RECLAMATION

Managing Water in the West

Yolo Bypass Salmonid Habitat and Fish Restoration Project

Plan Formulation Report

U.S. Department of the Interior
Bureau of Reclamation

February 2019

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List of Abbreviations and Acronyms

A	ampere
AF	acre-feet
AQMD	Air Quality Management District
ARCF	American River Common Features
BMP	best management practice
BO	biological opinion
BPM	Bypass Production Model
CAA	Clean Air Act
CAAQS	California Ambient Air Quality Standard
CCR	California Code of Regulations
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife (after January 1, 2013)
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
cfs	cubic foot per second
CGS	California Geological Survey
CO	carbon monoxide
CVFED	Central Valley Floodplain Evaluation and Delineation
CVFPP	Central Valley Flood Protection Plan
CVP	Central Valley Project
CWA	Clean Water Act
CY	cubic yards
Delta	Sacramento-San Joaquin Delta
DPS	distinct population segment
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ELAM	Eulerian-Lagrangian Agent Method
ESA	Endangered Species Act
FL	fork length
FWWA	Fremont Weir Wildlife Area
GHG	greenhouse gas
HEC-RAS	Hydrologic Engineering Center River Analysis System
hp	horsepower
I	Interstate
IMPLAN	Impact Planning and Analysis
ITA	Indian Trust Asset
JEET	Juvenile Entrainment Evaluation Tool
KLRC	Knights Landing Ridge Cut
kVA	kilovolt-amps
kW	kilowatt
LIER	Liberty Island Ecological Reserve

mm	millimeter
NAAQS	National Ambient Air Quality Standard
NAVD 88	North American Vertical Datum of 1988
NEPA	National Environmental Policy Act
NGO	non-governmental organization
NMFS	National Oceanic and Atmospheric Administration National Marine Fisheries Service
O&M	operations and maintenance
O_3	ozone
PR&G	2013 Principles, Requirements and Guidelines for Water and Related Land Resources Implementation Studies
PLC	programmable logic controller
$PM_{2.5}$	fine particulate matter, particles up to 2.5 microns
PM_{10}	coarse particulate matter, particles up to 10 microns
Project	Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project
Reclamation	United States Department of the Interior, Bureau of Reclamation
RM	river mile
RPA	reasonable and prudent alternative
SBM	Salmon Benefits Model
SBWA	Sacramento Bypass Wildlife Area
SPFC	State Plan of Flood Control
SRBPP	Sacramento River Bank Protection Project
SRFCP	Sacramento River Flood Control Project
State	State of California
SVAB	Sacramento Valley Air Basin
SWP	State Water Project
TCP	traditional cultural property
TN	ton
TUFLOW	two-dimensional unsteady flow
UCCE	University of California Cooperative Extension
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
VAC	volts alternating current
WTP	willingness to pay
YBWA	Yolo Bypass Wildlife Area

1 Introduction

This Plan Formulation Report describes the plan formulation process for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Project). The purpose of the Project is to improve fish passage in the Yolo Bypass and increase floodplain fisheries rearing habitat in Yolo Bypass and/or the lower Sacramento River basin. The Bureau of Reclamation (Reclamation) and California Department of Water Resources (DWR) (collectively referred to as the Lead Agencies) are working to identify and evaluate alternatives for implementing this Project.

1.1 Background

Substantial modifications have been made to the historical floodplain of California's Central Valley for water supply and flood damage reduction purposes. The resulting losses of rearing habitat, migration corridors, and food web production for fish have adversely affected native fish species that rely on floodplain habitat during part or all of their life history.

DWR is responsible for operating and maintaining the State Water Project (SWP), and Reclamation is responsible for managing the Central Valley Project (CVP). The SWP and CVP deliver water to agricultural, municipal, and industrial contractors throughout California. On June 4, 2009, the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) biological opinion (BO) concluded that, if left unchanged, CVP and SWP operations are likely to jeopardize the continued existence of four anadromous species listed under the Federal Endangered Species Act (ESA): Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and southern distinct population segment (DPS) North American green sturgeon. The NMFS BO sets forth Reasonable and Prudent Alternative (RPA) actions that allow CVP and SWP operations to remain in compliance with the ESA.

RPA actions I.6.1 and I.7 identify fish passage and habitat restoration actions in the lower Sacramento River basin, including the Yolo Bypass. The Yolo Bypass, which currently experiences at least some flooding in approximately 70 percent of years, retains many characteristics of the historical floodplain habitat that are favorable to various fish species. Implementation of the RPA actions would enhance existing floodplain benefits in the lower Sacramento River basin and improve fish passage in Yolo Bypass. The primary function of the Yolo Bypass is flood damage reduction, with most of the bypass also managed as agricultural land. Major California restoration planning efforts (e.g., CALFED Bay-Delta Program, the Bay Delta Conservation Plan, and California EcoRestore) have (or are) focused on the Yolo Bypass as a prime area of the Sacramento Valley for enhancement of seasonal floodplain fisheries rearing habitat.

The two RPA actions that form the basis for alternatives considered in this report include:

- RPA Action I.6.1: Restore floodplain rearing habitat for juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead through increased acreage of seasonal floodplain inundation within the lower Sacramento River basin
- RPA Action I.7: Reduce migratory delays and loss of salmon, steelhead, and sturgeon at Fremont Weir and other structures in Yolo Bypass (NMFS 2009)

In addition to the species included in the NMFS BO, two other species listed under the California Endangered Species Act (CESA) as fisheries Species of Special Concern may benefit from increased floodplain rearing habitat: Sacramento splittail and Sacramento River fall-run Chinook salmon.

1.2 Study Area Location and Description

The study area includes the lower Sacramento River basin, including Yolo Bypass, in Sacramento, Solano, Sutter, and Yolo counties, California. Major water bodies and infrastructure located within the study area include the Sacramento River; Fremont, Sacramento, and Lisbon weirs; Knights Landing Ridge Cut (KLRC) and Wallace Weir; Cache and Putah creeks; Willow Slough Bypass; Tule Canal; and the Toe Drain. Figure 1-1 shows the study area location.

Yolo Bypass is a flood bypass along the Sacramento River located in Yolo, Solano, and Sutter counties. The bypass separates the California cities of Sacramento and Davis. Flood inflow to the bypass primarily occurs through the Fremont Weir. Fremont Weir is one of five weirs along the Sacramento River. The weir overflows into Yolo Bypass at an elevation of 32 feet (crest elevation). Sacramento Weir can also be opened into the bypass to divert additional flood flows to protect Sacramento and West Sacramento. The bypass ends a few miles north of Rio Vista in the Liberty Farms area where it joins first Prospect Slough and then Cache Slough adjacent to the connection of the Sacramento Deep Water Ship Channel. Cache Slough then reconnects with the Sacramento River just north of Rio Vista. The Yolo Bypass has a maximum design flow capacity of 600,000 cubic feet per second (cfs) and covers an area of approximately 59,000 acres (DWR 2010). The Yolo Bypass experiences at least some flooding in approximately 80 percent of the years. The floods of 1986 and 1997 inundated the Yolo Bypass to maximum design capacity.

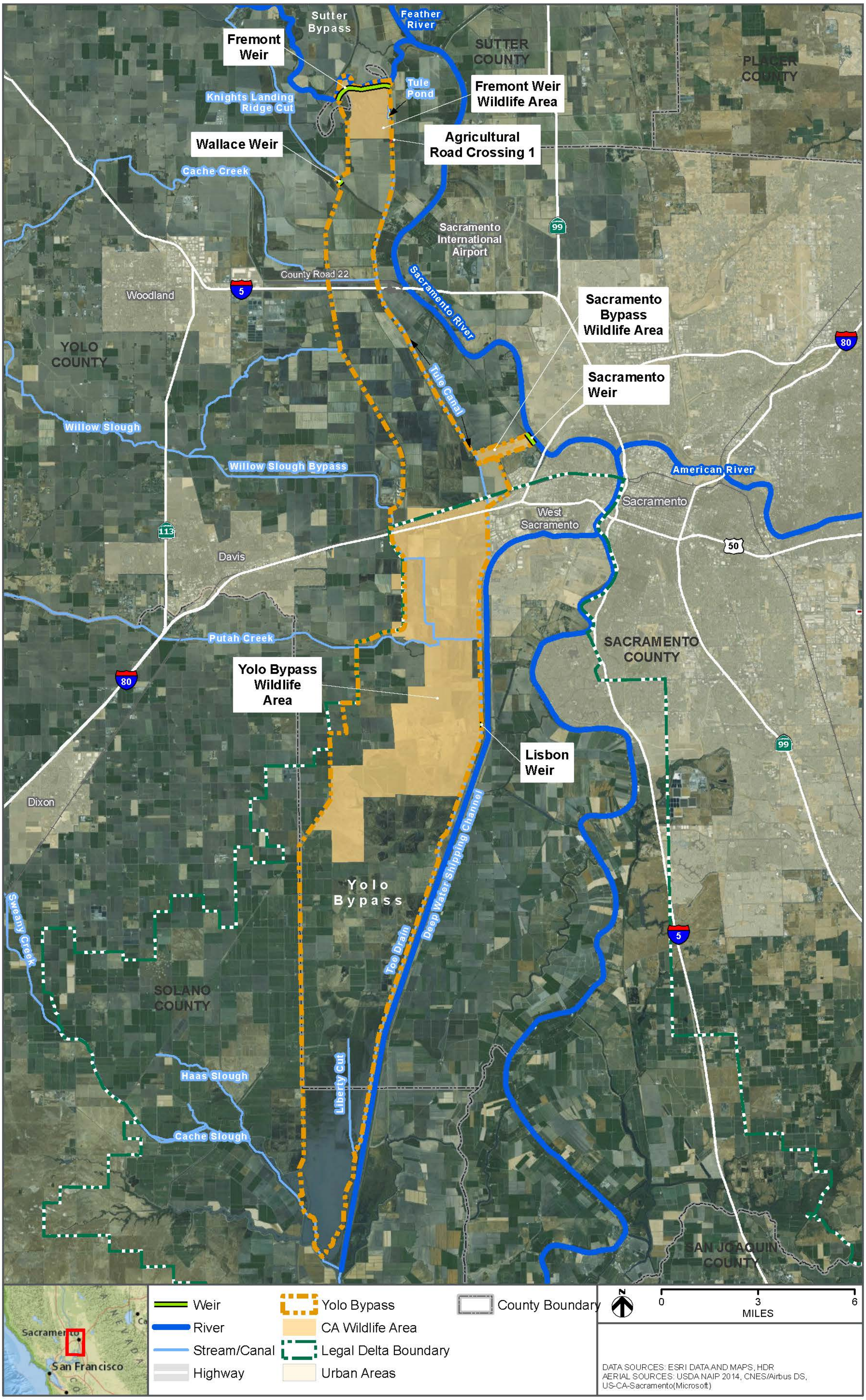

Figure 1-1. Project Area

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Major infrastructure in Yolo Bypass relevant to the Project includes:

- Fremont Weir – Fremont Weir allows relief from the Sacramento River in times of high flood stage to divert water around the City of Sacramento within Yolo Bypass.
- Sacramento Weir – Sacramento Weir is located along the right bank of the Sacramento River approximately two miles upstream from the mouth of the American River. Its primary purpose is to protect the City of Sacramento from excessive flood stages in the Sacramento River channel downstream of the American River.
- Agricultural Road Crossing 1 – Agricultural Road Crossing 1, which is the northernmost agricultural road crossing in Tule Canal at the southeastern corner of the Fremont Weir Wildlife Area (FWWA), serves as a vehicular crossing and a water delivery feature.
- Tule Pond – Tule Pond is an approximately 15-acre perennial pond in Yolo Bypass located about 13 miles north of Interstate (I) 80. It is likely the pond is sustained by multiple sources, including impounded floodwater, leakage from an agricultural canal at its southern end, and groundwater.
- Tule Canal – Tule Canal is a channel along the east side of Yolo Bypass, which begins south of Tule Pond. Tule Canal receives water from westside tributaries and agricultural diversions almost year-round. Tule Canal also drains the initial flows from the Sacramento River when the river rises above the crest of Fremont Weir.
- Toe Drain – Tule Canal becomes the Toe Drain south of the I-80 Yolo Causeway. The perennially wetted Toe Drain extends south approximately 20 miles and becomes increasingly tidal as it connects with Cache Slough, past Lower Yolo Bypass.
- Lisbon Weir – Lisbon Weir is the southernmost water-control structure that crosses the Toe Drain. Lisbon Weir provides higher and more stable water levels to water users north of the weir.

1.3 Authorization

Authority for combined Federal and State of California (State) documents is provided in Title 40, Code of Federal Regulations (CFR), Sections 1502.25, 1506.2, and 1506.4 (Council on Environmental Quality's Regulations for Implementing the National Environmental Policy Act [NEPA]) and California Code of Regulations (CCR) Title 14, Division 6, Chapter 3 (California Environmental Quality Act [CEQA] Guidelines), Section 15222 (Preparation of Joint Documents). This document also was prepared consistent with United States Department of the Interior regulations specified in 43 CFR, Part 46 (United States Department of the Interior Implementation of NEPA, Final Rule).

1.4 Problems, Opportunities, Constraints, and Objectives

The problems, opportunities, constraints, and objectives describe why Reclamation and DWR are considering the Project.

1.4.1 Problems

Populations of the four fish species in the NMFS BO have declined substantially from their historical numbers, primarily due to habitat degradation. The following paragraphs further describe the recent decline of fish populations for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and southern DPS green sturgeon as well as Sacramento River fall-run Chinook salmon and Sacramento splittail, two species of special concern under CESA. This section concludes with a discussion of the problems within the Yolo Bypass that are preventing it from providing rearing habitat and fish passage. Historical fish data and fish problems within the Yolo Bypass are summarized from NMFS 2009 unless otherwise noted.

Sacramento River winter-run Chinook Salmon – Historical Sacramento River winter-run Chinook salmon population estimates were as high as over 230,000 adults in 1969 but declined to under 200 fish in the 1990s. From 2006 to 2008, population estimates were fewer than 3,000 fish. The development of upstream facilities, such as Shasta Dam and Reservoir, blocked much of the winter-run Chinook salmon historical spawning and rearing habitat. Approximately 299 miles of tributary spawning habitat in the upper Sacramento River is now inaccessible to winter-run Chinook salmon. The remaining spawning and rearing habitat is severely degraded, and continued threats include impaired water temperatures, impaired water quality from agricultural runoff, degradation of freshwater rearing habitat from levee protection and disconnected rivers from the floodplains, and new water diversion sites.

Central Valley spring-run Chinook Salmon – Historically, spring-run Chinook salmon occupied the upper and middle reaches of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit rivers. There were 19 independent populations of spring-run Chinook salmon; now only 3 populations remain. The current spatial distribution for spring-run Chinook has been reduced to Butte, Mill, and Deer creeks. The Feather River also has a significant number of returning spring-run Chinook salmon; however, the hatchery at times spawns spring-run and fall-run together. This practice has compromised the genetic integrity of the Feather River spring-run and fall-run Chinook salmon stocks. Central Valley spring-run Chinook salmon have declined substantially from their historical numbers. These fish were once the second most abundant salmon species in the Central Valley, estimated at 600,000 between 1880 and 1940. A drastic decline in the spring-run Chinook population was experienced in the mid to late 1980s although it stabilized at low levels in the early to mid-1990s. In 2008, the population size was estimated at 10,000. Factors influencing the decline include the development of low elevation dams that have cut off spring-run Chinook salmon from most of their historical upstream spawning grounds. The remaining spawning and rearing habitat are also degraded and do not provide conservation value necessary for the recovery of the species. Other factors include interbreeding with fall-run Chinook salmon due to mismanagement of runs, poor ocean and in-river water quality, and over summering flows with increased water temperatures contributing to disease.

Central Valley Steelhead – Over the past 30 years, the steelhead population has steadily declined from 20,540 in the 1960s to 10,000 in 1993, which was when the last Central Valley steelhead population census was conducted. As such, data for steelhead populations is largely deficient. Historically, there were 81 independent populations of steelhead throughout the Central Valley. The development of upstream dams has contributed to 80 percent of the historical steelhead habitat being impassable or degraded, with 38 percent of the steelhead habitat permanently lost. Small populations of steelhead are still most commonly found in the Sacramento River and most of its tributaries and some tributaries of the San Joaquin River. The remaining habitat conditions are fragmented and degraded and provide little conservation value. Steelhead diversity has also declined due to hatchery-origin fish, which compromise the natural spawning run and threaten natural populations.

Southern DPS of North American Green Sturgeon – Little population data are available for green sturgeon, and some experts disagree on existing estimates due to their small sample sizes. Existing estimates conclude that in 1993 the green sturgeon population was as low as 175; however, after emphasis on improving the viability of the species, in 2001, the population estimate increased to 8,421, with an average increase of 1,509 fish per year. Historical spawning habitat for green sturgeon was widespread throughout the Sacramento River system. Green sturgeon spawning grounds were believed to stretch north past the current locations of Shasta Dam and up into the Pit and McCloud rivers. Today, the spatial distribution for green sturgeon has been relegated to a single spawning area, between the Keswick Dam and Hamilton City, outside of their historic spawning area. Additional factors of decline include loss of juvenile green sturgeon due to entrainment, alteration of food resources due to changes to Sacramento River and Sacramento-San Joaquin Delta (Delta) habitats, and exposure to various sources of contaminants throughout the basin. Reduced population and spatial structure has also led to a reduction in diversity of green sturgeon. Green sturgeon have been reduced to one population variation, which places the species at risk for long-term persistence.

Sacramento splittail – Sacramento splittail is a State Species of Special Concern and was delisted as a threatened species by the United States Fish and Wildlife Service (USFWS) in 2003. In October 2010, USFWS reviewed the status of finding for the Sacramento splittail and concluded it did not warrant protection under the ESA but will continue to monitor the population range (USFWS 2012). While there has been loss of habitat over the years, splittail populations can tolerate a wide variety of environmental conditions. A key to their long-term conservation is providing adequate spawning and rearing habitat and preventing excessive mortality on upstream migrating adults and downstream migrating juveniles (Moyle et al. 2004). Splittail typically spawn in April and May in seasonally inundated floodplains with cooler water temperatures and flowing water.

Sacramento River fall-run Chinook Salmon – Sacramento River fall-run Chinook salmon is a State Species of Special Concern and an NMFS Species of Concern. General factors for decline for fall-run Chinook salmon include habitat loss due to dams and other barriers, water development projects, pollution, hatchery fish interactions, and introduced species (NMFS 2010). Recently, the abundance of fall-run Chinook salmon has become increasingly variable. Increasing the diversity among populations of fall-run Chinook salmon by changing hatchery operations, restoring habitat, and managing for natural production could reduce variability (Lindley et al. 2009).

Yolo Bypass Passage and Habitat Concerns – The Yolo Bypass and Fremont Weir can cause migratory delays or loss of adult fish of the species described above. The Fremont Weir is not passable, and the fish ladder is not adequate under most operations. Other structures, such as the Lisbon Weir, Toe Drain, and agricultural road crossings, also cause delays or prevent passage. Additionally, juveniles can become stranded in scoured areas behind the weir and in other ponds in the bypass.

The Yolo Bypass currently provides rearing habitat for juvenile fish; however, the opportunities for habitat are limited by the frequency and duration of inundation, which is driven by flood management. Changing the inundation frequency and duration could provide additional rearing opportunities.

1.4.2 Opportunities

The Yolo Bypass has been identified as a potential opportunity for habitat restoration to address the problems facing native fish species described in Section 1.4.1. There is growing recognition that naturally functioning floodplains can provide benefits for many fish species by providing an abundant food supply and habitat diversity. The Yolo Bypass, which currently experiences at least some flooding in approximately 80 percent of years, still retains many characteristics of the historical floodplain habitat that are favorable to native fish species.

Inundated floodplains provide important rearing habitat for winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. Floodplain habitat could provide these fish species with physical habitat conditions that support juvenile growth and mobility, water quality, and the forage necessary to support juvenile development (Reclamation and DWR 2012).

Fish passage improvements through the Yolo Bypass could reduce migratory delays and potential stranding and poaching, reducing loss of adult and juvenile winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon. Currently, during flood events, salmon and sturgeon become stranded in isolated areas throughout the bypass where they are exposed to increased risk of mortality. Improving connectivity throughout the bypass is expected to increase rates of survival (Reclamation and DWR 2012).

The Yolo Bypass can also be high quality spawning grounds for splittail by providing sufficient inundation to attract spawning fish and remaining flooded long enough to allow for spawning and rearing of larvae and small juveniles. Restoration of the bypass could produce moderate to strong year classes of splittail that can survive downstream migration (Moyle et al. 2004).

1.4.2.1 Fish Use of the Bypass

The complete set of species benefitting from increasing inundation frequency and duration in the Yolo Bypass is still unclear. However, the species utilizing the bypass generally spawn or reside in the Sacramento River and its tributaries or the Delta. It is likely that most anadromous salmonid species potentially benefitting from the Yolo Bypass when it is inundated spawn in the Sacramento, Feather, and Yuba rivers, and Deer, Mill, Butte, and Clear creeks. However, during some conditions, American River anadromous salmonids could also utilize the Yolo Bypass. Studies have shown as many as 42 species (Sommer et al. 2001) and as few as 29 species (Feyrer et al. 2006a) have been found in the bypass during flooded periods. Feyrer et al. (2006b) found Chinook salmon (*Oncorhynchus tshawytscha*) and splittail (*Pogonichthys macrolepidotus*) made up 79 percent of the total catch in screw traps at the Yolo and Sutter bypasses. Additional native species found in the bypass include lamprey (*Entosphenus spp.*), hitch (*Lavinia exilicauda*), Sacramento blackfish (*Orthodon microlepidotus*), Sacramento pikeminnow (*Ptychochelius grandis*), Sacramento sucker (*Catostomus occidentalis*), prickly sculpin (*Cottus asper*), delta smelt (*Hypomesus transpacificus*), green sturgeon (*Acipenser medirostrus*), and white sturgeon (*Acipenser transmontanus*). A total of 15 native species have been documented in the Yolo Bypass. Much like the rest of the Delta, native species' diversity is less than that of introduced species (Sommer et al. 2003). The most common introduced species include American shad (*Alosa sapidissima*), common carp (*Cyprinus carpoi*), three species of black bass (*Micropterus spp*.), and striped bass (*Morone saxitilis*) (Sommer et al. 2003).

For anadromous species, primarily Chinook salmon and green and white sturgeon, the bypass is an alternate migration route up the Sacramento River. It is thought that anadromous species utilize floodplains as alternate migration routes as a life history strategy to minimize potential population-level effects of potential environmental perturbations in mainstem rivers. Currently, this life history strategy would allow migrating adults to avoid recreational anglers and other anthropogenic disturbances (e.g., water treatment plant outflow, diversion structures). Both Chinook salmon and striped bass showed migration peaks independent of flow in winter (November through December) and spring (March through April), according to Harrell and Sommer (2003). Similarly, American shad and white sturgeon also migrated in the greatest numbers in the spring.

Spawning habitat is potentially the most significant benefit of the Yolo Bypass for some fish species. Harrell and Sommer (2003) showed evidence that 12 of 19 species migrating to the bypass as adults were captured as age-0 fish in screw traps later in the flood season. Splittail are the most numerous native cyprinid in the Yolo Bypass when it is inundated. For most of the year, adult splittail are residents of the lower Delta and San Francisco estuary, moving up the delta to Sacramento River tributaries in the early winter and spring to forage and spawn (Sommer et al. 2003). Spawning typically occurs in shallow, vegetated areas, which historically have been inundated floodplains (Moyle 2002). However, due to the construction of levees in the Sacramento River system, splittail spawning habitat availability has become limited, which in turn results in reduced spawning success, initial year class strength, and low splittail populations, relative to historical conditions (Sommer et al 1997; USFWS 1995). Specifically, Feyrer et al. (2006b) stated that the amount of inundated floodplain available between January and June was the single most important factor in explaining annual production of juvenile splittail.

Generally, food production in floodplain habitats is substantially higher than in mainstem rivers and tributary streams, allowing for increased growth. Sommer et al. (2001) showed significantly higher levels of diptera versus zooplankton in the gut contents of juvenile Chinook salmon raised in the bypass relative to the Sacramento River. Jeffres et al. (2008) observed higher diversity of prey items in the gut contents of age-0 Chinook raised in floodplain ponds on the Cosumnes River versus main channel margins. Both studies also reported increased growth in fish reared on floodplain habitat as compared to the adjacent riverine habitats. Duration of inundation also appears to play a role in benefits to rearing fish. Juvenile Chinook salmon that foraged in the bypass for an annual mean of 30 to 56 days were significantly larger upon emigration out of the bypass according to Sommer et al. (2005). Logic would indicate that larger, more robust fish are of better overall condition and have an increased ability to withstand environmental stresses. However, Sommer et al. (2001) did not show a significant benefit to survival for juvenile Chinook in the bypass.

In addition to increased feeding and growth opportunities, floodplain habitat provides greater area for rearing. Sommer et al. (2002) observed splittail in the range of 15- to 20-millimeter (mm) fork length (FL), using the lower part of the water column in edge habitat of an experimental floodplain. Larger fish (28- to 4 mm FL) showed stronger tendencies toward open water. By 30 to 40 mm FL, age-0 splittail routinely emigrate off the floodplain (Feyrer et al. 2006b). The same report hypothesized that increased foraging opportunities in floodplain habitat would reduce the period required for age-0 splittail to reach lengths required to move into open water.

In addition to rearing native fishes, non-native predatory adult striped bass and black bass migrate onto the floodplain in search of spawning and foraging opportunities. However, the predation success of these fish likely is low. Moyle et al. (2004) suggests that expanded habitat from increased water levels has an inverse relationship to predator density, lowering these encounters for age-0 splittail. However, if water temperatures are suitable, spawning success could be high, potentially resulting in higher predator concentrations in the Toe Drain and Cache Slough complex after floodplain inundation.

1.4.3 Planning Constraints

Constraints provide limits on the planning process based on institutional, legal, and physical restrictions, among others. Alternatives for the Project must adhere to the following constraints:

- Regulations and Authorities: The Project must follow all relevant Federal, State, and local laws and regulations, including NEPA, CEQA, the Fish and Wildlife Coordination Action, Clean Air Act (CAA), Clean Water Act (CWA), ESA and CESA, Magnuson Stevens Act, and the CVP and SWP authorities.
- Flood Protection Limitations: The Yolo Bypass is included as a part of the Central Valley Flood Protection Plan (CVFPP) and the Sacramento Valley Flood Control Project and currently provides flood protection for much of the Sacramento Valley; thus, the level of flood protection in the area cannot be reduced.
- Physical Limitations: The NMFS BO specifies that the seasonal floodplain rearing habitat must be in the lower Sacramento River basin, including the Yolo Bypass. Actions in other locations were considered separately and would not be able to satisfy this requirement.

1.4.4 Planning Objectives

The planning objectives are described in the purpose and need statements and objectives, which describe the underlying need for and purpose of a proposed project. The purpose statement is a critical part of the environmental review process because it helps to set the overall direction of an Environmental Impact Statement (EIS)/ Environmental Impact Report (EIR), identify the range of reasonable alternatives, and focus the scope of analysis.

1.4.4.1 Purpose and Need

The need for action is decreased habitat quality and an inadequate ability to access that habitat, which has led to a decline in abundance, spatial distribution, and life history diversity associated with native ESA-listed and CESA-listed fish species. The purpose of the action is to enhance floodplain rearing habitat and fish passage in Yolo Bypass and/or other suitable areas of the lower Sacramento River by implementing RPA actions I.6.1 and I.7, as described in the NMFS BO, to benefit Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead.

1.4.4.2 Project Objectives

The objective of RPA action I.6.1 is to increase the availability of floodplain fisheries rearing habitat for juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead. This action can also improve conditions for splittail and Central Valley fall-run Chinook salmon under CESA. Specific biological objectives include:

- Improve access to seasonal habitat through volitional entry
- Increase access to and acreage of seasonal floodplain fisheries rearing habitat
- Reduce stranding and presence of migration barriers
- Increase aquatic primary and secondary biotic production to provide food through an ecosystem approach

The objective of RPA action I.7 is to reduce migratory delays and loss of fish at Fremont Weir and other structures in Yolo Bypass. Specific biological objectives include:

- Improve connectivity within Yolo Bypass for passage of salmonids and green sturgeon
- Improve connectivity between the Sacramento River and Yolo Bypass to provide safe and timely passage for:
  - Adult Sacramento River winter-run Chinook salmon between mid-November and May when elevations in the Sacramento River are amenable to fish passage
  - Adult Central Valley spring-run Chinook salmon between January and May when elevations in the Sacramento River are amenable to fish passage
  - Adult California Central Valley steelhead in the event their presence overlaps with the defined seasonal window for other target species when elevations in the Sacramento River are amenable to fish passage
  - Adult southern DPS green sturgeon between February and May when elevations in the Sacramento River are amenable to fish passage

1.5 Related Studies, Projects, and Programs

This section describes studies, projects, and programs conducted by various Federal, State, and local agencies that are directly or indirectly related to the Project.

1.5.1 Central Valley Flood Protection Plan

The CVFPP sets forth a comprehensive framework for system wide sustainable flood management and investment to improve flood risk management along the Sacramento and San Joaquin River basins. The CVFPP proposes three preliminary approaches for sustainable, integrated flood management in areas currently protected by facilities of the State Plan of Flood Control (SPFC).

1. The first approach would improve existing SPFC facilities to convey design flows.

2. The second approach evaluates improvements to levees to protect life safety and property for high risk population centers, including urban and small communities.
3. The last approach would provide enhanced flood system storage and conveyance capacity to protect high risk communities. This approach combines features of the first and second approach and allows flood conveyance channels to lower flood stages, with additional features and functions for ecosystem restoration and enhancements.

The Enhance Flood System Storage approach of the CVFPP recommends increasing the capacity of the existing bypass system, including the Sutter and Yolo bypasses. The approach includes: 1) widening the Sutter Bypass by up to 1,000 feet to increase its capacity by 50,000 cfs, 2) widening the Colusa Weir and Bypass and the Tisdale Weir and Bypass by up to 1,000 feet, 3) widening the Fremont Weir by about 1 mile and widening portions of the Yolo Bypass to increase its capacity by 40,000 cfs, and 4) widening the Sacramento Weir and Bypass by about 1,000 feet (DWR 2011).

1.5.2 American River Common Features General Reevaluation Report

The American River Common Features (ARCF) Reevaluation Report proposes measures in addition to current and other planned measures to reduce the risk of flooding in the Sacramento and American rivers watersheds.

The tentatively selected plan in the ARCF includes: 1) construction of nine miles of slurry cutoff walls to address levee seepage and stability issues along the Sacramento River, 10 miles of rock bank protection to address erosion problems along the Sacramento River east levee, 2.5 miles of geotextile stabilized slope and two miles of slope flattening to address levee stability and less than one mile of levee raise; 2) construction of rock bank protection and launchable rock trenches to address erosion problems along four miles of the right (north) bank and seven miles of the left (south) bank of the American River; 3) construction of four miles of slurry cutoff walls to address levee seepage and stability problems and 7.5 miles of levee raises to address potential overtopping of floodwaters along the Natomas East Main Drain Canal, Arcade Creek, and Dry Creek levees; and 4) widening of the Sacramento Weir and Bypass by 1,500 feet to reduce the water surface elevation in the Sacramento River and allow more water to flow into the Bypass system.

1.5.3 Sacramento River Bank Protection Project General Reevaluation Report

The Sacramento River Bank Protection Project (SRBPP) provides protection to the existing levee and flood control facilities of the Sacramento River Flood Control Project (SRFCP). Phase III of the SRBPP will be executed through a SRBPP General Reevaluation Report and includes the following: 1) comprehensive sediment stud, 2) thorough economic analysis, 3) continued biological studies and monitoring, 4) comprehensive cultural resources survey, 5) detailed real estate plan, and 6) updated mitigation site inventory and needs assessment (DWR and United States Army Corps of Engineers [USACE] 2009).

1.5.4 California EcoRestore

The California EcoRestore initiative accelerates the implementation of a comprehensive suite of habitat restoration actions to support the long-term health of the Delta's native fish and wildlife species. The project will coordinate and advance at least 30,000 acres of critical habitat restoration (25,000 acres associated with existing mandates for habitat restoration, pursuant to Federal BOs, and 5,000 acres of habitat enhancements). Several projects are being implemented in the Yolo Bypass:

1. Wallace Weir Fish Rescue Facility: Improvements to Wallace Weir to block fish passage into KLRC and construction of a new fish rescue facility
2. Fremont Weir Adult Fish Passage Modification Project: Modifications to the existing fish passage facility in Fremont Weir and improvements at two agricultural road crossings over the Tule Canal to provide fish passage
3. Lisbon Weir Fish Passage Modification Project: Modifications to Lisbon Weir to improve fish passage (without affecting water supplies)
4. Lower Putah Creek Realignment: Improvements to conditions in Putah Creek and realignment of the channel to connect to the Toe Drain downstream of Lisbon Weir

These projects are also RPA actions: Wallace Weir improvements and Fremont Weir Adult Fish Passage Modification Project are part of RPA action I.7, Lisbon Weir improvements are under RPA action I.6.4, and Lower Putah Creek Realignment is under RPA action I.6.3.

1.5.5 Experimental Agricultural Floodplain Habitat Investigation at Knaggs Ranch on Yolo Bypass

This experimental agricultural floodplain habitat investigation was developed to better understand how management of rice fields may affect water quality, invertebrate assemblages and abundance, juvenile salmon growth, survival, and behavior. Three concurrent studies were conducted in the northern portion of the Yolo Bypass on the Knaggs Ranch: 1) food web and salmon responses to agricultural management, 2) behavior of salmon in different agricultural habitat types, and 3) a pilot study evaluating the feasibility of extending inundation duration after natural flood events to prolong salmon rearing in floodplain habitats.

The experimental study was completed in 2013. It concluded that winter inundation of rice fields creates high-quality growth opportunities for juvenile Chinook salmon and agricultural landscapes can function as habitats for Chinook salmon populations using existing agricultural infrastructure (CalTrout et al. 2013).

1.5.6 Lower Sacramento/Delta North Regional Flood Management Plan

The Lower Sacramento/Delta North Regional Flood Management Plan establishes a flood management vision and a prioritized list of flood risk reductions within the study area, i.e., portions of Yolo, Solano, Sacramento and Sutter counties. The study will include expansions of both the Fremont and Sacramento weirs and widening of the Yolo and Sacramento bypasses. These modifications, in concert with improvements to Folsom Dam, will lower flood stages in the Sacramento River downstream of the Fremont Weir; the tributary channels around the Natomas Basin, the American River, Feather River, and Sutter Bypass channels upstream of the

Fremont Weir; and the Yolo Bypass itself. The regional partners believe these actions would also provide new regularly inundated floodplain that could be managed to improve fish rearing and passage as part of an overall framework that includes agricultural sustainability and other objectives (USACE 2015).

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2 Existing and Future Conditions

The existing conditions are the conditions within the Yolo Bypass study area that exist today. The future without project conditions are the future conditions expected to occur if the Project is not implemented. Existing and future without project conditions are defined to provide a better understanding of the challenges and potential opportunities for the Project effort.

The information in this chapter is presented at a general level of detail to provide background information and aid in initial alternatives development. This information will be further developed as the alternatives are refined and the environmental process moves forward.

2.1 Existing Conditions

2.1.1 Water Resources

2.1.1.1 Hydrology, Hydraulics, and Flood Management

The area of analysis for hydrology and hydraulics consists of the Sacramento River from Fremont Weir to Rio Vista and the southern end of the Yolo Bypass. The major features of the flood management system in and surrounding the area of analysis include reservoirs, levees, weirs, and bypasses. Flows within the Project area are regulated by Shasta, Oroville, and Folsom reservoirs. Each of these features is described below.

Sacramento River – The portion of the Sacramento River within the study area begins at Fremont Weir and extends to just upstream of Rio Vista near River Mile (RM) 12 (see Figure 2-1). Flood management facilities along Sacramento River and in the Delta include the levees, weirs, and bypasses of upper and lower Butte basin, Sacramento River between Colusa and Verona, and Sacramento River between Verona and Collinsville. When Sacramento River system flood flows are the highest, a portion of the flow is diverted from the Sacramento River through the Sacramento Bypass to Yolo Bypass. At the downstream end, Yolo Bypass flows reenter Sacramento River near Rio Vista.

Yolo Bypass – Yolo Bypass is a leveed floodway through the natural overflow Yolo Basin on the west side of Sacramento River between Verona and Rio Vista near Suisun Bay. The bypass flows generally north to south and extends from Fremont Weir (RM 83) downstream to Liberty Island (RM 14) in the Delta.

During high flows in the Sacramento River, water enters Yolo Bypass from the north over Fremont Weir and from the east via the Sacramento Weir and bypass. Flows are then conveyed south around the City of West Sacramento. During periods of high stage in the Sacramento River, flows from Colusa Basin are discharged through KLRC to Yolo Bypass. Additional flows enter the bypass from the west-side tributaries, including Cache Creek, Putah Creek, and Willow Slough Bypass. Flood waters reenter Sacramento River through Cache Slough, upstream from Rio Vista. Liberty Island is the southern outlet of Yolo Bypass.

Flood management facilities along Yolo Bypass include Fremont Weir at the northern end of the bypass, levees on either side of the bypass, and the bypass itself, which conveys floodwaters from the Sacramento, American, and Feather rivers away from West Sacramento. Yolo Bypass floods approximately once every three years, generally during the winter months of December, January, and February. However, in 1998, water entered the bypass in June. During the irrigation season, non-flood waters exit the bypass primarily through the east levee Toe Drain, a riparian channel running along the eastern edge of the bypass.

Shasta Reservoir – Maximum seasonal flood management storage space in Shasta Reservoir is 1.3 million acre-feet (AF). Releases from Shasta Dam can be made through the power plant, over the spillway, or through the river outlets. Releases from Shasta Dam are often made for flood management. Releases for flood management either occur after a storm event to maintain the prescribed vacant flood space in the reservoir or in the fall, beginning in early October, to reach the prescribed vacant flood space. During a storm event, releases for flood management occur either over the spillway during large events or through river outlets for smaller events.

Oroville Reservoir – The primary flood management feature of Feather River Basin is Oroville Reservoir, with a flood management reservation volume of 750,000 AF. Oroville Reservoir releases are used to help meet the objective flow on Feather River of 150,000 cfs and, in conjunction with New Bullards Bar Reservoir on the Yuba River, to meet an objective flow below the Yuba River confluence of 300,000 cfs. Levees line Feather River from its confluence with Sacramento River to the City of Oroville (RM 63).

Folsom Reservoir –The Folsom Reservoir flood management reservation volume is variable, ranging from 400,000 to 670,000 AF. The target maximum release on the American River is 115,000 cfs due to leveed capacity along the lower American River. The American River is leveed from its confluence with the Sacramento River to near Carmichael Bluffs on the north bank and to near Sunrise Boulevard Bridge on the south bank (RM 19).

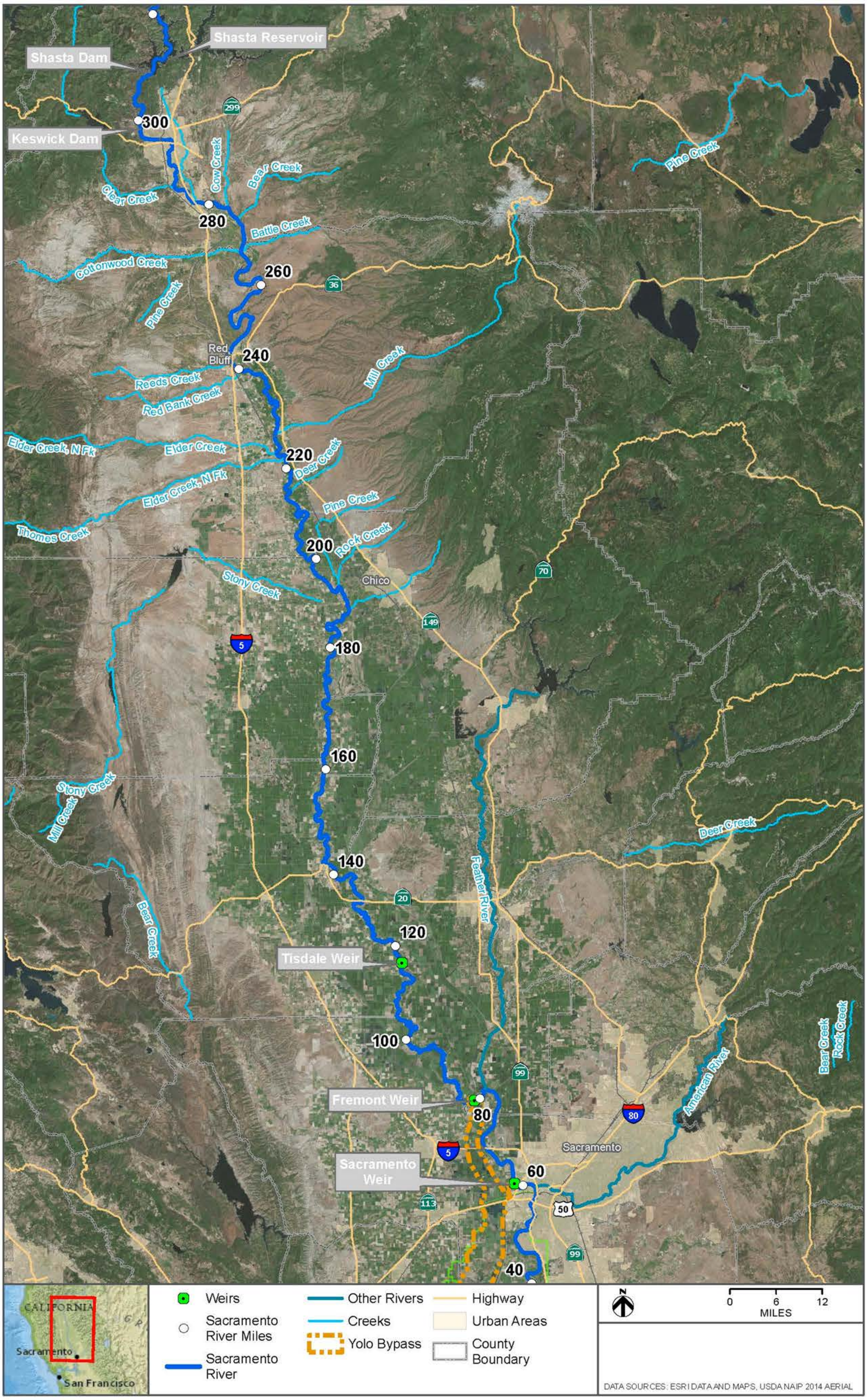

Figure 2-1. Sacramento River and Tributaries

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2.1.1.2 *Groundwater*

The area of analysis for groundwater resources is limited to the area around the Yolo Bypass and includes portions of the Colusa, Yolo, and Sutter subbasins as defined in Bulletin 118 (DWR 2003). Limited data exist to estimate groundwater pumping in these subbasins. Bulletin 118 states that an estimated 310,000 AF of groundwater was pumped for agricultural purposes in the Colusa subbasin. Municipal, industrial, and environmental/wetland pumping is estimated at 14,000 and 22,000 AF, respectively (DWR 2003). In the Sutter subbasin, DWR estimates pumping for agricultural uses at 171,400 AF and urban use at 3,900 AF (DWR 2003). DWR does not provide a groundwater pumping estimate for the Yolo subbasin in Bulletin 118.

Groundwater is recharged by deep percolation from rainfall infiltration, leakage from streambeds, lateral inflow along the basin boundaries, and other surface processes such as irrigation. Groundwater discharges primarily include evapotranspiration and discharge to streams or other surface features such as marshes. The estimated recharge to the Colusa subbasin due to deep percolation of applied water is 64,000 AF based on studies conducted in 1993, 1994, and 1999 (DWR 2003). In the Sutter subbasin, DWR estimates natural recharge to be 40,000 AF and applied water recharge to be 22,100 AF based on studies conducted in 1990. DWR does not provide groundwater recharge estimates for Yolo subbasin.

Land Subsidence: Groundwater-related land subsidence is a process that causes the elevation of the ground surface to lower in response to groundwater pumping occurring. This process, which is typically not reversible, occurs when groundwater extraction lowers groundwater levels below the historical level seen in that area. The reduction in water level causes the loss of pore pressure within the soil matrix. This loss in pore pressure can result in collapse (i.e., consolidation, compaction) of soils that may be susceptible to subsidence. Clays are typically the soils most susceptible to subsidence.

Historically, land subsidence occurred in the eastern portion of Yolo County and the southern portion of Colusa County because of extensive groundwater pumping in areas that have soils that are susceptible to subsidence (DWR 2014). As much as four feet of land subsidence has been measured east of Zamora over the last several decades. The area between Zamora, KLRC, and Woodland has been most affected (Yolo County 2009). DWR extensometer 09N03E08C004M near the Yolo Bypass, has recorded approximately 0.9 foot of subsidence from 1991 to the present (DWR 2016). Extensometer 11N01E24Q008M, near the Yolo-Zamora area has recorded approximately 1.1 feet decline from 1992 to the present (DWR 2016). DWR has prioritized the Colusa and Yolo subbasins as having a high potential for subsidence (DWR 2014).

Groundwater Quality: Groundwater quality in the area of analysis is generally good and of sufficient quality for municipal, agricultural, domestic, and industrial uses. In the Yolo, Colusa and Sutter subbasins, groundwater is generally hard (high in mineral content) and high in salt content. Groundwater in the Colusa and Yolo subbasins is characterized as sodium magnesium, calcium magnesium, or magnesium bicarbonate type. There are also some localized groundwater quality issues in all three subbasins. Localized areas of high electrical conductivity, total dissolved solids, adjusted sodium adsorption ratio, nitrate, and magnesium occur within the Project area. Elevated levels of boron as high as two to four milligrams per liter have been recorded along Cache Creek. Elevated selenium and nitrate concentrations have occurred in groundwater near the City of Davis (DWR 2003).

2.1.2 Land Use and Agricultural Resources

The area of analysis for land use and agricultural resources includes areas within Yolo, Sutter, and Solano counties where construction and operations would take place and could result in land use and/or agricultural resource effects. The Yolo Bypass is predominantly in Yolo County, with small areas of the bypass in Sutter and Solano counties. Construction activities would take place in Yolo and Sutter counties, in and between the FWWA and Tule Pond and the Tule Canal, near agricultural road crossings along Tule Canal, and in the adjacent Elkhorn Area. These lands are designated Agriculture and Public and Open Space by Sutter County and Agriculture by Yolo County (Yolo County 2009; Sutter County 2011). There are no established communities within the area of analysis. Although a small portion of southern Yolo Bypass is in Solano County, impacts to land use and agriculture are assumed to be minimal, and the county is not included in the area of analysis.

The Yolo Bypass is approximately 69,000 acres and is in the Yolo Basin of the Sacramento Valley, near the cities of Davis and West Sacramento in Yolo County. The bypass stretches north to the Fremont Weir and south to the City of Rio Vista and follows the west side of the Sacramento River. Physical infrastructure within the bypass includes the Fremont, Sacramento, and Lisbon weirs. Table 2-1 presents the land designations within the Yolo Bypass. The majority of the Yolo Bypass is designated as unique farmland. Unique farmland refers to lands, other than prime farmland, that are used for producing specific high-value food and fiber crops, such as citrus, tree nuts, olives, cranberries, and other fruits and vegetables, and is often located in special microclimates. Prime farmland is land that has the best combination of physical and chemical properties desired to produce food, feed, forage, fiber, and oilseed crops. Farmland of statewide or local importance are generally lands that nearly meet the requirements for prime or unique farmlands that are used to produce food, feed, fiber, forage, and oilseed crop. Figure 2-2 presents the prime farmland, unique farmland, and the farmland of statewide importance within the Yolo Bypass.

Table 2-1. Summary Land Use Category in the Yolo Bypass

Land Use Category	Acres
Prime Farmland	6,108
Farmland of Statewide Importance	2
Unique Farmland	18,429
Farmland of Local Importance	169
Important Farmland Subtotal	24,708
Grazing Land	17,389
Farmland of Local Potential	1,301
Agricultural Land Subtotal	43,398
Other Land	13,686
Water Area	584

Sources: Farmland Mapping and Monitoring Program 2014

As discussed above, most lands in Yolo and Sutter counties are designated as Agriculture. In both counties, a large portion of the lands are designated as Prime or Unique Farmland or Farmland of Statewide Importance. Table 2-2 presents the land use categories in the two counties for 2014.

Table 2-2. Summary Land Use Category in Yolo and Sutter Counties

Land Use Category	Yolo County (Acres)	Sutter County (Acres)
Prime Farmland	250,345	161,019
Farmland of Statewide Importance	18,861	104,003
Unique Farmland	44,604	16,087
Farmland of Local Importance	51,725	0
Important Farmland Subtotal	365,535	281,109
Grazing Land	166,367	54,327
Agricultural Land Subtotal	531,902	335,436
Urban and Built-up Land	31,049	13,607
Other Land	82,694	38,386
Water Area	7,804	1,883
Total Area Inventoried	653,449	389,312

Sources: California Department of Conservation 2016

Notes:

[1] Based on 2012 to 2014 Land Use Conversion Data.

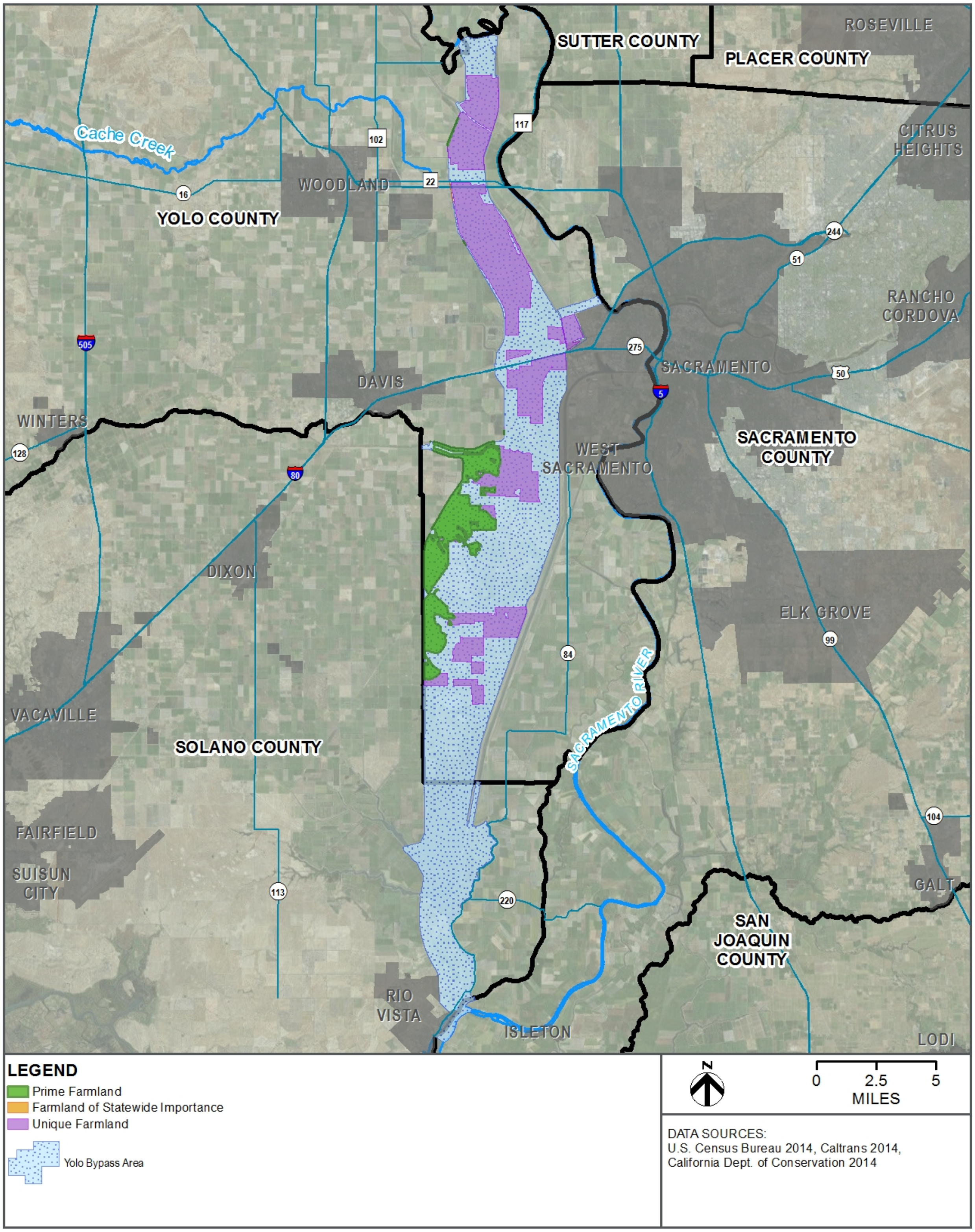

Figure 2-2. Land Use Classifications

2.1.3 Socioeconomics

The area of analysis for socioeconomics includes counties (Yolo and Sutter) that could be affected by the development of the Project alternatives. However, employment and spending associated with construction actions could also affect regional economies in the neighboring counties of Solano and Sacramento.

Table 2-3 presents employment, labor income, and output by industry for the combined regional economies of Yolo, Sutter, Solano, and Sacramento counties in 2014. In 2014, services provided the most jobs (601,176 jobs) in the area, followed by government (248,817 jobs), and trade (139,870 jobs). Services also had the highest output ($78.6 billion) of all industries in the region, followed by government ($32.4 billion), and manufacturing ($28.4 billion). Services and government were the top industries in terms of labor income in 2014.

Table 2-3. Summary of 2014 Regional Economy in Yolo, Sutter, Solano, and Sacramento Counties

Industry	Employment (Jobs)	Output (Million $)	Labor Income (Million $)
Agriculture	18,596	2,490.4	561.6
Mining	1,830	640.3	74.9
Construction	60,132	10,653.5	2,577.1
Manufacturing	43,261	28,417.0	4,153.9
Transportation, Information, Power, and Utilities	50,940	13,448.3	2,568.6
Trade	139,870	16,741.9	5,257.9
Service	601,176	78,598.7	25,355.7
Government	248,817	32,398.4	25,216.7
Total	1,164,624	183,388.5	65,766.4

Source: Minnesota IMPLAN Group 2016

[a] Employment is measured in number of jobs.

[b] Income is the dollar value of total payroll for each industry plus income received by self-employed individuals.

[c] Output represents the dollar value of industry production.

Nine major crop types were identified in Yolo Bypass, including corn, rice, wild rice, safflower, sunflower, processing tomatoes, vines (melons), irrigated pasture, and non-irrigated pasture. Table 2-4 provides labor and cost data to produce the identified crops from available University of California Cooperative Extension (UCCE) Agricultural Issues Center cost and return studies. The costs and returns presented in Table 2-4 represent costs in various years because UCCE crop studies are prepared and updated in different years for different crops.

Table 2-4. Crop Cost and Return in Yolo, Sutter, Solano, and Sacramento Counties

Crop Category	Crop Sub Category	Direct Labor Hours/Acre (hours/acre)	Gross Revenue/Acre ($/acre)	Operating Costs/Acre ($/acre)	Year Studied
Corn	Field Corn	2.83	$1,260	$1,117	2015
Rice	Rice Only Rotation, Medium Grain	4.52	$1,760	$1,225	2016
Safflower	Irrigated-Bed Planted, Dryland-Flat Planted	2.02	$363	$206	2011
Sunflower	For Seed	4.13	$1,360	$447	2011
Tomato, processing	Sub-surface, Drip Irrigated	24.96	$3,520	$2,733	2014
	Furrow Irrigated	22.38	$3,040	$2,859	2014

Source: UCCE 2011a, 2011b, 2014a, 2014b, 2015a, 2015b

Figure 2-3 presents the unemployment rate trends for Yolo, Sutter, Solano, and Sacramento counties between 2005 and 2016. The unemployment rate in all four counties increased from 2006 through 2010 and decreased from 2011 through 2016.

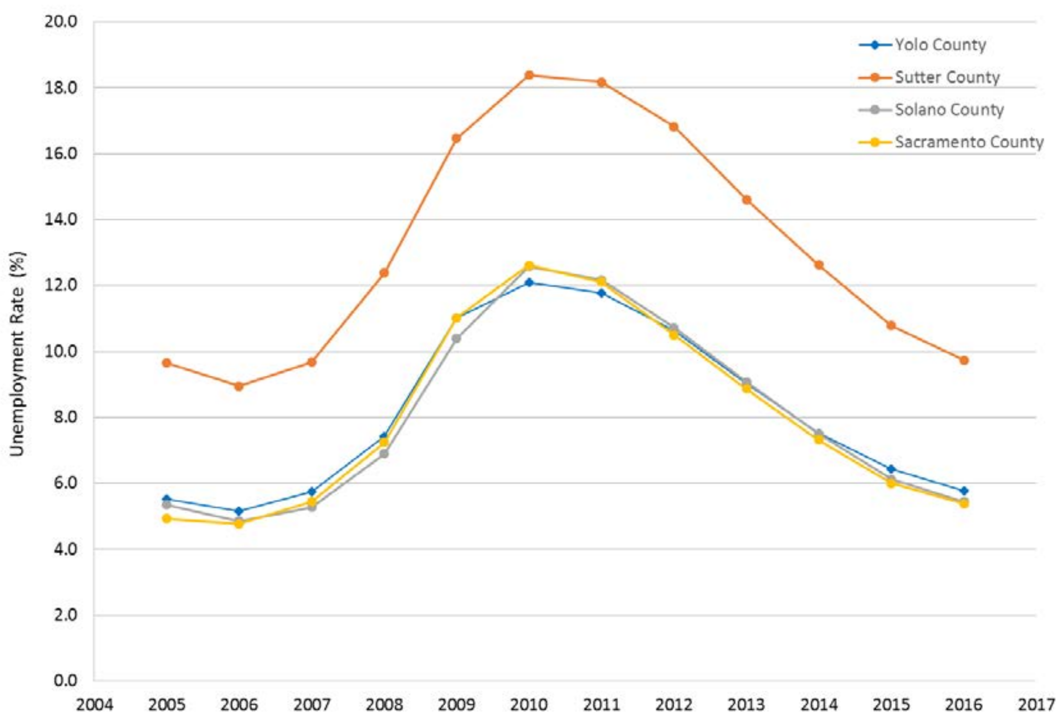

Figure 2-3. Unemployment Rate Profile for Yolo, Sutter, Solano, and Sacramento Counties

Table 2-5 presents household income and per capita income in Yolo, Sutter, Solano, and Sacramento counties relative to California. Yolo County had a median income approximately $7,000 less than the median household income in the State. Sutter County had a median income approximately $10,000 less than the median household income in the State. Solano County had a median income approximately $5,000 greater than the median household income in the State. Sacramento County had a median income approximately $6,000 less than the median household income in the State.

Table 2-5. 2011 through 2015 Household income by County

Income	Yolo County	Sutter County	Solano County	Sacramento County	California
Median Household Income	$54,989	$52,017	$66,828	$55,987	$61,818
Mean Household Income	$78,450	$69,238	$83,446	$74,159	$87,877
Per Capita Income	$28,116	$23,689	$29,185	$27,315	$30,318

Source: United States Census Bureau 2011 through 2015

2.1.4 Environmental Justice

Environmental justice refers to the equitable rights to healthy environmental conditions for minority and low-income populations relative to other populations. The area of analysis for environmental justice included areas where associated project construction would occur or construction traffic would increase, potentially causing an adverse and disproportionately high effect on neighboring minority and low-income populations, or where agriculturally productive land would be taken out of production. The regional level analysis includes Yolo and Sutter counties. Specific to construction-related employment, the environmental justice area of analysis expands to include Solano and Sacramento counties because it is assumed workers from these counties could commute in for construction-related work. A small portion of Yolo Bypass (the southern point) is in Solano County. Almost all of this area is water (Prospect Slough) and would have no environmental justice effects except when specific to construction-related employment impacts. The local level analysis includes Census Tracts 101.02, 112.06, 114, and 509. Construction would not occur in census tracts in the remainder of Yolo Bypass; therefore, they are not included in this analysis.

In 2015, both Yolo and Sutter counties exhibited a total minority proportion exceeding 50 percent at 52.5 and 52.9 percent, respectively, which indicates the presence of an environmental justice population. Solano and Sacramento counties also exhibited a total minority proportion that exceeded 50 percent. The total minority population percentage across all four counties is lower than that of the State (62.2 percent). Table 2-6 presents the racial and ethnic composition of Yolo County, and the median household income, the mean household income, and the percent of the population below the poverty threshold. As shown, Yolo and Solano counties have a smaller proportion of residents living below the poverty threshold than that for the State (8.8 and 9.6 percent compared to 11.3 percent), whereas the low-income residents in Sutter and Sacramento counties exceed that of the State at 16.9 and 12.6 percent, respectively. Yolo and Sutter counties have a median household income and mean household income lower than the State average; however, neither county falls below the United States Census Bureau's defined poverty thresholds for a four-person family unit (two adults and two children) or an individual ($24,339 and $12,486, respectively [United States Census Bureau 2016]). Similarly, Solano and Sacramento counties do not fall below the defined poverty thresholds for a four-person family unit or an individual.

Table 2-6. Regional-Level Environmental Justice Existing Conditions

		California	Yolo County	Sutter County	Solano County	Sacramento County
Ethnicity[1]	Hispanic or Latino	38.8%	31.5%	30.3%	26.0%	27.0%
Race[2]	White	60.9%	65.9%	70.5%	53.5%	59.8%
	African American	5.8%	2.7%	1.1%	14.1%	9.8%
	American Indian	0.7%	0.4%	1.0%	0.5%	0.6%
	Asian	14.2%	13.9%	15.7%	15.4%	15.6%
	Pacific Islander	0.4%	0.3%	0.4%	0.8%	1.1%
	Total Minority[3]	**62.2%**	**52.5%**	**52.9%**	**61.2%**	**54.2%**
Median Household Income [4,5]		$64,500	$58,966	$52,277	$67,443	$58,942
Mean Household Income		$91,757	$81,995	$67,427	$84,403	$76,613
Percent of Population Below Poverty Threshold [6]		11.3%	8.8%	16.9%	9.6%	12.6%

Source: United States Census Bureau 2015a and 2015b.

[1] The term "Hispanic" is an ethnic category and can apply to members of any race, including respondents who self-identified as "White." The total numbers of Hispanic residents for each geographic region are tabulated separately from the racial distribution by the United States Census Bureau.

[2] A minority is defined as a member of the following population groups: American Indian/Alaskan Native, Asian or Pacific Islander, Black (non-Hispanic), or Hispanic.

[3] "Total Minority" is the aggregation of all non-white racial groups with the addition of all Hispanics, regardless of race, with the total for "White Alone, Not Hispanic" subtracted from the total population.

[4] Household income is defined by the United States Census Bureau as “the sum of money income received in the calendar year by all household members 15 years old and over” (United States Census Bureau Undated).

[5] In 2015 inflation-adjusted dollars.

[6] Percentage of families and people whose income in the past 12 months was below the poverty level. The census classifies families and persons as below poverty “if their total family income or unrelated individual income was less than the poverty threshold” as defined for all parts of the country by the Federal government (United States Census Bureau Undated). For 2015, the preliminary Federal weighted average poverty level threshold for an individual was $12,486 and $24,339 for a four-person family unit (two adults and two children) (United States Census Bureau 2016).

Census tracts are defined as “small, relatively permanent statistical subdivisions of a county delineated by local participants as part of the United States Census Bureau’s Participant Statistical Areas Program” (United States Census Bureau Undated). Table 2-7 presents the racial and ethnic composition and economic characteristics of the census tracts that could be affected by Project actions. Most of the census tracts have total minority proportions greater than 50 percent. Census Tracts 101.02, 114, and 509 have a higher proportion of residents living below the poverty threshold than the State and county in which it is located. All but one of the census tracts (Census Tract 112.06) have median and mean household incomes lower than the State and county average; however, these census tracts do not fall below the United States Census Bureau's defined poverty thresholds for a four-person family unit (two adults and two children) or an individual.

Table 2-7. 2015 Local-Level Environmental Justice Existing Conditions

		California	CT 101.02	CT 112.06	CT 114	CT 509
Ethnicity[1]	Hispanic or Latino	38.4%	35.1%	30.4%	50.1%	35.7%
Race[2]	White	61.8%	57.9%	69.4%	72.4%	80.4%
	African American	5.9%	5.8%	1.2%	1.9%	1.9%
	American Indian	0.7%	0.1%	3.9%	2.6%	1.4%
	Asian	13.7%	9.2%	13.7%	5.2%	0.0%
	Pacific Islander	0.4%	1.9%	0.3%	0.0%	1.2%
	Total Minority[3]	**61.3%**	**52.5%**	**52.9%**	**61.2%**	**54.2%**
Median Household Income [4,5]		$64,500	$58,966	$52,277	$67,443	$58,942
Mean Household Income		$91,757	$81,995	$67,427	$84,403	$76,613
Percent of Population Below Poverty Threshold [6]		11.3%	8.8%	16.9%	9.6%	12.6%

Source: United States Census Bureau 2011-2015a and 2011-2015b.

[1] The term "Hispanic" is an ethnic category and can apply to members of any race, including respondents who self-identified as "White." The total numbers of Hispanic residents for each geographic region are tabulated separately from the racial distribution by the United States Census Bureau.

[2] A minority is defined as a member of the following population groups: American Indian/Alaskan Native, Asian or Pacific Islander, Black (non-Hispanic), or Hispanic.

[3] "Total Minority" is the aggregation of all non-white racial groups with the addition of all Hispanics, regardless of race, with the total for "White Alone, Not Hispanic" subtracted from the total population.

[4] Household income is defined by the United States Census Bureau as "the sum of money income received in the calendar year by all household members 15 years old and over" (United States Census Bureau Undated).

[5] In 2015 inflation-adjusted dollars.

[6] Percentage of families and people whose income in the past 12 months was below the poverty level. The census classifies families and persons as below poverty "if their total family income or unrelated individual income was less than the poverty threshold" as defined for all parts of the country by the Federal government (United States Census Bureau Undated). For 2015, the preliminary Federal weighted average poverty level threshold for an individual was $12,486 and $24,339 for a four-person family unit (two adults and two children) (United States Census Bureau 2016).

The Project could affect agricultural employment by reducing the amount of agriculturally productive land within the study area. This could potentially reduce the need for farm labor, which is typically classified as minority and low-income, and the number of agricultural jobs available in the study area. Farm operators in Yolo and Sutter counties are predominately White, their laborers and helpers are predominately Hispanic, and several agricultural worker groups receive annual wages below the United States Census Bureau's poverty level threshold for a family of four composed of two adults and two children (United States Department of Agriculture 2014). The race and ethnic composition of this sector suggests that laborers and helpers, as an employment sector, are generally of minority status, with Hispanics comprising the largest proportion of laborers and helpers in both Yolo and Sutter counties (68.3 and 75.5 percent, respectively [United States Census Bureau 2006-2010]). While the 2016 First Quarter Mean Annual Wages data (California Employment Development Department 2016) does not demonstrate as clearly as the United States Census data the proportion of residents living below the poverty threshold, the information provided therein does suggest that mean incomes in the farming industry are generally lower than the mean income for all industries, with less skilled workers (agricultural equipment operators and farmworkers) generally earning less than 50 percent of the mean wage for all industries.

2.1.5 Biological Resources

2.1.5.1 *Fisheries*

The area of analysis for fisheries includes Yolo Bypass, Sacramento River from the vicinity of Fremont Weir (near RM 83) to about Rio Vista (near RM 12), and the Delta (see Figure 2-4). Although Yolo Bypass is the primary region expected to be affected by the Project, changes in the frequency, duration, and volume of water spilling into Yolo Bypass from the Sacramento River could affect aquatic resources and fisheries in the river downstream of Fremont Weir and in the Delta.

Yolo Bypass – Yolo Bypass is California's largest contiguous floodplain and provides valuable habitat for a wide variety of aquatic and terrestrial species (Sommer et al. 2001). Yolo Bypass is inundated to some extent during about 70 percent of all years when total flow in the Sacramento River exceeds about 56,270 cfs (California Data Exchange Center 2017). When flooded, Yolo Bypass provides up to about 59,300 acres of shallow floodplain habitat. The bypass ranges from 1.2 to six miles wide over its about 40-mile length and has a typical mean depth (when flooded) of 6.5 feet or less (Sommer et al. 2008).

The Yolo Bypass provides aquatic habitat, including floodplain habitat, during seasonal flood events, and permanent wetlands, essential for fish spawning, rearing, and migratory passage. During flood pulses, the Yolo Bypass provides fish in the Sacramento River an alternative migration corridor. This seasonal floodplain habitat has been studied as a beneficial resource, providing fish better rearing conditions than that of the Sacramento River channel. This seasonal habitat provides fish an increased habitat and food supply (California Department of Fish and Game [CDFG] 2008).

Various native and non-native fish species occur in the Yolo Bypass, including nine special status species. Appendix A includes a preliminary list of the identified fish species, including special status species, commonly found in the Yolo Bypass and adjacent aquatic habitats in the Yolo Basin.

Sacramento River – The Sacramento River is California's largest river, with an average annual runoff of 22,000,000 AF. The segment of the Sacramento River located within the study area extends from Fremont Weir (about RM 83) downstream to just above Rio Vista near RM 12. The Sacramento River within the study area is predominantly channelized and leveed. It is bordered by agricultural land and the City of Sacramento and surrounding areas. This segment of the Sacramento River is characterized primarily by slow-water glides and pools, is depositional in nature, and has lower water clarity and habitat diversity relative to the upper portion of the river.

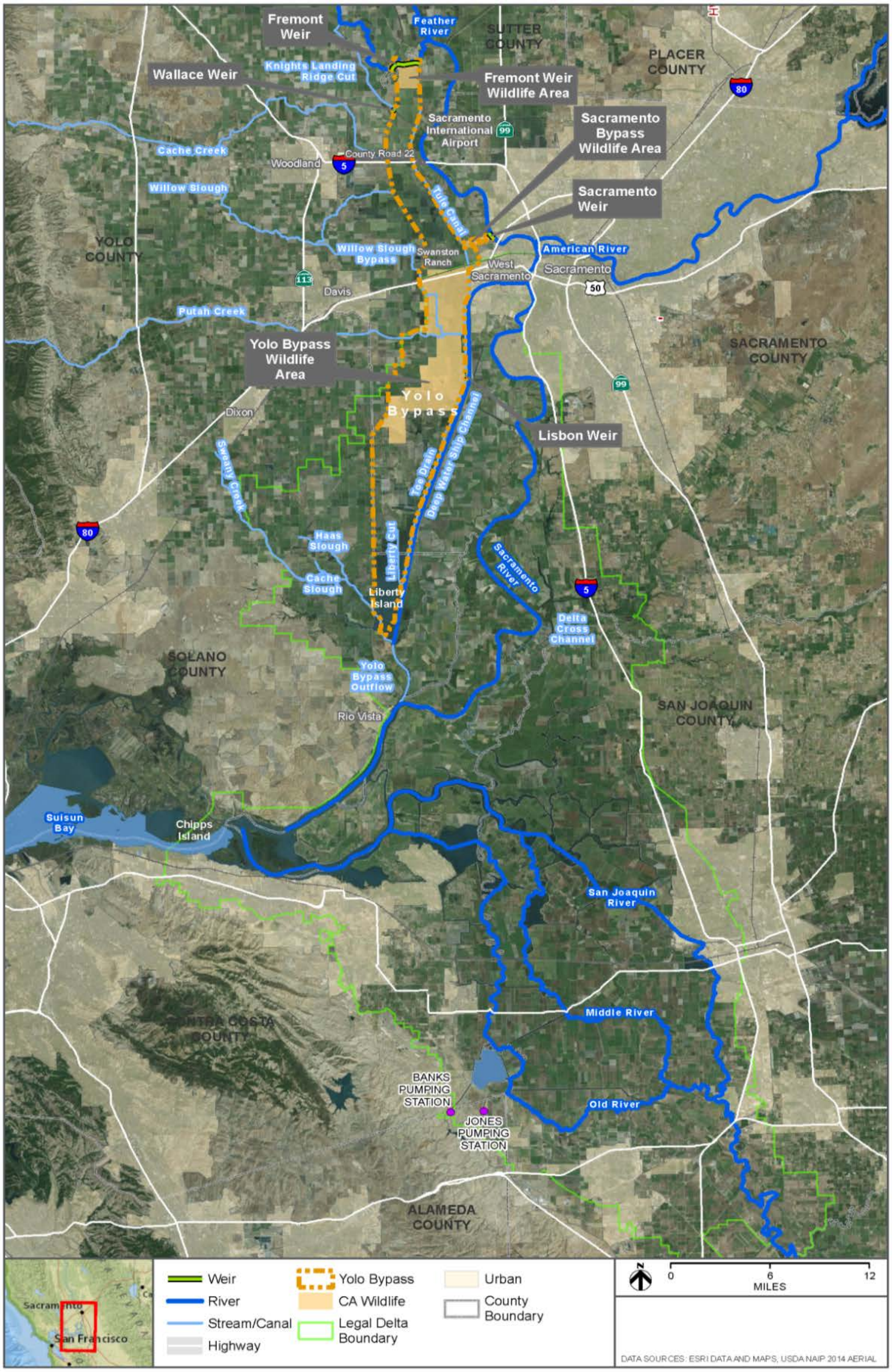

Figure 2-4. Overview of the Aquatic Resources and Fisheries Study Area

Over 30 fish species are known to occur within the Sacramento River. Many of these are anadromous, including both native and introduced species. Anadromous species include Chinook salmon (winter-run, spring-run, fall-run, and late fall-run), steelhead, green and white sturgeon, Pacific lamprey, river lamprey, American shad, and striped bass.

Most anadromous salmonid spawning occurs upstream of the study area between Keswick Dam and Red Bluff Diversion Dam (RM 243) (NMFS 2009 as cited in Reclamation 2015). Downstream from the City of Red Bluff, the Sacramento River provides a migration corridor and rearing habitat for salmonids as well as spawning and rearing habitat for a variety of other native fish species such as Sacramento stickleback and Sacramento pikeminnow.

Delta – The San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Estuary) is the largest intact estuary on the west coast of the United States (United States Environmental Protection Agency [USEPA] 2003). The portion of the Delta in the study area consists primarily of the Sacramento River and associated waters located downstream of the Yolo Bypass outlet near Rio Vista. Estuarine fishes occurring in this area include delta smelt and longfin smelt, which might use these areas depending on seasonal and diel (i.e., daily) salinity gradients. Additionally, many non-native warm water fish species are common in this area and use it for spawning and rearing purposes, whereas anadromous fish use this area primarily for migration and rearing.

Ecological processes in the Project area include floodplain ecology and distribution, Yolo Bypass hydrology, and Sacramento River hydrology. Floodplains are a valuable component of riverine ecosystems and provide important habitat for a variety of aquatic and terrestrial species (Junk et al. 1989; Tockner and Stanford 2002). Within California's Central Valley, including the Sacramento River system, floodplain habitat is generally considered one of the most important seasonal habitats for anadromous salmonids. Many California fish species have evolved life history strategies to take advantage of high-quality rearing habitat provided by predictable seasonal floodplain inundation (Katz et al. 2013 and references therein). Yolo Bypass' typical period of inundation is between January and March. However, it can flood as early as October and remain flooded as late as June. Typically, Yolo Bypass remains inundated between one and 68 days (Katz et al. 2013; Schemel et al. 2004; Sommer et al. 2008). Seasonal inundation of Yolo Bypass leads to an increase in phytoplankton and other food resources that support fish species residing in the floodplain and provides a source of these food resources to downstream habitats.

Stressors in the Project area include inundation in the Yolo Bypass, water quality, migration barriers and stranding, and various qualities and changes in the Sacramento River and Delta. During overtopping events at Fremont Weir, increased flows into the Cache Slough area can attract migrating anadromous species. Although fish are attracted to Yolo Bypass during these flood events, the bypass can cause migratory delays and increased mortality of adults relative to the Sacramento River migration corridor. The existing fish passage structure at Fremont Weir is inadequate to allow normal fish passage at most flows (NMFS 2009). As a result, adult salmonids and sturgeon migrating upstream through Yolo Bypass are unable to reach upstream spawning habitat in the Sacramento River and its tributaries when there is insufficient flow through Fremont Weir (Harrell and Sommer 2003). However, longer inundation duration can increase primary and secondary production, which can benefit fish species in the immediate area and contribute to food web systems in the Delta.

2.1.5.2 Vegetation and Wildlife

The area of analysis for vegetation and wildlife includes areas in Yolo Bypass that have been identified for ground disturbance. Most of the direct impacts associated with ground disturbance would occur in the northern portion of Yolo Bypass in the FWWA. The study area includes the area of temporary and permanent impacts plus a 100-foot buffer and the entirety of the Yolo Bypass.

Those portions of Yolo Bypass that are flooded in winter and early spring also function as a migration route and spawning and rearing habitat for many sensitive special-status fish species endemic to the region (as defined by the ESA and the CESA). This migration connection occurs when floodwaters are spilling over Fremont and Sacramento weirs, creating an upstream hydrologic connection between Yolo Bypass and Sacramento River. As the floodwaters inundate and then recede, Yolo Bypass also provides habitat for shorebirds, waterfowl, and terrestrial species (Jones and Stokes 2001). Large areas in the bypass are currently managed for wildlife habitat areas, including Yolo Bypass Wildlife Area (YBWA), Conaway Ranch, and private duck club lands in the southern section of the bypass (Jones and Stokes 2001)

Vegetation communities identified in the biological resources area of analysis include the following:

- Agriculture – Cropland consisting of major crops and cover types in agricultural production, including rice, corn, milo, sorghum, millet, safflower, tomatoes, and irrigated pastures. Non-cropland includes agricultural areas used for cattle grazing, small roads, and ditches and non-planted areas associated with cultivated lands (DWR 2013).
- Annual and Perennial Grassland – California annual herb/grassland (which includes native herbaceous plants although non-native grasses might still be dominant) and California naturalized annual and perennial grassland (which is dominated by non-native grass species with very little or no presence of native herbaceous plants).
- Open Water and Freshwater Aquatic Vegetation – Parts of the study area are covered by floating mats of vegetation dominated by mosquito fern (*Azolla* sp.) and water primrose (*Ludwigia* spp.) wetlands. There are also many native submerged aquatic species, including pondweeds such as sago pondweed (*Stuckenia pectinata*) and stoneworts (*Charales* spp., green algae structurally similar to vascular plants).
- Freshwater Emergent Marshes and Seeps – California and hardstem bulrush marsh, dominated by California bulrush (*Schoenoplectus californicus*) and hardstem bulrush (*Schoenoplectus acutus*); Douglas's mugwort patches, dominated by mugwort (*Artemisia douglasiana*); and managed annual wetland vegetation, which is managed to provide wildlife habitat.
- Riparian Forest/Woodland – Black willow thickets, box elder forest, Fremont cottonwood forest, mixed hardwood forest, and valley oak woodland
- Riparian Scrub – Non-native Himalayan blackberry brambles and sandbar willow thickets

Special-status species are defined as species that are legally protected or that are otherwise considered sensitive by Federal, State, or local resource agencies. Appendix B includes a list of the special-status plant and wildlife species that were identified during database queries, including 15 that are known from the study area and 41 that have the potential to occur in the study area because of the presence of suitable soils and habitat (freshwater marsh and alkaline grassland).

Wildlife movement corridors, also called dispersal corridors or landscape linkages, are linear features whose primary wildlife function is to connect at least two habitat areas (Beier and Loe 1992). The study area is adjacent to a natural waterway (Sacramento River) that is likely used by resident and migratory birds as a wildlife corridor. In addition, Yolo Bypass serves as a regional connection that provides connectivity for resident and migratory wildlife throughout this region. Federally listed species that might use this movement corridor include valley elderberry longhorn beetle, giant garter snake, western yellow-billed cuckoo, and anadromous fish.

Sensitive habitat types include those that are of special concern to California Department of Fish and Wildlife (CDFW) or that are afforded specific consideration through CEQA, Section 1602 of the California Fish and Game Code, the Porter-Cologne Water Quality Control Act, and/or Section 404 of the CWA, as discussed in Section 9.2, *Regulatory Setting*. The following vegetation communities in the study area are considered sensitive habitats:

- Black willow thickets
- Blue elderberry forest
- California and hardstem bulrush marsh
- Fremont cottonwood forest
- Mixed hardwood forest
- Sandbar willow thickets
- Valley oak woodland

The following vegetation communities are considered waters of the United States subject to regulation by USACE and the Regional Water Quality Control Board under Sections 404 and 401 of the CWA, respectively, because they are hydrologically connected to the Sacramento River. These vegetation communities are also considered waters of the state subject to regulation by Regional Water Quality Control Board under the Porter-Cologne Water Quality Control Act and by CDFW under Section 1600 of the California Fish and Game Code:

- California and hardstem bulrush marsh
- Managed annual wetland vegetation
- Temperate freshwater floating mat
- Open water
- Water primrose wetlands

2.1.6 Cultural Resources

Cultural resources are defined as prehistoric and historic archaeological resources, architectural/built-environment resources, places important to Native Americans and other ethnic groups, and human remains. The Project area is in the Sacramento Valley.

Early inhabitants of the Yolo Basin used the various habitats found throughout the valley, including those previously detailed. They created a sophisticated material culture and established a trade system involving a wide range of manufactured goods from distant and neighboring regions, and their population and villages prospered in the centuries prior to historic contact (Rosenthal et al. 2007). Many surface sites in the Sacramento Valley have been disturbed, buried, or destroyed by agricultural development, levee construction, and river processes. Untrained individuals and professionals with rudimentary methods performed many excavations of Sacramento Valley and Sacramento-San Joaquin Delta (Delta) sites in the early twentieth century. They focused on excavating burials and artifacts that could be arranged into chronological and stylistic groups and paid little attention to other artifacts such as tool stone manufacturing debris, dietary remains, and cooking features; thus, hampering modern attempts at reanalysis. Early professional efforts emphasized culture history rather than processes that drive culture change. There are three basic periods include Paleo-Indian, Archaic, and Emergent/Historic (1973, 1974). The discussion that follows is based on these divisions.

- **Paleo-Indian**: The earliest accepted evidence of human occupation in the Central Valley during the Paleo-Indian Period (11,550 to 8500 BC) comes from the discovery of basally thinned and fluted projectile points at three separate locations in the southern portion of the basin (Rosenthal et al. 2007).
- **Archaic**: The Archaic Period (5550–1100AD) includes a change to settlement subsistence in the early part of the period, followed by what appears to be increasingly sedentary lifestyle, Cultural resources identified includes refined and specialized tool assemblages and features, a wide range of non-utilitarian artifacts, abundant trade objects, and plant and animal remains indicative of year round occupation (Moratto 1984; Ragir 1972; White 2003a, 2003b). Further changes were noted in later as new technologies were developed during this period, including new types of bone tools and bone implements, and widespread manufactured goods such as ornaments and ceremonial blades (Bennyhoff and Fredrickson 1969; Fredrickson 1974; Moratto 1984) large quantities of habitation debris and features (such as fire-cracked rock heaps, shallow hearths, house floors, and flexed burials) that reflected long-term residential occupation.
- **Emergent**: The archaeological record for the Emergent/Historic Period (AD 1000) is more substantial and comprehensive than those of earlier periods in the Central Valley, and the artifact assemblages are the most diverse (Fredrickson 1974; Kowta 1988; Sundahl 1992).

According to ethnographer Alfred Kroeber (1932), the Project area falls between ethnographically reported Patwin and Nisenan areas. Heizer and Hester (1970) present information naming the Patwin village of Yo'doi at Knights Landing and the Nisenan village of Hol'lo-wi near the historic town of Fremont. The NAHC however has previously assigned the Patwin as Most Likely Descendants (MLDs) for the Project area. Both the Yocha Dehe Wintun Nation (Patwin) and the United Auburn Indian Community of the Auburn Rancheria (Nisenan and Miwok) claim cultural and traditional affiliation with the Project area.

- **Nisenan**: Nisenan villages, which ranged from "tribelets" of small extended families consisting of 15 to 25 individuals to larger communities with more than 100 people, have been documented as being along the western bank of the Sacramento River. Wilson and Towne (1978) defined three main subgroups within the Nisenan tribe: Northern Hill Nisenan, Southern Hill Nisenan, and Valley Nisenan. The traditional Valley Nisenan lived on both sides of the Feather River from above Marysville to the confluence of the Sacramento and Feather rivers, then down both sides of the Sacramento River past the city of Sacramento (Wilson and Towne 1978; Kroeber 1932).

- **Patwin**: The Patwin were a series of linguistically and culturally related tribelets that occupied a portion of the lower Sacramento Valley west of the Sacramento River and north of Suisun Bay. Today, the Patwin descendants affiliated with the Project area are the Yocha Dehe Wintun Nation. The Project area's historic-era environment is largely the product of agricultural and residential development as well as fishing, canning, and other industrialized produce processing. These were facilitated by land reclamation and by transportation development, the latter of which initially depended on Delta waterways but eventually surmounted those waterways. The Project area's environment has also been shaped by large-scale flood control and water management efforts as well as recreational activities such as fishing and boating.

Previous studies near the Project area provide reasonable expectations of the range of historic archaeological property types relevant to the study area. These property types are classified here in terms of function. Intensive historic-era use of waterways within the Project area coincides with the discovery of gold in 1848. The sudden influx of fortune seekers resulted in heavy use of waterways within the Project area for transportation of individuals and supplies. To accommodate the surge, cities and towns were established along the rivers. Both small- and large-scale mining endeavors were carried out in the Project area vicinity along the Feather, Sacramento, and American rivers. Agricultural endeavors followed quickly, and overland transportation routes were developed that often paralleled waterways in the Project area. Historic archaeological resources within the Project area are mostly related to these events. Six categories of historical archaeological property types have been identified within the Project area: building foundations, refuse scatters/dumps, transportation-related features, water conveyance systems, historic isolates, and maritime/riverine property types.

The paleontological setting in the area is defined by the two geologic deposits that characterize the Lower Sacramento River region: Holocene river deposits and Holocene flood-basin deposits. Pliocene and Holocene continental rocks and deposits are mixed into flood-basin deposits in the Sacramento Valley (Page 1986). The fossil-bearing Pleistocene Modesto formation may be present within the Lower Sacramento River floodplain. The Modesto formation consists of alluvial terraces and fans dating between 9,000 and 75,000 years ago (Page 1986). Fossil discovery within Sacramento and Yolo counties largely occurs within quarries and along river banks.

The Sacramento River and its tributaries have been heavily affected by anthropogenic processes. The natural flooding and meandering have been confined to manmade earthen structures with no course deviation. Agricultural irrigation is the most significant anthropogenic impact within and around the Project area, including a major canal (Tule Canal) intersecting with the Project area. Anthropogenic impacts to regional riverine landscapes contribute to disturbance and rearrangement of native surficial soils. The probability of paleontological resource discovery within the project area is unlikely without considerable excavation.

2.1.7 Water Quality

The Yolo Bypass region is primarily influenced by inputs from the Sacramento and Feather rivers as well as western stream inputs, including KLRC, Cache Creek, Willow Slough Bypass, and Putah Creek. The basin drains to the lower Delta through the Toe Drain channel along the Sacramento River. There are several high priority pollutants of concern identified in the YBWA Management Plan (CDFG 2008). These include mercury, toxic chemicals, salinity, bacteria, selenium, and boron. Several of these have been identified in the contributing waterbodies to the bypass as part of the 303(d) program.

Mercury. Mercury is a toxic pollutant that readily transports through the environment and accumulates within fish in both contaminated and seemingly pristine aquatic ecosystems (Cabana et al. 1994). Human and wildlife exposure to methylmercury, for organic form of the metal that accumulates in the food web, is a potent neurotoxin that can impair reproduction and fetal development (Ratcliffe et al. 1996). Mercury released during gold mining operations in the Sierra Nevada and mercury mining along the eastern edge of the Central Valley from south of Paso Robles to north of the Bay Area are primary sources of Hg to rivers and lakes, including the Sacramento River and Yolo Bypass. Many of the more than 500 mercury mines in California have not been remediated and many continue to release mercury to the environment (CDFG 2017). Yolo Bypass is essentially a seasonal wetland, with periodic flows of shallow slow-moving water over vegetated soils. In an analysis of a suite of wetlands managed for either agriculture or wildlife, the presence of shallow slow-moving water, flooding and drying cycles, and presence of plant matter overall enhance the production of methylmercury (Windham-Myers et al. 2014).

Toxic Chemicals. Toxic chemicals, including pesticides, are included as 303(d) listed constituents of concern primarily in the Sacramento River. Due to agricultural land uses, pesticides are found throughout the waters and sediments of the bypass (CDFG 2008). The major pesticides that have been used on rice in this region are molinate, thiobencarb, and carbofuran. Molinate and thiocarb are applied to control aquatic grasses and weeds on flooded rice fields while carbofuran is applied to control insects. These chemicals have been shown in the past to be acutely toxic to fish and were attributed to objectionable taste issues in drinking water in the City of Sacramento (Domagalski et al. 2000).

Salinity. High salt content is a concern for the entire bypass area (City of Woodland 2005). Salinity can reduce the productivity of the bypass agricultural fields and may create problems for seasonal wetlands, including stress on microorganisms, plants, and animals.

2.1.8 Air Quality

2.1.8.1 Criteria Pollutants

The study area is within the boundaries of Sacramento Valley Air Basin (SVAB). SVAB is bounded by North Coast Ranges on the west and Northern Sierra Nevada Mountains on the east, and the intervening terrain is relatively flat. The mountains surrounding SVAB create a barrier to airflow, which can trap air pollutants under certain meteorological conditions. Hot dry summers and mild rainy winters characterize the Mediterranean climate of SVAB (California Air Resources Board undated).

The USEPA regulates ambient concentrations of seven common pollutants: carbon monoxide (CO), lead, nitrogen dioxide, O_3, particulate matter (PM_{10} and $PM_{2.5}$), and sulfur dioxide. The Federal CAA requires states to classify air basins (or portions thereof) as either “attainment” or “nonattainment,” with respect to criteria air pollutants, based on whether the national ambient air quality standards (NAAQS) have been achieved. California also has its own ambient air quality standards (CAAQS) and has designated the air basins within the State based on whether the CAAQS are attained.

The project area is designated severe nonattainment for the O_3 NAAQS, nonattainment for the O_3 CAAQS (except Sutter County, which is designated nonattainment-transitional), nonattainment for the $PM_{2.5}$ NAAQS, nonattainment for the PM_{10} CAAQS, and maintenance for the CO and PM_{10} NAAQS. The area is designated attainment for all other pollutants.

2.1.8.2 Climate Change and Greenhouse Gases

The projected changes in climate conditions are expected to result in a wide variety of impacts in Yolo County and the Sacramento River area. In general, estimated future climate conditions include changes to: 1) average daily temperature, 2) extreme heat, 3) precipitation, 4) sea level and storm surge, and 5) snowpack and streamflow.

Global climate model data exhibit warming across California under multiple scenarios with a steady, linear increase over the 21st century. Temperatures in the study area are expected to be between 5.1 and 9.3°F higher than the historic average (1961 to 1990) by the end of the 21st century. The climate model results also consistently show increases in frequency, magnitude, and duration of heat waves when compared to historical averages (Cayan at al. 2012).

For Sacramento, several model simulations indicate a drying trend (i.e., less precipitation) when compared to the historical average. Under the low emissions scenario, the 30-year mean precipitation is projected to be more than five percent drier by mid-21st century and 10 percent drier by late-21st century (Cayan et al. 2012).

Streamflow amounts are projected to shift to more runoff in the winter and less in the spring months. This projected shift occurs because higher temperatures during winter cause more precipitation to occur as rainfall, which increases runoff and reduces snowpack (Reclamation 2014). The frequency of reduced cold water pool in Shasta Reservoir is expected to increase on average by five percent overall during the 21st century (Reclamation 2014).

Sea level rise is expected to increase water levels in the Delta. Additionally, the increase in water levels in the Delta will also increase salinity at the confluence of the Sacramento River and the Delta.

2.1.9 Soils, Geology, and Mineral Resources

The area of analysis includes the Yolo Bypass and surrounding areas within Yolo and Sutter counties. The southern point of the Yolo Bypass, in Solano County, is not considered because no project actions would occur there. Yolo and Sutter counties are in the southern part of Sacramento Valley. Sacramento Valley is bordered by the Coast Range to the west, the Sierra Nevada to the east, and San Joaquin Valley to the south. Yolo Basin is bounded to the north and east by the natural levees of the Sacramento River, to the west by the coalesced alluvial fans of Putah Creek and Cache Creek, and to the south by the tidal marshes of the Delta.

Yolo Bypass is in the Great Valley geomorphic province of California. The Great Valley is an alluvial plain that acts as a trough where sediment has been continuously deposited. Geologic units in the Great Valley Province generally consist of Quaternary alluvium and the Quaternary Modesto and Riverbank formations, both of which consist of somewhat older alluvium and make up the alluvial fan deposits.

The linear extensibility of the soils in the Project area indicate the presence of shrink-swell potentials, ranging from small to high. Soils near Fremont Weir indicate a low risk of damage due to shrinking or swelling. Soils near some of the agricultural road crossings indicate moderate to high shrink-swell potential. In Yolo County, most of the soils are defined by low erodibility and low to high shrink-swell potentials. There are some areas in Yolo County with mid-range erodibility and high erosion potentials. Soils with high to very high shrink-swell potentials, like most the soil in Yolo County, have the potential to cause damage to infrastructure such as buildings, roads, and bridges. Soils with high to very high shrink-swell potential also have high to very high linear extensibility percentages (six percent or higher), which can also lead to infrastructure damage. Soils in Sutter County have low to mid-range erodibility and low to high shrink-swell potentials.

The Project area is not within range of known active faults and experiences less frequent seismic activity than the rest of California (California Geologic Survey [CGS] 2008). The Project area is not located in an Alquist-Priolo Earthquake Fault Zone, and no active faults have been identified in the area; therefore, the risk for surface fault rupture in the Project area is low (CGS 2015 and 2010). The active fault closest to the Project area is the Hunting Creek fault, in the northwest portion of Yolo County, and the closest inactive fault is the Dunnigan Hills fault (CGS 2010). Although the potential for liquefaction in the area is assumed to be moderate, the potential for liquefaction is greater when there is a seismic event. Therefore, it is assumed that because the potential for seismic events is low, there is little to no concern for liquefaction.

2.1.10 Visual, Scenic, or Aesthetic Resources

The Project would take place in Sutter County, Yolo County, within the FWWA, near agricultural road crossings along Tule Canal, and in the adjacent Elkhorn Area. The wildlife area is a 1,461-acre riparian area surrounding part of the Sacramento River. It consists of a wide assortment of vegetation, ranging from large trees and shrubs to smaller shrubs and grasses and riparian areas. This wildlife area is publicly accessible year-round during daylight hours for fishing, wildlife viewing, bird watching, and seasonal hunting. The surrounding area is flat agricultural land and open fields. Agricultural fields are usually contained by small levees or berms, separated by ditches and canals that carry water from the major aqueducts to the fields. There are no residences within the Project area and very few residences and no neighborhoods or other concentrations of housing in the vicinity.

Existing features in the Project area include Tule Pond and Agricultural Road Crossing 1, situated along local scenic, County Road (CR) 16, Fremont Weir located in the northern portion of the wildlife area, and the existing fish ladder located near the eastern end of the Fremont Weir. These areas are intended for public use. The area is rural, with limited urban elements and has various visual elements such as ponds, trees and vegetation, and other various habitats, offering contrast that provides a pleasant visual experience, though there are distinct differences between the heavily vegetated wildlife area and the stark open concrete and dirt foundations of the weir.

2.1.11 Indian Trust Assets

Indian Trust Assets (ITAs) are defined as legal interests in property held in trust by the United States government for Indian tribes or individuals or property protected under United States law for federally recognized Indian tribes or individuals. ITAs can include land, minerals, Federally reserved hunting and fishing rights, Federally reserved water rights, and in-stream flows associated with a reservation or Rancheria. ITAs cannot be sold, leased, or otherwise encumbered without approval of the United States.

Figure 2-5 includes a map of ITAs within the southern Sacramento Valley. These ITAs are not within the vicinity of the Project area; therefore, there is no additional discussion of ITAs because of the geographical distance.

2.1.12 Recreation

The area of analysis for recreation is the Yolo Bypass in Yolo, Sutter, and Solano counties, as shown on Figure 2-6. Public lands in Yolo Bypass are limited and predominantly designated and managed by the CDFW as wildlife areas or ecological reserves. These public lands include FWWA, Sacramento Bypass Wildlife Area (SBWA), YBWA, and Liberty Island Ecological Reserve (LIER). Public access to these CDFW-managed areas typically occurs in the spring and summer when Yolo Bypass is not used as a floodplain for the Sacramento River. When Yolo Bypass is inundated, public access is restricted; thus, recreational use is severely limited. Each of these areas managed by CDFW for recreational uses, agricultural uses, wildlife habitat, and wetlands is described below from north to south. In addition, private recreation areas and sites are dispersed throughout the Project area.

FWWA – The FWWA is along the northern boundary of Yolo Bypass in Sutter and Yolo counties, northeast of the Town of Woodland on the south side of the Sacramento River, with Fremont Weir situated along the northern edge of FWWA. The area consists of 1,461 acres of wetland habitat, including weedy vegetation, brush, valley oaks, willows, and cottonwood trees (CDFW 2016a). FWWA is managed as a Type C wildlife area, with hunting opportunities for pheasant, waterfowl, quail, turkey, mourning dove, cottontail, jackrabbit, and deer (CDFW 2016a). CDFW defines Type C wildlife areas as areas that are generally open daily for hunting for all legal species and do not require the purchase of a hunting pass for entry (CDFW 2016b). Hunting is allowed during spring turkey season and daily from July 1 through January 31. Public access and recreation is allowed at the wildlife area.

SBWA – SBWA is adjacent to and east of Tule Canal in the central portion of Yolo Bypass in Yolo County. SBWA is managed as a Type C wildlife area. This 360-acre state wildlife area is an important cover and feeding area for wildlife during late fall, winter, and early spring. SBWA provides recreational opportunities for fishing (in Tule Canal), wildlife viewing, bird watching, and seasonal hunting (September 1 to January 31) (CDFW 2016c).

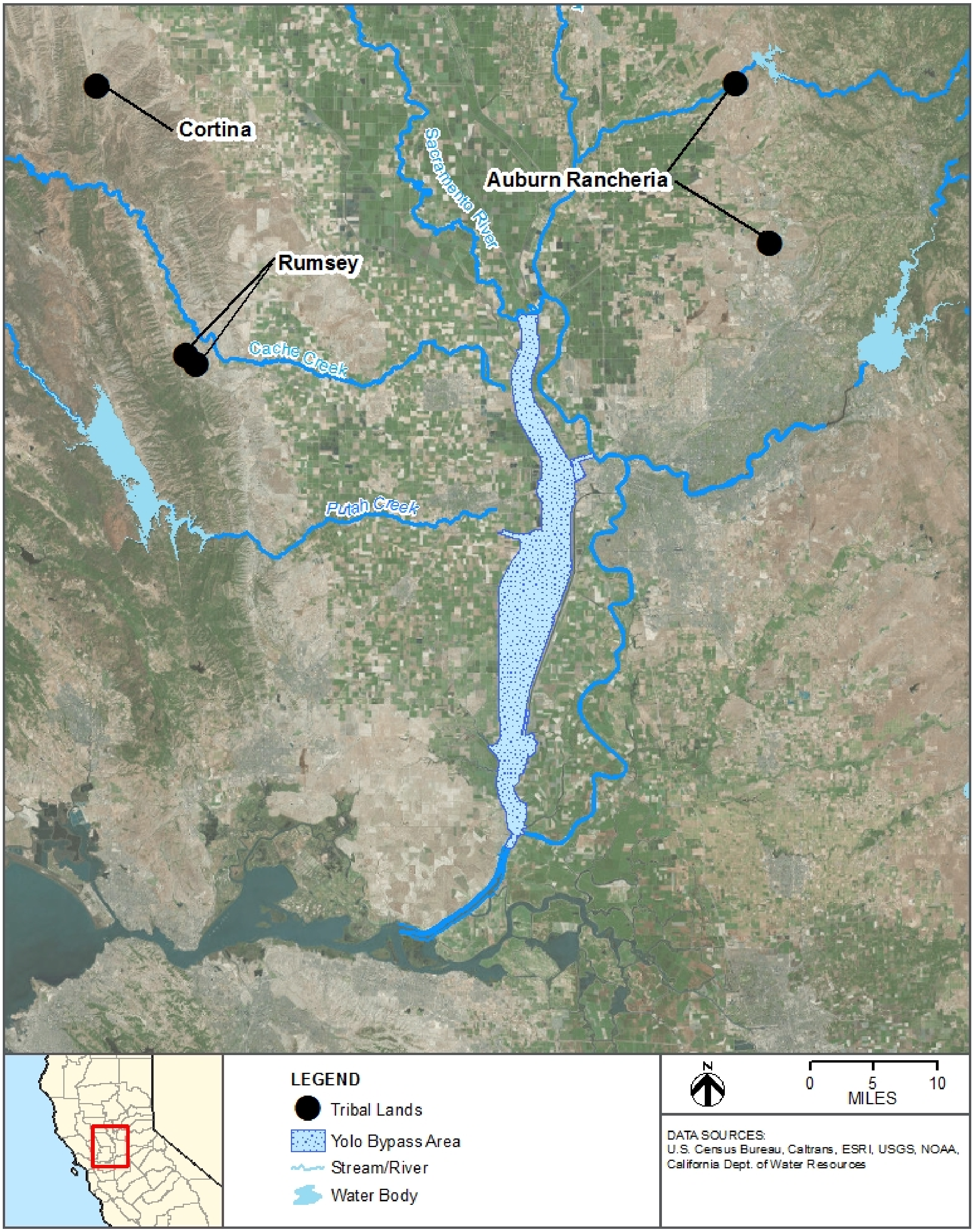

Figure 2-5. Yolo Bypass Proximity to ITAs in the Sacramento Valley

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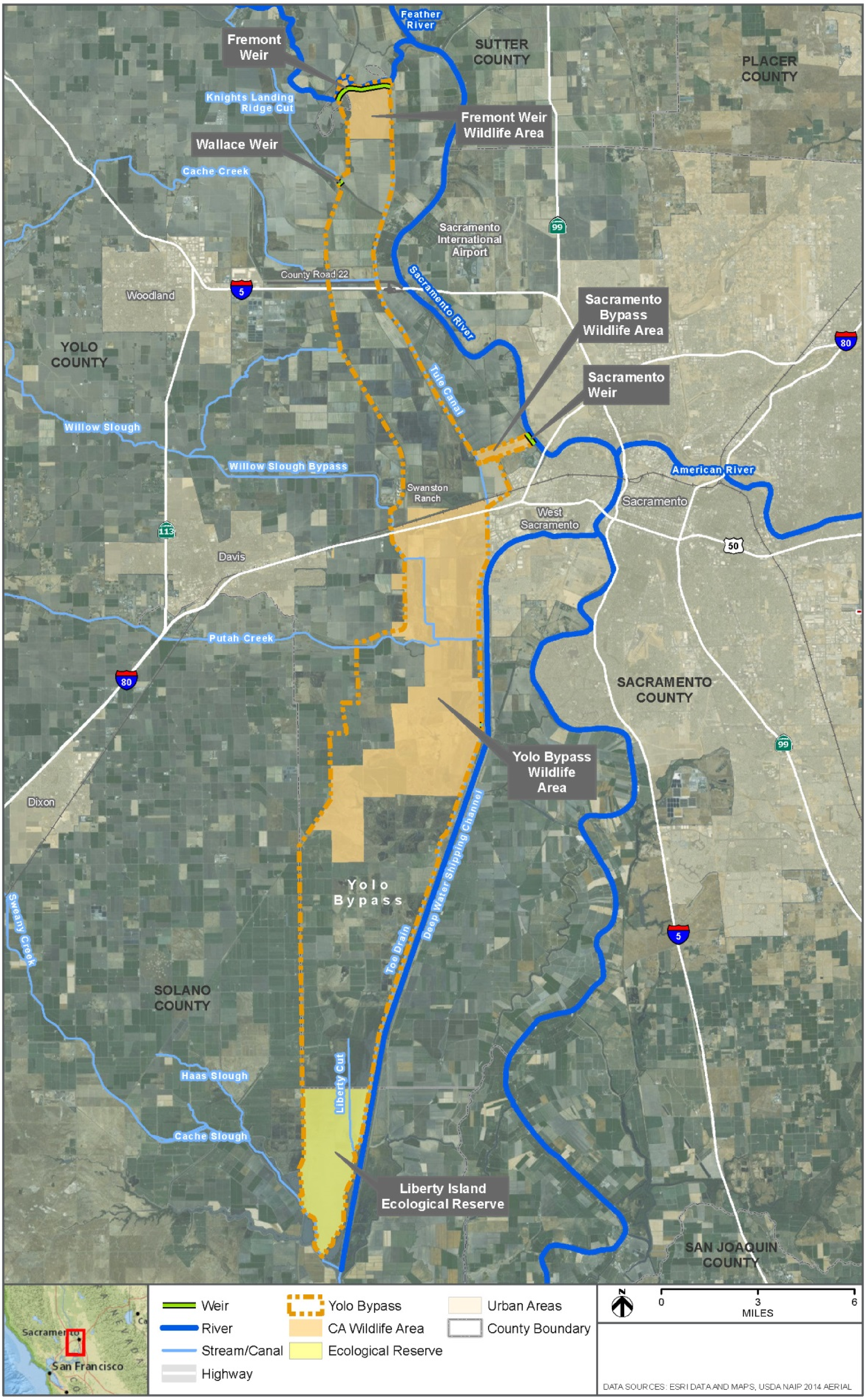

Figure 2-6. Recreation Resources in the Project Area and Region

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YBWA – YBWA is in the central portion of Yolo Bypass in Yolo County between the cities of Davis and West Sacramento. YBWA consists of 17 separate management units on about 16,770 acres of CDFW-managed wildlife habitat and agricultural land. CDFW manages YBWA as a Type A wildlife area, including hunting opportunities for waterfowl and upland game species (CDFW 2016d). CDFW defines a Type A wildlife area as an area with restricted hunter access during waterfowl season and requires a hunting pass to be purchased in advance and exchanged for an entry permit at the wildlife area. YBWA is open year-round from sunrise to sunset except for Christmas Day. Recreational uses for YBWA include hunting, fishing, walking, hiking, wildlife viewing, nature exploration and photography, and environmental education activities for students and the public (CDFW 2016d). Hunting historically has been a popular seasonal use of YBWA, with about 5,000 acres open for hunting. The hunting season runs from the opening of dove season (September) through January, but the most popular hunting season is for waterfowl from late October through January (about 100 days).

In addition, CDFW has partnered with Yolo Basin Foundation to provide educational programs and outreach. Facilities supporting the recreational and education uses include trails, gravel roads, parking areas, and hunting blinds. Yolo Bypass Foundation estimates that more than 4,000 students, teachers, and parents visit the area annually to participate in the Discover the Flyway program implemented in partnership with CDFW (Yolo Basin Foundation 2016).

YBWA is open to the public except during certain Yolo Bypass flooding occurrences. Currently, YBWA public-access policy is to close the entire area soon after water overtops Fremont Weir. Much of YBWA is closed to all non-hunting purposes from two weeks before waterfowl season to one week after waterfowl season though areas designated for wildlife viewing purposes are open on most days throughout the year (CDFG 2008). Significant flooding during the 100-day hunting season (mid-October to mid-January) requires CDFW to discontinue access to these areas, resulting in lost hunting time and other public uses (CDFG 2008). Under existing conditions, inundation results in wildlife area closures lasting for up to two weeks (14 days) out of the 100-day hunting season (Petrik et al 2012).

LIER – LIER is located along the southern boundary of Yolo Bypass in Solano County, southeast of the Town of Dixon. LIER consists of 4,450 acres of mostly inundated tidal marsh habitat in the southern portion of Liberty Island between Prospect Slough and Shag Slough (CDFW 2016e). Recreational uses include wildlife viewing, shoreline fishing, boat fishing, and waterfowl hunting. Hunting for waterfowl in the ecological reserve is allowed seven days per week during the regular waterfowl season, and specific regulations allow the use of temporary floating blinds that must be removed daily (CDFW 2016e).

Private Recreation Areas and Sites – The majority of private recreational use and opportunities occurs on the expansive private lands throughout the Yolo Bypass area where private landowners and their personnel and guests have access to private recreational opportunities, many of which occur without formal recreational facilities. Most of these opportunities are in Yolo County where 17 private hunting clubs, three marinas, and one yacht club are located (DWR 2013). The private hunting clubs are south of YBWA and north of LIER. Sutter County has a minor amount of private recreational opportunities (two marinas and boat clubs) adjacent to the Project area (DWR 2013). Solano County also has limited private recreational facilities, including two marinas, one yacht club, and one hunting club (DWR 2013).

2.2 Future Without Project Conditions

Future without project conditions represent the reasonably foreseeable future conditions in the study area in the absence of the Project. Yolo Bypass would continue to be inundated during overtopping events at Fremont Weir. Juvenile fish would enter the bypass with these flood flows, and the fish would benefit from the rearing opportunities in Yolo Bypass. Additional flow and fish would not pass through Fremont Weir when the Sacramento River is below Fremont Weir.

Adult fish may move upstream in Tule Canal when flows over Fremont Weir or from the westside tributaries provide attraction. As under existing conditions, fish would either pass over Fremont Weir, pass through the fish passage structure at Fremont Weir, become stranded at Fremont Weir, or move to the fish rescue facility at Wallace Weir.

The resources discussed in Section 2.1 are expected to remain largely the same into the future within the Yolo Bypass.

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3 Alternative Formulation Process

The purpose of the alternative formulation process is to identify a reasonable range of alternatives for inclusion in the EIS/EIR.

3.1 Process Overview

The alternatives development process involved input and review from resource agencies, local agencies, landowners, non-governmental organizations (NGOs), and stakeholders. Resource agencies and local agencies were involved at a detailed level, including participation in technical teams (such as the Fisheries and Engineering Technical Team). The process began in 2012 with the development of the *Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan* (Implementation Plan) (Reclamation and DWR 2012). In the Implementation Plan, Reclamation and DWR identified their overall plan to develop, refine, and implement projects to satisfy RPA actions I.6.1 and I.7.

The alternatives development process included public scoping conducted in March 2013. Public scoping allowed the Lead Agencies to provide preliminary information on the purpose and need for the project. This step also allowed the Lead Agencies to solicit ideas for achieving the Project’s purpose and need and learn of potential impacts. The purpose and need for the project includes:

- The need for action is to address decreased habitat quality and an inadequate ability to access that habitat, which has led to a decline in abundance, spatial distribution, and life history diversity for native ESA-listed and CESA-listed fish species. The purpose of the action is to enhance floodplain rearing habitat and fish passage in the Yolo Bypass and/or other suitable areas of the lower Sacramento River basin by implementing RPA actions I.6.1 and I.7, as described in the NMFS BO, to benefit Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and southern DPS North American green sturgeon

Alternative development focused on providing fish passage and juvenile floodplain rearing habitat. Key considerations for adult and juvenile fish movement included:

- Adult fish passage: Passage must consider both salmonids and green sturgeon, but sturgeon passage requirements are generally more stringent. As benthic swimmers, sturgeon generate speed through body curvature, which can limit passage if a channel has submerged obstacles, orifices, or jumps (DWR 2017). Sturgeon avoid turbulent flow conditions, so passage must be provided by non-turbulent, open channel flow structures (DWR 2017). Both salmonids and sturgeon need to pass on their own volition, eliminating trap and haul as a primary means for fish passage (DWR 2017).
- Juvenile migration: Structures must be designed so that fish are not disoriented as they pass through the gates. Juvenile salmonids migrate down the river in the top third of the water

column. Functional design concepts must avoid impingement[1] and the creation of eddies[2] that can increase predation. Juvenile fish should enter the Yolo Bypass on their own volition with the redirected flow from the Sacramento River; trapping fish in the Sacramento River and relocating them to the Yolo Bypass would not satisfy the requirement for volitional passage (DWR 2017).

The Lead Agencies developed fish passage criteria to comply with during design of structures so that adult salmonids and sturgeon would be able to pass. The criteria are presented in Table 3-1. Appendix C includes the basis for development of these criteria.

Table 3-1. Summary of Fish Passage Criteria for Federally-Listed Species within the Yolo Bypass and Sacramento River

Species	Adult Migration Time	Minimum Depth of Flow (Short Distance)	Minimum Depth of Flow (Long Distance)	Minimum Channel Width	Maximum Velocity (Short Distance)	Maximum Velocity (Long Distance)
Adult Sturgeon	Jan-May	3 feet	5 feet	10 feet	6 feet/ second*	4 feet/ second
Adult Salmonids	Nov-May	1 feet	3 feet	4 feet		

Source: DWR 2017

* Short distance velocity is for a maximum length of 60 feet

Juvenile salmonids out-migrate past Fremont Weir at different times of the year, depending on hydrologic conditions. The majority of juvenile winter-run Chinook salmon migrate through this area from December through January and continue to migrate through mid-April to early May (Reclamation and DWR 2012). The early pulse of out-migration is strongly correlated with the first flushing flow of over 15,000 cfs in the Sacramento River at the Wilkins Slough gage (Reclamation and DWR 2012). The majority of juvenile Central Valley spring-run Chinook salmon pass through this area in late-November through December, with out-migration continuing through mid-May (but primarily complete in mid-April) (Reclamation and DWR 2012). Diverting fish into the Yolo Bypass (or “entrainment”) would need to occur at times when fish are present in the river near Fremont Weir.

The alternatives development process was outlined in the Planning Framework Technical Memorandum (Reclamation and DWR 2013). This document identified the steps to formulate alternatives, including the screening process and initial criteria. Figure 3-1 shows a summary of the alternatives formulation process.

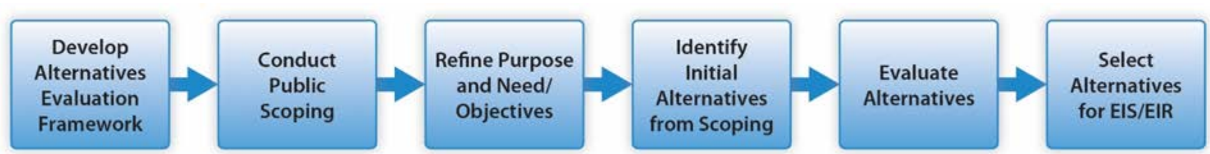


Figure 3-1. Alternatives Formulation Process

[1] Impingement occurs when fish are held against a structure.
[2] Eddies are circular flow patterns that can delay fish.

3.2 Initial Alternatives

3.2.1 Identification

After the public scoping process, the Lead Agencies collected initial components that could help achieve the purpose and need of the project. A component is a project or plan that could contribute to meeting the purpose and need but may not be able to fully accomplish it independently. The Bay Delta Conservation Plan included a planning effort to identify actions that could expand rearing habitat and improve fish passage in the Yolo Bypass. The materials developed in that effort provided initial components for consideration. These components were augmented with suggestions from the Lead Agencies' technical experts and comments during the public scoping process. The Bay Delta Conservation Plan also formed a stakeholder group, the Yolo Bypass Fisheries Enhancement Planning Team, which included resource agencies, landowners, and NGOs, to help develop a plan for the Yolo Bypass. The Lead Agencies solicited additional suggestions from the planning team.

The Lead Agencies performed an initial screening of the components that came out of this process. Components were not considered further if they would not contribute toward accomplishing the purpose and need or if they were deemed technically infeasible. Several options that were screened out are discussed below.

3.2.1.1 Switchbacks

Initial components included structures that had multiple connections from the Sacramento River through Fremont Weir into the FWWA. Each of these connections would have a canal system with switchbacks between the multiple connections. The team did not continue to consider components with switchbacks because they are not conducive to reliable sturgeon passage.

3.2.1.2 Create a Habitat "Shelf" Along the Tule Canal/Toe Drain

To expand floodplain area, this component considered developing a terrace on a portion of the land along the Tule Canal/Toe Drain to create a habitat "shelf" that inundates more frequently. This effort would have land use concerns because it would remove land from agricultural production or wetland use that is adjacent to the Tule Canal/Toe Drain, and the earthwork would be costly. Therefore, it was not retained for further consideration.

3.2.1.3 Create Berms along the Tule Canal/Toe Drain

This component considered creating berms along a portion of the land along the Tule Canal/Toe Drain to help keep water that gets onto the floodplain out of the channel for a certain distance. This component was not retained because it would impede fish passage, which must be improved as part of the Project.

3.2.1.4 Create Setback Levees along the Lower Sacramento River

This component considered creating rearing habitat along the lower Sacramento River system by setting back the Sacramento River levees (or levees on tributaries or adjacent waterways) and creating floodplain habitat. The Lead Agencies considered areas along the Sacramento River system where levees could be set back without encountering engineering constraints or causing substantial land use impacts. The Lead Agencies identified that this could be possible within the Elkhorn Area, which moved forward for more analysis. But the remaining areas within the lower Sacramento River system were not conducive to major setback levee projects. The levee setbacks would not result in enough floodplain habitat acreage to satisfy the requirements in the RPA, and the Lead Agencies would have had to construct in multiple places because construction in the Yolo Bypass would have been required to address adult fish passage concerns.

3.2.2 Formulation

After screening the initial components, the remaining components were combined into initial alternatives in 2014. These six alternatives had several variations, which are described below. The alternative numbering used here does not correspond to the final alternatives (identified in Section 3.3 and discussed in the later sections of this document). For this initial evaluation, the alternatives that increased inundation used the same date for the end of the inundation operations (either March 30 or April 30).

3.2.2.1 Common Elements

At this point in alternatives development, most alternatives included a set of common elements. These common elements included upstream adult fish passage, stranding reduction, agricultural road crossing modifications, Lisbon Weir improvements, Wallace Weir improvements, research and monitoring, and support and maintenance facilities. Several of these elements were later separated into stand-alone projects with independent utility and advanced for implementation outside of this Project, as described in Section 3.3.

3.2.2.2 Initial Alternative 1: No Action and No Project Alternative

The No Action and No Project Alternative describes conditions if no actions are taken as part of this Project to accomplish the project objectives. This alternative is required under NEPA and CEQA. This alternative is called the No Action alternative under NEPA and the No Project alternative under CEQA and is referred to in the remainder of the document as the “No Action Alternative.” Under the No Action Alternative, the Yolo Bypass would continue to be inundated during overtopping events at Fremont Weir. Juvenile fish would enter the bypass with these flood flows, and the fish would benefit from the rearing opportunities in the Yolo Bypass. Additional flow and fish would not pass through Fremont Weir when the Sacramento River stage is below the crest of Fremont Weir.

Adult fish may move upstream in Tule Canal when flows over Fremont Weir or from the westside tributaries attract fish. As under existing conditions, fish would either pass over Fremont Weir, pass through the existing fish passage structure at Fremont Weir, become stranded at Fremont Weir, or move to the fish rescue facility at Wallace Weir.

3.2.2.3 Initial Alternative 2: Fremont Weir Notch Alternative

The Fremont Weir Notch alternative would construct a new gated notch in Fremont Weir to function as the primary adult fish passage mechanism and allow flow and juvenile fish to enter the Yolo Bypass before the Sacramento River rises above the Fremont Weir crest. This alternative included variations with notches of different size and location. Some of these variations also considered developing a new gate structure in the Sacramento River levee near the Yolo Bypass with a transport channel through the Yolo Bypass levee into the bypass system. Figure 3-2 shows the potential locations for different variations. All notches would allow flows up to 6,000 cfs to enter the Yolo Bypass from the Sacramento River.

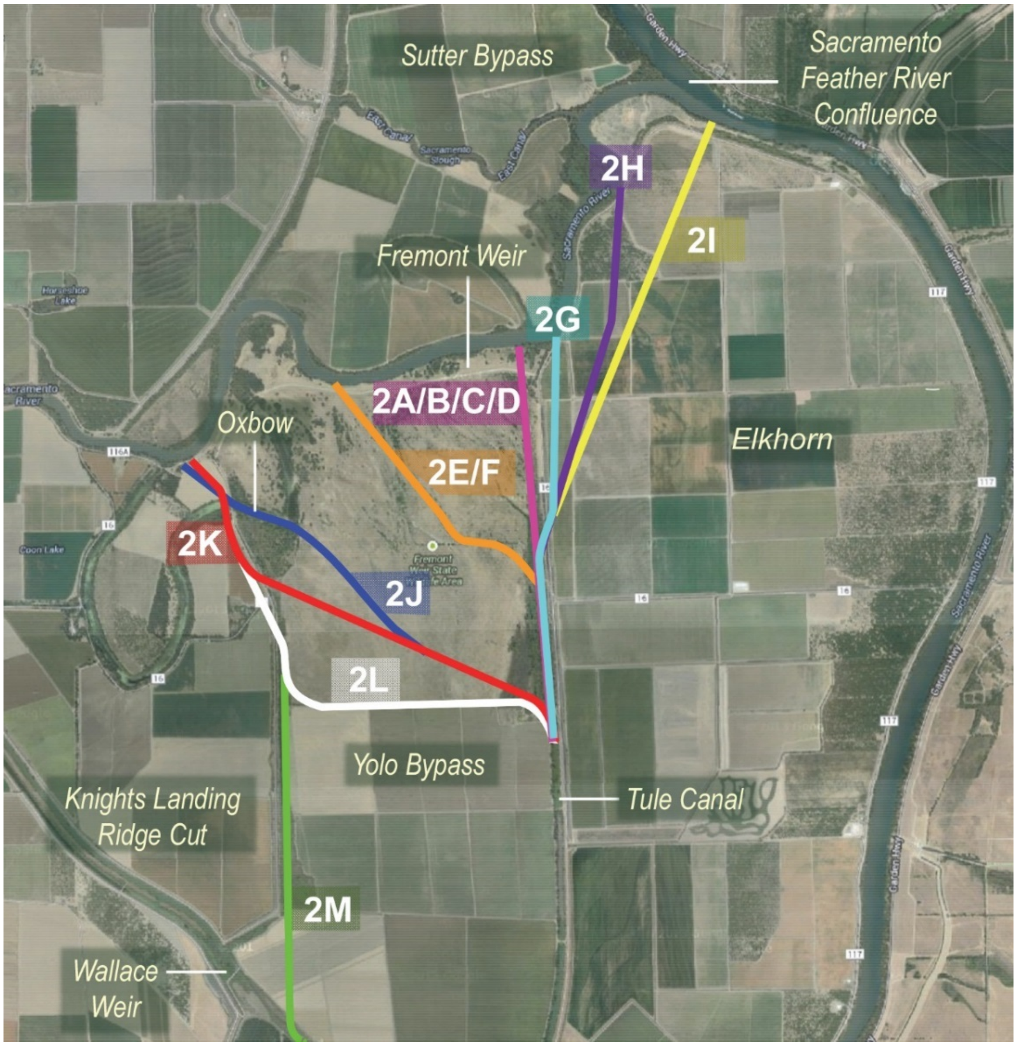


Figure 3-2. Variations for Initial Alternative 2: Fremont Weir Gated Notch

In addition to the different locations, the variations included different sizes of notches. Table 3-2 shows the different variations for this alternative, including the invert elevation (the elevation of the bottom of the gated channel) and the bottom width at this location. Each notch would be trapezoidal in shape and include gates for hydraulic control.

Table 3-2. Fremont Weir Gated Notch Initial Alternatives

Alternative Variation	Invert Elevation	Bottom Width	Notch Location	Connection Point to Tule Canal	Other Features
2a: Small east-side notch	14’	20’	East	Tule Pond	
2b: Medium east-side notch	17.5’	225’	East	Tule Pond	
2c: Medium east-side notch with supplemental flows	17.5’	225’	East	Tule Pond	Supplemental Flows from KLRC
2d: Large east-side notch	14’	225’	East	Tule Pond	
2e: Large central notch	14’	225’	Central	Tule Pond	
2f: Medium central notch	17.5’	225’	Central	Tule Pond	
2g: East of Fremont Weir	17.5’	225’	East of Fremont Weir	Tule Pond	
2h: Elkhorn notch	17.5’	225’	East of Fremont Weir and Alt 2G	Tule Pond	
2i: Eastern Elkhorn notch	17.5’	225’	Downstream of Feather River confluence	Tule Pond	
2j: West notch through oxbow	17.5’	225’	West	South end of FWWA	Canal alignment through oxbow
2k: West notch along levee	17.5’	225’	West	South end of FWWA	Canal alignment around oxbow
2l: West notch with canal connection	17.5’	225’	West	South end of FWWA	Canal alignment uses existing irrigation canals
2m: West notch with connection to KLRC	17.5’	225’	West	KLRC	Canal heads south along levee to connect to KLRC

Notes: FWWA = Fremont Weir Wildlife Area; KLRC = Knights Landing Ridge Cut

Previous efforts had focused on a “medium” notch with an invert elevation of 17.5 feet and a bottom width of 225 feet in the east location. The initial alternative analysis considered multiple notch sizes at this location and then considered multiple other locations with the medium notch size. These comparisons helped identify the benefits and drawbacks of different notch sizes and locations.

3.2.2.4 Initial Alternative 3: Westside Alternative

Alternative 3 would allow additional flow entering the bypass through the KLRC (west of Yolo Bypass). Under Alternative 3a, fish rearing would be accomplished through aquaculture, and upstream fish passage would be accomplished through fish rescue. Water from KLRC would be used for fish rearing. No new fish passage structures would be constructed at the Fremont Weir; fish passage would be accomplished by capturing adult fish on the downstream side of Fremont Weir and transporting them to the Sacramento River in trucks. Figure 3-3 shows the key features of Alternative 3a.

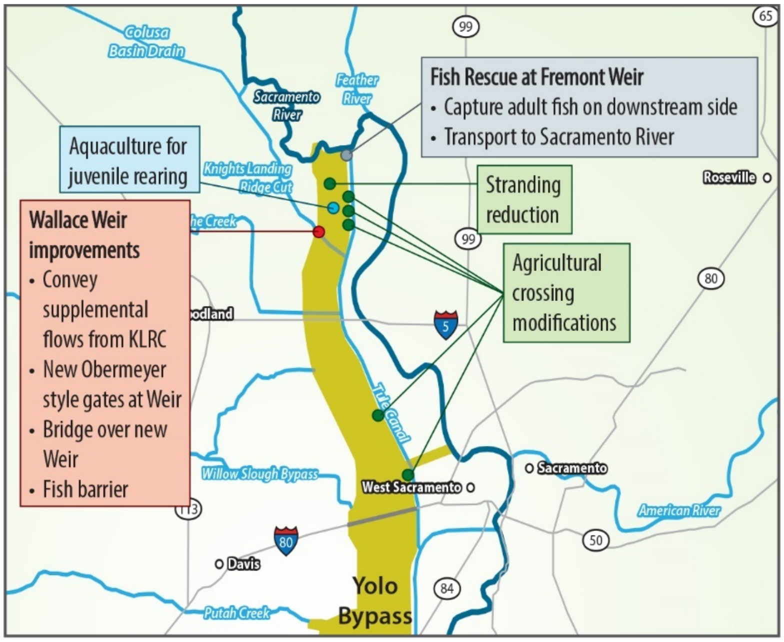


Figure 3-3. Initial Alternative 3a: Westside Alternative

Alternative 3 could have a different variation, which would work to allow volitional fish passage while retaining some concepts of Alternative 3. Alternative 3b would have Sacramento River water enter the KLRC at the Knights Landing Outfall Gates (upstream of the Fremont Weir near Knights Landing). Juvenile fish would enter the Yolo Bypass through the KLRC, and adult fish would have volitional passage upstream through the KLRC into the Sacramento River (through the Knights Landing Outfall Gates). Figure 3-4 shows the key features of Alternative 3b.

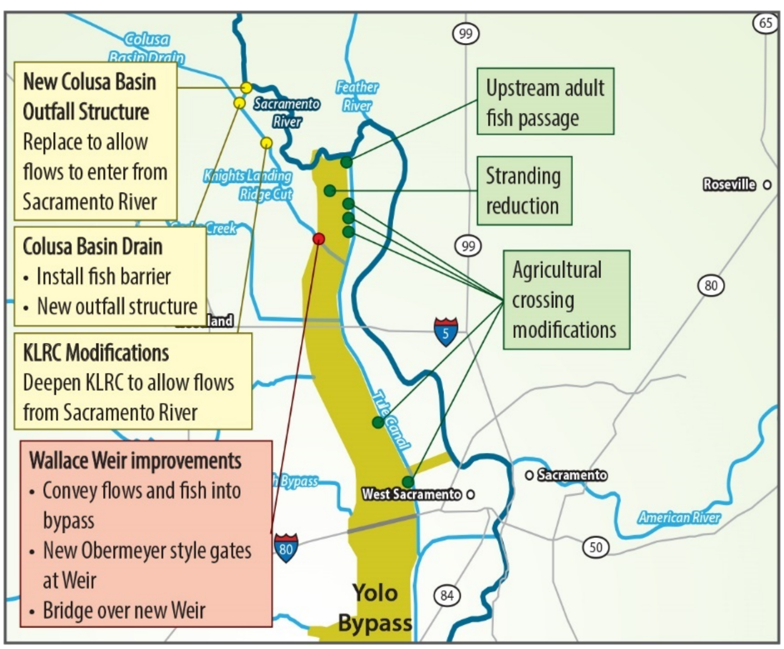


Figure 3-4. Initial Alternative 3b: Westside Alternative with Volitional Passage

Under current operations, the Colusa Basin Drain collects and conveys flood and irrigation return flows from the Colusa Basin watershed and agricultural lands and discharges them into the Sacramento River. When the river is at a higher elevation, the water flows into the KLRC and then into the Yolo Bypass. This alternative would have flows be diverted from the Sacramento River into the Colusa Basin Drain and into the KLRC to support volitional fish passage.

This alternative would require a new Colusa Basin Outfall structure to replace the Knights Landing Outfall Gates that would allow volitional fish passage but close during flood events. The portion of the Colusa Basin Drain from the Sacramento River to the KLRC would need to be regraded so flow would move toward the KLRC. The alternative would also require an outfall structure and fish barrier at the Colusa Basin Drain to control water flow and prevent fish from moving upstream into the drain. KLRC would require modifications to deepen the channel to allow flows from the Sacramento River into the bypass system. Additionally, fish passage structures would be required in the Tule Canal and at Fremont Weir to provide upstream fish passage after Fremont Weir overtopping events.

3.2.2.5 Initial Alternative 4: Elkhorn Alternative

Alternative 4 would include several options to develop floodplain rearing habitat within the Elkhorn Area, which is to the east of the upper Yolo Bypass (between the Yolo Bypass and the Sacramento River, bounded on the south by the Sacramento Bypass). Figure 3-5 shows four of the options (4a-4d), which included varying amounts of new floodplain in the Elkhorn area.

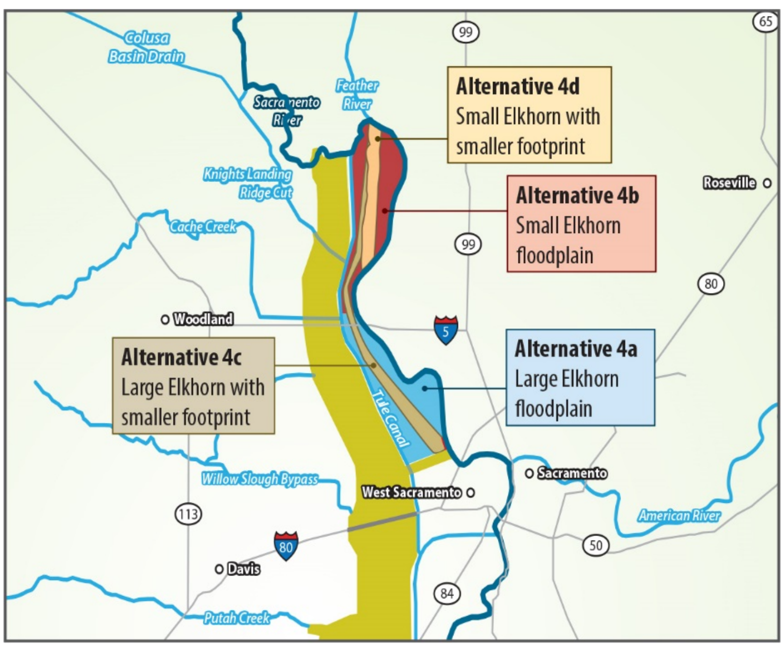


Figure 3-5. Initial Alternatives 4a-4d: Elkhorn Alternative

Alternatives 4a and 4b would expand Sacramento River floodplain into the Elkhorn Area. Alternative 4a would inundate the Elkhorn area to create new floodplain habitat and migratory passage. The levee between the Elkhorn area and the Sacramento River would be removed to allow flows into the Elkhorn area. Alternative 4b would be similar except it would only remove the levee for the northern portion of the Elkhorn area and would not alter the southern portion. The land surface of the Elkhorn area would need to be lowered to allow inundation and create new floodplain habitat. The northern portion and much of the area along the existing levee would be excavated to an average elevation of 18.5 feet. The outside part of the eastern bypass levee would need to be reinforced because it would be wet under this alternative. Alternative 4a would have about 12,400 acres of additional floodplain habitat, and Alternative 4b would have about 6,400 acres of new floodplain habitat.

Alternatives 4c and 4d are similar to Alternatives 4a and 4b but include less earthwork. Alternative 4c would allow inundation of the Elkhorn area but would only remove portions of the Sacramento River levee and excavate a channel between those portions. The areas outside the channel would inundate less frequently than under Alternative 4a. Alternative 4d would similarly inundate only the northern Elkhorn area and would remove portions of the northern Sacramento River levee and develop a channel between those portions. These alternatives would have a secondary channel and floodplain system in the Elkhorn area, but most of the Sacramento River levee would remain in place and some areas would rarely (if ever) be inundated. These alternatives would include ring levees to protect structures from flooding.

Alternative 4e would expand the Yolo Bypass into the Elkhorn area by moving the eastern bypass levee. Water would be diverted from a new notch in the Sacramento River levee. Figure 3-6 shows elements of Alternative 4e. The brown shaded area depicts the Elkhorn expansion. A portion of the bypass levee along the Tule Canal would be removed, and a new levee would be constructed to include the Elkhorn area. The southern area would be graded to a lower elevation to create new floodplain habitat. The expanded area would add about 5,000 acres of inundated floodplain habitat. Juvenile salmonids would be able to use the existing Yolo Bypass and the new Elkhorn area for rearing.

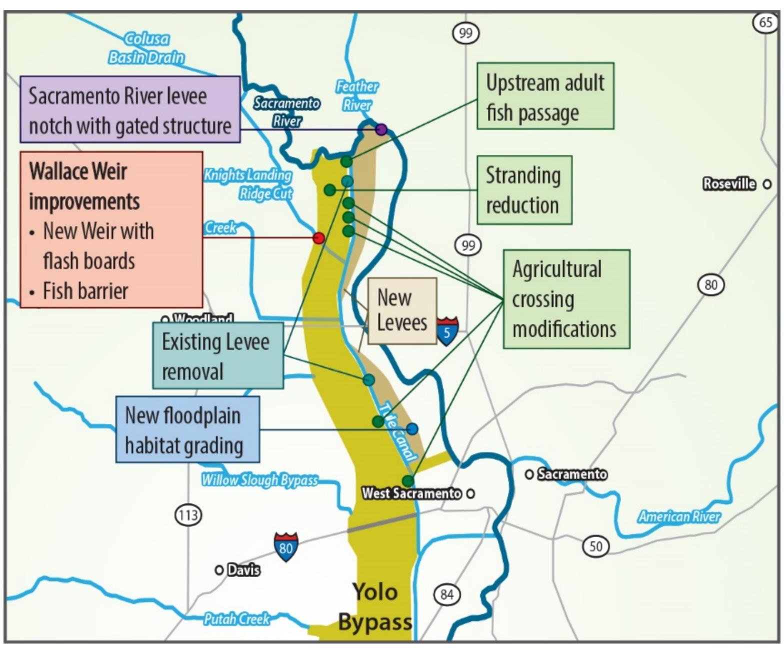


Figure 3-6. Initial Alternative 4e: Yolo Bypass Expansion

3.2.2.6 Initial Alternative 5: Sacramento Weir Notch Alternative

Alternative 5 would construct a new gated notch in the Sacramento Weir to function as the primary adult fish passage mechanism and allow flow and juvenile fish to enter Yolo Bypass through the Sacramento Bypass before the Sacramento River rises above the Sacramento Weir crest. Figure 3-7 shows Alternative 5a (a small notch) and Alternative 5b (a large notch).

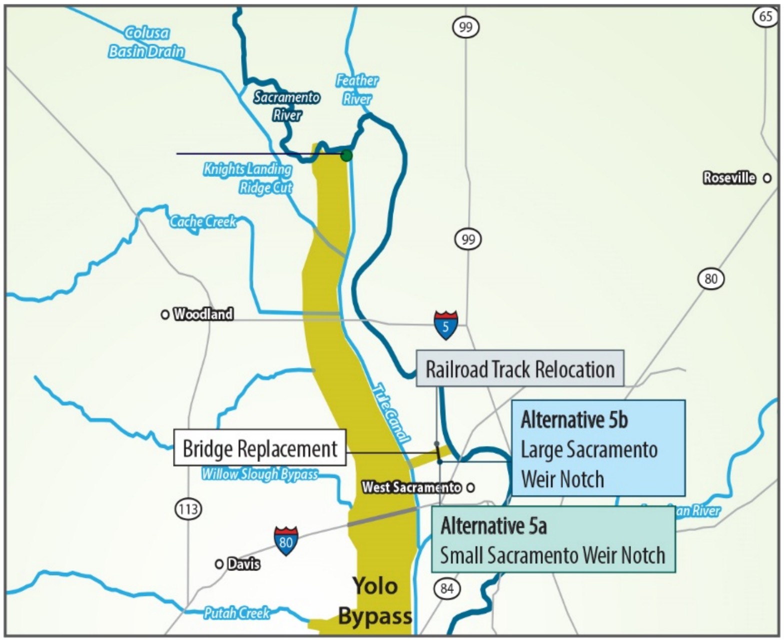


Figure 3-7. Initial Alternative 5: Sacramento Weir Notch

Alternative 5a included a small notch in the Sacramento Weir to allow for floodplain inundation and provide fish passage. The notch would have an invert elevation of two feet and a bottom width of 20 feet. The Sacramento Weir is connected to the southern portion of the Yolo Bypass by a one-mile channel; therefore, only the southern portion of the bypass would be inundated and provide additional rearing habitat. Migrating adult salmonids could swim past the channel to the Sacramento Weir to Fremont Weir. This alternative would also include a fish passage facility at Fremont Weir so that fish upstream of the Sacramento Bypass could pass into the Sacramento River.

Old River Road runs adjacent to the Sacramento Weir and a railroad track runs also along top of Sacramento Weir. Installation of a notch in the weir would destabilize these structures. The existing bridge would need to be strengthened. The railroad track over the weir would need to be relocated because there cannot be any interruptions in rail traffic during the construction period. Because railroad tracks cannot have sharp turns, a longer portion of the track would need to be realigned to accommodate the relocation.

Alternative 5b would include a larger notch in the Sacramento Weir with an invert elevation at two feet and a bottom width of 225 feet. Similar to Alternative 5a, the bridge would need to be strengthened and the railroad track would need to be relocated. Additionally, Alternative 5b would include a fish passage structure at Fremont Weir.

3.2.2.7 Initial Alternative 6: Sutter Bypass Alternative

Alternative 6 would include actions to increase floodplain rearing habitat in the Sutter Bypass, a flood bypass to the north of the Yolo Bypass. Tisdale Weir, north of Knights Landing, diverts flood water from the Sacramento River into the Sutter Bypass, which flows south into the Sacramento River near Fremont Weir. Multiple variations of Alternative 6 would include different actions within Sutter Bypass that could improve floodplain rearing habitat. Alternative 6 also includes fish passage actions in the Yolo Bypass to satisfy RPA action I.7. Figure 3-8 shows Alternatives 6a through 6f:

- Alternative 6a would create a gated notch in Tisdale Weir to allow flow and fish to enter and leave the Sutter Bypass at lower Sacramento River elevations. This alternative would also include a low-flow channel in the Tisdale Bypass to connect to the Sutter Bypass.
- Alternative 6b would set back the southern Tisdale Bypass levee by 1,000 feet to allow increased flow and fish rearing in this area.
- Alternative 6c would set back the west Sutter Bypass levee (south of the Tisdale Bypass) to provide increased floodplain rearing habitat.
- Alternative 6d would set back the east Sutter Bypass levee (south of the Tisdale Bypass) to provide increased floodplain and expand the Feather River floodplain in the southern portion of the bypass.
- Alternative 6e would create 800 acres of a habitat shelf in the Sutter Bypass that would be inundated seasonally from the Sacramento River to the south.
- Alternative 6f would connect several existing gravel pits to reduce predation and potentially provide habitat.

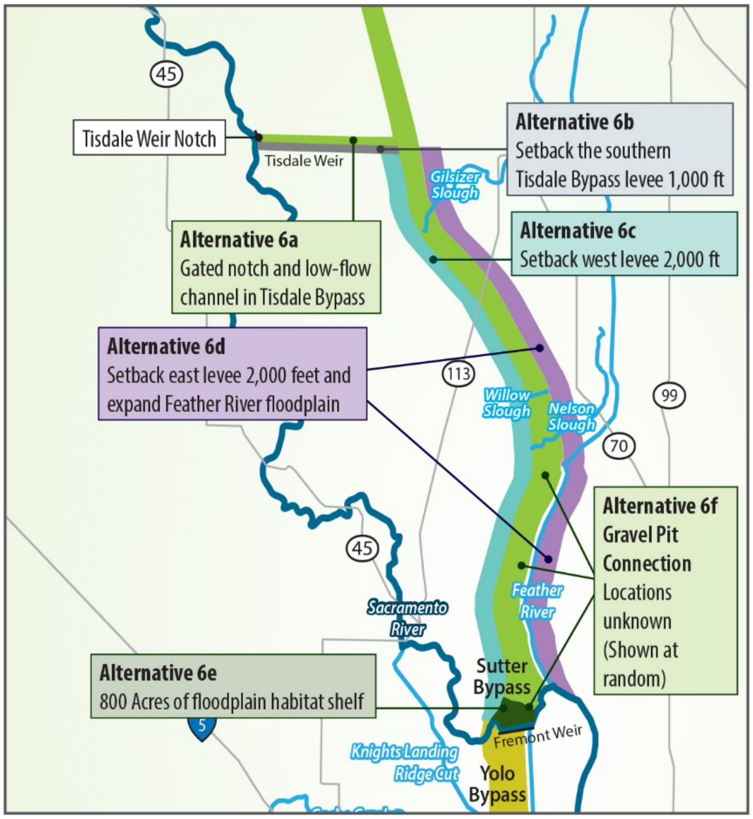


Figure 3-8. Initial Alternative 6a through 6f in the Sutter Bypass

Figure 3-9 shows two additional alternatives in the Sutter Bypass. Alternative 6g would modify the Nelson Rock Weir in the Sutter Bypass to increase inundation. It would not increase access for fish to habitat but would increase the length of inundation for fish in the Sutter Bypass. Alternative 6h would modify Weir 1 in the Sutter Bypass to increase inundation in the Sutter National Wildlife Refuge to the north of Tisdale Bypass.

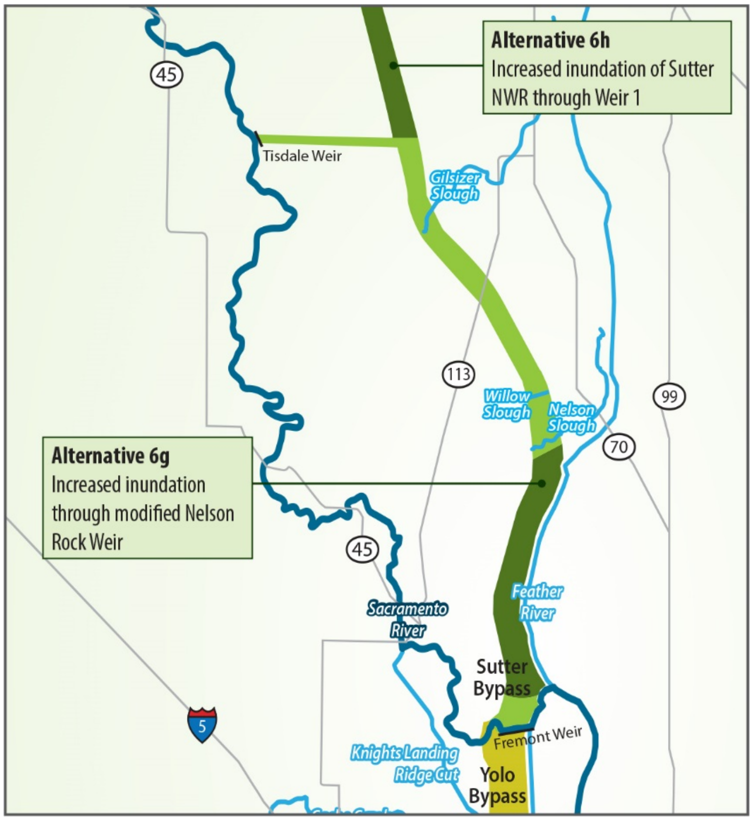


Figure 3-9. Initial Alternatives 6g and 6h in the Sutter Bypass

3.2.3 Alternative Screening

The Lead Agencies completed an initial evaluation of these alternatives based on the Federal planning criteria included in the 2013 Principles, Requirements and Guidelines for Water and Related Land Resources Implementation Studies (PR&Gs). The evaluation considered:

- Effectiveness: How well an alternative plan would achieve rearing habitat and fish passage objectives.
- Completeness: Whether an alternative plan would provide improvements for all four focus fish.
- Acceptability: Whether an alternative plan would be compatible with other efforts in the bypass and minimize effects to agriculture, waterfowl, education, and biological resources.
- Efficiency: How well an alternative plan would deliver economic benefits relative to project costs.

The Lead Agencies further defined these Federal planning criteria related to this project and developed a set of evaluation factors. The evaluation factors identify how well an alternative meets each Federal planning criterion. For initial alternative screening, most of the evaluation was at a qualitative level. Table 3-3 shows the planning criteria and evaluation factors.

Table 3-3. Federal Planning Criteria and Evaluation Factors

Federal Planning Criterion	Category	Evaluation Factors
Effectiveness: How well an alternative would alleviate problems and achieve opportunities	Increase access to floodplain habitat	Measure connectivity and potential to entrain winter-run Chinook onto floodplain
		Measure connectivity and potential to entrain spring-run Chinook onto floodplain
	Increase area of floodplain habitat	Inundation area (area inundated at least 14 days in 50 percent of years)
	Increase food production as part of ecosystem approach	Increase in food production
	Adult fish passage	Percent of season that meets adult fish passage criteria
	Juvenile fish passage	Potential for juvenile stranding or predation risk
Completeness: Whether an alternative would account for all investments or other actions necessary to realize the planned efforts	Provide complete fish benefits	Addresses all four focus fish
Acceptability: The viability of an alternative with respect to acceptance by other Federal, State, and local entities and compatibility with existing laws	Agricultural impacts	Inundation effects on agricultural production
	Waterfowl impacts	Available foraging habitat
		Inundation of areas that reduce waterfowl food production
		Impacts to access or increased inundation of recreation areas
	Education impacts	Inundation of areas used for educational outreach
	Biological impacts	Impacts from construction (benefits addressed under “effectiveness” criterion)
	Compatibility with other related efforts	Potential to affect future options or costs for other flood and restoration planning efforts
Efficiency: How well an alternative would deliver economic benefits relative to project costs	Cost-effectiveness	Relative benefits and costs

3.2.3.1 Effectiveness

The effectiveness planning criterion considers how well the alternatives would meet the purpose and need and project objectives. For this project, the evaluation factors consider the quantity and quality of floodplain rearing habitat, access to that habitat, and fish passage through the Yolo Bypass. The sections below describe how the alternatives perform compared to each evaluation factor, and the results are summarized in Table 3-4.

Table 3-4. Effectiveness Evaluation Results

Alternative	Winter-Run Entrainment	Spring-Run Entrainment	Inundation Area	Food Production	Adult Fish Passage	Juvenile Fish Passage
Alt 2a, Small East Notch						
Alt 2b, Medium East Notch						
Alt 2c, Medium East Notch with Supplemental Flows						
Alt 2d, Large East Notch						
Alt 2e, Large Central Notch						
Alt 2f, Medium Central Notch						
Alt 2g, East of Fremont Weir						
Alt 2h, Elkhorn Notch						
Alt 2i, Eastern Elkhorn Notch						
Alt 2j, West Notch through Oxbow						
Alt 2k, West Notch along Levee						
Alt 2l, West Notch with Canal Connection						
Alt 2m, West Notch with KLRC Connection						
Alt 3a, Westside						
Alt 3b, Westside with Volitional Passage						
Alt 4a, Large Elkhorn Floodplain						
Alt 4b, Small Elkhorn Floodplain						
Alt 4c, Large Elkhorn with Smaller Footprint						

Alternative	Winter-Run Entrainment	Spring-Run Entrainment	Inundation Area	Food Production	Adult Fish Passage	Juvenile Fish Passage
Alt 4d, Small Elkhorn with Smaller Footprint	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	High Performance	High Performance
Alt 4e, Yolo Bypass Expansion	Neutral Performance or Minor Benefits	Medium Performance	Medium Performance	Medium Performance	High Performance	Medium Performance
Alt 5a, Small Sacramento Weir Notch	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Poor Performance	Poor Performance	High Performance	Medium Performance
Alt 5b, Large Sacramento Weir Notch	Medium Performance	Medium Performance	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	High Performance	Medium Performance
Alt 6a, Tisdale Weir Notch	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	High Performance	Medium Performance
Alt 6b, Tisdale Bypass Setback	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	High Performance	Medium Performance
Alt 6c, West Sutter Bypass Setback	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	High Performance	Medium Performance
Alt 6d, East Sutter Bypass Setback	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	High Performance	Medium Performance
Alt 6e, Sutter Bypass Habitat Shelf	Neutral Performance or Minor Benefits	Poor Performance	Poor Performance	Poor Performance	High Performance	Medium Performance
Alt 6f, Gravel Pit Connection	Poor Performance	Poor Performance	Poor Performance	Poor Performance	High Performance	Medium Performance
Alt 6g, Nelson Rock Weir Modification	Poor Performance	Poor Performance	Poor Performance	Poor Performance	High Performance	Medium Performance
Alt 6h, Weir 1 Modifications	Poor Performance	Poor Performance	Poor Performance	Poor Performance	High Performance	Medium Performance

Legend

High Performance	Medium Performance	Neutral Performance or Minor Benefits	Poor Performance

3.2.3.1.1 Winter-Run Chinook Salmon Entrainment

Large numbers of juvenile winter-run Chinook salmon typically move downstream on the Sacramento River during the first wet event of the year. The type of event that causes fish to move downstream results in flows of about 15,000 cfs at Wilkins Slough; these flow events have Sacramento River elevations at Fremont Weir of about 18 feet. Alternative 2 with larger notches would better capture river flows at these lower elevations, but none of the facilities would capture a substantial amount of flow. Alternative 3a would not entrain juvenile salmonids, and Alternative 3b would have minimal flow at lower river elevations. Alternatives 4a through 4d would have grading with an average floodplain elevation of 18.5 feet. While some lower areas may be inundated to provide floodplain habitat at lower river elevations, most of the area would be above water and would not entrain fish. Alternative 5 would entrain more fish with a large notch than a small notch. Alternative 6 has some variations that would not have fish entering from the Sacramento River, and these variations would perform poorly.

3.2.3.1.2 Spring-Run Chinook Salmon Entrainment

Juvenile spring-run Chinook salmon migrate down the Sacramento River in the fall and winter after their birth. Generally, alternatives that allow more flow to quickly enter the Bypass are the alternatives that entrain the most spring-run salmon. In the Sutter Bypass, the Tisdale Weir overtops at lower river elevations than the Fremont Weir. Notching the Tisdale Weir would have a smaller increase compared to existing conditions for spring-run salmon than the alternatives in the Yolo Bypass. Additionally, alternatives that are upstream of Tisdale Weir or look at features without a Tisdale Weir notch would have poor performance related to spring-run salmon entrainment.

3.2.3.1.3 Inundation Area

The area of inundation is an indicator for the amount of floodplain rearing habitat provided by an alternative. For Alternative 2, the inundated area is driven by the size of the gated notch because larger notches would increase flows more quickly as the Sacramento River rises, resulting in larger inundated areas. Alternative 3 would include managed floodplain areas that have smaller areas than the other alternatives. The Alternative 4 inundated area is larger for the alternatives that include larger portions of the Elkhorn area and more grading to allow inundation on the land. Alternative 5 would have flows entering the Yolo Bypass through the Sacramento Weir, which would result in limited inundation north of the Sacramento Bypass. Alternative 6 would inundate portions of the Sutter Bypass, but the Sutter Bypass has less area available for inundation than the Yolo Bypass.

3.2.3.1.4 Food Production

Food production, as part of an ecosystem approach, is driven by larger areas that are inundated for longer periods. The food that is produced must then be moved through the system with flows moving through the Yolo Bypass. Alternatives perform better when they have a larger area of inundation that is inundated for a longer period.

3.2.3.1.5 Adult Volitional Fish Passage

Providing volitional passage for adults through the Yolo Bypass into the Sacramento River is a part of the purpose and need. While all alternatives may require some fish rescue operations at times, alternatives performed better for this criterion if they allow volitional fish passage at most times. Alternative 2c did not perform as well as other alternatives because the supplemental flows from KLRC could confuse fish compared to the other alternatives. Alternative 3a does not include volitional fish passage and performs poorly for this criterion. Alternative 3b has a convoluted route for fish to travel to reach the Sacramento River, which would increase the likelihood that fish require rescue.

Alternatives 2d and 2e include a large gated notch in the Fremont Weir. To limit the flows into the Yolo Bypass to 6,000 cfs or less, this gated notch requires operations to close gates as Sacramento River flows increase. The gate operations result in conditions that do not meet fish passage criteria as river levels approach Fremont Weir elevations (32 feet), so these alternatives did not perform as well for fish passage.

3.2.3.1.6 Juvenile Fish Passage

This evaluation factor considers if alternatives provide conditions for fish to enter and exit the floodplain in a safe and timely manner. Alternatives 4a through 4d perform the best for this factor because fish could move on and off the floodplain as Sacramento River water levels rise and fall without water control structures. Alternative 3a would require fish transport to move juveniles onto the floodplain, so it performs poorly related to this factor. Alternative 3b includes the ability for juveniles to move onto the Yolo Bypass through the KLRC without fish transport, but it requires the juveniles to travel through about eight miles of the KLRC before entering the Yolo Bypass. This passage route is not as timely as the remaining alternatives.

3.2.3.2 Completeness

All the alternatives include improvements for the four focus fish species; therefore, they all perform well for this evaluation factor.

3.2.3.3 Acceptability

Acceptability considers other factors that may make an alternative more or less acceptable to other Federal, State, and local entities. The sections below describe how the alternatives perform compared to each evaluation factor, and the results are summarized in Table 3-5.

Table 3-5. Acceptability Evaluation Results

Alternative	Agriculture: Late Spring Inundation	Waterfowl: Available Foraging Area	Waterfowl: Food Production	Waterfowl: Inundation of Recreation	Education	Biological Impacts from Construction	Compatibility with other Programs
Alt 2a, Small East Notch							
Alt 2b, Medium East Notch							
Alt 2c, Medium East Notch with Supplemental Flows							
Alt 2d, Large East Notch							
Alt 2e, Large Central Notch							
Alt 2f, Medium Central Notch							
Alt 2g, East of Fremont Weir							
Alt 2h, Elkhorn Notch							
Alt 2i, Eastern Elkhorn Notch							

Alternative	Agriculture: Late Spring Inundation	Waterfowl: Available Foraging Area	Waterfowl: Food Production	Waterfowl: Inundation of Recreation	Education	Biological Impacts from Construction	Compatibility with other Programs
Alt 2j, West Notch through Oxbow							
Alt 2k, West Notch along Levee							
Alt 2l, West Notch with Canal Connection							
Alt 2m, West Notch with KLRC Connection							
Alt 3a, Westside							
Alt 3b, Westside with Volitional Passage							
Alt 4a, Large Elkhorn Floodplain							
Alt 4b, Small Elkhorn Floodplain							
Alt 4c, Large Elkhorn with Smaller Footprint							
Alt 4d, Small Elkhorn with Smaller Footprint							
Alt 4e, Yolo Bypass Expansion							
Alt 5a, Small Sacramento Weir Notch							
Alt 5b, Large Sacramento Weir Notch							
Alt 6a, Tisdale Weir Notch							

Alternative	Agriculture: Late Spring Inundation	Waterfowl: Available Foraging Area	Waterfowl: Food Production	Waterfowl: Inundation of Recreation	Education	Biological Impacts from Construction	Compatibility with other Programs
Alt 6b, Tisdale Bypass Setback	Medium Performance	Neutral Performance or Minor Benefits	Medium Performance	Medium Performance	High Performance	Medium Performance	Medium Performance
Alt 6c, West Sutter Bypass Setback	Medium Performance	Neutral Performance or Minor Benefits	Medium Performance	Medium Performance	High Performance	Medium Performance	Medium Performance
Alt 6d, East Sutter Bypass Setback	Medium Performance	Neutral Performance or Minor Benefits	Medium Performance	Medium Performance	High Performance	Medium Performance	Medium Performance
Alt 6e, Sutter Bypass Habitat Shelf	High Performance	Medium Performance	Medium Performance	Medium Performance	High Performance	Medium Performance	Medium Performance
Alt 6f, Gravel Pit Connection	High Performance	Medium Performance	Medium Performance	Medium Performance	High Performance	High Performance	Medium Performance
Alt 6g, Nelson Rock Weir Modification	Medium Performance	Medium Performance	Medium Performance	Medium Performance	High Performance	Medium Performance	Medium Performance
Alt 6h, Weir 1 Modifications	High Performance	Medium Performance	Neutral Performance or Minor Benefits	Neutral Performance or Minor Benefits	High Performance	High Performance	Medium Performance

Legend

High Performance	Medium Performance	Neutral Performance or Minor Benefits	Poor Performance

3.2.3.3.1 Agricultural Impacts from Inundation

Agricultural production in the Yolo Bypass would be affected if fields are inundated in the spring when growers need to start field preparation and planting. For these types of impacts, the key driver in the potential for impacts is the closure date for the gated notch. All alternatives incorporate the same closure dates (either March 30 or April 30); thus, the key performance indicator is the size of the facility that allows water into the Yolo or Sutter bypasses. Larger notches allow more water to enter the bypass at lower Sacramento River flows, which could extend the inundation period on some parcels.

Agricultural uses could also be affected if alternatives change land use on specific parcels. Alternatives 4a through 4d would convert land uses for all (or part) of the Elkhorn area. While agricultural land uses may continue within the floodplain in the future, the extensive grading required would have a substantial effect on existing land uses in the Elkhorn area. Alternative 4e would involve less grading on existing land uses because the areas that would be incorporated within the Yolo Bypass are already at lower elevation. (The higher ground in the Elkhorn area tends to be closer to the river, caused by historical alluvial sediment deposition.)

3.2.3.3.2 Waterfowl Impacts to Available Foraging Habitat

Changes in water depth could affect the usefulness of an area for waterfowl foraging. Waterfowl need water shallower than 18 inches and prefer water shallower than 10 inches (Petrik et al. 2012). Depths over 18 inches are not used for foraging. Larger gated notch facilities would have greater depths of inundation at lower Sacramento River elevations, but the depths at higher river elevations would be consistent across alternatives because the alternatives have a peak notch flow of 6,000 cfs.

Alternatives 4a through 4d could have beneficial effects by providing new areas of inundation for waterfowl foraging that are currently not available. The remaining alternatives would have some new foraging areas but would lose some existing areas and likely have a small overall decrease in foraging area.

3.2.3.3.3 Waterfowl Impacts to Food Production

Swamp timothy (*Crypsis schoenoides*) is the primary food source on the seasonal wetlands in the Yolo Bypass, and it requires careful management of water levels starting at the beginning of March (Petrik et al. 2012). Increased inundation after this date could affect available food for waterfowl. The end dates for inundation are the same for all alternatives (March 30 or April 30), and these dates would influence the growth of swamp timothy for the alternatives that inundate refuge areas in the Yolo or Sutter bypasses. Facilities with larger notches that inundate more area at lower Sacramento River flows would inundate the refuge areas more frequently and have a greater potential to affect food production. Alternatives 3 and 4a through 4d would not increase inundation of the refuges in the Yolo or Sutter bypasses; therefore, these alternatives perform the best for this factor.

3.2.3.3.4 Waterfowl Impacts for Recreation Areas

Increased inundation could close waterfowl viewing and hunting areas more often. Longer periods of inundation would have greater effects, and these effects are more likely for the larger notches that would inundate more area with lower Sacramento River flows. Alternatives 3 and 4a through 4d would not increase inundation in areas used for recreational waterfowl viewing and hunting in the Yolo or Sutter bypasses; thus, these alternatives perform the best for this factor.

3.2.3.3.5 Educational Impacts

Inundating areas that are used for educational outreach could reduce the ability to conduct educational field trips. Inundating a small amount of land (or no land) used for educational outreach would be preferable to inundating more area. The YBWA (near Highway 80) is the main area that is used for educational activities, and larger notches would inundate this area for more of the winter. Alternatives 3, 4a through 4d, and 6 would not increase inundation in this area and perform the best for this factor.

3.2.3.3.6 Biological Impacts from Construction

The biological impacts of construction are related to how much construction is likely to occur and whether that construction occurs in sensitive areas. Generally, the only area where construction activities may be more sensitive is in the oxbow area in the western part of the

FWWA, which provides habitat area for multiple species. This area is affected in Alternative 2j. For remaining alternatives, the areas for construction are not more sensitive for some of the alternatives than others; thus, the key factor is the magnitude of construction. Larger notches generally perform less well than smaller notches because they require additional construction and could affect more biological resources. Alternatives 3b and 4 would require a substantial amount of earthwork that would also have increased potential for effects to biological resources.

3.2.3.3.7 Compatibility with Other Programs

The Yolo Bypass has multiple functions, and alternatives are more acceptable if they are compatible with other ongoing or new programs. A key consideration is that DWR and USACE flood-planning efforts are considering an expansion to the Yolo Bypass. The effort would expand Fremont Weir to the east into the Elkhorn Area and set back the east Yolo Bypass levee into the Elkhorn Area. It would also consider other efforts in the central and southern bypass to expand capacity and improve habitat. Alternatives that would have key construction elements in the Elkhorn Area may be less compatible with these flood-related plans, and the alternatives would have to be re-constructed when this project moves forward. These alternatives include Alternatives 2g through 2i and 4a through 4d. Alternative 4e has a similar alignment as the flood setback and would be more compatible than the other alternatives. The remaining alternatives would not conflict with the flood efforts and may provide some opportunities for collaboration.

3.2.3.4 Efficiency

Efficiency compares costs and benefits of each alternative, with the highest ranking for alternatives that have the highest benefits relative to costs. At this point in the process, detailed cost estimates were not yet available. A preliminary cost estimate (not including the common elements) was developed for each alternative using cost estimates from other, similar projects or comparing to other alternatives. These costs have changed as the alternatives have moved forward through the design process. Cost estimates in subsequent chapters reflect a higher level of design and cost estimate accuracy. However, these preliminary cost ranges helped to compare costs and benefits of the different initial alternatives.

The cost estimates found that a key driver in the alternative cost is the amount of earthwork. Alternatives that include substantial earthwork, including Alternatives 3b and 4a through 4e, have much higher costs than the alternatives with less earthwork.

These costs were compared to the benefits of each alternative, based on an average of the factors from the effectiveness table. For Alternative 2, the small notch produces smaller benefits for fish regarding floodplain inundation but has low costs relative to the other alternatives, which results in a cost-effective alternative. Alternative 3a has poor benefits that drive the poor cost-effectiveness rating. All Alternative 4 variations have poor cost-effectiveness because the construction costs associated with the earthwork are much higher than the other alternatives. Alternative 5 has similar costs for similarly sized facilities as Alternative 2 (with some added costs for additional fish passage facilities at Fremont Weir), but the benefits are decreased because the inundated area would generally be south of the Sacramento Bypass. The Sutter Bypass options in Alternative 6 generally require more construction (including levee setbacks or channel work) than Alternative 2 and produce fewer benefits because the area inundates less frequently. Table 3-6 summarizes the results of the efficiency analysis.

Table 3-6. Efficiency Evaluation Results

Alternative	Potential Cost Range	Benefits	Cost-Effectiveness
Alt 2a, Small East Notch	$0-50 million		
Alt 2b, Medium East Notch	$50-100 million		
Alt 2c, Medium East Notch with Supplemental Flows	$50-100 million		
Alt 2d, Large East Notch	$50-100 million		
Alt 2e, Large Central Notch	$50-100 million		
Alt 2f, Medium Central Notch	$50-100 million		
Alt 2g, East of Fremont Weir	$100-150 million		
Alt 2h, Elkhorn Notch	$100-150 million		
Alt 2i, Eastern Elkhorn Notch	$100-150 million		
Alt 2j, West Notch through Oxbow	$50-100 million		
Alt 2k, West Notch along Levee	$50-100 million		
Alt 2l, West Notch with Canal Connection	$50-100 million		
Alt 2m, West Notch with KLRC Connection	$50-100 million		
Alt 3a, Westside	$50-100 million		
Alt 3b, Westside with Volitional Passage	$550-$600 million		
Alt 4a, Large Elkhorn Floodplain	Greater than $700 million		
Alt 4b, Small Elkhorn Floodplain	$600-$700 million		
Alt 4c, Large Elkhorn with Smaller Footprint	$600-$700 million		
Alt 4d, Small Elkhorn with Smaller Footprint	$600-$700 million		
Alt 4e, Yolo Bypass Expansion	$500-$600 million		
Alt 5a, Small Sacramento Weir Notch	$50-100 million		
Alt 5b, Large Sacramento Weir Notch	$50-100 million		
Alt 6a, Tisdale Weir Notch	$50-100 million		
Alt 6b, Tisdale Bypass Setback	Greater than $500 million		
Alt 6c, West Sutter Bypass Setback	Greater than $500 million		
Alt 6d, East Sutter Bypass Setback	Greater than $500 million		
Alt 6e, Sutter Bypass Habitat Shelf	Greater than $100 million		

Alternative	Potential Cost Range	Benefits	Cost-Effectiveness
Alt 6f, Gravel Pit Connection	$50-100 million		
Alt 6g, Nelson Rock Weir Modification	$50-100 million		
Alt 6h, Weir 1 Modifications	$50-100 million		

Legend

High Performance	Medium Performance	Neutral Performance or Minor Benefits	Poor Performance

3.2.4 Screening Results

The preliminary screening effort resulted in a reduced range of alternatives for further evaluation in the EIS/EIR. The No Action Alternative moved forward for additional consideration in the EIS/EIR because it is a requirement of NEPA and CEQA. For Alternative 2 (Fremont Weir Gated Notch), the Lead Agencies identified that the smaller notch (in Alternative 2a) provided good fish passage, is cost-effective, and has higher acceptability compared to the other Fremont Weir notch alternatives. The benefits from increased inundation are not as high as the other Alternative 2 variations, but this notch design would provide benefits to juvenile fish. The Lead Agencies decided to move forward with this small notch because of the fish passage effectiveness, acceptability, and efficiency. This notch configuration will be considered in the east, central, and west location.

Alternative 3a (Westside Alternative) does not provide volitional fish passage, which is a key concern when considering the effectiveness of this alternative. The Lead Agencies decided not to carry this alternative forward for additional analysis because of the poor performance related to effectiveness. Alternative 3b (Westside Alternative with Volitional Passage) included options to provide volitional fish passage, but the increased construction effort led to higher potential for environmental impacts and higher costs. Alternative 3b had only a small improvement in effectiveness but had concerns for acceptability and efficiency, so this alternative did not move forward for additional evaluation in the EIS/EIR.

The Alternative 4 variations (Elkhorn Alternatives) all involved substantial earthwork, which resulted in the increased potential for environmental effects and high costs. Additionally, this alternative resulted in acceptability concerns because it would affect land uses and some existing structures in the Elkhorn area. For these reasons, the Lead Agencies decided not to carry forward the Alternative 4 variations for additional analysis in the EIS/EIR.

Alternative 5 (Sacramento Weir Gated Notch) would inundate a smaller area than Alternative 2, which would reduce the benefits of increased inundation for fish. The costs would be similar to Alternative 2 but higher because Alternative 5 includes separate fish passage facilities at Fremont Weir to allow fish passage after Fremont Weir overtopping events. The Lead Agencies decided not to carry forward Alternative 5 for additional analysis in the EIS/EIR because of the reduced benefits and increased costs.

Alternative 6 (Sutter Bypass) generally produced fewer benefits than Alternative 2. The Sutter Bypass is inundated more frequently than the Yolo Bypass under existing conditions because the Tisdale Weir is at a lower elevation. A new gated notch in Tisdale Weir would be used less frequently, and the area available for inundation is smaller. The Lead Agencies initially recommended removing Alternatives 6a through 6f from further consideration for these reasons but continued to consider incorporating Alternatives 6g and 6h as features in other alternatives. As the alternatives formulation process progressed, however, these features added costs and environmental impacts to other alternatives without increasing fishery benefits. These elements were not incorporated in the range of alternatives considered in the EIS/EIR.

3.2.5 Value Planning

Value Planning is part of the Federal process in planning projects. The purpose of value planning is to take a big-picture look at project alternatives and see if there is a better way to achieve the greatest value. Reclamation conducted a value planning study in August 2014. The value planning effort included agency representatives, landowners, NGOs, and other stakeholders and was designed to focus on those that have not been key participants in the alternatives formulation process. The value planning team concluded that more focus should be placed on integrating flood projects with restoration efforts and recommended including water control structures to help increase inundation on the Yolo Bypass. This effort led to a closer working relationship with this stakeholder group and alternative refinement (discussed in Section 3.3).

3.3 Alternative Refinement

The Lead Agencies continued to refine the initial alternatives after the screening effort. In 2015, the State started the EcoRestore program with a goal to advance restoration of at least 30,000 acres of habitat by 2020. Several of the common elements in the alternatives have independent utility as restoration projects and were separated from this effort to be a part of the EcoRestore program. These projects include Wallace Weir improvements, modifications to existing fish passage at Fremont Weir, removal and replacement of three agricultural road crossings in the Tule Canal, and modification of Lisbon Weir. These projects are now underway as separate efforts.

Key alternative refinements were developed from working closely with the Yolo Bypass Biological Opinion Working Group. This group includes Federal, State, and local agencies, landowners, land managers, water suppliers, and NGOs. A key consideration from this group is that an earlier inundation end date (initially suggested as March 15) would reduce impacts to agricultural users and wetlands. The Lead Agencies analyzed whether this change would result in a substantive decrease in benefits to the focus fish species and found little change in benefits. The end date was changed for all alternatives to March 15. Subsequent discussion with landowners identified potential benefits from an earlier closure date of March 7, and this date was incorporated into one of the alternatives as a variation. The stakeholder group also worked to update the evaluation criteria to incorporate other evaluation factors that could characterize an alternative’s effectiveness and acceptability; these updated factors are included in Chapter 5.

The Working Group expressed interest in a broader range of alternatives, and discussions resulted in several additional alternatives:

- Smaller inundation structure with water control structures: This alternative would have a smaller flow from the Sacramento River into the Yolo Bypass (3,000 cfs) and would incorporate water control structures in the Tule Canal to slow water and increase inundation on parcels with willing landowners.

- Multiple gated notches: This alternative would include four sets of gates to maximize capture of Sacramento River water (and juvenile fish) at lower river elevations but have a lower maximum flow of 3,400 cfs. This alternative initially included an excavated floodplain within the FWWA, but this feature was later removed because of concerns about biological, wetland, and air quality impacts of construction.
- Large gated notch: The initial evaluation limited flows from the Sacramento River to a maximum of 6,000 cfs based on previous studies. The larger notch variations considered for the Fremont Weir included gate operations to limit this flow that resulted in fish passage concerns. This alternative would include a larger notch in Fremont Weir that would allow flows up to 12,000 cfs to enter the Yolo Bypass.

The Lead Agencies compared these alternatives to the evaluation factors and identified that these three alternatives would be beneficial to include in the EIS/EIR for further evaluation in addition to the three alternatives identified in the process described in Section 3.2. The details of these six alternatives are included in Chapter 4.

3.4 References

DWR (California Department of Water Resources). 2017. *Adult fish passage criteria for federally listed species within the Yolo Bypass and Sacramento River*. Technical memorandum for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project. Sacramento, California.

Petrik, K., Petrie, M., Will, A., and J. McCreary. 2012. Waterfowl Impacts of the Proposed Conservation Measure 2 for the Yolo Bypass – An effects analysis tool. Accessed on: July 19, 2017. Available at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/YBFE_Planning_Team_-_Waterfowl_Impacts_of_the_Proposed_CM_2_-Report-_7-16-12.sflb.ashx

Reclamation and DWR. 2012. Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan, Long-Term Operation of the Central Valley Project and State Water Project Biological Opinion Reasonable and Prudent Alternative Actions I.6.1 and I.7. Accessed on August 3, 2017. Available at: https://www.usbr.gov/mp/BayDeltaOffice/docs/bypass-fish-passage-implementation-plan.pdf

———. 2013. Yolo Bypass Salmonid Habitat Restoration and Fish Passage Planning and Environmental Compliance, Planning Framework Technical Memorandum.

4 Features of Alternatives

4.1 Analysis Methodology

4.1.1 Hydraulic Modeling

The evaluation of impacts on flood control, hydraulics, and hydrology considers the potential for increased frequency or severity of damaging flood flows. This section describes the models used to evaluate effects of the Project alternatives.

4.1.1.1 HEC-RAS

The one-dimensional Central Valley Floodplain Evaluation and Delineation (CVFED) Hydrologic Engineering Center River Analysis System (HEC-RAS) hydraulic model of the SRFCP was used to evaluate changes in peak water surface elevation throughout the bypass and Sacramento River.

The CVFED HEC-RAS geometry was modified to represent assumed future hydraulic features for each of the alternatives. Hydrology was scaled down from the Central Valley Hydrology Study’s 1997 storm pattern to represent a storm with a peak flow at Fremont Weir close to 343,000 cfs, the capacity of Yolo Bypass. The resulting hydrograph was routed through the HEC-RAS model to find peak water surface elevations. Resulting peak water surface elevations from the alternatives were compared against the resulting peak water surface elevations from existing geometry.

The main limitation of the CVFED HEC-RAS model is the level of detail of its geometry, particularly at low flows. Results are averaged across cross-sections and represent the floodplain in coarser spatial detail than the two-dimensional unsteady flow (TUFLOW) model, discussed in Section 4.4.1.1.2. The HEC-RAS model is calibrated to represent peak water surface elevations during flood flows and is not calibrated to represent low flows.

4.1.1.1.1 TUFLOW

TUFLOW is a two-dimensional hydrodynamic modeling engine used to simulate the hydraulics within the Yolo Bypass. The two-dimensional capabilities of the engine allow for the comparison of the spatial distribution of flow, velocity, and depth, with or without assumed future hydraulic features. The TUFLOW model extends along the Sacramento River from RM 118 to RM 12 near Rio Vista and includes the entire Yolo Bypass. Historical flows from the year 1997 to 2012 were simulated for several channel and weir configurations on a 5- to 10-second time step as a part of the alternatives evaluation.

The two-dimensional TUFLOW model is more spatially detailed than the HEC-RAS model and calibrated for low and high flows.

4.1.1.1.2 CalSim II

CalSim II is the application of the Water Resources Integrated Modeling System software to the CVP and SWP. This application was jointly developed by Reclamation and DWR for planning studies relating to CVP/SWP operations. The primary purpose of CalSim II is to evaluate the water supply reliability of the CVP and SWP at current and/or future levels of development (e.g., 2005, 2030), with and without various assumed future facilities, and with different modes of facility operations. Geographically, the model covers the drainage basin of the Delta and CVP/SWP exports to the San Francisco Bay Area, San Joaquin Valley, Central Coast, and Southern California.

CalSim II typically simulates system operations for an 82-year period using a monthly time step. The model assumes that facilities, land use, water supply contracts, and regulatory requirements are constant over this period, representing a fixed level of development (e.g., 2005, 2030). The historical flow record of October 1921 to September 2003, adjusted for the influences of land use changes and upstream flow regulation, is used to represent the possible range of water supply conditions. Major Central Valley rivers, reservoirs, and CVP/SWP facilities are represented by a network of arcs and nodes. CalSim II uses a mass balance approach to route water through this network. Simulated flows are mean flows for the month; reservoir storage volumes correspond to end-of-month storage.

CalSim II models a complex and extensive set of regulatory standards and operations criteria. The hydrologic analysis conducted used CalSim II models with 2030 and 2070 hydrology from the California Water Commission Climate Change Water Supply Improvement Project modeling to approximate system-wide changes in storage, flow, salinity, and reservoir system reoperation associated with the alternatives. Although CalSim II is the best available tool for simulating system-wide operations, the model also contains simplifying assumptions in its representation of the real system. CalSim II's predictive capability is limited and cannot be readily applied to hourly, daily, or weekly time steps for hydrologic conditions. The model, however, is useful for comparing the relative effects of alternative facilities and operations within the CVP/SWP system on a monthly time step. Reclamation's CalSim II modeling of existing conditions and the existing conditions-level of development alternatives assumes a 2030 hydrology. Future conditions in the CalSim II modeling for the No Action Alternative and future conditions-level of development alternatives assume a 2070 hydrology, including estimates of climate change and sea level rise.

4.1.2 Fish Benefits and Fish Passage Modeling

This section describes the methodologies that the Lead Agencies implemented to evaluate the potential effects of the alternatives on fish species of focused evaluation and their habitats. In addition to generally qualitative methods for assessing potential construction- and maintenance-related impacts, impact assessment methodologies relied on simulated changes in hydrology, water temperature, and fisheries habitat parameters under the alternatives relative to the basis of comparison.

4.1.2.1 YBPASS Tool and HEC-RAS Modeling

To evaluate adult fish passage improvements, DWR and Reclamation formed the interagency Yolo Bypass Fisheries and Engineering Technical Team. Using hydraulic criteria developed by the team, DWR developed the YBPASS (Yolo Bypass Passage for Adult Salmonids and Sturgeon) tool to compare HEC-RAS modeled water depths and velocities in the alternative-specific intake structures and transport channels to compare against adult salmon and sturgeon fish passage criteria.

4.1.2.2 Salmon Benefits Model

The Lead Agencies used simulated daily flows overtopping Fremont Weir and flows through the proposed notches as well as modeled depths and velocities in Yolo Bypass and Sacramento River from TUFLOW as inputs to the Salmon Benefits Model (SBM). The SBM tracks key Chinook salmon life history stages from freshwater emigration in the lower Sacramento River (just upstream of Yolo Bypass) to numbers of returning adults. Specifically, the SBM quantifies effects of changes in flows entering Yolo Bypass on the size distribution of juvenile Chinook salmon emigrating to the ocean and on abundance of returning adults for each year of the simulation period (Hinkelman et al. 2017). The SBM accounts for the timing and duration of inundation of Yolo Bypass as well as modeled depths and velocities with respect to juvenile Chinook salmon habitat suitability criteria. The SBM uses data and assumptions to determine the proportion and abundance of juveniles entrained into the bypass, timing and duration of juvenile rearing, timing and duration of emigration through the bypass, amount of accessible suitable habitat, and growth and survival of juveniles on a daily basis during October through May for each year of the 15-year simulation period (1997 through 2011).

4.1.3 Agricultural Impact Modeling

This analysis used information estimated from multiple models to determine land use impacts resulting from the implementation of the Project alternatives. Models that contributed to this analysis include:

- **TUFLOW –** Used to assess hydraulic impacts, including inundation periods and affected acreages and agricultural impacts, in the Yolo Bypass and surrounding areas. TUFLOW facilitates a comparison of depth, duration, and frequency of flooding between existing and proposed conditions.
- **DAYCENT Model –** Used to estimate crop yields on a subset of fields throughout the Yolo Bypass. The DAYCENT model estimates the yield on any given field considering all production conditions, including climate and date the crop was planted. The model was calibrated against data for corn, rice, safflower, sunflower, processing tomato, alfalfa, and mixed melons.
- **Bypass Production Model (BPM) –** Used to model agriculture in the Yolo Bypass. The BPM relates changes in crop yield and total affected acres to changes in agricultural production and revenues. The BPM incorporates data from TUFLOW as inputs for anticipated overtopping events and other impacts from the proposed actions. Crop yield functions estimated by the DAYCENT model are used along with additional economic data to calibrate the BPM.

- **Impact Planning and Analysis (IMPLAN) –** Used to estimate the effects on employment, labor income, and total value output directly and indirectly associated with construction and reduced crop production. IMPLAN calculates the economic impacts of a change in value of production.

4.1.4 Economic Analysis

The socioeconomic analysis estimates economic effects from construction of the proposed alternatives. The economic analysis uses IMPLAN, an input-output software and data package, which calculates the economic impacts of a change in value of production. IMPLAN is used to estimate the direct effects of construction and reduced crop production as well as the indirect and induced effects in the area of analysis. The direct effects would occur in both the construction and agricultural industries. Indirect effects are caused by expenditures in the region by affected regional industries and include purchases of inputs. Induced effects are caused by expenditure of household income.

IMPLAN estimates effects of various economic measures, including employment, labor income, and total value output. Employment is the number of jobs, including full-time, part-time, and seasonal. Labor income consists of employee compensation and proprietor's income. Value of output is the dollar value of production.

IMPLAN estimates impacts on an annual basis. If the project effects occurred over a shorter period, economic effects would be less. The 2014 IMPLAN data sets were used for this analysis.

4.2 No Action Alternative

NEPA and CEQA require the evaluation of an alternative that presents the reasonably foreseeable future conditions in the absence of the project. This alternative is called the No Action Alternative under NEPA and the No Project Alternative under CEQA. The No Action or No Project Alternative allows decision makers to compare the impacts of approving the project to the impacts of not approving the project. This alternative is referred to in the remainder of the document as the "No Action Alternative." Under NEPA, the No Action Alternative also serves as the baseline to which action alternatives are compared to determine potential impacts. This differs from CEQA wherein existing conditions serve as the baseline to determine potential impacts of the alternatives. The No Action Alternative may differ from the existing conditions if other actions that could occur in the Project area in the future do not rely on approval or implementation of the project. The No Action Alternative and the existing conditions will be used as the environmental baseline for identifying project effects.

Under the No Action Alternative, the Yolo Bypass would continue to be inundated from the westside tributaries and overtopping events at Fremont and Sacramento weirs. Juvenile fish would enter the bypass with overtopping flood flows from Fremont and Sacramento weirs, and the fish would benefit from the rearing opportunities in the Yolo Bypass. Additional flow and fish would not pass through Fremont Weir when the Sacramento River elevation is below the crest of Fremont Weir or Sacramento Weir.

Adult fish may move upstream in Tule Canal in response to tidal influence in Cache Slough, flows over Fremont Weir, or when the westside tributaries attract fish. As under existing conditions, fish would either move downstream and migrate back into the Sacramento River, pass over Fremont Weir, pass through the existing fish passage structure at Fremont Weir, become stranded at Fremont Weir, or move to the Wallace Weir Fish Rescue Facility. Other projects in the Yolo Bypass and Sacramento River region would continue to move forward, including California EcoRestore projects, Battle Creek Salmon and Steelhead Restoration project, California WaterFix, Environmental Permitting for Operation and Maintenance of flood facilities, Oroville Facilities Federal Energy Regulatory Commission Relicensing and License Implementation, and Sacramento Regional Wastewater Treatment Plant Upgrade.

4.3 Components Common to Multiple Action Alternatives

This section describes components included in multiple action alternatives. As discussed in Chapter 3, the common elements originally included modifications to Wallace Weir to reduce straying, fish passage improvements in the Fremont Weir, modification of Agricultural Road Crossings 2 and 3 in the Tule Canal, and fish passage improvements to Lisbon Weir. These elements have become separate projects and are being implemented as part of the EcoRestore Program. The common elements that remain in the action alternatives are described below.

4.3.1 Agricultural Road Crossing 1 and Cross-Canal Berms

The northernmost agricultural road crossing in Tule Canal is both a vehicular crossing and water delivery feature (see Figure 1-1 for location). The crossing consists of two earthen berms, with the southern used as the road crossing. Together, the berms create a cross canal that conveys water across the Yolo Bypass from Wallace Weir to two 36-inch culverts that pass through the Yolo Bypass east levee. The culverts deliver water via gravity flow into the Elkhorn area for agricultural use.

The cross-canal berms are flow barriers in Tule Canal and form barriers that maintain water levels in the greater Tule Pond wetland (just upstream). The wetland area north of Agricultural Road Crossing 1 and south of Tule Pond is referred to as the “wooded area” and does not have a defined channel. The top of the berm has an elevation of approximately 21 feet[3] and holds water in the wooded area and Tule Pond (see Figure 4-1) after Fremont Weir overtopping events to cover an area of about 85 acres. During the late winter and early spring, shallow groundwater levels are high enough (HDR, Inc. 2017) that they likely contribute water to the Tule Pond and wooded area. Additionally, the berms leak in some years, which provides water inflow into the wooded area (and allows some outflow when water levels are high during the wet season). The local landowners typically make periodic repairs that decrease the leakage.

[3] Elevations in the EIS/EIR are compared to the North American Vertical Datum of 1988 (NAVD 88).

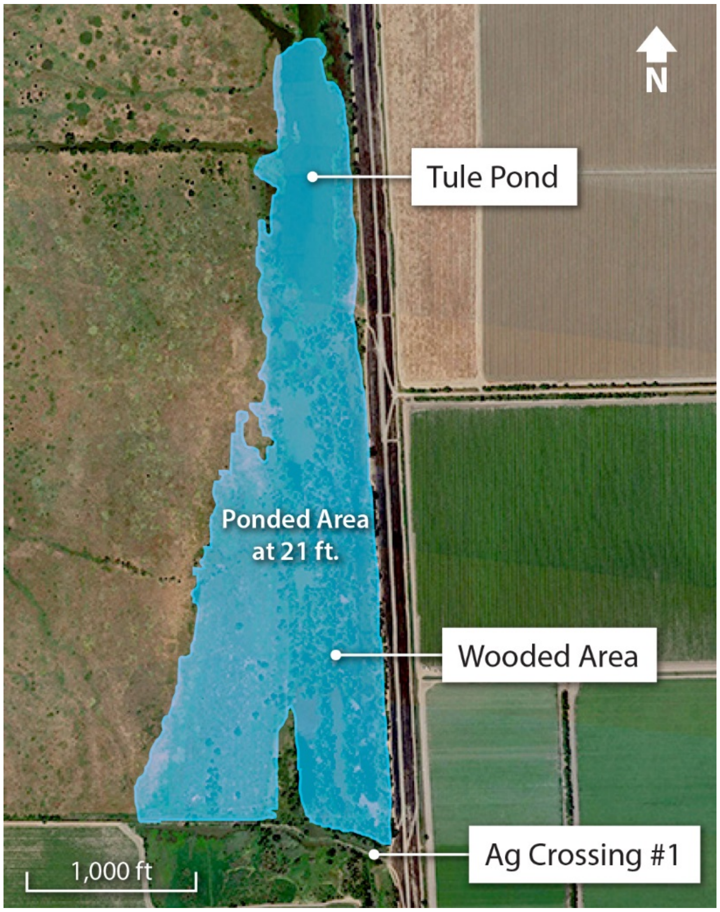


Figure 4-1. Existing Inundation Area North of Agricultural Road Crossing 1

Agricultural Road Crossing 1 improvements would include removal of the cross-canal berms and road crossing that create a fish passage barrier, construction of a bridge for vehicular traffic, and construction of an inverted siphon beneath the new Tule Canal connection to maintain water deliveries to the agricultural water users in the Elkhorn Area. Removing the barriers to fish passage would also remove a flow barrier that retains water in the Tule Pond and wooded area to the north and a source of water for these areas in the cross-canal. The bridge would be 18 feet wide and 80 feet long. It would include concrete abutments on each end to span Tule Canal. Figure 4-2 shows the proposed improvements at Agricultural Road Crossing 1. These improvements are included in all action alternatives.

The cross-canal berm would be removed and the channel regraded to connect proposed upstream channel improvements (described in Section 4.3.2) to Tule Canal. A turnout structure would be constructed on the west side of the new Tule Canal connector channel. Two 36-inch, 270-foot-long pipes would run under the new connection with Tule Canal from the turnout structure and tie into a concrete junction box on the east side of Tule Canal that would feed the supply pipes through the existing levee. An emergency overflow bypass structure would be installed immediately adjacent and northwest of the turnout structure to prevent overtopping the canal embankments into the surrounding fields during non-flood events. Overtopping the embankments could cause erosion; thus, the overflow bypass would reduce operations and maintenance needs on the canal embankments. The overflow bypass structure would discharge high flows south into the existing Tule Canal.

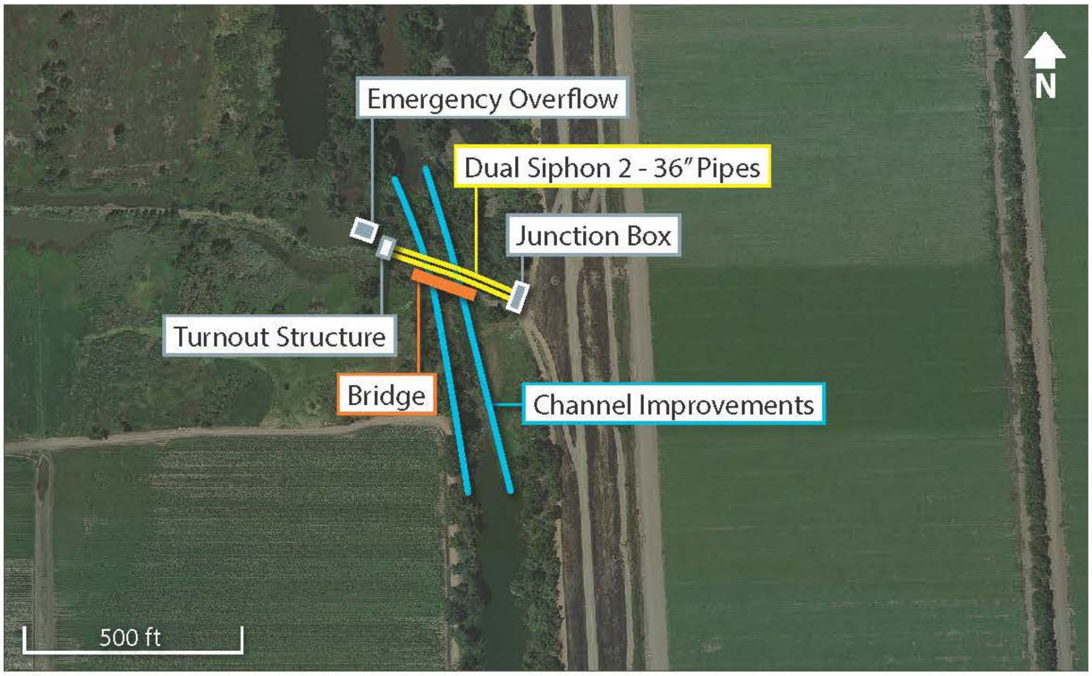


Figure 4-2. Agricultural Road Crossing 1 Improvements

4.3.2 Downstream Channel Improvements

Except for Alternative 5, all proposed alternatives include an engineered, trapezoidal channel that connects a new gated notch in Fremont Weir to Tule Pond. Alternative 5 varies from the other alternatives because it includes a multi-channel complex that connects to Tule Canal south of Tule Pond (near Agricultural Road Crossing 1); the conditions and improvements described in this section do not apply to Alternative 5.

The area just south of Tule Pond is referred to as the "wooded area" on Figure 4-1 and does not have a defined channel. Discussed as part of the Agricultural Road Crossing 1 improvements, water is often ponded in this area, allowing vegetation and tree growth. The area is often wet outside of the winter season and is dominated by tule growth.

The lack of a defined channel within the wooded area makes fish passage more difficult during periods when the entire area is not inundated. Fish do not have a clear path to move between Tule Pond and the wooded area just upstream of Agricultural Road Crossing 1.

Under Alternatives 1 through 4 and 6, improvements would be made to connect isolated pools within the wooded area that extends from the Tule Pond outlet downstream to Agricultural Road Crossing 1 where the Tule Canal begins. Improvements include a trapezoidal channel with constant slope. The improvements would facilitate upstream adult fish passage between the existing Tule Canal and Tule Pond. The engineered, trapezoidal channel would begin downstream of Agricultural Road Crossing 1 and extend north to Tule Pond. The channel would have a 20-foot-bottom width and a 3:1 side slope (horizontal to vertical). The top of channel would be 60 to 70 feet wide, with eight feet of revetment and a 12-foot wide maintenance corridor on either side.

To avoid concerns about levee seepage and stability near the channel improvements, Alternatives 1 through 4 and 6 would include a subsurface cutoff wall in the levee parallel to the channel. A subsurface cutoff wall is a structure that uses a slurry or cement mix to create a “wall” along a levee to prevent seepage under the levee or address other levee stability and seepage concerns. This cutoff wall would be included because the channel construction would cut through an existing clay blanket layer that currently prevents levee underseepage. The cutoff wall would be approximately 3,150 feet long and 30 feet deep. The location is at the toe of the levee, and the cutoff wall would be entirely underground. Figure 4-3 presents a preliminary concept for the channel improvements.

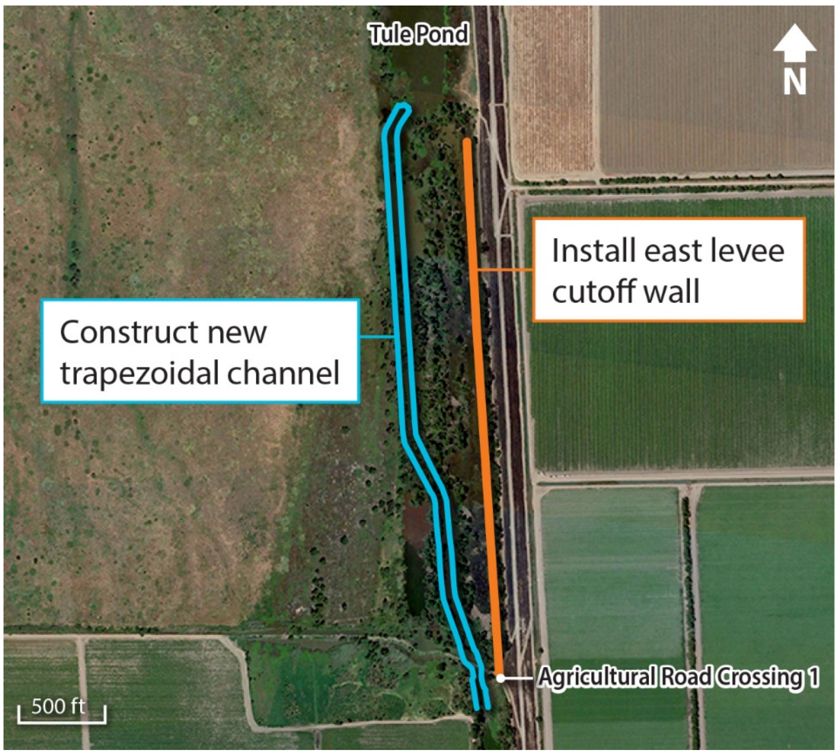


Figure 4-3. Downstream Channel Improvements

4.3.3 Operational Timeframe

All the new gated notch structures have the potential to begin operations on November 1. Juvenile salmonid out-migration typically begins during early storms in November. The gates would open as river elevations rise, which is discussed in more detail in the operations section of each alternative description.

The gated notch structures were originally planned to stay open through April to allow juveniles to enter the Yolo Bypass, but discussions with stakeholders indicated that an earlier inundation end date (originally suggested as March 15) would reduce impacts to agricultural users and wetlands. The Lead Agencies analyzed whether this change would result in a substantive decrease in benefits to the focus fish species and found little change in benefits, so the end date was changed for all alternatives to March 15. Subsequent discussion with landowners identified potential benefits from an earlier closure date of March 7, and this date was incorporated as a variation of Alternative 4.

After March 15 (or March 7 in the Alternative 4 variation), the new gated notch structure could remain partially open to provide adult fish passage until the end of May. The gated notch would only allow flows up to the available capacity in Tule Canal (typically about 300 cfs) to avoid inundating areas outside of Tule Canal. Alternative 6 would not allow operation during this period because the facilities would not provide sufficient depths and velocities for fish passage at these low flows.

4.3.4 Best Management Practices

All the alternatives incorporate typical measures to reduce impacts, typically called best management practices (BMPs). All action alternatives incorporate BMPs and have been designed to avoid and minimize impacts to the maximum extent practicable.

4.3.4.1 BMPs for Construction and Maintenance Activities to Reduce Greenhouse Gas (GHG) Emissions

The following measures are considered BMPs for DWR construction and maintenance activities. Implementation of these practices will reduce GHG emissions from construction projects by minimizing fuel usage by construction equipment, reducing fuel consumption for transportation of construction materials, reducing the amount of landfill material, and reducing emissions from the production of cement.

4.3.4.1.1 Pre-Construction and Final Design BMPs

Pre-construction and final design BMPs are designed to ensure that individual projects are evaluated and their unique characteristics taken into consideration when determining if specific equipment, procedures, or material requirements are feasible and efficacious for reducing GHG emissions from the project. While all projects will be evaluated to determine if these BMPs are applicable, not all projects will implement all the BMPs listed below.

- BMP 1. Evaluate project characteristics, including location, project work flow, site conditions, and equipment performance requirements, to determine whether specifications of the use of equipment with repowered engines, electric drive trains, or other high efficiency technologies are appropriate and feasible for the project or specific elements of the project.
- BMP 2. Evaluate the feasibility and efficacy of performing onsite material hauling with trucks equipped with on-road engines.
- BMP 3. Ensure that all feasible avenues have been explored for providing an electrical service drop to the construction site for temporary construction power. When generators must be used, use alternative fuels, such as propane or solar, to power generators to the maximum extent feasible.
- BMP 4. Evaluate the feasibility and efficacy of producing concrete on site and specify that batch plants be set up on site or as close to the site as possible.

- BMP 5. Evaluate the performance requirements for concrete used on the project and specify concrete mix designs that minimize GHG emissions from cement production and curing while preserving all required performance characteristics.
- BMP 6. Limit deliveries of materials and equipment to the site to off peak traffic congestion hours.

4.3.4.1.2 Construction BMPs

Construction BMPs apply to all construction and maintenance projects that DWR completes or for which DWR issues contracts. All projects are expected to implement all construction BMPs unless a variance is granted by the Division of Engineering Chief, Division of Operation and Maintenance Chief, or Division of Flood Management Chief (as applicable) and the variance is approved by the DWR CEQA Climate Change Committee. Variances will be granted when specific project conditions or characteristics make implementation of the BMP infeasible and where omitting the BMP will not be detrimental to the project's consistency with the GHG Emissions Reduction Plan.

- BMP 7. Minimize idling time by requiring that equipment be shut down after five minutes when not in use (as required by the State airborne toxics control measure 13 CCR 2485). Provide clear signage that posts this requirement for workers at the entrances to the site and provide a plan for the enforcement of this requirement.
- BMP 8. Maintain all construction equipment in proper working condition and perform all preventative maintenance. Required maintenance includes compliance with all manufacturer's recommendations, proper upkeep and replacement of filters and mufflers, and maintenance of all engine and emissions systems in proper operating condition. Maintenance schedules shall be detailed in an Air Quality Control Plan prior to commencement of construction.
- BMP 9. Implement a tire inflation program on the jobsite to ensure that equipment tires are correctly inflated. Check tire inflation when equipment arrives on site and every two weeks for equipment that remains on site. Check vehicles used for hauling materials off site weekly for correct tire inflation. Procedures for the tire inflation program shall be documented in an Air Quality Management Plan prior to commencement of construction.
- BMP 10. Develop a project-specific ride share program to encourage carpools, shuttle vans, transit passes, and/or secure bicycle parking for construction worker commutes.
- BMP 11. Reduce electricity use in temporary construction offices by using high efficiency lighting and requiring that heating and cooling units be Energy Star compliant. Require that all contractors develop and implement procedures for turning off computers, lights, air conditioners, heaters, and other equipment each day at close of business.

- BMP 12. For deliveries to project sites where the haul distance exceeds 100 miles and a heavy-duty class 7 or class 8 semi-truck or 53-foot or longer box type trailer is used for hauling, a SmartWay[4] certified truck will be used to the maximum extent feasible.
- BMP 13. Minimize the amount of cement in concrete by specifying higher levels of cementitious material alternatives, larger aggregate, longer final set times, or lower maximum strength where appropriate.
- BMP 14. Develop a project-specific construction debris recycling and diversion program to achieve a documented 50 percent diversion of construction waste.
- BMP 15. Evaluate the feasibility of restricting all material hauling on public roadways to off-peak traffic congestion hours. During construction scheduling and execution, minimize, to the extent possible, uses of public roadways that would increase traffic congestion.

4.3.4.2 Air Quality BMPs

Fugitive dust control measures required by the Sacramento Metropolitan Air Quality Management District (AQMD) will be implemented as environmental commitments for all alternatives. The BMPs required by the Sacramento Metropolitan AQMD (2016) to allow non-zero particulate matter significance thresholds are as follows:

1. Water all exposed surfaces two times daily. Exposed surfaces include but are not limited to soil piles, graded areas, unpaved parking areas, staging areas, and access roads.
2. Cover or maintain at least two feet of freeboard space on haul trucks transporting soil, sand, or other loose material on the site. Any haul trucks that would be traveling along freeways or major roadways should be covered.
3. Use wet power vacuum street sweepers to remove any visible track out mud or dirt onto adjacent public roads at least once a day. Use of dry power sweeping is prohibited.
4. Limit vehicle speeds on unpaved roads to 15 miles per hour.
5. All roadways, driveways, sidewalks, and parking lots to be paved should be completed as soon as possible. In addition, building pads should be laid as soon as possible after grading unless seeding or soil binders are used.
6. Minimize idling time either by shutting equipment off when not in use or reducing the time of idling to five minutes [required by CCR, Title 13, sections 2449(d)(3) and 2485]. Provide clear signage that posts this requirement for workers at the entrances to the site.
7. Maintain all construction equipment in proper working condition according to manufacturer’s specifications. The equipment must be checked by a certified mechanic and determined to be running in proper condition before it is operated.

[4] The USEPA has developed the SmartWay truck and trailer certification program to set voluntary standards for trucks and trailers that exhibit the highest fuel efficiency and emissions reductions. These tractors and trailers are outfitted at point of sale or retrofitted with equipment that significantly reduces fuel use and emissions, including idle reduction technologies, improved aerodynamics, automatic tire inflation services, advanced lubricants, advanced powertrain technologies, and low rolling resistance tires.

4.4 Alternative 1: East Side Gated Notch

Alternative 1, East Side Gated Notch, would allow increased flow from the Sacramento River to enter the Yolo Bypass through a gated notch on the east side of Fremont Weir. The gated notch would create an opening in Fremont Weir that is deeper than Fremont Weir, with gates to control water going through the facility into the Yolo Bypass. The invert of the new notch would be at an elevation of 14 feet, which is approximately 18 feet below the existing Fremont Weir crest. Water would be able to flow through the notch during periods when the river elevations are not high enough to go over the crest of Fremont Weir (at an elevation of 32 feet). The water through the gated notch would not be pumped but would flow through when the elevation in the Sacramento River is higher than the Tule Canal.

Alternative 1 would connect the new gated notch to Tule Pond with a channel that parallels the existing east levee of the Yolo Bypass. Alternative 1 would have the shortest and most direct access to the Tule Canal for migrating fish. Alternative 1 would allow flows up to 6,000 cfs, depending on Sacramento River elevation, through the gated notch to provide open channel flow for adult fish passage, juvenile emigration, and floodplain inundation. This alternative would include a supplemental fish passage facility on the west side of Fremont Weir and improvements to allow fish to pass through Agricultural Road Crossing 1 and the channel north of Agricultural Road Crossing 1, as described in Section 4.3. Figure 4-4 shows key components of the alternative and the common elements described in Section 4.3.

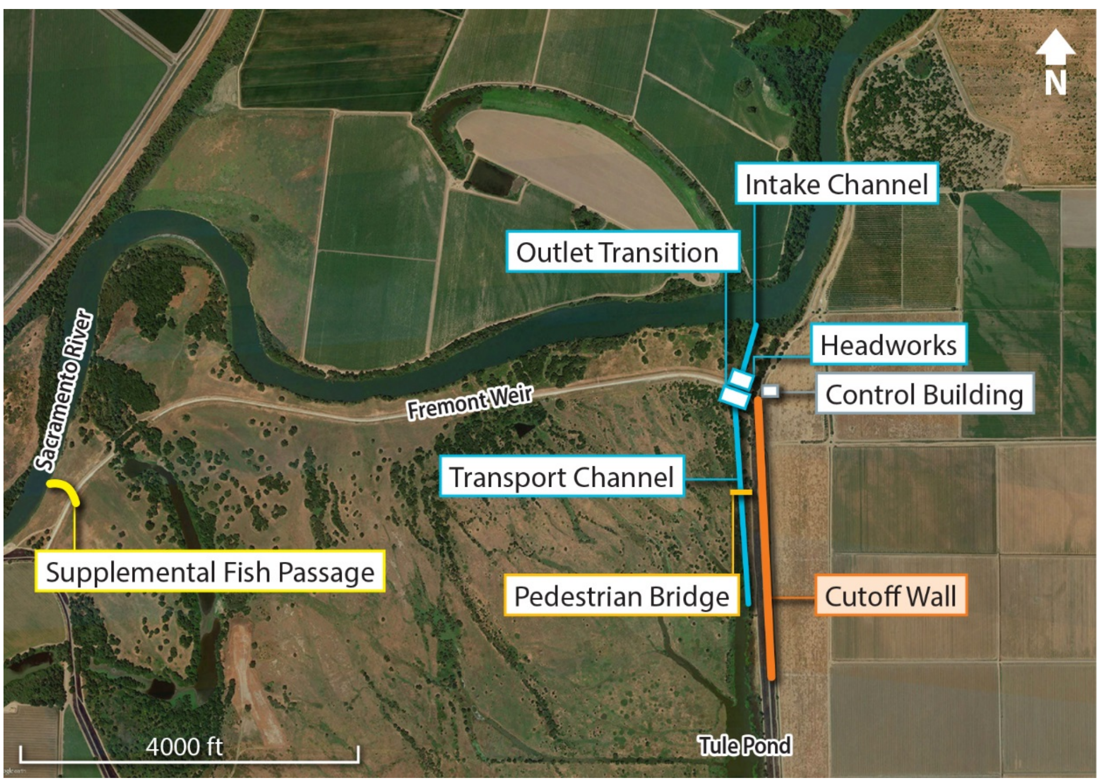


Figure 4-4. Alternative 1 Key Components

The next section includes descriptions of the facilities, construction methods, operations, required maintenance, and environmental commitments associated with this alternative. More detailed construction information is included in Appendix B of the EIS/EIR, *Constructability and Construction Considerations.*

4.4.1 Facilities

4.4.1.1 Intake Channel

The primary purpose of the intake channel is to draw juvenile salmonids and floodplain inundation flows from the Sacramento River to the new headworks structure (described in Section 4.4.1.2) and provide upstream adult fish passage between the headworks structure and the Sacramento River. The intake channel would be constructed with a 98-foot-bottom width with 3:1 side slopes (horizontal to vertical). It would have a gentle slope away from Fremont Weir so that flows would drain toward the river. It would reach the river with an invert elevation of 12 feet (compared to the invert of 14 feet at Fremont Weir). At the downstream end of the intake channel (near the headworks at Fremont Weir), there would be a short transition from the trapezoidal intake channel to the rectangular sides of the headworks structure. To avoid scour, the channel would be lined with angular rock placed along the bank slopes and rounded rock placed along the channel bottom.

4.4.1.2 Headworks Structure

The headworks structure would control the diversion of flow from the Sacramento River to the Yolo Bypass. It would serve as the primary upstream fish passage facility for adult fish and the primary facility for conveying floodplain inundation flows and juvenile salmonids onto the Yolo Bypass.

The headworks structure would be a three-bay, pile-supported, reinforced concrete structure that would bisect the existing Fremont Weir at an eastern location. It was designed to convey 6,000 cfs at a river elevation of 28 feet (14 feet of water depth in the headworks structure) with all gates fully open to meet the applicable requirements for fish passage and flood control. It would house three operating control gates and include a concrete control structure, an upstream vehicular bridge crossing, and a concrete channel transition, which would transition the rectangular sides of the control structure to the side channel slopes of the outlet channel. It would have a sheet pile cutoff wall on the river side of the structure under the gates and on both sides of the structure to prevent underseepage from the river. The gate structure would be 65 feet (upstream to downstream) by 108 feet, and the sheet piles would add 50 feet on either side of the gate structure.

Stoplogs would be provided at each of the three headworks bays upstream of the control structure to dewater the gates for maintenance and as a backup closure for the structure. Six stoplogs are required for the larger gate and four for the two smaller gates. Installation of the stoplogs would require a mobile crane capable of lifting approximately 10,000 pounds. Stoplogs would be stored off site and could only be installed or removed when there would be no flow through the headworks structure or when the gates are closed. The stoplogs would be used to prevent groundwater or small amounts of river flow from entering the structure during maintenance activities.

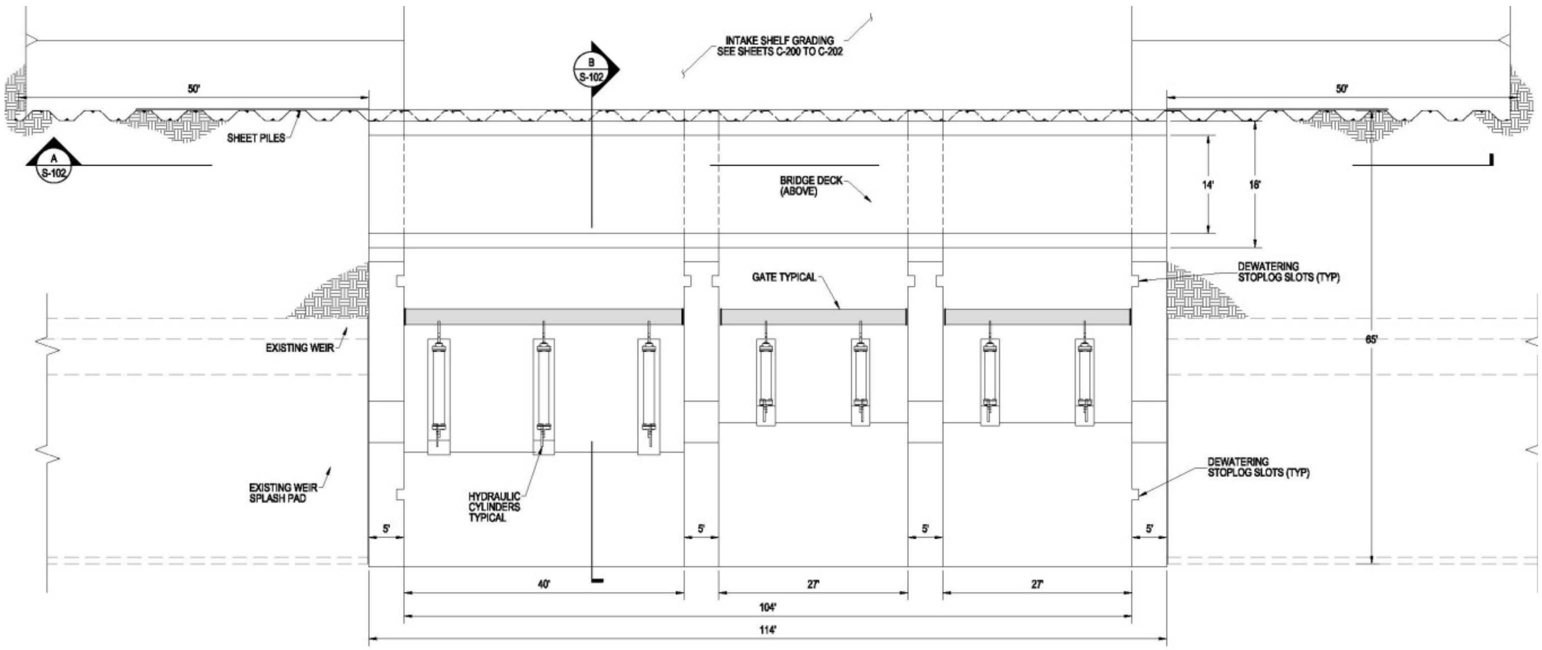
Three hydraulically or pneumatically operated, flush-mounted bottom hinge gates would be used in the headworks structure. These gates would be able to operate under variable river elevations and overtopping events. The top of the gate elevation of 32 feet would be flush with the existing Fremont Weir crest. The upstream face of the control gates would be approximately in-line with the upstream face of the existing Fremont Weir. When fully open, the gates would be flush with the channel invert. Table 4-1 presents the dimensions, invert elevation, and expected weight of the gates to be installed under Alternative 1.

Table 4-1. Gate Specifications for Alternative 1

Gate	Height x Width (feet)	Invert Elevation (feet)	Expected weight (pounds)
1	18 x 34	14.0	65,000
2 and 3	14 x 27	18.0	40,000 each

The gates would open to allow a maximum flow of 6,000 cfs when the water surface elevation in the river reaches 28 feet. Each gate would be capable of independent operation via submersible hydraulic cylinders or inflatable reinforced bladders located beneath the gate. Mechanical and electrical control components for each gate would be housed in a control building outside of the bypass on the eastern levee. Figure 4-5 and Figure 4-6 show the headworks structure design.

View from top of structure looking down



Cross-section (viewing from bypass side of Fremont Weir)

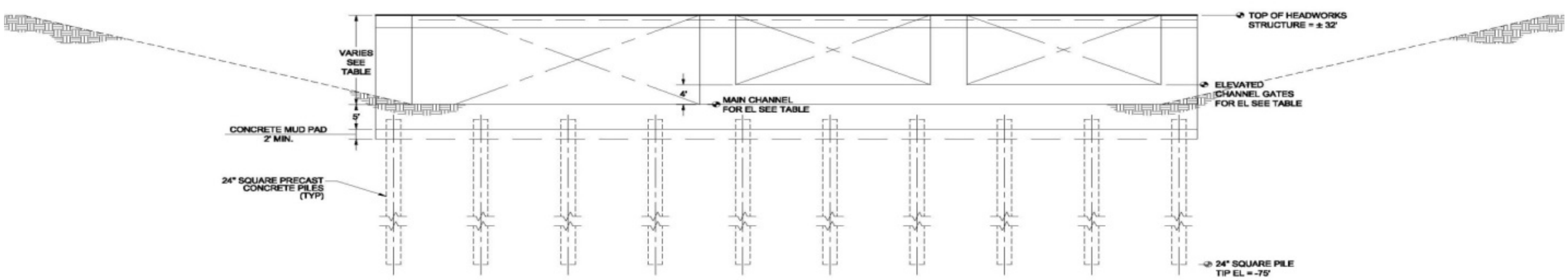


Figure 4-5. Alternative 1 Headworks Cross-Section and Top Views

View from side of structure

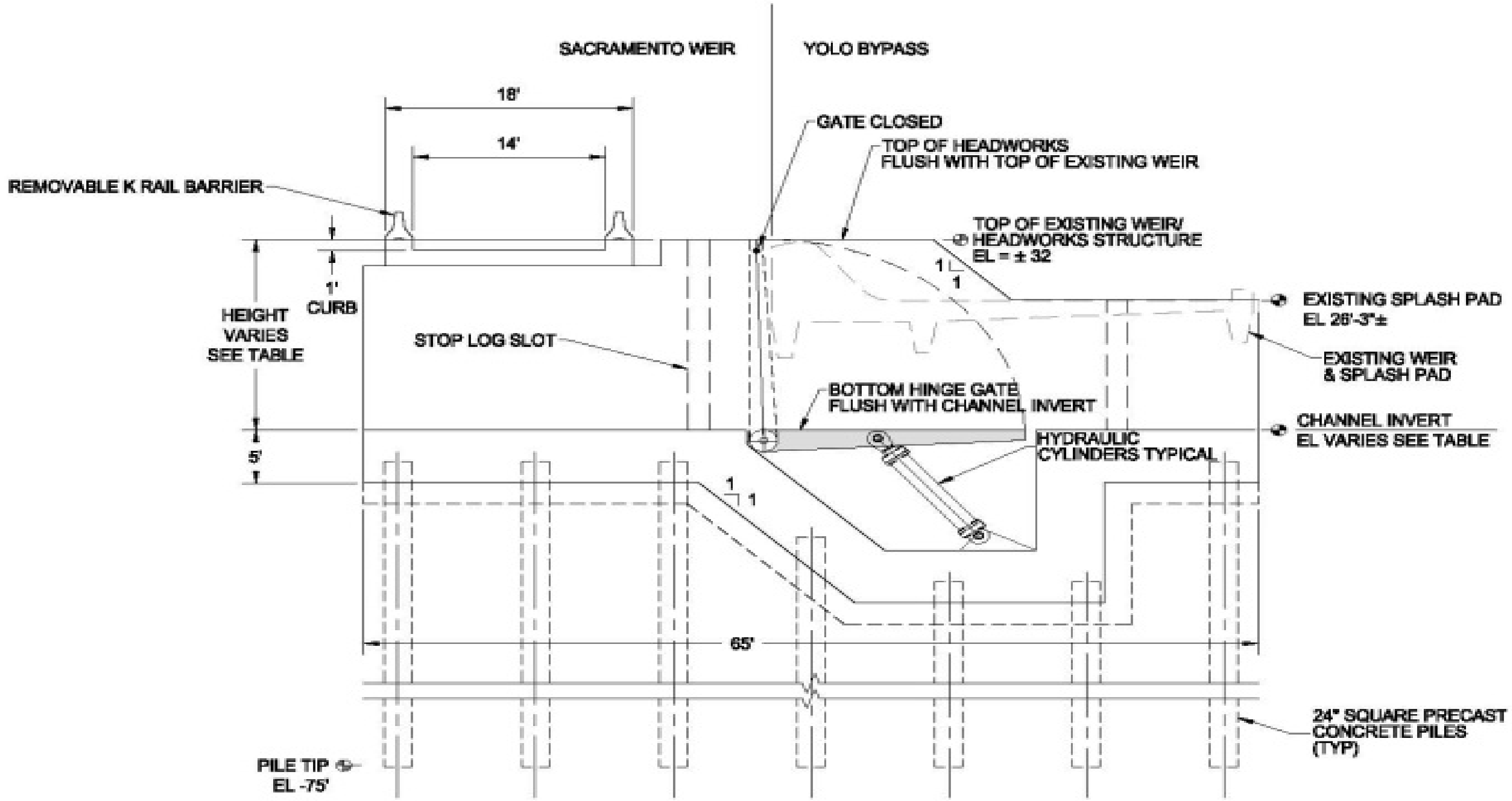


Figure 4-6. Alternative 1 Headworks Side View

Debris is expected within the Sacramento River, and debris accumulation could affect hydraulic performance or fish passage. Debris fins would be installed between gates of the headworks structure (on the river side) to redirect debris to pass through or over the gates rather than become stuck on the gate walls or facilities. Figure 4-7 shows an example of debris fins.

Figure 4-7. Debris Fins Incorporated at Headworks Structure (Example)

4.4.1.3 Control Building

The control building would be a single-story, 18- by 18-foot concrete masonry unit. The building would be located on the eastern levee. It would house, among other equipment, a programmable logic controller (PLC) for the gates, three hydraulic power units, and a motor control center. The electrical service required would be three- phase at approximately 100 amperes (A) and 480 volts alternating current (VAC) (80 kilovolt-amps [kVA]). There would be no backup or standby emergency generator; however, the units would include connections for a portable generator. Active ventilation would be required during the operation of the equipment and would be achieved by installing a roof-mounted fan that vents to the outside of the structure.

4.4.1.4 Access Structures

A reinforced concrete, three-span vehicular headworks bridge would be on the upstream side of Fremont Weir to connect to the existing access road. The bridge would span the channels through the new headworks structure. The bridge would be built at nearly the same alignment and elevation as the existing upstream maintenance road and would allow for continued patrolling and maintenance access along the weir. The bridge would have a roadway width of 14 feet and an overall width of 18 feet. Top curb elevation would be equal to the top of the weir elevation.

Temporary barrier rails (“K rails”) would be installed and removed such that no part of the bridge extends above the top of the weir during an overtopping event.

Table 4-2 presents the bridge span corresponding to each control gate.

Table 4-2. Bridge Span Specifications for Alternative 1

Gate	Bridge Span (feet)
1	34
2 and 3	27

The headworks bridge would provide a vehicular and pedestrian crossing on the north side of Fremont Weir. However, when water begins to flow through the new notch in Fremont Weir, the channels south of the weir would fill and create a barrier. If recreational users are in the FWWA, they may not be able to cross the channel back to where they accessed the area. For this purpose, Alternative 1 includes a 130-foot-long, eight-foot-wide steel-trussed pedestrian bridge just south of Fremont Weir (and north of Tule Pond), as shown on Figure 4-4.

4.4.1.5 Outlet Transition

The outlet transition would be a 100-foot-long reinforced concrete channel that provides gradual hydraulic transition from the headworks into the graded transport channel. The width varies from 108 feet at the headworks to 196 feet at the transport channel. The cross-section of the headworks includes three rectangular gates (one large gate with an invert elevation of 14 feet and two small gates with an invert elevation of 18 feet, shown on Figure 4-5). The outlet transition would be a structure that transitions from the headworks gates to the trapezoidal downstream transport channel. The transition would be accomplished with reinforced retaining walls that flair out from the headworks abutment piers and a reinforced concrete slab-on-grade bottom, which would gradually transition into the slopes of the trapezoidal transport channel. The outlet transition would have a gentle slope consistent with the downstream transport channel.

4.4.1.6 Transport Channel

The transport (outlet) channel would be a graded trapezoidal channel with an interior inline bench. Figure 4-8 shows the transport channels for Alternatives 1 (east), 2 (central), and 3 and 4 (west). The interior bench would help maintain acceptable velocities for fish passage at higher river elevations. The transport channel would serve as the primary facility for upstream adult fish passage between the existing Tule Pond and the headworks structure. It also would serve as the primary channel for conveying juvenile salmonids and rearing habitat flows from the headworks structure to the existing Tule Pond.

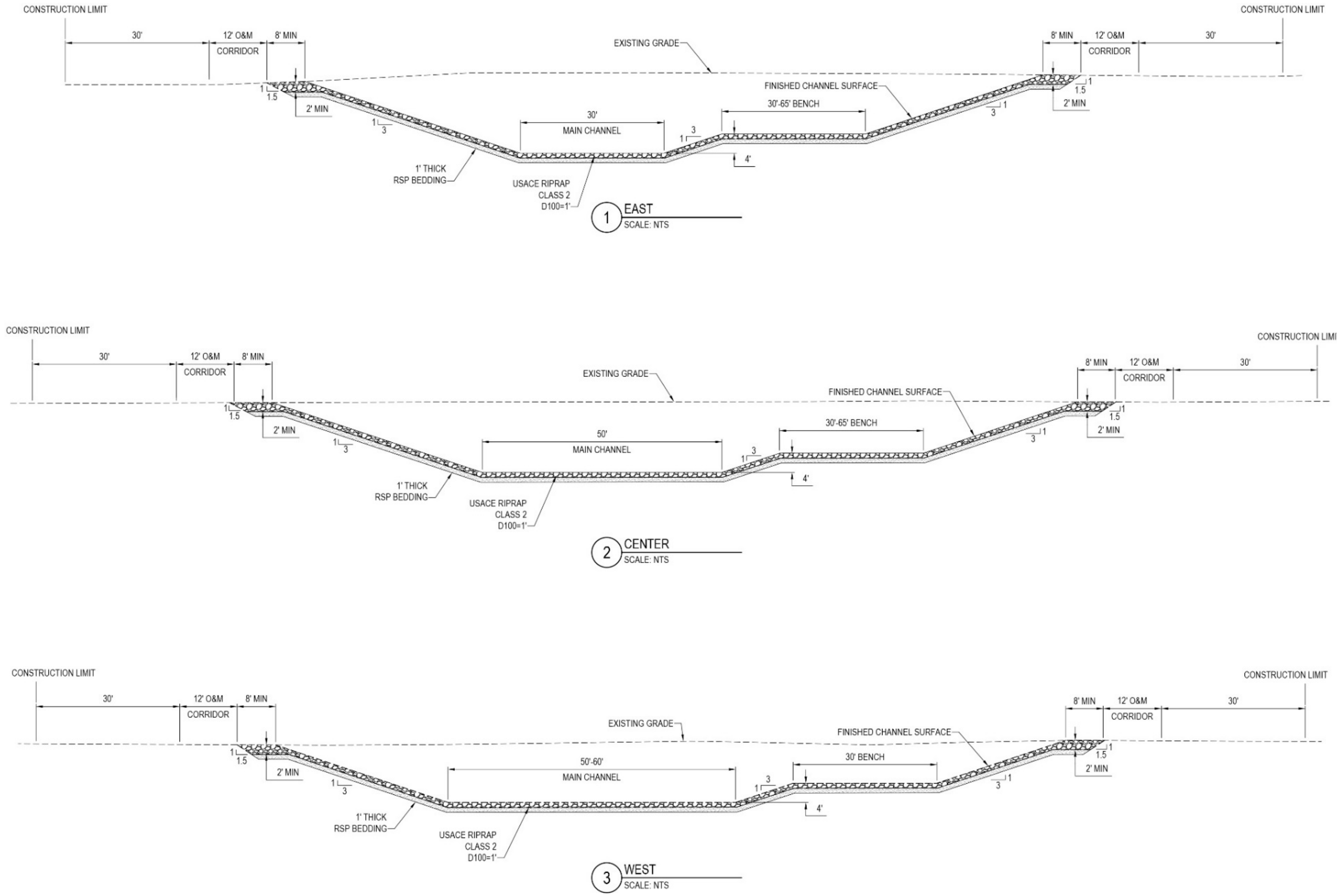


Figure 4-8. Transport Channel Cross-Section

The main channel within the trapezoidal channel would have a bottom width of 30 feet. The bench would be on the east side of the channel and elevated four feet above the main channel. The bench width would vary between 30 and 65 feet. The trapezoidal channel would have 3:1 side slopes (horizontal to vertical). The top of the channel would be approximately 150 feet wide. The channel would be about 2,650 feet long with a gradual downward slope toward Tule Pond (a slope of 0.00075). The entire channel would be lined with rounded rock revetment on the channel bottom and angular rock on the bank slopes. It would be designed to convey up to 6,000 cfs at a river elevation of 28 feet while maintaining velocities that permit fish passage. At the top of each side of the channel, an eight-foot-wide area with rock (a “rock key”) would be added to reduce the potential for the channel to head cut the channel banks. The facility also would have a 12-foot-wide maintenance corridor at the top of each side of the channel.

4.4.1.7 Seepage Measures

The transport channel for the new gated notch would be immediately adjacent to the east levee of the Yolo Bypass and would cut through the clay blanket layer at the toe of the levee, which raises concerns about increased levee underseepage. Levee underseepage could cause levee stability concerns. To reduce seepage, a cutoff wall would be constructed at the levee toe from Fremont Weir to the central part of Tule Pond. The cutoff wall would be approximately 2,850 feet long and 30 feet deep, and the wall would be completely underground.

4.4.1.8 Supplemental Fish Passage Facility

The proposed gated notch in Fremont Weir would serve as the primary fish passage facility in Alternative 1. Another project in the Yolo Bypass, the Fremont Weir Adult Fish Passage Modification Project, is constructing an improved fish passage facility at the location of the existing, smaller fish ladder (near the middle of Fremont Weir on the eastern side of Rattlesnake Island) to provide fish passage immediately after an overtopping event. These two facilities would improve fish passage from the Yolo Bypass into the Sacramento River; the proposed gated notch would provide the main passage route, and the improved fish passage structure would pass additional fish on the eastern side of Fremont Weir after overtopping events. However, after an overtopping event, fish on the western side of Fremont Weir would not be able to pass over to the eastern side to access these two fish passage facilities because Rattlesnake Island prevents movement.

An additional fish passage facility would be constructed at a western location along the existing Fremont Weir (Figure 4-9). This facility would provide another opportunity for adult fish to travel from the Yolo Bypass into the Sacramento River. This structure would allow fish that are trapped in the stilling basin (on the bypass side of Fremont Weir) to move back into the Sacramento River after an overtopping event. The facility would have a gentle slope away from Fremont Weir so that flows would drain toward the river. It would reach the river with an invert elevation at 20 feet (compared to the invert of 22 feet at Fremont Weir). The supplemental fish passage channel would have 10-foot-bottom width and 3:1 side slopes, stretch over 350 feet measured from Fremont Weir to Sacramento River, and connect to the fish passage facility through a channel transition. The transition would be 10 feet long and connect the 10-foot wide channel to the 15-foot width of the fish passage structure. The concrete fish passage structure would have an elevation of 22 feet at Fremont Weir and house an approximately 15-foot-wide hinge gate, recessed air bladder, and metal grate. Sheet piles would be installed north of Fremont

Weir to prevent underseepage. When open, the gate would allow less than approximately 1,000 cfs to enter the Yolo Bypass. At an elevation of 32 feet, the concrete wall of the fish passage structure would be flush with the top of the existing weir. The structure would have a 16-foot-wide traffic-rated deck to allow vehicular passage.

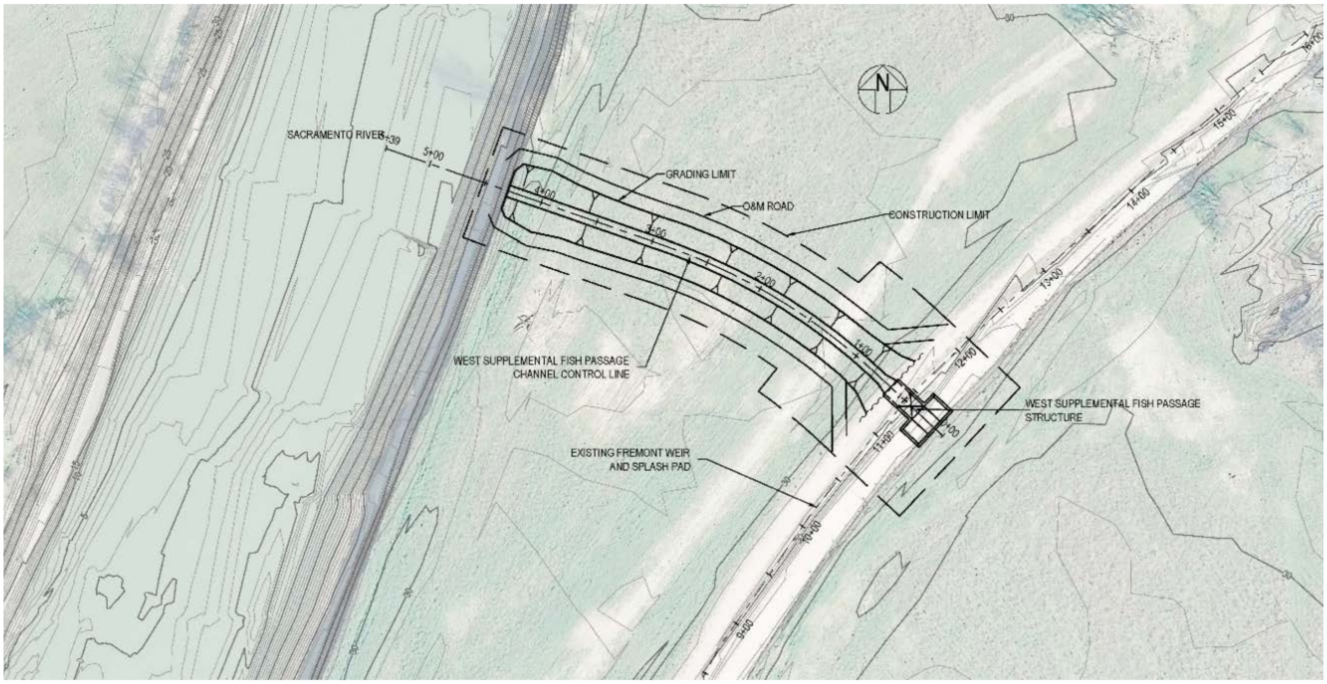


Figure 4-9. Alignment of the Western Supplemental Fish Passage Facility

4.4.2 Construction Methods

Construction of the components of Alternative 1 would begin with the demolition of a portion of the existing concrete Fremont Weir. This step would be completed in about one week. The limits for the weir demolition would extend a minimum of five feet beyond both sides of the headworks footprint to allow for excavation down to an elevation of seven feet and installation of a temporary sheet pile cofferdam.

Construction of the headworks structure, intake channel, and outlet channel would occur concurrently. It would take approximately 25 weeks to construct the headworks structure. Installation and testing of the gates and mechanical equipment would take an additional three to five weeks.

Grading of the transport channel would begin at the downstream outlet (at the northern end of Tule Pond) and progress upstream toward the headworks structure, with grading of the intake channel occurring last. This order would avoid potential interruptions to the headworks construction and allow construction to occur in the less saturated soil first as groundwater levels decrease with increasing distance from the Sacramento River. Groundwater levels are anticipated to be high, especially in the spring months, so dewatering efforts likely would be required to construct the headworks structure, especially where the intake channel meets the Sacramento River. About 60 to 80 percent of the channel excavation could be performed in dry unsaturated soil conditions by scrapers and bulldozers. The remaining portion would be performed in wet, saturated soil conditions by hydraulic excavators and haul trucks.

4.4.2.1 Excavated Material

Alternative 1 would require excavation of the intake channel, transport channel, and downstream facilities. Table 4-3 shows the estimated quantities of excess excavated material that would be generated from each facility and would require removal from the construction area. Depending on the type of material excavated, a portion of the material could be re-used within the project area or for other nearby projects.

Table 4-3. Estimated Excess Excavated Material Quantities for Alternative 1

Component	Estimated Excess Excavated Material (cubic yards)
East Intake Channel	64,150
East Transport Channel	116,600
Headworks	6,150
Downstream Channel	72,520
Supplemental Fish Passage (West)	3,230
Agricultural Road Crossing 1	3,170
TOTAL	*265,820*

Reclamation or DWR would purchase land within two miles of the edge of the Yolo Bypass to receive this excess material. Alternative 1 would require seven to eight acres of land to spoil excess construction-related material. This spoil site would be used for excess excavated soil and green waste. Other construction waste would be hauled to a landfill.

4.4.2.2 Construction Materials

Material imported to the Project site would be obtained from existing permitted commercial sources located within approximately 65 miles of the Project site. The haul routes for these materials would be along public streets, including I-5; State Route 99; and CRs 105, 16, 116A, and 117. Table 4-4 provides potential locations and haul routes for offsite import of materials. The exact source of the materials would be determined by the construction contractor, but these potential sources provide reasonable estimates for distances and haul routes.

Table 4-4. Construction Material Quantities, Sources, and Haul Routes

Material	Quantity	Potential Location	Haul Route	Distance
Aggregate base for road maintenance		Teichert Aggregates	Interstate 5; County Roads 16, 117, and 17; Old River Road	26 miles
Riprap material	66,860 tons	Parks Bar Quarry	County Roads 16 and 117, Old River Road, Interstate 5, State Route 99	66 miles

Material	Quantity	Potential Location	Haul Route	Distance
Rock slope protection bedding	68,618 tons	Parks Bar Quarry	County Roads 16 and 117, Old River Road, Interstate 5, State Route 99	66 miles
Equipment		Construction Contractor Office (likely access from Interstate 5)	County Roads 16 and 117, Old River Road, Interstate 5, Elkhorn Boulevard	20 miles (estimate, varies depending on contractor)

4.4.2.3 Staging Areas and Access

The construction easements for Alternative 1 would encompass staging areas for equipment, mobilization, and spoiling sites. The construction footprints analyzed in this EIS/EIR include space for staging areas. After construction, staging areas would be returned to pre-construction condition. Construction sites would be accessed using I-5 to CR 117 (paved rural road), north to CR 16 (paved and dirt road), west to the Yolo Bypass east levee, and then north on the east levee crown road to access the site. The use of CR 16 for equipment and offsite haul would substantially degrade the quality of the road and require re-grading and gravelling (and potentially repaving) to restore it to pre-project conditions. In addition, portions of the existing levee crown roads would be used for hauling. The levee crown consists of only aggregate surfacing in marginal conditions. It is anticipated that use of the levee crown for hauling would trigger the need to resurface the levee crown to pre-project conditions with six inches of aggregate base material.

The county roads and levee crown roads utilized for site access and haul would be inspected periodically during construction operations. As areas of damage are identified, they would be temporarily repaired to accommodate ongoing operations. At the completion of project construction, all roads that have been temporarily repaired would be repaved as specified by the governing local, county, or State standards.

4.4.2.4 Construction Equipment

A list of the major equipment needs for the construction of both the alternative-specific and common downstream channel improvement actions is provided in Table 4-5. Equipment specifics may vary based on the contractor’s capabilities and the availability of equipment. Appendix B of the EIS/EIR, *Constructability and Construction Considerations,* includes information on how many of each type of equipment would be used.

Table 4-5. List of Major Equipment Needed for Construction of Alternative 1

List of Major Equipment	
• 0.8-CY backhoe loaders • 1.5-CY front end loader crawler • 10-TN smooth roller • 100-TN off highway trucks • 100-foot auger track-mounted drill rig • 12-foot blade grader • 165-HP dozer • 2.5-CY hydraulic excavator • 2.5-inch diameter concrete vibrator • 24-TN truck end dump • 3.5-CY hydraulic excavator • 3-axle haul trucks • 30-CY scrapers • 300-kW generator	• 4.5-CY hydraulic excavator • 40-TN truck-mounted hydraulic crane • 4,000-gallon water truck • 450-HP dozer crawler • 6-inch diameter pump engine drive • 75-TN crane crawler pile hammer • Concrete mixer truck • Concrete pump boom, truck-mounted • Extended boom pallet loader • Flatbed truck • Haul truck oversize transport • Hydroseeding truck • Pickup trucks, conventional

Key: CY = cubic yards; HP = horsepower; kW = kilowatt; TN = ton

4.4.2.5 Construction Schedule and Workers

Alternative 1 construction likely would begin in late 2020 or early 2021 and is estimated to last 28 weeks. All project components are expected to be completed in one construction season during times that are outside the flood period (construction from April 15 through November 1). The headworks structure would have the longest construction duration and would start at the beginning of the construction period. Construction of channel improvements would commence the same week as the headworks structure construction activities.

Construction would occur six days per week, 10 hours per day between 7 a.m. and 6 p.m. Construction workers would be divided into multiple crews and would work one shift per day. Maintenance and equipment upkeep crews would work on equipment at night when it is not in use. The peak number of construction workers, which would be needed for one week in July, is estimated to be 202.

4.4.3 Operations

The goal of Alternative 1 operations is to maximize the number of out-migrating juvenile winter-run Chinook salmon that enter the Yolo Bypass. Downstream out-migration is triggered during the first wet season event. Gate operations could begin each year on November 1 and would first open based on river conditions. All gates would be opened when the river elevation reaches 15 feet, which is one foot above the lowest gate invert. At this river elevation, about 130 cfs would enter the gated notch. If the river continues to rise, the gates would stay open until the flow through the gates reaches 6,000 cfs. The flow through the gates would reach 6,000 cfs when the river elevation is about 28 feet; at this point, the two smaller gates would be programmed to start closing such that 6,000 cfs would not be exceeded. Gate closures would be controlled so that there is not a sudden reduction in flow. Gate 1, the larger gate, would remain fully open throughout operations.

Once Fremont Weir begins to overtop, the smaller gates would remain in their last position prior to the weir overtopping (generally both would be closed at this point). After the overtopping event is over, the smaller gates would open and close as needed to keep the flow through the gate below, but as close as possible to, 6,000 cfs. All gates would close when the river elevation falls below 14 feet. Gate operations to increase inundation could continue through March 15 of each year, based on hydrologic conditions. The gates may remain partially open after March 15 to provide adult fish passage. However, flows through the gates after March 15 could not exceed the available capacity of Tule Canal (typically about 300 cfs) so that these flows do not inundate areas outside of the canal and affect landowners.

The headworks structure would house three operating control gates and include a “dogging” device on each gate to be used when the gates are raised (closed) for long periods of time. The dogging device, when manually engaged, would relieve the hydraulic operating equipment of the need to maintain pressure to keep the gates from lowering.

Each control gate would be capable of independent operation via submersible hydraulic cylinders located beneath the gate. Operation of the gates would occur from an operating control building that would house the service panel board and electrical controls for the gates, including a PLC panel.

4.4.4 Inspection and Maintenance

Maintenance activities would include debris removal, sediment removal, and facility inspections. To prevent corrosion, the gates would be rinsed at the end of the flood season as part of the facility inspections. As the Sacramento River rises, some components would no longer be accessible for maintenance. Bridge guardrails would be removed before the river rises to 28 feet. The installation of dewatering stoplogs could not be performed under any flow conditions but rather could only be installed below a river elevation of 14 feet or when the river elevation is between 14 and 28 feet and the gates are raised. When the river elevation is greater than 28 feet, with the gates open or partially open, there would be no safe access to the headworks or bridges. Table 4-6 provides a list of accessible components at varying river stages.

Table 4-6. Maintenance Accessibility by River Elevation

River Elevation	Areas Accessible for Maintenance
Below 14 feet	All components of the headworks structure, bridges, gates (upstream and downstream), and operating components. Stoplogs could be installed for all gates.
14 to 28 feet (gate closed)	Upstream sides of Gates 2 and 3 (from 14 to 18 feet), downstream components of the headworks structure, bridges, gates, and operating components. Stoplogs could be installed for Gates 2 and 3.
14 to 28 feet (gate open)	Upstream bridge deck.
Above 28 feet (gate open)	All components inaccessible.

4.4.4.1 Sediment Deposition

Estimates indicate that approximately 659,000 cubic yards of sediment enter the bypass annually under existing conditions. A portion of this sediment settles in the Yolo Bypass and must be removed through current maintenance efforts. Alternative 1 would increase sediment entering the bypass to a total of about 743,000 cubic yards annually. Most of the additional sediment (about 45 percent) would settle out in the FWWA, about 25 percent would settle south of Agricultural Road Crossing 1 but north of Interstate 80, and the remaining 30 percent of sediment would remain in suspension and flow out of the bypass. Most of the sediment that settles out would be removed through flood maintenance in the FWWA, as under existing conditions. The additional deposition would be in areas inundated regularly under Alternative 1 (in and around channels), and sediment removal efforts associated with Alternative 1 would focus on the channel system. Alternative 1 would accumulate an additional 37,800 cubic yards of sediment annually that would be removed every five years.

Reclamation and DWR would seek opportunities for practical reuse of the sediment removed, including partnerships with local landowners to receive the excess soils or other local construction projects that may need additional materials. Partnerships with local landowners would be for landowners that could use additional sediment on their fields to assist in their agricultural operations, not convert agricultural land to other purposes. If no options are available for reuse, Reclamation or DWR would purchase land outside the bypass for the sediment removed during maintenance actions. Reclamation and DWR would complete appropriate environmental compliance for this transaction if land acquisition is desired in the future for sediment removal.

New channel areas that are constructed perpendicular to the direction of flow in the bypass would incur greater sedimentation. The eastern channel alignment included in Alternative 1 likely would have less sedimentation and debris accumulation than the other action alternatives because it is the shortest and most aligned with the direction of flood flows.

4.4.4.2 Headworks Inspection and Debris Removal

The serviceability and proper function of gates, their actuators, controls, hydraulic cylinders, and the recessed areas for stoplogs and gates would be inspected at the beginning and end of the flood season and after overtopping events. Concrete spalling or severe cracking, material corrosion, or identified weakness would be noted and evaluated to determine whether repair or replacement is necessary. Any sediment deposits or accumulated debris would be removed. Debris removal in and around the headworks would be accomplished using an excavator or a crane.

4.4.4.3 Vegetation Removal

Maintenance activities would include removing vegetation and debris from the project channels annually. Grasses and woody vegetation would be allowed to grow within the proposed transport channel, which is deeper than the existing ground within the Yolo Bypass. The grasses and woody vegetation would not be allowed to be higher than the elevation of the adjacent ground outside of the proposed transport channel or the Tule Pond/Tule Canal within the Fremont Weir Wildlife Area. Therefore, because the vegetation would not grow into the existing cross-section of the Yolo Bypass, vegetation within the channel would not reduce the flood capacity of the Yolo Bypass.

Maintenance, such as mowing or new tree growth removal, would be focused during dry periods but could occur when the channel is wet (such as for portions of the transport channel that may have standing water much of the year). Intake channel maintenance would occur during dry conditions.

4.4.5 Monitoring and Adaptive Management

During project implementation, DWR and Reclamation would monitor fish activity (in close coordination with CDFW) to identify if the project objectives are being met. Specifically, the agencies would monitor:

- Fremont Weir splash pad after overtopping events to identify if fish pass into the Sacramento River (through visual inspection)
- Structures within the Tule Canal/Toe Drain to identify fish passage concerns (through visual inspection)
- Stranding within the floodplain areas (through visual inspection and reports from landowners or visitors)
- Juvenile fish entrainment at the Fremont Weir gated notch (through camera footage at the structure)

If DWR and Reclamation identify concerns or areas where performance could improve, they would consider taking an adaptive management action. Appendix C of the EIS/EIR describes the Adaptive Management Framework that would be implemented.

In addition to monitoring for fish, DWR and Reclamation would monitor groundwater levels in the area surrounding the Yolo Bypass during and after periods when the gated notch would be operating. DWR has a groundwater monitoring network in this area, and the wells are checked regularly. DWR and Reclamation would consider groundwater levels each operating season to identify if the gated notch operations could be elevating shallow groundwater levels such that they could affect surrounding lands. The monitoring effort would identify times when the groundwater levels were shallower than five feet below ground surface. This indicates the elevation where groundwater levels would be within the crop root zone for surrounding agricultural areas and could affect agricultural productivity for the types of crops surrounding the Yolo Bypass (SJRRP 2017). Groundwater levels sometimes rise to this level under existing conditions because of high flow conditions in the Sacramento River and inundation events in the Yolo Bypass. If the agencies identify potential effects to surrounding landowners because of shallow groundwater levels from Alternative 1 (at times when the new gated notch structure allows increased flows into the Yolo Bypass), they would work with landowners to consider a physical solution to the high groundwater elevation, property easements, or consideration of damages.

4.4.6 Alternative 1 Preliminary Costs

Alternative 1 project facilities would be constructed within one year over a 28-week period between April to October. Construction of Alternative 1 project facilities would cost approximately $44.9 million. The operations and maintenance cost for Alternative 1 would be approximately $0.5 million annually.

4.5 Alternative 2: Central Gated Notch

Alternative 2, Central Gated Notch, would provide a new gated notch through Fremont Weir similar to the notch described for Alternative 1. The primary difference between Alternatives 1 and 2 is the location of the notch; Alternative 2 would site the notch near the center of Fremont Weir. This gated notch would be similar in size to Alternative 1 but would have an invert elevation that is higher (14.8 feet) because the river is higher at this upstream location. This location is on an outside bend of the river. Studies have indicated that juvenile fish may be found in greater numbers on the outside edge of river bends (DWR 2017). The new gated notch would allow flow to pass into the Yolo Bypass at lower river elevations than under existing conditions where flows only enter the Yolo Bypass when Fremont Weir overtops.

Alternative 2 would include facilities to connect the gated notch to the existing Tule Pond. Alternative 2 would allow flows up to 6,000 cfs, depending on Sacramento River elevation, through the gated notch to provide open channel flow for adult fish passage, juvenile emigration, and floodplain inundation. This alternative would also include a supplemental fish passage facility on the western end of Fremont Weir and improvements downstream of Tule Pond as described in Section 4.3. Figure 4-10 shows the key components of this alternative and the common elements described in Section 4.3.

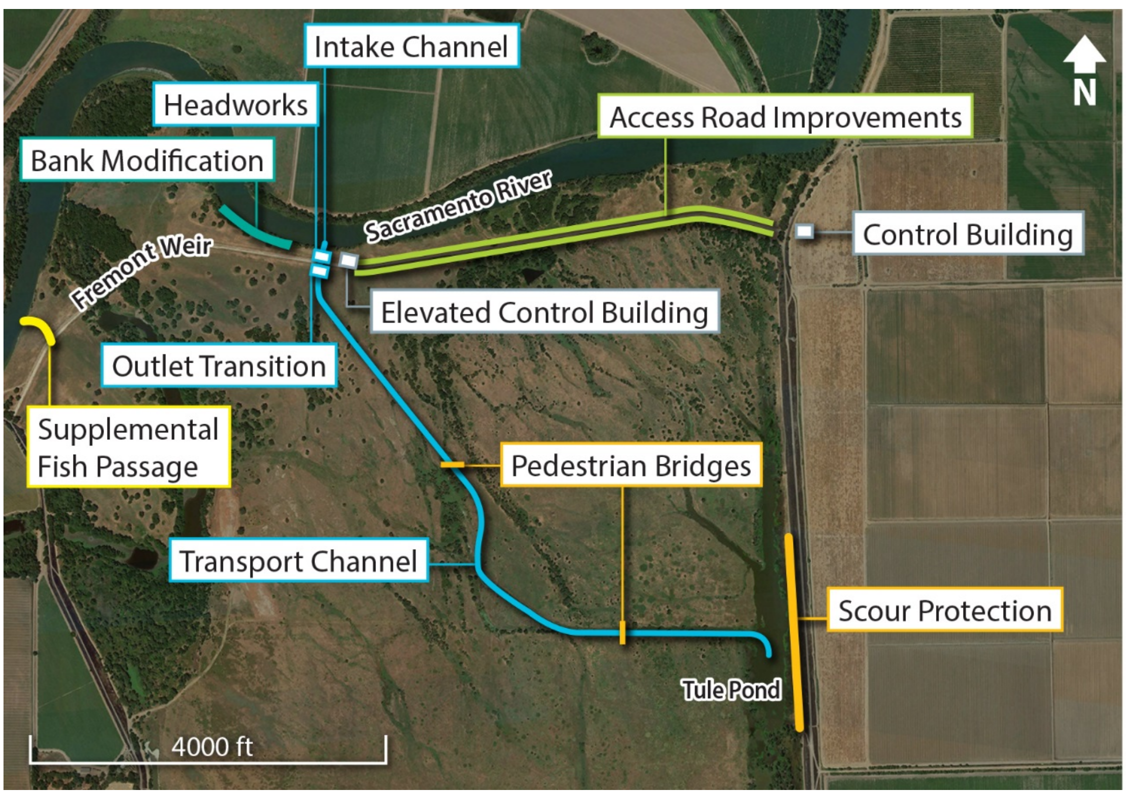


Figure 4-10. Alternative 2 Key Components

The next section includes descriptions of the facilities, construction methods, operations, required maintenance, and environmental commitments associated with this alternative. More detailed construction information is included in Appendix B of the EIS/EIR, *Constructability and Construction Considerations.*

4.5.1 Facilities

4.5.1.1 Intake Channel

Similar to Alternative 1, the primary purpose of the intake channel is to draw juvenile salmonids and floodplain inundation flows from the Sacramento River to the new headworks structure (described in Section 4.5.1.2) and provide upstream adult fish passage between the headworks structure and the Sacramento River. The dimensions and design details would be the same as described for Alternative 1, but the channel would be located in a central location. The Sacramento River bank just upstream and along the intake channel would be modified by removing roughage (existing rock revetment, piles and large wood) in the wetted channel, resloping the bed and embankment contours, and smoothing channel edges along the intake channel.

4.5.1.2 Headworks Structure

Because of the different location, the headworks structure in Alternative 2 would have a slightly different gate configuration than described for Alternative 1. The overall structure and foundation would be the same as described for Alternative 1, but the structure would be a little longer (the gate structure would be 114 feet compared to 108 feet for Alternative 1).

Three hydraulically operated, flush-mounted bottom hinge gates would be used in the headworks structure. These gates would be capable of operating under variable river elevations and overtopping events. The top of the gate elevation would be flush with the existing Fremont Weir crest (32 feet). The upstream face of the control gates would be approximately in-line with the upstream face of the existing Fremont Weir. When fully open, the gates would be flush with the channel invert. Table 4-7 presents the dimensions, invert elevation, and expected weight of the gates to be installed under this alternative. The layout of the facilities would be the same as described for Alternative 1, shown on Figures 4-5 and 4-6, including debris fins.

Table 4-7. Gate Specifications for Alternative 2

Gate	Height x Width (feet)	Invert Elevation (feet)	Expected weight (pounds)
1	17 x 40	14.8	65,000
2 and 3	13 x 27	18.8	40,000 each

4.5.1.3 Control Buildings

Due to the maximum distance over which hydraulic lines can function, two separate control buildings would be required: an operating control building and an elevated control building for hydraulics. The operating control building would be a concrete masonry unit, measuring approximately 12 by 12 feet, located on the eastern levee. The building would house a PLC for the gates and would require three-phase electrical service at approximately 100 A and 480-VAC

(80kVA). There would be no backup or standby emergency generator; however, the units would include connections for a portable generator. Active ventilation would be required during the operation of the equipment and would be achieved by installing a roof-mounted fan that vents to the outside of the structure.

The elevated control building would be located on the river side of the weir near the headworks structure. The building would be of similar size and construction as the operating control structure but would be raised above the probable maximum flood elevation (about 41.4 feet). The foundation of the raised building would consist of H-piles, a reinforced concrete pile cap, and a pair of streamlined reinforced concrete columns on which the building slab would rest.

4.5.1.4 Access Structures

A reinforced concrete, three-span vehicular headworks bridge would be on the upstream side of Fremont Weir to connect to the existing access road. The bridge would span the channels through the new headworks structure. Table 4-8 presents the bridge span corresponding to each control gate. The details of the headworks bridge, other than the span specifications, would be the same as discussed for Alternative 1.

Table 4-8. Bridge Span Specifications for Alternative 2

Gate	Bridge Span (feet)
1	40
2 and 3	27

The headworks bridge would provide a vehicular and pedestrian crossing on the north side of Fremont Weir. As discussed in Alternative 1, the channels south of Fremont Weir could be a barrier to access for recreational users in the FWWA. For this purpose, Alternative 2 includes two 170-foot-long, eight-foot-wide steel-trussed pedestrian bridges south of Fremont Weir (and north of Tule Pond), as shown on Figure 4-10. Alternative 2 includes two bridges (instead of the one bridge in Alternative 1) because of the longer length of the transport channel.

The Sacramento River carries a large amount of debris during high flow events that could accumulate in the new headworks gates. Access immediately after an overtopping event may be necessary to remove debris before a subsequent event, but the existing access roads near Fremont Weir are unpaved and too muddy to travel on for several weeks after overtopping. Alternative 2 would include stabilized access on the north and south sides of Fremont Weir to provide access following overtopping events earlier than under existing conditions. On the north side (closer to the Sacramento River), the 14-foot-wide existing access road would be excavated by two feet. The excavation would be filled with two feet of riprap with rocks less than 12 inches in diameter flush to existing grade. On the south side, the 14-foot-wide access road would be stabilized by placing two feet of riprap on top of the existing access road.

4.5.1.5 Outlet Transition

The outlet transition from the headworks to the transport channel would be the same as described for Alternative 1.

4.5.1.6 Transport Channel

The transport (outlet) channel would be a graded trapezoidal channel with an interior bench. The channel would serve the same function as described for Alternative 1. Figure 4-8 shows the cross-section of the transport channel for Alternative 2 (the central location).

The main channel within the trapezoidal channel would have a bottom width of 50 feet. The bench would be on the east side of the channel and elevated four feet above the main channel. The bench width would vary between 30 and 65 feet. The trapezoidal side slopes would have 3:1 slopes (horizontal to vertical). The top of the channel would be approximately 170 feet wide. The channel would be about 7,570 feet long with a gradual downward slope toward Tule Pond (a slope of 0.00037). The entire channel would be lined with rounded rock revetment on the channel bottom and angular rock revetment on the bank slopes. At the top of each side of the channel, an eight-foot-wide area of rock (a rock key) would be added to reduce the potential for the channel to head cut the channel banks. The facility also would have a 12-foot-wide maintenance corridor at the top of each side of the channel.

4.5.1.7 Scour Protection

The transport channel would enter Tule Pond at an angle, which could cause erosion concerns on the eastern Yolo Bypass levee. Rock revetment would be incorporated on the eastern edge of Tule Pond that is 50 feet wide, 2,500 feet long, and 2.5 feet thick, with 1.5:1 side slopes (horizontal to vertical). Additionally, there are several locations along the proposed transport channel where the channel could interact with existing scour channels. These five areas could experience head cutting as a result of the new facilities. Additional channel revetment would be incorporated at these locations; these improvements are included in the construction quantities.

4.5.1.8 Supplemental Fish Passage Facility

As discussed for Alternative 1, additional fish passage would be needed for the western side of Fremont Weir. Alternative 2 includes a supplemental fish passage facility with the same location and dimensions as described for Alternative 1.

4.5.2 Construction Methods

The construction methods and process would be similar to those described for Alternative 1. Construction would start with demolition of a portion of Fremont Weir and continue with the headworks and channel construction. In addition to the construction activities described for Alternative 1, dewatering (using a sheet pile cofferdam) would be required for the material removal and regrading at the bank of the Sacramento River near the intake channel.

4.5.2.1 Excavated Material

Alternative 2 would require excavation of the intake channel, transport channel, and downstream facilities. Table 4-9 shows the estimated quantities of excess excavated material that would be generated from each facility and would require removal from the construction area.

Table 4-9. Estimated Excess Excavated Material Quantities for Alternative 2

Component	Estimated Excess Excavated Material (cubic yards)
Central Intake Channel	3,360
Central Transport Channel	457,120
Headworks	6,460
Downstream Channel	72,520
Supplemental Fish Passage (West)	3,230
Agricultural Road Crossing 1	3,170
Sacramento River Bank Modification	44,523
Fremont Weir Access Road Improvements	4,961
TOTAL	*595,336*

Reclamation or DWR would purchase land outside of the bypass within two miles of the edge of the Yolo Bypass to receive this excess material. Alternative 2 would require 12 to 14 acres of land to spoil excess construction-related materials. This spoil site would be used for excess excavated soil and green waste. Other construction waste would be hauled to a landfill.

4.5.2.2 Construction Materials

Material imported to the Project site would be obtained from existing permitted commercial sources located within approximately 65 miles of the Project site. These sites and the associated haul routes would be the same as described for Alternative 1.

4.5.2.3 Staging Areas and Access

The construction easements for Alternative 2 would encompass staging areas for equipment, mobilization, and spoiling sites. The construction footprints analyzed in this EIS/EIR include space for staging areas. After construction, staging areas would be returned to pre-construction condition. Access roads would be the same as described for Alternative 1.

4.5.2.4 Construction Equipment

A list of the major equipment needs for the construction of both the alternative-specific and common downstream channel improvement actions is provided in Table 4-10. Equipment specifics may vary based on the contractor's capabilities and the availability of equipment. Appendix B of the EIS/EIR, *Constructability and Construction Considerations*, includes information on how many of each type of equipment would be used.

4.5.2.5 Construction Schedule and Workers

Construction of Alternative 2 likely would begin in 2020 or 2021 and is estimated to last 28 weeks. The construction schedule is the same as for Alternative 1. The peak number of construction workers, which would be needed during one week in early August, is estimated to be 223.

Table 4-10. List of Major Equipment Needed for Construction of Alternative 2

List of Major Equipment	
• 0.8-CY backhoe loaders	• 4.5-CY hydraulic excavator
• 1.5-CY front end loader crawler	• 40-TN truck-mounted hydraulic crane
• 10-TN smooth roller	• 4,000-gallon water truck
• 100-TN off highway trucks	• 450-HP dozer
• 100-foot auger track-mounted drill rig	• 450-HP dozer crawler
• 12-foot blade grader	• 6-inch diameter pump engine drive
• 165-HP dozer	• 75-TN crane crawler pile hammer
• 2.5-CY hydraulic excavator	• Concrete mixer truck
• 2.5-inch diameter concrete vibrator	• Concrete pump boom, truck mounted
• 24-TN truck end dumps	• Extended boom pallet loader
• 3.5-CY hydraulic excavator	• Flatbed truck
• 3-axle haul trucks	• Haul truck oversize transport
• 30-CY scrapers	• Hydroseeding truck
• 300-kW generator	• Pickup trucks conventional

Key: CY = cubic yards; HP = horsepower; kW = kilowatt; TN = ton

4.5.3 Operations

Alternative 2 operations would be the same as those described for Alternative 1, but the gates would open when the river elevation rises above 15.8 feet (one foot above the gate invert elevation of 14.8 feet).

The headworks operations would be the same as described for Alternative 1. Each gate would have a dogging device to relieve the hydraulic operating equipment of the need to maintain pressure to keep the gates from lowering. Each control gate would be capable of independent operation via submersible hydraulic cylinders located beneath the gate.

4.5.4 Inspection and Maintenance

Maintenance activities associated with Alternative 2 mainly would include debris removal, sediment removal, and facility inspections. Inspection and maintenance would be the same as described for Alternative 1.

4.5.4.1 Sediment Deposition

The amount of sediment entering the Yolo Bypass under Alternative 2 would be the same as described for Alternative 1. The removal frequency, methods, and quantities would be the same as described for Alternative 1.

New areas that are constructed perpendicular to the direction of flow in the bypass would incur greater sedimentation deposition. The central gated notch location, based on its location along the weir and observations of existing debris stranding, likely would experience a higher occurrence of debris accumulation as compared to the west and east alignments. Therefore, debris removal in this area would be required and accomplished using an excavator or a crane.

4.5.4.2 Headworks Inspection and Debris Removal

The serviceability and proper function of gates, their actuators, controls, hydraulic cylinders, and the recessed areas for stoplogs and gates would be inspected at the beginning and end of the flood season and after overtopping events. Concrete spalling or severe cracking, material corrosion, or identified weakness would be noted and evaluated to determine whether repair or replacement is necessary. Sediment deposits or accumulated debris would be removed. Debris removal in and around the headworks would be accomplished using an excavator or a crane.

4.5.4.3 Vegetation Removal

Periodic vegetation and debris removal from project channels would be the same as described for Alternative 1.

4.5.5 Monitoring and Adaptive Management

Monitoring activities and the adaptive management framework would be the same as described for Alternative 1.

4.5.6 Alternative 2 Preliminary Costs

Alternative 2 project facilities would be constructed within one year over a 28-week period between April to October. Construction of Alternative 2 project facilities would cost approximately $53.8 million. The operations and maintenance cost for Alternative 2 would be approximately $0.6 million annually.

4.6 Alternative 3: West Side Gated Notch

Alternative 3, West Side Gated Notch, would provide a new gated notch through Fremont Weir similar to the notch described for Alternative 1. The primary difference between Alternatives 1 and 3 is the location of the notch; Alternative 3 would site the notch on the western side of Fremont Weir. This gated notch would be similar in size to Alternative 1 but would have an invert elevation that is higher (16.1 feet) because the river is higher at this location. The western location is on the outside of a river bend, similar to Alternative 2, but would be easier to access for operations and maintenance (O&M) than a central location. The new gated notch would allow flow to pass into the Yolo Bypass at lower river elevations than under existing conditions where flows only enter the Yolo Bypass when Fremont Weir overtops.

Alternative 3 would include facilities to connect the gated notch to the existing Tule Pond. Alternative 3 would allow flows up to 6,000 cfs, depending on Sacramento River elevation, through the gated notch to provide open channel flow for adult fish passage, juvenile emigration, and floodplain inundation. This alternative would also include a supplemental fish passage facility on the eastern side of Fremont Weir and improvements downstream of Tule Pond as described in Section 4.3. Figure 4-11 shows the key components of Alternative 3 and the common elements described in Section 4.3.

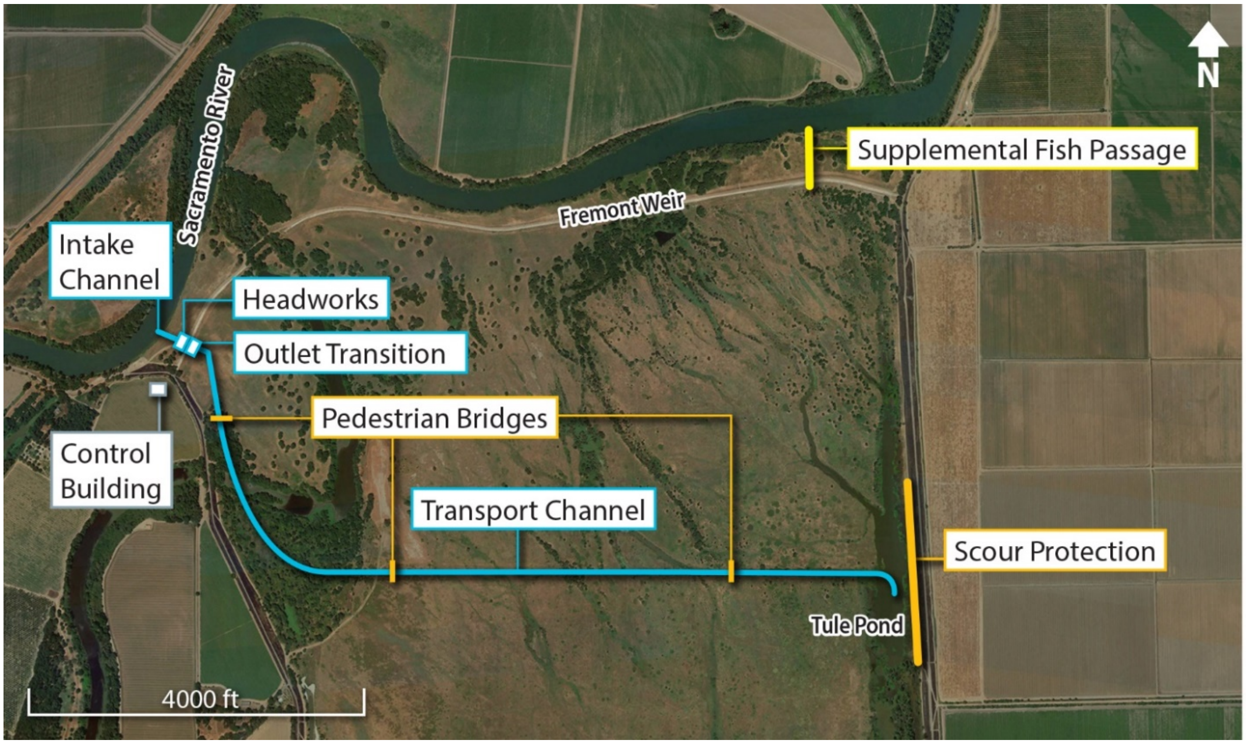


Figure 4-11. Alternative 3 Key Components

The next section includes descriptions of the facilities, construction methods, operations, required maintenance, and environmental commitments associated with this alternative. More detailed construction information is included in Appendix B of the EIS/EIR, *Constructability and Construction Considerations.*

4.6.1 Facilities

4.6.1.1 Intake Channel

Similar to Alternative 1, the primary purpose of the intake channel is to draw juvenile salmonids and floodplain inundation flows from the Sacramento River to the new headworks structure (described in Section 4.6.1.2) and provide upstream adult fish passage between the headworks structure and the Sacramento River. The dimensions and design details would be the same as described for Alternative 1, but the channel would be located in a western location.

4.6.1.2 Headworks Structure

Because of the different location, the headworks structure in Alternative 3 would have a slightly different gate configuration than described for Alternative 1. The overall structure and foundation would be the same as described for Alternative 1, but the structure would be a little longer (the gate structure would be 114 feet compared to 108 feet for Alternative 1).

Three hydraulically operated, flush-mounted bottom hinge gates would be used in the headworks structure. These gates would be capable of operating under variable river elevations and overtopping events. The top of the gate elevation would be flush with the existing Fremont Weir

(32 feet). The upstream face of the control gates would be approximately in-line with the upstream face of the existing Fremont Weir. When fully open, the gates would be flush with the channel invert. Table 4-11 presents the dimensions, invert elevation, and expected weight of the gates to be installed under this alternative. The layout of the facilities would be the same as described for Alternative 1 (Figures 4-5 and 4-6), including debris fins.

Table 4-11. Gate Specifications for Alternative 3

Gate	Height x Width (feet)	Invert Elevation (feet)	Expected weight (pounds)
1	16 x 40	16.1	65,000
2 and 3	12 x 27	20.1	40,000 each

4.6.1.3 Control Building

The control building would be a single-story concrete masonry unit, measuring 18 by 18 feet, located on the western levee. The building would house the same equipment as described for Alternative 1.

4.6.1.4 Access Structures

A reinforced concrete, three-span vehicular headworks bridge would be on the upstream side of Fremont Weir to connect to the existing access road. The bridge would span the channels through the new headworks structure.

Table 4-12 presents the bridge span corresponding to each control gate. The details of the headworks bridge, other than the span specifications, would be the same as discussed for Alternative 1.

Table 4-12. Bridge Span Specifications for Alternative 3

Gate	Bridge Span (feet)
1	40
2 and 3	27

The headworks bridge would provide a vehicular and pedestrian crossing on the north side of Fremont Weir. As discussed in Alternative 1, the channels south of Fremont Weir could be a barrier to access for recreational users in the FWWA. For this purpose, Alternative 3 includes three 185-foot-long, eight-foot-wide steel-trussed pedestrian bridges south of Fremont Weir (and north of Tule Pond), as shown on Figure 4-11.

4.6.1.5 Outlet Transition

The outlet transition from the headworks to the transport channel would be the same as described for Alternative 1.

4.6.1.6 Transport Channel

The transport (outlet) channel would be a graded trapezoidal channel with an interior bench. The channel would serve the same function as described for Alternative 1. Figure 4-8 shows the cross-section of the transport channel for Alternative 3 (the western location). The transport channel would cross the "oxbow" wetland area on the western side of the Yolo Bypass, but the channel would not have a hydraulic connection to the oxbow. A portion of the oxbow near the western Yolo Bypass levee would be filled to approximately existing grade, then the transport channel would be excavated through the filled section.

The main channel within the trapezoidal channel would have a bottom width of 50 to 60 feet. The bench would be on one side of the channel and elevated four feet above the main channel. The bench width would be approximately 30 feet. The trapezoidal side slopes would have 3:1 slopes (horizontal to vertical). The top of the channel would be approximately 180 feet wide. The channel would be about 10,180 feet long with a gradual downward slope toward Tule Pond (a slope of 0.0004). The entire channel would be lined with rounded rock revetment on the channel bottom and angular rock revetment on the bank slopes. At the top of each side of the channel, an eight-foot-wide area of rock (a rock key) would be added to reduce the potential for the channel to head cut the channel banks. The facility also would have a 12-foot-wide maintenance corridor at the top of each side of the channel.

4.6.1.7 Supplemental Fish Passage Facility

Alternative 3 would provide primary fish passage through the new gated notch on the western side of Fremont Weir. The improved fish passage facility at the existing fish ladder would provide passage immediately after an overtopping event near the center of Fremont Weir, but the eastern section of Fremont Weir is very long. To further improve fish passage from the Yolo Bypass into the Sacramento River after an overtopping event, Alternative 3 would include an additional fish passage facility at an eastern location along the existing Fremont Weir (see Figure 4-12). The supplemental fish passage channel would stretch over 500 feet and connect to the fish passage facility through a channel transition. The 10-foot-long channel transition facilitates the transition from the 10-foot width of the channel to the 15-foot width of the fish passage structure. The concrete fish passage structure would house an approximately 12-foot-wide hinge gate, a recessed air buffer, and a metal grate. The concrete wall of the fish passage structure would be flush with the top of the existing weir (elevation 32 feet).

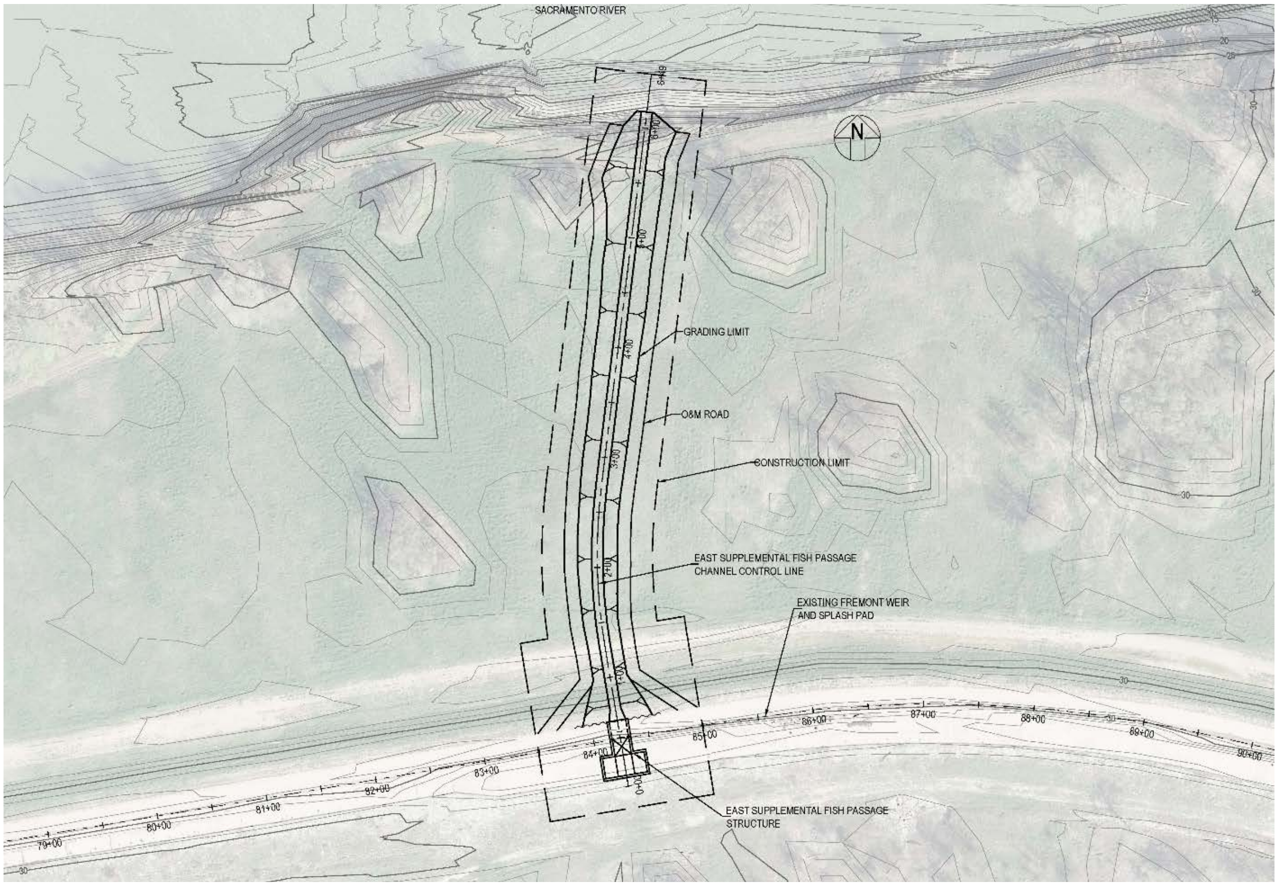


Figure 4-12. Eastern Supplemental Fish Passage

4.6.1.8 Scour Protection

The transport channel would enter Tule Canal at an angle, which could cause erosion on the eastern Yolo Bypass levee. Rock revetment would be placed on the eastern edge of Tule Pond that is 50 feet wide, 2,500 feet long, and 2.5 feet thick, with 1.5:1 side slopes (horizontal to vertical). Additionally, there are several locations along the proposed transport channel where the channel could interact with existing scour channels. These areas could experience head cutting as a result of the new facilities. Additional channel revetment would be incorporated at these locations; these improvements are included in the construction quantities.

4.6.2 Construction Methods

The construction methods and process would be similar to those described for Alternative 1. Construction would start with demolition of Fremont Weir and continue with the headworks and channel construction.

4.6.2.1 Excavated Material

Alternative 3 would require excavation of the intake channel, transport channel, and downstream facilities. Table 4-13 shows the estimated quantities of excess excavated material that would be generated from each facility and would require removal from the construction area.

Table 4-13. Estimated Excess Excavated Material Quantities for Alternative 3

Component	Estimated Excess Excavated Material (cubic yards)
West Intake Channel	32,720
West Transport Channel	687,640
Headworks	6,460
Downstream Channel	72,520
Supplemental Fish Passage (East)	3,540
Agricultural Road Crossing 1	3,170
TOTAL	*806,050*

Reclamation or DWR would purchase land outside of the bypass within two miles of the edge of the Yolo Bypass to receive this excess material. Alternative 3 would require 17 to 20 acres of land to spoil excess construction-related materials.

4.6.2.2 Construction Materials

Material imported to the Project site would be obtained from existing permitted commercial sources located within approximately 65 miles of the Project site. These sites and the associated haul routes would be the same as described for Alternative 1.

4.6.2.3 Staging Areas and Access

The construction easements for Alternative 3 would encompass staging areas for equipment, mobilization, and spoiling sites. The construction footprints analyzed in this EIS/EIR include space for staging areas. After construction, staging areas would be returned to pre-construction condition. Access roads would be the same as described for Alternative 1.

4.6.2.4 Construction Equipment

A list of the major equipment needs for the construction of both the alternative-specific and common downstream channel improvement actions is provided (Table 4-14). Equipment specifics may vary based on the contractor’s capabilities and the availability of equipment. Appendix B of the EIS/EIR, *Constructability and Construction Considerations*, includes information on how many of each type of equipment would be used.

Table 4-14. List of Major Equipment Needed for Construction of Alternative 3

List of Major Equipment	
• 0.8-CY backhoe loaders • 1.5-CY front end loader crawler • 10-TN smooth roller • 100-TN off highway trucks • 100-foot auger track-mounted drill rig • 12-foot blade grader • 165-HP dozer • 2.5-CY hydraulic excavator • 2.5-inch diameter concrete vibrator • 24-TN truck end dump • 3.5-CY hydraulic excavator • 3-axle haul trucks • 30-CY scrapers • 300-kW generator	• 4.5-CY hydraulic excavator • 40-TN truck-mounted hydraulic crane • 4,000-gallon water truck • 450-HP dozer crawler • 6-inch diameter pump engine drive • 75-TN crane crawler pile hammer • Concrete mixer truck • Concrete pump boom, truck mounted • Extended boom pallet loader • Flatbed truck • Haul truck oversize transport • Hydroseeding truck • Pickup trucks, conventional

Key: CY = cubic yards; HP = horsepower; kW = kilowatt; TN = ton

4.6.2.5 Construction Schedule and Workers

Construction of Alternative 3 likely would begin in 2020 or 2021 and is estimated to last 28 weeks. The construction schedule is the same as for Alternative 1. The peak number of construction workers, which would be needed during one week in the middle of July, is estimated to be 277.

4.6.3 Operations

Alternative 3 operations would be the same as those described for Alternative 1, but the gates would open when the river elevation rises above 17.1 feet (one foot above the gate invert elevation of 16.1 feet).

The headworks operations would be the same as described for Alternative 1. Each gate would have a dogging device to relieve the hydraulic operating equipment of the need to maintain pressure to keep the gates from lowering. Each control gate would be capable of independent operation via submersible hydraulic cylinders located beneath the gate.

4.6.4 Inspection and Maintenance

Maintenance activities associated with Alternative 3 would mainly include debris removal, sediment removal, and facility inspections. Inspection and maintenance would be the same as described for Alternative 1.

4.6.4.1 Sediment Deposition

The amount of sediment entering the Yolo Bypass under Alternative 3 would be the same as described for Alternative 1. The removal frequency, methods, and quantities would be the same as described for Alternative 1.

New areas that are constructed perpendicular to the direction of flow in the bypass would incur greater sedimentation deposition. This alignment (the western alignment) likely would have the highest amount of sedimentation and debris accumulation because it is the longest and has more changes in direction than the eastern or central alignments. Therefore, debris removal in this area would be required and accomplished using an excavator or a crane.

4.6.4.2 Headworks Inspection and Debris Removal

The serviceability and proper function of gates, their actuators, controls, hydraulic cylinders, and the recessed areas for stoplogs and gates would be inspected at the beginning and end of the flood season and after overtopping events. Concrete spalling or severe cracking, material corrosion, or identified weakness would be noted and evaluated to determine if repair or replacement is necessary. Sediment deposits or accumulated debris would be removed. Debris removal in and around the headworks would be accomplished by excavator or crane.

4.6.4.3 Vegetation Removal

Periodic vegetation and debris removal from project channels would be the same as described for Alternative 1.

4.6.5 Monitoring and Adaptive Management

Monitoring activities and the adaptive management framework would be the same as described for Alternative 1.

4.6.6 Alternative 3 Preliminary Costs

Alternative 3 project facilities would be constructed within one year over a 28-week period between April to October. Construction of Alternative 3 project facilities would cost approximately $61.5 million. The operations and maintenance cost for Alternative 3 would be approximately $0.6 million annually.

4.7 Alternative 4: West Side Gated Notch – Managed Flow

Alternative 4, West Side Gated Notch – Managed Flow, would have a smaller amount of flow entering the Yolo Bypass through the gated notch in Fremont Weir than the other alternatives, but it would incorporate water control structures to maintain inundation in defined areas for longer periods of time within the northern Yolo Bypass. Alternative 4 would include the same gated notch and associated facilities as described for Alternative 3. However, it would be operated to limit the maximum inflow to approximately 3,000 cfs.

Alternative 4 includes two water control structures on Tule Canal to extend periods of inundation locally. A bypass channel would be constructed around each water control structure to provide adult fish passage when the water control structures are controlling flow. This alternative would also provide means for fish passage on the eastern side of Fremont Weir through a supplemental fish passage facility. In addition, improvements to Agricultural Road Crossing 1 and the downstream channel would be implemented under this alternative (see Section 4.3). Figure 4-13 shows the key components of Alternative 4 and the common elements described in Section 4.3.

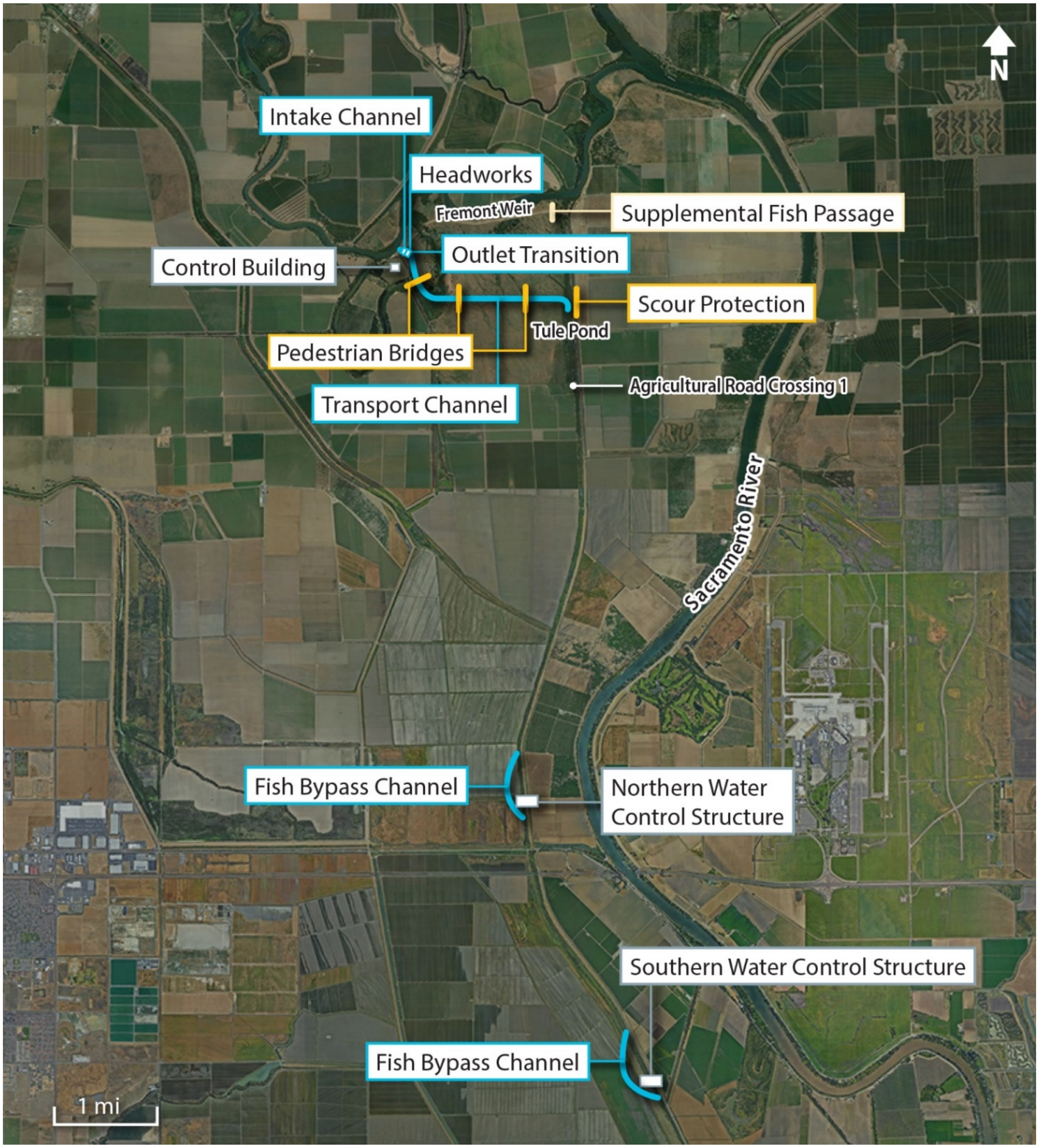


Figure 4-13. Alternative 4 Key Components

The next section includes descriptions of the facilities, construction methods, operations, required maintenance, and environmental commitments associated with this alternative. More detailed construction information is included in Appendix B of the EIS/EIR, *Constructability and Construction Considerations.*

4.7.1 Facilities

The gated notch and associated facilities (intake channel, headworks, outlet transition, transport channel, control building, access structures, and supplemental fish passage) are identical to those described for Alternative 3. The decrease in flows through the gated notch would be accomplished through operations described in Section 4.7.3. This section focuses on the features that are unique to Alternative 4, including the water control structures and bypass channels.

Two bypass channels would be constructed, each as an open channel sized for 300 cfs with a 10-foot-bottom width and 3:1 side slopes. The channel near the northern water control structure would be approximately 3,275 feet long, whereas the channel near the southern water control structure would be 4,180 feet long. The channels would have no operable weir features.

4.7.1.1 Northern Water Control Structure

The northern water control structure would be just north of CR 22, as shown on Figure 4-14. The water control structure would be used to manage water levels upstream from this facility and pond water to increase duration of flooded fish-rearing habitat above this location. The concrete water control structure would include three 16-foot-wide “Obermeyer”-style inflatable gates, or bladder-type dams, that would raise to maintain water levels at an elevation of 21.5 feet. Figure 4-15 shows a picture of an Obermeyer gate with inflatable bladders that raise the gate. The structure would have a concrete bridge on top of the structure for access. It would have sheet pile walls that tie into the Tule Canal banks.

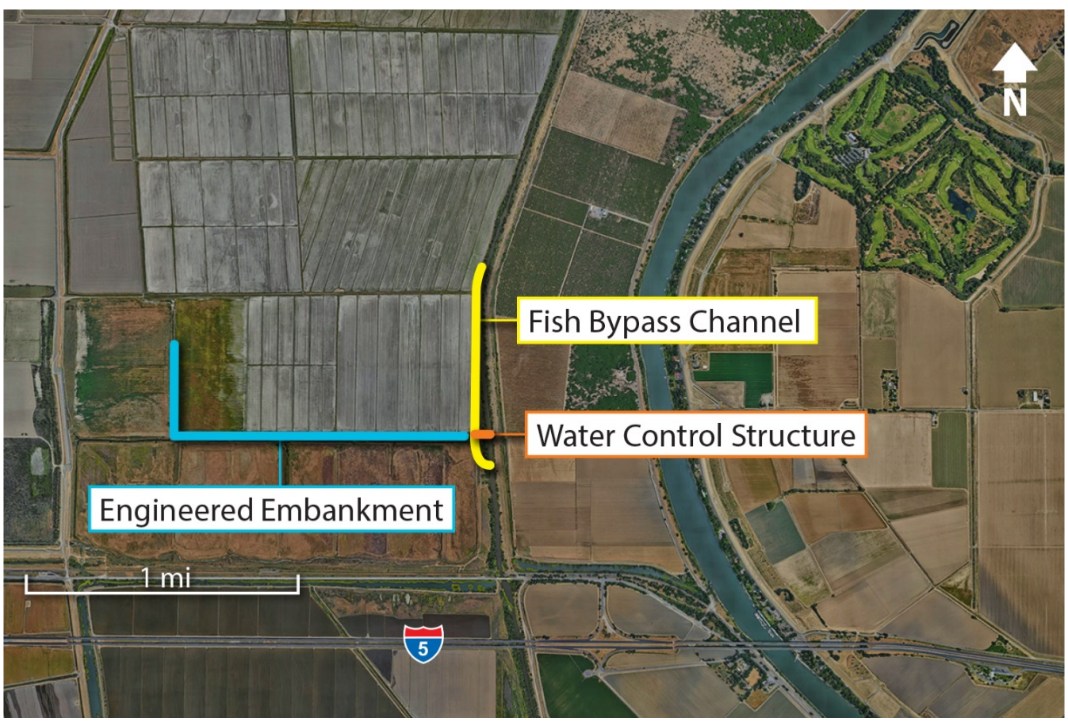


Figure 4-14. Northern Water Control Structure and Bypass Channel

Figure 4-15. Example of Obermeyer-Style Inflatable Gates

When the gates are raised, they would block fish passage through Tule Canal. To reduce fish passage delays, a bypass channel would go around the water control structure, as shown on Figure 4-14. The bypass channel would be an open, trapezoidal channel with a 10-foot-bottom width and 3:1 side slopes. Berms (two to five feet in height) would be constructed on each side of the channel to maintain water levels in the bypass channel. The channel would include two areas where it would be constricted down to a five-foot-bottom width for 60 feet. This constriction would help slow the water and meet fish passage criteria. Figure 4-16 shows a cross-section schematic of the bypass channel next to Tule Canal. The channel would be approximately 3,275 feet long with no operable features in the bypass channel. It would convey up to 300 cfs. The bypass channel would include a box culvert adjacent to the water control structure to allow vehicular access across both facilities.

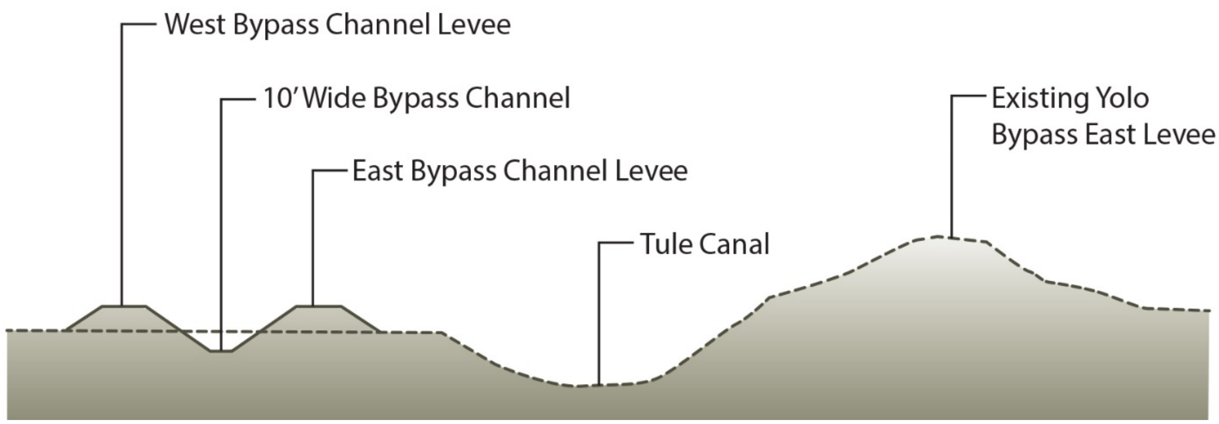


Figure 4-16. Cross-Section of Bypass Channel

An engineered, armored embankment would be added in the area of existing roads or berms west and north of the water control structure to maintain water levels north of the water control structure. This embankment would add two to six feet above the surrounding ground. The engineered embankment would be about 7,200 linear feet, as shown on Figure 4-14. The embankment would be designed to have a top elevation of 23 feet inside the Yolo Bypass.

4.7.1.2 Southern Water Control Structure

The southern water control structure would be south of CR 22 and north of the Sacramento Weir, as shown on Figure 4-17. The water control structure would be used to manage water levels upstream from this facility and pond water to increase rearing habitat. The concrete water control structure would include three 16-foot-wide Obermeyer-style inflatable gates or bladder-type dams that would raise to maintain water levels at an elevation of 17.5 feet. The structure would include a concrete bridge on top of the structure for access. It would have sheet pile walls that tie into the Tule Canal banks.

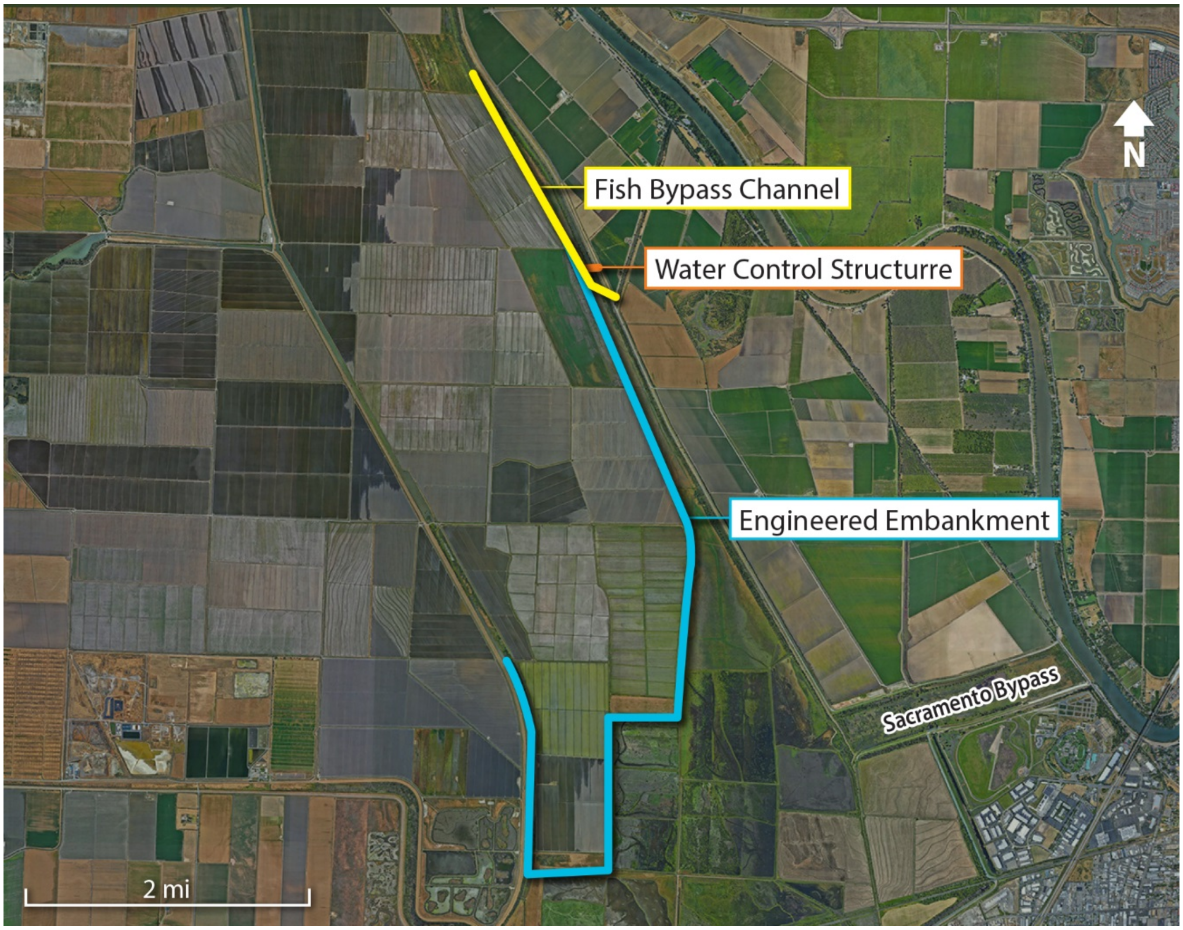


Figure 4-17. Southern Water Control Structure and Bypass Channel

When the gates are raised, they would block fish passage through Tule Canal. To reduce fish passage delays, a bypass channel would go around the water control structure, as shown on Figure 4-17. The bypass channel would be an open, trapezoidal channel with a 10-foot-bottom width and 3:1 side slopes. Berms would be constructed on each side of the channel to maintain water levels in the bypass channel. The cross-section would be similar to the northern channel, as shown on Figure 4-16. The channel would be roughly 4,180 feet long with no operable features in the bypass channel (but existing agricultural facilities would be maintained). The channel would convey up to 300 cfs. The bypass channel would include a box culvert adjacent to the water control structure to allow vehicular access across both facilities.

An engineered embankment (armored with rock) would be constructed along the alignments of existing roads or berms south then west of the water control structure to maintain water levels north of the water control structure. The existing berms would be degraded and rebuilt to meet the stability requirements to hold back water. The rebuilt embankments would be two to six feet above the existing grade on the surrounding property. The engineered embankment would be about 37,870 linear feet, as shown on Figure 4-17. The embankment would be designed to have a top elevation of 19 feet inside the Yolo Bypass.

4.7.2 Construction Methods

Construction of the intake channel, headworks, transport channel, Agricultural Road Crossing 1, and the downstream channel improvements would follow the same construction methods as discussed for Alternative 3.

The water control structures would be constructed in Tule Canal, which has a non-flood flow of approximately 1,000 cfs that would need to be maintained during the construction period. Construction would begin by creating a temporary bypass channel around the construction site to convey these flows, and then cofferdams would be installed upstream and downstream of the site with dewatering pumps to dry out the construction site. The bypass channel construction would mostly be in dry areas except for the transitions to Tule Canal.

4.7.2.1 Excavated Material

The intake channel, headworks, transport channel, downstream channel, and Agricultural Road Crossing 1 improvements under Alternative 4 would be the same as described for Alternative 3, so the excess excavated material would be the same as shown in Table 4-13. Additionally, construction activities would occur at the two water control structures and bypass channels. The excavated materials from these facilities would be re-used to construct the berms on the bypass channel and the engineered embankments. Table 4-15 shows the estimated quantities of material that would be excavated or required for fill during construction of the water control structures and bypass channels.

Table 4-15. Estimated Material Quantities for Water Control Structures in Alternative 4

Component	Net Fill (cubic yards)	Net Excavation (cubic yards)	Net Material (cubic yards)
Northern Water Control Structure and Bypass Channel	75,000	65,000	10,000 Borrow Need
Southern Water Control Structure and Bypass Channel	178,000	134,000	44,000 Borrow Need

The borrow need would be met from excess material generated during construction of the gated notch and channel at Fremont Weir. Reclamation or DWR would purchase land within two miles of the edge of the Yolo Bypass to receive excess material. Alternative 4 would require 16 to 19 acres of land to spoil excess construction-related materials.

4.7.2.2 Construction Materials

Material imported to the Project site would be obtained from existing permitted commercial sources located within approximately 65 miles of the Project site. These sites and the haul routes would be the same as described for Alternative 1.

4.7.2.3 Staging Areas and Access

The construction easements for Alternative 4 would encompass staging areas for equipment, mobilization, and spoiling sites. The construction footprints analyzed in this EIS/EIR include space for staging areas. After construction, staging areas would be returned to pre-construction condition. Site access for work at Fremont Weir and in the FWWA would be the same as described for Alternative 1.

Construction access for the northern water control structure would be via I-5 to CR 117. The route would then follow CR 22 north onto existing agricultural roads in the bypass. CRs 22 and 117 are paved rural two-lane roads that, based on preliminary site assessment visits, are anticipated to sufficiently accommodate minor construction traffic associated with equipment and material haul for site mobilization. The agricultural roads are basic dirt roads that would need to be maintained during construction to accommodate construction traffic equipment.

Construction access for the southern water control structure would be via I-5 to CR 117 to CR 22, then south onto existing agricultural roads for the northern end of the project. The southern end of the project would be accessed via I-5 to CR 102 to CR 28H, then onto the west bypass levee down to existing agricultural roads. CRs 22, 117, 102, and 28H are paved rural two-lane roads that, based on preliminary site assessment visits, are anticipated to sufficiently accommodate minor construction traffic associated with equipment and material haul for site mobilization. The levee and agricultural roads are basic dirt roads that would need to be maintained during construction to accommodate construction traffic equipment.

4.7.2.4 Construction Equipment

A list of the major equipment needs for the construction of both the alternative-specific and common downstream channel improvement actions is provided (Table 4-16). Equipment specifics may vary based on the contractor's capabilities and the availability of equipment. Appendix B of the EIS/EIR, *Constructability and Construction Considerations*, includes information on how many of each type of equipment would be used.

Table 4-16. List of Major Equipment Needed for Construction of Alternative 4

List of Major Equipment	
• 0.8-CY backhoe loaders	• 4.5-CY hydraulic excavator
• 1.5-CY front end loader crawler	• 40-TN truck-mounted hydraulic crane
• 10-TN smooth roller	• 4,000-gallon water truck
• 100-TN off highway trucks	• 450-HP dozer crawler
• 100-foot auger track-mounted drill rig	• 6-inch diameter pump engine drive
• 12-foot blade grader	• 75-TN crane crawler pile hammer
• 165-HP dozer	• Concrete mixer truck
• 2.5-CY hydraulic excavator	• Concrete pump boom, truck mounted
• 2.5-inch diameter concrete vibrator	• Extended boom pallet loader
• 24-TN truck end dump	• Flatbed truck
• 3.5-CY hydraulic excavator	• Haul truck oversize transport
• 3-axle haul trucks	• Hydroseeding truck
• 30-CY scrapers	• Pickup trucks, conventional
• 300-kW generator	

Key: CY = cubic yards; HP = horsepower; kW = kilowatt; TN = ton

4.7.2.5 Construction Schedule and Workers

Construction of Alternative 4 likely would begin in 2020 or 2021 and is estimated to last 28 weeks. The construction schedule for the gated notch and associated facilities in FWWA is the same as for Alternative 1. Construction of channel improvements, including water control structures and bypass channels, would be completed concurrently with construction on the headworks facility.

Construction would occur six days per week for 10 hours per day between 7 a.m. and 6 p.m. Construction workers would be divided into multiple crews and would work one shift a day. Maintenance and equipment upkeep crews would work on equipment at night when it is not in use. The peak number of construction workers, which would be needed for one week in the middle of July, is estimated to be 363.

4.7.3 Operations

The goal of Alternative 4 operations is to increase rearing time and food production in the bypass while managing flows. Under Alternative 4, the Fremont Weir gates would be operated to limit flows to 3,000 cfs. Gate operations could begin each year on November 1 and would first open based on river conditions. All gates would be opened when the river elevation at this location reaches 17.1 feet, which is one foot above the lowest gate invert. If the river continues to rise, the gates would stay open until the flow through the gates reaches 3,000 cfs. The flow through the gates would reach 3,000 cfs when the river elevation is about 26.6 feet; at this point, the two smaller gates would be programmed to start closing such that 3,000 cfs would not be exceeded. Gate closures would be controlled so that there is not a sudden reduction in flow. Gate 1, the larger gate, would remain fully open throughout operations.

Once Fremont Weir begins to overtop, the smaller gates would remain in their last position prior to the weir overtopping (generally both would be closed at this point). After the overtopping event is over, the smaller gates would open and close as needed to keep the flow through the gate below, but as close as possible to, 3,000 cfs. The notch would close when the river falls below an elevation of 16.1 feet. Gate operations to increase inundation could continue through March 7 or March 15 of each year, based on hydrologic conditions. The gates may remain partially open after March 7 or March 15 to provide adult fish passage. However, flows through the gates after March 7 or March 15 could not exceed the available capacity of Tule Canal (typically about 300 cfs) so that these flows do not inundate areas outside of the canal and affect landowners.

Under Alternative 4, Reclamation and DWR would not select a different inundation end date (March 7 or March 15) each year. This EIS/EIR analyzes the potential impacts and benefits from each end date, and if this alternative is selected, Reclamation and DWR would use this analysis as a basis to select one end date in their decision documents.

Water control structures in Tule Canal would be raised when the notch is open. The northern water control structure would be managed to achieve a target water surface elevation of 21.5 feet. The southern water control structure would be managed to achieve a target water surface elevation of 17.5 feet. As canal stage rises above the target elevation, the water control structure gates would begin to lower so that the elevation is held constant. The gates would remain lowered after March 7 or March 15.

4.7.4 Inspection and Maintenance

Maintenance activities associated with Alternative 4 would mainly include debris removal, sediment removal, and facility inspections. Inspection and maintenance for the headworks, channels, and associated facilities would be the same as described for Alternative 3.

4.7.4.1 Sediment Deposition

Estimates indicate that approximately 659,000 cubic yards of sediment enter the bypass annually under existing conditions. A portion of this sediment settles in the Yolo Bypass and must be removed through current maintenance efforts. Alternative 4 would increase sediment entering the bypass to an estimated total of 701,000 cubic yards annually. About 25 percent would settle south of Agricultural Road Crossing 1 but north of Interstate 80, and the remaining 30 percent of sediment would remain in suspension and flow out of the bypass. Most of the sediment that settles out would be removed through flood maintenance in the FWWA, as under existing conditions. Alternative 4 would accumulate an additional 18,900 cubic yards of sediment annually that would be removed every five years.

Reclamation and DWR would seek opportunities for practical reuse of the sediment removed, including partnerships with local landowners to receive the excess soils or other local construction projects that may need additional materials. Partnerships with local landowners would be for landowners that could use additional sediment on their fields to assist in their agricultural operations, not convert agricultural land to other purposes. If no options are available for reuse, Reclamation or DWR would purchase land outside the bypass for the sediment removed during maintenance actions. Reclamation and DWR would complete appropriate environmental compliance for this transaction if land acquisition is desired in the future for sediment removal.

4.7.4.2 Water Control Structures

The areas around the water control structures and the bypass channels would need to be inspected periodically to identify areas where sedimentation may be reducing the size of the bypass channel and affecting fish passage at the facilities. If inspections find that sedimentation is causing fish passage concerns, Reclamation or DWR would remove sediment to restore fish passage capability.

4.7.5 Monitoring and Adaptive Management

Monitoring activities and the adaptive management framework would be the same as described for Alternative 1.

4.7.6 Alternative 4 Preliminary Costs

Alternative 4 project facilities would be constructed within one year over a 28-week period between April to October. Construction of Alternative 4 project facilities would cost approximately $90.3 million. The operations and maintenance cost for Alternative 4 would be approximately $0.75 million annually.

4.8 Alternative 5: Central Multiple Gated Notches

Through the strategy of using multiple gates and intake channels at Fremont Weir, Alternative 5, Central Multiple Gated Notches, has the goal of increasing the number of out-migrating juvenile fish that enter the Yolo Bypass. Trapezoidal channels create some limitations for fish passage because they have smaller flows at lower river elevations (because the channel is smaller at this elevation) when winter-run Chinook salmon are out-migrating. Alternative 5 includes multiple gates so that the deeper gate could allow more flow to enter the bypass when the river is at lower elevations. Flows would move to other gates when the river is higher to control inflows while maintaining fish passage conditions.

Alternative 5 incorporates multiple gated notches in the central location on the existing Fremont Weir that would allow combined flows of up to 3,400 cfs. As the river rises, the deeper gate would close and the next gate would open. This alternative would include a supplemental fish passage facility on the western side of Fremont Weir and improvements to allow fish to pass through Agricultural Road Crossing 1 (see Section 4.3). Figure 4-18 shows the key components of this alternative.

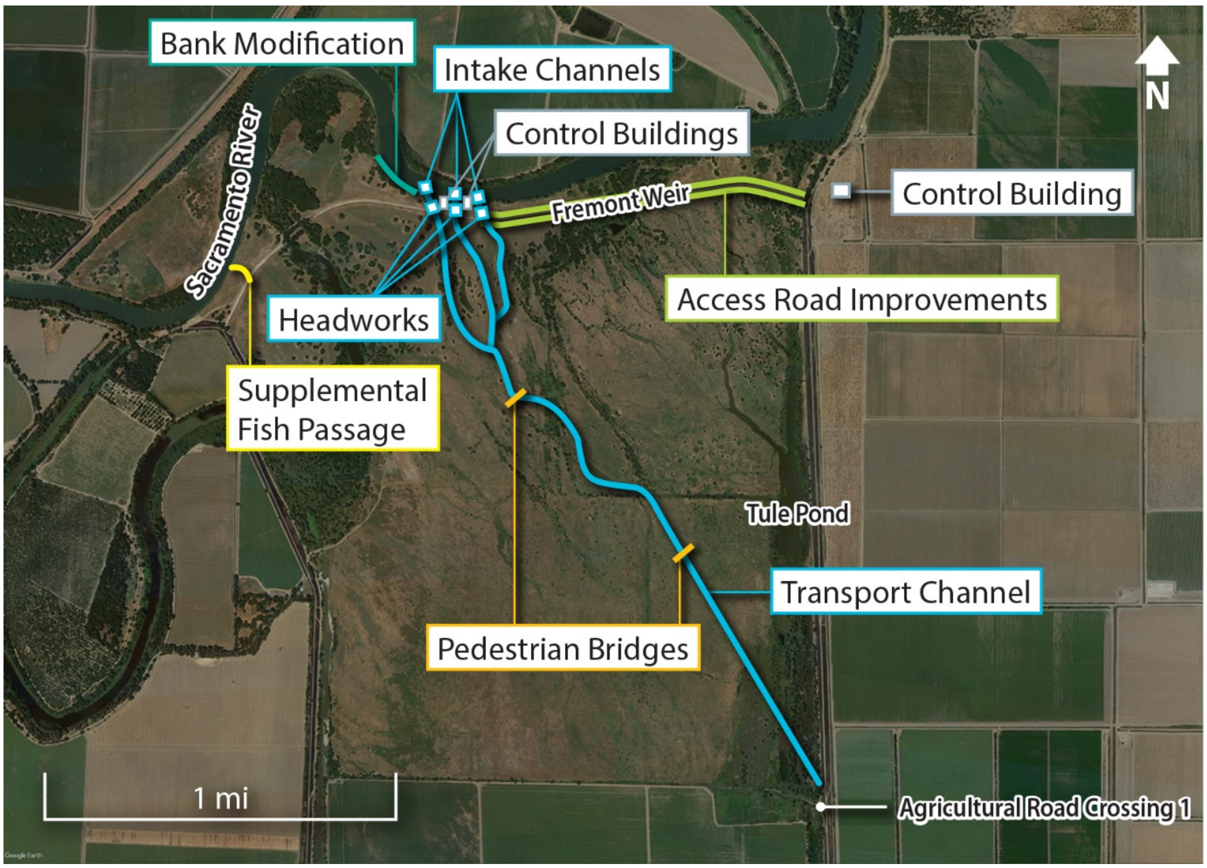


Figure 4-18. Alternative 5 Key Components

The next section includes descriptions of the facilities, construction methods, operations, required maintenance, and environmental commitments associated with this alternative. More detailed construction information is included in Appendix B of the EIS/EIR, *Constructability and Construction Considerations.*

4.8.1 Facilities

4.8.1.1 Intake Channel

Alternative 5 includes four gated headworks, with two sets of gates co-located in the westernmost location of the structures. Each headworks structure would be connected to the Sacramento River with an intake channel. Also, the Sacramento River bank just upstream and along the intake channel would be modified by removing roughage (existing rock revetment, piles, and large wood) in the wetted channel, resloping the bed and embankment contours, and smoothing channel edges along the intake channel. The channels would be lined with angular rock placed along the bank slopes and rounded rock placed along the channel bottom to avoid scour.

4.8.1.2 Headworks Structure

The headworks structure would house four sets of bottom-hinge control gates with varying invert elevations, as shown on Figures 4-19 and 4-20. Gates A and B would be located on the west side of the structure (at the central notch location at the existing Fremont Weir), Gate C would be in the middle, and Gate D would be on the eastern side of the structure. The structure would be foundationally supported by multiple 24-inch square piles with the bottom of the pile at elevation of 75 feet below NAVD 88. The gate dimensions are as follows:

- Gate group A includes three culverts with 10-foot-high by 10-foot-wide gates, with an invert set at 14 feet.
- Gate group B includes three culverts with gates that would be the same size as Gate A, with an invert set at 17 feet. These are in the same location as Gate A.
- Gate group C includes 10 box culverts with gates that would be 10 feet high by 10 feet wide, with an invert set at 20 feet.
- Gate group D includes 11 box culverts with gates that would be 10 feet wide by 7 feet high, with an invert set at 23 feet.

All box culverts include downstream bottom-hinged gates.

4.8.1.3 Control Buildings

Due to the maximum distance over which hydraulic lines can function, two types of control buildings are required: a control building on the east levee and two elevated control buildings near the gates. The operating control building on the east levee would be the same as described for Alternative 2.

Alternative 5 would include two additional elevated control buildings to house the hydraulics controls on the river side of the weir near the headworks structures. The buildings would be of similar size and construction as the operating control structure on the east levee but would be raised above the probable maximum flood elevation. The foundation of the raised buildings would consist of H-piles, a reinforced concrete pile cap, and a pair of streamlined reinforced concrete columns on which the building slab would rest.

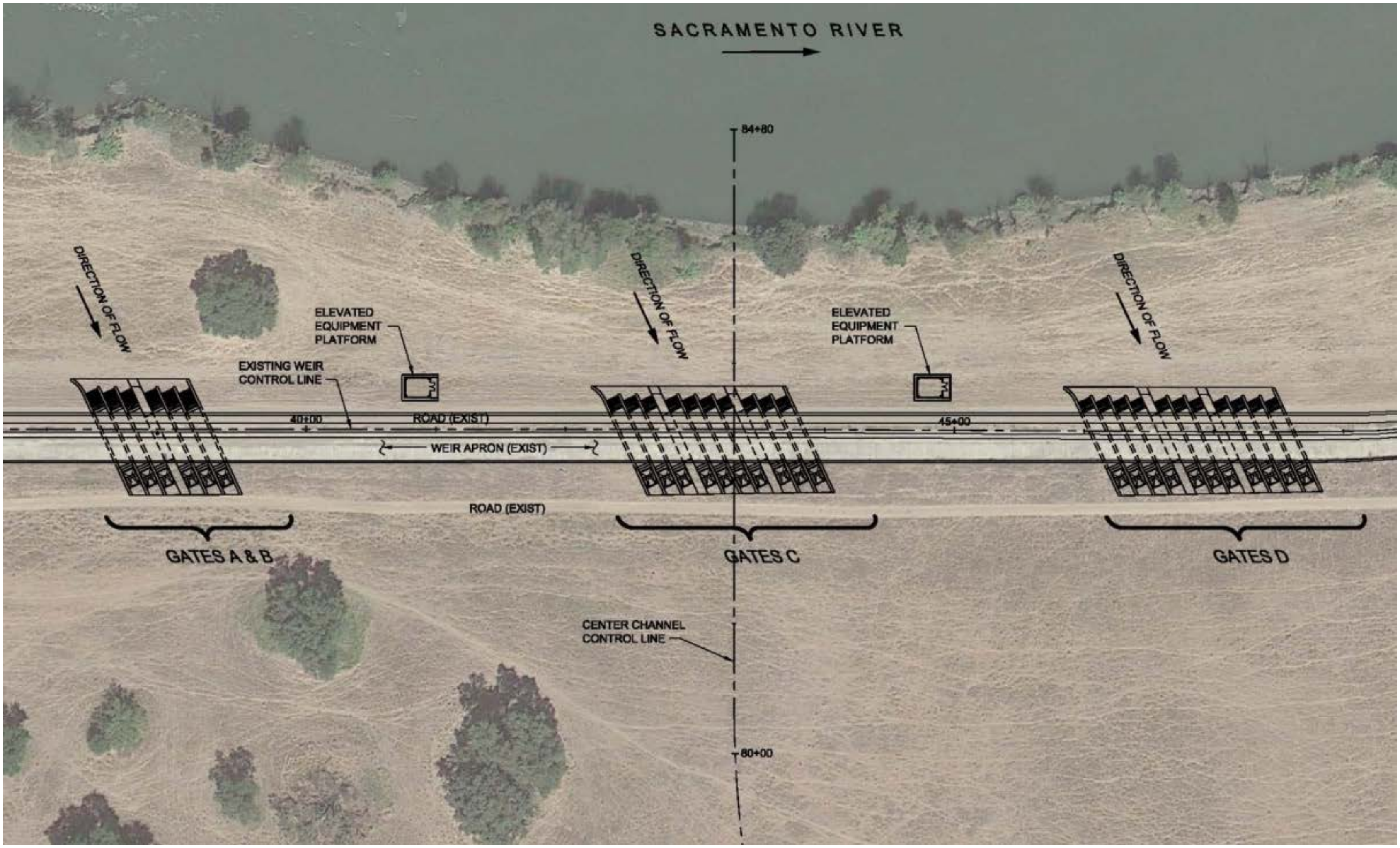


Figure 4-19. Alternative 5 Headworks (view from top looking down)

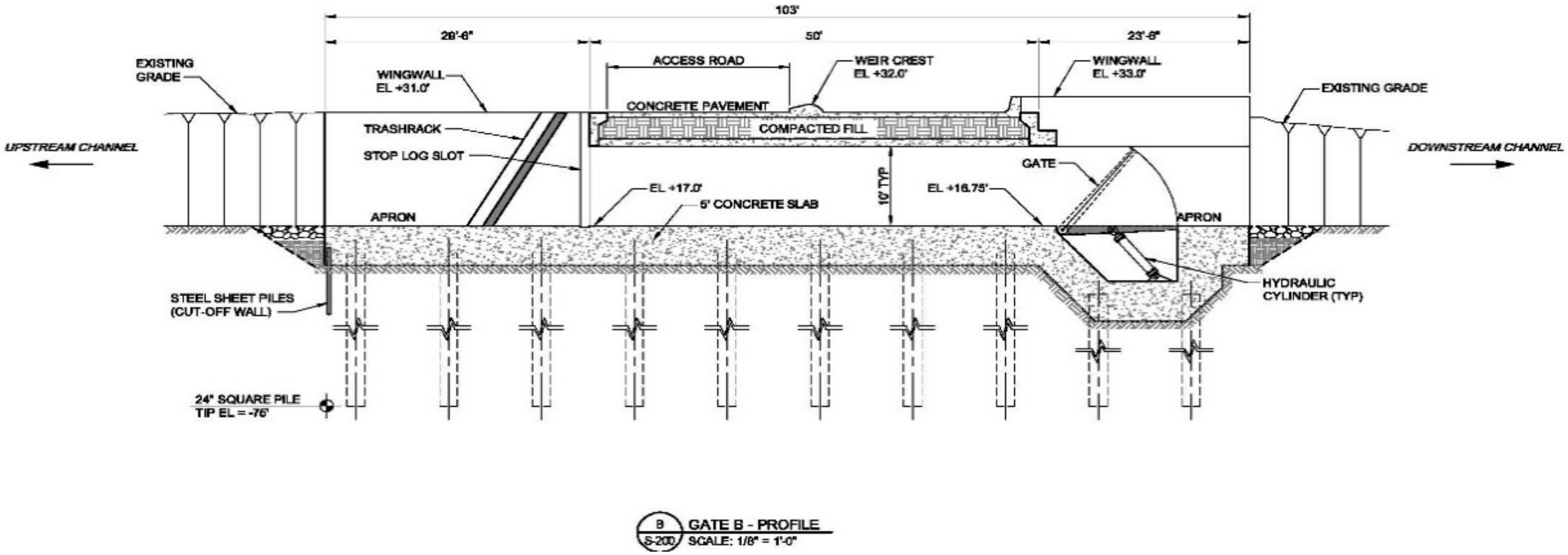


Figure 4-20. Alternative 5 Headworks (view from side of Gate Group B)[5]

[5] Figure shows trash rack on headgates, but this feature has been removed as part of the process to refine alternatives and avoid impacts.

4.8.1.4 Transport Channel

Alternative 5 includes three meandering transport channels between the intakes and the point where they come together, about 2,000 feet downstream from Fremont Weir. At this point, one channel flows toward Tule Canal, near Agricultural Road Crossing 1 (see Figure 4-18). A description of the three channels follows:

- Channel AB would connect A and B gate groups to the Tule Canal and would be a rock-lined compound trapezoidal channel 2,250 feet long with a left bench set three feet above the channel bed.
- Channel C would connect the C gate group to the Tule Canal and would be a rock-lined trapezoidal channel 1,930 feet long that connects to Channel AB at its bench.
- Channel D would connect the D gate group to the Tule Canal and would be a rock-lined trapezoidal channel 1,400 feet long that connects to Channel C.

Channel side slopes generally would be 3:1, and a 12-foot-wide maintenance access would be created on either side of each channel. From the point where all three channels are connected, the channel length would be about 8,500 feet to the connection with Tule Canal near Agricultural Road Crossing 1, with a gentle downhill slope (a slope of 0.00014).

4.8.1.5 Access Structures

The design of the gates in Alternative 5 includes an area of compacted fill that would allow vehicular passage (see Figure 4-20). Alternative 5 also includes two 200-foot-long, eight-foot-wide steel-trussed pedestrian bridges (see Figure 4-18) to allow recreational users to move through the area when inundation starts, similar to the other alternatives. Similar to Alternative 2, Alternative 5 includes stabilized access roads on the north and south sides of Fremont Weir.

4.8.1.6 Supplemental Fish Passage Facility

An additional fish passage facility would be constructed at a western location along the existing Fremont Weir. This facility would be the same as described for Alternative 1.

4.8.1.7 Tule Canal Floodplain Improvements (Program Level)

Alternative 5 would include floodplain improvements along Tule Canal, just north of I-80. These improvements would not be constructed at the same time as the remaining facilities. They would not be necessary for the project-level components to function but would enhance the performance of the overall alternatives. They are included at a program level of detail to consider all the potential impacts and benefits of Alternative 5. Subsequent consideration of environmental impacts would be necessary before construction could begin.

The floodplain improvements would develop a series of channels that connect to Tule Canal north of I-80 (see Figure 4-21). These channels would increase inundation and available fish-rearing habitat in the surrounding areas, which are currently managed as wetland habitat for waterfowl. The floodplain improvement channels would have a 30-foot-bottom width with 3:1 side slopes (horizontal to vertical). An operable weir in Tule Canal would help increase the water surface elevation upstream and move water into these channels. These improvements also include a bypass channel around the weir with a 10-foot-bottom width and 3:1 side slopes (horizontal to vertical). The bypass channel would be about 2,100 feet long and convey up to 300 cfs.

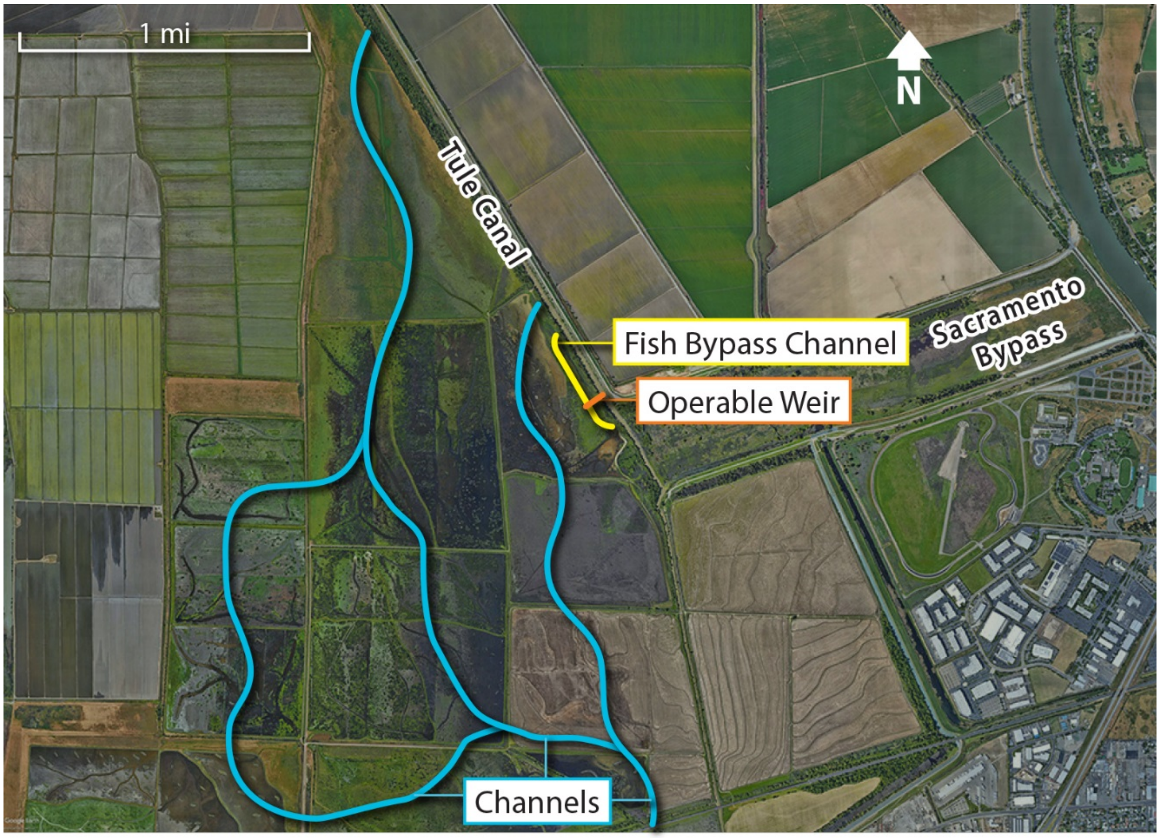


Figure 4-21. Tule Canal Floodplain Improvements (Program Level)

4.8.2 Construction Methods

Construction of the components of Alternative 5 would begin with the demolition of a portion of the existing concrete weir and the clearing and grubbing associated with the channels and canals. These activities are expected to be completed within eight weeks. Groundwater levels are anticipated to be high, especially in the spring months, so dewatering efforts prior to the construction of the floodway control and diversion structures are currently estimated to take three weeks. Additional dewatering would be required for the material removal and regrading at the bank of the Sacramento River near the intake channel.

Channel excavation would begin early in the construction efforts, with an estimated five construction crews working concurrently on the initial excavation. Grading efforts likely would start at the southern portion of the FWWA because groundwater levels would be deeper in this part of the construction area at the beginning of the construction season. With multiple crews, construction may proceed in multiple locations. The channel excavations would be completed under both dry and wet conditions (approximately 80 percent dry and 20 percent wet) and would not require dewatering efforts. Excavation of the downstream portion of the transport channel (near Agricultural Road Crossing 1) would be performed under wet conditions.

4.8.2.1 Excavated Material

Alternative 5 would require excavation of the intake channels, transport channels, and downstream facilities. Table 4-17 shows the estimated quantities of excess excavated material that would be generated from each facility and would require removal from the construction area.

Table 4-17. Estimated Excess Excavated Material Quantities for Alternative 5

Component	Estimated Excess Excavated Material (cubic yards)
Intake and Transport Channels	956,776
Headworks	28,710
Supplemental Fish Passage (West)	3,230
Agricultural Road Crossing 1	3,170
Sacramento River Bank Modification	44,523
Fremont Weir Access Road Excavation	4,961
TOTAL	*1,041,370*

In addition to the components included in Table 4-17, Alternative 5 could include additional Tule Canal floodplain grading (analyzed at a program level in this EIS/EIR, as described in Section 4.8.1.7). This Tule Canal floodplain grading would generate an estimated 1,053,970 cubic yards of material. If this element were constructed, the total excess materials would be 2,095,340 cubic yards.

Reclamation or DWR would purchase land within two miles of the edge of the Yolo Bypass to receive this excess material. Alternative 5 would require 69 to 79 acres of land to spoil excess construction-related materials.

4.8.2.2 Construction Materials

Material imported to the Project site would be obtained from existing permitted commercial sources located within approximately 65 miles of the Project site. These sites and the haul routes would be the same as described for Alternative 1.

4.8.2.3 Staging Areas and Access

The construction easements for Alternative 5 would encompass staging areas for equipment, mobilization, and spoiling sites. The construction footprints analyzed in this EIS/EIR include space for staging areas. After construction, staging areas would be returned to pre-construction condition. Site access would be on the same roads as described in Alternative 1. If the Tule Canal floodplain improvements are constructed, access would follow the same routes as described for the southern water control structure under Alternative 4.

4.8.2.4 Construction Equipment

A list of the major equipment needs for the construction of both the alternative-specific and common downstream channel improvement actions is provided in Table 4-18. Equipment specifics may vary based on the contractor's capabilities and the availability of equipment.

Table 4-18. List of Major Equipment Needed for Construction of Alternative 5

List of Major Equipment	
• 0.8-CY backhoe loaders	• 4.5-CY hydraulic excavator
• 1.5-CY front end loader crawler	• 40-TN truck-mounted hydraulic crane
• 10-TN smooth roller	• 4,000-gallon water truck
• 100-TN off highway trucks	• 450-HP dozer crawler
• 100-foot auger track-mounted drill rig	• 6-inch diameter pump engine drive
• 12-foot blade grader	• 75-TN crane crawler pile hammer
• 165-HP dozer	• Concrete mixer truck
• 2.5-CY hydraulic excavator	• Concrete pump boom, truck mounted
• 2.5-inch diameter concrete vibrator	• Extended boom pallet loader
• 24-TN truck end dump	• Flatbed truck
• 3.5-CY hydraulic excavator	• Haul truck oversize transport
• 3-axle haul trucks	• Hydroseeding truck
• 30-CY scrapers	• Pickup trucks, conventional
• 300-kW generator	

Key: CY = cubic yards; HP = horsepower; kW = kilowatt; TN = ton

4.8.2.5 Construction Schedule and Workers

Construction of Alternative 5 likely would begin in 2020 or 2021 and continue for two construction seasons. Construction in the first year is estimated to last 28 weeks and would be conducted during the non-flood season (construction from April 15 through November 1). No construction would occur after November 1, and efforts would continue for 13 weeks during the following year (after April 15).

Alternative 5 includes multiple headworks structures; construction of these structures would have the longest duration and would start at the beginning of the construction period. Construction would begin in the first season, but the final installation of operating gates and associated equipment would occur in the second season. After the first season of construction, the temporary cofferdam installed for dewatering of the headworks structure would remain in place through the flood season.

Construction would occur six days per week for 10 hours per day between 7 a.m. and 6 p.m. Construction workers would be divided into multiple crews and would work one shift per day. Maintenance and equipment upkeep crews would work on equipment at night when it is not in use. The peak number of construction workers, which would be needed for one week in July of the first season, is estimated to be 358.

4.8.3 Operations

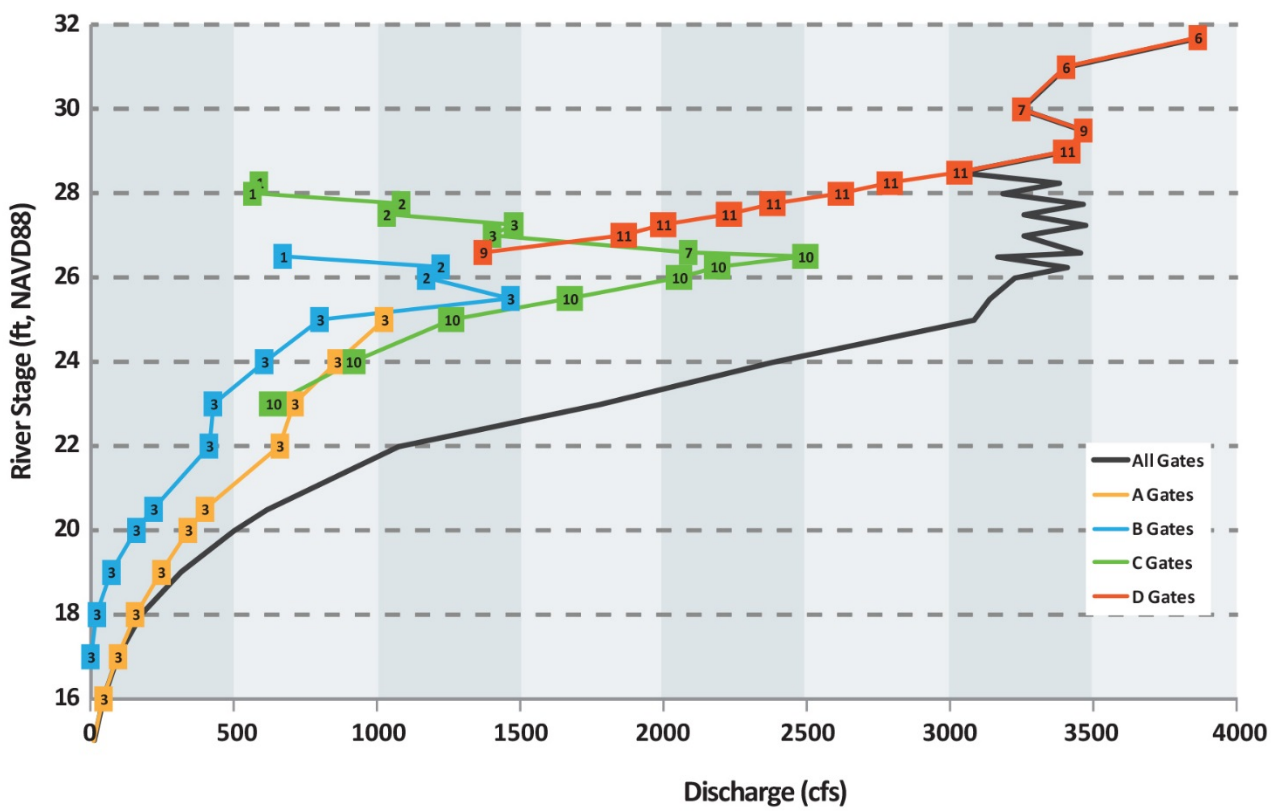
Operations of the notches would limit flows to about 3,400 cfs. Gate operations could begin each year on November 1 and would first open based on river conditions. The lowest intake (A gates) would operate from a Sacramento River elevation of 15 to 25 feet and would close at higher river elevations. The B gates would operate from 17 feet (i.e., the intake invert elevation) to 26.5 feet. Above 25.5 feet, some B gates would begin to close to reduce flows up to a river elevation of 26.6 feet when the last B gate is fully closed.

The C gates would start to operate as the B gates start to close. The C gates would operate from 23 to 28.25 feet. Above 26.5 feet, some C gates would begin to close to reduce flows through the gates up to a river elevation of 28.5 feet when the last C gate is fully closed.

The D gates would start to operate as the C gates start to close. The D gates would operate from 26.6 to 31.7 feet, which is just below the crest of Fremont Weir. Above 29 feet, the D gates would begin to close to restrict flows through the gates just prior to Fremont Weir overtopping. Because the velocities exceed fish passage criteria above 29 feet as flows approach 3,400 cfs, a minimum of six gates should remain open up to (and during) an overtopping event to prevent supercritical flow (rapid or unstable flow) within the culverts.

Note: Numbers show the numbers of gates open at one time

Figure 4-22 shows the overlap in the gate operations, with the number in each box showing the number of gates open at each time. The line indicating "all gates" shows the flow added together from all gates operating at the same time. Gate operations to increase inundation could continue through March 15 of each year, based on hydrologic conditions. The gates may remain partially open after March 15 to provide adult fish passage. However, flows through the gates after March 15 could not exceed the available capacity of Tule Canal (typically about 300 cfs) so that these flows do not inundate areas outside of the canal.



Note: Numbers show the numbers of gates open at one time

Figure 4-22. Alternative 5 Gate Operations

4.8.4 Inspection and Maintenance

Inspection and maintenance associated with Alternative 5 mainly would include sediment removal, facility inspections, and vegetation removal. As the river elevation rises, some components would no longer be accessible for maintenance. For river elevations greater than 28 feet, there would be no safe access to the headworks or bridges. Bridge guardrails would be removed before the river elevation reaches 28 feet. The installation of dewatering stoplogs could not be performed under any flow conditions. Table 4-19 provides a list of accessible components at varying river elevations.

Table 4-19. Maintenance Accessibility by River Elevation

River Elevation	Areas Accessible for Maintenance
Below 14 feet	All components of the headworks structures, bridges, gates (upstream and downstream), and operating components. Stoplogs could be installed.
14 to 20 feet (all gates closed)	Gates C and D are accessible; downstream components of Gates A and B, bridges, and operating components. Stoplogs could be installed.
14 to 20 feet (Gates A and B open)	Gates C and D are accessible and upstream bridge deck.
20 to 23 feet (all gates closed)	Gate D is accessible; downstream components of Gates A, B, and C; bridges; and operating components. Stoplogs could be installed.
20 to 23 feet (Gates A, B, and C partially or fully open)	Gate D is accessible and upstream bridge deck.
23 to 28 feet (all gates closed)	Downstream components of gates, bridges, and operating components. Stoplogs could be installed.
23 to 28 feet (gates partially or fully open)	Upstream bridge deck.
Above 28 feet	All components inaccessible.

4.8.4.1 Sediment Deposition

Estimates indicate that approximately 659,000 cubic yards of sediment enter the bypass annually under existing conditions. A portion of this sediment settles in the Yolo Bypass and must be removed through current maintenance efforts. Alternative 5 would increase sediment entering the bypass to a total of around 701,000 cubic yards annually. Most of the additional sediment (about 45 percent) would settle out in the FWWA, about 25 percent would settle south of Agricultural Road Crossing 1 but north of Interstate 80, and the remaining 30 percent of sediment would remain in suspension and flow out of the bypass. Most of the sediment that settles out would be removed through flood maintenance in the FWWA, as under existing conditions. Alternative 5 would accumulate an additional 18,900 cubic yards of sediment annually that would be removed every five years.

Reclamation and DWR would seek opportunities for practical reuse of the sediment removed, including partnerships with local landowners to receive the excess soils or other local construction projects that may need additional materials. Partnerships with local landowners would be for landowners that could use additional sediment on their fields to assist in their agricultural operations, not convert agricultural land to other purposes. If no options are available for reuse, Reclamation or DWR would purchase land outside the bypass for the sediment removed during maintenance actions. Reclamation and DWR would complete appropriate environmental compliance for this transaction if land acquisition is desired in the future for sediment removal.

4.8.4.2 Vegetation Removal

Periodic vegetation and debris removal from project channels would be the same as described for Alternative 1.

4.8.5 Monitoring and Adaptive Management

Monitoring activities and the adaptive management framework would be the same as described for Alternative 1.

4.8.6 Alternative 5 Preliminary Costs

Alternative 5 project facilities would be constructed within two years over two 28-week periods between April to October. Construction of Alternative 5 project facilities would cost approximately $96.3 million. The operations and maintenance cost for Alternative 5 would be approximately $1.04 million annually.

4.9 Alternative 6: West Side Large Gated Notch

Alternative 6, West Side Large Gated Notch, is a large notch in the western location that would allow flows up to 12,000 cfs to enter the Yolo Bypass. It was designed with the goal of entraining more fish while allowing more flow into the bypass when the Sacramento River is at lower elevations. Typically, winter-run Chinook salmon move downstream during the first high flow event of the season. This flow event is sometimes not high enough to result in what would be considered substantial flows into the bypass under Alternatives 1 through 5. The gated notch could allow more flow to enter during winter-run Chinook salmon out-migration, potentially maximizing fish entrainment. This alternative would include a supplemental fish passage facility on the eastern side of Fremont Weir and improvements to allow fish passage through Agricultural Road Crossing 1 and the channel north of Agricultural Road Crossing 1 (see Section 4.3). The alignment is the same as shown for Alternative 3 on Figure 4-8. Figure 4-23 shows the key components of Alternative 6 and the common elements described in Section 4.3.

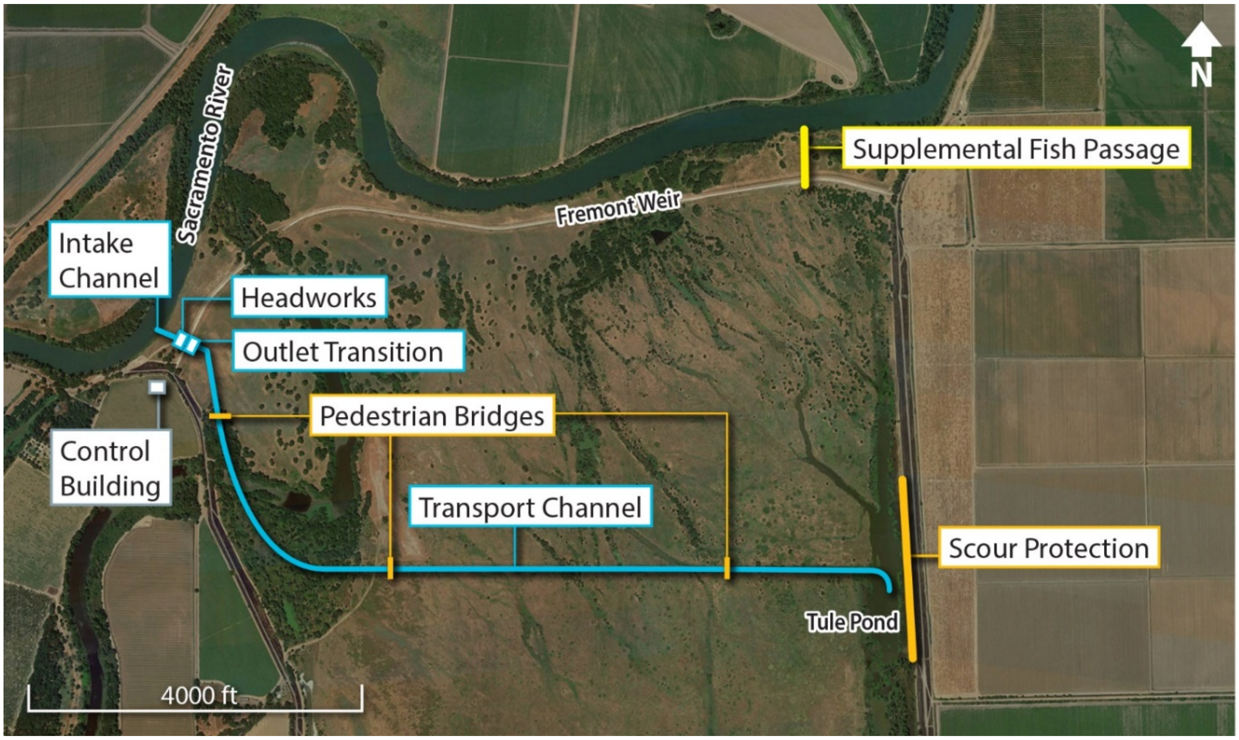


Figure 4-23. Alternative 6 Key Components

The next section includes descriptions of the facilities, construction methods, operations, required maintenance, and environmental commitments associated with this alternative. More detailed construction information is included in Appendix B of the EIS/EIR, *Constructability and Construction Considerations.*

4.9.1 Facilities

4.9.1.1 Intake Channel

The primary purpose of the intake channel is to draw juvenile salmonids and floodplain inundation flows from the Sacramento River to the new headworks structure (described in Section 4.9.1.2) and provide upstream adult fish passage between the headworks structure and the Sacramento River. The intake channel would be constructed with a 230-foot-bottom width. At the downstream end of the intake channel (near the headworks at Fremont Weir), there would be a short transition from the intake channel to the headworks. The intake channel would be rock-lined with rounded rock revetment on the channel bottom and angular rock revetment on the bank slopes to avoid scour. The transition would be constructed with concrete.

4.9.1.2 Headworks Structure

The headworks structure would control the diversion of flow from the Sacramento River to the Yolo Bypass. It would serve as the primary upstream fish passage facility for adult fish and the primary facility for conveying fish-rearing habitat flows and juvenile salmonids onto the Yolo Bypass.

The headworks structure would have five bays that are 40 feet wide and 13.1 feet high. The structure would be a pile-supported, reinforced concrete structure that would bisect the existing Fremont Weir at the western location. The invert elevation would be 16.1 feet. The structure would convey 12,000 cfs at a river elevation of 29.9 feet with all gates lowered (fully open) to meet the applicable requirements for fish passage and flood control. It would house five operating control gates and would include a concrete control structure, an upstream vehicular bridge crossing, and a concrete channel transition that transitions the rectangular sides of the control structure to the side channel slopes of the outlet channel. The overall structure would be 65 feet (upstream to downstream) by 230 feet.

Stoplogs would be provided at each of the five headworks bays upstream of the control structure to dewater the gates for maintenance and as a backup closure for the structure. Six stoplogs are required for each gate. Installation of the stoplogs would require a mobile crane capable of lifting approximately 10,000 pounds. Stoplogs would be stored off site and could only be installed or removed if no flow is moving through the notch or a small amount of flow that would not provide fish passage.

Five hydraulically operated, flush-mounted bottom hinge gates would be used in the headworks structure. These gates would be able to operate under variable river elevations and overtopping events. The top of gate elevation would be flush with the existing Fremont Weir (32 feet). The upstream face of the control gates would be approximately in-line with the upstream face of the existing Fremont Weir. When fully open, the gates would be flush with the channel invert. The gates would all be the same size, with an invert elevation of 16.1 feet and a size of 40 feet wide by 13.1 feet tall. Debris fins would be installed on the walls between gates to reduce debris accumulation.

The gates would open to allow a maximum flow of 12,000 cfs when the water surface elevation in the river reaches 29.9 feet. Each gate would be capable of independent operation via submersible hydraulic cylinders located beneath the gate. Mechanical and electrical control components for each gate would be housed in a control building outside of the bypass on the eastern levee. Figures 4-24 and 4-25 show the details of the headworks structure.

4.9.1.3 Control Building

The control building would be a single-story concrete masonry unit, measuring 18 feet by 18 feet, located on the western levee. The building would house the same equipment as described for Alternative 1.

4.9.1.4 Access Structures

The headworks bridge would be a reinforced concrete, five-span vehicular bridge on the upstream side of Fremont Weir to connect to the existing access road on the upstream side of Fremont Weir. The bridge would span the channels through the new headworks structure. The bridge would be built at nearly the same alignment and elevation as the existing upstream maintenance road and would allow for continued patrolling and maintenance access along the weir as currently exists. The bridge would have a roadway width of 14 feet and an overall width of 18 feet. The top curb elevation would be equal to the top of weir elevation.

View from river side of Fremont Weir

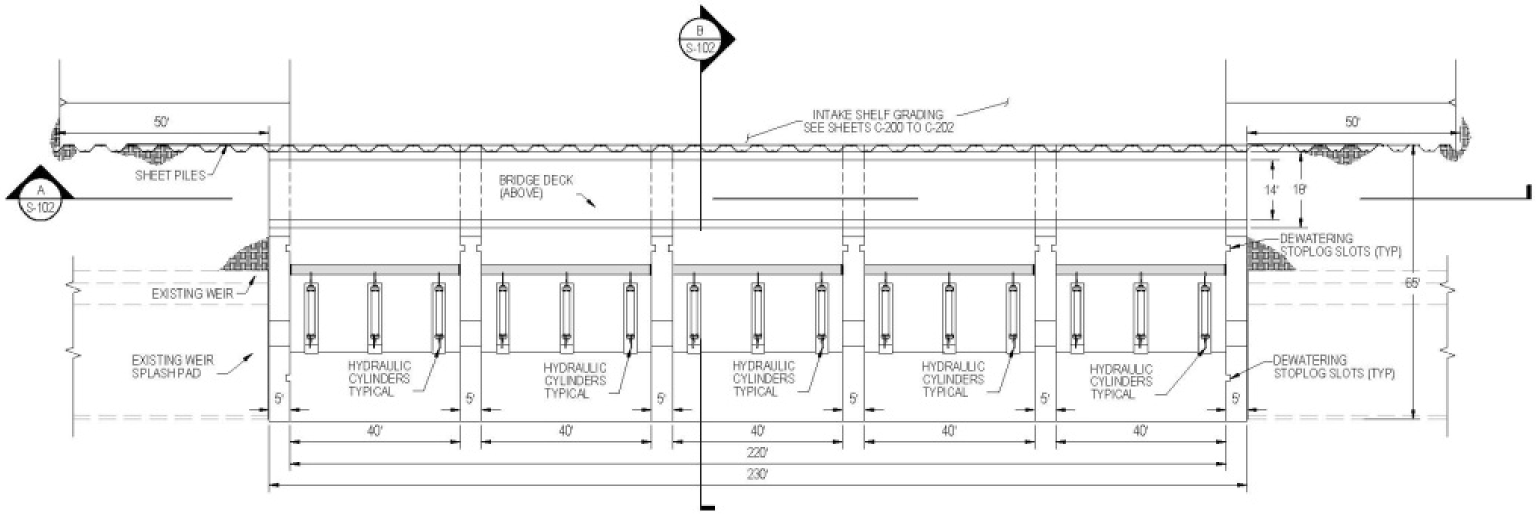


Figure 4-24. Alternative 6 Headworks Cross Section (view from river side)

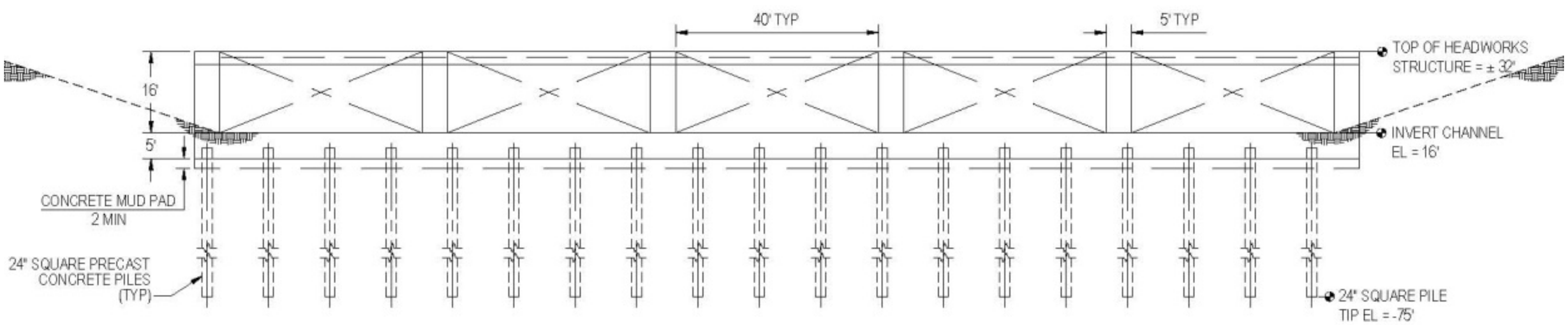


Figure 4-25. Alternative 6 Headworks (view from top of structure)

Temporary barrier rails (K rails) would be installed and removed such that no part of the bridge extends above the top of weir during an overtopping event. Each bridge span would be 40 feet long, with an end-to-end length of 230 feet.

The headworks bridge would provide a vehicular and pedestrian crossing on the north side of Fremont Weir. As discussed in Alternative 1, the channels south of Fremont Weir could be a barrier to access for recreational users in the Fremont Weir Wildlife Area. For this purpose, Alternative 6 includes three 310-foot-long, eight-foot-wide steel-trussed pedestrian bridges, as shown on Figure 4-23.

4.9.1.5 Outlet Transition

The outlet transition would be a 100-foot-long reinforced concrete channel that provides a gradual hydraulic transition from the headworks into the graded transport channel. The cross-section of the headworks includes five rectangular gates with an invert of 14 feet. The outlet transition would be a small structure that transitions from the headworks gates to the trapezoidal downstream transport channel. The transition would be accomplished with reinforced retaining walls that flair out from the headworks abutment piers and a reinforced concrete slab-on-grade bottom slab, which gradually transitions into the slopes of the trapezoidal transport channel.

4.9.1.6 Transport Channel

The transport (outlet) channel would be a graded trapezoidal channel with a bottom width of 200 feet and side slopes of 3:1 (horizontal to vertical). The transport channel would serve as the primary facility for upstream adult fish passage between the existing Tule Pond and the headworks structure. It would also serve as the primary channel for conveying juvenile salmonids and fish-rearing habitat flows from the headworks structure to the existing Tule Pond. Unlike the other transport channels, this channel would convey higher flows and does not need to incorporate benches to help meet velocity criteria. The channel route, length, and slope would be the same as in Alternative 3. The channel would be constructed through the oxbow wetland area in the same area as Alternative 3 so that it is not connected to this wetland area. At the top of each side of the channel, an eight-foot-wide area of rock (a rock key) would be added to reduce the potential for the channel to head cut the channel banks. The facility would also have 12-foot-wide maintenance corridors on each side of the channel.

4.9.1.7 Scour Protection

The transport channel would enter Tule Canal at an angle, which could cause erosion on the eastern Yolo Bypass levee. Rock revetment would be incorporated on the eastern edge of Tule Pond that is 50 feet wide and 2.5 feet thick, with 1.5:1 side slopes (horizontal to vertical). Additionally, there are several locations along the proposed transport channel where the channel could interact with existing scour channels. These areas could experience head cutting as a result of the new facilities. Additional channel revetment would be incorporated at these locations.

4.9.1.8 Supplemental Fish Passage Facility

Alternative 6 would include the same eastern supplemental fish passage facility as described for Alternative 3.

4.9.2 Construction Methods

Construction of the components of Alternative 6 would begin with the demolition of a portion of the existing Fremont Weir and the clearing and grubbing associated with the channels and canals. These activities are expected to be completed within four weeks.

Grading of the transport channel would begin at the downstream outlet at Tule Pond and progress upstream toward the headworks structure, with grading of the intake channel occurring last. This would avoid potential interruptions to the headworks construction and allow construction to occur in the less saturated soil first. Groundwater levels are anticipated to be high, so dewatering efforts prior to the construction of the floodway control and diversion structures are currently estimated to take three weeks. The channel and canal excavations would be completed under both dry and wet conditions and would not require dewatering efforts. Excavation of the downstream reach would be performed under wet conditions. About 60 to 80 percent of the channel excavation could be performed in dry unsaturated soil conditions by scrapers and bulldozers. The remaining 20 to 40 percent would be performed in wet saturated soil conditions by hydraulic excavators and haul trucks.

4.9.2.1 Excavated Material

Alternative 6 would require excavation of the intake channel, transport channel, and downstream facilities. Table 4-20 shows the estimated quantities of excess excavated material that would be generated from each facility and would require removal from the construction area.

Table 4-20. Estimated Excess Excavated Material Quantities for Alternative 6

Component	Estimated Excess Excavated Material (cubic yards)
West Intake Channel	65,710
West Transport Channel	1,552,990
Headworks	12,750
Downstream Channel	72,520
Supplemental Fish Passage (East)	3,540
Agricultural Road Crossing 1	3,170
TOTAL	*1,710,680*

Reclamation or DWR would purchase land within two miles of the edge of the Yolo Bypass to receive this excess material. Alternative 6 would require 35 to 40 acres of land to spoil excess construction-related materials.

4.9.2.2 Construction Materials

Material imported to the Project site would be obtained from existing permitted commercial sources located within approximately 65 miles of the Project site. These sites and the haul routes would be the same as described for Alternative 1.

4.9.2.3 Staging Areas and Access

The construction easements for Alternative 6 would encompass staging areas for equipment, mobilization, and spoiling sites. The construction footprints analyzed in this EIS/EIR include space for staging areas. After construction, staging areas would be returned to pre-construction condition. Site access would be on the same roads as described for Alternative 1.

4.9.2.4 Construction Equipment

A list of the major equipment needs for the construction of both the alternative-specific and common downstream channel improvement actions is provided in Table 4-21. Equipment specifics may vary based on the contractor's capabilities and the availability of equipment.

Table 4-21. List of Major Equipment Needed for Construction of Alternative 6

List of Major Equipment	
• 0.8-CY backhoe loaders	• 4.5-CY hydraulic excavator
• 1.5-CY front end loader crawler	• 40-TN truck-mounted hydraulic crane
• 10-TN smooth roller	• 4,000-gallon water truck
• 100-TN off highway trucks	• 450-HP dozer crawler
• 100-foot auger track-mounted drill rig	• 6-inch diameter pump engine drive
• 12-foot blade grader	• 75-TN crane crawler pile hammer
• 165-HP dozer	• Concrete mixer truck
• 2.5-CY hydraulic excavator	• Concrete pump boom, truck mounted
• 2.5-inch diameter concrete vibrator	• Extended boom pallet loader
• 24-TN truck end dump	• Flatbed truck
• 3.5-CY hydraulic excavator	• Haul truck oversize transport
• 3-axle haul trucks	• Hydroseeding truck
• 30-CY scrapers	• Pickup trucks, conventional
• 300-kW generator	

Key: CY = cubic yards; HP = horsepower; kW = kilowatt; TN = ton

4.9.2.5 Construction Schedule and Workers

Construction of Alternative 6 likely would begin in 2020 or 2021 and is estimated to last a total of 28 weeks. Construction is anticipated to be completed in multiple construction seasons (construction from April 15 to November 1). Construction of the headworks structure would have the longest duration and would start at the beginning of the construction period. Construction of channel improvements would commence the same week as the Alternative 6 construction activities.

Construction would occur six days per week for 10 hours per day between 7 a.m. and 6 p.m. Construction workers would be divided into multiple crews and would work one shift per day. Maintenance and equipment upkeep crews would work on equipment at night when it is not in use. The peak number of construction workers, which would be needed for one week in the middle of August, is estimated to be 414.

4.9.3 Operations

Alternative 6 would be operated much the same as Alternatives 1 through 3 but would allow flows of up to 12,000 cfs, rather than limiting them to 6,000 cfs. Gate operations could begin each year on November 1 and would first open based on river conditions. All gates would be opened when the river elevation reaches 17.1 feet, which is one foot above the lowest gate invert. If the river continues to rise, the gates would stay open until the flow through the gates reaches 12,000 cfs. The flow through the gates would reach 12,000 cfs when the river elevation is about

29.8 feet; at this point, three of the gates would be programmed to start closing such that 12,000 cfs would not be exceeded. Gate closures would be controlled so that there is not a sudden reduction in flow. Two of the gates would remain fully open throughout operations.

Once Fremont Weir begins to overtop, the three gates being operated would remain in their last position prior to the weir overtopping (generally they would be closed at this point). After the overtopping event is over, the three operating gates would open and close as needed to keep the flow through the gate below, but as close as possible to, 12,000 cfs. All gates would be closed once river elevations fall below 16.1 feet. Gate operations to increase inundation could continue through March 15 of each year, based on hydrologic conditions. The gates may remain partially open after March 15 to provide fish passage. However, flows through the gates after March 15 could not exceed the available capacity of Tule Canal (typically about 300 cfs) so that these flows do not inundate areas outside of the canal and affect landowners.

4.9.4 Inspection and Maintenance

Inspection and maintenance associated with this alternative would mainly include sediment removal, facility inspections, and vegetation removal. Inspection and maintenance would be the same as described for Alternative 1.

4.9.4.1 Sediment Deposition

Estimates indicate that approximately 659,000 cubic yards of sediment enters the bypass annually under existing conditions. A portion of this sediment settles in the Yolo Bypass and must be removed through current maintenance efforts. Alternative 6 would increase sediment entering the bypass to an estimated total of 827,000 cubic yards annually Most of the additional sediment (about 45 percent) would settle out in the FWWA, about 25 percent would settle south of Agricultural Road Crossing 1 but north of Interstate 80, and the remaining 30 percent of sediment would remain in suspension and flow out of the bypass. Most of the sediment that settles out would be removed through flood maintenance in the FWWA, as under existing conditions. The additional deposition would be in areas inundated regularly under Alternative 6 (in and around channels), and sediment removal efforts associated with Alternative 6 would focus on the channel system. Alternative 6 would accumulate an additional 75,600 cubic yards of sediment annually that would be removed every five years.

Reclamation and DWR would seek opportunities for practical reuse of the sediment removed, including partnerships with local landowners to receive the excess soils or other local construction projects that may need additional materials. Partnerships with local landowners would be for landowners that could use additional sediment on their fields to assist in their agricultural operations, not convert agricultural land to other purposes. If no options are available for reuse, Reclamation or DWR would purchase land outside the bypass for the sediment removed during maintenance actions. . Reclamation and DWR would complete appropriate environmental compliance for this transaction if land acquisition is desired in the future for sediment removal.

4.9.5 Monitoring and Adaptive Management

Monitoring activities and the adaptive management framework would be the same as described for Alternative 1.

4.9.6 Alternative 6 Preliminary Costs

Alternative 6 project facilities would be constructed within one year over a 28-week period between April to October. Construction of Alternative 6 project facilities would cost approximately $111.6 million. The operations and maintenance cost for Alternative 6 would be approximately $1.1 million annually.

4.10 References

DWR (California Department of Water Resources). 2017. *Adult fish passage criteria for federally listed species within the Yolo Bypass and Sacramento River*. Technical memorandum for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project. Sacramento, California.

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5 Evaluation and Comparison of Alternatives

An important element of the plan formulation process is the evaluation and comparison of alternatives. This chapter presents results of this evaluation and comparison of the alternatives consistent with the standards outlined in the PR&Gs for planning and water resources-related projects. The alternatives summarized in Chapter 4 is in comparison to existing conditions.

5.1 Evaluation Factors

The evaluation factors presented in Chapter 3 were revised after the initial screening based on feedback from agencies and stakeholders. Table 5-1 shows the revised evaluation factors and the tools used to assess each factor in this detailed alternatives analysis.

Table 5-1. Alternative Evaluation Factors

Federal Planning Criterion	Category	Evaluation Factor	Method to Measure Performance
Effectiveness: How well an alternative would alleviate problems and achieve opportunities	Increase access to floodplain habitat	Measure connectivity and potential to entrain winter-run Chinook onto floodplain	Entrainment model
		Measure connectivity and potential to entrain spring-run Chinook onto floodplain	Entrainment model
	Increase seasonal floodplain fisheries rearing habitat	Percent increase in winter-run Chinook escapement	Juvenile floodplain production model
		Percent increase in spring-run Chinook escapement	Juvenile floodplain production model
	Increase area of floodplain habitat	Inundation area (area inundated at least 14 days in 50 percent of years)	TUFLOW model
	Increase duration of flooded habitat	Wetted acre-days when fish are likely present	TUFLOW model
	Increase food production as part of ecosystem approach	Increase in food production	Qualitative assessment
	Adult fish passage	Days with depth barrier to adult volitional passage	Fish passage tool
		Days with velocity barrier to adult volitional passage	Fish passage tool
		Operational range for adult fish passage	Fish passage tool

Federal Planning Criterion	Category	Evaluation Factor	Method to Measure Performance
		Percent of season that meets adult fish passage criteria	Fish passage tool
		Fish passage facilities incorporate open channel flow	Qualitative assessment of number of fish passage facilities to provide passage and complexity of operations between passage facilities
	Juvenile fish passage	Potential for juvenile stranding or predation risk	Qualitative assessment of need for complex mechanized operation
Completeness: Whether an alternative would account for all investments or other actions necessary to realize the planned efforts	Provide complete fish benefits	Addresses all four focus fish	Qualitative assessment
		Long-term stability of facilities	Qualitative assessment of maintenance requirements
Acceptability: The viability of an alternative with respect to acceptance by other Federal, (State, and local entities and compatibility with existing laws	Agricultural impacts	Inundation effects on agricultural production	Bypass Production Model
		Inundation effects on winter maintenance activities (increased wetted acre-days)	TUFLOW model
	Recreation impacts	Inundation of recreational areas that could impact hunting activities	TUFLOW model
	Waterfowl impacts	Available foraging habitat	TUFLOW model
		Inundation of areas that reduce waterfowl food production	TUFLOW model
		Impacts to road access for bird viewing in refuge	TUFLOW model
		Impacts to refuge drainage	Qualitative assessment
	Education impacts	Inundation of areas used for educational outreach	TUFLOW model
	Biological impacts	Impacts from construction (benefits addressed under “effectiveness” criterion)	Qualitative assessment

Federal Planning Criterion	Category	Evaluation Factor	Method to Measure Performance
	Cultural impacts	Potential to encounter unexpected resources	Qualitative assessment
	Flood impacts	Potential to affect flood management or operations and maintenance	TUFLOW model and qualitative assessment (for operations and maintenance)
	Water supply impacts	Potential to affect agricultural or municipal water supplies	Qualitative assessment
		Potential to affect groundwater resources	TUFLOW model
		Potential to affect Delta diversions or a future WaterFix facility	CalSim
	Compatibility with other related efforts	Potential to affect future options or costs for other flood and restoration planning efforts	Qualitative assessment
Efficiency: How well an alternative would deliver economic benefits relative to project costs	Cost-effectiveness	Relative benefits and costs	Rough cost estimates compared to benefits

5.2 Alternatives Evaluation and Comparison

Consistent with the standards for formulating and evaluating alternatives for planning and water resource-related projects outlined in the PR&Gs, the evaluation and comparison of alternatives in this report relies on the Federal planning criteria of completeness, effectiveness, acceptability, and efficiency. The alternatives in Chapter 4 were compared and evaluated using the criteria described below. All evaluations were completed quantitatively when possible. For criteria that could not be completed quantitatively, a qualitative analysis was provided.

5.2.1 Effectiveness

The effectiveness criterion addresses how well an alternative plan would alleviate problems and achieve opportunities. The evaluation factors for this criterion quantitatively and qualitatively compare how well each alternative plan achieves the components of the purpose and need/project objectives.

As discussed in Chapter 1, the main objective of this project is to alleviate the decline in fish population by providing increased inundation and fish passage. The effectiveness sub-criterion discussed in Table 5-2 quantifies the degree to which each alternative meets this objective.

Table 5-2. Effectiveness Evaluation Results

Category	Evaluation Factor	Alternative 1	Alternative 2	Alternative 3	Alternative 4 March 7 closure	Alternative 4 March 15 closure	Alternative 5	Alternative 6
Increase access to floodplain habitat	Increase in entrainment of winter-run Chinook onto floodplain[1]	+7.4%	+7.4%	+7.4%	+5.6%	+5.6%	+5.8%	+13.4%
	Increase in entrainment of spring-run Chinook onto floodplain[1]	+7.3%	+7.3%	+7.3%	+5.3%	+5.3%	+5.8%	+13.0%
Increase seasonal floodplain fisheries rearing habitat	Percent increase in winter-run Chinook escapement[2]	+8.0%	+8.0%	+8.0%	+6.2%	+6.1%	+6.5%	+13.4%
	Percent increase in spring-run Chinook escapement[2]	+6.0%	+6.0%	+6.0%	+4.5%	+4.4%	+4.9%	+9.5%
Increase area of floodplain habitat	Number of times that at least 20,000 acres would be inundated at least 14 consecutive days over the 16-year modeling period[3]	Alt 1 has 14 occurrences, existing conditions have 8 occurrences	Alt 2 has 14 occurrences, existing conditions have 8 occurrences	Alt 3 has 14 occurrences, existing conditions have 8 occurrences	Alt 4 has 14 occurrences, existing conditions have 8 occurrences	Alt 4 has 14 occurrences, existing conditions have 8 occurrences	Alt 5 has 13 occurrences, existing conditions have 8 occurrences	Alt 6 has 15 occurrences, existing conditions have 8 occurrences
Increase duration of flooded habitat	Wetted acre-days[6] when fish are likely present[4]	4,448,723 wetted acre-days	4,448,723 wetted acre-day	4,448,723 wetted acre-day	6,308,138 wetted acre-days	6,856,744 wetted acre-days	3,979,693 wetted acre-days	7,015,298 wetted acre-days
Increase food production as part of ecosystem approach	Increase in food production	Medium	Medium	Medium	High	High	Low	High

[6] Wetted acre-days is cumulative daily acres inundated in the Yolo Bypass. The data are presented as the difference between the alternatives and existing conditions.

Category	Evaluation Factor	Alternative 1	Alternative 2	Alternative 3	Alternative 4 March 7 closure	Alternative 4 March 15 closure	Alternative 5	Alternative 6
Adult fish passage	Days with depth barrier to adult volitional passage from November through April[5]	107 ± 41 days	108 ± 41 days	109 ± 41 days	109 ± 41 days	109 ± 41 days	106 ± 41 days	111 ± 41 days
	Days with velocity barrier to adult volitional passage from November through April[5]	32 ± 31 days	31 ± 30 days	30 ± 29 days	39 ± 32 days	39 ± 32 days	32 ± 31 days	36 ± 34 days
	Operational range for adult fish passage[5]	21.14–29.92 feet	21.20–30.57 feet	21.25–30.87 feet	21.25–26.73 feet	21.25–26.73 feet	21.71–30.80 feet	21.12–28.30 feet
	Percent of season that meets adult fish passage criteria[5]	23%	23%	23%	18%	18%	24%	19%
	Fish passage facilities incorporate open channel flow and conditions that support fish passage[5]	Medium	Medium	Medium	Medium	Medium	Low	Low
Juvenile fish passage	Potential for juvenile stranding or predation risk	Medium	Medium	Medium	High	High	Medium	Medium

Source:

[1] DWR 2017a

[2] Hinkelman et al. 2017

[3] TUFLOW modeling results

[4] TUFLOW modeling results

[5] DWR 2017b

5.2.1.1 Access to Floodplain Habitat

Fisheries rearing habitat would only benefit fish if they have access to this habitat. Entrainment onto the Yolo Bypass estimates the number of fish that flow through the gated notch (or over Fremont Weir). The Lead Agencies used several methods to estimate juvenile entrainment: the Juvenile Entrainment Evaluation Tool (JEET), the Eulerian-Lagrangian Agent Method (ELAM) fish model, and a critical streakline analysis. The JEET analysis considered the proportion of flow that would enter the Yolo Bypass from the river and the fish present at that time of year (based on monitoring data from the Knights Landing rotary screw trap) and assumed that the fish entering the bypass would be proportional to the flow. The ELAM model applied a fish behavior tool to assess the differences between fish entrainment. The critical streakline tool identified a line that divided the portion of the river flow that would stay in the river and the portion that would enter the bypass, and estimated that fish within the portion of the river that would enter the bypass (based on monitoring data) would also enter the bypass with that flow. The results from these tools are included on Figures 5-1, 5-2, and 5-3, respectively.

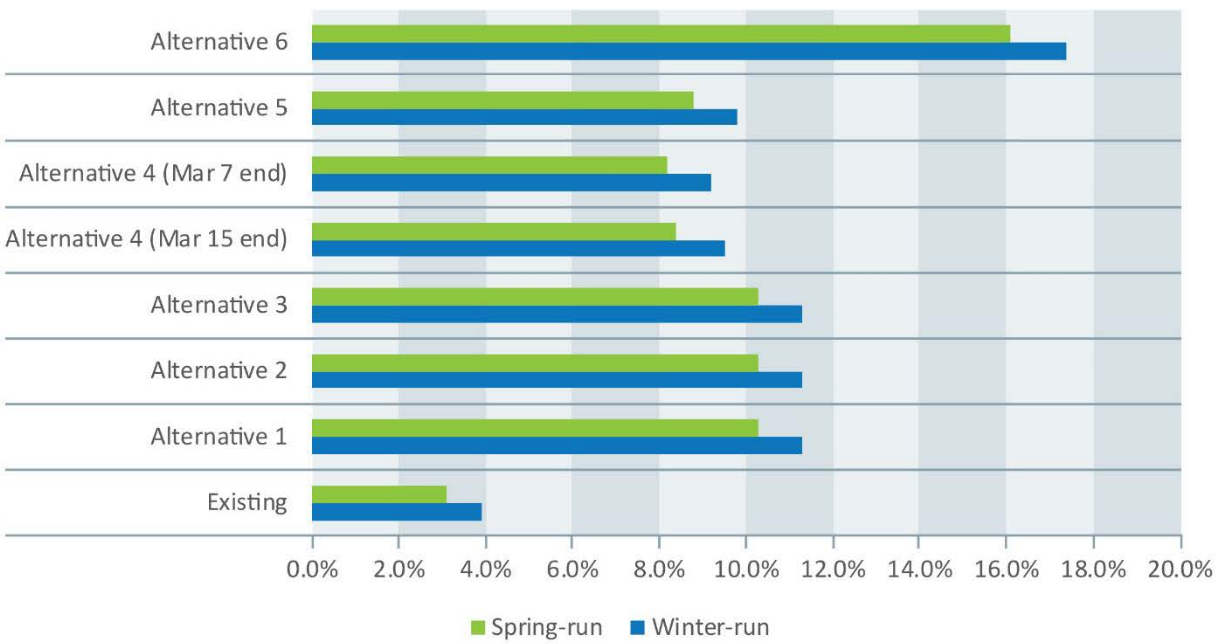

Figure 5-1. JEET Estimate of Juvenile Fish Entrainment

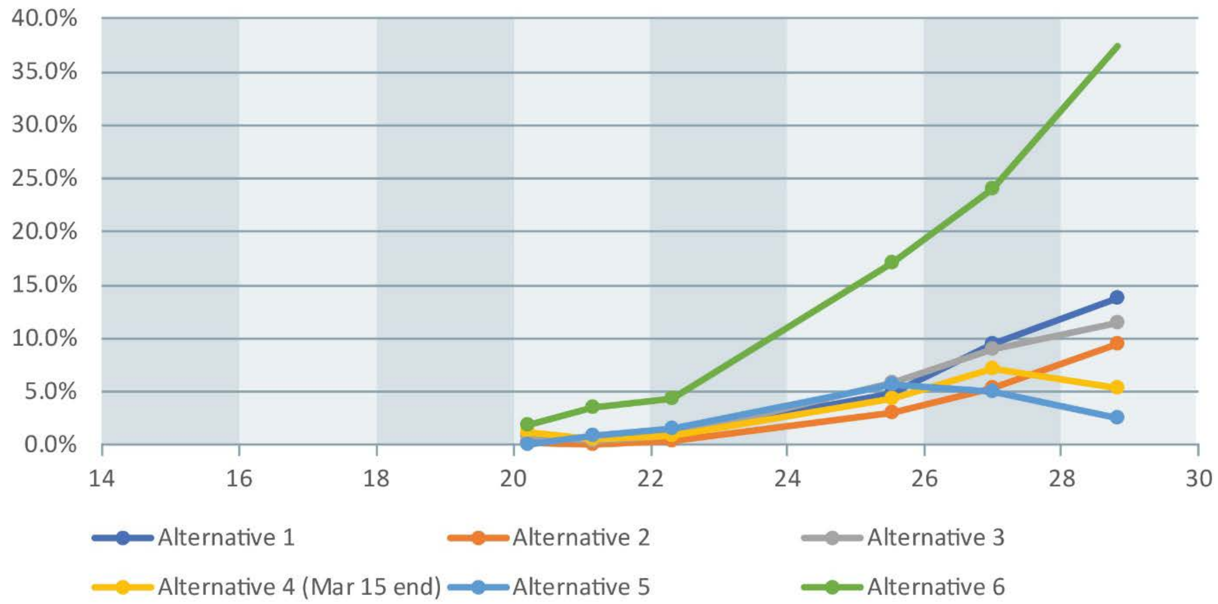

Figure 5-2. ELAM Model Estimate of Juvenile Fish Entrainment

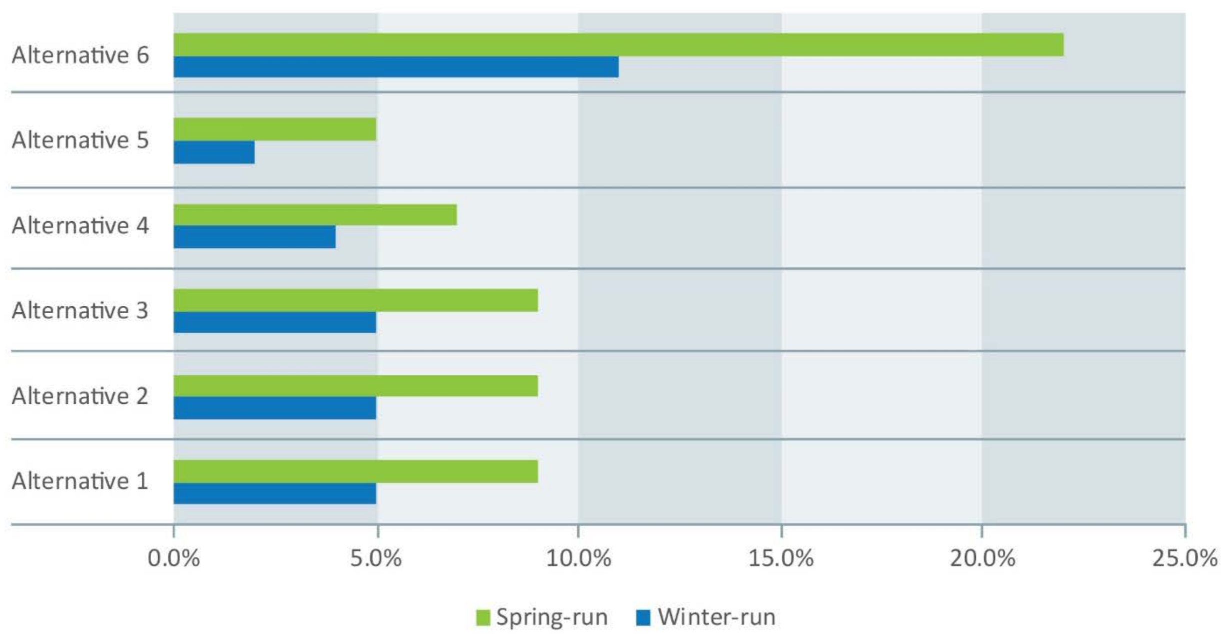

Figure 5-3. Critical Streakline Estimate of Juvenile Fish Entrainment

In addition to these analyses of all juvenile fish, there was additional study of fry entrainment. Fry are of a size that would benefit from increased floodplain rearing opportunities, and the analysis uses the JEET tool to assess the differences in fry entrainment between alternatives. Figure 5-4 shows the results for fry up to 60 mm FL. The analysis also considered up to 70 and 80 mm FL, but the trends were similar to Figure 5-4.

Figure 5-4. JEET Estimate of Fry Entrainment (up to 60 mm FL)

While the absolute numbers for entrainment vary between assessment tools, the trends are similar. All three tools indicate that Alternative 6 would have the highest entrainment because it would have the highest flow entering the Yolo Bypass through the gated notch. Generally, Alternatives 4 and 5 have the lowest entrainment, which is also related to the lower flows entering the Yolo Bypass through the gated notch. Alternatives 1, 2, and 3 have medium entrainment and fall between the other alternatives.

5.2.1.2 Seasonal Floodplain Fisheries Rearing Habitat

The purpose of increasing floodplain rearing habitat is to help fish grow before they enter the Delta and the ocean, which increases their chances of survival. Escapement indicates the adult fish that return to their freshwater spawning habitat. The purpose of the project is to improve conditions so that more fish are able to survive, return, and spawn. As shown on Figures 5-5 and 5-6, the action alternatives all improve average escapement for winter-run and spring-run Chinook salmon. Alternative 6 would have the greatest improvement because the increased flow through the gated notch would bring more fish into the bypass to benefit from the floodplain, and the larger inundated area would provide more opportunity for the fish to grow. Alternatives 4 and 5 would improve conditions for fish, but would have smaller benefits than the other alternatives because they would bring fewer fish into the bypass to benefit from the floodplain.

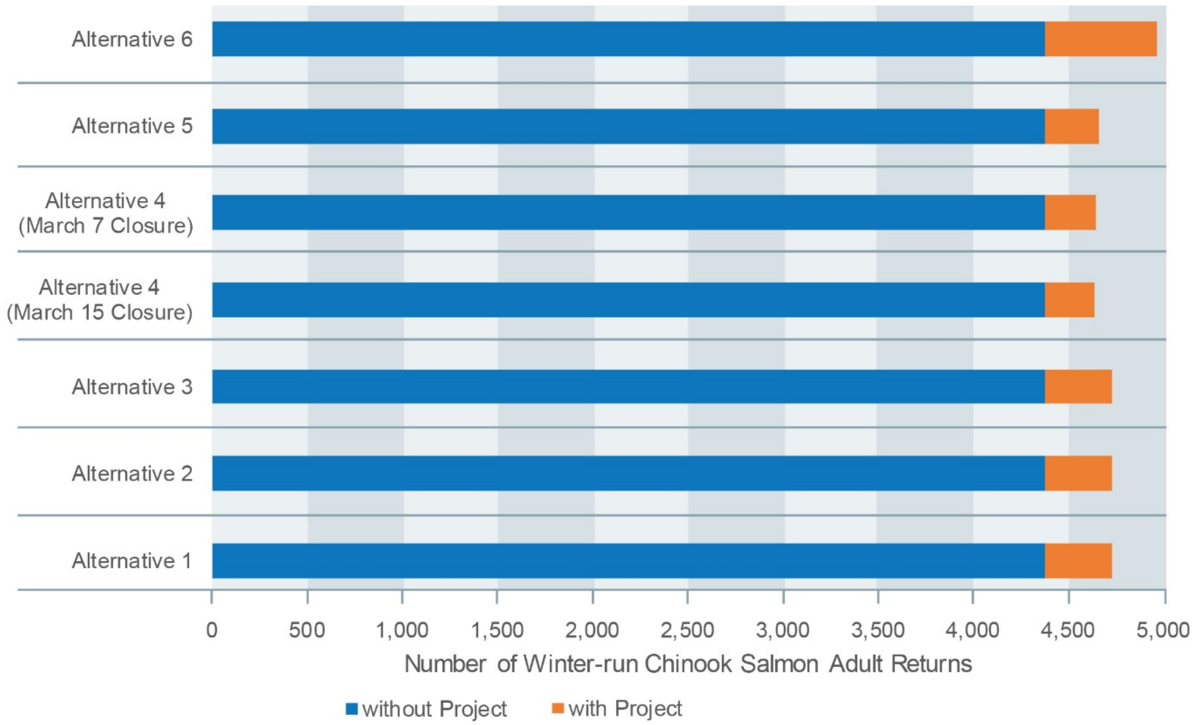

Figure 5-5. Average Change in Returns for Winter-Run Chinook Salmon

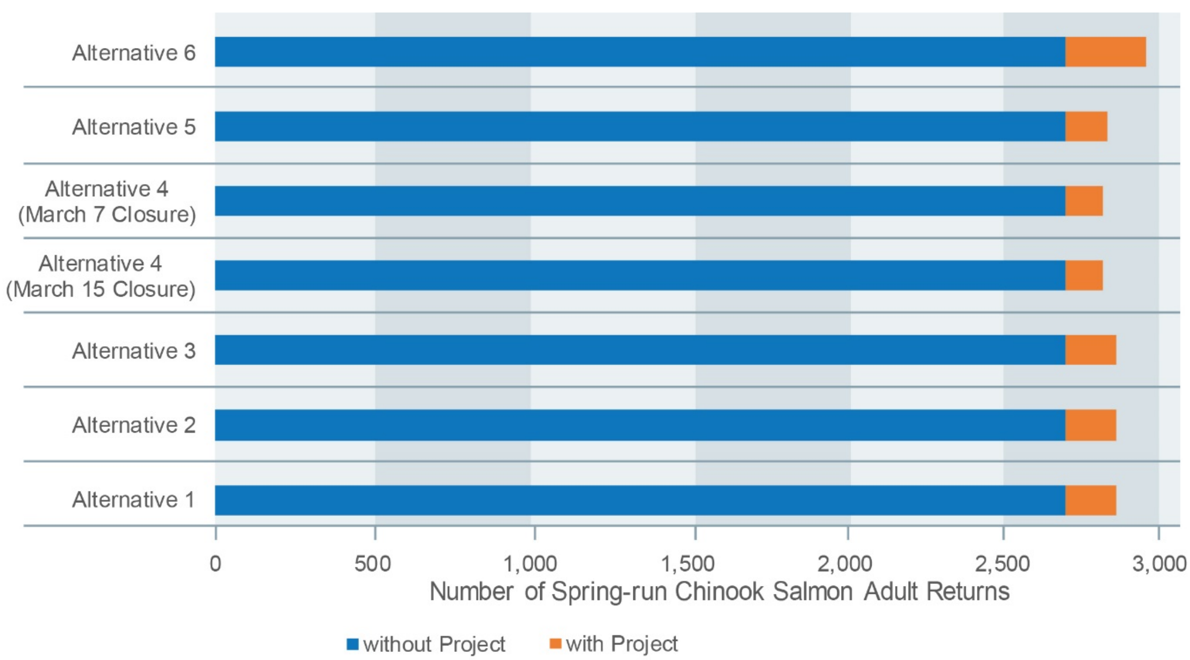

Figure 5-6. Average Change in Returns for Spring-Run Chinook Salmon

5.2.1.3 Area of Floodplain Habitat

The area of inundated floodplain habitat provides and indicator of project effectiveness in providing fisheries rearing habitat. All action alternatives increase inundated area in the Yolo Bypass. Figures 5-7 and 5-8 show the number of times that 10,000 acres and 20,000 acres, respectively, are inundated for at least 14 days during the 16-year period in the model. This analysis shows that Alternative 6 provides the greatest increase because it has the largest flows entering through the Fremont Weir gated notch. Alternatives 1, 2, 3, and 4 have the next highest increase in floodplain habitat.

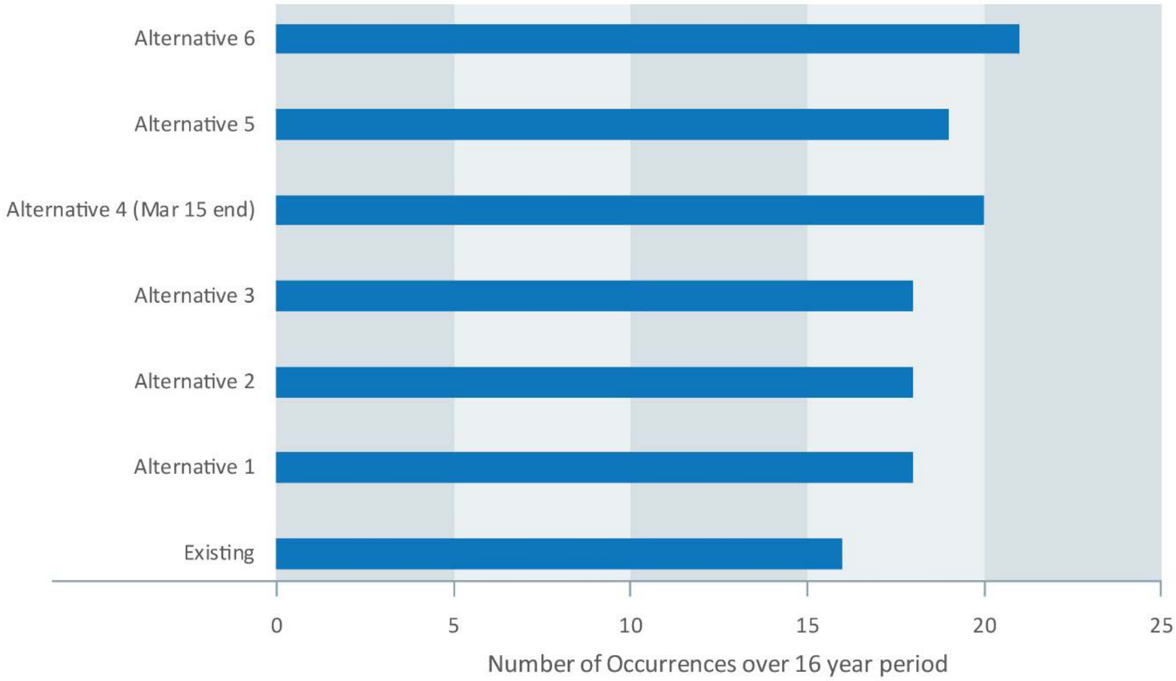

Figure 5-7. Number of Occurrences of 14 Consecutive Days with Greater than 10,000 Acres Inundated

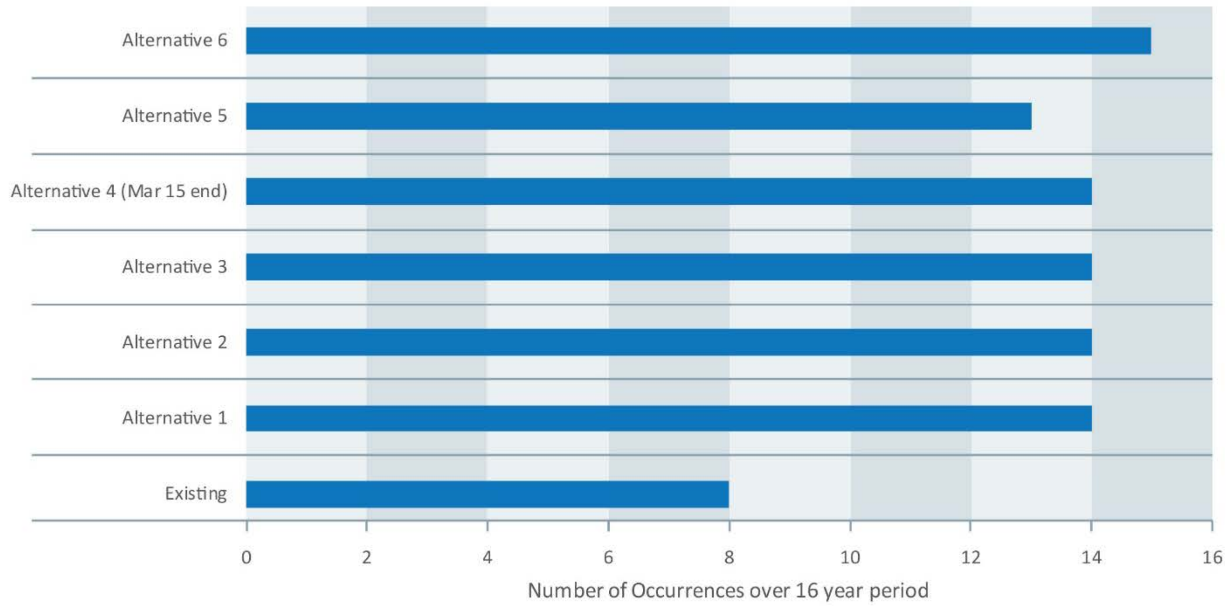

Figure 5-8. Number of Occurrences of 14 Consecutive Days with Greater than 20,000 Acres Inundated

5.2.1.4 Duration of Flooded Habitat

The duration of flooded habitat also provides an indicator of the project effectiveness in providing fisheries rearing habitat. Increased flow into the bypass under all action alternatives would increase the duration of inundation in the bypass. This factor is measured by considering the increase in wetted acre-days, which estimates how many days each acre is wet in the Yolo Bypass over the 16-year simulation period (1997 to 2012). Figure 5-9 shows the increase in wetted acre-days as a total for the entire simulation period, and Figures 5-10, 5-11, and 5-12 show existing and increased wetted acre-days for a wet year, normal year, and dry year. The highest increase is for Alternative 6, which has the largest flows entering through the Fremont Weir gated notch. The second highest increase is for Alternative 4 with the March 15 closure date, which includes water control structures to maintain water on the floodplain for longer periods. Alternative 4 also exceeds the performance of Alternative 6 during drier years.

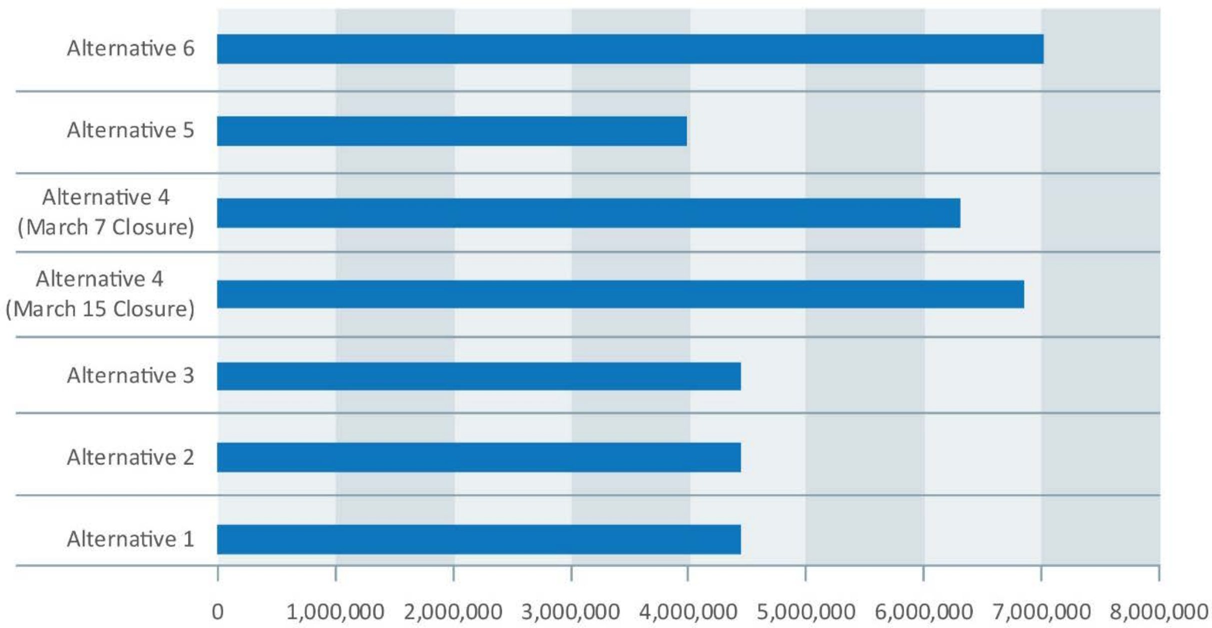

Figure 5-9. Increase in Wetted Acre-Days During the 16-Year Model Period

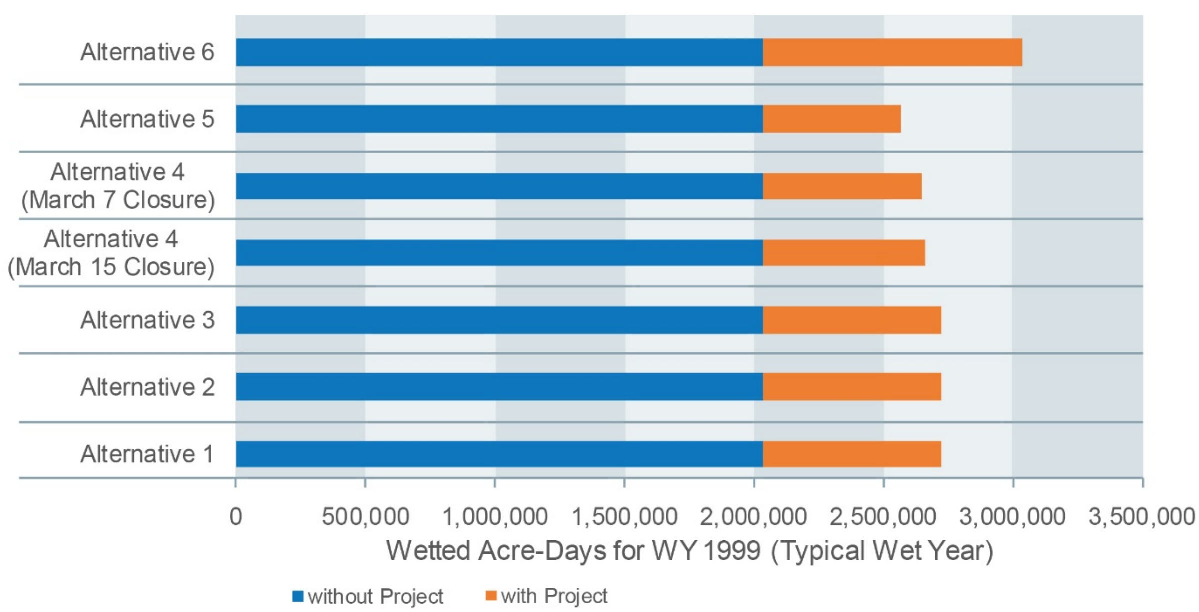

Figure 5-10. Increase in Wetted Acre-Days During a Wet Year

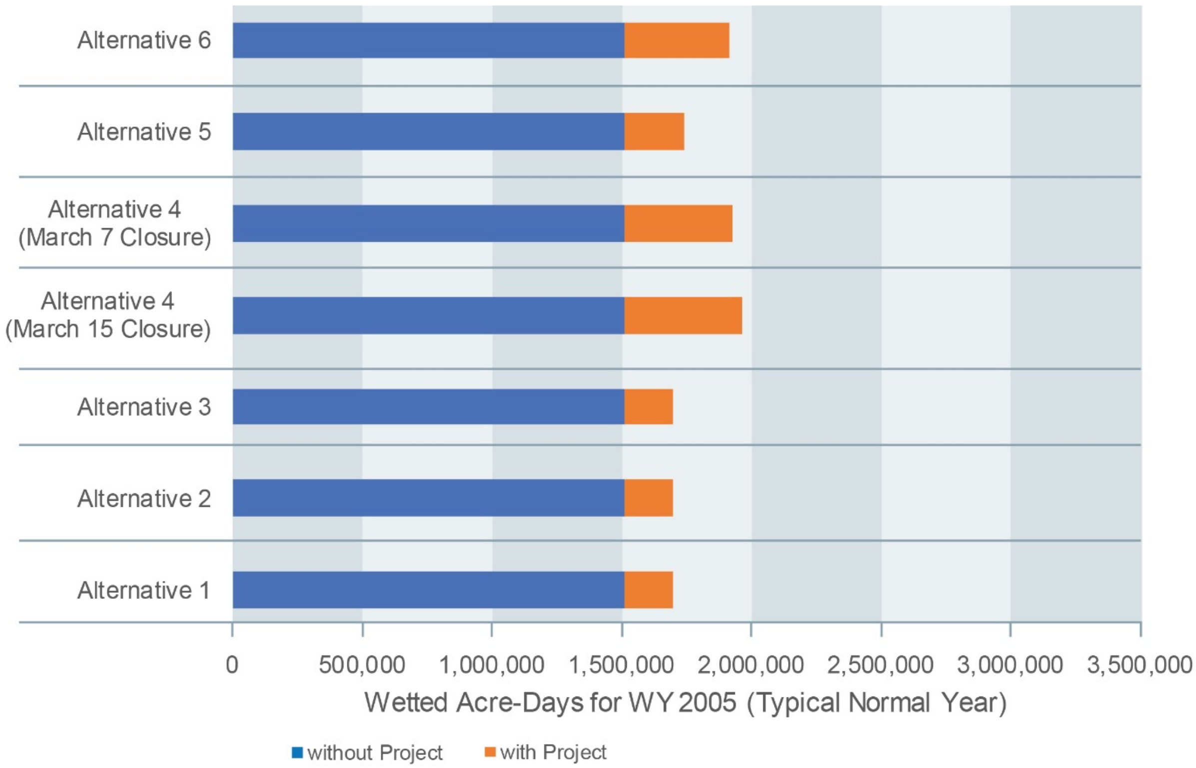

Figure 5-11. Increase in Wetted Acre-Days During a Normal Year

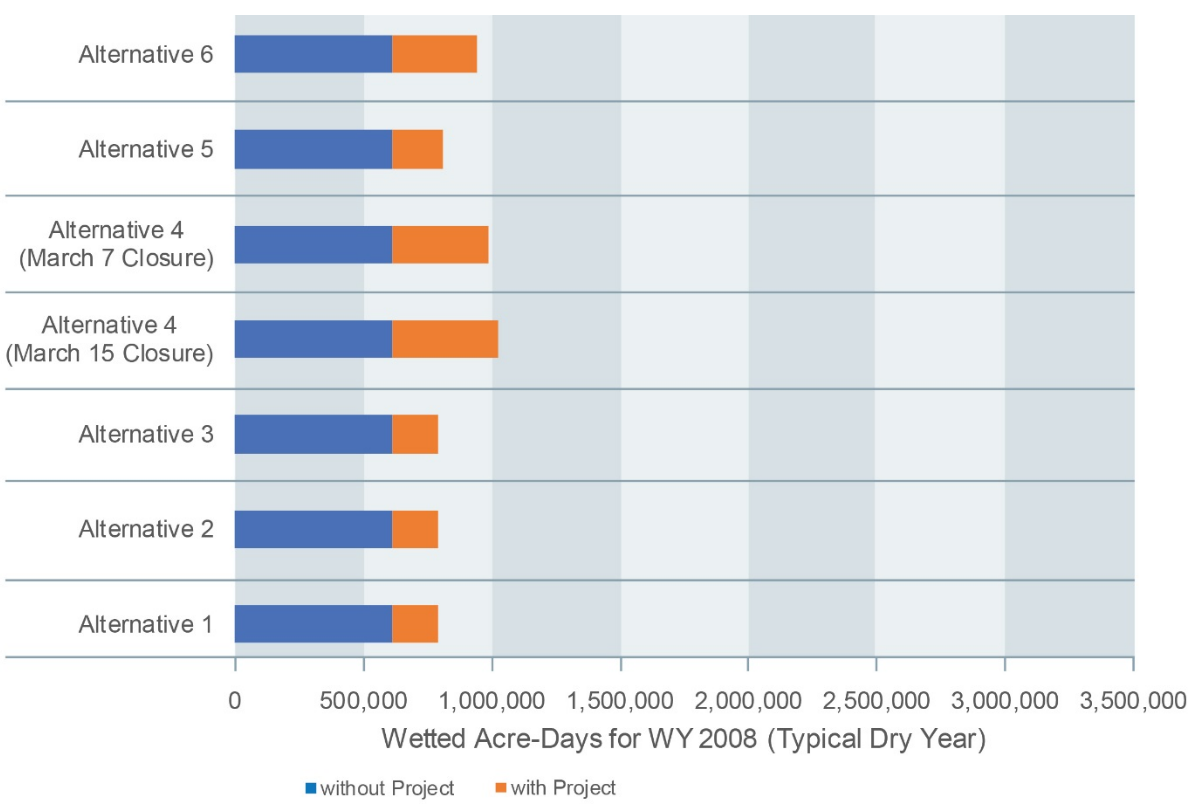

Figure 5-12. Increase in Wetted Acre-Days During a Dry Year

5.2.1.5 Food Production with an Ecosystem Approach

Inundated land in the Yolo Bypass stimulates food production for use by fish in the bypass and downstream in the Delta. Food production is increased as more area is wetted (for a longer time). Additionally, food production requires flow to move the food produced through the bypass and into the Delta. Generally, alternatives with more inundated area and flow perform better for food production. Alternatives 4 and 6 have a larger inundated area than the other alternatives and would produce the most food. Alternative 5 would inundate a smaller area and have less flow; therefore, it would provide a smaller benefit than the other alternatives relative to food production.

5.2.1.6 Adult Fish Passage

Adult fish would likely be attracted into the Yolo Bypass during times that the new inundation structure is operating, and they would move toward the gated notch where flow is entering. Fish passage at this structure is important to allow these adult fish to move upstream into the Sacramento River. The gated structures for Alternatives 1, 2, 3, and 5 are similar and would provide conditions that meet depth and velocity passage criteria for most of the operational range of the gated notch. They would not be able to pass fish as Sacramento River elevations climb over about 30 feet (because of high velocities) until the Fremont Weir starts to overtop at 32 feet. While Alternative 5 has the same operational range and similar fish passage operations as Alternatives 1, 2, and 3, it has a potential for fish stranding in the multiple gate system. As flows in the Sacramento River rise and fall, different gates in Alternative 5 would open and close. Fish may be traveling up a transport channel to a set of gates as they are closing. Fish must then backtrack, find the correct transport channel, and move upstream to the gates. This operation presents a potential fish passage concern.

Alternative 6 would operate gates to prevent flows from exceeding 12,000 cfs through the gated notch. During gate operations, conditions in the gates and just downstream of the gates may not meet fish passage criteria. This structure would no longer meet fish passage as the Sacramento River rises above 28.3 feet. Additionally, the other alternatives could operate after the March 15 closure date at lower flow rates (below 1,000 cfs) that would stay within the Tule Canal. Alternative 6 does not have this capability because the transport channel is larger and would not provide suitable depth for fish passage at flows below 1,000 cfs.

Figure 5-13 shows the average percent of the season that each alternative would meet depth and velocity passage criteria at Fremont Weir. Figure 5-14 provides additional detail about the timing of passage for adult sturgeon. Upstream passage would be available more time during February (when the gated notch is fully operational) but available for fewer days in March and April. Sturgeon that are unable to pass during these periods would either face passage delays at Fremont Weir or would turn around and travel to the Wallace Weir collection facility. Sturgeon that stay near Fremont Weir could also end up stranded (temporarily or for a longer period) in the channels and ponds in the FWWA or in the Tule Canal/Toe Drain.

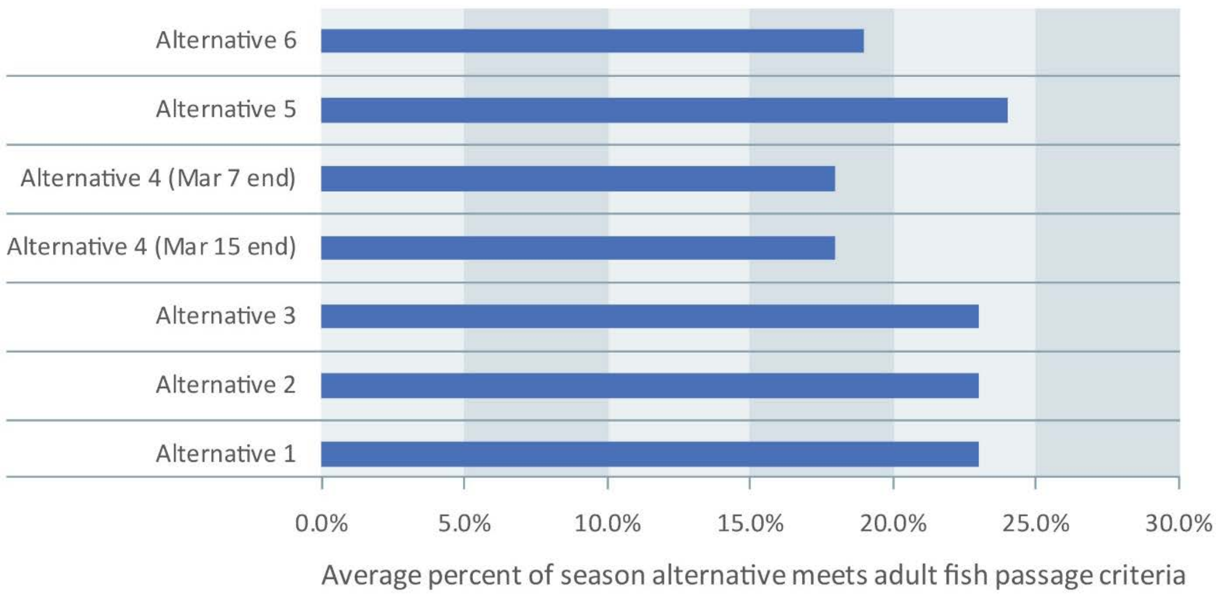

Figure 5-13. Average Fish Passage Availability at Fremont Weir

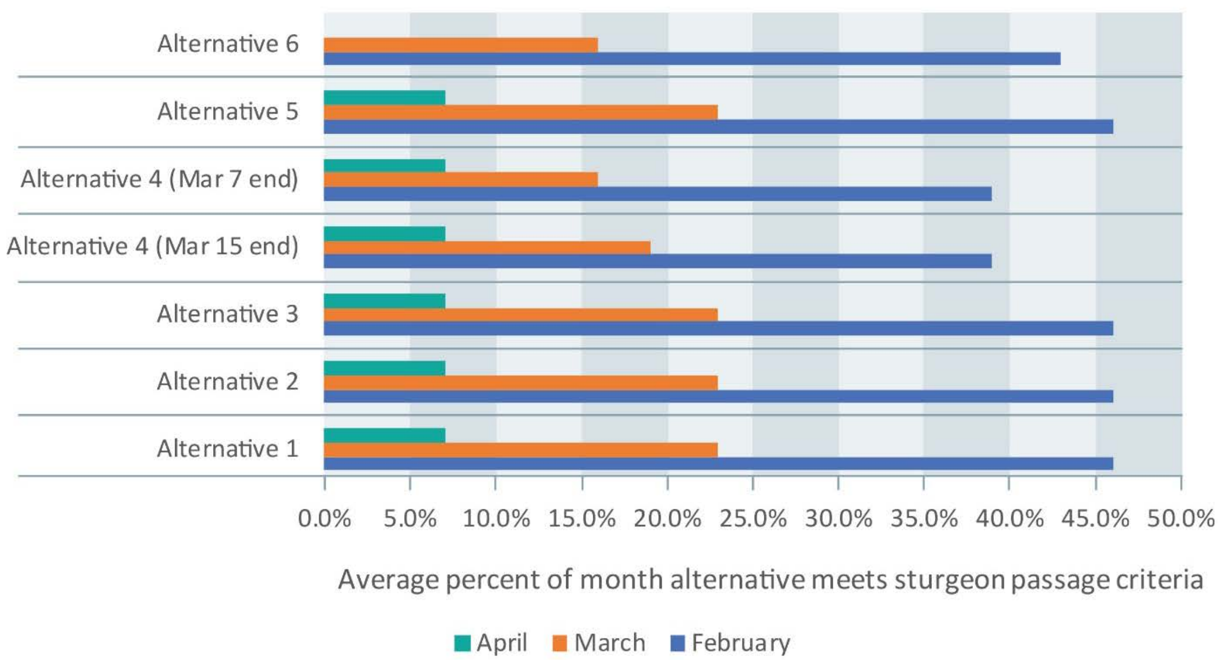

Figure 5-14. Average Timing of Adult Sturgeon Fish Passage

Alternative 4 would start to close gates as the Sacramento River rises to maintain flows below 3,000 cfs through the gated notch. These operations would increase velocities through the gates that remain open and result in conditions that are not passable as the river rises above about 26.7 feet. Alternative 4 also includes water control structures in the Tule Canal that would provide a barrier to fish passage when they are operating. The alternative includes bypass channels around the structures to reduce effects from the structures. While the fish bypass channels would reduce the effects, it would not be possible to achieve full fish passage around the structures. At best, bypass channels tend to provide passage during about 90 percent of the hydraulic conditions. Adding two of these structures would reduce the adult passage up through the Tule Canal compared to existing conditions. This reduction in fish passage does not satisfy the purpose of RPA I.7 (providing fish passage through the Yolo Bypass) as effectively as the other alternatives.

5.2.1.7 Juvenile Fish Passage

All the action alternatives except Alternative 4 perform well for providing safe and timely juvenile fish passage without substantial risk of stranding predation. Under Alternative 4, the water control structures are expected to increase juvenile Chinook salmon stranding in the Yolo Bypass. The Lead Agencies would continue to monitor for areas that may experience stranding or predation and consider adaptive management actions to reduce these conditions.

5.2.2 Completeness

The completeness criterion evaluates whether the alternative plan would account for all investments or other actions necessary to realize the planned effects. The evaluation factor for this criterion will focus on whether the alternative plans include benefits to all focus species outlined in the NMFS BO. Generally, providing floodplain rearing habitat provides benefits to Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon. These salmon, steelhead, and green sturgeon benefit from improved fish passage within the Yolo Bypass and connection to the Sacramento River. These actions are included in all alternatives; therefore, all alternatives satisfy the completeness criterion.

5.2.3 Acceptability

The acceptability criterion addresses the viability of a comprehensive plan with respect to acceptance by other Federal, State, and local entities and compatibility with existing laws. The evaluation factors for the acceptability criterion focus on concerns identified by agencies and stakeholders. The evaluation factors for this criterion consider the alternatives’ performance related to these acceptability issues.

5.2.3.1 Agricultural Impacts

This evaluation factor considers how each alternative plan could affect agriculture in the Yolo Bypass. Inundation in the late winter/early spring has the potential to affect agricultural land uses if the land has not drained in time for planting. For this evaluation, a comparison of how often the alternative plans could affect agriculture through inundation in the late winter/early spring was analyzed. The evaluation factors for agricultural impacts are:

- Inundation effects on agricultural production (reduced revenue)
- Inundation effects on winter maintenance activities (increased inundation duration)

Longer inundation of agricultural parcels in the Yolo Bypass could delay planting dates, which in turn would affect crop yields thereby impacting profitability. Table 5-3 shows the changes in agricultural income for each modeled year (1997 through 2012) using the BPM tool. On an average annual basis, Alternative 4 with the March 15 closure date would have the highest impact on net income by approximately $173,903. In comparison, Alternatives 1, 2, and 3 would have the least impact with an average annual net income reduction of approximately $64,026. Figure 5-15 shows these average changes. Theoretically, longer inundation events could cause growers to decide not to plant crops in the Yolo Bypass. This situation occurs under existing conditions with late season flood events; however, none of the action alternatives resulted in an increase of years where crops were not planted on a parcel.

Figure 5-15. Change in Average Annual Agricultural Income

Table 5-3. Modeled Changes in Agricultural Land Use and Income for all Alternatives (1997 through 2012)

	Alternative 1		Alternative 2		Alternative 3		Alternative 4 (March 7 closure)		Alternative 4 (March 15 closure)		Alternative 5		Alternative 6	
Year	Decrease in Acres Planted due to Inundation	Decrease in Net Income (Income minus Expenses)	Decrease in Acres Planted due to Inundation	Decrease in Net Income (Income minus Expenses)	Decrease in Acres Planted due to Inundation	Decrease in Net Income (Income minus Expenses)	Decrease in Acres Planted due to Inundation	Decrease in Net Income (Income minus Expenses)	Decrease in Acres Planted due to Inundation	Decrease in Net Income (Income minus Expenses)	Decrease in Acres Planted due to Inundation	Decrease in Net Income (Income minus Expenses)	Decrease in Acres Planted due to Inundation	Decrease in Net Income (Income minus Expenses)
1997	8	-$82,535	8	-$82,535	8	-$82,535	19	-$128,852	23	-$218,321	17	-$102,490	15	-$133,880
1998	0	-$37,548	0	-$37,548	0	-$37,548	0	-$36,806	0	-$36,806	0	-$36,623	0	-$36,766
1999	64	-$35,222	64	-$35,222	64	-$35,222	244	-$184,416	255	-$194,167	66	-$47,112	11	-$35,744
2000	0	$0	0	$0	0	$0	0	-$6,658	0	-$7,340	77	-$39,297	0	$0
2001	13	-$162,466	13	-$162,466	13	-$162,466	11	-$80,231	36	-$213,035	12	-$160,049	15	-$228,390
2002	40	-$165,590	40	-$165,590	40	-$165,590	42	-$282,893	71	-$409,931	43	-$222,091	51	-$313,744
2003	3	$0	3	$0	3	$0	256	-$215,248	256	-$215,248	9	-$20,166	3	-$24,376
2004	10	-$52,411	10	-$52,411	10	-$52,411	309	-$82,534	320	-$124,659	197	-$87,550	21	-$103,358
2005	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
2006	0	-$3,301	0	-$3,301	0	-$3,301	0	-$4,272	0	-$4,272	0	-$12,108	0	-$2,345
2007	22	-$144,628	22	-$144,628	22	-$144,628	36	-$226,712	66	-$359,300	23	-$147,626	32	-$205,243
2008	67	-$70,495	67	-$70,495	67	-$70,495	77	-$135,637	97	-$253,327	79	-$82,400	90	-$128,421
2009	126	-$256,106	126	-$256,106	126	-$256,106	104	-$170,738	126	-$271,717	126	-$213,513	137	-$317,084
2010	1	-$14,118	1	-$14,118	1	-$14,118	411	-$232,549	408	-$237,027	4	-$17,546	39	-$63,966
2011	0	$0	0	$0	0	$0	8	-$63,226	8	-$64,226	50	-$25,101	0	$0
2012	0	$0	0	$0	0	$0	4	-$109,857	31	-$173,064	0	$0	0	$0
Average	22	-$64,026	22	-$64,026	22	-$64,026	95	-$122,602	106	-$173,903	44	-$75,855	26	-$99,645

In addition to impacts to agricultural production in the Yolo Bypass, increased inundation during the winter months could affect winter maintenance activities in the fields. All alternatives would experience an increase in inundation duration, which is indicated by the change in wetted acre-days in Table 5-2. The highest increase is for Alternative 6, which has the largest flows entering through the Fremont Weir gated notch. The second highest increase is for Alternative 4 with the March 15 closure date, which includes water control structures to maintain water on the floodplain for longer periods.

5.2.3.2 Recreation Impacts

This evaluation factor considers how each alternative plan could affect recreation activities within the bypass. For this evaluation, a comparison of how often the alternative plans could affect recreation activities due to inundation of recreational areas or inundation of access to recreation areas was analyzed. The evaluation factors for recreation impacts are:

- Inundation of recreational areas or access to recreational areas that could impact hunting activities (include pheasant, waterfowl, quail, turkey, mourning dove, cottontail, jackrabbit, and deer hunting), wildlife viewing, or other recreational activities

This impact focuses on non-waterfowl recreation (because waterfowl is addressed separately). While non-waterfowl hunting activities could occur at the FWWA, YBWA, or the SBWA, this assessment focuses on the FWWA. The FWWA is likely to experience the greatest effects because of its location near Fremont Weir and because construction would occur within the area. The YBWA functions differently from the FWWA in that users can access the area by vehicle, and recreational access is limited by vehicular access. The access issues are further considered under the Education Impacts criterion. SBWA is managed for upland habitat and has hunting and fishing opportunities.

The FWWA within the Yolo Bypass provides opportunities for seasonal hunting and fishing, bird watching, and wildlife viewing. Hunting opportunities include pheasant, waterfowl, quail, turkey, mourning dove, cottontail, jackrabbit, and deer. The popular hunting seasons occur during spring turkey season and daily from July 1 through January 31. Construction and operations associated with each alternative would directly affect the amount of land available for recreational use at FWWA due to the creation of the transport channel and downstream channel improvements along the eastern boundary of FWWA. Table 5-4 summarizes the expected temporary (construction-related) and permanent (long-term project features) impacts to lands within FWWA. Permanent lands affected under each alternative are predominantly along the eastern boundary of FWWA. The conversion of these areas would have limited effect on recreational use in FWWA. To maintain the use of the recreational area and allow for safe movement of recreational users across the alternative’s components, all alternatives include installation of pedestrian bridges along the transport channel to maintain FWWA access for recreational use. Alternative 5 would use a large excavated and graded floodplain in place of the transport channels and downstream channels under the other alternatives. In total, the loss of accessible FWWA lands would be highest under Alternative 5 at approximately 462.7 acres (31.7 percent) as shown in Table 5-4.

Table 5-4. Effects on Recreational Access to Lands in the 1,461-acre Fremont Weir Wildlife Area

	Permanent Affected FWWA Land (acres)[1]	Temporary Affected FWWA Land (acres)[2]	Total Affected FWWA Land (acres)[3]
Alternative 1	26.7	163.3	190.0
Alternative 2	65.4	346.3	411.7
Alternative 3	48.4	286.9	335.3
Alternative 4	48.4	286.9	335.3
Alternative 5	78.9	345.7	424.6
Alternative 6	65.8	302.1	367.9

[1] *Permanent* refers to lands affected during the operation of the alternative only.

[2] *Temporary* refers to lands affected during the construction of the alternative, not including lands permanently affected during operation. Includes a 150-yard “no hunting” buffer area around the construction area.

[3] *Total* refers to lands affected by operation (permanent) plus lands affected during construction only (temporary).

Key: FWWA = Fremont Weir Wildlife Area

5.2.3.3 Waterfowl Impacts

The wetlands and flooded agricultural fields in the Yolo Bypass provide an important food source and resting place for waterfowl. Consequently, the abundance in waterfowl population in FWWA, SBWA, YBWA, LIER, and other private recreational areas within Yolo County provide ample waterfowl hunting potential within the Yolo Bypass. Modifying the inundation regime could affect waterfowl in several ways, including:

- Recreational opportunities: Increased inundation could close waterfowl viewing and hunting areas more often.
- Available foraging habitat: Ducks need water shallower than 18 inches and prefer water shallower than 10 inches (Petrik et al. 2012). Increased inundation could decrease available suitable habitat.
- Food production: Swamp timothy is the primary food source on the seasonal wetlands in the Yolo Bypass, and it requires careful management of water levels starting at the beginning of March (Petrik et al. 2012). Increased inundation after this date could affect available food for waterfowl.

Decrease in waterfowl foraging habitat, food production or access to recreation areas due to increased inundation would affect water hunting opportunities within the Yolo Bypass. Increased inundation especially during the waterfowl hunting season beginning in late October and running through January could affect waterfowl recreational hunting. The following changes to inundation frequency and depth of inundation are expected in the recreational areas within Yolo Bypass:

- At FWWA, Alternative 1, 2, and 3 would decrease the inundation frequency by up to one week for the majority of the wildlife area, and Alternative 4 would decrease the inundation frequency by more than two weeks. As shown on Figure 5-16, the total area of inundation is similar between all action alternatives. Under Alternative 1, 2, 3, and 4, areas on the eastern portion of the wildlife area would experience an increase in the frequency of inundation (up to four additional weeks) compared to the No Action Alternative. Alternative 5 would result in an overall increase in inundation frequency by greater than four weeks in

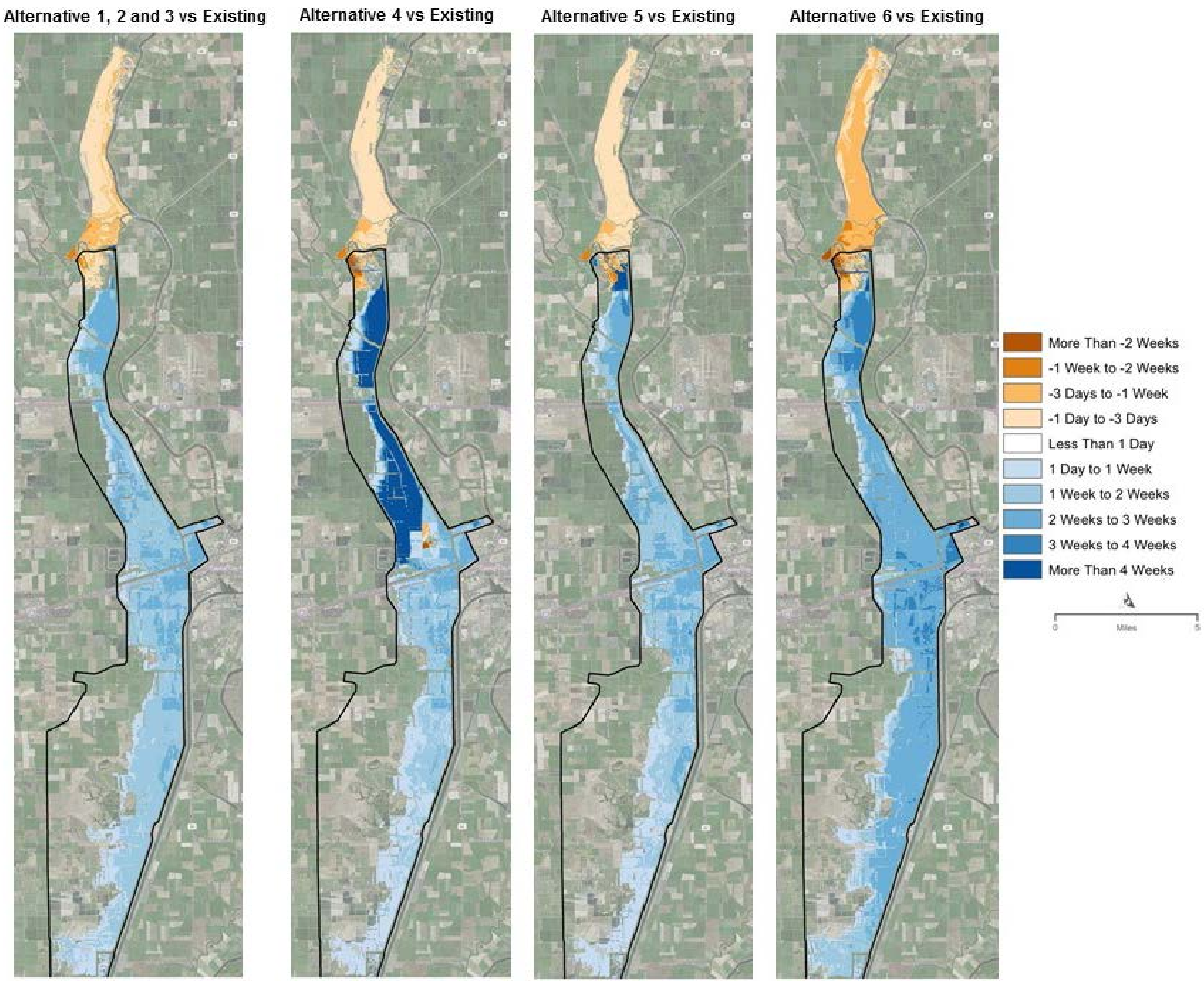

Figure 5-16. Changes in Wet Days for Land in the Yolo Bypass

approximately 30 percent of the area within the FWWA. The remaining 70 percent of the lands within FWWA would largely experience a decreased inundation frequency up to two weeks. Under Alternative 6, most of the wildlife area would experience a decreased inundation frequency up to two weeks compared to the No Action Alternative. In contrast, Tule Pond and transport channel component areas would experience an increased inundation frequency of more than four weeks.

- At SBWA, all alternatives would increase the inundation frequency up to three weeks for most of the wildlife area. Local areas mostly in the central and eastern portions of the wildlife area would experience increases in inundation of more than four weeks.
- At YBWA, all alternatives would increase the inundation frequency one to three weeks, on average. The areas where inundation frequency would occur for an average of one to two weeks would be widespread, whereas the areas where inundation would occur three additional weeks, on average, would be limited and localized in the northern and eastern portions of YBWA.
- At LIER and private recreation areas south of YBWA, these areas would not be affected under all alternatives.

Under all alternatives, in the northern Yolo Bypass (north of I-80), the eastern edge of the northern Yolo Bypass would experience increased inundation that could result in deeper ponding up to 10 feet deeper than under existing conditions (simulated under water year 2011 hydrologic conditions as an example). Figures 5-17, 5-18, and 5-19 show the changes in managed wetland inundation throughout the Yolo Bypass under wet, above normal, and dry hydrologic conditions (based on information from Ducks Unlimited 2017). These figures show the acreage of managed wetland habitat that has shallow flooding—less than 18 inches—that is suitable for waterfowl habitat. All alternatives would reduce the area of suitable wetlands; Alternative 6 shows the greatest change in availability, and Alternatives 3 and 4 have the smallest change.

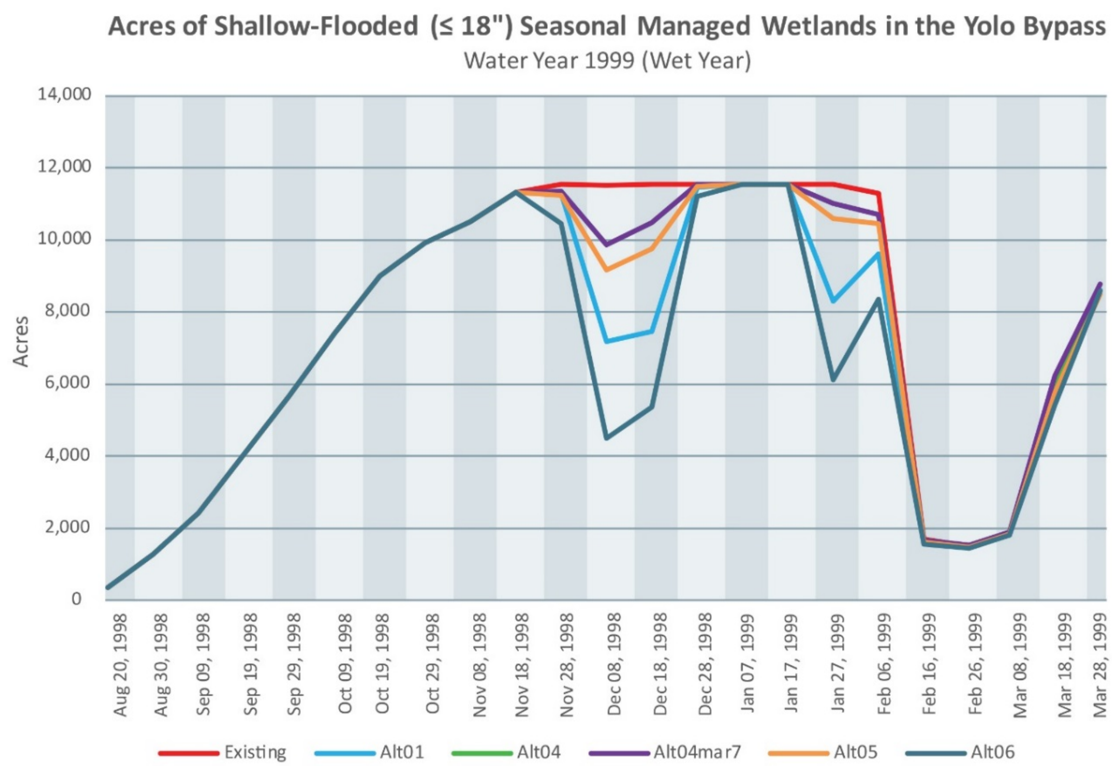

Figure 5-17. Change in Inundation of Managed Wetlands in a Wet Year

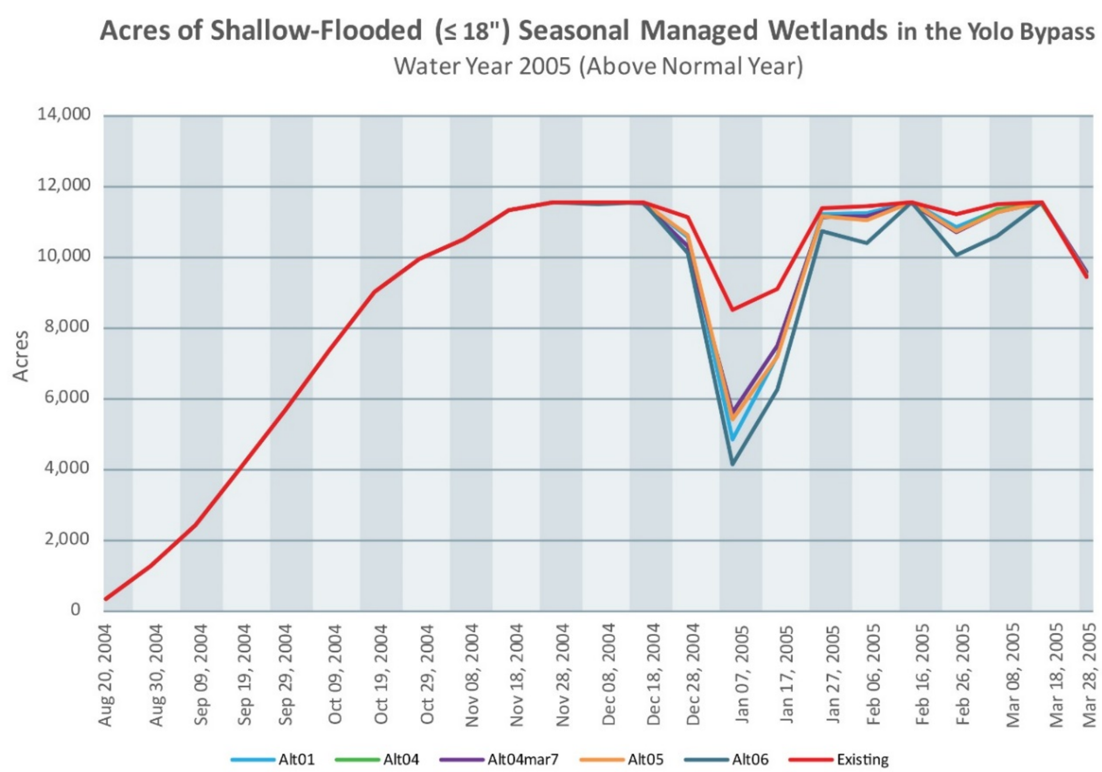

Figure 5-18. Change in Inundation of Managed Wetlands in an Above Normal Year

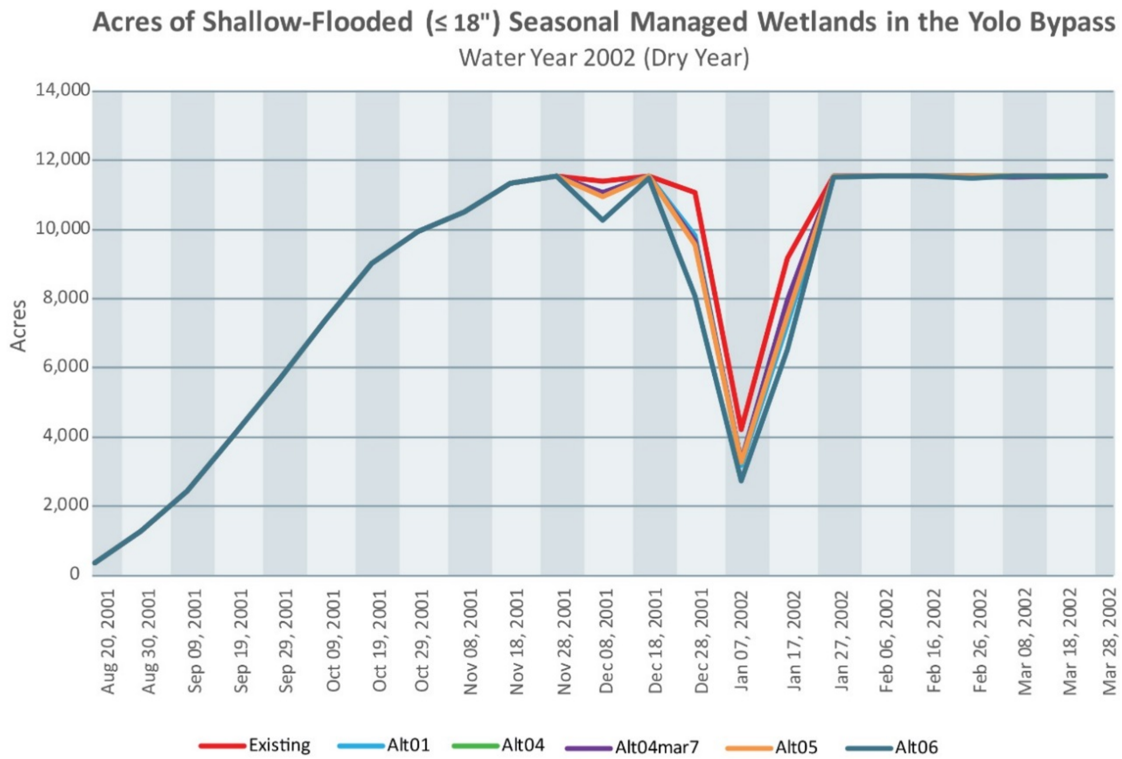

Figure 5-19. Change in Inundation of Managed Wetlands in a Dry Year

All alternatives would end inundation operations by March 15, which would limit effects to swamp timothy growth in wildlife and refuge areas. Waterfowl energetics modeling with TRUMET found that the alternatives would affect food supplies but not at times that those supplies are needed to meet the demands of existing or future (projected) bird populations (Ducks Unlimited 2017).

5.2.3.4 Education Impacts

This evaluation factor considers how each alternative affects the education use of the YBWA, measured by increased inundation of areas used for educational outreach or access roads. Increased inundation under all alternatives could increase the number of wet days in the YBWA. Increased number of wet days could result in impassable road conditions and/or reduced access to bus routes and facilities due to high water levels. If road and facility access is not available, the educational uses of the YBWA would be reduced, which could conflict with the goals included in the YBWA Land Management Plan to support and expand public use of the YBWA for environmental education and interpretation.

As shown on Figure 5-16, most areas within the YBWA would experience an increase in wet days of up to two weeks, whereas other areas would remain wet for an additional two to three weeks for all alternatives. Inundation at YBWA can be estimated with water levels at Lisbon Weir:

- If Lisbon Weir water levels exceed 8.5 feet, YBWA experiences low-level flooding.
- If Lisbon Weir water levels exceed 10 feet, Parking Lot F floods.

- If Lisbon Weir water levels exceed 12 feet, YBWA closes.

Figure 5-20 shows the average annual change in the number of days that these water levels would be exceeded under each alternative. Alternative 6 would limit YBWA educational opportunities the most often, followed by Alternatives 1, 2, and 3. Alternatives 4 and 5 would have the least effect on educational opportunities but would still have an adverse effect. The differences between Alternatives 1, 2, 3, 4, and 5 are relatively minor.

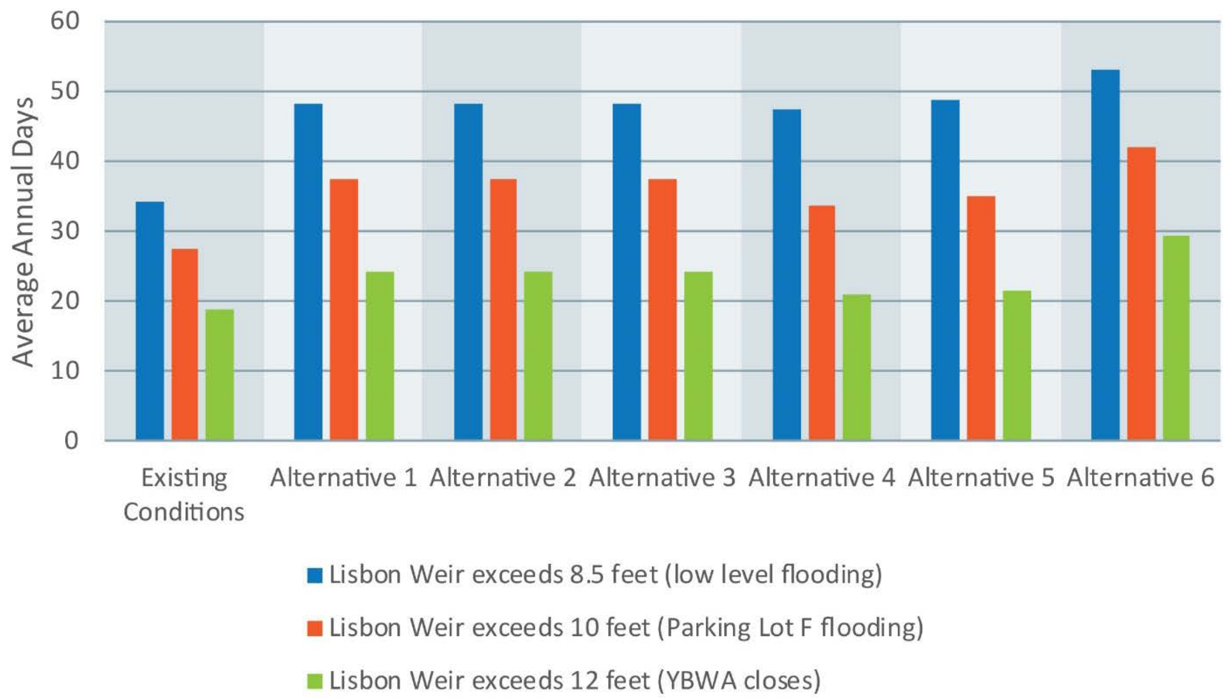

Figure 5-20. Average Annual Days with Potential Limitations on Educational Opportunities at the YBWA

5.2.3.5 Biological Impacts

This evaluation factor considers impacts from construction to biological resources, including fisheries and terrestrial resources. Construction activities would have direct and indirect effects on sensitive vegetation communities, including areas potentially subject to USACE and CDFW jurisdiction. Tables 5-5 and 5-6 summarize temporary (construction-related) and permanent (inundation-related) impacts under each alternative to USACE and CDFW jurisdiction habitat.

Table 5-5. Impacts to Potential USACE Jurisdiction by Project Alternative

Potential USACE Jurisdiction	Alt. 1 Temp. (acres)[a]	Alt. 1 Perm. (acres)[a]	Alt. 2 Temp. (acres)[a]	Alt. 2 Perm. (acres)[a]	Alt. 3 Temp. (acres)[a]	Alt. 3 Perm. (acres)[a]	Alt. 4 Temp. (acres)[a]	Alt. 4 Perm. (acres)[a]	Alt. 5 Temp. (acres)[a]	Alt. 5 Perm. (acres)[a]	Alt. 6 Temp. (acres)[a]	Alt. 6 Perm. (acres)[a]
Wetlands	**3.8**	**11.8**	**2.6**	**13.3**	**3.2**	**14.1**	**27.1**	**28.2**	**0.6**	**7.5**	**2.9**	**14.8**
Temperate freshwater floating mat	0.5	1.3	0.5	1.3	0.5	1.3	0.5	1.3	0.1	0.9	0.5	1.3
Water primrose wetlands (semi-natural stands)	0.4	1.8	0.5	2.7	0.5	2.7	0.7	2.7	0.0	1.7	0.4	3.0
California and hardstem bulrush marsh	2.9	8.7	1.6	9.3	1.6	9.3	1.6	9.3	0.5	4.9	1.6	9.5
Managed annual wetland vegetation	<0.001	0.0	<0.001	0.0	0.6	0.8	24.3	14.9	0.0	<0.001	0.4	1.0
Non-wetland Waters of the United States	**0.3**	**0.3**	**1.5**	**5.8**	**0.8**	**0.8**	**7.9**	**3.0**	**1.1**	**5.0**	**1.5**	**1.4**
Water	0.3	0.3	1.5	5.8	0.8	0.8	7.9	3.0	1.1	5.0	1.5	1.4
Total	**4.1**	**12.1**	**4.1**	**19.1**	**4.0**	**14.9**	**35.0**	**31.2**	**1.7**	**12.5**	**4.4**	**16.2**

[a] These acreages represent a preliminary effort at determining the jurisdictional boundaries in the absence of a formal jurisdictional delineation, using the most recent regulations, policy, and guidance from the regulatory agencies. However, only the regulatory agencies can make a final determination of jurisdictional boundaries.

Table 5-6. Impacts to Potential CDFW Jurisdiction by Project Alternative

Potential CDFW Jurisdiction	Alt. 1 Temp. (acres)[a]	Alt. 1 Perm. (acres)[a]	Alt. 2 Temp. (acres)[a]	Alt. 2 Perm. (acres)[a]	Alt. 3 Temp. (acres)[a]	Alt. 3 Perm. (acres)[a]	Alt. 4 Temp. (acres)[a]	Alt. 4 Perm. (acres)[a]	Alt. 5 Temp. (acres)[a]	Alt. 5 Perm. (acres)[a]	Alt. 6 Temp. (acres)[a]	Alt. 6 Perm. (acres)[a]
Riparian	**11.0**	**27.9**	**8.8**	**30.1**	**12.0**	**34.2**	**47.7**	**52.9**	**7.9**	**19.7**	**10.9**	**41.5**
Temperate freshwater floating mat	0.5	1.3	0.5	1.3	0.5	1.3	0.5	1.3	0.1	0.9	0.5	1.3
Water primrose wetlands (semi-natural stands)	0.4	1.8	0.5	2.7	0.5	2.7	0.7	2.7	0.0	1.7	0.4	3.0
California and hardstem bulrush marsh	2.9	8.7	1.6	9.3	1.6	9.3	1.6	9.3	0.5	4.9	1.6	9.5
Managed annual wetland vegetation	<0.001	0.0	<0.001	0.0	0.6	0.8	24.3	14.9	0.0	<0.001	0.4	1.0
Black willow thicket	<0.1	<0.1	<0.1	0.1	<0.1	0.1	4.2	0.9	0.1	1.4	<0.1	0.1
Box elder forest	0.0	0.0	0.0	0.0	0.1	0.6	0.1	0.6	0.0	0.0	0.1	1.3
Fremont cottonwood forest	5.7	12.0	5.4	11.8	7.0	14.3	14.3	17.9	6.6	8.8	6.6	18.8
Mixed hardwood forest	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0
Valley oak woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0
Unvegetated Streambed	**1.4**	**4.0**	**0.6**	**4.6**	**1.6**	**5.1**	**1.6**	**5.1**	**0.5**	**1.7**	**1.2**	**6.5**
Water	0.3	0.3	1.5	5.8	0.8	0.8	7.9	3.0	1.1	5.0	1.5	1.4
Total	**0.3**	**0.3**	**1.5**	**5.8**	**0.8**	**0.8**	**7.9**	**3.0**	**1.1**	**5.0**	**1.5**	**1.4**

[a] These acreages represent a preliminary effort at determining the jurisdictional boundaries in the absence of a formal jurisdictional delineation, using the most recent regulations, policy, and guidance from the regulatory agencies. However, only the regulatory agencies can make a final determination of jurisdictional boundaries.

Construction activities are also expected to have direct and indirect impacts on suitable and/or occupied habitat for State- or Federally listed wildlife species, including valley elderberry longhorn beetle, giant garter snake, western pond turtle, Swainson's hawk, western yellow-billed cuckoo, bank swallow, special-status plant species, special-status bird species (including birds protected under the Migratory Bird Treaty Act), and other special-status wildlife species (including bats and American badger). Impacts to each species listed are summarized below:

Valley Elderberry longhorn beetle: Based on 2014 surveys, construction footprints for Alternatives 1, 2, and 5 do not contain any elderberry shrubs, the host plant for valley elderberry longhorn beetle.

Construction footprints for Alternatives 3, 4, and 6 contain two elderberry shrubs. An additional elderberry shrub is located outside the footprint but within the study area for all three alternatives. Construction of Alternatives 3, 4, and 6 would result in permanent effects on two elderberry shrubs and temporary effects on one elderberry shrub. Alternatives 3 and 4 would result in permanent effects on 1.8 acres of suitable valley elderberry longhorn beetle habitat (all areas within 50 feet of an elderberry plant and all riparian habitat) and temporary effects on 1.3 acres of suitable valley elderberry longhorn beetle habitat. Alternative 6 would result in permanent effects on 2.7 acres and temporary effects on 1.2 acres of suitable valley elderberry longhorn beetle habitat.

Under Alternatives 3, 4, and 6, the frequency of inundation within the FWWA would be reduced overall by one week, whereas the frequency of inundation within YBWA would increase overall by one week. The Lead Agencies do not expect operations to result in adverse effects on valley elderberry longhorn beetle or its elderberry host plant as the limited increase in the frequency of inundation is not likely to lead to conversion of elderberry plant habitat that would prevent reproduction and growth of elderberry plants.

Giant Garter Snake: Table 5-7 below summarizes impacted giant garter snake habitat within the Yolo Bypass (all aquatic habitat and suitable upland habitat within 200 feet of aquatic habitat). The active season for giant garter snakes is May 1 to October 1. The potential for direct mortality during the active season is lower than during the dormant period because snakes can move to avoid danger. Construction activities under all alternatives would extend through the active season and would extend past October 1 (the end of the active season).

Temporary effects on giant garter snake aquatic habitat would result from earth removal associated with grading, dewatering activities, placement of engineered streambed material (rock slope protection and riprap) along the outlet channel, and general construction activities in the impact area along Tule Pond and at the agricultural road crossing of Tule Canal (including removing an earthen berm and replacing it with a railcar bridge). Additionally, temporary effects on suitable giant garter snake upland habitat would result from construction activities associated with vegetation removal. Construction- and operations-related effects on giant garter snakes could result in the direct take of individuals and would result in a reduction in the quantity and quality of giant garter snake habitat.

Implementation of Mitigation Measures identified in the EIS/EIR would ensure that impacts to giant garter snake habitat would be minimized.

Table 5-7. Potential Impacts to Suitable Giant Garter Snake Aquatic and Upland Habitat by Alternative

Alternative	Habitat	Temporary Impact (acres)	Permanent Impact (acres)
Alternative 1	Aquatic	3.9	11.8
	Upland	20.5	21.4
Alternative 2	Aquatic	2.6	13.3
	Upland	12.7	11.9
Alternative 3	Aquatic	3.2	14.1
	Upland	15.9	15.7
Alternative 4	Aquatic	44.9	47.4
	Upland	71.7	43.7
Alternative 5	Aquatic	0.6	7.5
	Upland	0.6	8.6
Alternative 6	Aquatic	3.0	12.3
	Upland	17.1	16.5

Western pond turtle: Construction-related effects on western pond turtle could include disturbance, removal of suitable or occupied aquatic or upland habitat, vehicle strikes, or destruction of active pond turtle nests. Table 5-8 summarizes impacted suitable western pond turtle habitat within the Yolo Bypass (all aquatic habitat and suitable upland habitat within 200 feet of aquatic habitat). Construction- and operations-related activities could injure western pond turtles if they are present in the project area.

Implementation of mitigation measures identified in the EIS/EIR would ensure that impacts to western pond turtles would be minimized.

Table 5-8. Potential Impacts to Western Pond Turtle Aquatic and Upland Habitat by Alternative

Alternative	Habitat	Temporary Impact (acres)	Permanent Impact (acres)
Alternative 1	Aquatic	3.0	8.7
	Upland	25.1	35.3
Alternative 2	Aquatic	2.2	15.0
	Upland	24.8	59.2
Alternative 3	Aquatic	2.2	10.0
	Upland	28.4	62.9
Alternative 4	Aquatic	25.9	24.2
	Upland	85.0	90.4
Alternative 5	Aquatic	0.5	9.9
	Upland	25.0	78.2
Alternative 6	Aquatic	2.0	10.6
	Upland	28.7	87.0

State/Federally Listed Bird Species (includes Swainson's hawk, least Bell's vireo, western yellow-billed cuckoo, and bank swallow): Table 5-9 summarizes impacted suitable nesting and foraging habitat within the Yolo Bypass. Construction associated with all alternatives would occur over one season (between April 15 and November 1), which would overlap with the nesting season for Swainson's hawk (late March to August), least Bell's vireo (mid-April to mid-September), western yellow-billed cuckoo (mid-June to August), and bank swallow (early May to July). Construction activities associated with all alternatives could result in destruction of nests and eggs, mortality of nestlings, or nest abandonment.

Additionally, operations of all alternatives could result in adverse effects on suitable nesting habitat for listed bird species as the alternatives might extend the duration of flooding between November and March, which is outside the nesting season. Operational effects on foraging habitat are not expected to be significant as there is ample foraging and nesting habitat in Yolo Bypass.

Table 5-9. Potential Impacts to Suitable Nesting and Foraging Habitat by Alternative

Alternative	Habitat	Temporary Impact (acres)	Permanent Impact (acres)
Alternative 1	Nesting	7.1	16.0
	Foraging	18.2	19.7
Alternative 2	Nesting	6.0	16.5
	Foraging	22.3	55.1
Alternative 3	Nesting	8.8	20.1
	Foraging	20.4	43.6
Alternative 4	Nesting	20.6	24.7
	Foraging	72.3	68.6
Alternative 5	Nesting	7.2	11.9
	Foraging	20.0	76.6
Alternative 6	Nesting	8.1	26.8
	Foraging	22.0	61.6

5.2.3.6 Cultural Impacts

This evaluation factor considers the potential of construction activities to encounter unexpected archeological, cultural, and/or paleontological resources. The 2014 cultural resources survey identified nine sites, including four new sites and five previously identified sites. These resources occur within the footprint of both temporary work areas and permanent surface impacts. The resources are generally distributed evenly across the alignment for all alternatives but are somewhat clustered where construction of large above-ground features would occur such as the northern end of the Project area near the banks of the Sacramento and Old Rivers. Ground-disturbing construction activities likely would disturb the deposits and thus materially alter their ability to convey their significance. Much of the data potential in archaeological resources exist in the spatial associations of different artifacts and other cultural material. Where artifacts that have known associations with particular periods occur adjacent to other material, such as faunal bone or plant remains from subsistence activity, the proximity of the materials allows an inference as to the age of the subsistence remains, thereby allowing researchers to infer particular subsistence strategies during different prehistoric periods. Intrusive ground-disturbing construction, vibration, and other physical disturbance may disrupt these associations and thus disrupt the qualities for which the sites may qualify as historical resources or historic properties.

In addition to the sites identified in the 2014 cultural resources survey, archaeological resources are likely to be found in the portion of the footprint where surveys have not been conducted once access is available and such studies can be completed. The presence of archaeological sites that qualify as historical resources and historic properties in the portion of the footprint that has been inspected previously provides a sample of the likely density and occurrence of resources in the remaining footprint. Ground-disturbing construction activities likely would disturb the deposits and thus materially alter their ability to convey their significance. These impacts are similar for all action alternatives, and implementation of pre-construction surveys, avoidance measures, and mitigation for resource discovery would minimize potential impacts on cultural, archaeological, and historic resources.

5.2.3.7 Flood Impacts

This evaluation factor considers the potential to affect flood management or O&M under each alternative. This factor considers if the changes from each alternative could affect high flow flood events in the Yolo Bypass or if changes in the Yolo Bypass could affect flood conditions in the Sacramento River.

An alternative could affect flood management in the Yolo Bypass if it would increase the number of occurrences of high flows in the bypass. This was measured by considering the number of times that monthly flows would exceed 244,900 cfs in Yolo Bypass (244,900 cfs is the historical one percent annual exceedance probability of monthly average flows, corresponding to a one-in-100-year flood event). Similarly, an alternative could affect flood management if it changed how flows entered the Yolo Bypass in a way that more flows stayed in the Sacramento River during high flow events. This could be an issue if alternatives would increase the number of occurrences of monthly flows above 77,790 cfs in the Sacramento River at Freeport (77,790 cfs is the historical one percent annual exceedance probability of monthly average flows, corresponding to a one-in-100-year flood event).

Flows in the Sacramento River at Freeport and flows from the Sacramento River to Yolo Bypass were simulated using CalSim II models with 2030 and 2070 hydrology from the California Water Commission Climate Change Water Supply Improvement Project modeling to approximate system-wide changes in storage, flow, salinity, and reservoir system reoperation associated with the alternatives. The model simulates system operations for an 82-year period from October 1921 to September 2003.

As shown in Table 5-10, flows in the Yolo Bypass would not exceed 244,900 cfs in any years under the No Action Alternative or any of the action alternatives. Flows in the Sacramento River at Freeport would exceed 77,790 cfs in multiple years under the No Action Alternative. These conditions are either the same or slightly better for the action alternatives.

Table 5-10. Occurrence of Flow Exceedance from Sacramento River to Yolo Bypass and in the Sacramento River at Freeport

		Occurrence of flow exceedance from Sacramento River to Yolo Bypass[1]	Occurrence of flow exceedance in the Sacramento River at Freeport[2]
No Action	Under 2030 hydrology conditions	0 years	12 years
	Under 2070 hydrology conditions	0 years	19 years
Alternative 1	Under 2030 hydrology conditions	0 years	11 years
	Under 2070 hydrology conditions	0 years	19 years
Alternative 2	Under 2030 hydrology conditions	0 years	11 years
	Under 2070 hydrology conditions	0 years	19 years
Alternative 3	Under 2030 hydrology conditions	0 years	11 years
	Under 2070 hydrology conditions	0 years	19 years
Alternative 4	Under 2030 hydrology conditions	0 years	12 years
	Under 2070 hydrology conditions	0 years	19 years
Alternative 5	Under 2030 hydrology conditions	0 years	12 years
	Under 2070 hydrology conditions	0 years	19 years
Alternative 6	Under 2030 hydrology conditions	0 years	11 years
	Under 2070 hydrology conditions	0 years	17 years

[1] Occurrence flows exceeding 244,900 cfs in Yolo Bypass

[2] Occurrence of flows exceeding 77,790 cfs in the Sacramento River at Freeport

Adding new structures to the Yolo Bypass could affect the O&M practices within the bypass. A concern is the potential for the new gated notch structure to trap large debris, which could result in gates being stuck in the open position. During flood events, debris (including trees and large woody debris) is washed downstream and could enter the gated notch. The gated notch structures in Alternatives 1 through 4 and 6 have incorporated wide bays (27 to 40 feet) with debris fins to align the debris to pass through the gates rather than being stuck on supports between bays. Alternative 5 has a greater potential to become blocked with debris because the gated notch structures have bays that are 10 feet wide with no debris fins. Modeling has indicated that leaving the gates open during a flood event (which could occur if debris is in a gate area) would not increase high flows in the Yolo Bypass; however, an increase in trapped debris would increase the O&M requirements in the Yolo Bypass.

5.2.3.8 Water Supply Impacts

This evaluation factor considers how each alternative plan could affect water supply. The evaluation factors for water supply impacts are:

- Expected changes in agricultural or municipal water supplies to north-of-Delta contractors
- Expected change in groundwater resources
- Expected changes to Delta diversion under a future with WaterFix scenario

Table 5-11 summarizes long-term average changes that would occur in CVP and SWP deliveries to north-of-Delta and south-of-Delta contractors under all alternatives. While there are occasionally individual months and years where the reduced flow in the Sacramento River could influence deliveries to north-of-Delta and south-of-Delta contractors, changes to deliveries are rare, infrequent, and of small magnitude (less than 1 percent). The No Action Alternative and alternatives (under future conditions) include the WaterFix facility; therefore, the minor changes in deliveries to south-of-Delta contractors reflect potential changes in Delta diversions with a WaterFix facility.

Because the action alternatives would not result in substantive changes to CVP and SWP water deliveries, they would not change groundwater in the contractors' areas. The action alternatives also have the potential to affect groundwater levels near the Yolo Bypass. Existing conditions show that groundwater levels in and around the Yolo Bypass increase during years when the Yolo Bypass is inundated. These increases are likely because precipitation, river flows, and bypass flows are high during these years. The high flow in the Yolo Bypass under flood conditions (about 244,000 cfs) is much higher than flows that would occur under the action alternatives (3,000 cfs to 12,000 cfs). All alternatives could result in small increases in groundwater levels and storage, but these changes would likely be small and not affect water supply available from groundwater.

5.2.3.9 Compatibility with Related Programs

The Yolo Bypass is a flood facility with multiple purposes, including agriculture, wetlands, and fisheries rearing. Several other efforts are ongoing within the bypass, including flood management efforts to expand the bypass and provide additional habitat opportunities. The flood management planning includes the Lower Elkhorn Setback project, which would set back part of the eastern Yolo Bypass levee into the Elkhorn Area. Other efforts include efforts to extend Fremont Weir, set back levees throughout the Yolo Bypass, expand Sacramento Weir and Bypass, and connect the Tule Canal to the Deep Water Ship Channel with gates. The Lead Agencies have been coordinating with the flood planning efforts to prevent conflicts with proposed action alternatives, and all alternatives would be compatible with potential projects that are moving forward in flood planning. Compatibility with other related activities in the Yolo Bypass, including agriculture, wetlands, recreational uses, and education, are considered in the other acceptability criteria.

Table 5-11. Changes in Water Supplies

	Alternatives 1-3		Alternative 4		Alternative 5		Alternative 6	
	Change in water supply under 2030 hydrologic conditions (cfs[%])	**Change in water supply under 2070 hydrologic conditions (cfs[%])**	**Change in water supply under 2030 hydrologic conditions (cfs[%])**	**Change in water supply under 2070 hydrologic conditions (cfs[%])**	**Change in water supply under 2030 hydrologic conditions (cfs[%])**	**Change in water supply under 2070 hydrologic conditions (cfs[%])**	**Change in water supply under 2030 hydrologic conditions (cfs[%])**	**Change in water supply under 2070 hydrologic conditions (cfs[%])**
CVP contractors north of Delta deliveries	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
SWP contractors north of Delta deliveries	0 (0)	1 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)
CVP contractors south of Delta deliveries	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
SWP contractors south of Delta deliveries	0 (0)	-5 (0)	0 (0)	-3 (0)	0 (0)	-5 (0)	0 (0)	-7 (0)

Key: cfs = cubic feet per second; CVP = Central Valley Project; SWP = State Water Project

5.2.4 Efficiency

The efficiency criterion addresses how well an alternative plan would deliver economic benefits relative to project costs. The performance measure for the efficiency criterion is defined as an alternative's net benefits. Each alternative's efficiency (economic benefits) was evaluated consistent with the standards outlined in the PR&Gs for planning and water resources-related projects.

Table 5-12 summarizes the costs by alternative. In addition to construction and O&M costs incurred under each alternative, the costs consider agricultural impacts. Each alternative would incur additional agricultural impact costs that account for loss of income and profitability in years when increased inundation would delay planting. These costs were estimated using the changes in net income approach defined in the PR&Gs. The methodology estimates the annual agricultural income with and without the project in the Yolo Bypass. This loss of income is assumed to occur over the 100-year planning period. Similarly, estimated annual O&M costs are also assumed to occur annually over the entire planning period (100-year period). Construction would occur over a one-year period. Construction costs are annualized using the Federal discount rate of 3.125 percent and added together with the other costs to develop the total annual costs.

Table 5-12. Project Costs by Alternative (in millions)

	Alternative 1	Alternative 2	Alternative 3	Alternative 4 (March 7)	Alternative 4 (March 15)	Alternative 5	Alternative 6
Total Construction Cost[1]	$45.4	$66.2	$64.4	$94.8	$94.8	$157.8	$115.9
Annual O&M Cost[1]	$0.5	$0.6	$0.6	$0.7	$0.7	$2.0	$1.1
Annual Loss of Agricultural Income[2]	$0.1	$0.1	$0.1	$0.1	$0.2	$0.1	$0.1
Annual Costs (Construction + O&M+ Agricultural Impact)[3]	$2.0	$2.7	$2.7	$3.9	$3.9	$7.0	$4.8

Source:

[1] HDR 2017

[2] ERA Economics 2017

[3] For a 100-year period using 3.125 percent discount rate

Note: O&M = operations and maintenance

The PR&Gs recommend the following approaches to evaluate economic benefits:

(a) Willingness to pay (WTP): This method monetizes the project benefits by determining the value of the project benefits or value of resource to the consumer. WTP refers to the value that a "seller" would obtain if able to charge each individual user a price that captures the full value to the user. This method requires the estimation of demand curve of the resource.

(b) Actual or simulated market prices: In cases where additional resources from the project would be too small to impact existing market prices, actual or simulated market prices can be used to estimate WTP for the resource.

(c) Changes in net income: The total value of the resource is determined by estimating the net change in income to the project proponent with and without the project.

(d) Most likely alternative: The cost of the most likely or least-cost action to obtain the same level of output is used as a proxy to estimate economic benefits.

(e) Administratively established values: Representative values for specific goods and services that are cooperatively established by the water resources agencies are used to estimate economic benefits.

The primary benefits under this project are the fish habitat enhancement and fish passage benefits. Because habitat improvement-related benefits are difficult to monetize, actual or simulated market prices and changes in net values approaches were disregarded for this analysis. The administratively established values approach of estimating economic benefits is the least preferred alternative for evaluating benefits and was not used in this analysis. Valuation of fish habitat enhancement benefits were estimated based on the most likely alternative and WTP approaches.

Under the most likely alternative approach, the unit cost of each adult return is used to estimate the economic benefits of each alternative. Alternative 6 would result in the most net benefits because it has the highest adult returns; therefore, it was considered the basis of this analysis as the specified accomplishment for the most likely action to meet or exceed. Using the adult returns summarized in Table 5-13, the unit cost of each returning adult fish was estimated to be $17.76 under Alternative 6. For this analysis, increases in adult returns were included for fall-run and late-fall run Chinook salmon, even though they are not the focus species for this evaluation. Most likely alternative benefits were calculated for each alternative using the adult returns summarized in Table 5-13 and using the $17.76/adult return unit cost.

Table 5-13. Modeled Total Number of Adult Returns under Each Alternative between 1997 and 2012

	Existing Conditions	Alternative 1, 2 and 3	Alternative 4 (March 7)	Alternative 4 (March 15)	Alternative 5	Alternative 6
Fall-run Chinook	2,580,375	2,748,021	2,695,812	2,699,379	2,714,532	2,859,071
Late-Fall run Chinook	875,858	862,998	866,154	866,154	864,672	854,541
Spring-run Chinook	89,396	95,858	93,854	93,886	94,502	100,353
Winter-run Chinook	82,769	84,447	84,255	84,257	84,434	86,190
Total	**3,628,398**	**3,791,324**	**3,740,075**	**3,743,676**	**3,758,140**	**3,900,155**
Percentage increase in comparison to Existing Conditions		**4.81%**	**3.42%**	**3.32%**	**3.85%**	**8.02%**

Source: Hinkleman personal communication, based on Hinkelman et al. 2017

The WTP approach is the second approach used to evaluate benefits for this project. The WTP approach refers to the value a potential seller of the commodity would obtain if able to charge each user with a price. Because the commodity offered under this project is fish habitat enhancements that cannot be directly purchased or consumed by an individual, existing non-use survey data were used to evaluate economic benefits. A non-use value survey estimates the value an individual places on environmental changes even when the individual does not personally "use" the benefits. Several non-use value studies that estimate fishery values exist, and some value ESA-listed species. The Loomis and White (1996) study estimates the WTP for preserving Pacific salmon steelhead as $63 per household (in 1996 dollars). A later study by Richardson and Loomis (2009) concluded that the WTP values have increased per-capita since the conclusion of the 1996 study. The Hanneman, Loomis, and Kanninen (1991) study estimated the WTP for Chinook salmon restorations in Upper San Joaquin Watershed to be $181 (1989 dollars) per household. Layton, Brown, and Plummer (1999) evaluated the economic value of increasing migratory salmon in Washington to be between $9.92 and $21.07 per household. The RTI International (2012) study estimated the value of a 30 percent increase in wild Chinook salmon and steelhead trout returning to the Klamath River Basin to be $43.85 per household (2011 dollars) in the 12-county Klamath River Basin, $89.21 per household (2011 dollars) in the rest of California and Oregon, and $86.33 per household (2011 dollars) in the rest of the United States. Although the multiple non-use survey results for fish habitat improvements offer important information and context for economic valuation, there remains considerable difficulty in valuing fish habitat enhancements due to the absence of markets and associated information to provide guidance of value.

For this analysis, the RTI International (2012) Klamath Basin River Restoration WTP values were used as it is the most recent evaluation available and the proximity of the study area to the Project actions. For the Klamath Basin Study, RTI International estimated the non-use value for increasing the population of Chinook salmon and reducing the risk of extinction for Coho salmon from high to moderate in the Klamath Basin. The study separated the surveyed population by geographic location into the 12-county Klamath region, the rest of Oregon and California, and the rest of the United States (see Table 5-14). The 12-county Klamath region WTP value was used as a proxy WTP value for the four-county region around the Yolo Bypass (Yolo, Solano, Sutter and Sacramento). The Klamath Basin Study estimated the annual value of WTP per household (over a 20-year period) to increase wild Chinook salmon and steelhead populations in the Klamath river by 30 percent each year and reduce the extinction rate for suckers from very high to high and Coho salmon from high to moderate. This project does not have exactly the same conditions and looks at varying percent recovery for fish (as shown in Table 5-13) over 100 years. To estimate fish habitat benefits, the Klamath Basin WTP values were applied over a 20-year period and annualized over a 100-year period. The WTP values were also scaled based on the percent recovery of fish in each alternative (based on the values shown for the four fish in Table 5-13). WTP numbers for each region were multiplied by the projected 2030 number of households in these regions (see Table 5-15) to estimate the fish habitat benefits.

Table 5-14. Klamath Basin River Restoration Non-Use Survey Results

Region	20-Year Annual Value per House (2011 dollars)[1]	20-Year Annual Value per House (2016 dollars)
12-county Klamath area	$79.09	$84.66
Rest of Oregon and California	$160.90	$172.22
Rest of United States	$155.70	$166.66

[1] For action plan (30 percent increase in wild Chinook salmon and steelhead trout returning to the river each year; reducing extinction risk for sucker from very high to high; reducing extinction risk for Coho salmon from high to moderate.

Table 5-15. Projected Population and Housing Units

Region	2015 Census Population[1]	2015 Census Housing Units[1]	2030 Projection Population[2]	2030 Projections Housing Units[3]
4-county region	2,194,152	824,806	2,645,830	994,574
Yolo County	207,320	76,090	262,418	96,312
Sutter County	95,247	34,065	111,423	39,850
Solano County	425,753	154,380	509,230	184,649
Sacramento County	1,465,832	560,271	1,762,759	673,763
California	38,421,464	13,845,790	44,019,846	15,863,257
United States	316,515,021	133,351,840	359,402,000	151,420,675

Source:

[1] United States Census Bureau. 2011-2015.;

[2] California Department of Finance 2017

[3] Calculated using the projected 2030 populations; assume same population to housing units ratio

Table 5-16 summarizes the costs and benefits using the most likely alternative and WTP approaches discussed above. Using the most likely alternative approach, Alternatives 1, 2, and 3 would have net benefits. Alternatives 4 and 5 would have net costs. Alternative 5 has the highest net cost due to the high capital cost of the project.

The WTP approach indicates that all alternatives would have net benefits. Alternative 6 would have the greatest net benefits because the number of returning adult fish are the highest. While Alternative 6 also has costs that are greater than most of the other alternatives, the benefits are great enough to offset this difference. Alternatives 1, 2, and 3 provide the next-highest net benefits. These alternatives are similar because they achieve the same benefits and have only minor differences in costs. Alternatives 4 and 5 have the smallest net benefits because they have the smallest number of returning adult fish to produce benefit.

Table 5-16. Alternatives Efficiency Evaluation

	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4 (March 7)**	**Alternative 4 (March 15)**	**Alternative 5**	**Alternative 6**
Annual Costs (Million $)[1]	$2.02	$2.74	$2.71	$3.85	$3.90	$7.03	$4.83
MOST LIKELY ALTERNATIVE APPROACH							
Annual Benefits (Million $)[2]	$2.89	$2.89	$2.89	$1.98	$2.04	$2.30	$4.83
Net Annual Benefits or Costs (Million $)[3]	$0.86	$0.15	$0.18	-$1.88	-$1.86	-$4.73	-$0.01
WTP APPROACH							
Four-County Region: Annual Benefits (Million $)[4,5]	$6.51	$6.51	$6.51	$4.49	$4.62	$5.21	$10.85
Rest of California: Annual Benefits (Million $) [4,6]	$197.86	$197.86	$197.86	$136.54	$140.62	$158.53	$329.89
California Level: Net Annual Benefits or Costs (Million $)	**$202.35**	**$201.63**	**$201.65**	**$137.17**	**$141.33**	**$156.72**	**$335.91**
Rest of United States: Annual Benefits (Million $)[4,7]	$1,745.61	$1,745.61	$1,745.61	$1,204.58	$1,240.58	$1,398.63	$2,910.44
United States Level: Net Annual Benefits or Costs (Million $)	**$1,947.96**	**$1,947.24**	**$1,947.27**	**$1,341.75**	**$1,381.92**	**$1,555.35**	**$3,246.35**

[1] Includes construction cost, annual maintenance cost, and agricultural impact cost (i.e., cost of land fallowing and crop shifting)

[2] Alternative 6 achieves the highest increase in adult return of all focus fish species and is assumed to be the specified accomplishment for least-cost action to meet or exceed.

[3] Net Benefits or costs = Annual Benefits - Annual Cost

[4] Uses RTI International's Klamath River Basin WTP Survey Results. Twenty-year annual WTP values for 30 percent increase in wild Chinook salmon and steelhead trout returning to the river each year and reduction in risk for suckers from very high to high and Coho salmon from high to moderate was used. Benefits were applied over a 20-year period after construction and annualized over a 100-year planning period using a 3.125 percent Federal interest rate.

[5] Calculated WTP fish benefits in the four-county region (Yolo, Solano, Sutter, and Sacramento) in and around the project. The WTP values from the Klamath River Basin Restoration Study were applied directly as geographically proximate to the affected portion in and around the Yolo Bypass. The four-county region (Yolo, Solano, Sutter, and Sacramento) surrounding the Yolo Bypass were assumed to be similar to the 12-county Klamath area in terms of household WTP (annualized benefits per household of $40.79 in 2016 dollars).

[6] Calculated WTP fish benefits for the rest of California i.e., (projected 2030 households in California less projected 2030 households in the four counties) times WTP for the rest of California and Oregon from the Klamath Basin Restoration Study. It is assumed that the average WTP per household is equivalent to the Klamath River Basin Restoration Study value for the rest of California and Oregon (annualized benefits per household of $82.98 in 2016 dollars).

[7] Calculated WTP fish benefits for the rest of the Unites States i.e., (projected 2030 households in the United States less projected 2030 households in California) times WTP for the rest of the United States from the Klamath Basin Restoration Study. It is assumed that the average WTP per household is equivalent to the Klamath River Basin Restoration Study value for the rest of the United States (annualized benefits per household of $80.30 in 2016 dollars).

5.3 Summary of Comparisons

Table 5-17 summarizes the relative ranking by alternative plan for project effectiveness, completeness, acceptability, and efficiency criteria.

Table 5-17. Alternative Evaluation Results

Evaluation Factor	Alt 1 East Side Gated Notch	Alt 2 Central Gated Notch	Alt 3 West Side Gated Notch	Alt 4 West Side Managed Flow (Mar 7 closure)	Alt 4 West Side Managed Flow (Mar 15 closure)	Alt 5 Central Multiple Notches	Alt 6 West Side Large Gated Notch
Effectiveness							
Winter-run entrainment							
Spring-run entrainment							
Winter-run escapement							
Spring-run escapement							
Inundation area							
Wetted acre-days							
Food production							
Fish passage: Depth barrier							
Fish passage: Velocity barrier							
Fish passage: Operational range							
Fish passage: Percent of season passable							
Fish passage: Open channel flow							
Juvenile stranding or predation risk							
Completeness							
Addresses all four focus fish species							
Acceptability							
Effects on agricultural production							

Evaluation Factor	Alt 1 East Side Gated Notch	Alt 2 Central Gated Notch	Alt 3 West Side Gated Notch	Alt 4 West Side Managed Flow (Mar 7 closure)	Alt 4 West Side Managed Flow (Mar 15 closure)	Alt 5 Central Multiple Notches	Alt 6 West Side Large Gated Notch
Effects on winter maintenance activities							
Inundation of recreation areas							
Waterfowl: Foraging habitat							
Waterfowl: Reduced food production							
Waterfowl: Access restriction							
Inundation of educational areas							
Impacts to biological resources							
Impacts to cultural resources							
Impacts to flood management							
Impacts to surface water supplies							
Impacts to groundwater supplies							
Changes in WaterFix diversions							
Compatibility with other related efforts							
Efficiency							
Cost-effectiveness							

Legend

High Performance	Medium Performance	Neutral Performance or Minor Benefit/Impact	Poor Performance

5.4 References

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Appendix A Commonly Found Fish Species in the Yolo Bypass

Table A-1. Commonly Found Fish Species in the Yolo Bypass

Common Name	Scientific Name	Common Name	Scientific Name
American shad	*Alosa sapidissima*	Redear sunfish	*Lepomis microlophus*
Bigscale logperch	*Percina macrolepida*	River lamprey	*Lampetra ayersii*
Black bullhead	*Ameriurus melas*	California roach	*Hesperoleucus symmetricus*
Black crappie	*Pomoxis negromaculatus*	Sacramento blackfish	*Orthodon microlepidotus*
Bluegill	*Lepomis macrochirus*	Sacramento perch	*Archoplites interruptus*
Brown bullhead	*Ameriurus nebulosus*	Sacramento pikeminnow	*Ptychocheilus grandis*
Channel catfish	*Ictalurus punctatus*	Sacramento sucker	*Catostomus occidentalis*
Chinook salmon	*Oncorhynchus tshawytscha*	Shimofuri goby	*Tridentiger bifasciatus*
Common carp	*Cyprinus carpio*	Smallmouth bass	*Micropterus salmoides*
Delta smelt	*Hypomesus transpacificus*	Splittail	*Pogonichthys macrolepidotus*
Fathead minnow	*Pimephales promelas*	Spotted bass	*Micropterus punctulatus*
Golden shiner	*Notemigonus crysoleucas*	Steelhead	*Oncorhynchus mykiss*
Goldfish	*Carassius auratus*	Striped bass	*Morone saxatilis*
Green sunfish	*Lepomois cyanellus*	Threadfin shad	*Dorosoma petenense*
Green sturgeon	*Acipenser medirostris*	Threespine stickleback	*Gasterosteus aculeatus*
Hardhead	*Mylopharodon conocephalus*	Tule perch	*Hysterocarpus traski*
Hitch	*Lavinia exilicauda*	Wakasagi	*Hypomesus nipponensis*
Inland silverside	*Menidia beryllina*	Warmouth	*Chaenobryttus gulosus*
Largemouth bass	*Micropterus salmoides*	Western mosquitofish	*Gambusia afinis*
Pacific lamprey	*Lamoetra tridentate*	White catfish	*Ameiurus catus*
Pacific staghorn Sculpin	*Leptocottus armatus*	White crappie	*Pomoxis annularis*
Prickly sculpin	*Cottus asper*	White sturgeon	*Acipenser transmontanus*
Red shiner	*Cyprinella lutrensis*	Yellowfin goby	*Acanthogobius flavimanus*

Source: Modified from Sommer et al. 2001.

Table A-2. Fish Species of Focused Evaluation in the Project Area

Common Name	Status
Sacramento River winter-run Chinook salmon evolutionarily significant unit (ESU)	Federal and State endangered
Central Valley spring-run Chinook salmon ESU	Federal and State threatened
Central Valley fall-/late fall-run Chinook salmon ESU	Federal species of concern; State species of special concern
Central Valley steelhead distinct population segment (DPS)	Federal threatened
Klamath Mountains Province Steelhead DPS	State species of special concern
Southern DPS of North American green sturgeon	Federal threatened; State species of special concern
Delta smelt	Federal threatened; State endangered
Longfin smelt	Federal candidate[a]; State threatened
White sturgeon	State species of special concern
River lamprey	State species of special concern
Pacific lamprey	State species of special concern
Sacramento splittail	State species of special concern
Hardhead	State species of special concern
Sacramento hitch	State species of special concern
Sacramento pikeminnow	Native predatory species
American shad	Recreational and/or commercial importance
Striped bass	Recreational and/or commercial importance
Warm water game fishes	Recreational and/or commercial importance

Note: Federal candidate status applies to the San Francisco Bay-Delta DPS of longfin smelt.

Reference

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Appendix B
Commonly Found Special-Status Plant and Wildlife Species in the Project Area

Table B-1. Commonly Found Special-Status Plants in the Project Area

Common Name	Scientific Name	Common Name	Scientific Name
Depauperate milkvetch	*Astragalus pauperculus*	Heckard's peppergrass	*Lepidium latipes var. heckardii*
Alkali milk-vetch	*Astragalus tener var. tener*	Woolly-headed lessingia	*Lessingia hololeuca*
Brittlescale	*Atriplex depressa*	California alkali grass	*Puccinellia simplex*
Parry's rough tarplant	*Centromadia parryi ssp. rudis*	Sanford's arrowhead	*Sagittaria sanfordii*
Palmate-bracted bird's-beak	*Chloropyron palmatum*	Wright's trichocoronis	*Trichocoronis wrightii var. wrightii*
San Joaquin spearscale	*Extriplex joaquinana*	Saline clover	*Trifolium hydrophilum*
Woolly rose-mallow	*Hibiscus lasiocarpos var. occidentalis*		

Source: California Native Plant Society 2016

Table B-2. Commonly Found Special-Status Wildlife in the Project Area

Common Name	Scientific Name	Common Name	Scientific Name
Tricolored blackbird	*Agelaius tricolor*	Northern California black walnut	*Juglans hindsii*
Grasshopper sparrow	*Ammodramus Savannarum*	Silver-haired bat	*Lasionycteris noctivagans*
Pallid bat	*Antrozous pallidus*	Western red bat	*Lasiurus blossevillii*
Sacramento perch	*Archoplites interruptus*	Hoary bat	*Lasiurus cinereus*
Great egret	*Ardea alba*	Delta tule pea	*Lathyrus jepsonii var. jepsonii*
Great blue heron	*Ardea Herodias*	Heckard's pepper-grass	*Lepidium latipes var. heckardii*
Ferris' milk-vetch	*Astragalus tener var. ferrisiae*	Vernal pool tadpole shrimp	*Lepidurus packardi*
Alkali milk-vetch	*Astragalus tener var. tener*	Mason's lilaeopsis	*Lilaeopsis masonii*
Burrowing owl	*Athene cunicularia*	California linderiella	*Linderiella occidentalis*
Heartscale	*Atriplex cordulata var. cordulata*	Song sparrow ("Modesto" population)	*Melospiza melodia*
Brittlescale	*Atriplex depressa*	Antioch multilid wasp	*Myrmosula pacifica*

Common Name	Scientific Name	Common Name	Scientific Name
Crotch bumble bee	*Bombus crotchii*	Baker's navarretia	*Navarretia leucocephala ssp. bakeri*
Western bumble bee	*Bombus occidentalis*	Colusa grass	*Neostapfia colusana*
Conservancy fairy shrimp	*Branchinecta conservatio*	Black-crowned night heron	*Nycticorax*
Vernal pool fairy shrimp	*Branchinecta lynchi*	Steelhead – Central Valley DPS	*Oncorhynchus mykiss irideus*
Midvalley fairy shrimp	*Branchinecta mesovallensis*	Chinook salmon – Central Valley spring-run ESU	*Oncorhynchus tshawytscha*
Swainson’s hawk	*Buteo swainsoni*	Chinook salmon – Sacramento River winter-run ESU	*Oncorhynchus tshawytscha*
Bristly sedge	*Carex comosa*	Bearded popcorn flower	*Plagiobothrys hystriculus*
Western snowy plover	*Charadrius alexandrines nivosus*	White-faced ibis	*Plegadis chihi*
Mountain plover	*Charadrius montanus*	Sacramento splittail	*Pogonichthys macrolepidotus*
Palmate-bracted salted bird’s-beak	*Chloropyron palmatum*	Purple martin	*Progne subis*
Sacramento Valley tiger beetle	*Cicindela hirticollis abrupta*	California alkali grass	*Puccinellia simplex*
Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*	Bank swallow	*Riparia*
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	Sanford's arrowhead	*Sagittaria sanfordii*
Snowy egret	*Egretta thula*	Longfin smelt	*Spirinchus thaleichthys*
White-tailed kite	*Elanus leucurus*	Suisun Marsh aster	*Symphyotrichum lentum*
Elderberry Savanna	*Elderberry Savanna*	American badger	*Taxidea taxus*
Western pond turtle	*Emys marmorata*	Eulachon	*Thaleichthys pacificus*
San Joaquin spearscale	*Extriplex joaquinana*	Giant gartersnake	*Thamnophis gigas*
Merlin	*Falco columbarius*	Saline clover	*Trifolium hydrophilum*
Great Valley Cottonwood Riparian Forest	*Great Valley Cottonwood Riparian Forest*	Crampton's tuctoria or Solano grass	*Tuctoria mucronata*
Great Valley Mixed Riparian Forest	*Great Valley Mixed Riparian Forest*	Least Bell's vireo	*Vireo bellii pusillus*
Woolly rose-mallow	*Hibiscus lasiocarpos var. occidentalis*	Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Delta smelt	*Hypomesus transpacificus*		

Source: California Department of Fish and Wildlife 2016

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Appendix C
Adult Fish Passage Criteria for Federally Listed Species within the Yolo Bypass and Sacramento River

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State of California
California Natural Resources Agency
Department of Water Resources

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Adult fish passage criteria for federally listed species within the Yolo Bypass and Sacramento River

Technical Memorandum

May 2017

Edmund G. Brown Jr.	John Laird	Mark W. Cowin
Governor	Secretary for Resources	Director
State of California	Natural Resources Agency	Department of Water Resources

Suggested Citation

[DWR] California Department of Water Resources. 2017. Adult fish passage criteria for federally listed species within the Yolo Bypass and Sacramento River. Technical memorandum for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project. Sacramento, California.

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Acronyms and Abbreviations

Caltrans	California Department of Transportation
DPS	Distinct Population Segment
DWR	California Department of Water Resources
ESA	Endangered Species Act
FETT	Yolo Bypass Fisheries and Engineering Technical Team
NMFS	National Marine Fisheries Service
PWT	Project Work Team
Reclamation	United States Bureau of Reclamation
RPA	Reasonable and Prudent Alternative

1. Introduction

In June 2009, the National Marine Fisheries Service (NMFS) issued the Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and the State Water Project (2009 Biological Opinion). The 2009 Biological Opinion stated that current operations were likely to jeopardize the continued existence of four federally listed anadromous fish species: Sacramento River winter-run Chinook salmon *Oncorhynchus tshawytscha*, Central Valley spring-run Chinook salmon *O. tshawytscha*, California Central Valley steelhead Distinct Population Segment (DPS) *O. mykiss*, and Southern DPS of North American Green Sturgeon *Acipenser medirostris* (NMFS 2009). Under the 2009 Biological Opinion, Reasonable Prudent Alternative (RPA) Actions were set forth to improve the current conditions to meet compliance with the federal Endangered Species Act (ESA). Specifically, RPA 1.7 of the 2009 Biological Opinion states the need to improve connectivity for both migrating juvenile and adult federally listed fish species within the Yolo Bypass (NMFS 2009). In response to the RPA Actions, the California Department of Water Resources (DWR) and the United States Bureau of Reclamation (Reclamation) developed the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan to guide fish passage improvement projects within the Yolo Bypass (DWR and Reclamation 2012).

Historically, engineers designed fish passage improvement structures in the Central Valley for salmonid passage with minor modifications to pass other anadromous species. Within the Yolo Bypass, the Fremont Weir acts as a migratory barrier to anadromous fish due to an existing Denil fish ladder that was designed for salmonid passage. Unfortunately because of its size and elevation, the Denil fish ladder does not provide adequate passage for salmonids or sturgeon (DWR and Reclamation 2012). Due to morphological and physiological variances between salmonids and sturgeon, salmonid passage structures do not provide efficient multi-species passage (Webber et al. 2007, FETT 2015). Sturgeon are benthic cruising fish that are often blocked by passage structures designed for jumping, an innate swimming behavior of salmonids.

To evaluate fish passage improvements for multi-species access, DWR and Reclamation formed the interagency Yolo Bypass Fisheries and Engineering Technical Team (FETT). The Sturgeon Project Work Team (PWT), a cooperative of fisheries professionals involved with Central Valley sturgeon issues, provided FETT with additional guidance for sturgeon passage via personal communication documented throughout this memorandum. With assistance from the Sturgeon PWT, FETT proposed multi-species fish passage criteria for use in modeling Yolo Bypass improvement projects (FETT 2015). As defined by FETT (2016), reliable fish passage includes passage meeting depth and velocity criteria when target species are present, passage with non-pressurized flow and limited reliance on flow control devices, and passage with entrances to channels placed to maximize fish attraction. FETT criteria are expected to allow passage of native species within the Yolo Bypass, but are focused on passage requirements for the four federally listed species addressed in the 2009 Biological Opinion. This memorandum provides specific criteria for accessing passage success for each species addressed, including Green Sturgeon, which require the most stringent criteria among target listed species.

2. Target Species

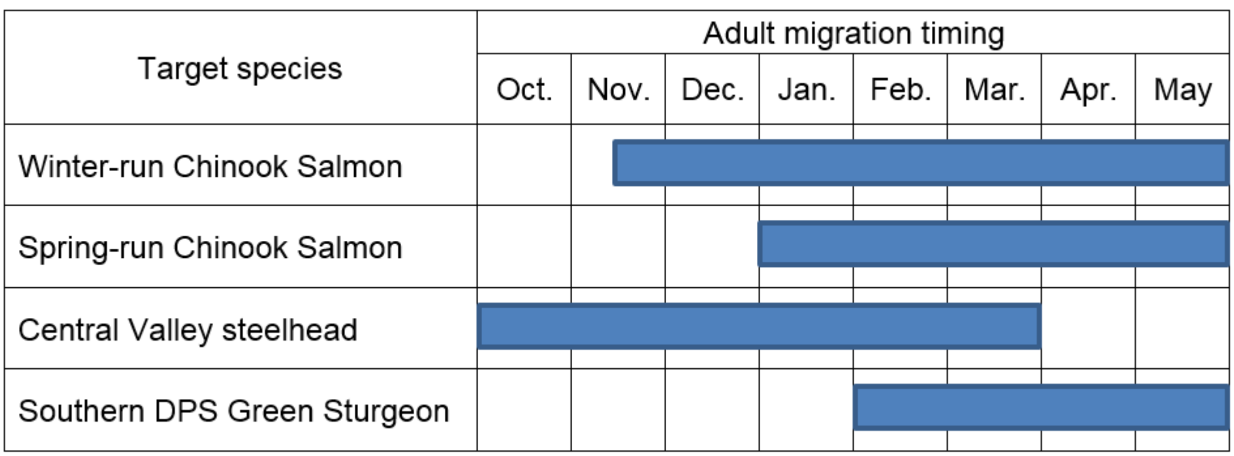
2.1 Chinook Salmon

2.1.1 Sacramento River Winter-run Chinook Salmon

Sacramento River winter-run Chinook salmon are endemic to the Sacramento River Basin with historical spawning grounds upstream of now Lake Shasta Dam. Following the 1945 construction of the Shasta Dam, winter-run Chinook salmon have been cut off from upstream natal spawning grounds (Moyle 2002). Currently, winter-run persist below Keswick Dam on the Sacramento River and rely solely on cold water releases from the Shasta Reservoir to provide adequate environmental conditions (Reynolds et al. 1993, Yoshiyama et al. 1998).

Adult winter-run enter freshwater in the winter or early spring (NMFS 2009), with long-term fish monitoring in the Sacramento River predicting presence near Fremont weir between mid-November and May (Table 1; Hallock and Fisher 1985, Fisher 1994, Yoshiyama et al. 1998, DWR and Reclamation 2012, FETT 2015). The majority of winter-run are known to spawn during the spring or early summer in the 5 mile area downstream of Keswick Dam (NMFS 2009). Due primarily to limited and degraded spawning habitat, the last remaining population of winter-run Chinook salmon is listed under the federal ESA and California ESA as Endangered (Williams and Williams 1991, 59 FR 440).

Table 1. Adult fish migration timing in the Sacramento River, near Fremont Weir, for NMFS (2009) target species.



*sourced from DWR and Reclamation 2012 and FETT 2015

2.1.2 Central Valley Spring-run Chinook Salmon

Central Valley spring-run Chinook salmon were historically present throughout the Sacramento-San Joaquin River System, making this run one of the most abundant races on the Pacific coast (Reynolds et al. 1993). With similar spawning areas to winter-run, spring-run were also cut off from upstream Sacramento River habitat with the construction of the Shasta Dam. The construction of the Friant Dam in 1948 eliminated San Joaquin habitat; therefore, limiting principle populations to Deer, Mill, and Butte

Creeks (tributaries to the Sacramento River), which until then only served as minor habitat (Yoshiyama et al. 1998, Moyle 2002). Based on hydroacoustic and video monitoring in Mill Creek, DWR and Reclamation (2012) predict adult spring-run migration timing near Fremont Weir to occur between January and mid to late May (Table 1; Johnson et al. 2011, FETT 2015).

In addition to the lack of suitable spawning habitat, spring-run Chinook salmon also face natural and artificial hybridization with fall-run as a result of similar run timing and incorrect hatchery designations (Yoshiyama et al. 1998). Due to the small number of non-hybridized populations remaining, Central Valley spring-run Chinook salmon are listed under the federal ESA and California ESA as Threatened (CDFG 1998, 64 FR 50394).

2.2 CA Central Valley steelhead DPS

The CA Central Valley steelhead DPS represents the anadromous form of Rainbow Trout native to the Sacramento-San Joaquin River System (71 FR 834). Like spring-run Chinook salmon, CA Central Valley steelhead were once widely distributed (Yoshiyama et al. 1998); however, the construction of multiples dams throughout their range has severely limited available spawning habitat (Moyle 2002). Steelhead are listed under the federal ESA as Threatened with few remaining wild populations in Cottonwood, Antelope, Deer, and Mill Creeks and in lower Yuba River (63 FR 13347, Moyle 2002, NMFS 2014). Existing populations in the Central Valley are winter steelhead, meaning that adults migrate into freshwater at maturity and spawn shortly after. Fyke data indicates that steelhead migration near Fremont weir peaks in early October and extends through March (Table 1; Hallock et al. 1957, Hallock 1989, DWR and Reclamation 2012, FETT 2015).

2.3 Southern DPS North American Green Sturgeon

North American Green Sturgeon are native to coastal waters from Mexico to Alaska and consist of two DPS: the Northern DPS and the Southern DPS (68 FR 4433, Israel et al. 2004). The Northern DPS of Green Sturgeon spawn in the Rogue River, OR and in the Klamath-Trinity River, CA and are listed as a NMFS Species of Concern (Moyle 2002, Adams et al. 2002). The Southern DPS includes sturgeon populations south of the Eel River, CA with spawning grounds found in the Sacramento River, CA (Moyle 2002) and recently in the Feather River, CA (Seesholtz et al. 2015). Under the federal ESA, the Southern DPS are listed as Threatened with population declines attributed primarily to a reduction in spawning and juvenile rearing habitat (71 FR 17757). As marine-oriented anadromous fish, Green Sturgeon spend most of their lives along the Pacific coast, returning to freshwater to spawn upon reaching sexual maturity. Based on telemetry studies within the Sacramento River, Green Sturgeon migration to spawning grounds begins in February and extends through early May (Table 1; Heublein et al. 2009, FETT 2015).

While migrating upstream, Green Sturgeon encounter impassable dams and water diversion structures that severely impede their ability to reach spawning grounds (Heublein et al. 2009, Poletto et al. 2014). Many facilities are equipped with screens and fish ladders designed to accommodate salmonids; however, these structures can cause sturgeon to become impinged and often block sturgeon from upstream passage. Compared to salmonids, sturgeon are believed to have reduced swimming ability attributed to the presence of a heterocercal tail, scutes, and a notochord, causing increased drag and reduced thrust (Deslauriers and Kieffer 2011, Webber et al. 2007). Because of variation among species, it is important to consider size and behavior of all fish species utilizing a structure when designing a multi-species passage structure.

Providing efficient passage for Green Sturgeon is a conservation priority, however few studies have been done to support development of design criteria specific to Green Sturgeon. Green Sturgeon fish passage studies are limited by low abundance of the species and availability of fish for use in the studies. Therefore, White Sturgeon *Acipenser transmontanus* of similar size and swimming performance are often utilized as a surrogate in adult life stage studies (DWR 2007, Verhille et al. 2014). Life history traits are also comparable between the sympatric species, with both species spawning in similar areas and at overlapping times (Moyle et al. 2015, Poytress et al. 2015). Juvenile studies comparing Green and White Sturgeon have noted differences in swimming abilities, which limits juvenile surrogacy studies (DWR 2007, Polette et al. 2014, Verhille et al. 2014). Although White Sturgeon are currently State listed as a Species of Special Concern in California, consistent fisheries monitoring have detected robust populations spawning in the Sacramento River (Schaffter 1997, Moyle et al. 2015).

3. Passage Criteria

3.1 Timing

Migration timing criteria established in the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan and revised by FETT provide distinct timing criteria for each species at Fremont Weir (Table 1). Based on these windows for migration, operational criteria at Fremont Weir should focus on the time period between November and the end of April. Although steelhead migration peaks in early fall, October is omitted from this timing window because fall conditions at Fremont Weir exhibit low flow that is not conducive to fish migration. Instead, it is assumed that steelhead will migrate through higher attraction flows in the Sacramento River main stem (DWR and Reclamation 2012). According to various fish monitoring efforts within the Sacramento River, April accounts for the peak of fish migration; therefore, May is excluded from fish passage analyses (Hallock et al. 1957, Hallock and Fisher 1985, Hallock 1989, Heublein et al. 2009, Johnson et al. 2011, DWR and Reclamation 2012). The migration timing of November 1 through April 30 should be used as a generalized timing window to provide better understanding of passage performance for analyses.

3.1 Depth

In addition to timing, fish passage design must also take into consideration specific requirements needed to allow passage of all migrating species. Because salmonids and sturgeons are morphologically very different, they exhibit different swimming performances, especially in shallow, high velocity fishways (Webber et al. 2007, FETT 2015).

As established by the California Department of Fish and Game (DFG) and the California Department of Transportation (Caltrans), salmonids require a minimum depth of 1 ft of flow throughout the structure to allow for passage (Caltrans 2007, NMFS 2011). NMFS (2014) Recovery Plan for Chinook salmon and CA Central Valley steelhead acknowledges the minimum depth criterion of 0.8 ft for adult salmonids (Thompson 1972). Other studies have found that salmonids are capable of passage in depths as low as 0.5 ft; however, multi-species passage requires a structure that allows for species with the most stringent depth requirements (DWR and Reclamation 2012).

When designing a passage structure for Green Sturgeon, minimum depth is an important factor not only due to sizing constraints for fish but also swimming physiology. When depths only provide for partial submergence, sturgeon are unable to achieve efficient thrust especially without some risk of physical injury due to contact with the substrate or structure (Caltrans 2007). Heublein et al. (2009) found Green Sturgeon passing in shallow, high velocity areas injured with ventral striations and damage to scutes and fins, possibly due to trauma while maneuvering passage structures. Shallow depths can also cause partial exposure of gills, which can result in a reduced oxygen uptake that can affect swimming performance. Therefore, as larger bodied, benthic swimmers, sturgeon often avoid passage structures that do not provide sufficient depth.

Studies conducted within a laboratory swimming flume have shown adult White Sturgeon capable of successfully passing at depths of 4.59 ft across 80 ft of flume length (Webber et al. 2007, DWR 2007, Cocherell 2011), with additional trials providing passage at pool depths of 3.3 and 3.0 ft (DWR 2007). Although no swimming flume trials have been conducted on adult Green Sturgeon, several studies have documented depths for Green Sturgeon spawning habitat. Spawning habitat studies provide some insight into minimum depths sturgeon are able to successfully navigate and spawn in. Poytress et al. (2009, 2010, 2011, 2012, 2013, and 2015) found newly spawned eggs on artificial substrate mats at depths ranging from 2 to 37 ft within the Sacramento River. Similar studies conducted within the Lower Columbia River on White Sturgeon found spawned eggs at greater depths of 13 to 79 ft (Parsley et al. 1993) and 10 to 75 ft (McGabe and Tracy 1994).

To provide additional guidance, a federal interagency design team led by NMFS established design guidelines for Atlantic Coast diadromous fish reviewing published literature, conducting controlled experiments, and by analyzing performance data at constructed fish passage structures (Turek et al. 2016). These guidelines can be adapted for Pacific coast fishes by incorporating data on body morphology in the study area. Because sturgeon require the most stringent criteria, Turek et al. (2016) guidelines were adapted for Green and White Sturgeon. The minimum weir opening depths for Green and White Sturgeon were calculated as 3.75 and 4 ft, respectively (Appendix A).

In addition to these findings, NMFS (2011) guidelines for successful salmonid passage recommend a minimum depth for fishway entrances and pools to be 6 ft and 5 ft, respectively. Considering these studies and guidelines, FETT (2015) recommends a minimum of 3 ft of depth to facilitate sturgeon passage at fish passage structures less than 60 ft and 5 ft of depth in project channels greater than or equal to 60 ft (Table 2;

DWR and Reclamation 2012). These depths are expected to provide a positive behavioral response for both salmonids and sturgeon, which are likely to avoid shallow channels.

Table 2. FETT design criteria for adult fish passage structures.

Structure	Project feature length	Depth criterion	Velocity criterion	Width criterion
Intake structure/short channel transitions	< 60 ft	≥ 3 ft	≤ 6 ft/sec	≥ 10 ft
Downstream channel	≥ 60 ft	≥ 5 ft	≤ 4 ft/sec	≥ 10 ft

3.2 Velocity

Velocity criteria also vary among target species, with high velocity areas acting as barriers to passage once flow exceeds burst speed capabilities of either species. Adult salmonids are able to maintain prolonged swim speeds of 6 ft/sec, with burst speeds as high as 10 ft /sec (DFG 2010). NMFS (2014) Recovery Plan for Chinook salmon and CA Central Valley steelhead accepts Thompson (1972) established maximum water velocity criterion of 8 ft/sec for upstream salmonid migration.

Swimming performance varies with an individual's size and life stage, with larger adult sturgeon having greater speed and endurance than juveniles (DWR 2007, Boysen and Hoover 2009, Verhille et al. 2014). During times of high velocity, sturgeon can anchor their pectoral fins against the bottom of passage structures which allows them some opportunity to rest between periods of upstream movement. Larger body size also correlates to greater anchoring ability, presumably because of larger pectoral fins (DWR 2007, Cocherell et al. 2011). Even with the anchoring ability of sturgeon, in order to limit fatigue, slower velocity sections are needed throughout long structures to provide recovery periods (Webber 2007, DWR and Reclamation 2012).

Several studies have documented White Sturgeon swimming performance through flume studies with some telemetry studies documenting travel rates through the Sacramento River and confluences. By conducting laboratory swimming flume studies, Webber et al. (2007) determined adult White Sturgeon were able to pass through structures at velocities ranging from 2.76 to 8.27 ft/sec over 80 ft of flume length. Similar studies showed White Sturgeon were capable of swimming through flumes at velocities between 5.5 and 6.9 ft/sec across 80 ft (DWR 2007 and Cocherell et al. 2011) with 50% of healthy adults capable of ascending the flume at a 4% incline (Cocherell et al. 2011).

In comparison, Nguyen et al. (2015) found sub-adult (mean fork length of 95.5 cm) White Sturgeon able to maintain station (via anchoring or swimming) at velocities of 3.77 ft/sec for 10 minutes, after which fish reached fatigue. Results also indicated that sub-adult sturgeon remained stationary by anchoring when velocities through the structure were less than 1.96 ft/sec (Nguyen et al. 2015, Zac Jackson, Lodi Fish and

Wildlife Office, personal communication, March 28, 2015). Webber et al. (2007) found similar results with no sturgeon attraction to flows between 2.5 and 3.5 ft/sec.

Telemetry studies within the Sacramento River have reported upstream migrations of adult White Sturgeon to be as fast as 0.95 ft/sec (25.0 km/day), with an average swim speed of 0.45 ft/sec (11.9 km/day) (Schaffter 1997). Heublein et al. (2009) showed similar, albeit more variable rates of movement through the Sacramento River, with fish traveling at speeds below 0.58 ft/sec (15.3 km/day). Within the Tule Canal, White Sturgeon telemetry studies have reported similar mean upstream migration velocities at 0.59 ft/sec (Myfanwy Johnston, University of California Davis, personal communication, November 11, 2015). Telemetry studies in the river provide some insight into sustained swim speeds. However, downstream velocity in the river is variable across time and location and therefore limits an accurate representation of swim speed of tagged fish.

During spawning, White Sturgeon have been recorded in velocities of 9.2 ft/sec (mean 6.9 ft/sec) within the Lower Columbia River (Parsley et al. 1993). Artificial egg mat studies within this system showed newly spawned eggs at near-bottom velocities ranging from 2 to 7.9 ft/sec (McGabe and Tracy 1994). Similar studies for Green Sturgeon in the Sacramento River found newly spawned eggs in waters with a mean velocity of 2.6 ft/sec (Poytress 2015).

In addition, Turek et al. (2016) guidelines for Atlantic Coast diadromous fish were adapted for maximum velocity at a fish passage structure for Green and White Sturgeon. Based on known body morphology in the Sacramento River, maximum water velocities for Green and White Sturgeon should not exceed 12.75 and 8 ft/sec, respectively (Appendix A).

Based on these findings, FETT (2015) recommends a maximum velocity criterion of 6 ft/sec at fish passage structures and 4 ft/sec in project channels greater than 60 ft (Table 2; Caltrans 2007). Stable and uniform flow through the structure is necessary to provide efficient passage for larger bodied sturgeon and to prevent premature fatigue caused by turbulent flows (DWR 2007).

3.3 Width

To provide efficient passage for salmonids and sturgeon, the minimum width of a structure should be considered to prevent potential passage delay or physical injury to the fish. A structure too narrow to pass fish will deter fish from moving upstream and may cause harm to the fish while maneuvering. NMFS (2011) guidelines for salmonid passage specify that fishway entrance widths should be a minimum of 4 ft wide and that pools should be a minimum of 6 ft wide (Table 2). However, as with other passage criteria, sturgeon differ from salmonids in body size and physiology. Therefore, larger bodied sturgeon will require additional area for unobstructed maneuvering in a passage structure than salmonids.

Swimming flume studies conducted with adult White Sturgeon found that fish were able to pass successfully through a flume measured at 6.9 ft wide (Webber et al. 2007, DWR 2007, Cocherell et al. 2011). Further trials found that sturgeon could pass through slotted widths between 1.42 and 2.92 ft wide, with recommended slot width no less than 2 ft (DWR 2007). Vertical slot passage was also observed within the Columbia

River at Dalles Dam, in which more adult White Sturgeon were found ascending the east fish ladder than the north fish ladder (Parsley et al. 2007). Preference was assumed due to lack of slots and greater width in the east fish ladder (30.0 ft) than the north fish ladder (24.0 ft). The east fish ladder also has greater cross-sectional areas for orifices than the north fish ladder, which may facilitate upstream passage (Parsley et al. 2007).

Although slot passage may provide some indication of minimum width, slot passage should not be used as a width criterion for efficient sturgeon passage through a fishway (Parsley et al. 2007, DWR and Reclamation 2012). Instead, DWR and Reclamation (2012) suggest using a body length approach, whereby the fishway is designed wide enough to allow for sturgeon to make a complete directional change. Therefore, it is recommended that a minimum width criterion of 10 ft be used when designing fish passage structures and project channels (Table 2; Moyle 2002, DWR and Reclamation 2012). This criterion is more conservative than the adapted guidelines from Turek et al (2016) that calculate a minimum width for Green and White Sturgeon as 5 and 5.5 ft, respectively.

4. Additional Design Considerations

Considerations for designing an effective passage structure for sturgeon goes beyond dimensions to include open bottom and open channel concepts and flow requirements. As benthic swimmers, sturgeon generate speed through body curvature. This behavior can limit passage success or lead to structure avoidance if a channel concept (e.g., fish ladder) includes submerged impediments or orifices designed for salmonid passage (Parsley et al. 2007, Dennis Cocherell, University of California Davis, personal communication, April 3, 2015). Therefore, orifices should be designed to accommodate sturgeon passage for dimensioning and velocity thresholds.

In addition to dimension criteria, fishway design preference should be open channel concepts, with limited use of tunnels and pressurized flow (NMFS 2011). If tunnels are constructed due to site requirements, pressure throughout the tunnel should be equal to the atmospheric pressure with transitions in pressures avoided. Fishways should also avoid hydraulic and lighting transitions (NMFS 2011) as well as light, sound, or partial barriers due to unknown effects on sturgeon (Parsley et al. 2007).

Turbulent flows also limit passage for sturgeon as well as salmonids by preventing fish from maintaining station and potentially causing disorientation or injury (DFG 2010, NMFS 2011). Studies conducted by Cheong et al. (2006) found that increased turbidity caused a delay in passage for White Sturgeon. In a similar study, Cocherell et al. (2011) found that White Sturgeon passage performance increased as turbulence and eddies decreased, indicating that non-turbulent flow improves passage success. Therefore, passage structures should avoid high velocity transitions and turbulent areas with designs favoring non-turbulent flow (NMFS 2011, Dennis Cocherell, University of California Davis, personal communication, April 3, 2015, Boyd Kynard, University of Massachusetts Amherst, personal communication, March 27, 2015).

The fish passage design considerations addressed in this memorandum provide guidance for early designing stages. These criteria are not universally applicable and should not replace site specific criteria dependent on local hydrology and other site specific considerations. As the design process develops sufficient information, engineers should incorporate the use of modeling (e.g., FishXing) to provide refined design considerations specific to the study site's hydraulic conditions and target species behavior and swimming performance.

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Appendix A

The following calculations for design considerations were adapted from Turek et al. (2016) with specific body morphology measurements sited. While these values were not adopted due to other considerations, they were helpful in providing some validation that the adopted criteria were appropriate for target species.

Green Sturgeon

Minimum Total Length = 130 cm (Moyle 2002)
Maximum Total Length = 284 cm (M. Manual, DWR, unpublished data)

Minimum Weir Opening Depth: 3.75 ft
Minimum Depth = 3 × Maximum Body Depth
Maximum Body Depth = 0.13 × Maximum Total Length
This value was rounded up by 0.25 ft.

Maximum Weir Opening Water Velocity: 12.75 ft/sec
Maximum Velocity = 3 × Minimum Total Length/Second
This value was rounded down by 0.25 ft.

Minimum Weir Opening Width: 5 ft
Minimum Width = 2 × Maximum Body Width
Maximum Body Width = 0.27 × Maximum Total Length
This value was rounded up by 0.25 ft.

White Sturgeon

Minimum Total Length = 82 cm (Moyle 2002)
Maximum Total Length = 305 cm (Moyle 2002)

Minimum Weir Opening Depth: 4 ft
Minimum Depth = 3 × Maximum Body Depth
Maximum Body Depth = 0.13 × Maximum Total Length
This value was rounded up by 0.25 ft.

Maximum Weir Opening Water Velocity: 8 ft/sec
Maximum Velocity = 3 × Minimum Total Length/Second
This value was rounded down by 0.25 ft.

Minimum Weir Opening Width: 5.5 ft
Minimum Width = 2 × Maximum Body Width
Maximum Body Width = 0.27 × Maximum Total Length
This value was rounded up by 0.25 ft.

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Appendix B
Constructability and Construction Considerations

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Draft Technical Memorandum

Constructability and Construction Considerations

Yolo Bypass Salmonid Habitat Restoration & Fish Passage Project – Ten Percent Design

Yolo County, CA
September 19, 2017

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Yolo Bypass Salmonid Habitat Restoration & Fish Passage Project – Ten Percent Design

Constructability and Construction Considerations

September 19, 2017

1 PURPOSE AND BACKGROUND

HDR assessed the potential construction period, and the associated equipment and personnel requirements to construct the key components of the six Environmental Impact Statement and Environmental Impact Report (EIS/EIR) alternatives selected through the plan formulation process. This technical memorandum (TM), which is intended to accompany Volume II –10% Design Drawings, describes the approach, assumptions, and results of the construction related evaluations.

The six project alternatives that were selected through the plan formulation process are listed below. The associated key project components are summarized in Table 1, the general alignments in the Yolo Bypass Fremont Weir State Wildlife Area are presented in Figure 1, the general location of the Tule Canal water control structures associated with Alternatives 4 and 5 are presented in Figure 2, and the 10 percent design drawings are contained in Volume II – 10% Design Drawings.

Six project alternatives have been developed:

- Alternative 1 – East Channel, 6,000 cubic feet per second (cfs) Design Flow
- Alternative 2 – Central Channel, 6000 cfs Design Flow
- Alternative 3 – West Channel, 6,000 cfs Design Flow
- Alternative 4 – West Channel, 3,000 cfs Design Flow and Managed Floodplain
- Alternative 5 – Multiple Channels, 3,400 cfs Design Flow
- Alternative 6 – West Channel, 12,000 cfs Design Flow and Managed Floodplain

Table 1. Alternative Components

Components	Alt 1 East	Alt 2 Center	Alt 3 West	Alt 4 West	Alt 5 Multiple	Alt 6 West
Peak Design Flow (CFS)	**6,000**	**6,000**	**6,000**	**3,000**	**3,400**	**12,000**
East Channel (Intake Channel, Headworks, & Outlet Channel)	X					
Central Channel (Intake Channel, Headworks, & Outlet Channel)		X			X	
West Channel (Intake Channel, Headworks, & Outlet Channel)			X	X		X
Sacramento River Grading		X			X	
Supplemental Fish Passage West	X	X			X	
Supplemental Fish Passage East			X	X		X
Downstream Channel	X	X	X	X		X
Sacramento River Grading		X			X	
Ag Crossing 1	X	X	X	X	X	X
Knaggs Area Improvements				X		
Conaway Area Improvements				X		
Swanston Area Improvements					X	

Figure 1. Yolo Bypass Alternatives and Components

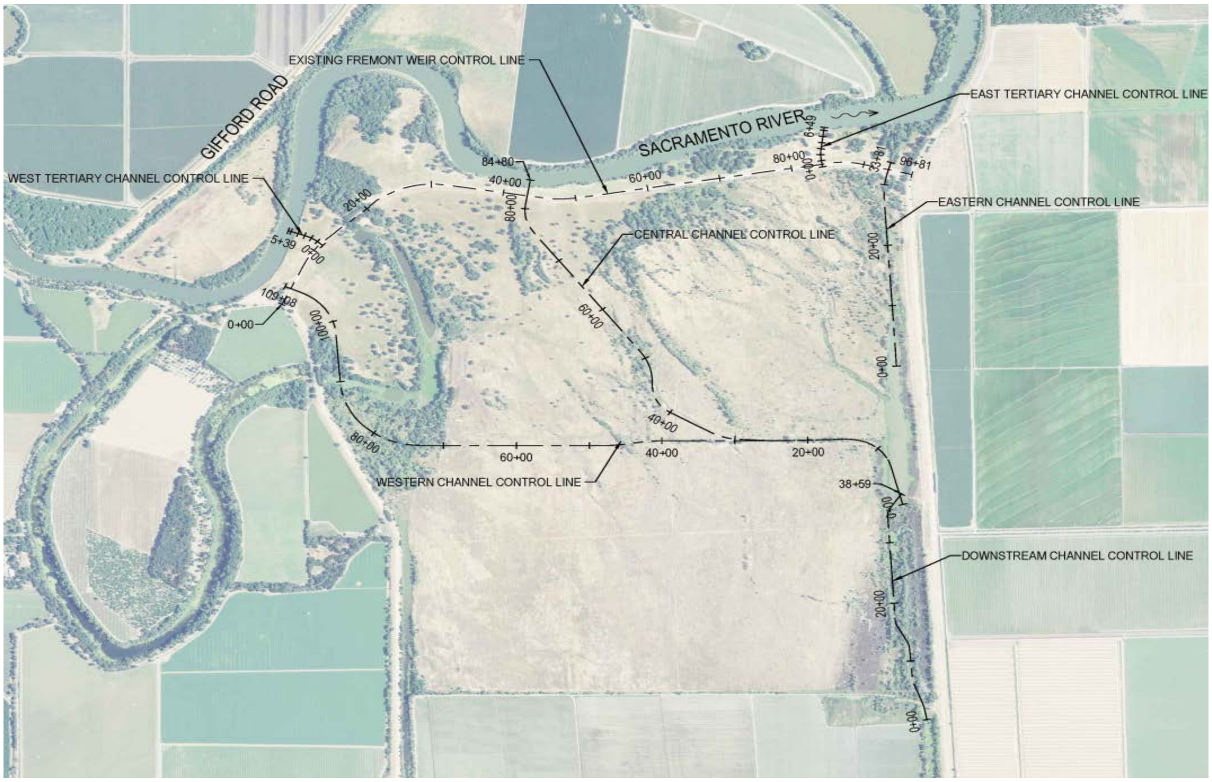
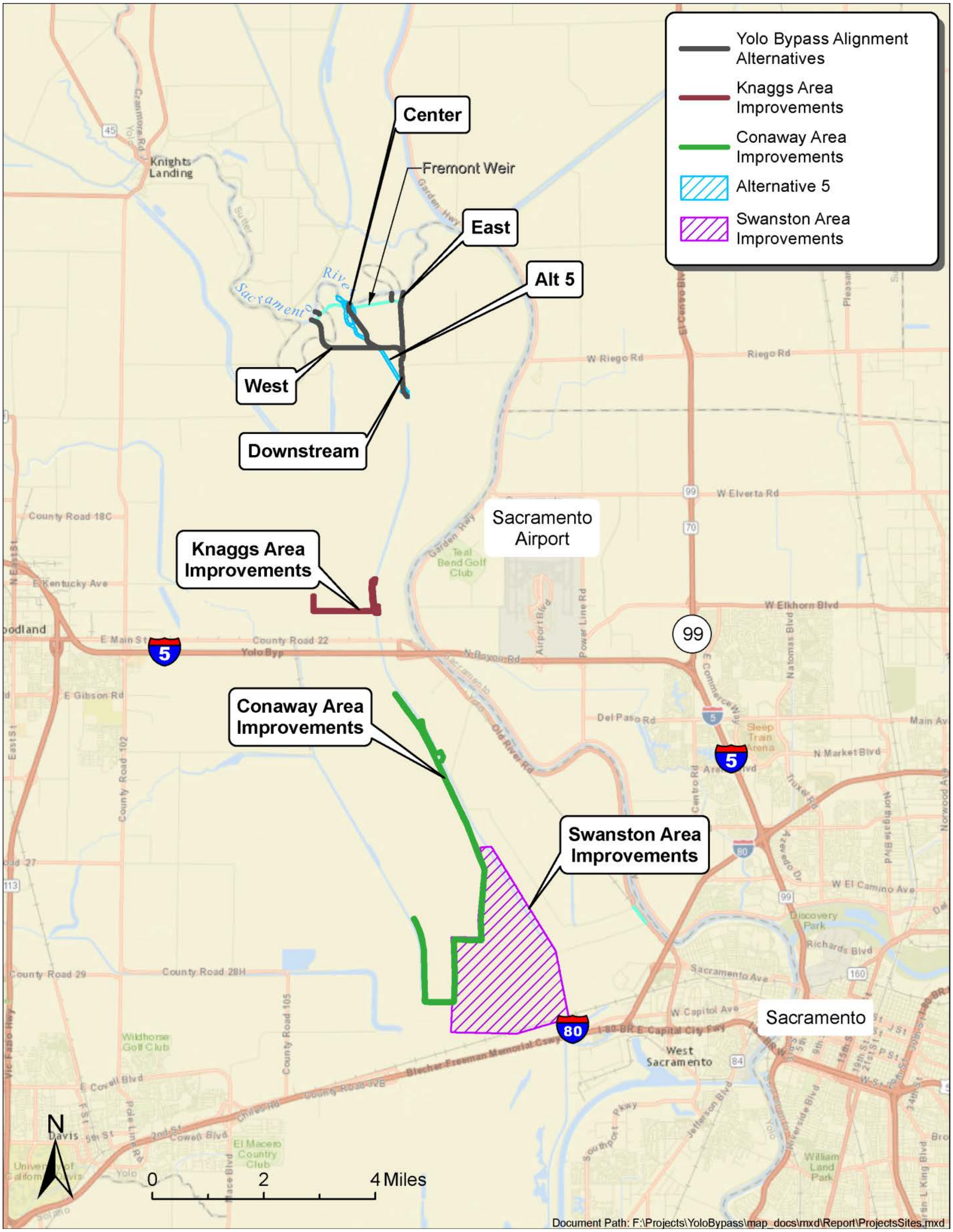


Figure 2. Yolo Bypass Alternatives and Components



2 KEY CONSTRUCTABLITY ISSUES

A few of the key constructability issues that may affect the cost and schedule for constructing the project alternatives are discussed in this section. They include flood regulatory agency requirements, air quality, protected species, high groundwater, and the Tule Canal operational requirements.

The allowable construction window will be driven by various schedule constraints and it is anticipated that the estimated allowable annual construction period will extend from April 15 to November 1, with potentially additional schedule restrictions on work in close proximity to the Sacramento River and Tule Canal. The allowable period was established reflecting the following anticipated regulatory requirements.

Flood Regulatory Agency Requirements

The Yolo Bypass is a critical element of the State Plan of Flood Control and is designed to flood. If all of the project features cannot be constructed in one construction season, provisions will need to be made to allow for the constructed project features to withstand being inundated during the flood season and to then prepare them for continuing the construction process the following season.

As such, the flood season construction window as dictated by the Central Valley Flood Projection Board (CVFPB) and the Army Corps of Engineers (USACE) is from April 15 through November 1, which is the typical construction window for working on a flood protection project.

Air Regulatory Agency Constraints

Additionally, the construction operations will likely have daily, monthly, and annual exceedence levels for air pollution limits that could limit the operational rates of equipment, which could also drive the construction schedule. At this time, the construction schedule is based upon a standard 10 hour work shift, anticipated equipment, staffing levels, and the associated production rates to determine if it is realistically possible to complete the project construction within a single season without consideration for limits of air pollution. This does not preclude the contractor from, or consider, performing extended or multiple shifts for the various project components, which could ultimately alter schedule and air pollution impacts.

National Marine Fisheries Service Constraints – Confirm Tule Canal or not

The National Marine Fisheries Service (NMFS) will likely further restrict work in close proximity to the Sacramento River and Tule Canal, roughly within 100 to 150 feet of the ordinary high water mark (OHWM), to the periods between July 1 and October 31.

Protected Species

Giant Gardner Snake habitat has been identified within the project area. As a result, major earthwork disturbance operations will be prohibited between November and April, when the snakes are typically hibernating underground.

Ground Water

The Yolo Bypass experiences relatively high groundwater levels, which vary significantly, spatially, and seasonally. Refer to the Assessment of Groundwater Impact on Project Excavation TM January 26, 2017, by HDR for more information. It is anticipated that some construction activities will require excavation below the groundwater. For limited areas, such as the headworks, groundwater may be controlled for construction purposes by excluding it from the site via installing a cutoff wall around the perimeter of the excavation with some limited groundwater pumping to remove leakage. It may also be possible to control groundwater locally in the vicinity of a limited excavation site by pumping alone. These methods will likely not be practical for very large excavation sites such as those required for constructing the channels. It is anticipated that the portion of the channels located near and below the groundwater levels will be constructed in the wet using excavators.

Tule Canal Operational Requirements

The Tule Canal serves as both an irrigation supply and a drainage facility. Flow in the Canal will need to be maintained during the construction period. Constructing the water control structures in the Tule Canal, for the Knaggs, Conaway, and Swanston areas will require provisions for maintaining flows in the canal as well as controlling groundwater for excavation. The flows that will need to be maintained in the canal during construction are estimated to be roughly 1,000 cfs.

3 CONSTRUCTION SEQUENCE AND PERIOD

Based upon estimated equipment numbers, crew sizes, and production rates, it is anticipated that all project components could be constructed in a single season for all of alternatives except for Alternative 5. The construction period for Alternative 5 is estimated to be 2 years due to the complexity of and the number of gates that need to be installed for the headworks. However, for all of the alternatives higher than anticipated ground water levels, inclement weather, cultural discoveries, and protected species observances may impact constructability and adversely extend the construction schedule into the following season. Refer to **Table 9** through **Table 22** for a detailed breakdown of the baseline project sequencing by component.

It is anticipated that the outlet channel grading will begin at the downstream end and progress upstream towards the headworks structure. There are three reasons for supporting this sequence. First, with construction starting in spring when groundwater levels are highest, it is known from the project's groundwater assessment that groundwater levels decrease with increasing distance from the Sacramento River. Second, is to avoid potential interruptions to the construction of the headworks foundation. Third, if for some reason channel construction extends beyond one season, having the channel already constructed downstream may facilitate draining the site in the spring for continued excavation.

Roughly 60 to 80 percent of the channel excavations are assumed to be performed in dry, unsaturated soil conditions by scrapers and dozers. The remaining 40 to 20 percent is assumed to be performed in wet, saturated soil conditions by hydraulic excavators and haul trucks. As the channel inverts are anticipated to be below river stage for the Sacramento River or groundwater levels, it is anticipated that much of the wet excavation may be performed underwater, which makes grading the channels a considerable constructability challenge. Additionally, the significant portion of the revetment prescribed for the habitat shelf is also anticipated to be placed in the wet, further complicating the construction.

The headworks is the most complex component of the project, and the activities associated with its completion will likely be the critical path of the overall construction schedule. Completing the headworks in one season is possible, but may be challenging. Care will be needed in scheduling the design and ordering of long lead items, such as the gates and mechanical and electrical facilities. Like other project components, work on the headworks can move independently from the other activities for the most part.

It is estimated that it will take approximately 12 to 15 weeks, depending on the alternative, to construct the headworks structure to a point at which it is ready for the installation of the gates and mechanical equipment. It is estimated to take upwards of and additional 3 to 5 weeks for the gate installation, mechanical and electrical installation, and testing. If unforeseen constructability challenges occur and the contractor is not able to meet a single season schedule that the temporary measures such as the cofferdam installed for dewatering of the headworks structure would remain in place through the flood season, and would result in the completion of the construction of the headworks structure during the following construction season.

Equipment and mobilization staging areas are assumed to be identified within construction easements. Spoiling sites have not been identified at this time, but are assumed to be located within an approximately 1-mile radius of the project site. Refer to the Access Roads, Haul Routes, and Spoils Sites Draft Technical Memorandum for additional information.

4 PERSONNEL AND EQUIPMENT

The number of construction personnel and equipment required by week were estimated for each alternative. The number of personnel is summarized by key project component of each alternative in **Table 2** through **Table 8**. In general, rock haul and placement, and earthwork excavation and haul require the greatest number of personnel, which will peak in the months of July and August. The estimations assume a standard 10-hour shift work day and 6-day work week. However as noted above, this does not preclude the contractor from utilizing multiple shifts and extended hours of operations in which to expedite efforts. Additionally, on large construction projects it is very common that the equipment maintenance and up-keep operations are handled during the night shift.

A detailed breakdown of estimated construction personnel and equipment is provided in Table 8 through Table 20. The estimate is broken down into cost codes based on the cost estimating guide developed by the USACE, Engineering and Design Civil Works Cost Engineering, ER 1110-2-1302, June 30, 2016. The tables present the construction activities, a description of the associated personnel and equipment needs, and the duration of the activity.

Table 2. Alternative 1, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	31	18	18	18	8	12	32	35	36	36	28	27	56	84	84	84	56	56	31	0	0	4	4	4	0	0	0	0
2	Headworks Structure	0	0	50	7	7	7	23	23	23	16	16	43	30	3	19	19	3	30	3	3	5	25	25	25	29	23	52	0
3	Bridges, Buildings, & Operating Equipment	17	20	20	10	19	10	9	0	0	0	0	0	0	5	13	9	7	5	0	0	0	0	0	0	0	0	8	5
4	Supplemental Fish Passage, West	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
	Total per Week:	**89**	**66**	**135**	**57**	**55**	**86**	**155**	**98**	**126**	**105**	**102**	**119**	**144**	**163**	**202**	**191**	**134**	**182**	**73**	**14**	**9**	**55**	**39**	**31**	**29**	**23**	**68**	**10**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: 202

Table 3. Alternative 2, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	53	18	18	18	24	24	68	64	64	64	40	56	112	112	112	112	112	112	84	56	53	0	4	4	0	0	0	0
2	Headworks Structure	0	0	50	7	7	7	23	23	23	16	16	16	43	30	19	19	3	3	30	3	5	19	25	25	29	29	52	0
3	Bridges, Buildings, & Operating Equipment	17	20	20	10	19	10	9	0	0	0	0	0	0	0	5	13	9	7	7	5	0	0	0	0	0	0	8	5
4	Supplemental Fish Passage, West	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
	Total per Week:	**111**	**66**	**135**	**57**	**71**	**98**	**191**	**127**	**154**	**133**	**114**	**121**	**213**	**213**	**222**	**223**	**192**	**213**	**160**	**75**	**62**	**45**	**39**	**31**	**29**	**29**	**68**	**10**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: 223

Table 4. Alternative 3, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	53	18	18	18	24	24	68	68	68	68	68	120	120	176	112	112	112	112	140	165	56	56	4	4	0	0	0	0
2	Headworks Structure	0	0	50	7	7	7	23	23	23	16	16	16	43	30	19	19	3	3	30	3	5	19	25	25	29	29	52	0
3	Bridges, Buildings, & Operating Equipment	17	20	20	10	19	10	9	0	0	0	0	0	0	0	5	13	9	7	7	5	0	0	0	0	0	0	8	5
4	Supplemental Fish Passage, East	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
	Total per Week:	**111**	**66**	**135**	**57**	**71**	**98**	**191**	**131**	**158**	**137**	**142**	**185**	**221**	**277**	**222**	**223**	**192**	**213**	**216**	**184**	**65**	**101**	**39**	**31**	**29**	**29**	**68**	**10**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: 277

Table 5. Alternative 4, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	53	18	18	18	24	24	68	68	68	68	68	120	120	176	112	112	112	112	140	165	56	56	4	4	0	0	0	0
2	Headworks Structure	0	0	50	7	7	7	23	23	23	16	16	16	43	30	19	19	3	3	30	3	5	19	25	25	29	29	52	0
3	Bridges, Buildings, & Operating Equipment	17	20	20	10	19	10	9	0	0	0	0	0	0	0	5	13	9	7	7	5	0	0	0	0	0	0	8	5
4	Supplemental Fish Passage, East	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
7	Knaggs Area	26	19	24	26	44	46	65	43	39	59	19	23	9	11	9	11	13	13	4	8	8	10	2	0	0	0	0	0
6	Conoway Area	30	28	33	36	44	46	101	79	75	95	82	75	73	75	73	75	77	77	68	20	32	15	2	0	0	0	0	0
	Total per Week:	**167**	**113**	**192**	**119**	**159**	**190**	**357**	**253**	**272**	**291**	**243**	**283**	**303**	**363**	**304**	**309**	**282**	**303**	**288**	**212**	**105**	**126**	**43**	**31**	**29**	**29**	**68**	**10**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: 363

Table 6. Alternative 5, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		Year 1																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	95	90	40	100	100	100	100	184	168	168	172	172	168	168	168	168	168	84	4	0	0	0	95	0	0	0	0	0
2	Headworks Structure	0	0	103	10	83	63	10	10	83	63	42	10	83	63	42	57	57	57	3	3	3	3	57	57	103	0	0	0
3	Bridges, Buildings, & Operating Equipment	53	40	40	10	19	19	9	9	9	0	0	0	0	0	0	0	0	4	13	9	7	7	4	0	0	13	0	0
4	Supplemental Fish Passage, West	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
6	Swanston Area	50	64	64	64	82	84	83	42	39	59	86	87	84	88	94	94	94	92	51	51	13	44	16	4	0	0	0	0
	Total per Week:	**221**	**213**	**285**	**197**	**296**	**296**	**261**	**253**	**338**	**316**	**330**	**290**	**358**	**334**	**334**	**342**	**331**	**272**	**82**	**70**	**23**	**67**	**174**	**61**	**103**	**13**	**8**	**5**

* Estimated Beginning of the Construction is April 15th

Year 1 Weekly Maximum: 358

#	Project Major Components	Estimated Number of Personnel per Week														
		Year 2														
		April*		May					June				July			
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
2	Headworks Structure	4	43	43	43	43	43	43	43	43	47	23	4	0	0	0
	Total per Week:	**4**	**43**	**43**	**43**	**43**	**43**	**43**	**43**	**43**	**47**	**23**	**4**	**0**	**0**	**0**

* Estimated Beginning of the Construction is April 15th

Year 2 Weekly Maximum: 47

Table 7. Alternative 6, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	76	27	27	27	32	32	36	32	32	32	288	288	288	288	288	288	288	288	288	316	284	112	116	80	0	0	0	0
2	Headworks Structure	0	77	14	14	23	23	49	49	42	69	30	30	19	19	19	3	30	30	5	19	19	19	31	31	35	35	19	79
3	Bridges, Buildings, & Operating Equipment	20	30	30	10	19	10	9	0	0	0	0	0	5	13	9	7	7	5	0	0	0	0	0	0	0	0	8	8
4	Supplemental Fish Passage, East	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
	Total per Week:	**137**	**162**	**118**	**73**	**95**	**122**	**185**	**121**	**141**	**154**	**376**	**367**	**370**	**391**	**402**	**377**	**393**	**414**	**332**	**346**	**307**	**157**	**157**	**113**	**35**	**35**	**35**	**92**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: 414

Table 8. Alternative 2 & 5 River Grading Site, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		Year 1																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	River Repair	15	9	35	19	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	63	28	32	4	15	0	0	0
	Total per Week:	**15**	**9**	**35**	**19**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**63**	**28**	**32**	**4**	**15**	**0**	**0**	**0**
	Year 1 Weekly Maximum:	**63**																											

* Estimated Beginning of the Construction is April 15th

Table 9. Alternative 1, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations[2]																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	5																											5
2	Fremont Weir Concrete Demo[5]	450	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	12		10	10																									
3	Levee O&M Road Regrading (6" AB)	119,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	4																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	31																		31									
6	Clearing and Grubbing[6]	61	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	16		18	18	18																								
7	Excavation (Wet Conditions)[7]	61,810	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	35							20	20	20	20	20	20																
8	Excavation/Grading (Dry Conditions)[8]	118,960	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	34					8	8	8	8	8	8																		
9	Earthen Backfill[12]	8,950	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	9						4	4																					
10	Riprap - Class 2	24,940	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	25														28	28	28	28	28										
11	Riprap - Class 3	9,420	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	10																	28	28										
12	RSP Bedding Material	36,150	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	2	2,000	19													56	56	56	56												
13	Erosion Control Seeding	31	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	16																						4	4	4				
11 - Levees and Floodwalls																																				
		-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2						14		7 Mobilization and Demobilization[9]				7																
15	Soil Cement Bentonite Cutoff Wall	84,480	SF	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (1) 2.5 CY Hydraulic Excavator (1) 16 CY 3 Axle Dump Truck (1) Flash Mixer (1) Slurry Pump (1) Pickup Truck Conventional (5)	7,000	1	7,000	13									8	8	8																	
dway Control and Diversion Structures																																				
16	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			50																								50	
17	Construction Site Dewatering (Temporary Cofferdam)	21,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	18				7	7	7																						
18	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	120							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
		6,130	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 19 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	Excavation (Wet Conditions)[7] 1,800	1	1,800	4							20																					
20	Sheet Pile Wall	7,790	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	7								7	7																			
21	Headworks Structure Concrete Piles	5,040	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	28								13	13	13	13	13																
22	Headworks Structure	3,080	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	18												27	27					27										
23	Headworks Channel Transition	1,330	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	10															16	16												
24	Hinged Bottom Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24																						6	6	6	6			
s, Railroads, and Bridges																																				
25	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2														5				5										
26	Pedestrian Bridge Concrete Piles	320	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	2															13													
27	Pedestrian Bridge Concrete Abutments and Wingwalls	24	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1																9												
28	Pedestrian Bridge Span Installation	1,040	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	3																	7											
19 - Buildings, Grounds, and Utilities																																				
29	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	9						9																					
30	CMU Building and Earthwork Pad Construction[10]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
31	Concrete Duct Bank	190	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	4					9																							
20 -Permanent Operating Equipment[11]																																				
32	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																					2						2	
33	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
34	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
35	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
36	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
37	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																									4	4		
								Estimated Total Number of Construction Workers:	48	38	88	35	34	29	64	58	59	52	44	70	86	92	116	112	66	91	34	3	5	29	29	29	29	23	60	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Assumption: 30 days for CMU building construction.
11 Assumption: 30 days for permanent equipment installation
12 Excavated material assumed to be reused for backfill (including construction of working surface for Soil Cement Bentonite Cutoff Wall), hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed

Table 10. Alternative 2, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	5																											5
2	Fremont Weir Demo	420	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	11		10	10																									
3	Levee O&M Road Regrading (6" AB)	119,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	4																											8	
4	Temporary Electrical Power	5,280	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	4	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	53																				53							
6	Clearing and Grubbing[5]	70	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	18		18	18	18																								
7	Excavation (Wet Conditions)[7]	93,610	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	2	3,600	27							40	40	40	40	40																	
8	Excavation/Grading (Dry Conditions)[8]	372,680	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	3	10,500	36					24	24	24	24	24	24																		
9	Earthen Backfill[10]	1,010	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	2							4																					
10	Riprap - Class 2	87,580	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	2	2,000	44													56	56	56	56	56	56	56	56								
11	Riprap - Class 3	1,530	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	2																			28									
12	RSP Bedding Material	81,050	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	2	2,000	41												56	56	56	56	56	56	56										
13	Erosion Control Seeding	13	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	7																							4	4				
15 - Floodway Control and Diversion Structures																																				
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			50																								50	
15	Construction Site Dewatering (Temporary Cofferdam)	21,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	18				7	7	7																						
16	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	120							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
17	Excavation (Wet Conditions)	6,460	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	4							20																					
18	Sheet Pile Wall	7,940	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	7								7	7																			
19	Headworks Structure Concrete Piles	5,600	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	32								13	13	13	13	13	13															
20	Headworks Structure	3,140	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	18													27	27					27									
21	Headworks Channel Transition	1,370	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	10															16	16												
22	Hinged Bottom Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24																							6	6	6	6		
08 - Roads, Railroads, and Bridges																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2															5					5								
24	Pedestrian Bridge Concrete Piles	640	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	4																13												
25	Pedestrian Bridge Concrete Abutments and Wingwalls	48	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1																	9											
26	Pedestrian Bridge Span Installation	2,720	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	7																		7	7									
19 - Buildings, Grounds, and Utilities																																				
27	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
28	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
29	Concrete Duct Bank	1,350	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	23					9																							
20 -Permanent Operating Equipment[12]																																				
30	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																					2						2	
30	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
31	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
32	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
33	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
34	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																									4	4		
								Estimated Total Number of Construction Workers:	70	38	88	35	50	41	100	87	87	80	56	72	155	142	136	144	124	122	121	64	58	19	29	29	29	29	60	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 11. Alternative 3, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	5																											5
2	Fremont Weir Demo	470	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	12		10	10																									
3	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	53																			53								
6	Clearing and Grubbing[6]	88	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	23		18	18	18																								
7	Excavation (Wet Conditions)[7]	161,750	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	2	3,600	45							40	40	40	40	40	40	40	40															
8	Excavation/Grading (Dry Conditions)[8]	581,540	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	3	10,500	56					24	24	24	24	24	24	24	24	24	24														
9	Earthen Backfill[10]	27,510	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	28							4	4	4	4	4																	
10	Riprap - Class 2	98,070	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	2	2,000	50														56	56	56	56	56	56	56	56	56						
11	Riprap - Class 3	3,600	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	4																			28									
12	RSP Bedding Material	109,330	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	2	2,000	55												56	56	56	56	56	56	56	56	56								
13	Erosion Control Seeding	18	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	10																							4	4				
15 - Floodway Control and Diversion Structures																																				
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			50																									50	
15	Construction Site Dewatering (Temporary Cofferdam)	21,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	18				7	7	7																						
16	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	120							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
17	Excavation (Wet Conditions)	6,460	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	4							20																					
18	Sheet Pile Wall	7,940	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	7								7	7																			
19	Headworks Structure Concrete Piles	5,600	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	32								13	13	13	13	13	13															
20	Headworks Structure	3,080	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	18													27	27					27									
21	Headworks Channel Transition	1,370	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	10															16	16												
22	Hinged Bottom Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24																							6	6	6	6		
08 - Roads, Railroads, and Bridges																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2															5					5								
24	Pedestrian Bridge Concrete Piles	640	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	4																13												
25	Pedestrian Bridge Concrete Abutments and Wingwalls	48	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1																	9											
26	Pedestrian Bridge Span Installation	2,930	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	8																		7	7									
19 - Buildings, Grounds, and Utilities																																				
27	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
28	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
29	Concrete Duct Bank	120	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	2					9																							
20 -Permanent Operating Equipment[12]																																				
30	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																					2						2	
30	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
31	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
32	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
33	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
34	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																								4	4		
								Estimated Total Number of Construction Workers:	70	38	88	35	50	41	100	91	91	84	84	136	163	206	136	144	124	122	177	173	61	75	29	29	29	29	60	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 12. Alternative 4, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	5																											5
2	Fremont Weir Demo	470	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	12		10	10																									
3	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	53																			53								
6	Clearing and Grubbing[6]	88	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	23		18	18	18																								
7	Excavation (Wet Conditions)[7]	161,750	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	2	3,600	45							40	40	40	40	40	40	40	40														
8	Excavation/Grading (Dry Conditions)[8]	581,540	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	3	10,500	56					24	24	24	24	24	24	24	24	24	24														
9	Earthen Backfill[10]	27,510	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	28							4	4	4	4	4																	
10	Riprap - Class 2	98,070	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	2	2,000	50														56	56	56	56	56	56	56	56	56						
11	Riprap - Class 3	3,600	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	4																			28									
12	RSP Bedding Material	109,330	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	2	2,000	55												56	56	56	56	56	56	56	56	56								
13	Erosion Control Seeding	18	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	10																							4	4				
15 - Floodway Control and Diversion Structures																																				
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			50																								50	
15	Construction Site Dewatering (Temporary Cofferdam)	21,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	18				7	7	7																						
16	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	120							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
17	Excavation (Wet Conditions)	6,460	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	4							20																					
18	Sheet Pile Wall	7,940	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	7								7	7																			
19	Headworks Structure Concrete Piles	5,600	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	32								13	13	13	13	13	13															
20	Headworks Structure	3,080	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	18													27	27					27									
21	Headworks Channel Transition	1,370	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	10															16	16												
22	Hinged Bottom Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24																							6	6	6	6		
08 - Roads, Railroads, and Bridges																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2															5					5								
24	Pedestrian Bridge Concrete Piles	640	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	4																13												
25	Pedestrian Bridge Concrete Abutments and Wingwalls	48	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1																	9											
26	Pedestrian Bridge Span Installation	2,930	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	8																		7	7									
19 - Buildings, Grounds, and Utilities																																				
27	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
28	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
29	Concrete Duct Bank	120	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	2					9																							
20 -Permanent Operating Equipment[12]																																				
30	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																					2						2	
30	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
31	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
32	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
33	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
34	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																									4	4		
								Estimated Total Number of Construction Workers:	70	38	88	35	50	41	100	91	91	84	84	136	163	206	136	144	124	122	177	173	61	75	29	29	29	29	60	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
12 Assumption: 30 days for CMU building construction.
13 Assumption: 30 days for permanent equipment installation

Table 13. Alternative 5, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																																								
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28		29	30	31	32	33	34	35	36	37	38	39	40	41
02 - Relocations																																																		
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	11																									5																
2	Fremont Weir Demo	1,610	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	3	120	14	30	30	30																																						
3	Levee O&M Road Regrading (6" AB)	119,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	4																										8																
4	Temporary Electrical Power	5,280	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	4	3																																								
09 - Channels and Canals																																																		
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	95																						95																				
6	Clearing and Grubbing[6]	110	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	10	20	6		90																																							
7	Excavation (Wet Conditions)[7]	148,830	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	3	5,400	28				60	60	60	60	60																					END OF THE CONSTRUCTION SEASON													
8	Excavation/Grading (Dry Conditions)[8]	600,290	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	5	17,500	35			40	40	40	40	40	40																																		
9	Riprap - Class 2	163,254	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	3	3,000	55									84	84	84	84	84	84	84	84	84	84																							
10	RSP Bedding Material	174,806	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	3	3,000	59								84	84	84	84	84	84	84	84	84	84																								
11	Erosion Control Seeding	31	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	17											4	4							4																							
15 - Floodway Control and Diversion Structures																																																	
12	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			103																						103					2											2	
13	Construction Site Dewatering (Temporary Cofferdam)	1	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	3	3,600	1					21	21			21	21			21	21																											
14	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	186				3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3							3	3	3	3	3	3	3	3	3	3		
15	Excavation (Wet Conditions)	28,710	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	16					20				20				20																													
16	Sheet Pile Wall	26,840	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	23				7			7	7				7																													
17	Headworks Structure Concrete Piles	26,400	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	3	540	49					39	39			39	39	39		39	39	39																										
18	Headworks Structure	11,040	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	6	360	31																54	54	54					54	54																	
19	Hinged Bottom Gates	27	EA	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	0.1	4	0.5	54																															24	24	24	24	24	24	24	24	24			
08 - Roads, Railroads, and Bridges																																																	
20	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																		4					4																				
21	Pedestrian Bridge Concrete Piles	320	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	2																			13																							
22	Pedestrian Bridge Concrete Abutments and Wingwalls	24	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1																				9																						
23	Pedestrian Bridge Span Installation	1,600	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	5																					7	7																				
19 - Buildings, Grounds, and Utilities																																																	
24	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9								9																																	
25	CMU Building and Earthwork Pad Construction[10]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																																			
26	Concrete Duct Bank	1,350	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	23					9	9	9	9																																		
20 -Permanent Operating Equipment[11]																																																	
27	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																														2											2	
27	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	1	-	60																															4	4	4	4	4	4	4	4	4	4		
28	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	1	-	60																															4	4	4	4	4	4	4	4	4	4		
29	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	1	-	60																															4	4	4	4	4	4	4	4	4	4		
30	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	1	-	60																															4	4	4	4	4	4	4	4	4	4		
31	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	1	-	12																																							4	4		
								Estimated Total Number of Construction Workers:	148	130	183	120	202	182	119	203	260	231	214	182	251	231	210	225	225	145	20	12	10	10	156	57	103	13	0	0	0	4	43	43	43	43	43	43	43	43	47	23	4	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Assumption: 30 days for CMU building construction.
11 Assumption 60 days for permanent equipment installation

Table 14. Alternative 6, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	8																											8
2	Fremont Weir Demo	920	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	2	80	12		20	20																									
3	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	76																							76				
6	Clearing and Grubbing[6]	109	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	3	6	19		27	27	27																								
7	Excavation (Wet Conditions)[7]	350,390	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	3	5,400	65											60	60	60	60	60	60	60	60	60	60	60							
8	Excavation/Grading (Dry Conditions)[8]	1,270,140	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	4	14,000	91					32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32								
9	Earthen Backfill[10]	2,200	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	3							4																					
10	Riprap - Class 2	313,940	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	4	4,000	79											112	112	112	##	##	##	##	##	##	##	##	##	##					
11	Riprap - Class 3	11,460	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	12																				28	28							
12	RSP Bedding Material	197,000	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	3	3,000	66											84	84	84	84	84	84	84	84	84	84	84							
13	Erosion Control Seeding	13	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	7																							4	4				
15 - Floodway Control and Diversion Structures																																				
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2		77																										77
15	Construction Site Dewatering (Temporary Cofferdam)	29,900	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	2	2,400	13			14	14																								
16	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	138					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
17	Excavation (Wet Conditions)	12,750	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	8					20	20																						
18	Sheet Pile Wall	10,220	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	9							7	7																				
19	Headworks Structure Concrete Piles	11,440	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	3	540	22							39	39	39	39																		
20	Headworks Structure	4,480	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	25										27	27	27					27	27										
21	Headworks Channel Transition	2,310	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	17													16	16	16													
22	Hinged Bottom Gates	5	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	2	0.3	20																							12	12	12	12		
08 - Roads, Railroads, and Bridges																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2													5					5										
24	Pedestrian Bridge Concrete Piles	640	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	4														13														
25	Pedestrian Bridge Concrete Abutments and Wingwalls	48	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1															9													
26	Pedestrian Bridge Span Installation	2,480	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	7																7	7											
19 - Buildings, Grounds, and Utilities																																				
27	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
28	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
29	Concrete Duct Bank	120	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	2					9																							
20 -Permanent Operating Equipment[12]																																				
30	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																			2									2
30	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	50																				4	4	4	4	4	4	4	4	
31	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	50																				4	4	4	4	4	4	4	4	
32	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	50																				4	4	4	4	4	4	4	4	
33	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	50																				4	4	4	4	4	4	4	4	
34	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																								4	4		
Estimated Total Number of Construction Workers:									96	134	71	51	74	65	94	81	74	101	318	318	312	320	316	298	325	323	293	335	303	131	147	111	35	35	27	87

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 50 days for permanent equipment installation

Table 15. Downstream Reach, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	2																							2				
2	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																							8					
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	13																					13						
5	Clearing and Grubbing[6]	42	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	21		9	9	9	9																							
6	Excavation (Wet Conditions)[7]	73,850	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	42						20	20	20	20	20	20	20																
7	Earthen Backfill[10]	10,550	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	11							4	4																				
8	Riprap - Class 2	32,500	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	33														28	28	28	28	28	28									
9	RSP Bedding Material	32,470	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	1	1,000	33													28	28	28	28	28	28										
10	Erosion Control Seeding	28	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	15																				4	4							
11 - Levees and Floodwalls																																				
11	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2									7				7															
12	Soil Cement Bentonite Cutoff Wall	94,500	SF	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (1) 2.5 CY Hydraulic Excavator (1) 16 CY 3 Axle Dump Truck (1) Flash Mixer (1) Slurry Pump (1) Pickup Truck Conventional (5)	7,000	1	7,000	14										8	8	8																
								Estimated Total Number of Construction Workers:	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill (including construction of working surface for Soil Cement Bentonite Cutoff Wall), hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed

Table 16. Supplemental Fish Passage East, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days
02 - Relocations								
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
2	Fremont Weir Demo	180	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	5
3	Levee O&M Road Regrading (6" AB)	119,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	4
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1
09 - Channels and Canals								
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
6	Clearing and Grubbing[6]	2	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	1
7	Excavation/Grading (Dry Conditions)[8]	2,080	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	1
8	Excavation (Wet Conditions)[7]	520	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	1
9	Riprap - Class 3	1,520	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	2
10	RSP Bedding Material	1,190	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	1	1,000	2
11	Erosion Control Seeding	1	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	1
15 - Floodway Control and Diversion Structures								
12	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
13	Excavation/Grading (Dry Conditions)[8]	940	CY	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	3,500	1	3,500	1
14	Sheet Pile Wall	1,730	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2
15	Headworks Structure	130	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	3
16	Headworks Channel Transition	130	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	2
17	Hinged Bottom Gates	1	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	8
20 -Permanent Operating Equipment[11]								
18	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
19	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30

Estimated Duration, Weeks[4]

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																												
1	5																											5
2		10																										
3																											8	
4	3																											
09 - Channels and Canals																												
5			18						18																			
6				9																								
7					8																							
8						20																						
9							28																					
10							28																					
11								4																				
15 - Floodway Control and Diversion Structures																												
12									18						18													
13										8																		
14											7																	
15												9																
16													8															
17													6	6														
20 -Permanent Operating Equipment[11]																												
18																2			2									
19																	4	4										
Estimated Total Number of Construction Workers:	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 10 days for permanent equipment installation

Table 17. Supplemental Fish Passage West, Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	5																											5
2	Fremont Weir Demo	180	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	5		10																										
3	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			18						18																			
6	Clearing and Grubbing[6]	2	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	1				9																								
7	Excavation/Grading (Dry Conditions)[8]	1,830	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	1					8																							
8	Excavation (Wet Conditions)[7]	460	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	1						20																						
9	Riprap - Class 3	1,070	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	2							28																					
10	RSP Bedding Material	850	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	1	1,000	1							28																					
11	Erosion Control Seeding	1	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	1								4																				
15 - Floodway Control and Diversion Structures																																				
12	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2									18						18													
13	Excavation/Grading (Dry Conditions)[8]	940	CY	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	3,500	1	3,500	1										8																		
14	Sheet Pile Wall	1,730	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2											7																	
15	Headworks Structure	130	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	3												9																
16	Headworks Channel Transition	130	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	2													8															
17	Hinged Bottom Gates	1	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	8													6	6														
20 -Permanent Operating Equipment[11]																																				
18	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																2			2									
19	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	10																	4	4										
								Estimated Total Number of Construction Workers:	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 10 days for permanent equipment installation

Table 18. Agricultural Crossing 1, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																			
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	2																						2					
2	Levee O&M Road Regrading (6" AB)	10,400	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	1																						8						
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																			
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	10					10																						
5	Clearing and Grubbing[6]	3	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	2		9																										
6	Excavation (Wet Conditions)[7]	150	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	1			20																									
7	Erosion Control Seeding	2	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	2				4	4																							
11 - Levees and Floodwalls																																			
8	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (3) Temp. Mobile Office Building (1)	-	-	-	2							3		3																			
9	Reinforced AG Berm	2,120	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	3								4																				
15 - Floodway Control and Diversion Structures																																			
10	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2										18								18										
11	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	42											3	3	3	3	3	3	3											
12	Excavation (Wet Conditions)	5,140	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	3											20																	
13	Concrete Turnout Structure	1	EA	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	1	1	1	1												9																
14	36-inch RCP	680	LF	25 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (1) Pickup Truck Conventional (4)	90	1	90	8													6	6														
15	Trashrack	3	EA	Flatbed Truck (1) Pickup Truck Conventional (2)	3	1	3	1															3													
16	Screw Gate	3	EA	Flatbed Truck (1) Pickup Truck Conventional (2)	3	1	3	1															3													
17	Outlet Fish Screen	1	EA	Flatbed Truck (1) Pickup Truck Conventional (2)	1	1	1	1															3													
18	Concrete Emergency Spillway	19	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	70	1	70	1																9												
19	Concrete Connection Vault	1	EA	40 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (3)	1	1	1	1																9												
08 - Roads, Railroads, and Bridges																																			
20	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																	5					5						
21	Rail Car Bridge Concete Piles	480	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	3																		13										
22	Rail Car Bridge Concrete Abutments and Wingwalls	58	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1																			9									
23	Rail Car Bridge Span Installation	1,000	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	3																				7								
								Estimated Total Number of Construction Workers:	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed

Table 19. Knaggs Area, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	2																						2					
2	Levee O&M Road Regrading (6" AB)	104,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																						8						
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	12											12																
5	Clearing and Grubbing[6]	17	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	9		9	9																									
6	Excavation/Grading (Dry Conditions)[8]	54,870	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	16				8	8	8																						
7	Riprap - Class 2	20,210	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	21							28	28	28	28																		
8	Erosion Control Seeding	3	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	2											4																	
11 - Levees and Floodwalls																																				
9	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (3) Temp. Mobile Office Building (1)	-	-	-	2			5								5																	
10	Berm/Levee Fill	72,330	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	2	2,000	37				8	8	8	8	8	8	8																		
15 - Floodway Control and Diversion Structures																																				
11	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2					9													9										
12	Construction Site Dewatering (Temporary Cofferdam)	9,300	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	8								7																				
13	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	54									3	3	3	3	3	3	3	3	3											
14	Excavation (Wet Conditions)[11]	25,960	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	15						20	20			20																		
15	Sheet Pile Wall	1,840	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2											7																	
16	Culvert Headwall	110	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	60	1	60	2												8																
17	Precast Box Culvert 10'x8' 30'	30	LF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (4)	100	1	100	1													6															
18	Water Control Structure	280	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	4														8														
19	Inflatable Obermeyer Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24															6	6	6											
19 - Buildings, Grounds, and Utilities																																				
20	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
21	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
22	Concrete Duct Bank	40	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1					9																							
20 -Permanent Operating Equipment[12]																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																2						2						
24	Power, Electrical, & Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																	4	4	4	4	4							
25	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																				4	4							
								Estimated Total Number of Construction Workers:	26	19	24	26	44	46	65	43	39	59	19	23	9	11	9	11	13	13	4	8	8	10	2	0	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 20. Conaway Area, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (2) Temp. Mobile Office Building (1)	-	-	-	2	2																						2					
2	Levee O&M Road Regrading (6" AB)	218,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	6																						8						
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	16																				16							
5	Clearing and Grubbing[6]	67	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	17		18	18	18																								
6	Excavation/Grading (Dry Conditions)[8]	133,580	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	39					8	8	8	8	8	8	8																	
7	Riprap - Class 2	153,590	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	2	2,000	77							56	56	56	56	56	56	56	56	56	56	56	56	56									
8	Erosion Control Seeding	24	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	13																				4								
11 - Levees and Floodwalls																																				
9	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (3) Temp. Mobile Office Building (1)	-	-	-	2			5																			5						
10	Berm/Levee Fill	213,520	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	2	2,000	107				8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8							
15 - Floodway Control and Diversion Structures																																				
11	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2					9													9										
12	Construction Site Dewatering (Temporary Cofferdam)	93,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	78								7																				
13	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	54									3	3	3	3	3	3	3	3	3											
14	Excavation (Wet Conditions)	25,960	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	15						20	20			20																		
15	Sheet Pile Wall	1,840	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2											7																	
16	Culvert Headwall	110	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	60	1	60	2												8																
17	Precast Box Culvert 10'x8' 30'	30	LF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (4)	100	1	100	1													6															
18	Water Control Structure	280	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	4														8														
19	Inflatable Obermeyer Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24															6	6	6											
19 - Buildings, Grounds, and Utilities																																				
20	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
21	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
22	Concrete Duct Bank	40	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1					9																							
20 -Permanent Operating Equipment[12]																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																2						2						
24	Power, Electrical, & Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																	4	4	4	4	4							
25	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																				4	4							
								Estimated Total Number of Construction Workers:	30	28	33	36	44	46	101	79	75	95	82	75	73	75	73	75	77	77	68	20	32	15	2	0	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 21. Swanston Area, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (2) Temp. Mobile Office Building (1)	-	-	-	2	2																							2				
2	Levee O&M Road Regrading (6" AB)	221,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	6																							8					
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	36																					36						
5	Clearing and Grubbing[6]	503	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	6	12	42		54	54	54	54	54	54																					
6	Excavation (Wet Conditions)[7]	213,710	CY	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	1,800	2	3,600	60											40	40	40	40	40	40	40	40	40	40								
7	Excavation/Grading (Dry Conditions)[8]	854,860	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	3,500	4	14,000	62								32	32	32	32	32	32	32	32	32	32	32										
8	Erosion Control Seeding	46	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	25																					4							
11 - Levees and Floodwalls																																				
9	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (3) Temp. Mobile Office Building (1)	-	-	-	2								3					3															
10	Berm/Levee Fill	21,070	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	22									4	4	4	4																
15 - Floodway Control and Diversion Structures																																				
11	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2					9													9										
12	Construction Site Dewatering (Temporary Cofferdam)	93,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	78								7																				
13	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	54									3	3	3	3	3	3	3	3	3											
14	Excavation (Wet Conditions)	25,960	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	15						20	20			20																		
15	Sheet Pile Wall	1,840	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2											7																	
16	Culvert Headwall	110	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	60	1	60	2												8																
17	Precast Box Culvert 10'x8' 30'	30	LF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (4)	100	1	100	1													6															
18	Water Control Structure	280	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	4														8														
19	Inflatable Obermeyer Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24															6	6	6											
08 - Roads, Railroads, and Bridges																																				
20	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2														5							5							
21	Rail Car Bridge Concete Piles	2400	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	14															13	13	13											
22	Rail Car Bridge Concrete Abutments and Wingwalls	290	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	5																		9										
23	Rail Car Bridge Span Installation	4500	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	12																			7	7								
19 - Buildings, Grounds, and Utilities																																				
20	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
21	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
22	Concrete Duct Bank	40	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1					9																							
20 -Permanent Operating Equipment[12]																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																		2						2				
24	Power, Electrical, & Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																			4	4	4	4	4					
25	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																						4	4					
								Estimated Total Number of Construction Workers:	**50**	**64**	**64**	**64**	**82**	**84**	**83**	**42**	**39**	**59**	**86**	**87**	**84**	**88**	**94**	**94**	**94**	**92**	**51**	**51**	**13**	**44**	**16**	**4**	**0**	**0**	**0**	**0**

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 22. Alternative 2 & 5 River Grading Site: Detailed Weekly Estimate of Construction Activities

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days
09 - Channels and Canals								
1	Mobilization and Demobilization[8]	-	-	Flatbed Truck (1 per piece of equipment not on barge) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1) Barges (4) (Including 1 Excavator or 1 Clamshell Crane, and 1 Sounding Boat) Tug Boat (2)	-	-	-	2
2	Clearing and Grubbing[5]	4	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	1	1	1	4
3	Excavation (From Bank)[6]	6,652	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	700	1	700	10
4	Excavation/Dredging (From Barge)[7]	44,177	CY	Clamn Shell Bucket (1) Barge Mounted Excavator (1) Tug Boat (1) Barge (2) Sounding Boat (1) Pickup Truck Conventional (4)	400	1	400	111
5	Riprap - Graded Stone 'C'	17,546	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	18
6	Erosion Control Seeding	31	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	16

Estimated Duration, Weeks[4,9]

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	15																								15			
2		9																										
3			20																		20							
4			15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15							
5																					28	28	28					
6				4																			4	4				
Estimated Total Number of Construction Workers:	15	9	35	19	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	63	28	32	4	15	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site (estimated 80 CY/AC)
6 Includes off haul of material to the spoil site (within 1 mile radius) by dump truck
7 Includes spoiling material onto and then 2nd handling and off haul of material to the upland spoil site.
8 The number of flatbed truck drivers required to bring equipment associated with a given task

RECLAMATION
Managing Water in the West

Adaptive Management Biological Objectives

February 2019

U.S. Department of the Interior
Bureau of Reclamation

August 2018

1 Introduction

The goal of maintenance and management of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Project) sites is to promote the long-term improvements of the Proposed Action area in providing functions and services associated with Valley Lowland floodplain habitat. The approach to adaptive management of the site is to conduct annual site visits and monitor select characteristics to determine the benefits of the project and ongoing trends in physical and biological processes. Unexpected trends in the biological or physical characteristics of the project's sites will require examination to determine if they are risking the goals and objectives of the Proposed Action. The Adaptive Management Plan describes how the Proposed Action will incorporate focused monitoring efforts and proposed potential management responses.

2 Adaptive Management in the Yolo Bypass Salmonid Habitat and Fish Passage Project

Adaptive management is an iterative process (Figure 1) that promotes improved decision making and adjustments to management activities as uncertainty in outcomes from these activities become more well understood. Scientific understanding advances through careful monitoring to help adjust policies or operations through annual and biannual learning exercises. This framework aims to achieve more effective decisions that enhance benefits and moderate risks. The success of adaptive management will be measured in how well the process meets environmental, social, and economic goals; increases scientific knowledge, and reduces barriers among participants and agencies (Department of the Interior [DOI] 2009).

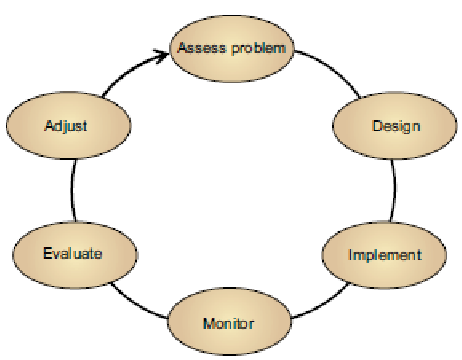


Figure 1. Diagram of the adaptive management process (DOI 2009)

During the Environmental Impact Statement/Environmental Impact Report (EIS/EIR) process for the Project, considerable effort has gone into describing problems and potential alternative solutions to address limiting factors associated with poor access to floodplains and poor fish passage on the Yolo Bypass. Upon a Record of Decision/Notice of Determination regarding a

Project to implement, this adaptive management plan will be used to guide monitoring, evaluation, and potential adjustments and management responses. Utilizing existing technical teams (i.e., Interagency Ecological Program Yolo Bypass Project Work Team, Fisheries Engineering Technical Team) to ensure compliance monitoring associate with the Project meets the requirements for measuring Restoration Objectives, implementing agencies will provide an opportunity to stakeholders and agencies to review the monitoring plan. Annually, these monitoring efforts will report to these technical teams and the Biological Opinion's Implementation Management Team their findings. Utilizing existing teams (i.e., Fishery Agency Strategy Team) these findings will be integrated into our existing understanding to determine how the Project's operations and facilities may require intervention to achieve Restoration Objectives. Finally, adjustments will be considered through an Adaptive Management Team, supported by the DOI Bureau of Reclamation (Reclamation) and Department of Water Resources (DWR).

3 Governance Framework

The Project will be adaptively managed to ensure that biological goals and objectives are met and in turn will address impacts and the uncertainties of future impacts. Adaptive Management governance is discussed in a separate document which outlines a framework for a structured decision-making process to reduce uncertainty and increase effectiveness of habitat restoration and fish passage.

Decisions on adaptive management will be divided into three categories based on level of impacts and appropriate level of involvement. These categories will, as appropriate, help landowners, stakeholders, and the public provide input into minimizing economic impacts and accomplishing the goals and objectives of the project. Reclamation and DWR will retain decision-making authority on the project and adaptive management actions.

4 Conceptual Models of Salmonids and Central Valley Floodplains

Two recent conceptual models are useful for considering adaptive management of Valley Lowland floodplains are the Salmon and Sturgeon Assessment of Indicators by Life State conceptual model (Windell et al 2017) and a conceptual model regarding floodplain function (Opperman 2012). Similarities of these models include ecological outcomes for Chinook salmon and food web contribution, but differ in the structure of linkages between hydrology and environmental attributes and habitat conditions. Thus, we modified these models to simplify the likely processes affected by the Proposed Action and maintained the ecological responses likely to be observed.

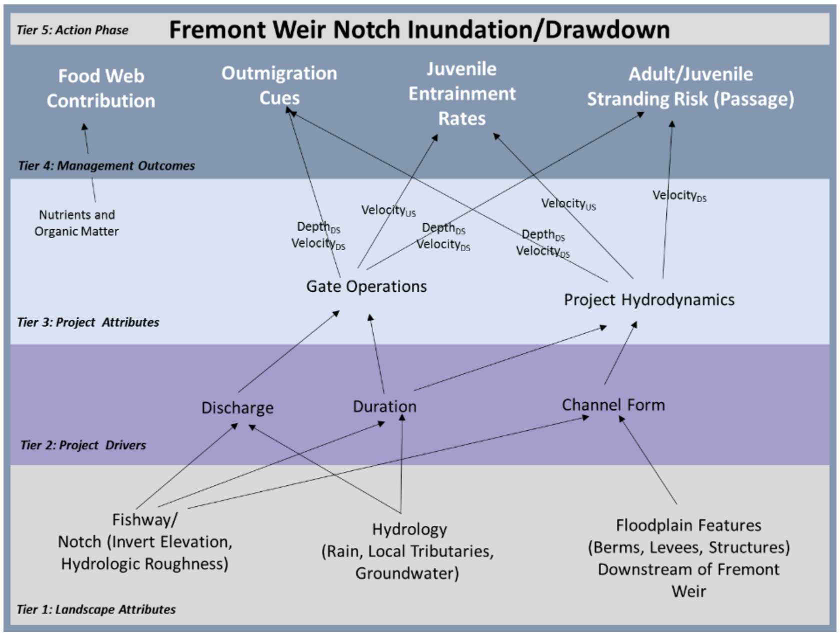


Figure 2. Fremont Weir Notch Flood Up/Drawdown Operation Conceptual Model

Fremont Weir notch operation in the initial phase of the Project's operational action primarily focuses on increased connectivity between the Sacramento River and Yolo bypass to improve adult fish passage and juvenile salmon entrainment (Figure 2). Also, Fremont Weir notch operation during the drawdown phase of the Project's operational action primarily focuses on passage benefits related to reducing adult and juvenile stranding risks while creating fish outmigration cues. As the Fremont Weir notch opens and closes, it connects the Sacramento River and Yolo Bypass landscape leading to nutrient exchange priming the floodplain and subsequently the Sacramento-San Joaquin Delta (Delta) food webs.

Inundation of a notch and fishways in Fremont Weir are directly affected by the elevation of these facilities. The notch's design and hydrology (e.g., rain, local tributaries, and groundwater) are key landscape attributes leading to the discharge rate and duration of inundation. The channel form of the notch and fishway facilities are also critical to flow-related project attributes and biological outcomes, that can be measured biological and physically and are representative of the effectiveness of a notch and fishway's design to contribute to the success of the Project.

Gate operations and project hydrodynamics (roughness/secondary circulation) are project attributes that are affected by the project drivers, and directly impact the benefits of the Project to juvenile and adult Endangered Species Act (ESA) listed species. Salmonids and sturgeon are affected by the Project through the key processes of being entrained onto the Yolo Bypass through the notch and cued to outmigrate into Cache Slough's tidal wetlands. Entrainment rates through a notch are dependent on the upstream (riverside) velocities, accelerations and turbulence characteristics created through gate operations and project hydrodynamics. Depending on the daily discharge and duration of potential notch flows, gate operation in a notch may be modified following the adaptive management process to affect the entrainment rate.

The success of juvenile outmigration or increased juvenile stranding are controlled by discharge and duration of notch flows control gate operations. Discharge also directly affects the project hydrodynamics (roughness/ secondary circulation). These project attributes influence downstream velocity and water depths on the inundated floodplain's channel forms. While many floodplain attributes and fish characteristics cue outmigration (i.e., temperature, dissolved oxygen [DO], and physiology), the Project does not actively control these. Localized hydrodynamics (i.e., velocities) are a project attribute that may be managed to reduce stranding of juvenile fish trying to migrate off a receding floodplain. The risk of adult stranding in the Fremont Weir fishways or on the Yolo Bypass is dependent on the downstream velocity and water depths created by gate operations and project hydrodynamics. The Yolo Bypass's floodplain features contain many channel form features including berms, water control structures, canals, agricultural crossings, and rice checks, which all impact the project hydrodynamics at a localized scale. This can result in some level of localized stranding risk. Depending on the daily discharge and duration of potential notch flows, gate operations in a notch may be modified following the adaptive management process to affect juvenile and adult migration on the Yolo Bypass. To improve outmigration and reduce stranding, modification of channel forms may also be considered through the adaptive management process. Ultimately, drawdown has an important impact on juvenile salmon migration timing and survival, as well as adult salmon passage condition, passage rate, and passage survival.

The connection between the Sacramento River and Yolo Bypass via a Fremont Weir notch is important to nutrient availability. This connection imports allochthonous riverine nutrients and organic matter to the broad floodplain of the Yolo Bypass. Primary productivity is stimulated by temperatures and DO concentrations, which are not actively controlled by the Project.

Yolo Bypass inundation is the Project's operational action focused on improving juvenile salmonid growth, survival, and increased life history diversity in the lower Sacramento River (Figure 3). Also, inundation of the Yolo Bypass is a major contributor of secondary production to the Delta food web. As the Yolo Bypass floodplain is inundated via the Fremont Weir, additional flows from western tributaries (Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek) play a pivotal role in the extent and duration of inundation.

The notch and human-built floodplain features provide habitat connectivity. The volume and duration of flows through a Fremont Weir notch are directly affected by the elevation of these facilities. The notch's design and hydrology and key landscape attributes affect gate operations and project hydrodynamics. These Project attributes influence outmigration cue and residence times that result in biological outcomes that can be measured biologically and physically and are representative of the effectiveness of a notch's design to contribute to the success of the Project.

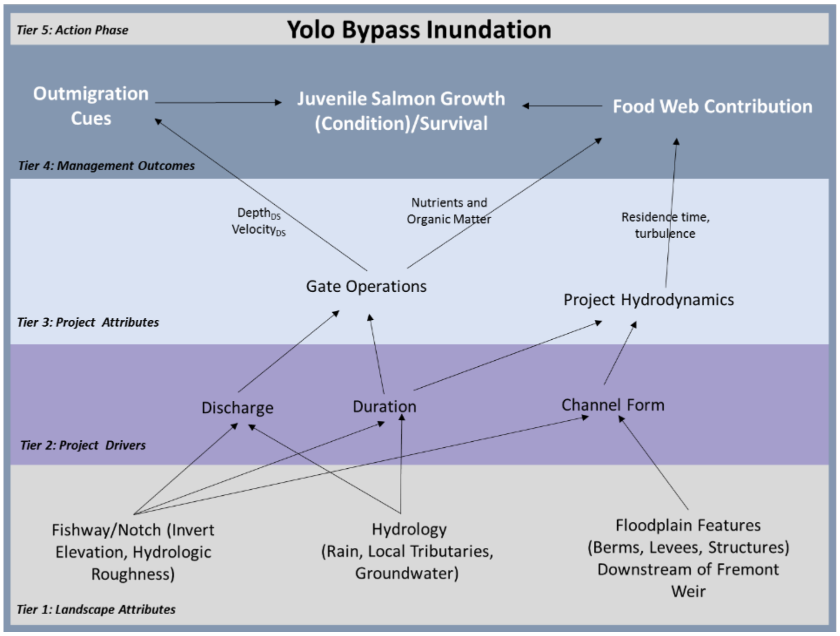


Figure 3. Yolo Bypass Inundation Conceptual Model

Floodplain features are likely to be quite influential in affecting project hydrodynamics and the residence times of water. The Project attribute stimulates secondary production. Hydrology (i.e., rain events) may influence turbidity, which affects light availability. Hydrologic events may also transport nutrients and organic matter. Light and nutrient availability impacts primary productivity and vegetation growth. Increases in primary productivity and vegetation growth allow for increases in secondary productivity (i.e., food web contribution), which effects salmon survival and migration. While the majority of these drivers are not Project attributes, features on the floodplain may be modified following the adaptive management process to affect growth, survival, and life history diversity of juvenile salmonid benefiting from the Project.

5 Restoration Objectives

While it is not anticipated that major modification of the Proposed Action's facilities or project sites will be needed, an objective of this plan is to guide monitoring and to identify the thresholds that may comprise the Proposed Action's objectives. This section summarizes the Proposed Action's Objectives that were initially described in the Implementation Plan. Then, expected outcomes are described related to the objectives. Further synthesis of published baseline data and technical reports, which are part of this EIS/EIR are required to inform metrics by which progress towards meeting the objective will be measured, as well as thresholds for undertaking a management response if objectives are not being met.

5.1 Food Web Contribution

Objective: Enhance food web productivity and export into Cache Slough in support of native ESA-listed fish recovery.

Expected Outcome: The increased duration and frequency of floodplain inundation will increase terrestrial exchange on the site. This productivity exchange will increase the export of primary and secondary productivity from the Yolo Bypass.

Monitoring Category: Physical Process and Hydrology

> **Metric:** Elevation and topography. Hydrology measured with level-loggers in various locations along channel cross sections.
>
> **Goal:** A notched Fremont Weir will supply flows to increase terrestrial-aquatic exchange within the Action Area.
>
> **Intervention Threshold**: If floodplain inundation area changes for 2 or more years in a row from excessive sedimentation of Action Area. Also, an obstruction such as a large tree blocks the notch site.
>
> **Potential Management Response:** Work with Land Owners on appropriate actions to take, but not limited to, removal of obstruction or grading or dredging. Any non-agricultural work will be limited to work windows outside of the period of sensitive and ESA-listed species. A log of action location, and cause will be reported as part of an Annual Report. Equipment may include long-reach excavator, barge-mounted dragline, or backhoe

Monitoring Category: Food Web

> **Metrics:** Chlorophyll a, Phytoplankton, zooplankton, benthic macroinvertebrates.
>
> **Goal:** Food web contributions from the Action Area are higher than the Sacramento River entering the North Delta. Food web contributions from the various habitat components with the Action Area are maximized to the extent possible.
>
> **Intervention Threshold:** Food web components in floodplains and the Toe Drain are lower in concentration than those found in the lower Sacramento River entering the Delta.
>
> **Potential Management Response:** Increase water quality monitoring to determine conditions that may be leading to lower productivity. Modify the floodplain to increase residence times or other water quality characteristics favorable to increased productivity. Prior to any modifications to Project features, information describing the proposed work, the elevation of existing landforms, expected response, and on-site inspection results for protected species.

5.2 Juvenile Salmonid Entrainment

Reclamation and DWR will release marked (either PIT- or acoustically-tagged), hatchery-origin juvenile Chinook salmon into the Sacramento River upstream of the Fremont Weir to monitor the entrainment rate of fish as they pass the Fremont Weir. This monitoring action will occur each year for five years (if river stage is sufficient) following the construction of the Project.

Objective: Provide juvenile entrainment rates at least 90 percent the proportion of flow entrained through the Fremont Weir.

Expected Outcome: The Action Area will provide approximately a 0.9:1.0 ratio between juvenile entrainment rates and flow entrainment rates. Reclamation and DWR anticipate lower entrainment by want to strive for this entrainment rate.

Monitoring Category: Fish

Metric: Juvenile Chinook salmon entrainment

Goal: Measure the entrainment of tagged, hatchery-raised juvenile Chinook salmon.

Intervention Threshold: Additional consideration if results from five-year special study of juvenile entrainment does not support expected outcome being met.

Potential Management Response: Additional monitoring and study of obstacles to entrainment. Develop model for behavioral guidance structures to improve entrainment and implement if likely to provide desired objective. Improve upstream bank channel.

5.3 Salmonid Rearing

DWR will continue to monitor an existing rotary screw trap located in the lower Yolo Bypass. All juvenile Chinook salmon, including tagged fish, will be recorded.

Objective: Provide rearing habitats for a diverse range of life histories of juvenile salmonids.

Expected Outcome: The Action Area will provide an increase occupied habitat for rearing and outmigrating salmonids compared to the prior conditions during a similar water year type.

Monitoring Category: Fish

Metric: Juvenile Chinook salmon presence

Goal: Observe Chinook salmon at southern Yolo Bypass rotary screw trap site

Intervention Threshold: Duration of juvenile Chinook salmon presence (during times when juvenile salmon are typically present at the south Yolo Bypass screw trap site) is shorter than during years with operation of the Fremont Weir notch than without operation.

Potential Management Response: Lengthen period of Fremont Weir notch operation between first and last operational dates during the Fremont Weir notch operation period.

Monitoring Category: Fish

Metric: Enhanced growth rate of juvenile Chinook salmon during Fremont Weir notch operations.

Goal: Measure Chinook salmon at southern Yolo Bypass rotary screw trap site.

Intervention Threshold: Range of sizes of juvenile Chinook salmon at the southern Yolo Bypass rotary screw trap site is narrower during years with operation of the Fremont Weir notch than without operation.

Potential Management Response: Evaluate water control structures at select locations to extend the duration of floodplain inundation and increase growth.

Monitoring Category: Water Quality

Metric: DO, temperature, pH.

Goal: Maintain suitable water quality conditions for rearing salmonids.

Intervention Threshold: If juvenile Chinook salmon are present within the site and water quality conditions are unsuitable, consider potential management response. No threshold for intervention is appropriate if juvenile Chinook salmon are not found within the site.

Potential Management Response: Reduce inundation flows to move juvenile Chinook salmon off of floodplain habitat and maintain migration flows in Tule Canal to move fish into Cache Slough.

5.4 Adult Fish Passage

Reclamation, DWR, and CDFW staff will continue to visually inspect the Fremont Weir splash basin, the deep pond, and all Project channels for stranded fish following Project operation. This may be done in conjunction with regular CDFW fish rescue operations. CDFW periodically inspects the deep pond for sturgeon presence following an overtopping event using DIDSON sonar-imaging and gill nets. Reclamation and DWR staff may supplement monitoring with ARIS sonar-imaging equipment if necessary.

Objective: Provide volitional passage to adult salmon and sturgeon so that they remain in good condition passing through the Yolo Bypass to spawning grounds.

Expected Outcome: The Project will improve passage of adult salmon and sturgeon by reducing delays and minimizing straying.

Monitoring Category: Fish

Metric: Percent of salmon escapement captured at Wallace Weir.

Goal: Measure number of adult salmon and sturgeon straying to Wallace Weir during fish rescue operations.

Intervention Threshold: More than 1 percent of salmon evolutionarily significant unit (ESU) or green sturgeon annual escapement stray to Wallace Weir during project operations.

Potential Management Response: Operate Fremont Weir fish passage structures to increase volitional passage window following end of overtopping. Re-operate Knights Landing Ridge Cut to reduce Wallace Weir attractions flows. Evaluate if creating a connection to the Sacramento River from Wallace Weir may reduce impact of Wallace Weir stranding on ESU escapement.

Monitoring Category: Fish

Metric: The number of salmonids and sturgeon observed or rescued from the Fremont Weir splash basin, the deep pond, and the Project channels once flows begin to recede.

Goal: Compare numbers of adult and juvenile salmonids and sturgeon stranded in the Fremont Weir splash basin, the deep pond, and the Project channels following Project operation to historical records.

Intervention Threshold: Any adult or juvenile salmonid or sturgeon stranded in the Fremont Weir splash basin, the deep pond, or the project channels.

Potential Management Response:

Should one southern distinct population segment (sDPS) Green Sturgeon or >0.1% of the 10-year average of the annual escapement or juvenile production estimate of any evolutionarily significant unit (ESU) of Chinook salmon become stranded, the hydraulic conditions in the structure will be examined to determine if fish passage criteria have been exceeded. If stranding is found to be a result of shallow depth, excessive velocity, or turbulence, evaluate physically modifying the structure. Note that any sturgeon observed via sonar imaging will be assumed to be a sDPS Green Sturgeon. Potential modifications include, but are not limited to:

- Adjust gate operations to add depth, reduce velocity, or to increase attraction flows
- Add roughness to reduce velocities
- Add velocity refugia to allow fish to better navigate through structure
- Remove or modify features that may cause turbulence
- Modify entrance to structure to improve transition to and from the Sacramento River

Additionally, the splash basin could be re-graded so that it drains towards the fish passage structure and isolated low spots that may cause juvenile stranding could be leveled to improve connectivity.

To divert adult salmonids out of the Yolo Bypass sooner (i.e., farther downstream), the potential for constructing a low-flow fish ladder in the Sacramento Weir could be evaluated.

Monitoring Category: Physical processes and hydrology

Metric: Length of time Fremont Weir notch is passable by adult salmon and sturgeon.

Goal: Measure velocity and depth in fish passage channel during fish passage period.

Intervention Threshold: Volitional passage conditions through the fish passage structure are unsuitable within 36 hours following cessation of natural and project-operated overtopping.

Potential Management Response: Extend operation to slightly less conservative conditions to improve passage. Alternately, roughen the fish passage channel.

Monitoring Category: ARIS Sonar Imaging Study

Reclamation and DWR will operate an ARIS sonar imaging station in the fish passage structure to monitor the behavior and passage success for adult salmonids and sturgeon during the Project’s first five years.

Metric: The percentage of adult salmonid and sturgeon passage attempts that result in successful passage. The ARIS sonar imaging station will monitor the entrance of the structure and it is anticipated that some milling behavior may be observed prior to a passage attempt. Therefore, fish will not be counted as attempting to pass until they have completely passed the midpoint of the ARIS frame (also known as “Finish Line Mode Counting” in the ARISFish software).

Goal: Use sonar imaging to document how adult salmonids and sturgeon behave upon encountering the fish passage structure.

Intervention Threshold: More than 10% of the adult salmonids and sturgeon that encounter the structure fail to pass using the "Finish Line Counting" approach.

Potential Management Response: ARIS footage will be analyzed in conjunction with depth and velocity measurements (see "Flow Monitoring" below) to determine if shallow depth, excessive velocity, or turbulence in the structure are found to negatively affect passage efficiency. Once a source of passage inefficiency has been identified, evaluate options for modifying structure to provide more favorable flow conditions as described previously (see Direct Observation).

Monitoring Category: Yolo Bypass Adult Salmon and Sturgeon Acoustic Telemetry Study

Reclamation and DWR will maintain an acoustic telemetry array in the Yolo Bypass and in the Sacramento River along the Fremont Weir to monitor the movement of adult fall-run Chinook salmon and White Sturgeon during the Project's first five years. Upward-migrating adult fall-run Chinook salmon and White Sturgeon will be captured in the lower Yolo Bypass and affixed with acoustic transmitters. Receivers will be located downstream of the fish passage structure and upstream of the structure in the Sacramento River to provide information on fish passage success. The Sacramento River rarely overtops the Fremont Weir coincident with the arrival of adult fall-run Chinook salmon, so this dataset may be limited.

Metric: The percent of acoustically tagged adult fall-run Chinook salmon and White Sturgeon that successfully pass the Fremont Weir.

Goal: Acoustically tagged fish will be tracked above and below the Fremont Weir.

Intervention Threshold: More than 10% of tagged fish that are detected at the fish passage structure are not subsequently detected at the receiver upstream of the structure in the Sacramento River.

Potential Management Response: Telemetry results will be analyzed in conjunction with depth and velocity measurements (see "Flow Monitoring" below) to determine if shallow depth, excessive velocity, or turbulence in the structure are found to negatively affect passage efficiency. Once a source of passage inefficiency has been identified, evaluate options for modifying structure to provide more favorable flow conditions as described previously (see Direct Observation).

Monitoring Category: Flow Monitoring (November 1 – March 7/15, TBD)

Reclamation and DWR will monitor water velocity and depth in the Project structure. The YBSHRFP structure will cease to inundate the Yolo Bypass in March (March 7 or March 15, depending on the selected Project alternative). Following this operational end date, the Project will continue to convey flows to pass adult fish with a maximum flow capacity of roughly 1,000 cfs. This flow cap will be dictated by the downstream capacity of the Tule Canal/Toe Drain to avoid causing out of bank flow. Avoiding out of bank flow will minimize effects to farming operations in the Yolo Bypass while still providing adult fish passage at the Fremont Weir.

Metric #1: Length of time adult fish passage criteria are exceeded at the fish passage structure.

Goal: Combine ARIS monitoring with velocity and depth measurements to identify sources of fish avoidance or failure to pass the fish passage structure.

Intervention Threshold: Adult fish passage criteria in the fish passage structure are exceeded for 36 hours or more following cessation of natural overtopping events and YBSHRFP Project operation.

Potential Management Response: Compare depth and velocity measurements to telemetry results, ARIS recordings, and direct observations to determine if shallow depth, excessive velocity, or associated turbulence are negatively affecting adult fish passage. Once a source of passage inefficiency has been identified, examine modifying structure to provide more favorable flow conditions beginning with roughening the fish passage channel as described above (see Direct Observation).

However, if target species can pass under conditions deemed outside of the prescribed fish passage criteria, consider adjusting criteria to include observed conditions. This would be useful in planning future fish passage projects.

Metric #2: Wetted acres.

Goal: Monitor acres of inundation as a result of the Project operating after March 7/15 at 1,000 cfs.

Intervention Threshold: Flows overtop the banks of the Tule Canal/Toe Drain after the March 7/15 operational end date creating new wetted habitat.

Potential Management Response: Adjust flow cap such that all diverted water stays within the banks of the Tule Canal/Toe Drain. If overtopping is confined to only a few low spots, determine if this is acceptable. If not, investigate adding material to repair weak slopes or fill the low spots to prevent overtopping.

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