hatchery production 2025-2029- PNI >0.67	2030+- Significant natural production 2031- Fish in first full-scale release will have spawned three times 2032- <15% of total adult natural production is of hatchery origin (i.e., pHOS <15%) 2032+- Hatchery production phased out once population goals and objectives are achieved/met

3.8.2 Interim SCARF

The small-scale Interim SCARF has been in operation since fall 2010. The SJRRP began collecting spring-run donor stock from FRH in 2012 and first spawned adult broodstock in fall 2015 when brood year (BY) 2012 attained sexual maturity. Since 2010, additional tanks, egg incubation equipment, water recirculation and chiller equipment were installed to meet production targets. When the SCARF is operational, the Interim SCARF will be repurposed for other Program-related activities such as additional spawning and rearing, quarantine/holding of natural origin broodstock, fish rescue refugia (e.g., during periods of high water temperatures), and/or targeted research.

3.8.3 Satellite Incubation and Rearing Facility (SIRF)

The Satellite Incubation and Rearing Facility (SIRF) is a temporary facility near Friant Dam that uses a trailer for spawning and egg incubation, as well as four self-contained rearing units. Currently it is used for small scale spawning of fall-run Chinook salmon, providing juveniles for research and monitoring. Beginning in 2016, spring-run Chinook salmon translocated from FRH as eyed-eggs were incubated and reared at the SIRF before being released to the San Joaquin River. Although the SJRRP currently does not have plans for hatchery production of fall-run Chinook salmon, the Restoration Administrator recommended that the SJRRP consider using captive propagation to establish fall-run Chinook salmon in the early years of the Program and consider initiating a hatchery program in the future if the establishment of fall-run Chinook salmon through volitional colonization is not effective (Hanson et al. 2008)[16].

3.9 Segregation of Spring-run and Fall-run Chinook Salmon

As the Program establishes populations of both spring-run and fall-run Chinook salmon in the Restoration Area, the potential exists for these populations to interbreed or interfere with successful spawning through redd superimposition. Although spring-run and fall-run Chinook salmon have different spawn timing, enough overlap may exist such that in the absence of any management efforts to preclude hybridization, introgression may occur in the Restoration Area (Tomalty et al. 2014).

Tomalty et al. (2014) examined the causes and consequences of hybridization of Chinook salmon runs in the San Joaquin River and provided the following observations:

- Hybridization is defined as the mating and production of offspring by individuals from genetically distinct groups, be they species or genetically divergent populations within a single species.
- In the San Joaquin, overlap in migration spawn timing and lack of spatial separation between spring-run and fall-run Chinook salmon runs would likely create conditions that encourage introgression. However, at this time, little is known about spring-run Chinook salmon spawn timing or habitat selection.
- If introgression occurs, it has the potential to lead to the loss of distinct spring-run and fall-run phenotypes and/or genotypes.
- If introgression leads to a situation where distinct phenotypes are lost, the population may consist primarily of hybrids.

[16] Currently, the Program is conducting spawning of fall-run adults captured above Hills Ferry Barrier. The juveniles produced from this effort have been used for juvenile studies in Reach 1 of the Restoration Area, or released into the river below migration barriers.

- Or, run timing phenotypes may be preserved, but the genetic distinction between runs may be lost.

The NMFS 10(a)(1)(A) permit 17781 requires the USFWS to develop a segregation protocol to ensure, to the greatest extent possible, the prevention of: (1) genetic introgression of fall-run Chinook salmon with spring-run Chinook salmon, and (2) superimposition of fall-run Chinook salmon redds on spring-run Chinook salmon redds (79 FR 26944).

Both of these factors can reduce the survival and performance of spring-run Chinook salmon. These concerns and their scientific support are discussed in more detail in the HGMP (SJRRP 2016), the 10(a)(1)(A) permit application,[17] and Appendix D. This section summarizes the segregation protocol recommendations in the HGMP and the 10(a)(1)(A) permit application and includes the draft implementation dates identified in the permit application. See Appendix E for the full segregation protocol recommendations from the NMFS 10(a)(1)(A) permit application.

Some of the key recommendations from the HGMP were summarized in the draft segregation protocol developed for the NMFS 10(a)(1)(A) application as follows:

1) High priority to reduce hybridization between spring-run and fall-run Chinook salmon.
2) A performance measure for genetic introgression should be established with data collected and reported.
3) Genetic analysis should be used to evaluate the degree of hybridization occurring in re-established spring-run Chinook salmon population.
4) Placement and use of a segregation weir should be evaluated.
5) Carrying capacity of the spawning habitat should be evaluated.
6) Flow management should be used to help segregate runs.
7) Marking and tagging techniques should be used to distinguish between runs.

Total "prevention" of introgression might not be possible because there may be fish with one genotype exhibiting the other phenotype. For example, in the Feather River, a few adult salmon with a fall-run Chinook salmon genotype migrate in spring and a few adult salmon with a spring-run Chinook salmon genotype migrate in the fall. If this occurs in the Restoration Area, it will not be possible to completely segregate the two runs.

However, the Genetics Subgroup concluded a low rate of genetic introgression (< 2 percent) will not have serious consequences to spring-run Chinook salmon and may actually facilitate the adaptation of reintroduced spring-run fish to environmental conditions in the Restoration Area.

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[17] USFWS will apply for the permit from NMFS in 2017.

The March 12, 2014 recommendation of the Genetics Subgroup is to monitor the level of introgression to ensure there is no loss of the spring-run Chinook salmon phenotype due to genetic introgression. Following their recommendation, a segregation weir would be used only if monitoring determines genetic introgression is likely to exceed 2 percent, there is fall-run Chinook salmon superimposition on spring-run Chinook salmon redds, and it is determined that a segregation weir could be effective in the Restoration Area. Another option is to limit fall-run Chinook salmon access to the Restoration Area until after spring-run Chinook salmon spawning is completed.

There are many questions about the need to manage interactions between spring-run and fall-run Chinook salmon and the effectiveness of potential strategies. Therefore, the draft protocol described below focuses on actions to be implemented during the initial 5-year time frame of the 10(a)(1)(A) permit 17781, which expires on December 31, 2019. These actions are designed to reduce the risk of genetic introgression and redd superimposition while informing the long-term, adaptive strategy for managing the two runs in the Restoration Area.

The Program has identified several questions that will be evaluated during the first few years of protocol implementation.

1. *Will spring-run and fall-run Chinook salmon segregate spatially within the Restoration Area thus resulting in little risk of genetic introgression or superimposition?*

One hypothesis for how spring-run and fall-run Chinook salmon will interact within the Restoration Area is that the two runs will have very little interaction with each other. The two runs may segregate spatially if seasonal shifts in water temperature influence spring-run Chinook salmon to primarily use habitat closer to Friant Dam and fall-run Chinook salmon to use habitat lower in the Restoration Area. They may also use different portions of the habitat within the stream channel. Spring-run Chinook salmon may spawn toward the center of the channel whereas fall-run Chinook salmon may be more likely to spawn in habitat toward the margins of the stream channel (Stillwater 2003).

The Program has been monitoring fall-run Chinook salmon spawning site selection and timing for the past few years. Fall-run Chinook salmon were translocated to the river below the spawning area, so they could naturally select redd locations. Similarly, spring-run Chinook salmon holding behavior, spawning site selection, and spawn timing will be examined by monitoring ancillary broodstock that will be released from the SCARF into Reach 1. Ancillary broodstock will be released in the spring/summer when natural sub-adult spring-run Chinook salmon would be expected to be returning from the sea.

Spawning site selection is likely to vary on an annual basis due to environmental conditions and population size. The first few years of spring-run Chinook salmon returns will provide initial insights into available habitat and timing of spawning. Continual monitoring will be required as flows increase, in different water year types, and as spring-run Chinook salmon adult returns increase.

2. *Will spring-run and fall-run Chinook salmon segregate temporally in the Restoration Area resulting in little risk of genetic introgression?*

It is possible spring-run Chinook salmon spawning will be completed by the time fall-run Chinook salmon spawning begins, which would minimize the chance of hybridization. If the two runs spawn during distinct time frames, the risk of genetic introgression will be minimal. However, the Program will still need to evaluate whether spring-run Chinook salmon redds need to be protected from superimposition from fall-run Chinook salmon.

3. *Can a segregation weir be effective for separating spring-run and fall-run Chinook salmon during spawning?*

Although segregation weirs have been used to separate spring-run and fall-run Chinook salmon in other systems, several factors must be addressed to determine if it can be an effective tool within the Restoration Area. If spring-run Chinook salmon spawn throughout the entire range of suitable spawning habitat, a segregation weir would not preclude spring-run and fall-run Chinook salmon from having some habitat overlap, assuming both runs are allowed to spawn in the Restoration Area. If spring-run Chinook salmon do spawn throughout the entire range of available habitat, the Program would need to decide how much habitat should be protected for spring-run Chinook salmon. The effectiveness of a weir also depends on finding a suitable location to construct and operate a segregation weir.

As information addressing these and more specific questions becomes available to the Program, annual strategies will be adjusted by Program managers.

3.9.1 Implementation of Segregation Protocols: 2016–2019

Fish passage will likely remain mostly blocked under normal conditions during this time period, which will allow the Program to control when and how many spring and fall-run Chinook are able to access the spawning area.

Tissue samples will be collected from all fish for genetic analysis and fish will be externally marked. Regular monitoring of these fish will occur over the summer to determine whether they find suitable holding habitat and hold successfully in cool pools over the summer. Beginning in late August and continuing into October, it is anticipated that spring-run Chinook salmon adults will move into spawning habitat and spawn. Redd and carcass surveys will be conducted to recover post-spawn fish and document redd locations.

From October–December, returning fall-run Chinook salmon will attempt to reach the Restoration Area. If spring-run Chinook salmon are spawning in Reach 1, fall-run Chinook salmon would be transported only after spring-run Chinook salmon have completed spawning to minimize the potential for any introgression. If no spring-run Chinook salmon are spawning in Reach 1, trapping and transporting of fall-run Chinook salmon adults could take place as soon as they enter the Restoration Area. The Program will also test the ability to protect spring-run Chinook salmon redds with physical barriers (“redd grates”) and evaluate the likelihood of fall-run Chinook salmon superimposition. Since only a limited number of spring-run Chinook salmon redds are anticipated during the first years of the reintroduction period, the Program will be able to deploy and monitor redd grates for all spring-run Chinook salmon redds as permitted.

This strategy will allow Program managers to learn where spring-run and fall-run Chinook salmon choose to spawn and whether fall-run Chinook salmon may damage spring-run Chinook salmon redds. Studies of the effects of flow management on run segregation are not likely to occur during the initial 5-year time frame because Reach 1 is not expected to be volitionally accessible by adult salmon.

During this same period, potential locations, designs, and operations of segregation weirs can be evaluated and tested. The effectiveness of all passage facilities constructed in the Restoration Area will be evaluated to assess their ability to limit or block migrating adult fall-run Chinook salmon. Such facilities may be the most cost-effective means of managing spring-run/fall-run Chinook salmon interactions when passage is restored, rather than operating an independent segregation weir. In addition, spawning habitat carrying capacity will be evaluated and both physical and biological study results will be finalized.

Prior to passage being restored and expiration of this time frame, a revised segregation protocol will be developed that reflects changes due to fish passage and study results during the initial period. This protocol will include relevant information such as population estimates, spawning locations and timing, genetic analysis results, effectiveness of physical barriers tested, and segregation weir evaluations.

3.9.2 Segregation Protocols: 2020+

Segregation protocols, if needed, will be based on the results of testing conducted from 2015-2019.

3.10 Spring-run Chinook Salmon Reintroduction Phases

Spring-run Chinook salmon reintroduction will be implemented in three phases: Recolonization, Local Adaptation and Full Restoration. Each of the three phases has different biological and population objectives as described below.

Program phase will be adjusted based on the specific triggers described below. Program phase will be reviewed annually as part of the Adaptive Management process described in Section 3.1.

3.10.1 Recolonization

The Program initiated the Recolonization Phase for spring-run Chinook salmon in 2014 by releasing 54,000 juveniles from the Feather River Fish Hatchery into the Restoration Area. The Program will remain in the Recolonization Phase until the 5-year running average adult NOR spawning escapement is equal to or exceeds 500 fish. The population size associated with a low risk of extinction is defined as an effective natural spawner population size (Ne) of > 500 fish or a census size (N) of > 2,500 (Lindley et al. 2007). The 500-fish target is based on what is deemed the minimum annual adult abundance to maintain an effective and viable population assuming a 50:50 sex ratio (SJRRP 2010a, SJRRP 2016). Biological and population objectives for this phase of the Program are:

- Increase spring-run Chinook salmon NOR abundance
    - Population Objective – NOR adult abundance of 500 fish (5-year running average)
    - Biological Objective – Redd superimposition rate of < 10 percent (per brood year)

- Increase the number of adult spring-run Chinook salmon spawning naturally
  - Population Objective – NOR + HOR natural spawning escapement of > 3,000 (5-year running average)
- Increase genetic diversity and identity of the spring-run Chinook salmon population
  - Biological Objective – Incorporate NOR spring-run Chinook salmon from other Central Valley populations into broodstock (minimum 4–8 years)[18]
  - Biological Objective – Introgression rate with fall-run Chinook salmon of < 2 percent (per brood year)
- Establish hatchery production of spring-run Chinook salmon
  - Population Objective – HOR adult abundance > 2,500 (5-year running average)
  - Biological Objective – Use only spring-run Chinook salmon for broodstock
  - Biological Objective – Release one million hatchery spring-run Chinook salmon juveniles
- Establish adult and juvenile volitional fish passage
  - Biological Objective – Adult upstream passage survival rate of > 90 percent
  - Biological Objective – Juvenile downstream passage survival rate of > 70 percent

3.10.1.1 Adult Management

In the Recolonization Phase, the Program will rely on hatchery production to facilitate population building and thereby contribute to the achievement of the adult abundance objectives (SJRRP 2010b, SJRRP 2016). The management priority for returning HOR adults is first for hatchery broodstock (if needed[19]), and second to meet the 3,000 (NOR + HOR) adult natural spawning escapement target. No restrictions will be placed on the number of spring-run Chinook salmon HORs spawning naturally (i.e., pHOS), as the goal is to increase fish abundance in the Restoration Area.

Prior to volitional passage being restored, adults collected for broodstock in the Restoration Area will be collected at a site downstream of existing fish passage barriers. All adults collected as broodstock will be genetically sampled to ensure only spring-run Chinook salmon are used for broodstock (SJRRP 2016). In addition, the Program intends to incorporate fish from other natural origin spring-run Chinook populations into the broodstock for 4–8 years once the Program has obtained the necessary permits and the SCARF is operational. This action is designed to increase population genetic diversity, which will allow natural selection to occur to help facilitate local adaptation.

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[18] The number of fish to be imported and their origin is described in the HGMP for the program.

[19] If captive broodstock can meet all hatchery production needs, all returning HOR adults would be allowed to spawn naturally. The 2016 HGMP anticipates using NOR and HOR adult returns for broodstock over time.

Until upstream volitional passage is established (2024), all captured adults not used for broodstock or testing will be transported and released near the spawning grounds in reaches that exhibit protective water temperatures (< 20˚C). The adult trap and haul program may be implemented when adults are unable to migrate volitionally to suitable holding and spawning habitat or if adult pre-spawn survival is less than the Program's target of 85 percent (SJRRP 2010a).

3.10.1.1.1 Introgression and Redd Superimposition

The Program's biological objective is to maintain the spring-run and fall-run introgression rate below 2 percent (see Appendix E; SJRRP 2015b). A 2 percent introgression rate would result in a less than 20 percent decrease in adult abundance potential (see Appendix D, Table 3). The program will test the need for, and effectiveness of, weirs, river flow, and adult release timing and numbers to maintain spatial and temporal separation of the two runs (see Appendix E).

Introgression testing may occur for five years. At the end of the study period, if managers determine the introgression criterion could not be achieved, one or more of the following management actions may be implemented:

- Prioritize spring-run Chinook salmon for reintroduction.
- Control the number and timing of fall-run Chinook salmon released to the Restoration Area.
- Construct weirs or alter the flow regime to prevent fall-run Chinook salmon from spawning in the same area as spring-run Chinook salmon.
- Other actions identified as a result of M&E.

As the number of adult spring-run and fall-run Chinook salmon increases toward the long-term abundance target (40,000 adults), competition for spawning habitat is expected to become intense. As spawning densities increase, there is a high probability later spawning fall-run Chinook salmon will superimpose their redds onto spring-run Chinook salmon redds. Redd superimposition has the potential to reduce egg survival rates for spring-run Chinook salmon, which in turn reduces spring-run abundance and productivity.

The Program expects to achieve a redd superimposition rate of less than 10 percent. If this rate is exceeded, additional management actions, similar to those proposed for introgression, will be implemented until the criterion is achieved or abandoned.

3.10.1.2 Harvest

The program will operate under the assumption that the total fishery exploitation rates for spring-run and fall-run Chinook salmon will average 50 percent, as described in Section 3.5. If the program fails to meet adult return targets while meeting juvenile escapement targets, it may be necessary to verify program assumptions related to fishery exploitation or other potential adult fish losses.

3.10.1.3 Juvenile Management

HOR spring-run Chinook salmon juveniles will be released into the Restoration Area at the highest upstream point of river connectivity or in locations that are hypothesized to maximize survival and adult return rates with minimal straying. Hatchery fish released into the Restoration Area can be used to estimate juvenile survival, behavior and adult production from different release strategies. The exact number of juveniles released each year will depend on study design and statistical precision requirements.

All HOR juveniles will be ad-clipped and coded wire tagged. This action allows for calculation of SARs and allows managers to estimate the number of Restoration Area spring-run Chinook salmon captured during operations of the Central Valley Project and State Water Project. Genetic sampling of naturally spawning adults (Parentage Based Tagging [PBT]) and juvenile offspring may also be conducted to determine the number of naturally produced Chinook salmon captured at these locations during their outmigration.

A juvenile trap and haul program may be used to move juvenile fish out of the Restoration Area when fish are unable to emigrate volitionally from the Restoration Area. Further, juvenile trap and haul may be implemented to mitigate the effects of poor survival despite having volitional passage. As Interim flows connect the river, the survival rate of migrating juveniles is expected to be very low (<70 percent) with the exception of high flow years (SJRRP 2012d).

The total juvenile fish passage survival objective for the Program is 70 percent for fish greater than 70 mm. No juvenile passage survival criterion was established for fish less than 70 mm due to difficulty in separating rearing mortality from passage mortality (SJRRP 2010a).

The decision to implement juvenile Chinook salmon trap and haul to mitigate passage or survival issues will be made annually. The decision will be based on expected natural origin juvenile production, water year type, stream temperatures, system configuration, effectiveness of collection facilities, SAR of volitional migrants and transported fish, and adult stray rate of transported salmon.

Downstream passage facilities will be designed to achieve NMFS screening and design criteria for anadromous salmonids (Table 7). Criteria will apply both to the screening systems and outfalls where fish are returned to the river to continue their migration. Expected juvenile passage success through the Restoration Area will be greater than 70 percent.

3.10.1.4 Decision Rules

The Decision Rules used to manage spring-run Chinook salmon during the Recolonization Phase are as follows:

1. Phase ends when the 5-year running average NOR adult abundance exceeds 500 salmon.

2. Priority for returning HOR adults is (1) hatchery broodstock (if needed) and (2) natural escapement.

3. Adult trap and haul program may be implemented when adults are unable to migrate volitionally, at a high rate of survival (> 90 percent) to suitable holding and spawning habitat or if adult pre-spawn survival is less than the Program's target of 85 percent.

4. Additional management actions will be implemented if introgression exceeds 2 percent.

5. Additional management actions will be implemented if redd superimposition is greater than 10 percent.

6. Existing fish passage barriers will be evaluated and/or modified if found not to comply with NMFS criteria for juvenile or adult spring-run Chinook salmon (Table 7).

7. Juvenile trap and haul may be operated when fish are unable to emigrate volitionally through the Restoration Area or have poor survival (survival rate < 70 percent) within the Restoration Area.

8. Initially, the Program may import wild spring-run Chinook salmon for use as broodstock. This decision will be reevaluated in 2024 (see Table 21).

3.10.2 Local Adaptation

The Program will remain in the Local Adaptation Phase until the annual minimum abundance of NORs is equal to or exceeds 500 individuals and the 5-year running average adult NOR spawning escapement is between 500–2,500 fish. The priority in this phase of the Program switches from reintroducing fish to vacant habitat to promoting local adaptation of the natural population. Key considerations are that the reintroduced population is self-sustaining, spatially and temporally distributed to avoid catastrophic losses, and with a large enough effective population size to maintain genetic variation for natural selection to act upon (SJRRP 2010a). While the focus on local adaptation implies a reduced contribution of hatchery fish to natural production, the hatchery still retains value in its ability to enhance population growth and as a demographic safety net in case of unexpected, severe declines in natural abundance.

Biological and population objectives for the Local Adaptation Phase are:

- Create a viable population of natural origin spawners
  - Population Objective – Achieve NOR spawner abundance of > 2,500 fish (5-year running average); minimum abundance of 500 NORs
  - Biological Objective – Use < 10 percent of NOR adults for broodstock
- Increase population fitness, reproductive success and life history diversity
  - Biological Objective – Establish a successful adult run and spawn-timing over multiple months
  - Biological Objective – Establish a minimum of three successful juvenile life histories including fry (≥ 20 percent of emigrating juveniles), parr (≥ 20 percent of emigrating juveniles), smolt (≥ 10 percent of emigrating juveniles), or yearling (≥ 10 percent of emigrating juveniles)
  - Biological Objective – Establish a minimum of three adult age classes for hatchery returns including a minimum of 10 percent age-two, 10 percent age-three, and 10 percent age-four individuals
  - Biological Objective – Achieve juvenile growth rate targets during the spring (0.4g/day) and summer (0.07g/day)

- Biological Objective – Achieve 70% juvenile passage survival throughout the Restoration Area

- Increase population productivity
  - Biological Objective – Produce a minimum of 44,000 NOR juveniles annually
  - Biological Objective – Achieve egg-to-fry survival rate target of ≥ 50 percent
  - Biological Objective – Achieve fry-to-juvenile survival rate target (subyearling 5 percent, yearling 2.5 percent)
  - Biological Objective – Achieve pre-spawn adult survival rate target of ≥ 85 percent
  - Biological Objective – Superimposition rate of < 10 percent (per brood year)
- Decrease hatchery influence on natural population
  - Biological Objective – Achieve PNI > 0.67 (4-year running average)[20]
  - Biological Objective – Reevaluate hatchery production levels
  - Biological Objective – HOR fish make up less than 15 percent of total spring-run Chinook salmon population[21]
  - Biological Objective – Use < 10 percent of NOR adults for broodstock
  - Maintain population genetic identity and diversity
  - Biological Objective – Introgression rate of < 2 percent (per brood year)
- Improve adult and juvenile fish passage survival rates
  - Biological Objective – Adult upstream passage survival rate of > 95 percent
  - Biological Objective – Juvenile downstream passage survival rate of > 90 percent[22]

3.10.2.1 Adult Management

The abundance objective is to achieve an adult spawning escapement of 2,500 NOR fish measured as a 5-year running average. This level of adult abundance is presumed to have low extinction risk based on its ability to maintain adequate genetic variation for natural selection to occur (Table 6). The Program will move to the Full Restoration Phase with achievement of the NOR adult spawning escapement objective.

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[20] The PNI criterion is described in the HGMP (SJRRP 2016).
[21] The 2016 HGMP states less than 15 percent of the Chinook salmon population should be of hatchery origin 10 years following full-scale releases from the SCARF in 2022 (FMP).
[22] These are the adult and juvenile survival rates needed to reach the Program's adult targets in the next phase of the program. Thus, they are higher than the initial fish passage assumptions.

In the Recolonization Phase, no restrictions were placed on the number of hatchery fish spawning naturally because the objective of this phase was to recolonize unoccupied habitat. In the Local Adaptation Phase, NOR and HOR adults on the spawning grounds and those being used for hatchery broodstock will be managed to achieve a PNI of > 0.67 (5-year average). The larger the PNI value, the more local adaptation is driven by the natural rather than the hatchery environment, which is theorized to increase population fitness and lead to higher abundance.

Managers will have the option to operate the Program at lower PNI levels during years when NOR abundance is less than 500 fish. At low adult escapement levels, it may be more important to achieve the minimum adult spawner escapement objective identified in the Recolonization Phase rather than the PNI objective. The decision is based on risk tolerance and is a policy decision to be made by managers.

The collection of broodstock from populations outside of the San Joaquin River may be terminated 8 years after the collections were initiated (SJRRP 2016) or when the NOR abundance target and the genetic objectives are met.

Hatchery juvenile production in this phase may be reduced over time as NOR abundance increases, to a level that yields a minimum of 500 HOR adults returning to the Restoration Area (SJRRP 2016). These adults will provide a genetic reserve of spring-run Chinook salmon that can be used to supplement the natural population in the event of catastrophic loss or periods of extended poor marine and/or freshwater productivity (e.g., drought).

3.10.2.1.1 Introgression and Superimposition By the time the Program enters the Local Adaptation Phase, studies on methods to achieve the introgression (< 2 percent) and superimposition (< 10 percent) objectives will have been completed and a preferred method implemented if necessary. If the introgression rate is still greater than 2 percent with the proposed solution in place, additional measures will be implemented until the criterion was achieved or altered by fisheries managers.

3.10.2.1.2 Harvest Multiple years of data will be available on harvest exploitation rates of Program spring-run Chinook salmon by the time this phase is implemented. These data will be reviewed in the context of adult escapement to determine if the adult spawner objective is likely to be achieved given the observed exploitation rate. Ocean survival is one of many factors affecting Program success and will be evaluated as data become available.

3.10.2.2 Juvenile Management

The number of NOR juveniles produced each year will vary depending on system configuration, environmental conditions, spawner abundance, and survival rates of early life stages (e.g., egg-to-juvenile). However, the Program will strive to achieve the juvenile production target (Table 7).

Ecosystem Diagnosis and Treatment (EDT) modeling results indicated environmental conditions may produce a winter fry life history that leaves the Restoration Area when less than 60 mm in length. If this occurs, the juvenile numbers assumed in the working hypothesis would need to be updated because the number of juveniles leaving the Restoration Area would increase dramatically (ICF 2014).

Downstream passage facilities will be designed to achieve NMFS screening and design criteria for anadromous salmonids (Table 7). Criteria will apply both to the screening systems and outfalls where fish are returned to the river to continue their migration. Expected adult and juvenile passage survival through the Restoration Area would be > 95 percent and > 90 percent, respectively[23].

A juvenile trap and haul program may occur when fish are unable to emigrate volitionally from the Restoration Area during critically dry water years. Further, juvenile trap and haul may be implemented to mitigate the effects of poor survival despite having volitional passage. Juvenile trap and haul would likely not be needed during most water years when volitional passage is complete, and the juvenile survival target is being met. The decision to allow juvenile Chinook salmon to migrate volitionally through the system each year will continue to be made annually.

Habitat actions including gravel augmentation and predator control may be implemented to achieve egg-to-fry survival rates ≥ 50 percent and fry-to-juvenile (> 70 mm) survival rates of ≥ 5 percent.

The number of hatchery juvenile fish released will decrease as NOR adult abundance increases. The Decision Rules used to reduce hatchery production are[24]:

- Hatchery production will be reduced by less than 50 percent when the 5-year running average NOR adult abundance is > 1,500.
- Hatchery production will be reduced by more than 50 percent when the 5-year running average NOR adult abundance is > 2,500.

The exact level of hatchery production will be determined by fisheries managers.

3.10.2.3 Decision Rules

The Decision Rules used to manage the Program in the Local Adaptation Phase are as follows:

1. Phase moves to Full Restoration when NOR adult abundance is equal to or exceeds an annual minimum of 500 fish for five consecutive years and the 5-year running average adult NOR spawning escapement is equal to or exceeds 2,500 fish.

2. Additional management actions (e.g., installation of segregation weirs) will be implemented if the introgression rate exceeds 2 percent.

3. Adult trap and haul may be used when fish are unable to migrate volitionally to suitable holding and spawning habitat during critically dry water years.

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[23] These are the adult and juvenile survival rates needed to reach the Program's adult targets in the next phase of the program. Thus, they are higher than the initial fish passage assumptions.

[24] The HGMP calls for hatchery production to be phased out as the natural population becomes established.

4. Additional management actions will be implemented if redd superimposition is greater than 10 percent.

5. Additional management actions (e.g., alternative flow regimes, gravel augmentation and predator control) may be implemented if pre-spawn survival rates are < 85 percent, egg-to-fry survival rates < 50 percent, growth rates do not meet targets, or fry-to-juvenile (> 70 mm) survival rates of < 5 percent.

6. Priority for returning HOR adults is (1) natural escapement, and (2) broodstock.

7. The collection of broodstock from populations outside of the San Joaquin River will be eliminated when HOR returns > 2,500 adults and genetic diversity targets are met. Broodstock would come from HOR and NOR adult returns.

8. Juvenile trap and haul may be operated when fish are unable to emigrate volitionally from the Restoration Area during critically dry water years.

9. Evaluate and reduce hatchery production of HOR juveniles when NOR adult abundance is greater than 1,500.

10. Managers would formally consider operating the Program under priorities outlined for the Recolonization Phase if NOR abundance is less than 500 adults two years in a row.

3.10.3 Full Restoration

The Program will enter the Full Restoration Phase when the annual minimum abundance of NOR fish is equal to or exceeds 500 individuals and the 5-year running average adult NOR spawning escapement exceeds 2,500 fish. In the Full Restoration Phase, biological and population objectives are as follows:

- Maintain a viable population of spring-run Chinook salmon
  - Population Objective – Achieve an average of 30,000 adult spawners
  - Biological Objective – Produce an annual average of 1,575,000 NOR juveniles
- Eliminate hatchery effects on natural population
  - Biological Objective – Eliminate hatchery production
- Maintain genetic identity and life history diversity
  - Biological Objective – Introgression rate of < 2 percent with fall-run Chinook salmon
  - Biological Objective – Maintain a minimum of three distinct juvenile life histories
  - Biological Objective – Maintain a minimum of three adult age classes for returning NOR spawners

3.10.3.1 Adult Management

Managers will formally consider terminating hatchery production in 2028 as called for in the HGMP or when NOR adult spawner abundance exceeds 2,500 fish (5-year running average), whichever occurs first. A population with this level of abundance and productivity is expected to have a low risk of extinction and is not likely to require hatchery supplementation to rebound from periods of low marine and freshwater productivity. The decision to terminate hatchery production of spring-run Chinook salmon will be made through formal consultation with NMFS.

Adult fish passage facilities will be monitored to ensure adult pre-spawn survival rate is greater than 85 percent and passage success rate is greater than or equal to 95 percent.

3.10.3.1.1 Introgression and Superimposition

The system will be managed to achieve introgression and superimposition rates of < 2 percent and < 10 percent, respectively.

3.10.3.2 Juvenile Management

Juvenile fish passage facilities will be monitored to ensure survival through the entire Restoration Area is greater than 90 percent during the majority of water year types.

3.10.3.3 Decision Rules

Decision Rules used to manage the Program in the Full Restoration Phase are as follows:

1. Formally evaluate the need for hatchery production in 2028 as called for in the HGMP or when NOR adult spawner abundance exceeds 2,500 (5-year running average), whichever comes first.

2. Implement additional mitigation measures if introgression rate is > 2 percent or superimposition rate is > 10 percent.

3. Adult trap and haul program may be implemented when adults are unable to migrate volitionally with high survival (> 90 percent) to suitable holding and spawning habitat during critically dry water years.

4. Juvenile trap and haul program may be implemented when juveniles are unable to emigrate volitionally at high survival (> 70 percent) from the Restoration Area during critically dry water years.

5. Managers will formally consider operating the Program under priorities outlined for the Local Adaptation Phase if NOR abundance averages less than 2,500 adults for five years or the Recolonization Phase if NOR abundance is less than 500 adults for two consecutive years.

3.11 Fall-run Chinook Salmon Reintroduction Phases

Similar to spring-run Chinook salmon, reintroduction of fall-run Chinook salmon will be implemented in three phases: Recolonization, Local Adaptation and Full Restoration. Each of the three phases has different biological and population objectives as described below.

Program phase will be adjusted based on the specific triggers described below. For example, the fall-run Chinook salmon Program will remain in the Recolonization Phase until natural NOR or HOR fall-run Chinook salmon adult spawning escapement in the Restoration Area is equal to or exceeds 500 fish for five consecutive years. Program phase will be reviewed annually as part of the Adaptive Management process described in Section 3.1.

3.11.1 Recolonization

The current trap and haul efforts (since 2012) were not the beginning of active reintroduction of fall-run Chinook salmon into the Restoration Area. Those efforts were designed to observe and learn about salmon in the upper reaches of the Restoration Area, and to gain knowledge and experience of trap and haul methods in the San Joaquin River. The Program will enter the Recolonization Phase for fall-run Chinook salmon when fall-run Chinook can successfully complete their life cycle, which will require (1) sufficient flows within the Restoration Area and (2) removal or modification of fish passage barriers within the Restoration Area to allow adequate passage for all life stages. However, the Program may initiate the Recolonization Phase for fall-run Chinook salmon prior to resolving passage constraints if effective tools, such as trap and haul programs, are established for both adult and juvenile life stages.

The Program will remain in the Recolonization Phase until natural NOR or HOR fall-run Chinook salmon adult spawning escapement in the Restoration Area is equal to or exceeds 500 fish for five consecutive years. The population size associated with a low risk of extinction is defined as an effective natural spawner population size of Ne > 500 fish or a census size (N) of > 2,500 (Lindley et al. 2007). The 500 fish target is based on what is deemed the minimum annual adult abundance to maintain a viable population assuming a 50:50 sex ratio (SJRRP 2010a, SJRRP 2016). Biological and population objectives for this phase of the Program are as follows:

- Increase fall-run Chinook salmon abundance
  - Population objective – HOR + NOR adult spawner abundance of 500 fish (5 consecutive years)
  - Biological Objective – Superimposition rate of < 10 percent (per brood year)
- Increase genetic diversity and identity of the fall-run Chinook salmon population
  - Biological objective – Introgression rate with spring-run of < 2 percent (per brood year)
- Establish adult and juvenile volitional fish passage
  - Biological objective – Adult upstream passage survival rate of 90 percent
  - Biological objective – Juvenile downstream passage survival rate of >70 percent

3.11.1.1 Adult Management

During the Recolonization Phase, the Program will be dependent on HOR and NOR fall-run Chinook salmon from other rivers within the San Joaquin River basin straying into the Restoration Area. No restrictions will be placed on the number of HOR fall-run Chinook salmon entering the Restoration Area as the objective in this phase is to increase fall-run abundance in the Restoration Area. However, the removal or modification of the Hills Ferry Barrier needs to occur or be assessed during this phase. Because Hills Ferry Barrier is funded outside of the Program as a mitigation measure, the removal or modification of the barrier will require the agreement of numerous stakeholders outside of the Program.

In years prior to volitional passage being restored, the program may use trap and haul to support the reintroduction process. A minimum of 500 adult fall-run Chinook salmon will be trapped and hauled to locations containing suitable spawning habitat in the Restoration Area each year consistent with segregation protocols. The adult trap and haul program may be implemented at any time thereafter when adults are unable to migrate volitionally to suitable spawning habitat or if adult pre-spawn survival is less than the Program's target of 85 percent.

Introgression testing may occur for five years when spring-run and fall-run Chinook salmon co-occur in the Restoration Area. If at the end of the study period managers determine that the introgression criterion (< 2 percent of spring-run) cannot be achieved, additional actions as described below will be implemented.

3.11.1.2 Introgression and Superimposition

The hypothesis for introgression is that the higher the introgression rate between spring-run and fall-run Chinook salmon, the greater the loss in Chinook salmon population fitness and resulting adult abundance (HSRG 2014). In addition, high rates of introgression may lead to the loss of distinct spring-run and fall-run phenotypes and/or genotypes (Tomalty et al. 2014).

The biological objective is to maintain an introgression rate between spring-run and fall-run Chinook salmon below two percent (see Appendix E; SJRRP 2015b). The program will test the effectiveness of weirs, river flow and adult release timing to maintain spatial and temporal separation of the two runs.

Introgression testing may occur for five years. If at the end of the study period managers determine that the introgression criterion cannot be achieved, one or more of the following management actions would be implemented:

- Prioritize spring-run Chinook salmon for reintroduction.
- Control the number and timing of fall-run Chinook salmon released to the Restoration Area.
- Construct weirs to prevent fall-run Chinook salmon from spawning in the same area as spring-run Chinook salmon.
- Abandon the criterion and allow the fish to develop the run-timing best adapted to the environmental conditions in the Restoration Area.

- Managers may implement actions such as the use of grating (covers redds), segregation weirs, or alternative flow regimes to prevent introgression between spring-run and fall-run Chinook salmon. This information will be used to determine the probability of introgression and redd superimposition.

As the number of adult spring-run and fall-run Chinook salmon increases toward the abundance target (40,000 adults), competition for spawning habitat is expected to become intense. As spawning densities increase, there is a high probability later spawning fall-run Chinook salmon will superimpose their redds on spring-run Chinook salmon redds. Redd superimposition has the potential to reduce egg survival rates for spring-run Chinook salmon and, in turn, reduce spring-run Chinook salmon abundance and productivity (YRDP 2013).

The Program expects to achieve a superimposition rate of less than 10 percent. If this rate is exceeded, additional management actions will be implemented until the criterion is achieved or abandoned.

3.11.1.3 Harvest

The Program will operate under the assumption that the total fishery exploitation rates for spring-run and fall-run Chinook salmon will average 50 percent, as described in Section 3.5. If the program fails to meet adult return targets while meeting juvenile escapement targets, it may be necessary to verify program assumptions related to fishery exploitation or other potential adult fish losses.

3.11.1.4 Juvenile Management

The Program may use a juvenile trap and haul program to move juvenile fish out of the Restoration Area when fish are unable to emigrate volitionally from the Restoration Area at a survival rate of > 70 percent. Further, juvenile trap and haul may be implemented to mitigate the effects of poor survival despite the presence of volitional passage. As Interim flows connect the river, the survival rate of migrating juveniles is expected to be low (< 70 percent) with the exception of high flow years (SJRRP 2012d).

The overall juvenile fish passage survival objective for the Program is 70 percent for fish greater than 70 mm. No juvenile passage criterion was established for fish less than 70 mm due to the difficulty in distinguishing rearing mortality from passage mortality.

The decision to allow juvenile fall-run Chinook salmon to migrate volitionally through the system each year will be made by managers. The decision will be based on expected natural origin juvenile production of both spring-run and fall-run Chinook salmon, water year type, stream temperatures, system configuration, effectiveness of collection facilities, SAR of volitional migrants and transported fish, and the adult stray rate of transported fish.

In addition, HOR juvenile fall-run Chinook salmon may be produced at the Program's SIRF to facilitate research in the Restoration Area and inform future adaptive management decisions. All HOR juveniles produced at the SIRF will be marked and will possess a CWT.

Downstream passage facilities will be designed to achieve NMFS screening and design criteria for anadromous salmonids (Table 7). Criteria would apply both to the screening systems and outfalls where fish are returned to the river to continue their migration. Expected juvenile passage success through the Restoration Area would be > 70 percent.

3.11.1.5 Decision Rules

The Decision Rules used to manage the program in the Recolonization Phase are as follows:

1. The Hills Ferry Barrier will be modified or removed based on discussions with managers.

2. The Recolonization Phase of fall-run Chinook salmon begins when (1) sufficient flows are maintained within the Restoration Area, (2) fish passage barriers within the Restoration Area have been removed or modified to allow adequate passage for all life-stages, and (3) the Hills Ferry Barrier has been removed or its operations modified to allow adult fall-run access to spawning habitat.

3. The Recolonization Phase ends when a five-year running average of NOR fall-run Chinook salmon adult spawning escapement to the Restoration Area is equal to or exceeds 500 fish.

4. The Program may initiate the Recolonization Phase for fall-run prior to resolving passage constraints (e.g., Hills Ferry Barrier) if effective and efficient trap and haul programs are established for both adult and juvenile life stages.

5. The adult trap and haul program may be implemented when adults are unable to migrate volitionally to suitable spawning habitat at a high rate of survival (> 90 percent) or if adult pre-spawn survival is less than the Program's target of 85 percent.

6. Additional management actions will be implemented if the introgression rate exceeds 2 percent.

7. Additional management actions will be implemented if the rate of redd superimposition is greater than 10 percent.

8. Existing fish passage barriers will be evaluated and/or modified if found not to comply with NMFS criteria for juvenile or adult fall-run Chinook salmon (Table 7).

9. Juvenile trap and haul may be operated when fish are unable to emigrate volitionally from or have poor survival (survival rate < 70 percent) within the Restoration Area.

3.11.2 Local Adaptation

The Program will remain in the Local Adaptation Phase until the annual minimum abundance of NORs is equal to or exceeds 500 individuals and the 5-year running average adult NOR spawning escapement is between 500–2,500 salmon. The priority in this phase of the Program switches from reintroducing fish to vacant habitat to promoting local adaptation of the natural population. Key considerations are that the reintroduced population is self-sustaining, spatially distributed to avoid catastrophic losses and has a large enough effective population size to maintain genetic variation for natural selection to act on (SJRRP 2010a).

Biological and population objectives for the Local Adaptation Phase are:

- Create a viable population of natural origin spawners.
    - Population Objective – Achieve NOR spawner abundance of > 2,500 fish (5-year running average); minimum annual abundance of 500 NOR fish
- Increase population fitness, reproductive success and life history diversity
    - Biological Objective – Establish successful adult run and spawn-timing over multiple months
    - Biological Objective – Establish a minimum of three successful juvenile life histories including fry (≥ 20 percent of emigrating juveniles), parr (≥ 20 percent of emigrating juveniles), smolt (≥ 10 percent of emigrating juveniles), or yearling (≥ 10 percent of emigrating juveniles)
    - Biological Objective – Achieve 70% juvenile survival throughout the restoration area
    - Biological Objective – Achieve the juvenile growth rate targets during the spring (0.4g/day) and summer (0.07g/day)
- Increase population productivity
    - Biological Objective – Produce a minimum of 63,000 NOR juveniles annually
    - Biological Objective – Achieve egg-to-fry survival rate target of ≥ 50 percent
    - Biological Objective – Achieve fry-to-juvenile (> 70 mm) survival rate target of ≥ 5 percent
    - Biological Objective – Achieve pre-spawn adult survival rate target of ≥ 85 percent
    - Biological Objective – Superimposition rate of < 10 percent (per brood year)
- Decrease hatchery influence on the natural population
    - Biological Objective – Reduce hatchery strays from outside the Restoration Area to < 5 percent of the total naturally spawning fall-run Chinook salmon population (i.e., pHOS < 5 percent)[25]
- Maintain population genetic identity and diversity
    - Biological Objective – Introgression rate with spring-run Chinook salmon of < 2 percent (per brood year)

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[25] To achieve this objective will require coordination and help from fisheries managers in other basins, specifically, a reduction in adult HOR strays from other programs.

  - Biological Objective – Introgression rate with HOR fall-run Chinook salmon from other rivers in the San Joaquin River basin of < 2 percent (per brood year)
- Improve adult and juvenile fish passage survival rates
  - Biological Objective – Adult upstream passage survival rate of > 95 percent
  - Biological Objective – Juvenile downstream passage survival rate of > 90 percent[26]

3.11.2.1 Adult Management

The biological objective is to achieve an adult spawning escapement of 2,500 NORs (measured as a 5-year running average), with at least 500 NORs returning each year. This level of adult abundance has low extinction risk (T) based on its ability to maintain genetic variation and allow natural selection to occur. The Program would move to the Full Restoration Phase when the NOR adult spawning escapement objective is achieved based on a 5-year running average of 2,500 NORs, with an annual minimum of 500 NORs.

A large number of hatchery strays from other fall-run Chinook salmon programs are expected to enter the Restoration Area once volitional passage is established. These fish will spawn with Program fall-run Chinook salmon, which may negatively affect population fitness (CA HSRG 2012). The data in Appendix D, Table 3 show that even at a low introgression rate of 2 percent, fitness is reduced to 0.85 of that of a fully fit Chinook salmon population. Management actions (e.g., adult sorting at the lowest passage facility) may be implemented to reduce the number of HOR fall-run Chinook salmon from other rivers spawning with NOR fall-run Chinook salmon from the Restoration Area.

In general, only 25 percent of the fall-run Chinook salmon strays from these hatchery programs are marked externally (ad-clip) and internally (CWT). Thus, 75 percent of the hatchery strays will not be distinguishable from naturally produced fall-run Chinook salmon from the Restoration Area. The Program may be able to use genetic analysis to distinguish HOR from NOR fish. This action would require that adult fish be held for a short period (2-3 days) to collect and analyze data.

3.11.2.1.1 Introgression and Superimposition

The biological objective in the Local Adaptation Phase is to achieve an introgression rate of less than 2 percent between (1) Program fall-run Chinook salmon and stray hatchery fall-run Chinook salmon from other rivers in the San Joaquin River basin, and (2) Program spring-run and fall-run Chinook salmon. Achievement of this criterion may require actions both within and outside of the Restoration Area. The actions designed to reduce the introgression rate with spring-run Chinook salmon are described under spring-run Chinook salmon management (Section 3.10).

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[26] These are the adult and juvenile survival rates needed to reach the Program's adult targets in the next phase of the program. Thus, they are higher than the initial fish passage assumptions.

Actions that would be used to achieve the less than 2 percent introgression rate with HOR fall-run Chinook salmon from other rivers in the basin are as follows:

- Reduce stray rates from other hatchery programs. This may entail working with managers of hatchery facilities in other basins to reduce the potential straying of hatchery fish.
- Work with agency fish managers to develop alternative marking and tagging procedures that would allow for identification of hatchery fall-run Chinook salmon adults that stray into the Restoration Area.
- Remove HOR fish at adult collection facilities below or at Sack Dam.
- Create a fall-run Chinook salmon population with a later migration timing than HOR fall-run Chinook salmon from other rivers in the basin.

The Program expects to achieve a redd superimposition rate of less than 10 percent. If this rate is exceeded, management actions in addition to those described for the Recolonization Phase would be implemented until the criterion is achieved or altered by managers.

3.11.2.1.2 Harvest Multiple years of data will be available on harvest exploitation rates of Program fall-run Chinook salmon by the time this phase is implemented. These data will be reviewed in the context of adult escapement to determine if the adult spawner objective is likely to be achieved given the observed exploitation rate. Ocean survival is one of many factors affecting Program success and will be evaluated as data become available.

3.11.2.2 Juvenile Management

The number of NOR juveniles produced each year will vary depending on system configuration, environmental conditions, spawner abundance, and survival rates of early life stages (e.g., egg-to-juvenile). However, the Program will strive to achieve the juvenile production target of at least 63,000 salmon.

Downstream passage facilities will be designed to achieve NMFS screening and design criteria for anadromous salmonids (Table 7). Criteria would apply both to the screening systems and outfalls where fish are returned to the river to continue their migration. Expected adult and juvenile passage survival through the Restoration Area would be > 90 percent.

A juvenile trap and haul program may occur when salmon are unable to emigrate volitionally at high survival rates (> 70 percent) from the Restoration Area during critically dry water years when the river is disconnected. Further, juvenile trap and haul may be implemented to mitigate the effects of poor survival despite the availability of volitional passage. Juvenile trap and haul would likely not be needed during most water years when volitional passage is complete, and the juvenile survival target is met. The decision to allow juvenile Chinook salmon to migrate volitionally through the Restoration Area each year will be made annually by managers.

Habitat actions including gravel augmentation and predator control may be implemented to achieve egg-to-fry survival rates of ≥ 50 percent and fry-to-juvenile survival rates of ≥ 5 percent.

3.11.2.3 Decision Rules

The Decision Rules used to manage the program in the Local Adaptation Phase are as follows:

1. This phase ends when fall-run Chinook salmon NOR adult spawning escapement to the Restoration Area is > 2,500 (5-year average).

2. Additional management actions will be implemented if fall-run Chinook salmon introgression with spring-run Chinook salmon exceeds 2 percent.

3. Additional management actions will be implemented if fall-run Chinook salmon introgression with stray HOR fall-run Chinook salmon exceeds 2 percent

4. Additional management actions (e.g., alternative flow regimes, gravel augmentation and predator control) may be implemented if pre-spawn survival rates are < 85 percent, egg-to-fry survival rates < 50 percent, growth rates do not meet targets, or fry-to-juvenile (> 70 mm) survival rates of < 5 percent.

5. Additional management actions will be implemented if spring-run Chinook salmon redd superimposition is greater than 10 percent.

6. Adult trap and haul program may be implemented when adults are unable to migrate volitionally, at high survival (> 90 percent) to suitable holding and spawning habitat during critically dry water years.

7. Juvenile trap and haul program may be implemented when juveniles are unable to emigrate volitionally, at high survival (> 70 percent) from the Restoration Area during critically dry water years.

8. Managers would formally consider operating the Program under priorities outlined for the Reintroduction Phase if NOR abundance is less than 500 adults two years in a row.

3.11.3 Full Restoration

The Program will enter the Full Restoration Phase when the annual minimum abundance of NOR fish is equal to or exceeds 500 individuals and the 5-year running average adult NOR spawning escapement exceeds 2,500 salmon. In the Full Restoration Phase, biological and population objectives are as follows:

- Maintain a viable population of fall-run Chinook salmon
  - Population Objective – Achieve an average of 10,000 NOR adult spawners
  - Population Objective – Produce an annual average of 750,000 NOR juveniles
- Maintain genetic identity and life history diversity
  - Biological Objective – Introgression rate of < 2 percent with spring-run Chinook salmon
  - Biological Objective – Introgression rate of < 2 percent with stray hatchery fall-run Chinook salmon
  - Biological Objective – Maintain a minimum of three distinct juvenile life histories

- Biological Objective – Maintain a minimum of three adult age classes for returning NOR spawners.

3.11.3.1 Adult Management

Adult fall-run Chinook salmon management in this phase would be highly dependent on the actions implemented in the Local Adaptation Phase. These include reducing the risks posed by hatchery strays from other fall-run Chinook salmon hatchery populations to attaining the adult NOR spawner abundance objective.

Adult fish passage facilities would be monitored to ensure that the adult pre-spawn survival rate is greater than 85 percent and passage survival rate is equal to or greater than 95 percent.

3.11.3.2 Introgression and Superimposition

The system would be managed to achieve introgression and redd superimposition rates of < 2 percent and < 10 percent, respectively.

3.11.3.3 Juvenile Management

Juvenile fish passage facilities would be monitored to ensure that survival through the entire Restoration Area is equal to or greater than 90 percent.

3.11.3.4 Decision Rules

Decision Rules used to manage the program in the Full Restoration Phase are as follows:

1. Implement additional mitigation measures if the introgression rate with spring-run Chinook salmon or hatchery fall-run Chinook salmon is > 2 percent.

2. Adult trap and haul program may be implemented when adults are unable to migrate volitionally, at high survival (> 90 percent) to suitable spawning habitat during critically dry water years.

3. Juvenile trap and haul program may be implemented when juveniles are unable to emigrate volitionally, at high survival (> 70 percent) from the Restoration Area during critically dry water years.

4. Managers would formally consider operating the Program under priorities outlined for the Local Adaptation Phase if NOR abundance averages less than 2,500 adults for five years or the Recolonization Phase if NOR abundance is less than 500 adults for two consecutive years.

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