Recommendations on Restoring Fall-run Chinook Salmon to the Upper San Joaquin River

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1 INTRODUCTION

The San Joaquin River Restoration Program Technical Advisory Committee (TAC) is required under the Stipulation of Settlement in *NRDC* v. *Rodgers* (CIV-S- 88-1658-LKK/GGH) (Settlement) to develop recommendations for interim and long-term population targets, goals and milestones for restoration of spring- and fall-run Chinook salmon, as well as recommendations on stock selection and strategies for reintroduction. The recommendations of the TAC are provided to the Restoration Administrator (RA) for consideration in preparing recommendations to the Secretary of the Interior for the targets, goals, and milestones as required under the Settlement.

The TAC previously provided recommendations for Central Valley spring-run Chinook salmon (TAC 2007); this document completes the TAC's responsibility by providing similar recommendations for fall-run Chinook salmon. Because there is considerable overlap in the rationale for the spring-run Chinook salmon recommendations with those for fall-run Chinook salmon, this report relies on much of that rationale, providing brevity in this document.

The TAC, which includes members from the California Department of Fish and Game (CDFG) and Department of Water Resources (DWR), with input from the federal implementing agencies, developed the following recommendations based on the best available information. These recommendations are intended to provide technical guidance as required by the Settlement based on the expertise of TAC members who have all worked on San Joaquin River restoration issues for many years. The TAC anticipates, and recommends in several places, the development of new information to further refine some of these recommendations.

2 INTERIM AND LONG-TERM TARGETS, GOALS, AND MILESTONES FOR FALL-RUN CHINOOK SALMON RESTORATION IN THE SAN JOAQUIN RIVER

As indicated in the recommendations on spring-run Chinook salmon (TAC 2007), the TAC is required under the Settlement to develop recommendations for interim and long term population targets, goals and milestones for restoration for both spring- and fall-run Chinook salmon. This document makes recommendations regarding fall-run Chinook salmon, using the structure and much of the information present in the spring-run Chinook salmon report (TAC 2007).

Here we present recommendations for interim and long-term goals, milestones, and targets for annual escapement of wild adult fall-run Chinook salmon, including late fall-run Chinook salmon. The goals, milestones, and targets for fall-run Chinook salmon, however, are complementary to the spring-run Chinook salmon goals, which, consistent with the Settlement, have the higher priority where conflicts develop. Establishing goals, milestones, and targets for fall-run Chinook salmon in the San Joaquin River is challenging for the same reasons given for spring-run Chinook salmon; however, they are essential to develop a successful program for restoring self-sustaining populations. Thus, in this document, we recommend goals, milestones, and targets for the re-establishment of fall-run Chinook salmon and provide rationales for the recommendations. As populations grow and better information develops, other factors may also have to be taken into consideration.

2.1 Goals and Objectives

The general goal for this effort is to *re-establish a self-sustaining population of Central Valley fall-run Chinook salmon in the upper San Joaquin River (between the mouth of the Merced River and Friant Dam), provided it does not interfere with re-establishment of spring-run Chinook salmon*. By “self-sustaining” we mean a population that maintains itself by completing its entire life cycle with no artificial propagation or migration assistance. Hatchery or other artificial propagation operations may be deployed for scientific evaluations, initial stock introduction, emergency population intervention, or adaptive management experiments. Accomplishing the goal may require a combination of Settlement and non-Settlement actions, such as improving habitat for all life stages, improving passage ways, providing good water quality, managing fisheries, and reducing human-caused sources of mortality. Beneath this general goal are three objectives that should be achieved in order to achieve the general goal.

1. *Establish a naturally-reproducing and self-sustaining population of fall-run Chinook salmon that is specifically adapted for conditions in the upper San Joaquin River (Friant Dam to mouth of Merced River*). In other words, allow natural selection to operate on the population to produce a strain that has its timing of upstream migration, spawning and outmigration, as well as its physiological and behavioral characteristics, adapted to the environmental conditions created by the Settlement. In this case, the nature of the Settlement flow regime indicates that it may be desirable to establish late-spawning (November-December) fall-run Chinook salmon from tributaries of the San Joaquin River (e.g., Merced or Tuolumne rivers), or use late fall-run Chinook salmon from the Sacramento River that spawn between January and April. Late fall-run Chinook salmon are recognized as distinct from fall-run Chinook salmon because of a number of life history differences and small genetic differences (Moyle 2002), although National Marine Fisheries Service (NMFS) places them together in one evolutionarily significant unit (ESU) (fall-run) because the genetic differences are limited.

2. *Establish a fall-run Chinook salmon population that is genetically diverse so that it is not subject to the genetic problems of small populations, such as founder effects and inbreeding*. The Settlement establishes a lower annual escapement threshold of 500 wild spring-run adult Chinook salmon as one of several criteria to be considered when evaluating requests for changes in restoration

flows and non-flow restoration measures (see section 2.3). While this Settlement criterion does not necessarily apply to fall-run Chinook salmon escapement, it does underscore the importance of both genetic and population viability associated with low salmon populations.

3. *Establish a fall-run Chinook salmon population that is demographically diverse in any given year, so returning adults represent more than two age classes*. Given the vagaries of ocean conditions, the likelihood of extreme droughts, and other factors that can stochastically affect salmon numbers in any given year, resiliency of the population requires that multiple cohorts be present. Chinook salmon populations in the Central Valley are dominated by three year old fish, plus two year old jacks, partly as the result of fisheries management. Both population resiliency and genetic diversity require that multiple age classes of adults (e.g., two, three, four, and five-year old Chinook salmon) be part of the population each year.

2.2 Milestones

Milestones are the years by which specific targets should be reached to accomplish the goals of the restoration. We recommend some of the same milestones for fall-run Chinook salmon as were recommended for spring-run Chinook salmon (Table 1). Lambda refers to population growth, where a value <1 indicates a shrinking population and a value >1 indicates a growing population when averaged over a fixed period. It should be noted, however, that the ability of the restoration program to meet the target goals may be difficult in some years because of uncertainty in the suitability of habitat conditions (e.g., seasonal water temperatures during juvenile migration in the spring, drought conditions). The basis for the target numbers is discussed in the following sections.

If numeric targets are not reached at a given milestone, then restoration strategies need to be reviewed in order to establish the nature and severity of the reasons for failing to attain numeric targets and to find means, consistent with the Settlement, of reaching the numeric targets in a reasonable length of time. If the analysis of limiting factors cannot identify remedies that appear capable of attaining the target in a reasonable timeframe, a major re-evaluation of restoration strategies may be required to develop solutions that meet the following milestone targets.

Table 1. Milestones and targets for re-establishing a self-sustaining population of naturally produced fall-run Chinook salmon in the San Joaquin River. The five year running average for the 2040 milestone is a combination of fall-run and late-fall-run Chinook salmon escapement, and is meant to reflect an increasing trend over the Growth Population Period, which starts at 2,500 and achieves a long-term average of 10,000 by 2040 (as indicated in Figure 1).

Milestone Year	Milestone Name	Milestone Period	Lambda	Minimum Threshold	5-year Running Average Target
N/A	Experimental	1/1/2010-12/31/2011	N/A	N/A	N/A
2019	Reintroduction	1/1/2012-12/31/2019	>1	Variable	variable
2024	Interim Population	1/1/2020 - 12/31/2024	>1	500	2,500
2040	Growth Population	1/1/2025-12/31/2040	>1	500	2,500 - 10,000+

2.3 Targets

Target numbers of fall-run and late fall-run Chinook salmon spawners (combined escapement) for each milestone are provided in Table 1. The basis for the numbers is presented in Section 2.4. Ideally, the targets will reflect both minimum viable population size (demographic minimum) and minimum effective population size (genetic minimum), transitional targets as the population slowly builds over time, as well as average and maximum number of spawners that the habitat can support under future restored conditions. As shown in Table 1 and illustrated conceptually in Figure 1, escapement should increase as habitat and water quality improve, as returning adults add nutrients to the system, and as better management practices are implemented in the river, estuary, and ocean. Realistically, it may require an unknown number of three-year generations to achieve the target population because the additional stressors on the tributary fall-run Chinook salmon populations (via their life-history strategy) may make recovery slower than that anticipated for spring-run populations. However, the recovery of winter-run Chinook salmon in the Sacramento River following intense management (Figure 2), the recovery of spring-run Chinook salmon in Butte Creek following removal of barriers (Figure 3), and the cyclical recovery of fall-run Chinook salmon escapement in the San Joaquin River tributaries (Figures 4-6) suggest that reaching target numbers can occur more rapidly than our conceptual model indicates.

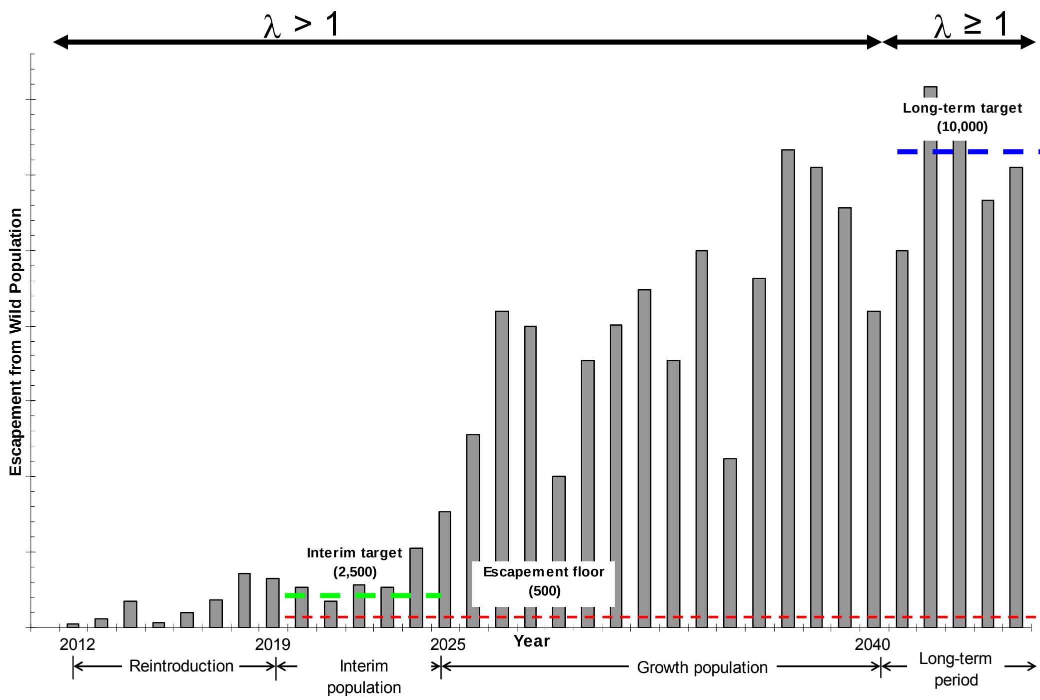

Figure 1. Conceptual model of potential trajectory and population fluctuations of fall-run Chinook salmon in the San Joaquin River. This model is meant to show one potential scenario; it does not represent populations that have gone through a long period of drought (for example). The bars are **not** *performance standards for individual years.*

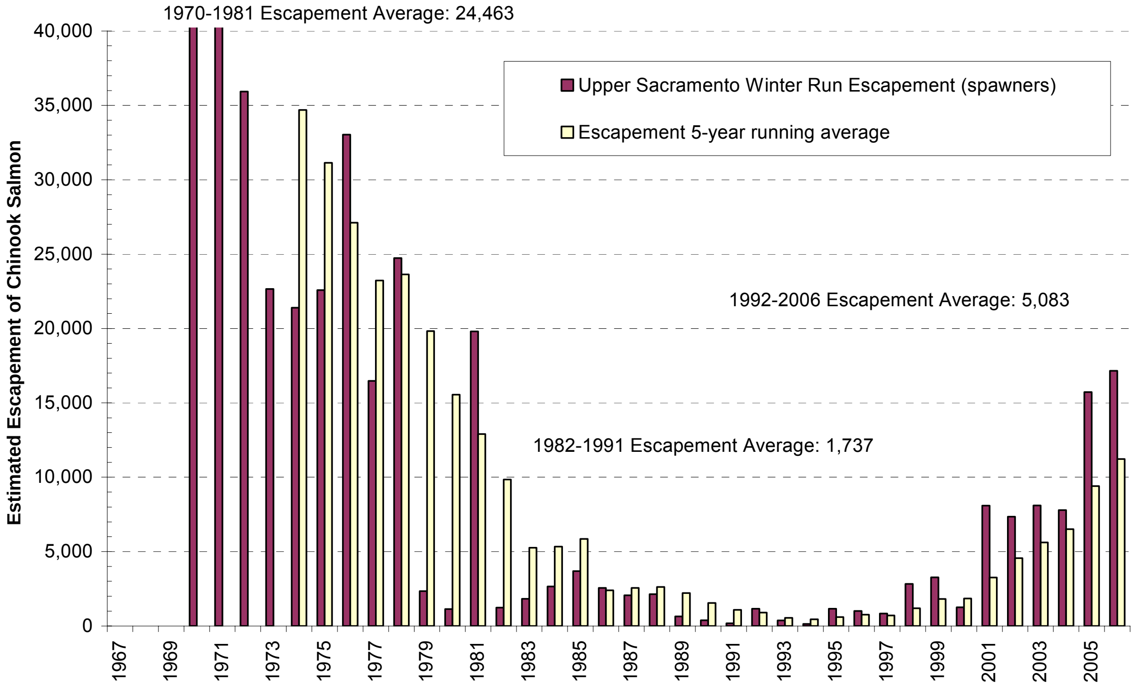

Figure 2. Trends in annual population of winter-run Chinook salmon in the Sacramento River (1970-2006), showing both actual escapement estimates for each year and the five-year running average. Data from USFWS Anadromous Fish Restoration Program (http://www.delta.dfg.ca.gov/afrp).

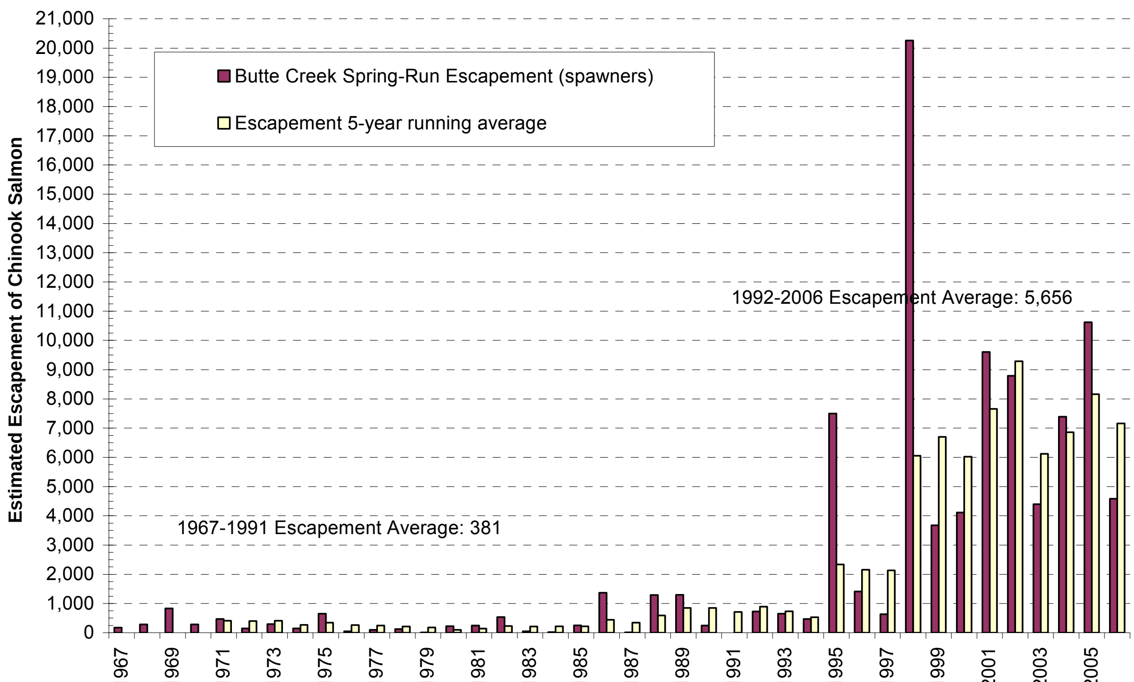

Figure 3. Trends in annual population of spring-run Chinook salmon in Butte Creek (1967-2006), showing both actual escapement estimates for each year and the five-year running average. Data from USFWS Anadromous Fish Restoration Program (http://www.delta.dfg.ca.gov/afrp).

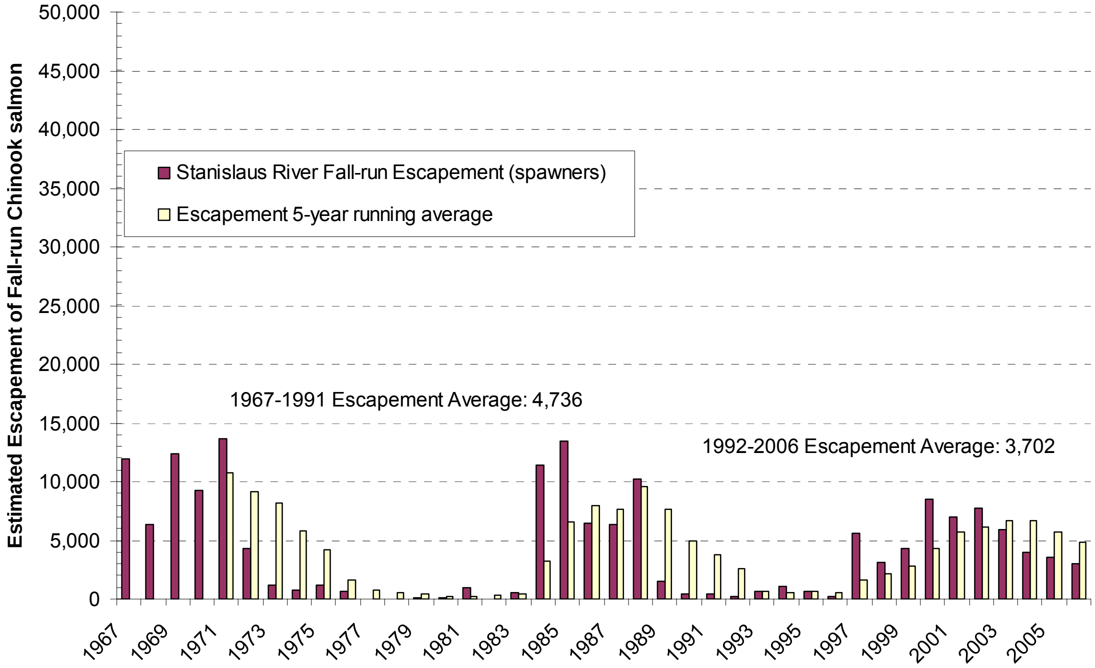

Figure 4. Estimated escapement of fall-run Chinook salmon from the Stanislaus River. Data from USFWS Anadromous Fish Restoration Program (http://www.delta.dfg.ca.gov/afrp).

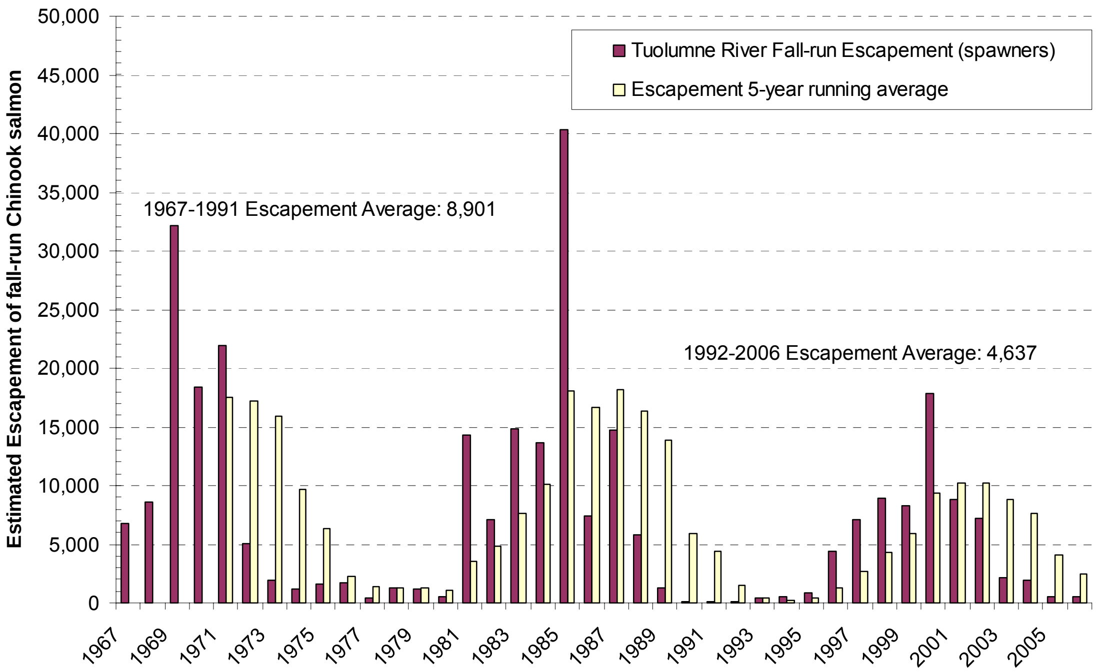

Figure 5. Estimated escapement of fall-run Chinook salmon from the Tuolumne River. Data from USFWS Anadromous Fish Restoration Program (http://www.delta.dfg.ca.gov/afrp).

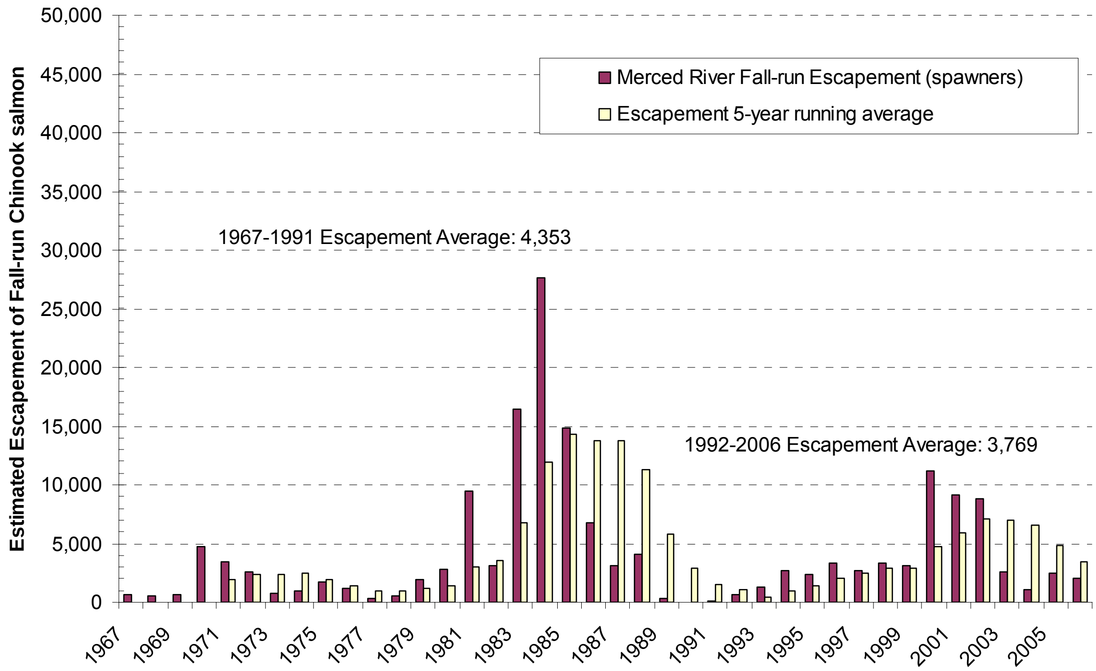

Figure 6. Estimated escapement of fall-run Chinook salmon from the Merced River. Data from USFWS Anadromous Fish Restoration Program (http://www.delta.dfg.ca.gov/afrp).

2.4 Rationale for Escapement Targets

In developing reasonable targets and goals for annual escapement of wild fall-run Chinook salmon, we have taken into account: (1) spring-run Chinook salmon escapement estimates immediately after Friant Dam was completed; (2) post-dam fall-run Chinook salmon escapement on the Merced, Tuolumne, and Stanislaus rivers below the lowest major dams; (3) estimates of the number of spawners that can be supported by existing and/or improved habitat (habitat carrying capacity); and (4) basic genetic and demographic models for minimum viable population sizes.

2.4.1 Spring-run Chinook Salmon Escapement after Friant Dam

Until Friant Dam began full storage and diversion operations in the late 1940s, water from the reservoir was released down the river and the San Joaquin River continued to support a small fall-run Chinook salmon population; however, no data exist that provide an estimate of post-dam fall-run Chinook salmon escapement. We can safely assume that the post-dam fall-run escapement was much smaller than the spring-run escapement during these years, and the fall-run population was likely extirpated sooner than the spring-run population. Population estimates of returning spring-run Chinook salmon for the years immediately preceding and after the closure of Friant Dam are: 35,000 in 1943, 5,000 in 1944, 56,000 in 1945, 30,000 in 1946, 6,000 in 1947, and 2,000 in 1948 (Yoshiyama et al. 1998). After 1949, there were occasional records of spring-run Chinook salmon during the 1950s and 1960s, during wetter years.

Upstream access was blocked to spawners in 1941, so fish returning post-1943 (including jacks) represent escapement produced from a post-dam river. Progeny from spawners in fall 1941 (both spring- and fall-run Chinook salmon) began to return in 1943 (2-yr olds), with the majority of the run returning in 1944. Therefore, spring-run Chinook salmon escapement for 1944, 1945, 1946, 1947, and 1948 would be fish wholly derived from spawning under post-dam, pre-diversion conditions. However, flows in the river in 1944 were greatly reduced to fill the dam, which likely affected returns both in 1944 and three years later in 1947. While river flows gradually became less favorable to spring-run Chinook salmon, flows were much worse for fall-run Chinook salmon. The spring snowmelt runoff period, when adult spring-run Chinook salmon would immigrate and juveniles outmigrate, still occurred, albeit at a rapidly reducing scale between 1941 and 1948 (Figure 7). However, the reduction in the spring snowmelt hydrograph likely had a greater impact on fall-run Chinook salmon smolt outmigration due to their slightly later timing and generally smaller smolt size. In addition, fall flows for adult migration were very low (compounded by barriers), particularly in the lower river, such that adults would have had a more difficult time migrating upstream than the spring-run adults. Therefore, the spring-run Chinook salmon escapement estimates above are likely much larger than actual fall-run Chinook salmon escapement during this same period, and therefore, these numbers should be used with caution when considering them in the fall-run Chinook salmon population goals.

2.4.2 Fall-run Chinook Salmon Escapement in San Joaquin Tributaries

Early dams on the Stanislaus, Tuolumne, and Merced rivers probably eliminated spring-run Chinook salmon from these rivers in the 19th century, but fall-run Chinook salmon populations persisted below the lowest dams. On the Merced River, the fall-run is sustained at least partially by a hatchery. Fall-run escapement estimates show considerable fluctuation, and the fluctuations are usually, but not always, synchronous. Estimated escapement into the rivers ranges from a few hundred fish in some years to over 40,000 fish over a 15 year period. In recent years, numbers have generally been low (Figures 4-6), and there is a high degree of uncertainty and disagreement on the causal mechanisms. Recent models suggest that adult run sizes are determined mainly by smolt survival, which is highest in years when outflows of all three rivers are high and synchronous. Research on the Tuolumne River suggests that in-river mortality factors (e.g., predation by piscivores in gravel pits, exposure to seasonally elevated water temperatures, particularly during drier water years with low velocities, and hungry bass) are substantial (EA Engineering 1992). It also appears that much of the smolt and fry mortality takes place after they leave the tributary rivers, within the Delta or the ocean where there are a number of adverse conditions. Thus, understanding what factors influence fall-run escapement numbers in the three San Joaquin River tributaries should help to understand future population dynamics of San Joaquin fall-run Chinook salmon and help to find ways to reduce mortality once the juvenile salmon leave the river.

In summary, recent fall-run Chinook salmon escapement averages from 1992-2006 were 3,700 for the Stanislaus River, 4,600 for the Tuolumne River, and 3,800 for the Merced River (Figures 4-6). Maximum fall-run escapement from 1967-2006 was between 10,000 to 14,000 for the Stanislaus River, between 10,000 to 20,000 for the Tuolumne River, and between 10,000 to 15,000 for the Merced River (excluding a couple of unusually high escapement years). When considering applicability of these 1992-2006 fall-run Chinook salmon escapement numbers to potential San Joaquin River fall-run Chinook escapement targets during the Interim Population Period (Table 1), the San Joaquin River escapement targets should be of similar scale because spring outmigration flows for sub-yearling fall-run Chinook salmon smolts are usually larger than the individual tributaries. However, the outmigration distance for the San Joaquin River fall-run smolts is nearly three times the outmigration distance for tributary smolts, and the later spawning timing of upper San Joaquin River fall-run Chinook salmon will likely result in smaller sub-yearling pre-smolts and smolts. In the currently degraded habitat conditions between Friant Dam and the Merced River, the combination of later spawning with greater migration distance could result in lower outmigration success during the Interim Population Period than in the tributaries; however, with habitat and water quality improvements in the lower San Joaquin River, the greater distance could improve smolt survival and adult returns due to greater growth and size when reaching the Delta.

When considering applicability of the larger range of tributary escapement numbers to San Joaquin River fall-run Chinook escapement targets during the Growth Population Period (Table 1), the San Joaquin River escapement targets should be on the lower end of the upper range of populations on the tributaries because: (1) the San Joaquin River is at the southern extreme of the range for fall-run

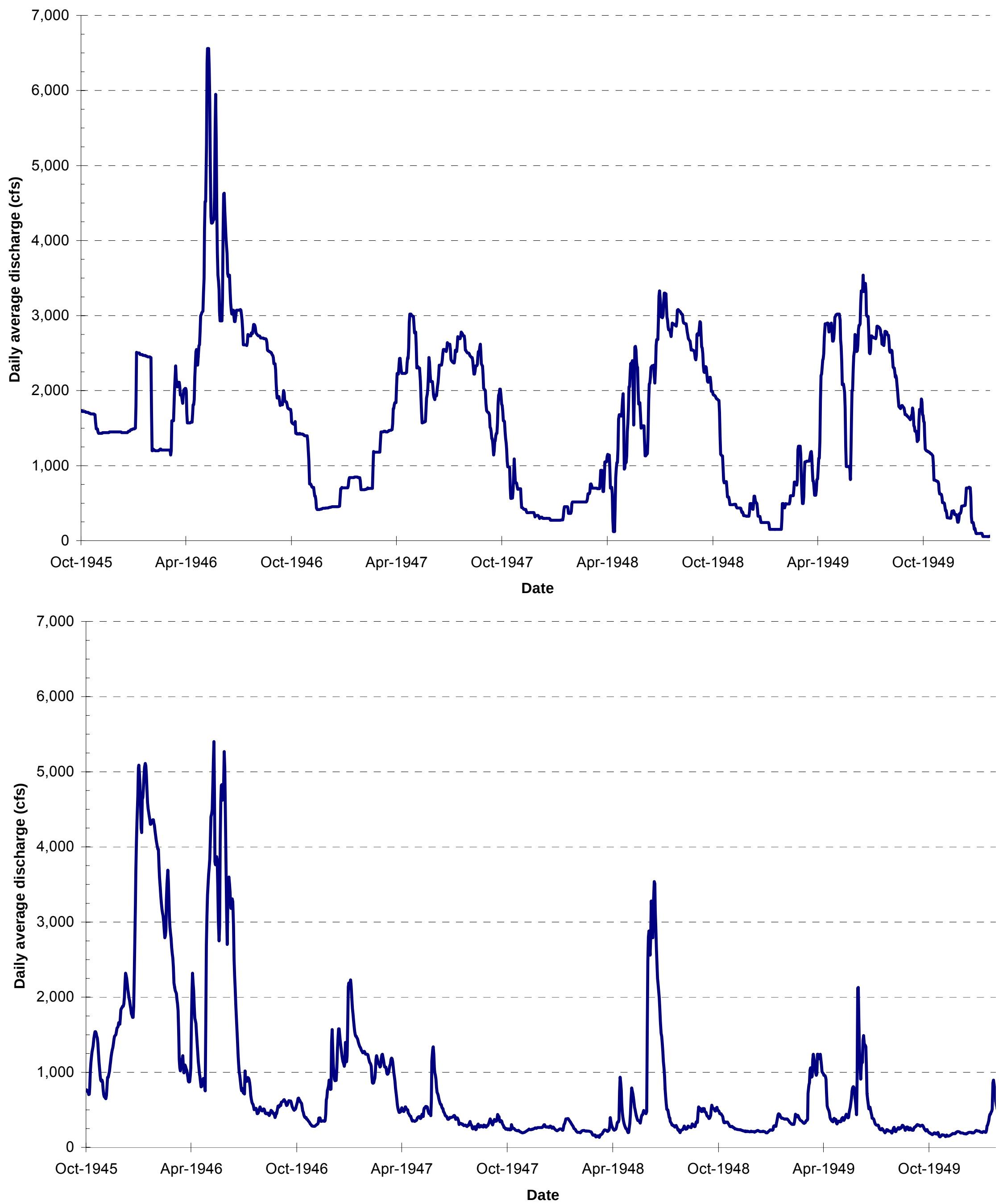

Figure 7. San Joaquin River streamflows (A) immediately downstream of Friant Dam, and (B) immediately above the mouth of the Merced River near Newman to illustrate fish migration conditions between water years 1946 and 1950.

Chinook salmon, (2) adult immigration and juvenile outmigration distances are much longer than tributaries, which may result in larger mortality given the expected extremes in hydrology, water temperature, and habitat conditions, and (3) there will be competition between fall-run and spring-run Chinook salmon fry and pre-smolts for rearing habitat, and spring-run rearing habitat will be managed via flows and other means to prioritize spring-run rearing over fall-run rearing.

Overall, when considering the factors mentioned above, we expect adult fall-run Chinook salmon escapement over the Interim Period to be of slightly smaller scale and equal or greater inter-annual variability to recent adult fall-run Chinook salmon escapement from the San Joaquin River tributaries, and we expect the long-term escapement targets on the San Joaquin River to be on the lower end of the upper range of escapement peaks observed on the tributaries. However, with improved habitat conditions on the upper San Joaquin River and corresponding improvements in juvenile growth and fitness, assumptions of lower escapement on the San Joaquin River compared to downstream tributaries may prove false.

2.4.3 Recovering Populations

One reason to be optimistic about recovery of San Joaquin fall-run Chinook salmon is that there are two populations of Chinook salmon in the Sacramento River watershed that have apparently recovered dramatically as the result of improved management: Sacramento River winter-run Chinook salmon and Butte Creek spring-run Chinook salmon. Winter-run Chinook salmon populations plunged to near-extinction (Figure 2) but then rebounded following diverse efforts to improve their survival, including: (1) opening the gates at Red Bluff Diversion Dam to avoid impeding migration and lower the vulnerability of downstream migrating juvenile salmon to predation mortality, (2) lowering summer temperatures in the Sacramento River below Shasta Dam, (3) improving spawning habitat by gravel addition, and (4) reducing take of juveniles at the South Delta pumps. The spring-run Chinook salmon population in Butte Creek rose quickly to higher levels (Figure 3) mainly after barriers to adult migration were removed in the lower creek. Both populations rose to average population sizes of 5,000-6,000 fish in less than 10 years. In the case of Butte Creek, the present run may be close to the number the habitat can actually sustain, although the numbers of winter-run Chinook salmon are still far below their historic abundance.

In addition, population recovery on the Stanislaus, Tuolumne, and Merced rivers can also inform the expected speed and scale of population recovery. When a series of wetter years follows a series of drier years (e.g., the 1989-1992 drought and wetter years from 1995-1998), fall-run Chinook salmon populations have recovered from the low point to the high point in 7-10 years (Figure 4), presumably due to higher spring flows improving juvenile and smolt survival rates to the ocean.

The population recovery data shown in Figures 2-6 suggest that a sustainable population size (2,500+ fish) may be reached in a shorter period of time than our targets assume in Table 1. We assume a slower recovery time will occur on the upper San Joaquin River because:

- The recovery of the two Sacramento River basin populations took place during a relatively benign climatic period (i.e., no severe droughts), which is not likely to be duplicated in the projected recovery period for San Joaquin spring-run and fall-run Chinook salmon.
- The channel of the Sacramento River through which both runs migrate is fully watered year-round and does not need the large-scale restoration efforts the upper San Joaquin River requires.
- There are no gravel pits potentially impeding outmigration of juveniles on the Sacramento River.
- Water quantity and quality (temperature, nutrients, dissolved oxygen, etc.) of the Sacramento River is generally favorable to salmon at all times of the year, especially as a result of augmented cold-water trans-basin diversions from the Trinity River and releases from Shasta Dam in the summer months.
- The San Joaquin River is at the southern extreme of Chinook salmon historic range, and typically experiences more extreme environmental conditions (both naturally and human induced) than watersheds to the north.

- Pathways through the northern Delta are different than those through the southern Delta. In the southern Delta, juvenile salmon must thread their way through complex channels and face problems of poor water quality, exposure to unscreened water diversions, increased vulnerability to predation mortality, entrainment in the large pumps of the State Water Project and Central Valley Project, lack of shallow water habitat, and other health and mortality factors.

Despite these differences, the potential for rapid recovery of San Joaquin fall-run Chinook salmon exists under favorable conditions of climate and implementation of restoration actions.

2.4.4 Habitat Carrying Capacity

Every cold-water river system has a limited carrying capacity for salmon, wherein one or more habitat elements limit the system's ability to support larger populations of fish. Potential limiting factors for fall-run Chinook salmon habitat in the San Joaquin River are discussed in Stillwater Sciences (2003), and include gravel riffles for spawning and incubation of embryos, and instream habitat for juvenile rearing. The reach still possesses habitat that is suitable for different life stages of fall-run Chinook salmon, given adequate flows and seasonal water temperatures. Additional habitat can be restored to suitability using known restoration techniques. The spawning riffle area discussion below is used as an estimate of carrying capacity when considering Interim Population Period adult escapement targets, and does not necessarily imply that spawning habitat is the primary limiting factor.

2.4.4.1 Spawning riffles

Spawning riffles with walnut to apple-sized gravels suitable for fall-run Chinook salmon spawning and egg incubation still exist in the reach from the Friant Dam to Gravelly Ford. The suitability of spawning gravel (e.g., amount and quality) for spawning and incubation still needs careful evaluation (along the lines of Sommer et al. 2001b), but there is clearly adequate gravel today to support a limited population of fall-run Chinook salmon in the reach below Friant Dam (Table 2). Additional surveys of spawning gravel quantity and quality are reported by Stillwater Sciences (2003). In many areas, the existing gravels are intermixed with a relatively high percentage of sand, which affects the ability of salmon fry to successfully emerge. Cain (1997) estimated there was adequate gravel to support spawning by about 5,000 pairs of salmon below Friant Dam. This estimate was 80-90% lower than CDFG estimates from the 1950s and reflects the results of vegetation encroachment, instream gravel mining, channel incision, siltation, and reduction in flows due to operation of Friant Dam. Future fall-run Chinook salmon spawning will likely focus on the reach between Friant Dam and the Highway 99 Bridge, but may extend further downstream, especially during years with higher flows and/or higher adult salmon escapement. Spawning habitat estimates from Table 2 (assuming a conservatively large redd size of 216 ft^2 (20 m^2)) suggest that current conditions could support spawning for at least 3,000 adults, and considerably more if smaller redd sizes are assumed and spawning occurs downstream of the Highway 99 Bridge. Coarse sediment augmentation would increase the quantity and quality of spawning habitat, better distribute spawners longitudinally and laterally in the channel, and reduce redd superimposition to better achieve the recommended long-term population targets. In addition, once adult salmon are re-established, the frequent digging and movement of gravel by spawning salmon can improve spawning gravel quality through the mobilization of fine sediment. As part of establishing a restoration strategy for the river, the availability of suitable gravels for Chinook salmon spawning and the carrying capacity under existing and enhanced habitat conditions will be important factors to consider.

2.4.4.2 Juvenile rearing habitat

Most fall-run Chinook salmon juveniles rear in their natal streams for less than one year. Juvenile rearing habitat requirements are complex and closely tied to flows, and smolt outmigration

Table 2. Summary of potential spawning habitat capacity information that may inform recommended targets of a self-sustaining population of naturally produced fall-run Chinook salmon in the San Joaquin River. Potential adult carrying capacity assumes two adults per redd, excluding jacks and pre-spawner mortality.

Source	Extent of Survey	Habitat Area	Potential Adult Population Carrying Capacity		Discussion
			Lower limit based on redd size of 216 ft^2 (Burner 1951)	Upper limit based on redd size of 55 ft^2 (EA Engineering 1992)	
Spawning habitat (Clark 1942)	Lanes Bridge to Kirkhoff Powerhouse RM 255.2 – RM 281.5	266,800 ft^2	2,470 adults	9,702 adults	Existing habitat is likely less than 1942 habitat, but could create much more spawning habitat for future conditions
Spawning habitat (Fry and Hughes 1958)	Gravelly Ford to Friant Dam RM 229 – RM 267.5	1,000,000 ft^2	9,259 adults	36,364 adults	Includes estimates downstream to Gravelly Ford, which probably would not be used for spawning by spring-run Chinook salmon
Spawning habitat (Cain 1997)	Gravelly Ford to Friant Dam RM 229 – RM 267.5	303,000 ft^2	2,806 adults	11,018 adults	Numbers based on existing habitat. Could create much more habitat for future conditions
Spawning habitat (R. Ehlers, pers. comm.., in Cain 1997)	Gravelly Ford to Friant Dam RM 229 – RM 267.5	1,820,000 ft^2	16,852 adults	66,182 adults	Includes estimates downstream to Gravelly Ford, which probably would not be used for spawning by spring-run Chinook salmon
Spawning habitat (Jones and Stokes Assoc 2001)	Friant Dam to Skaggs Bridge RM 267.5 – RM 234.1	408,000 ft^2	3,785 adults	14,836 adults	Based on existing habitat, similar to Cain and Stillwater Sciences. Could create much more habitat for future conditions
Spawning habitat (Stillwater Sciences 2003)	Friant Dam to Highway 99 Bridge RM 267.5 – RM 243.2	357,000 ft^2	3,306 adults	12,982 adults	Based on existing habitat, similar to Cain and Jones and Stokes. Could create much more habitat for future conditions

requirements are closely tied to flows and water temperatures. Once the alevins emerge from the gravel, salmon fry require shallow (< 1 m) edge habitat, where they can find small prey and hold at relatively low velocities. They typically hold and feed in riffles with complex substrates (boulders, logs, etc.) and at the tails of pools during the day, where they feed on drifting invertebrates. Such habitat is presently available and should expand with increased flows and improved habitat quality via additional structure (logs, boulders, alluvial features) and riparian vegetation. As the fry grow larger and more active, they move out into deeper, higher velocity water where larger prey is more available and predators are fewer. Young-of-year (age 0) Chinook salmon often start to move gradually downstream at this stage, the speed of movement and number moving depending, in part, on flows, as well as density-dependent factors (e.g., competition for rearing habitat). At this stage, overhead and complex cover are often needed for protection from predators, especially when fish are holding during the day (most migration is at night). Studies by Sommer et al. (2001a, 2001b) in the Yolo Bypass and by Jeffres (2006) on the Cosumnes River indicate that, if provided the opportunity, these juveniles will move on to floodplains where they grow faster and larger than fry that stay in the mainstem river channel. As the floodplains drain, the juvenile salmon move off with the receding floodwaters. These fish migrate downstream as either fry, juveniles, or smolts.

2.4.5 Genetic and Demographic Models

The standard model based on both genetic and random population (stochastic) factors suggests that a minimum viable (= indefinitely self-sustaining) salmonid population is around 500 spawners (Allendorf et al. 1997, Lindley et al. 2007). Cass and Riddell (1999), for example, suggest that 100 female spawners are needed to maintain a population, which translates into 300-500 fish when males and unsuccessful spawners are taken into account. The minimum number suggested by Hedrick et al. (1995) for Sacramento winter-run Chinook salmon, counting adult fish both spawned in the wild and in restoration hatcheries, is 500+ annual spawners.

In order to achieve a long-term target of >500 spawning fish, 500 fish is recommended to be used as the interim minimum target after six years (starting in 2020). This would show the results of three years of returns from restoration efforts and would indicate the success of the reintroduction strategy. If returns fail to meet the 500 escapement goal in this period, monitoring data should be reviewed, and restoration strategies and efforts should be assessed by the TAC in consultation with implementing agencies to recommend refinements in management actions to improve returns.

It is worth noting that for long-term maintenance of genetic diversity within a population, an *effective population size* of 500 is recommended (Allendorf et al. 1997). This is essentially the minimum number of fish in each year that actually have offspring that survive to contribute to the next generation. Lindley et al. (2007) suggest that for Central Valley Chinook salmon, the proportion of fish that make up the effective population is 20%, so the actual minimum escapement needed is estimated to be approximately 2,500 fish.

2.5 Synthesis

Our recommended target of 500 fish as a minimum population size for fall-run Chinook salmon is based on the same genetic and demographic arguments as for spring-run Chinook salmon. Of the available historic information, recent escapement data on the San Joaquin River tributaries and estimates of present spawning habitat conditions on the upper San Joaquin River provide the primary justification for developing interim and long-term population targets. Based on the recent averages of escapement on the tributaries and spawning habitat carrying capacity, we recommend a 5-year running average escapement of 2,500 adults for the Interim Population Period, and 10,000 adults as a long-term target for the average annual population size after the Growth Population Period. Historic numbers and post-dam escapements on downstream tributaries indicate that the reach between Friant Dam and Lanes Bridge could ultimately support an average of 10,000 spawners, especially if habitat improvements were made. Existing spawning habitat and juvenile rearing habitat, either combined or independently, would most likely limit fall-run Chinook salmon populations at the present time to somewhere between 2,200 and 6,500 spawning pairs (ca. 5,000- 15,000 fish, including jacks). If we assume that potential spawning area is the most limiting factor based on recent estimates in Table 2, then an estimate of 3,500 adults supportable by existing conditions could be a reasonable interim target. However, because: (1) juvenile rearing habitat will be utilized by both spring-run and fall-run Chinook salmon juveniles (with flow management to prioritize habitat use by spring-run juveniles), (2) spawning habitat may be used by both fall-run and spring-run adults (with flow and barrier management to prioritize habitat use by spring-run adults), (3) sub-yearling fall-run pre-smolts will be smaller in size than spring-run pre-smolts (resulting in lower survival-to-adult return success), and (4) the adult immigration and smolt/pre-smolt outmigration distance (and hydrologic conditions) for fall-run is longer, the interim target may need to be lower for fall-run Chinook salmon than our estimate for spring-run Chinook salmon. Nutrients provided by the dead adult salmon and other improvements will also enhance ecosystem productivity, improving conditions for rearing of juvenile salmon.

The recent population fluctuations of fall-run Chinook salmon in the three major tributaries to the lower San Joaquin River indicate that outside factors may present additional challenges that need to be addressed to achieve the stated targets. However, the history of recovery of winter-run Chinook salmon and Butte Creek spring-run Chinook salmon in the Sacramento River basin, as well as population recoveries in tributaries to the San Joaquin River, indicates that recovery could be even more rapid than expected. Furthermore, as discussed in Section 3, the TAC recommends that both fall-run (November-December spawning) and late fall-run (January-April spawning) Chinook salmon be introduced. Because their escapement numbers are considered additive towards the Interim and Long-term targets, we believe the fall-run Chinook salmon escarpment targets in Table 1 are reasonable.

Our recommended escapement targets assume restoration will provide adequate spawning and rearing habitat and that there are sufficient cold water and other habitat components to support the salmon. While target escapements will depend on the success of the instream restoration actions called for under the Settlement, there are also a number of potentially harmful conditions that fish could encounter (e.g., adverse rearing conditions within the ocean, high juvenile mortality within the Delta, etc.) that are completely outside of the control of the Settlement Parties. If these conditions persist, they could affect the ability to meet the stated targets.

2.6 Other Considerations

Once the initial efforts to establish a population have started, additional types of information will be useful to establish the carrying capacity of the upper San Joaquin River for fall-run Chinook salmon and to engage in adaptive management of the river and its fish, consistent with the framework of the Settlement.

2.6.1.1 Delta and Ocean Conditions

As habitat improvements such as gravel augmentation, floodplain restoration, habitat rehabilitation, and growth of riparian vegetation progress, the ability of the environment to support fall-run Chinook salmon should increase, but factors outside the responsibility of the Settlement (e.g., predation, Delta and ocean conditions) may remain unpredictable and potentially limiting.

2.6.1.2 Population models

It would be useful to develop a population model that indicates how much fluctuation would be expected and acceptable, based on: (1) studies of fall-run Chinook salmon on the Tuolumne, Merced, and Stanislaus rivers; (2) models for winter-run Chinook salmon on the Sacramento River (Botsford and Brittnacher 1998, Beckman et al. 2007); (3) a model being developed for spring-run Chinook salmon on Butte Creek at UC Davis (L.A. Thompson, pers. comm. 2007); and (4) a model for fall-run and spring-run Chinook salmon on the San Joaquin River (Stillwater Sciences 2003).

2.6.1.3 Straying

The TAC recognizes that a key issue will be the degree to which fall-run Chinook salmon “stray” into and/or from the Merced, Tuolumne, and Stanislaus rivers. Concern falls mainly into three areas: (1) in the initial years before the upper San Joaquin begins to substantially contribute to basin salmon production, periodic removal of the Hills Ferry Barrier to allow adults to stray into the upper San Joaquin River may reduce adult escapement from the tributaries, thereby potentially impacting mitigation requirements of water managers on those tributaries, (2) reduced adult brood stock returns and subsequent reductions in juvenile production from the Merced River Hatchery; and (3) upper San Joaquin adults straying into the tributaries such that upper San Joaquin River escapement targets will not be achieved. To alleviate these concerns, the TAC recommends that until there are returning adult fall-run Chinook produced in the upper San Joaquin River, the Hills Ferry Barrier be managed to allow most of the fall-run Chinook salmon to migrate into the tributaries, and periodically removed to allow some of the fall-run Chinook salmon (perhaps emphasizing the latter end of the fall-run) to migrate upstream into the upper San Joaquin River. As fall-run production from the upper San Joaquin River begins contributing to overall production of returning adults to the basin (including strays into downstream tributaries), the need for the Hills Ferry Barrier diminishes and should eventually be removed.

This strategy would manage straying of tributary-produced adults while allowing some natural re-seeding of the upper San Joaquin River with portions of the fall-run (October-November) and late fall-run (December/January) Chinook salmon, which would likely encourage a more successful life-history strategy. The late fall-run adults will immigrate when water temperatures in the upper San Joaquin River are more suitable, and the spawning timing difference from the spring-run will greatly reduce hybridization and superimposition risk. Some of the progeny may try to outmigrate as sub-yearlings, and some will over-summer and outmigrate the following year as yearlings. Survival of the sub-yearlings probably won't be very high as a result of exposure to elevated water temperatures within the river in the spring and summer. Over-summering progeny will likely be more successful, further encouraging a late fall-run life history trait. In the event of low escapement years in the Reintroduction and Growth Population periods, or during years with low escapement of spring-run Chinook salmon in the upper San Joaquin River (due to potential fall-run superimposition impacts on incubating spring-run eggs), the TAC recommends that the Hills Ferry Barrier again be considered for managing fall-run Chinook salmon escapement between the tributaries and the upper San Joaquin River. The TAC acknowledges that these additional management actions, designed to help protect the Chinook salmon populations within the lower tributaries, may retard the rate of re-establishing a fall-run salmon population on the upper river that meets the abundance targets identified in Table 1. Marking studies should be conducted to understand how fall-run juvenile production and adult escapement is distributed between the two regions (lower San Joaquin River tributaries versus upper San Joaquin River mainstem).

2.7 Recommendations

From our review of the information above, and in our best professional judgment, we offer fourteen recommendations for Interim and Long-term targets and milestones for naturally-produced escapement of fall-run Chinook salmon.

2.7.1 2019 Reintroduction Period

The Settlement requires the following to be considered as one of the criteria in an evaluation of a requested change in the Restoration Flows:

> ". . . beginning 7 years after the reintroduction of fall-run Chinook salmon to the San Joaquin River, whether the annual escapement of wild fall-run adult salmon has dropped below 500 in any year,"

Recommendation 1: The Reintroduction Period should be defined as January 1, 2012, through December 31, 2019.

Recommendation 2: Population targets should be for the total escapement of fall-run and late fall-run Chinook salmon.

Recommendation 3: A combined escapement of 500 fall-run and late fall-run spawners (male + female) should be the minimum target for fish returning to spawning areas at the end of six years (2019). If returns fail to meet the annual 500 fish target by December 31, 2019, monitoring data should be reviewed, and restoration strategies and efforts should be assessed by the TAC in consultation with implementing agencies to recommend refinements in management actions to improve returns.

2.7.2 2020-2024 Interim Population Period

Recommendation 4: The Interim Population Period should be defined as January 1, 2020, through December 31, 2024.

Recommendation 5: The five-year running average target for escapement should be at least 2,500 fish (fall-run plus late fall-run), with allowable population fluctuation between 500 and 5,000 spawners (upper limit guided by maximum capacity of spawning habitat).

Recommendation 6: 500 spawners should be the minimum target for fish returning to spawning areas for any given year after 2019. If the number drops below 500 fish in any given year, or if the targets outlined in Recommendations 4 and 5 are not achieved, monitoring data should be reviewed, and restoration strategies and efforts should be assessed by the TAC in consultation with implementing agencies to recommend refinements in management actions to improve returns.

Recommendation 7: Assessment of success of achieving interim targets should take into account fluctuations of other salmon populations in the Central Valley, to serve as indicators of unfavorable conditions for survival of juvenile salmon outside the San Joaquin River system.

2.7.3 2025-2040 Growth Population Period

Recommendation 8: The Growth Population Period should be defined as January 1, 2025, through December 31, 2040.

Recommendation 9: Between 2025 and 2040, the target for the 5-year running average of spawners should increase from 2,500 to 10,000 spawners (fall-run plus late fall-run), and the rate of increase of the number of spawners (cohort replacement rate) should be greater than 1.0.

Recommendation 10: During Phase 1 and Phase 2 Restoration Actions, create in-river holding, spawning, and rearing habitat necessary to support the upper range of returns (10,000+ spawners) for the Long-term Period.

2.7.4 2041+ Long-term Population Period

Recommendation 11: The Long-term Period should be defined as beyond January 1, 2041.

Recommendation 12: By 2040, the long-term target for annual escapement of fall-run Chinook salmon (fall-run plus late fall-run) should be a 5-year running average of at least 10,000 spawners, providing for 50% range of fluctuation (5,000-15,000 spawners).

Recommendation 13: A major re-evaluation of population status should occur at a maximum of every 15 years (in addition to routine annual population status assessment).

Recommendation 14: Program performance should focus on meeting population targets over a period of years reflecting multiple cohorts and generations. With the exception of minimum population targets, Program performance should not be based on results from any one year.

3 RECOMMENDED STOCK SELECTION AND INITIAL STRATEGIES FOR REINTRODUCING FALL-RUN CHINOOK SALMON INTO THE SAN JOAQUIN RIVER

The purpose of this section is to describe the TAC recommendations to the RA with regard to: (1) objectives, criteria, and procedures for use in selecting the appropriate stock(s) for reintroduction; (2) objectives and principles used to develop a reintroduction strategy; (3) initial recommendations on stock selection and reintroduction strategies; and (4) the need for a robust adaptive management strategy to serve as an appropriate framework for the restoration program. These recommendations apply the same principles and procedures as for spring-run Chinook salmon (TAC 2007).

3.1 Stock Selection Objectives, Criteria, and Procedures

3.1.1 Goals and Objectives

The primary goal is to establish a naturally reproducing and self-sustaining population of Central Valley fall-run and late fall-run Chinook salmon. Reintroducing late fall-run Chinook salmon is recommended in addition to fall-run because the late fall-run life history may be more suited to adapting to the Settlement flow regime as follows:

- Fall-run Chinook salmon juveniles (spawned in October-December) outmigrate as sub-yearlings the following spring. Growth models predict that rearing time and corresponding growth rates may cause the sub-yearling smolts to outmigrate in late spring and early summer, at times when water temperatures may exceed thermal tolerances in the lower San Joaquin River. Because spring-run Chinook salmon spawn earlier than fall-run (September and October), sub-yearling smolts would outmigrate earlier in the following spring, presumably with more favorable water temperatures (Stillwater Sciences 2003).
- Late fall-run Chinook salmon spawning occurs in January-April; juveniles that over-summer in the upper river (with favorable water temperatures) would outmigrate the following spring as larger and fitter yearling smolts, and smolt-to-adult success rates for late fall-run could be much higher than fall-run Chinook salmon.

Therefore, the primary objective is to identify the stocks of fall-run and late fall-run Chinook salmon with the greatest likelihood of establishing a self-sustaining population in the upper San Joaquin River. The 'best' stock should have life history traits (e.g., adult and juvenile migration timing, habitat requirements, and environmental tolerance) that are compatible with anticipated future habitat conditions (e.g., seasonal hydrology, water temperatures, and physical habitat) within the upper San Joaquin River.

3.1.2 Recommended Stock Selection Criteria and Procedures

The general process recommended for evaluating and selecting a preferred fall-run and late fall-run Chinook salmon stock as a founding population for the San Joaquin River reintroduction strategy is shown in Figure 8. The individual criteria recommended for stock selection are briefly outlined below. For each criterion, we provide reasons for its consideration (importance) as part of stock selection. We also provide a professional judgment of the level of certainty regarding the confidence in the recommendation. The certainty measure is a reflection of the importance of the criterion: high certainty indicates that it should be part of the stock selection process, while lower certainty categories indicate that research is needed to evaluate the importance of the criterion in stock selection decisions. For this report, only criteria with a high level of certainty or, in one case, a moderate level of certainty, are recommended. Potential criteria thought to have lower levels of certainty are not discussed. Recommended criteria to be used in evaluation and selection of a preferred founding stock are described in the following sections.

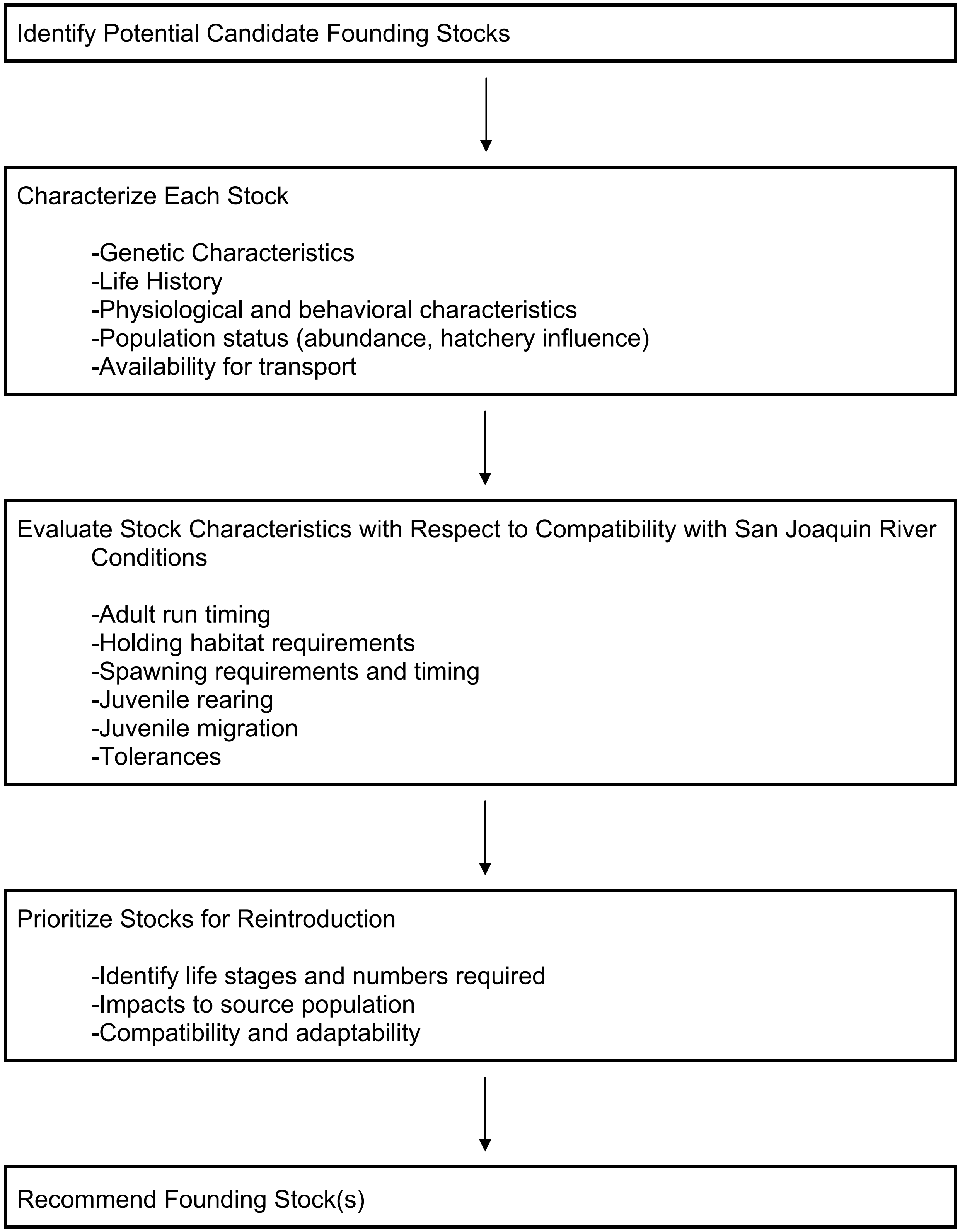

Figure 8. Overview of recommended stock selection process.

3.1.2.1 Stock should be of local or regional origin (Central Valley)

Fall-run and late fall-run Chinook salmon inhabiting the San Joaquin River will be exposed to a variety of potentially stressful environmental conditions, including exposure to seasonally elevated water temperatures. We hypothesize that fall-run Chinook salmon stocks that have adapted to local or regional environmental conditions within the Central Valley will be most successful in adapting to the future environmental conditions on the San Joaquin River. Stocks currently inhabiting other Central Valley rivers and tributaries are expected to exhibit regional adaptation (e.g., populations inhabiting the southern boundary of the species' geographic distribution may have higher thermal tolerances, compatible migration times and residence patterns, etc.). Local stocks are also expected to create fewer problems associated with potential straying and interbreeding with existing stocks. Based on the best available information, our confidence is high in recommending that the stock be selected from currently existing stocks inhabiting the Central Valley.

3.1.2.2 Stock should be genetically diverse

Given the inherent variation in potential future environmental conditions affecting fall-run Chinook salmon on the San Joaquin River, and the desire to provide opportunities for local selection pressures (e.g., seasonal run timing of adults and/or juveniles to coincide with the seasonal restoration hydrograph, tolerance to seasonally elevated water temperatures, etc.), we recommend that the founding stock has adequate genetic material (i.e., population abundance and genotypic/phenotypic diversity) to allow San Joaquin River-specific pressures to eventually produce a locally adapted stock. To achieve this objective in stock selection, we recommend that a genetic management plan be developed, in consultation with a qualified fish geneticist, to help guide selection of the founding stock. The genetic management plan should be inclusive of all three runs under consideration (spring-run, fall-run, and late fall-run). Several topics to be determined in the genetic management plan include: (1) how adult brood stock should be selected from a population to enhance genetic diversity, (2) what the appropriate number of brood adults should be, (3) what types of genetic testing should be done to characterize the existing population, and (4) other factors. Based on the best available information, our confidence is high in recommending that the founding stock be genetically diverse to ensure the greatest potential for local adaptation to San Joaquin River conditions.

3.1.2.3 Stock use should take into account the potential impacts to the source population

The selection of fall-run Chinook salmon from tributaries to the San Joaquin River as a founding stock has both potential beneficial and adverse effects on existing population dynamics. The collection of a large number of adults from an existing wild population of fall-run Chinook salmon could potentially result in adverse impacts to the existing stock (e.g., loss of reproduction within a given tributary and independent population) if not carefully managed as part of the stock selection process. In contrast, establishing another fall-run Chinook salmon population on the San Joaquin River that expands the range of current populations inhabiting the San Joaquin River tributaries could increase the stability of the Central Valley population and contribute to a substantial increase in population abundance of Chinook salmon within the San Joaquin River system.

As part of stock selection, we recommend that consideration be given to factors reflecting the status of the source population, such as the current trends in abundance and whether existing habitat within the source watershed is fully used (i.e. "surplus" fish are available for relocation with minimal adverse effects or with potentially beneficial effects). Our confidence is moderate that a stock can be selected from an existing population with minimal or no adverse impact to the founding stock, while satisfying the first two criteria (Section 3.1.2.1 and 3.1.2.2). If we adopted a strategy where we allowed natural re-seeding of San Joaquin River tributary stocks during a series of high escapement years using the Hills Ferry Barrier as described in Section 2.6.1.3, then our confidence in minimal or no adverse impacts to the founding stock would be high. We recognize that it is possible that removal of some fish from tributary or Sacramento River populations for the San Joaquin River reintroduction program may have a negative impact on those source stocks if those source populations are in low numbers. However, this will have to be balanced against the long-term potential for the San Joaquin River reintroduction to contribute to overall Central Valley fall-run Chinook salmon stock recovery.

3.1.2.4 Stock use should take into account the potential impacts to the tributary populations

The San Joaquin River tributaries currently provide habitat and support populations of fall-run Chinook salmon but do not support populations of late fall-run Chinook salmon. The selection of a northern Central Valley late fall-run Chinook salmon stock(s) for reintroduction into the upper San Joaquin River will probably result in a few adults straying into downstream tributaries. Adult straying, although a natural phenomenon among salmon, has the potential to introduce new diseases into an existing salmon population, or hybridize with local fall-run Chinook salmon populations. Neither of these problems is likely to be a major concern with fall-run or late fall-run Chinook salmon because the stocks proposed to be used are of regional origin and should have the same disease exposures. Straying of fall-run Chinook salmon from the upper San Joaquin River to downstream tributaries should not be a major concern, since these tributaries will likely be the source population. Central Valley stocks are genetically fairly uniform; straying will help maintain genetic diversity of the overall San Joaquin River fall-run stocks, and straying of upper San Joaquin River produced adults should benefit escapement numbers on the downstream tributaries. Some future straying of San Joaquin River late fall-run Chinook salmon is expected and will need to be monitored for potential effects (beneficial and adverse). We recommend that measures to assure fidelity to the San Joaquin River spawning areas, such as juvenile imprinting and marking programs, be used to help monitor inter-basin movement of late fall-run Chinook salmon from the upper San Joaquin River to downstream tributaries while establishing the initial population on the upper San Joaquin River. Based on the best available information, our confidence is high that stocks used for introduction can be selected and managed to minimize adverse impacts to existing Chinook salmon stocks within the San Joaquin River and tributaries.

3.1.2.5 Stock should have life history characteristics that maximize the probability of successful reintroduction into the upper San Joaquin River

We acknowledge that the Settlement hydrographs are limited in both magnitude and duration. Based on the best available information, we expect that: (1) seasonal exposure to elevated water temperatures during migration will occur, (2) competition and predation will affect fall-run Chinook salmon abundance, and (3) other environmental and biological factors will affect survival and abundance of fall-run Chinook salmon inhabiting the upper San Joaquin River. To increase the likelihood of success of the selected stock in adapting to local environmental conditions in the San Joaquin River, we recommend that a founding stock be selected that has behavioral and life history characteristics most compatible with the anticipated conditions on the San Joaquin River. Existing populations currently inhabiting the Central Valley exhibit a range of life history characteristics (e.g., variation in seasonal migration timing for adults and juveniles, etc.). A close match between the behavioral characteristics and habitat requirements of the founding stock and the anticipated habitat constraints on the San Joaquin River is more likely to result in successful establishment of the run. In selecting a founding stock, careful consideration should be given to selecting the stock that has a life history most compatible with projected San Joaquin River conditions and therefore would maximize the likelihood of a successful reintroduction. Results of a preliminary assessment of potential founding stocks indicate that the fall-run Chinook salmon from the Stanislaus, Tuolumne, and Merced rivers have life history characteristics that may be compatible with the anticipated future environmental conditions on the upper San Joaquin River, and are genetically similar to Central Valley fall-run Chinook salmon stocks. For late fall-run Chinook salmon (whose life history characteristics may be more successful under the Settlement restoration actions than the fall-run), Sacramento River late fall-run Chinook salmon would likely be the most compatible for the upper San Joaquin River. The TAC recommends that a more detailed analysis be conducted to further evaluate the potential use of the Sacramento River late fall-run founding stocks as part of refining the San Joaquin River reintroduction strategy. Based on the best available information, our confidence is high in recommending that the stock should be selected based, in part, on the compatibility of current life history characteristics with anticipated habitat conditions and potentially limiting factors on the San Joaquin River.

3.1.2.6 Stock should have behavioral and physiological characteristics that fit conditions expected to occur on the San Joaquin River

The San Joaquin River is anticipated to have distinctive environmental conditions that will affect the seasonal timing of migration, reproduction, growth, and survival of the fall-run and late fall-run Chinook salmon populations. Although a population would be expected to adapt to these conditions over a period of generations in response to natural selection pressures, the most rapid adaptation would occur if the founding stock had behavioral and physiological characteristics that were most compatible with the future environmental conditions of the San Joaquin River. Therefore, we recommend that the late fall-run be included as a reintroduced stock, as we feel that its life history characteristics may be better suited to anticipated Settlement conditions than the fall-run. We recommend that information on behavioral characteristics such as seasonal run timing, adult holding, spawning period, habitat requirements, and response to seasonally elevated water temperatures be compiled for potential candidate founding stocks and evaluated in comparison to the anticipated conditions in the San Joaquin River. Even small or subtle variation in these characteristics among stocks may have an influence on their long-term survival within the San Joaquin River. We recognize that fall-run and late fall-run Chinook salmon may hybridize in this situation. We regard this as desirable as a means of producing a distinct San Joaquin River stock and increasing genetic diversity of the fall-run stock. Based on the best available information, our confidence is high in recommending that the stock should be selected based, in part, on the compatibility of current behavioral and physiological characteristics with anticipated habitat conditions and potentially limiting factors on the San Joaquin River.

3.1.2.7 Existing hatchery stock should not be used as a reintroduction founding stock

Several salmon hatcheries exist within the Central Valley, including hatcheries on the Merced River, Feather River, and upper Sacramento River, that could potentially provide adult salmon, fertilized eggs, or juvenile salmon for use in the San Joaquin River restoration program. There has been considerable concern expressed regarding potential effects of past and uncontrolled hatchery propagation on the genetic characteristics and diversity of salmonids within the Central Valley, as well as their fitness and behavioral traits. To ensure the greatest degree of success in reintroducing fall-run Chinook salmon, it is important that the stock chosen have the best fitness and behavioral traits to survive and flourish. Although efforts are currently underway to develop genetic management programs for these hatcheries, the TAC recommends that these existing and possibly genetically altered hatchery stocks not be used for founding the San Joaquin River salmon restoration program. The TAC recommends that only wild stocks be used; however, the TAC recommends that use of hatcheries to carefully rear and supplement juvenile production from wild adults not be excluded during the Reintroduction and Interim Population periods. To the extent hatcheries are deployed for any aspect of salmon reintroduction or population maintenance, their deployment should be: (1) in consultation with the RA (who would seek input from the TAC), and (2) in accordance with formally developed genetic management and hatchery management plans developed by the five-agency work teams, and approved by the State and Federal fishery agencies. Our confidence in this recommendation is high.

3.1.2.8 Develop a Genetic Management Plan

As with the spring-run Chinook salmon, we should evaluate whether the reintroduction of fall-run and late fall-run Chinook salmon should be based on one founding stock or multiple founding stocks, assuming life history characteristics of all stocks are similar. Thus, evaluating potential founding stocks for use in the reintroduction strategy should require analysis of genetic information on each of the candidate stocks, as well as consider genetic effects of hatchery management for reintroduction and conservation. We recommend that a genetic management plan be developed that compiles, synthesizes, and integrates this genetic information to go along with an assessment of the compatibility of each stock based on the seven evaluation criteria outlined above. This plan should guide the reintroduction process, and results of the analysis should be used to refine (if needed) the recommended founding stock(s) for the reintroduction strategy. The genetic plan should also address the best way to maintain annual populations above the minimum threshold population size of 500 fish, and should include a genetic monitoring program. Our confidence in this recommendation is high.

3.2 Reintroduction Strategy Objectives and Principles

3.2.1 Goals and Objectives

The primary goal is to establish a self-sustaining population of fall-run and late fall-run Chinook salmon following the goals and objectives outlined in Sections 2.1 and 3.1.1.

3.2.2 Reintroduction Principles

The process recommended for reintroducing fall-run and introducing late fall-run Chinook salmon into the upper San Joaquin River is identical to the recommended process for spring-run Chinook salmon (TAC 2007), which is based on a tiered strategy that includes:

(1) Extensive experimental investigations designed to inform adaptive management decisions using a variety of techniques and diverse approaches, including a range of human interventions (e.g., trap and haul, streamside incubators, etc.), to test and identify the most successful approach to transfer and reintroduce fall-run and late fall-run Chinook salmon, based on the best available information; and

(2) A phased reduction in the level of human intervention as a self-sustaining population of fall-run Chinook salmon becomes established within the river.

A slightly different strategy will likely be required for late fall-run Chinook salmon because it does not currently inhabit the San Joaquin River watershed. The factors and considerations used in developing the reintroduction strategy and specific recommendations by the TAC are briefly outlined below.

3.2.2.1 Use best available stock(s)

As discussed above, the greatest likelihood of achieving a successful reintroduction of fall-run and late fall-run Chinook salmon to the San Joaquin River depends, in part, on the compatibility of the life history characteristics of the founding stock(s) with future environmental conditions on the San Joaquin River. Careful stock selection based on the compatibility of the stock and ability to adapt to San Joaquin River conditions will be important determinants in the long-term success of the reintroduction strategy. Stock selection should not necessarily be made solely on the basis of those stocks that are most available.

3.2.2.2 Use a mixture of reintroduction strategies

One of the principles used by the TAC in developing the framework for the proposed reintroduction strategy is to identify a wide variety of potential management actions and integrated reintroduction strategy elements in the initial phase of the program. This mixture of strategies can then be refined and modified based on results of a genetic management plan. Further analyses can be used to develop a specific recommended reintroduction strategy and associated performance monitoring, as well as inform an adaptive management plan. Reintroduction of a stock from one watershed into another with highly variable environmental conditions and other constraints is characterized by a high degree of uncertainty. The success of various reintroduction strategies within the San Joaquin River is currently uncertain and will be subject to some degree of experimentation and performance evaluation within the overall framework of adaptive management. A number of alternative strategies exist for reintroduction that could range from complete reliance on in-river natural reproduction to complete human intervention through hatchery propagation (e.g., spawning and rearing wild stocks in a hatchery with planting in the river).

In contrast to the spring-run Chinook salmon reintroduction strategy, a substantial or complete contribution to fall-run Chinook salmon reintroduction could come simply from removing the barrier on the lower San Joaquin River at Hills Ferry, and allowing lower San Joaquin River tributary populations of fall-run Chinook salmon to “stray” into the upper San Joaquin River. Fall-run Chinook salmon adults frequently aggregate at the barrier, indicating that, if the barrier were removed during certain times (as described in Section 2.6.1.3), and hydrologic and temperature conditions were favorable, a portion of these adults would migrate up the San Joaquin River. However, since late fall-run Chinook salmon do not currently exist within the San Joaquin River basin, late fall-run Chinook salmon from the Sacramento River basin would need to be introduced on the San Joaquin River. Therefore, the TAC recommends that in the early stages of the reintroduction, a blended strategy be used that relies on a wide variety of techniques offering a diversified approach to reintroduction while avoiding the use of hatchery rearing, if at all possible. The goal of this strategy is to diversify the approaches and actions supporting reintroduction to maximize the likelihood of success and to increase genetic diversity within the founding stock. The recommended approach includes a phased reintroduction strategy that includes greater intervention (e.g., trap and haul, use of hatch boxes and streamside incubators, etc.) in the early years until the stock has been established and local adaptation begins to occur, followed by a phasing out of the level of intervention and a greater reliance on a self-sustaining, in-river, naturally reproducing population. The degree of intervention for fall-run Chinook salmon should be less than late fall-run and spring-run based on the high likelihood of natural straying of existing fall-run adults from the Merced River, and possibly contributions from the Tuolumne and Stanislaus rivers.

3.2.2.3 Choose reintroduction strategies at least partly based on the ability to maximize learning opportunities and provide information on potential adaptive management decisions

While we have high certainty that reintroduction can successfully be done, there is a significant amount of information that needs to be developed to improve the success and effectiveness of reintroducing fall-run and late fall-run Chinook salmon to the upper San Joaquin River. Recognizing the value of additional information, which will reduce inherent uncertainties, the TAC recommends that the structure of the reintroduction strategy and subsequent performance evaluation of management actions and success of reintroduction be conducted within a formal adaptive management framework. The reintroduction strategy and performance evaluation would be structured to include hypothesis testing to inform refinements and adjustments in the implementation of future management actions. The reintroduction strategy should include, in part, identifying those restoration and management actions that could be designed to maximize the information and learning during the initial phases of implementing the reintroduction strategy that would have long-term value in refining future decisions. For example, introducing adult fall-run Chinook salmon into the upper San Joaquin River prior to the Reintroduction Period could provide information on the availability and quality of holding and spawning habitat. Releasing juvenile fish at a size that allowed them to be marked or remotely tracked could provide information on rearing habitat, migration corridors, and sources of mortality. Once the Reintroduction Period begins and study fish could potentially contribute to future escapement, the TAC recommends that hatchery fish no longer be used.

The use of artificial spawning and hatch boxes would permit the genetic tracking of progeny of each pair of fish through the use of Single Nucleotide Polymorphism (SNP) markers and/or mitochondrial

DNA characterization. Thus, the source (from alternative reintroduction techniques) and numbers (performance evaluation) of fish returning to the upper San Joaquin River could be determined, and this information could be used subsequently to modify or refine future elements of the reintroduction strategy. The need for information, especially early in the program, may be one of the primary considerations in selecting methods for reintroduction, even though those methods may not be the most efficient means by which to reintroduce salmon. Based on the best available information, our confidence is high in recommending that the reintroduction strategy be based, in part, on the ability to identify testable hypotheses and conduct performance evaluations that provide information useful in modifying or refining future elements of the reintroduction strategy through a formal adaptive management framework.

3.2.2.4 Application of natural straying, hatchery production, human intervention, and trap and haul techniques as part of the reintroduction strategy

Although a long-term goal of the San Joaquin River restoration program is to establish a self-sustaining naturally produced Chinook salmon population, the TAC expects that intervention will be required in the early phases of reintroduction, and potentially periodically throughout the program (e.g., in response to extended drought conditions). The TAC recommends that direct human intervention in enhancing salmon numbers should be gradually phased out as part of the ongoing management strategy and subsequently reserved for emergencies (e.g., extreme drought). Intervention can take a variety of forms that include, but are not limited to, trap and haul of adults and/or juveniles, use of streamside egg incubators and hatch boxes, and so on. As discussed above, the TAC recommends that a wide variety of techniques, including allowing natural straying (for fall-run) and human intervention techniques (for late fall-run), be used to help establish the initial founding population on the river. As the founding population becomes better established over time and able to respond to conditions through local adaptation, the reliance on intervention techniques can be reduced with a greater proportion of the production originating from in-river spawning and rearing. The San Joaquin River watershed, however, is subject to wide variation in hydrologic conditions, including both floods and droughts that affect habitat conditions, reproduction, and survival of salmonids. For example, under future conditions of an extended drought, conditions on the San Joaquin River for adult and/or juvenile migration may be highly stressed or unacceptable for one or more years. Under these conditions, future limited intervention may periodically be required in order to protect and maintain the founding stock. Additionally, the use of hatcheries and other intervention techniques as part of the reintroduction strategy is discussed in Section 3.2.2.6. Based on the best available information, our confidence is high in recommending that the reintroduction strategy be based on a phased program of reducing intervention over time, with a progressively greater reliance on in-river reproduction and rearing as part of the long-term management framework and as necessary to meet the population targets that are based on naturally reproduced adult escapement.

3.2.2.5 Hatchery management during Reintroduction Period and Interim Population Period

As stated in section 3.1.2.7, hatchery use should be minimized to the greatest degree possible, and limited to: (1) habitat use and behavioral experiments prior to the Reintroduction Period, (2) potentially small supplementation and experimentation during the Reintroduction Period, and (3) emergency conservation during years when escapement falls below the minimum thresholds recommended in Table 1. The TAC envisions that juvenile fall-run Chinook salmon reared from a preferred hatchery could be imported to the San Joaquin River prior to the Reintroduction Period for habitat use and behavioral experiments. Any hatchery use for supplementation and conservation should apply updated rearing techniques (e.g., natural channels or retrofitted raceways that simulate natural channels) that attempt to instill natural behavioral patterns and increased fitness over traditional hatchery rearing (e.g., concrete raceways). A summary of this proposed conceptual hatchery use strategy is illustrated in Table 3, and is discussed below for fall-run and late fall-run Chinook salmon.

During the Experimental Period (2010-2011), a combination of artificial propagation methods should be considered to provide experimental fish as needed to reduce priority uncertainties. Methods may include placement of adults to identify spawning habitat preferences and egg-to-emergence evaluations, importing of eggs into streamside incubators or Friant Hatchery for rearing and release into the river, and/or importing of juveniles from preferred hatcheries for release into the river. Subsequent juvenile outmigration may or may not be successful; those juveniles that do successfully outmigrate will "seed" the ocean for subsequent natural adult migration beginning in the Reintroduction Period (2012).

Artificial migration and propagation methods, such as trap and haul of adults and hatchery production of juveniles, should diminish and eventually be discontinued (Table 3). For example, beginning in 2014, when two-year olds from the 2012 spawner cohort begin to return to the upper San Joaquin River, the Friant Hatchery could begin to be used for population conservation (for those years where adult escapement falls below the minimum thresholds shown in Table 1), using appropriate genetic and hatchery management plans. Most years should rely on natural escapement, spawning, and rearing to provide the outmigrant production needed to grow and sustain the population.

The Friant Hatchery should be retrofitted to provide the short-term experimental and reintroduction uses described above, and periodic use for conserving the population during low escapement years. The Friant Hatchery retrofit should emphasize the latest techniques and infrastructure to improve juvenile salmon behavioral traits and fitness that better reflect those of naturally produced juveniles. In addition, a hatchery management plan should be developed to best achieve these desired juvenile behavioral and fitness improvements, and should incorporate a genetic management plan within the hatchery management plan. As the Reintroduction Period progresses and adult escapement exceeds the minimum population targets in Table 1 (500 fish), the Friant Hatchery should be used for other purposes, or mothballed until needed again when adult escapement falls below 500 fish.

3.2.2.6 Barrier management during Reintroduction Period and Interim Population Period

Hills Ferry Barrier is located on the mainstem San Joaquin River immediately upstream of the Merced River confluence, and has been managed for many years by CDFG to prevent fall-run Chinook salmon migration into the upper San Joaquin River. Throughout the 1970s, salmon were observed migrating upstream past the Merced River confluence into the upper San Joaquin River. Absent a wetted, viable upstream path to upstream spawning areas near Friant Dam, adult fall-run Chinook salmon commonly turned westward into Mud Slough and Salt Slough, where substantial agricultural return flow existed in the fall. They also occasionally ran eastward into Bear Creek and the Mariposa Bypass in those rare times when sufficient flow existed in those channels. Adult Chinook salmon entering those tributary waterways were demographically lost to the San Joaquin River fall-run populations (i.e., perished and thus did not contribute to production from the San Joaquin River basin), given the absence of available spawning habitat in any of the accreting upstream waterways above the Merced River.

Between 1975 and 1989, CDFG operated a spawning station on Salt Slough at the Los Banos Wildlife Area. Salmon spawned at this facility numbered from a few dozen in light-run years to several hundred in heavy-run years. Recovered eggs were transported to the Merced River Hatchery, where the eggs were hatched and juveniles reared to smolt size before being released into the Merced River. Based on the inefficiency and poor viability of the Salt Slough operations, CDFG elected to discontinue the remote spawning station in 1990. Alternatively, they sought financial assistance to construct and operate an adult fish barrier on the San Joaquin River at Hills Ferry, located a short distance upstream from the Merced River confluence. The Hills Ferry Barrier was initially funded through the DWR Four Pumps Mitigation Account, as one means of increasing salmon survival and therefore offsetting direct losses of juvenile salmon at the DWR pumping facilities. Intuitively, the

Table 3. Summary of barrier and hatchery management recommendations on the upper San Joaquin River based on hypothetical future escapement.

	Experimental period				Reintroduction Period (Target=Variable)								Interim Population Period (Target=2,500)					Growth Population Period		
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Hypothetical Adult Fall-Run Escapement to upper San Joaquin River	0	0	0	0	20	50	50	150	500	100	500	1,000	2,000	2,000	1,500	750	200	850	2,600	5,600
Hypothetical Adult Late Fall-Run Escapement to upper San Joaquin River	0	0	0	0	50	200	500	2,000	1,500	300	1,500	2,200	2,500	3,500	1,700	250	150	1,750	1,800	5,200
Hypothetical TOTAL Adult Fall-Run Escapement to upper San Joaquin River	0	0	0	0	70	250	550	2,150	2,000	400	2,000	3,200	4,500	5,500	3,200	1,000	350	2,600	4,400	10,800
Portion of fall-run timing with Hills Ferry Barrier in place	Complete	Complete	Complete	Complete	Periodic	Periodic	Periodic	Periodic	Periodic	Periodic	Periodic	Periodic	Removed	Removed	Removed	Removed	Periodic	Removed	Removed	Removed
Portion of fall-run timing with barriers on Mud and Salt sloughs	None needed	None needed	None needed	None needed	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete
Importing late-fall run eggs/juveniles from preferred adult trap or hatchery			X	X	X	?	?													
Allow natural adult fall-run migration into upper San Joaquin River (Preferred Strategy)					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Importing fall-run eggs/adults from downstream tributaries (Optional Strategy)			Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional									
Experimental, Reintroduction, and Conservation production from Friant Hatchery				R	E, R	E, R	E, R			C							C			

Notes:

1) Adult Fall-Run Escapement would initially occur from allowing a small proportion of fish to migrate to the Upper San Joaquin River via periodic removal of Hills Ferry Barrier; after first few years of Reintroduction Period, natural production from upper San Joaquin River would begin to make a greater proportion of returning adults and Hills Ferry Barrier should be removed except possibly during future low escapement years

2) Adult Late Fall-Run Escapement would initially originate from planting juveniles from a preferred hatchery; after first 2-3 years, natural production from upper San Joaquin River would begin to make a greater proportion of returning adults

3) Hatchery use for conservation production shown for illustrative purposes, specific criteria (e.g., escapement <500 adults) will need to be developed

Barrier operations were known to have avoided the pre-existing losses in Mud and Salt sloughs (and at times in Bear Creek and Mariposa Bypass), and it was universally presumed that the redistributed fish ascended the other downstream tributaries, particularly the Merced River, which is most proximal to the Hills Ferry Barrier.

The original decisions to construct and operate the Hills Ferry Barrier were based on observed mortality of adult salmon in Mud Slough and Salt Slough, and the ineffectiveness of attempts to recover viable eggs from those entrained fish that were able to make it to the spawning station on Salt Slough. Had any viable spawning opportunity then existed in the upper San Joaquin River, the Hills Ferry Barrier would not have been contemplated or operated. Rather, barriers would have been installed at the mouths of Salt and Mud sloughs (and potentially Bear Creek and Mariposa Bypass) to assure that the adult salmon were not diverted away from the viable spawning areas upstream.

The Hills Ferry Barrier is currently installed by October 1 each year, and is typically removed by December 31 (or washed out by a high flow). Restoring fall-run Chinook salmon to the upper San Joaquin River will obviously require management changes to the Hills Ferry Barrier; however, the Barrier can provide some benefits to fall-run and spring-run Chinook salmon reintroduction efforts. Potential management objectives for Hills Ferry Barrier could include managing adult fall-run straying between the upper San Joaquin River and downstream tributaries, encouraging the late fall-run life history strategy, minimizing hybridization of fall-run and spring-run Chinook salmon, and minimizing superimposition losses from fall-run adults spawning on top of spring-run redds. Once fall-run and spring-run Chinook salmon populations are established in the upper San Joaquin River during the Reintroduction and Interim Population periods, management of Hills Ferry Barrier should end (except perhaps during very low escapement years) because straying between the downstream tributaries and the upper San Joaquin should occur in a balanced way to the benefit of all streams. Given historical experience, however, barriers would also likely need to be installed at the outlet of Mud Slough and Salt Slough (and potentially Bear Creek) to prevent adult migration, since these sloughs could often contribute substantial flows to the San Joaquin River and thus provide false pathways for upstream adult fall-run and spring-run Chinook salmon migration.

A barrier management plan for Hills Ferry Barrier should be developed to meet multiple objectives (upper San Joaquin River objectives as well as tributary objectives), and should include coordination with managers on downstream tributaries. As restoration proceeds, viable salmon reproductive opportunity is expected to be recovered within the historical San Joaquin River spawning areas immediately downstream of Friant Dam. As such, it should then become appropriate to cease operation of the Hills Ferry Barrier while maintaining barriers on Mud and Salt sloughs (and potentially Bear Creek). Within a small number of generations, production arising from the upper San Joaquin River should more than offset any reductions to the annual runs within the lower tributaries occurring due to loss of salmon redirection at the Hills Ferry Barrier, and straying adults that were produced from the upper San Joaquin River could eventually begin benefiting adult escapement on downstream tributaries.

Lastly, there is concern about superimposition losses and hybridization imposed on spring-run Chinook salmon redds by spawning fall-run or late fall-run Chinook salmon. Late fall-run spawners would pose a smaller risk because many/most of the spring-run alevins would have emerged prior to late fall-run spawning; however, fall-run spawning would occur during spring-run egg incubation, and superimposition losses may be greater. Therefore, the TAC recommends that spawning timing, location, and superimposition be closely monitored, and if needed, temporary barriers be considered to segregate spawning between the two runs to reduce superimposition and hybridization.

3.2.2.7 A multifaceted monitoring program and adaptive management framework should be integral to the reintroduction strategy

The TAC recommends that the San Joaquin River reintroduction strategy should be developed using the best available information to identify appropriate restoration objectives and corresponding restoration actions. As recommended above, the reintroduction program should include a wide variety of management actions and a corresponding monitoring program to evaluate success and to inform future decisions regarding the prioritization of management actions, refinements or modifications to implementation, or to identify new or alternative management actions as part of the long-term reintroduction strategy. The adaptive management framework should be responsive to changes in environmental conditions, results of habitat and fishery monitoring, and to potential future changes in state or federal environmental regulations, management, species conservation, or protections. Although the TAC has not identified a specific recommendation for a monitoring program to evaluate performance of individual management actions, several of the key elements recommended to be included in a monitoring program are outlined below.

<u>Population and genetic monitoring programs of both source and San Joaquin Riverstocks are necessary to determine success</u>

Determining the numbers of spawners, numbers of juvenile outmigrants, survival rates, genetic diversity, and other parameters can allow models to predict immediate effects of the reintroduction program, as well as long-term stock persistence. This element of the monitoring program should consider both the success of various reintroduction actions in producing fall-run, late fall-run, and spring-run Chinook salmon and the genetic characteristics of the population over time as it adapts and responds to selective pressures within the San Joaquin River. The value of the resulting information in evaluating the long-term performance of the reintroduction strategy and the effectiveness of individual management actions in contributing to the overall restoration goals will be large.

<u>Habitat quantity and use within various reaches of the San Joaquin River should be monitored</u>

A variety of habitat features have been identified that may affect adult migration, holding, spawning, egg incubation, juvenile rearing, or survival of emigrating juveniles within the San Joaquin River. There is a considerable amount of uncertainty in the biological response of salmonids to these factors. For example, the pathway, environmental cues, and rate of upstream and downstream migration within the river, and the response to factors such as exposure to seasonally elevated water temperatures, alternative migration pathways, physical impediments, and hydrologic conditions, will require further investigation. Similarly, there is uncertainty in the importance of features such as captured gravel pits on the migration pathway, rate of migration, exposure to elevated temperatures, and vulnerability to increased predation mortality. The TAC recommends that a focused effort be given to the compilation of information available from monitoring salmonid populations on other Central Valley river systems and a critical assessment of monitoring needs and alternative approaches be conducted. The TAC recommends that a robust monitoring and evaluation program be designed and implemented to address and evaluate these and other key issues affecting the design, implementation, priorities, and success of the reintroduction strategy and for informing future decisions regarding refinements or modifications to the reintroduction strategy. The value of the resulting information in evaluating the long-term performance of the reintroduction strategy, and the effectiveness of individual management actions in contributing to the overall reintroduction strategy, will be large.

3.2.2.8 Consider a range of environmental factors when assessing the restoration program performance

Salmonid populations are affected by a wide variety of biological and environmental factors beyond those that occur within the upstream spawning and juvenile rearing habitat (e.g., conditions in the

Delta and ocean). In addition, factors such as natural variation in hydrologic conditions within a watershed can also have a significant effect on salmonid survival and abundance. In developing the recommended goals for the San Joaquin River restoration program (Section 1), the TAC acknowledged that population abundance on the San Joaquin River is expected to be highly variable among years and that variation should be taken into consideration when evaluating program performance. Annual variation in fall-run Chinook salmon escapement in tributaries to the San Joaquin River is high (e.g., Figures 4-6), thus escapement trends on the San Joaquin River should be evaluated with respect to concurrent escapement trends on the downstream tributaries. This comparison should help enable us to evaluate whether population trends are a result of river-specific causes (e.g., spawning habitat, water quality) or other causes (e.g., Delta or ocean conditions), which would result in similar escapement trends between the San Joaquin River and its downstream tributaries. In this regard, the TAC recommends that evaluation of program performance not be based on results from any one year, but rather performance should include consideration of meeting the minimum population target over a period of years reflecting multiple cohorts and generations. Thus, the number of fish returning (for example) in a single year may not be indicative of re-establishment success. Results of the monitoring program can be used to help evaluate the contribution, or lack thereof, of various elements of the reintroduction strategy in meeting the long-term goals of the program. The TAC recommends, however, that caution be exercised in modifying the fundamental reintroduction strategy until a clear trend has been established, which may take a number of years to become evident. Rapid modifications to the fundamental reintroduction strategy in response to short-term or individual events is expected to make interpretation of long-term monitoring and performance evaluation results difficult to interpret and use for making meaningful modifications within the adaptive management framework.

3.2.2.9 Spring-run Chinook salmon should have higher priority for reintroduction than fall-run Chinook salmon

The Settlement envisions restoration of both spring-run and fall-run Chinook salmon to the upper San Joaquin River. Spring-run Chinook salmon typically spawn during September and October while fall-run Chinook salmon typically spawn during October-December. As a result of the overlap in seasonal timing and location of spawning within the upper San Joaquin River, there is the potential for: (1) hybridization between the two runs that may adversely or beneficially affect population genetics, and (2) fall-run Chinook salmon superimposition of redds that would adversely affect reproductive success of the earlier spawning spring-run Chinook salmon. Hybridization between the two run types, especially early in the reintroduction program, could reduce the potential for establishing a spring-run phenotype and increase problems with fish that might stray into spring-run Chinook salmon streams in the Sacramento Valley. Very large fall-runs could overwhelm small populations of spring-run Chinook salmon and eliminate the spring-run phenotype. However, in the Feather River, the two forms apparently hybridize freely and both phenotypes are maintained. The TAC recognizes that the potential for these effects to occur is uncertain, but recommends that the reintroduction strategy make the reintroduction of spring-run Chinook salmon as the primary objective in the early phase of restoration. Various types of management actions could be implemented on an adaptive basis in the event that monitoring results show adverse effects of fall-run Chinook salmon in meeting the primary restoration objective (e.g., segregation weirs, altered hydrology to regulate migration of fall-run Chinook salmon, management of fish passage and ladders, etc.). In addition, the TAC recommends that late fall-run Chinook salmon be prioritized over fall-run Chinook salmon because the late fall-run life history strategy will likely be more successful than the fall-run life history strategy.

3.3 Synthesis

The reintroduction strategy relies on a phased program of intervention. During the early phases of reintroduction, experimental investigations and monitoring will be important in informing adaptive management decisions and refinements to the reintroduction strategy as new information becomes available. During the early phases of reintroduction, a wide variety of techniques and approaches would be applied and tested, and the late fall-run Chinook salmon would originate from out-of-basin stocks with a relatively high degree of human intervention. As a self-sustaining population of late fall-run Chinook salmon becomes established on the upper San Joaquin River, the transfer of Sacramento River basin stocks would decrease and the proportion of in-river spawning to support the population would increase with the ultimate restoration goal of re-establishing a self-sustaining and naturally reproducing late fall-run Chinook salmon population (and fall-run Chinook salmon population) on the San Joaquin River. The sections below briefly outline the TAC expectations and vision of the phased approach to the reintroduction strategy.

3.3.1 Phase 1 – Experimental Period (through 2011)

The early phase of restoration implementation is expected to be experimental and designed to test basic hypotheses and provide information useful in refining the reintroduction strategy under an adaptive management framework. In the Experimental Period, emphasis would focus on identifying uncertainties, hypotheses to be tested, and key management decisions that require additional information or validation. Within the context of the framework provided by the initial reintroduction strategy, specific questions would be identified for preliminary testing using various life history stages of fall-run Chinook salmon. During the Experimental Period, experiments with different reintroduction methods could be designed and tested. For example, 50 pairs of adult salmon (subject to availability from downstream sources) could be transported to the reach between Friant Dam and Lanes Bridge. Their spawning behavior, choice of adult holding and spawning sites, and survival of embryos in gravel could be monitored. In addition, embryos could be experimentally incubated in hatch boxes at various locations in the below-dam reach to determine optimal sites for such procedures. Salmon fry reared in a hatchery under normal crowded conditions, and in low density enriched environments, could be individually marked and released into the river to compare survival. Results of these and other tests could then be used to help refine population models of the number of broodstock, eggs, fry, or smolts that would need to be introduced in a particular year to achieve the target for returning adults.

In the last 2 years (2010-2011) of the Experimental Period, juvenile salmon should be allowed to emigrate to the ocean to “seed” upper San Joaquin River fish in the ocean that would return as adults during the Reintroduction Period. Given that habitat restoration efforts will just be starting, and flow releases will be limited to the Interim Flow schedule, outmigration and “seeding” success of these juveniles may be low or zero. Use of study fish from available hatchery stock or other appropriate facilities (e.g., streamside incubation boxes) will be needed during most phases of reintroduction to evaluate success and survival of instream rearing and downstream migrating juvenile salmon, or for differentiating downstream migratory “pulses” of upper San Joaquin River produced salmon from evaluation populations within the other tributaries. Wherever hatchery salmon are utilized in studies, appropriate study plans should be developed to assure that: (1) all salmon are marked and distinguishable from naturally produced fish, and (2) hatchery salmon are utilized concordantly with a genetic management plan for San Joaquin River fall-run Chinook salmon. The Experimental Period runs some risk that experimental fish may ‘escape’ from the study area (e.g., with high flows) and then return after the reintroduction has begun, but efforts should be made to minimize this risk. If study fish are used during the last 2-3 years of the Experimental Period or during the Reintroduction Period, when we are actively trying to encourage smolt production from the upper San Joaquin River, then study fish should come from eggs obtained from adults in San Joaquin River tributaries. The eggs should be incubated in hatch boxes on the upper San Joaquin River, or in the San Joaquin Hatchery facility at Friant, so as to assure behavioral imprinting of juveniles to the Friant Reach.

This approach would make use of both conceptual and quantitative life-history models to identify uncertainties and apportion the expected number of returning adults (or available broodstock) to each of these life history stages (or experimental designs) as part of the reintroduction strategy.

Information gained from these experimental tests during the early phase of the program implementation would help refine both the predictive models as well as improve water and fish management and habitat conditions as part of the overall reintroduction strategy. This approach adopts a variety of different methods (or mixed strategies) for reintroduction. The range of methods and test conditions would be reduced as specific questions are addressed and as uncertainty in the reintroduction strategy performance is reduced.

3.3.2 Phase 2 – Reintroduction Period (2012-2019)

Introductions of fall-run Chinook salmon to the upper San Joaquin River would be made by selective removal of the Hills Ferry Barrier and allowing natural immigration of adults. Until production from the upper San Joaquin River offsets any straying-related reductions to the annual runs within the downstream tributaries, the TAC recommends that the Hills Ferry Barrier be managed to allow most of the fall-run to migrate into the Stanislaus, Tuolumne, and Merced rivers, then remove the Barrier to allow the entire late fall-run to migrate to the upper San Joaquin River. Barrier management could also reduce hybridization and superimposition risk between fall-run and spring-run Chinook salmon. Use of the Hills Ferry Barrier should be phased out as populations become established, and the potential positive and negative effects of straying are shared amongst the tributaries and upper San Joaquin River. However, the TAC recommends that the option for Barrier management beyond the Reintroduction Period be retained if conditions warrant.

For late fall-run Chinook salmon, all introductions would be made of fish with known genetic history, using progeny of a minimum of 50 pairs of late fall-run Chinook salmon each year (obtained from the Sacramento River basin). If there is high success using stream incubation boxes in the Experimental Period, then this should be the primary method of introduction for Sacramento River basin late fall-run Chinook salmon. In a manner similar to and integrated with the spring-run Chinook salmon reintroduction, each stream incubation box should contain embryos (eggs) of known parentage so the young can be tracked genetically. This will allow close monitoring of effective population sizes, with genetic diversity gradually increasing with each year. If stream incubation boxes prove too limiting in numbers of fish produced, then hatchery options should be explored whereby embryos of known parentage are incubated, imprinted, and planted as fry to augment in-river spawning. Eggs from the Sacramento River basin stocks may also be reared to various developmental stages and imprinted at the San Joaquin Hatchery facility in order to produce markable, uniform size lots of the chosen reintroduction genetic stock for particular survival or other evaluations, as may be prescribed in the adaptive management process. Direct use of these fish would be much preferred over use of non-target genetic stocks (which may behave differently) for evaluations. During Phase 2, experimental testing and monitoring of the performance and contribution of various management actions and approaches would continue to inform adaptive management decisions and identify refinements to the reintroduction strategy. As the population of late fall-run Chinook salmon becomes better established and increases in abundance, the Reintroduction Period would serve as a transition from a greater reliance on human intervention, as in the Experimental Period, to a greater reliance on natural, in-river spawning and production to support a self-sustaining population.

3.3.3 Phase 3 – Interim and Growth Population Period (2020-2040)

If indicated from close monitoring of returning adult escapement, stream incubator boxes could continue to be used if needed in the first years of Phase 3, until it is determined that genetic diversity and population demographics (e.g., trends in abundance relative to the targets outlined in Section 2.3, reproductive success of in-river spawning Chinook salmon, juvenile survival, age structure, etc.) is adequate for a self-sustaining population. Consideration will also need to be given to identifying environmental conditions where human intervention in the future can be reduced and those circumstances (such as under an extended drought) when management actions, such as limited trap and haul or other actions, may be required to protect the population. We assume that annual escapement and management actions will be reviewed each year by the Implementing Agencies, and the Settlement requires a substantial review if spring-run populations fall below 500 in any year after 2019 (7 years after reintroduction). In addition, if by 2030, it appears that population sizes are still too small, monitoring data and restoration strategies and efforts should be assessed by the TAC in consultation with the other implementing agencies, and recommendations should be developed to improve returns. Given the hydrology provided for by the Settlement and natural climatic conditions in the lower San Joaquin River, the TAC expects that the two fall-run populations, through natural selection, will evolve their life histories into a single population with an adult spawning timing in the winter months (December-March), and juveniles over-summering and outmigrating to the Delta as yearlings. This life-history strategy should be much more successful than the existing fall-run Chinook salmon populations on San Joaquin River tributaries.

3.4 Information Needed to Refine and Implement Reintroduction Strategy

In developing the initial reintroduction recommendations outlined above, a range of additional information would be useful to refine and implement the reintroduction strategy. These needs include, but are not limited to the following:

- Review additional literature on the design and success of reintroduction strategies for salmonids to help develop restoration guidelines and milestones. Information is available on the life-history requirements, behavior, environmental conditions, and other factors that should be taken into consideration in developing and refining the reintroduction strategy. In addition, information is available from other fishery restoration programs, involving salmonids and other fish species, that would help provide insight into those management techniques and experimental/monitoring programs that have proven to be successful and potentially applicable to the San Joaquin River.
- Develop a genetic management plan. Protecting and promoting genetic diversity within the re-established San Joaquin River Chinook salmon populations is an important consideration in developing and implementing the reintroduction strategy. A qualified geneticist, familiar with salmonid populations, should assist in evaluating the potential beneficial or adverse effects of alternative management actions on population genetics, developing the criteria and monitoring protocols for genetic management, and the overall integration of genetic considerations into the development and implementation of the reintroduction and restoration plan. The genetic management plan should consider spring-run, fall-run, and late fall-run Chinook salmon.
- Evaluate potential stocks for late fall-run Chinook salmon reintroduction. As discussed above, a variety of late fall-run Chinook salmon stocks are potentially available for use as a founding stock for reintroduction. Selection of a founding stock would be based on a variety of considerations including, but not limited to, the geographic location of the stock, seasonal timing of adult and juvenile migration relative to the anticipated environmental conditions on the San Joaquin River, population genetics, compatibility with Central Valley habitat conditions, and other factors. The general considerations and process recommended by the TAC for stock selection are outlined in Section 3.1.
- Evaluate alternative management actions and methods for reintroduction. Actions and methods may include: evaluation of trap and haul (timing and location of trapping and release, transport of immature adults vs. fertilized eggs, etc.); determining locations for trapping adults and juveniles within the San Joaquin River as part of trap and haul operations in dry and critical water years; determining allocations and performance of alternative production techniques, such as streamside egg incubators with volitional release, egg incubator boxes and artificial redds; using the hatchery to produce various life stages of juvenile Chinook salmon and alternative planting strategies; evaluating the allocation between in-river production and alternative production techniques; evaluating needs for

segregation between fall-run and spring-run Chinook salmon; determining adult spawning and juvenile rearing habitat opportunities and constraints; and other elements of the initial reintroduction strategy.

- Develop monitoring plan. Establish monitoring methods and procedures (e.g., SNP markers, weirs, screw traps, thermal or chemical otolith marks, coded wire or PIT tagging) to evaluate performance of each element of the reintroduction strategy in contributing to long-term adult population trends (e.g., adult migrants, spawning, juvenile growth rates, rearing survival, production, smolt survival during migration, migration timing, migration rates, and population genetics). Monitoring should also include physical habitat conditions, hydrology, and water quality at various locations within the river as well as within Millerton Lake.
- Conceptual and quantitative population models. Develop the necessary data inputs to support conceptual and quantitative models of fall-run and late fall-run Chinook salmon life history and the effects of various alternative management actions and environmental stressors on population dynamics. The model should eventually be linked with fall-run Chinook salmon populations inhabiting downstream tributaries.
- Adaptive management framework. Develop the testable hypotheses and structure for integrating program monitoring and performance evaluations within the framework of adaptive management for refining and modifying the reintroduction strategy. Management issues appropriate for an adaptive management approach need to be identified, and testable hypotheses for these management issues need to be developed and incorporated into the overall experimental design and work plan. The adaptive management framework should be responsive to changes in environmental conditions, results of habitat and fishery monitoring, and to potential future changes in state or federal environmental regulations, management, species conservation, or protections.

The TAC recommends that a phased plan of implementation be developed that addresses these and other information needs and initial decisions regarding refinement and evaluation of the reintroduction strategy. The phased plan would be an evolving document designed to provide program guidance as new information is developed and as new challenges in meeting the program goals are identified based on evaluation of the performance and contribution of specific management actions.

3.5 Recommendations

From our review of the available literature, criteria and procedures described above, and our best professional judgment, we offer eighteen recommendations for Stock Selection and Reintroduction Strategy for re-establishing naturally-produced fall-run and late fall-run Chinook salmon on the upper San Joaquin River.

3.5.1 Stock Selection

Recommendation 15: The founding stock for late fall-run Chinook salmon should be selected from currently existing stocks inhabiting the Central Valley to maximize the likely success of local adaptation to the San Joaquin River. Preliminary assessment of potential founding stocks indicate that the Sacramento River late fall-run Chinook salmon has life history characteristics that may be most compatible with the anticipated future environmental conditions on the upper San Joaquin River. The TAC recommends that a more detailed analysis be conducted to further evaluate the potential use of the Sacramento River founding stocks as part of refining the San Joaquin River reintroduction strategy.

Recommendation 16: The founding stock for fall-run Chinook salmon should be the currently existing stocks inhabiting the lower San Joaquin River tributaries (Stanislaus, Tuolumne, and Merced rivers) to maximize the likely success of local adaptation to the upper San Joaquin River. We recommend that the Hills Ferry Barrier be managed so these stocks be reintroduced by natural migration as a means preferable to: (1) trap and haul from the lower San Joaquin River, (2) adult trapping on one of the tributary streams (Merced, Tuolumne, or Stanislaus rivers), or (3) planting from the Merced River Hatchery.

Recommendation 17: The founding stock should have adequate genetic material (i.e., population abundance and genotypic/phenotypic diversity) to allow San Joaquin River specific pressures to eventually produce a locally adapted stock.

Recommendation 18: Factors that should be considered when selecting the founding stock(s) include: (1) current trends in abundance of source fall-run and late fall-run Chinook salmon populations; (2) whether existing habitat conditions within a source watershed are fully used (e.g., are “surplus” fish available for relocation with minimal or potentially beneficial effects); (3) logistic conditions affecting the ability to successfully collect and transport adults, eggs, or juveniles; and (4) the genetic characteristics of the founding stock. These recommendations are intended to inform the Secretary of the Interior, as well as state and federal fishery biologists who are responsible for final identification and selection of the founding stock(s) for reintroduction on the San Joaquin River.

Recommendation 19: Measures to assure fidelity to the San Joaquin River spawning areas, such as juvenile imprinting and marking programs, should be used to help monitor and reduce inter-basin movement of late fall-run Chinook salmon from the upper San Joaquin River to downstream tributaries while establishing the initial population on the upper San Joaquin River.

Recommendation 20: A founding stock should be selected that has behavioral and life history characteristics most compatible with the anticipated conditions on the San Joaquin River.

Recommendation 21: Wild stocks should be evaluated from various Central Valley rivers as a founding stock with the goal of maximizing, to the extent possible, the genetic diversity of the founding stock to support the greatest degree of local adaptation to the San Joaquin River and to match the compatibility of life history characteristics with anticipated future environmental conditions.

Recommendation 22: A technical report should be developed that compiles, synthesizes, and integrates information on the life history characteristics and genetics of candidate stocks along with an assessment of the compatibility of each stock with anticipated future environmental conditions on the San Joaquin River to support a recommendation regarding the selection of one or multiple founding stocks for the reintroduction strategy. This technical report should include spring-run, fall-run, and late fall-run Chinook salmon stocks.

3.5.2 Reintroduction Strategy

Recommendation 23: A phased strategy should be used during the early stages of reintroduction that blends a wide variety of techniques, incorporates additional information developed in the coming years, and offers a diversified approach to reintroduction.

Recommendation 24: The structure of the reintroduction strategy and subsequent evaluation of the performance of the management actions and success of reintroduction should be conducted within a formal adaptive management framework.

Recommendation 25: Juveniles produced for studies in the upper San Joaquin River in the 2-3 years prior to commencing the Reintroduction Period in 2012 should be allowed/encouraged to successfully outmigrate to “stockpile” upper San Joaquin River stocks in the ocean to encourage rapid adult returns when the Reintroduction Period begins.

Recommendation 26: The fall-run Chinook salmon reintroduction strategy should initially allow natural straying of adults via selective and periodic removal of Hills Ferry Barrier. Careful monitoring of adult populations in the donor streams (Merced, Tuolumne, and Stanislaus rivers) needs to be conducted to inform Hills Ferry Barrier management and reduce risk of adverse impacts to donor populations as well as reintroduced San Joaquin River populations. In years prior to the upper San Joaquin River producing larger numbers of returning adult fall-run Chinook salmon, the Hills Ferry Barrier should be managed to allow most of the fall-run escapement to migrate into the Stanislaus, Merced, and Tuolumne rivers, and allow the entire late fall-run to migrate into the upper San Joaquin River. The Barrier should be phased out as adult production from the upper San Joaquin River increases, yet flexibility should be retained to potentially use the Barrier in low escapement years. The Barrier should be managed by CDFG in consultation with regulatory agencies, the TAC, tributary managers, and other appropriate groups. Marking studies should be conducted to better understand the origin of juvenile production and distribution of adult escapement between the tributaries and the upper San Joaquin River. Barriers should be installed on Mud and Salt sloughs (and considered for Bear Creek) to prevent adult migration to false pathways.

Recommendation 27: The late fall-run Chinook salmon reintroduction strategy will require initial intervention techniques to establish the initial founding population because the late fall-run stocks will originate from the Sacramento River basin. A marking program should be developed for late fall-run juveniles to allow distinction from winter-run juveniles at the State Water Project and Central Valley Project pumping plants and fish salvage facilities.

Recommendation 28: As the founding population becomes better established over time and able to respond to conditions through local adaptation, the reliance on intervention techniques should be reduced, with a greater proportion of the production originating from in-river spawning and rearing in order to meet the recommended population goals, targets, and milestones.

Recommendation 29: The information available from monitoring salmonid populations in other Central Valley river systems should be compiled, and a critical assessment of monitoring needs and alternative approaches should be conducted prior to reintroduction. The monitoring and evaluation program should be designed to address and evaluate these and other key issues affecting the design, implementation, priorities, and success of the reintroduction program and for informing future decisions regarding refinements or modifications to the reintroduction strategy.

Recommendation 30: Caution should be exercised in modifying the fundamental reintroduction strategy until a clear trend is established, which may take a number of years to become evident.

Recommendation 31: The monitoring program and implementation of the reintroduction strategy should give priority status, in the early phase of restoration, to establishing spring-run Chinook salmon as the primary objective of the reintroduction strategy. Late fall-run and fall-run Chinook salmon should be the next priority objective.

Recommendation 32: In developing the phased reintroduction strategy, information should be gathered and compiled to provide technical support for initial decisions regarding the proposed reintroduction strategy. Tasks and information should include:

- Review available literature on the design and success of reintroduction strategies for salmonids to help develop restoration guidelines and milestones;
- Select stock for reintroduction;
- Evaluate alternative management actions and methods for reintroduction including: (1) developing a management plan for the Hills Ferry Barrier to allow for managed natural fall-run straying into the upper San Joaquin River; (2) considering trap and haul of adult fall-run if natural straying proves unsuccessful; (3) determining locations for trapping adults and juveniles within the San Joaquin River if trap and haul operations are needed in dry and critical water years; (4) developing a basin-wide fall-run and late fall-run Chinook salmon management plan to address fish management issues with downstream tributary managers; (5) determining allocations and performance of alternative production techniques such as

streamside egg incubators with volitional release, egg incubator boxes and artificial redds; (6) using the hatchery to produce various life stages of juvenile salmonids and alternative planting strategies; (7) allocating between in-river production and alternative production techniques; (8) identifying needs for segregation between spring-run Chinook salmon and fall-run Chinook salmon, including temporary barriers in the spawning reach; (9) determining adult spawning and juvenile rearing habitat opportunities and constraints; and (10) other elements of the initial reintroduction strategy;

- Establish monitoring methods and procedures to evaluate performance of each element of the reintroduction strategy in contributing to long-term adult population trends. Monitoring should also include physical habitat conditions, hydrology, and water quality at various locations within the river, as well as within Millerton Lake;
- Develop the necessary data inputs to support conceptual and quantitative models of salmonid life history and the effects of various alternative management actions and environmental stressors on population dynamics; and
- Develop testable hypotheses and a structure for integrating program monitoring and performance evaluations within the framework of adaptive management for refining and modifying the reintroduction strategy.

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