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

Mid-Pacific Region
Sacramento, CA

California Department
of Water Resources

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Mission Statements

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

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

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Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profilers
BDCP	Bay Delta Conservation Plan
CDEC	California Data Exchange Center
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CM2	BDCP’s Yolo Bypass Conservation Measure 2
CV	Central Valley
CVFPB	Central Valley Flood Protection Board
CVFPP	Central Valley Flood Protection Plan
CVP	Central Valley Project
DEM	Digital Elevation Map or Digital Elevation Model
DFG	California Department of Fish and Game
DIDSON	Dual-Frequency Identification Sonar
DILFS	Delta Islands and Levees Feasibility Study
DO	Dissolved oxygen
DOSS	Delta Operations for Salmon and Sturgeon
DPS	Distinct Population Segment
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	California Department of Water Resources
EIR/EIS	Environmental Impact Report/Environmental Impact Statement
ERP	Ecosystem Restoration Plan
ESA	Endangered Species Act

FERC	Federal Energy Regulatory Commission
FONSI	Finding of no significant impact
FRPA	Fish Restoration Program Agreement
HEC-RAS	Hydrologic Engineering Center–River Analysis System
IMT	Implementation Management Team
ITP	Incidental Take Permit
IULT	Incipient Upper Lethal Temperature
JPE	Juvenile Production Estimate
KLRC	Knights Landing Ridge Cut
NAVD	North America Vertical Datum
NCCPA	California Natural Communities Conservation Planning Act
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NRC	National Research Council
NTU	Nephelometric Turbidity Unit
Operation BO	Biological Opinion and Conference Opinion on the Long-Term Operation of the Central Valley Project and State Water Project
PIT tag	Passive Integrated Transponder Telemetry Tag
RPA	Reasonable and Prudent Alternative
RSTR	Rotary Screw Trap
SFCWA	State Federal Contractors Water Agency
SRC	Spring-run Chinook Salmon
SRFCP	Sacramento River Flood Control Project
SWP	State Water Project
UCD	University of California, Davis

USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USFWS	United States Fisheries and Wildlife Service
USGS	United States Geographical Survey
WOMT	Water Operations Management Team
WRC	Winter-run Chinook salmon
WSE	Water Surface Elevation
WY	Water Year
WYT	Water Year Type
YBAMT	Yolo Bypass Adaptive Management Team
YBFEP	Yolo Bypass Fishery Enhancement Plan
YBFEPT	Yolo Bypass Fishery Enhancement Planning Team
YBRT	Yolo Bypass Restoration Team

1. Introduction

Significant modifications have been made to the historic 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 significantly hindered native fish species that rely on floodplain habitat during part or all of their life history. The Yolo Bypass (Bypass), which currently experiences at least some flooding in approximately 80% of years, still retains many characteristics of the historic floodplain habitat that are favorable to various fish species. In approximately 70% of years, Fremont Weir overtops, joining flows from western tributaries. In approximately 10% of years, localized flooding is due to western tributary contributions only (DWR 2008, Woodland gauge, unpublished analysis). The primary function of the Bypass is flood damage reduction, with most of it also managed as agricultural land. The Bypass has also been identified by several State and federal entities as a potential site for habitat restoration to ease pressure on and increase benefits to threatened and endangered fish species. On June 4, 2009, the National Marine Fisheries Service (NMFS) issued its Biological Opinion and Conference Opinion on the Long-term Operation of the Central Valley Project (CVP) and State Water Project (SWP) (NMFS Operation BO). The NMFS Operation BO concluded that, if left unchanged, CVP and SWP operations were likely to jeopardize the continued existence of four federally- listed anadromous fish species: Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and Southern Distinct Population Segment (DPS) North American green sturgeon. The NMFS Operation BO sets forth Reasonable and Prudent Alternative (RPA) actions that would allow continuing SWP and CVP operations to remain in compliance with the federal Endangered Species Act (ESA).

This Yolo Bypass Salmonid Habitat Restoration and Fish Passage Draft Implementation Plan (Implementation Plan) was prepared jointly by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) to address two specific RPA Actions set forth in the NMFS Operation BO:

- RPA Action I.6.1: Restoration of Floodplain Rearing Habitat, through the increase of seasonal inundation within the lower Sacramento River basin; and

- RPA Action I.7: Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon, through the modification of Fremont Weir and other structures of the Yolo Bypass.

As mandated by the NMFS Operation BO, this Implementation Plan describes the activities, process, and timeline required to implement actions to address the requirements of RPA Actions I.6.1 and I.7.

Major California restoration planning efforts over several decades (e.g., CALFED, the Bay Delta Conservation Plan) have focused on the Yolo Bypass as a prime area of the Sacramento Valley for enhancement of seasonal floodplain rearing habitat. The Yolo Bypass is generally seen as one of the best places in the lower Sacramento River Basin on which to focus implementation resources in order to achieve implementation of floodplain enhancements because of these efforts. Some of the technical foundation for these efforts has been well laid and interaction with stakeholders and local property owners has been initiated and is on-going.

Implementation procedures related to RPA Action I.6.1 within the NMFS Operation BO specify that this Implementation Plan include an evaluation of options to “increase aquatic inundation of publicly and privately owned suitable acreage within the Yolo Bypass.” Therefore, this Implementation Plan focuses on restoration of floodplain rearing habitat within the Yolo Bypass to address RPA Action I.6.1. However, the planning and environmental compliance process will consider a reasonable range of alternatives for implementing this RPA action. Additional discussion regarding the availability and suitability of areas for seasonal floodplain inundation is provided in Section 6: Proposals to Refine the RPA Actions.

2. Biological Objectives and Performance Measures

The following biological objectives and performance measures relate to increased seasonal inundation and fish passage actions.

2.1 Increased Seasonal Inundation Biological Objectives

The goal of RPA Action I.6.1 is to restore floodplain rearing habitat for juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and California Central Valley steelhead in the Yolo Bypass by providing floodplain connectivity that will provide physical habitat conditions that will in turn support juvenile growth and mobility, water quality, and the forage necessary to support juvenile development. Specific biological objectives related to implementing RPA Action I.6.1 include:

- Increase access for juvenile salmonids onto seasonally inundated aquatic habitat, generally from late November through April, except when hydrologic conditions do not allow.
- Significantly increase the acreage of seasonal floodplain rearing habitat, generally from late November through April, as hydrologic conditions allow[1].
- Significantly reduce stranding of juvenile salmon and steelhead and minimize the presence of migration barriers that limit the passage of juvenile salmon and steelhead.
- Increase aquatic primary and secondary biotic production in the Yolo Bypass, thus increasing the abundance and availability of food for native aquatic organisms.
- Provide juvenile salmonids access to inundated aquatic habitat through volitional entry to avoid potential adverse effects to salmonid population diversity associated with 'trap and haul' operations.

[1] Potential operations will be further evaluated during the planning and environmental compliance process.

2.2 Increased Seasonal Inundation Performance Measures

Success of the actions taken to implement RPA Action I.6.1 will be assessed based on in-season data, which could be used to adaptively manage associated fish passage facilities and habitat restoration projects to meet plan goals. Data will be drawn from two measurable areas of performance measures:

- **Habitat attributes:** including the area, duration, and depth of inundation, the velocity, temperature, and turbidity of waters in the Yolo Bypass, critical chemical attributes of the water (dissolved oxygen, pH, nitrogen levels, pesticide levels, and methylmercury levels), and the proportion of Sacramento River water flow that passes through the Bypass.

- **Juvenile and adult measures for targeted fish populations:** including survival rates, growth (comparing measurements of fish captured in the Bypass rotary screw traps [RSTR] against those of fish captured in the Sacramento River), residence time in the Bypass (based on telemetry from fish captured and tagged at the RSTR), presence and abundance of fish in expanded habitat areas, average percent of fish populations with access to appropriate habitat, and abundance of various food sources (based on measurements in the water and examination of the gut contents of captured fish).

2.2.1 Amount of Inundated Acreage

Based on technical efforts associated with past and current planning efforts, including BDCP, several assumptions can be made about the inundated acreage that can be achieved in the Bypass. The following text describes potential inundation using a notch at Fremont Weir as an example. However, the planning and environmental compliance documents for implementing these actions will evaluate a reasonable range of alternatives. Although biological benefits would be expected to be significant at 6,000 cfs, this quantity of flow would not always be attainable. Modeling has shown that sufficient velocities, depths, and general residence times to provide enhanced biological benefits might start to be achieved from flows greater than 2,000 to 3,000 cfs (BDCP Technical Team Draft Technical Memo #2[2])[3]. However, the habitat potentially created under this level of flow through a notch in Fremont Weir that could be constructed (Section 3.1.1) would likely be largely contained within the Tule Canal, which is less preferred than shallower, lower-velocity conditions that are achieved over the floodplain at a higher flow range. A potential operation would be to inundate when at least 3,000 cfs is available. This would be a proposed minimum operational guideline for which to initiate floodplain inundation.

At 6,000 cfs, 21,500 acres of shallow, low-velocity floodplain would be inundated. At 3,000 cfs, 11,000 acres of floodplain would be inundated with similar depths and velocities well within the preferred ranges for juvenile salmonids (Table 1). 3,000 cfs is identified as the minimum flow at

[2] BDCP Technical Team Draft Technical Memo #2 does not account for the Westside tributary flows and may not represent the capacity of Tule Canal.
[3] BDCP Technical Team Draft Technical Memo #2 reported inundated acres includes 3,700 acres that are permanently inundated at Liberty Island.

which inundation will initiate, and design would allow for that flow to increase to 6,000 cfs as flow is available before overtopping the existing Fremont Weir crest.

Table 1. HEC-RAS Model Results for Mean Depth, Area, Mean Velocity, and Water-Travel Time for Different Flows at the Modified Fremont Weir (BDCP Technical Team Draft Technical Memo #2).

Flow	Mean depth for the entire Yolo Bypass	Surface area (from GIS mapping)	Mean velocity	Travel time
(Q) cfs	**(D) ft**	**(A) Acres**	**(V) ft/s**	**(t) day**
1,000	5.9	4,100	1.66	8.8
2,000	5.3	5,700	1.94	4.9
3,000	3.9	11,000	1.77	4.2
4,000	2.8	15,900	1.49	4.2
5,000	2.6	18,600	1.32	4.0
6,000	2.6	21,500	1.26	3.9
7,000	2.6	23,100	1.19	3.7
8,000	2.6	24,600	1.20	3.6
9,000	2.7	25,900	1.20	3.5
10,000	2.8	27,100	1.20	3.4

Regardless of the alternative that is ultimately implemented for providing increased seasonal inundation, adaptive management will play a key role in operation. Available inundation flows of 3,000 cfs occur with a higher degree of frequency, and the hypothesis of whether or not 3,000 cfs is a good measure to initiate floodplain inundation would be evaluated during the first ten years of operation of flow and habitat restoration in the Bypass. Depending upon results, adaptive management will be used to identify alternate operational regimes to attain desired juvenile metrics for targeted fish populations. Although more inundated acreage presumably creates greater productivity and nutrient export, these enhanced food web linkages do not necessarily translate into enhanced benefits for juvenile salmonids. Operational guidelines may be adapted as information is learned from modeling improvements. Please see Appendix A for more detailed information.

2.2.2 Percent of Fish Population with Access to Appropriate Habitat

The timing and number of juvenile fishes exposed to available habitat may be more important than the amount of habitat available. Biological and physical models will be used to assess the available hydrology to set performance measures for the percentage of a population that could gain access to the increased seasonal floodplain habitat. Long-term monitoring could be used to help determine whether sufficient benefits are provided to rearing salmonids at flow magnitudes greater than 3,000 cfs. The acreage inundated is an important performance measure to evaluate if the implementation of seasonally inundated habitat restoration is seen as resulting in predicted landscape impacts similar to those identified during the previous planning and modeling efforts.

A performance measure for inundated acreages will be established, based on modeling during the planning phase for a Fremont Weir juvenile fish passage notch. This performance measure will be used to evaluate monitoring results of inundated acres to assess the effectiveness of implementation of the initial notch design. Monitoring following operation of flow and habitat restoration in the Bypass could be used in adaptive management in future planning efforts for attaining biological objectives.

2.3 Fish Passage Biological Objectives

The overall goal of RPA Action I.7 is to reduce migratory delays and loss of adult and juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and Southern DPS of green sturgeon at Fremont Weir and other structures in the Bypass. RPA Action I.7 calls for the provision of a reliable means of fish passage through the Bypass. Reducing stranding by means of improved passage would provide ancillary benefits to fish utilizing the floodplain. Under current conditions, in addition to being unable to reach spawning grounds, fish stranded on the Bypass are vulnerable to illegal harvesting by poachers.

Fremont Weir is 1.8 miles long and is divided into two sections by earthen fill where the weir intersects an old river channel (oxbow). There is currently no passage provided for fish that approach the western section of the weir and are unable to negotiate it. A minimum goal could be that during floods and following a flood event, fish passage that meets criteria for targeted species be provided at both the east and west lengths of the weir, however, this will be further evaluated during the planning process. Additionally, depending on the alternative implemented for increased seasonal inundation, once operation of a notch proceeds for seasonal juvenile rearing habitat restoration, adult fish passage could be required that meets these criteria during operation of the inundating flow facility (i.e. notch, operable gate). Fish passage structures would be designed and operated so as to allow improved passage conditions through the bypass to be concurrent with peak migration periods for targeted species as hydrology allows fish to navigate into the Bypass.

The primary migration barrier present in the Bypass for adult Chinook salmon, California Central Valley steelhead, and green sturgeon is the Fremont Weir. The weir is the primary inundation source for the Bypass (Sommer et al. 2001) and currently provides adult fish passage via a single fish ladder which is opened once the Fremont Weir stops overtopping. Due to irregularities in the splash basin at the foot of the weir and inadequate attraction flows to the single ladder, adult passage is impeded. Because of this, it is essential that fish passage be improved at Fremont Weir for targeted fish species and that the chosen passage structure be able to pass these anadromous fish during their peak mainstem migration periods, so that the opportunity for fish to be stranded at Fremont Weir is minimized.

Most fish passage structures in the Central Valley have been designed specifically to enable salmon passage. As such, they are not well suited to many other fish species, which vary in a number of behavioral and physiological characteristics. Sturgeon in particular require modification of the current structures if they are to achieve successful migration. The existing Denil fish ladder at the Fremont Weir was designed specifically for passage of adult salmonids; however, the efficiency for salmonid passage is questionable, and it failed to accommodate adult sturgeon passage. Based on observed stranding of sturgeon and salmon historically, the current fish ladder does not appear to reduce stranding risks to sturgeon and salmon caused by the Fremont Weir during much of their migration periods. The lack of a functioning fish ladder, in conjunction with the stilling basin immediately downstream, regularly strands adult salmon and sturgeon that have been attracted into the Bypass by flood flows but are unable to pass over the weir or through the ladder. Farther downstream, there are multiple road crossings and agricultural impoundments in Tule Canal that block hydraulic connectivity, thus impeding fish passage. As a result of these barriers, adult salmonids and sturgeon experience significant delays and increased mortality while attempting to navigate through the Bypass.

Biological objectives of RPA Action I.7 include:

- **Improve connectivity** between the Sacramento River and the Bypass to ensure safe and timely passage of:
    - **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.
- **Improve connectivity** between scoured areas south of Fremont Weir in order to ensure safe and timely passage of juvenile salmonids and green sturgeon at times when the northern portion of the Yolo Bypass floods.

2.4 Fish Passage Performance Measures

Success of the actions taken to implement RPA Action I.7 will be assessed based on performance measures concentrating on the successful passage of adult salmonids and green sturgeon which will include:

- **Habitat attributes pertaining to the fish passage structure:** These will include depth, velocity, width, and other attributes.
- **Juvenile and adult performance measures for targeted fish populations:** Reclamation and DWR will evaluate all fish passage structures upon their completion to determine whether the new or modified structures meet set criteria for the targeted fish populations with regard to depth of water, velocity of water, width of channel, and a lack of overbank flow during nonflood periods. Other performance measures will also be used to determine whether the fish passage structure is successful at passing adult migrants,

including: number of passable days; number of fish passing; and passage efficiency, determined by comparing downstream fish counts with counts of those using the fish passage structure. All of these observations will be conducted via video monitoring and radio telemetry. Stranding data will also be used to assess whether these efforts have significantly reduced juvenile stranding in the Bypass. Data will be drawn from seining of isolated ponds left in the Bypass after inundation waters have receded (Sommer et al. 2005).

Please see Appendix A for more detail on Biological Objectives and Performance Measures.

3. Increased Seasonal Inundation and Fish Passage Actions

The following sections briefly describe potential alternatives that could be further evaluated to implement Actions I.6.1 and 1.7 of the NMFS RPA. It is important to note that the environmental compliance and federal planning process documentation for these actions will analyze a reasonable range of alternatives, and therefore there may be additional alternatives, or elements of alternatives that are developed through the public involvement, environmental analysis, and federal planning processes.

3.1 Increased Seasonal Inundation Actions

3.1.1 Physical Elements

Over the course of developing the Bay Delta Conservation Plan (BDCP) and NMFS Operation BO, three main options have so far emerged for increasing floodplain inundation events in the Yolo Bypass: East Side Fremont Weir Modifications, Sacramento Weir Modifications, and West Side Fremont Weir Modifications (Figure 1). Potential design details will be further evaluated for these and any other feasible options during planning and environmental compliance efforts.

East Side Fremont Weir

The primary inundation notch could be located on the eastern end of the Fremont Weir. The notch should be adjacent to the fish passage structure, or near enough to it so that additional passage can be provided through the inundation notch. It should also be far enough to the east to allow it to be connected directly to the Tule Canal. This location would provide a high level of biological benefit, while also keeping the amount of disruption to the Bypass resulting from the necessary earthwork to a minimum. Reducing this disruption also reduces the risk of negative effects on other resources, such as oversummering invertebrate eggs and larvae in the floodplain soil, which will help create beneficial conditions for salmonid growth following inundation.

Sacramento Weir

The Sacramento Weir notch option, intended to improve fish passage and floodplain inundation, would be along either a portion or the whole length of the current weir, which is approximately 0.25 mile long. The Sacramento Weir has a channel more than 1 mile long connecting it to the Yolo Bypass floodplain. Sacramento Weir is located 13 miles south of Fremont Weir, which is about one third of the 42-mile length of the Yolo Bypass. This option could provide water to inundate the floodplain south (downstream) of the site.

West Side Fremont Weir

The West side (Fremont Weir) notch option, intended to improve fish passage and floodplain inundation, would be located between the west side levee and where the weir is interrupted by earthen fill at the oxbow. This west section is only about 0.3 mile long and its floodplain is segregated from the rest of the Yolo Bypass by the oxbow (see Figures 2, 3 and 4). The oxbow approaches Fremont Weir near the west end of this section. The oxbow is effectively a large water fish trap, presumably populated with exotic fish. Flood flows in this portion of the Yolo

Bypass are only provided by Fremont Weir overtopping events. Flows from these events pass over the oxbow and flow out over the unimproved State Wildlife Area and across farm fields.

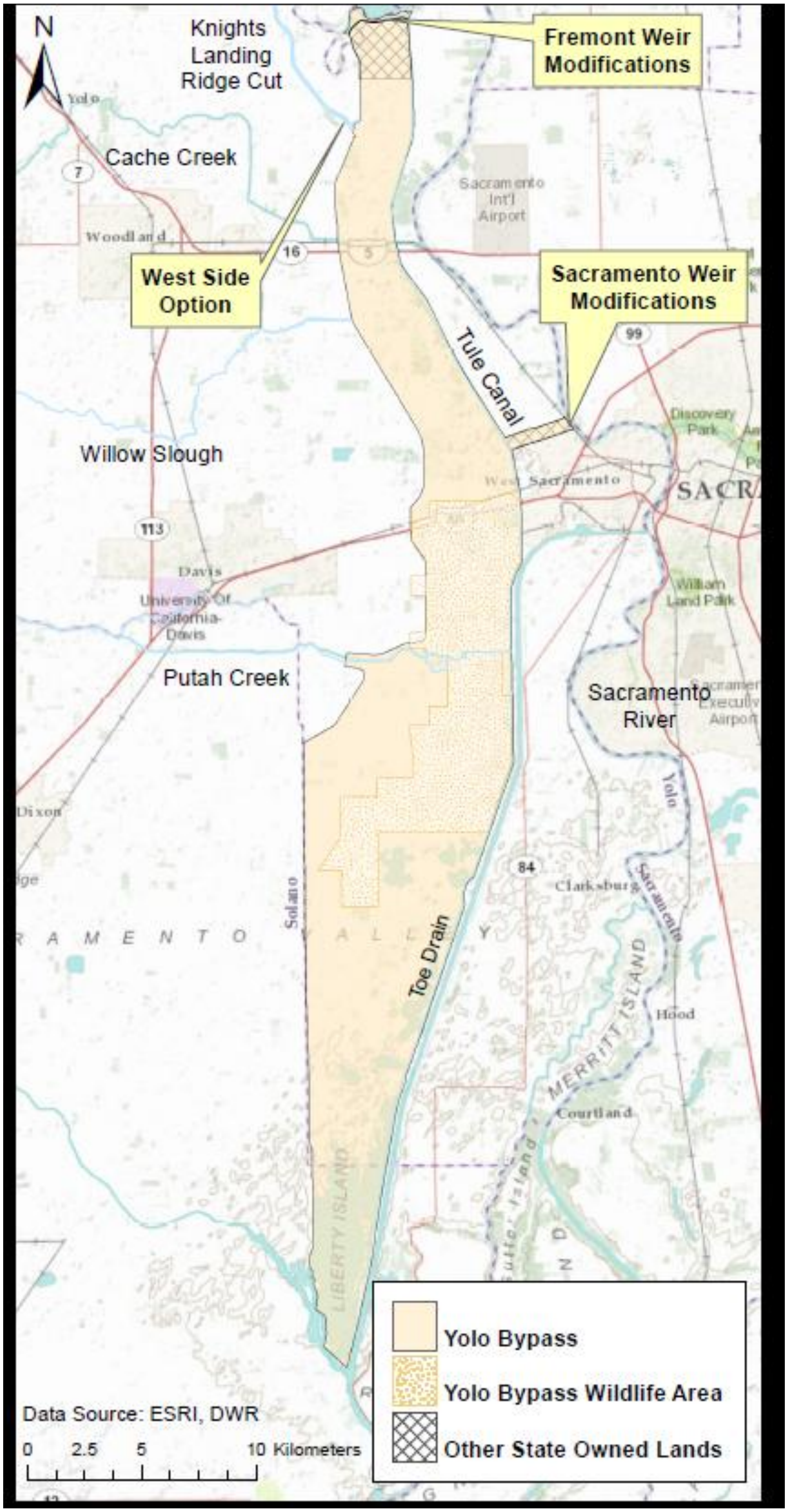


Figure 1. Potential General Locations for Projects Increasing Seasonal Inundation

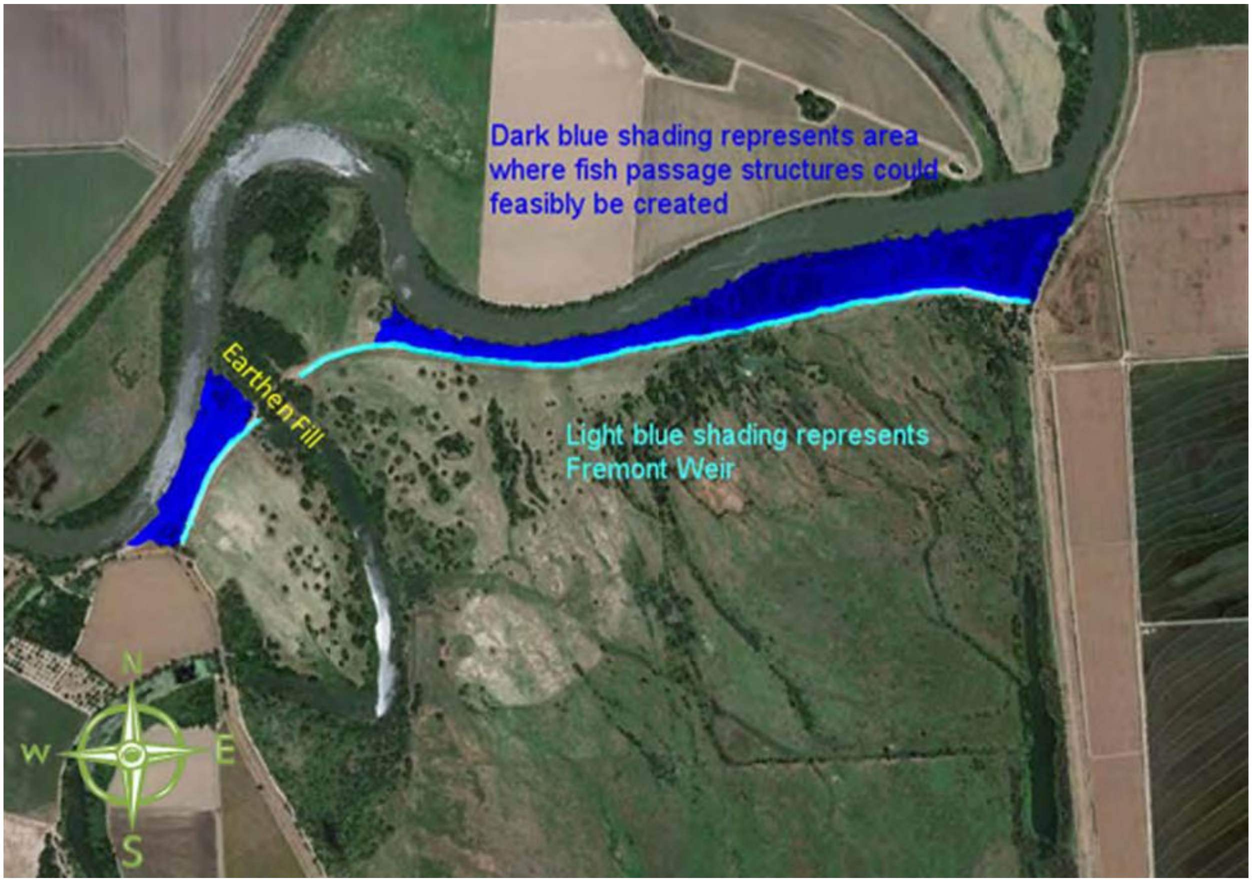


Figure 2. Northern Section of Yolo Bypass Illustrating Fish Passage Constraints

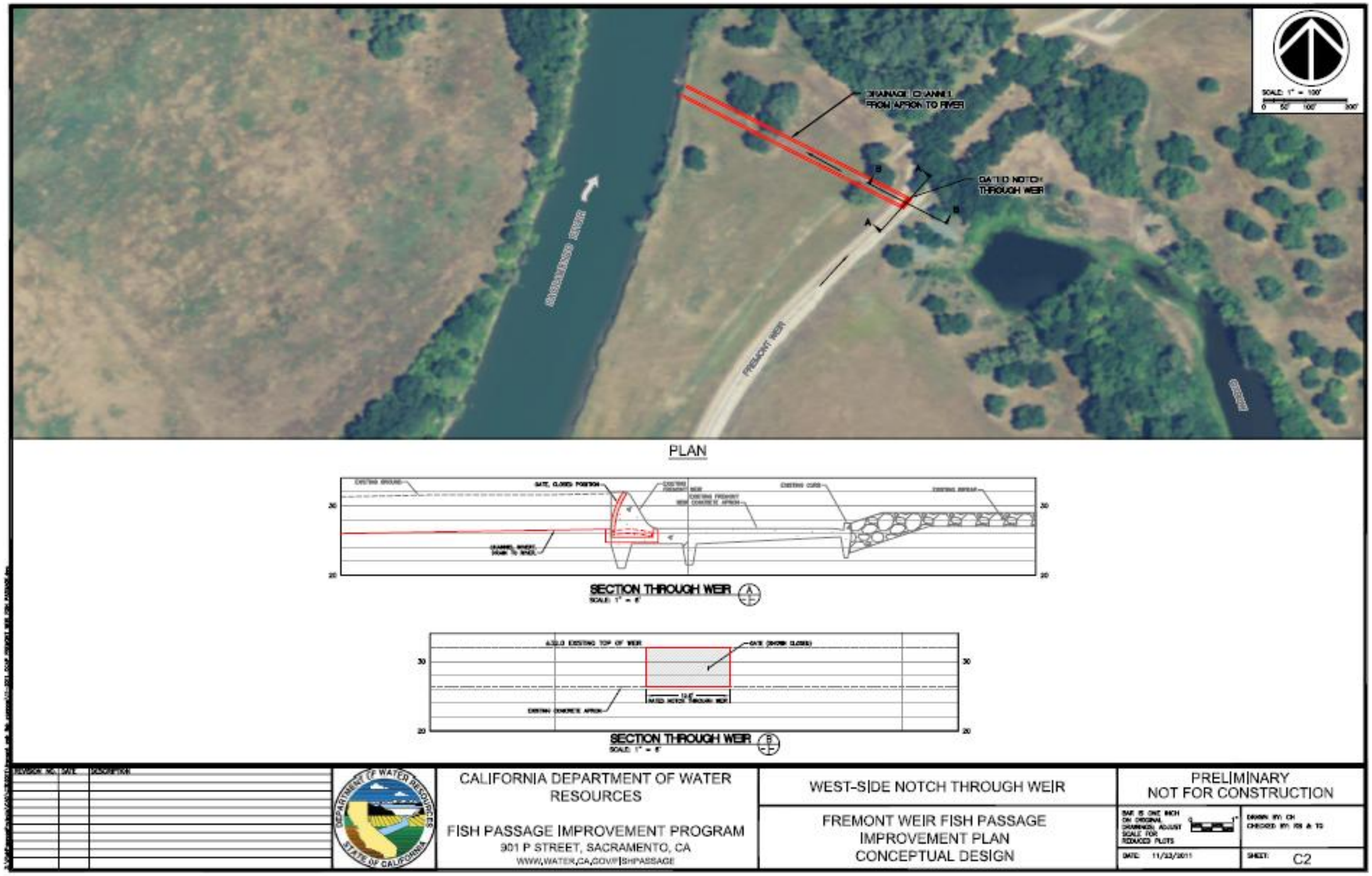


Figure 3. Potential Location for West Side Option

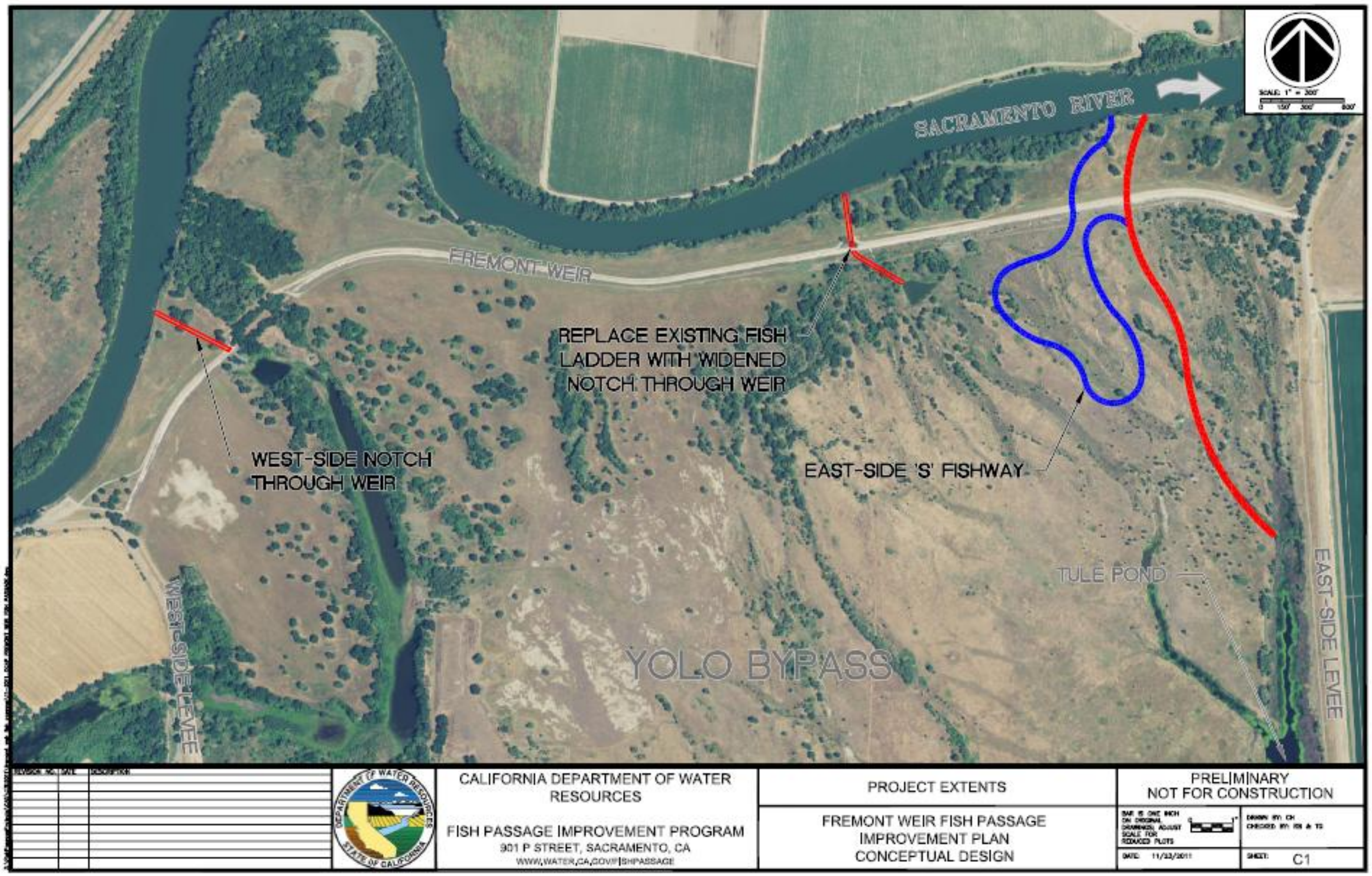


Figure 4. Potential Extent of Fish Passage Component at Fremont Weir

3.1.2 Operational Elements

The timing, duration, frequency, and hydrology of inundation flows are critical if those flows are to occur for the benefit of target fish species. Based on their periods of migration, the majority of potential benefit to the three targeted fish species is likely realized from inundation events in the period starting in late November and ending in April. Some additional benefit could be gained for Central Valley spring-run Chinook salmon and California Central Valley steelhead by extending inundation into May.

Inundation events provide a range of benefits to aquatic species that are related to the duration of the event. Generally, longer inundation events allow for greater primary and secondary production, and as a result provide greater benefits to fish species than a shorter event. Longer inundation events may contribute to the food web both on seasonal floodplains and exported to the Cache Slough region of the north Delta. However, even short inundation events may provide ecological benefits to many endangered and threatened fish species on the Bypass's seasonally inundated aquatic habitats (Sommer et al. 2004). An inundation event lasting 14 days or more would allow sufficient time for development of chironomid populations, an important food source for California Central Valley steelhead and Chinook salmon. Inundation periods of fewer than 7 days could present fewer benefits for targeted fish species, and potential alternative inundation periods will be evaluated to determine if benefits outweigh risks. Under current conditions, based on Fremont Weir overtopping,[4] inundation events lasting at least 14 days occurred in approximately 10 of the last 24 years. Restoration actions to increase seasonal inundation would increase the frequency and duration of such inundation events.

Preliminary modeling indicated that flow begins to exceed the capacity of the Tule Canal/Toe Drain between 1,000 and 2,000 cfs. Flows that contribute to seasonal floodplain inundation will come from existing western tributary flows, existing flows over Fremont and Sacramento Weirs, as well as flows that result from actions to increase seasonal inundation. Within the operation range of the actions to increase seasonal inundation, the Yolo Bypass Adaptive Management Team (YBAMT) (Section 4.1.3) will exercise judgment regarding the timing, duration, frequency, and hydrology of additional flows associated with the project. Regarding drawdown rate, for example, the adaptive management team will identify drawdown rates that are protective of fish at other sites, that take steps to mimic the descending limb of a natural hydrograph, and allow fish to navigate from the floodplain to the Tule Canal/Toe Drain and into the Delta as flow recedes.

Knaggs Ranch Restoration Study

The Knaggs Ranch Restoration Study is located on Knaggs Ranch, an agricultural parcel with a total area of 1,703.55 acres. Knaggs Ranch is located in the northern part of the Yolo Basin, north of Interstate 5, and is near the Sacramento River between River Miles 72 and 76. It lies entirely within the Yolo Bypass and is currently used for rice production and waterfowl hunting. This study's intent is to undertake a multi-year experimental evaluation of the Yolo Bypass as winter floodplain habitat for Chinook salmon and improve upon the current understanding of how juvenile salmonids utilize various habitat types common in the Bypass. This study is related

[4] Not including tributary flows

to operational elements of habitat restoration by attempting to answer the following questions over the next 3 years:

1. What is the relative growth of fish in the three habitat types being studied?

2. What is the food web contribution of each of these habitat types?

3. Do salmonids exhibit a habitat preference related to these habitat types?

Other potential questions that could be addressed in subsequent years of study at Knaggs Ranch include:

1. Are there best management land practices to create optimal rearing habitats while minimizing stranding?

2. Do fish entering the bypass later in the season show similar growth as fish that have already been on the bypass or growth rates similar to the early period of these fish still on the bypass?

3. How long does it take for macroinvertebrates to be produced in reasonable densities?

Additionally, this study will investigate how these different habitat types contribute to salmonid growth. Specifically, it will examine the food web contributions of both fallow floodplain vegetation and rice fields by comparing chironomid seed banks, as well as levels of phytoplankton, zooplankton, and drift invertebrates. Observed growth rates will be compared with growth rates from juvenile salmon residing on the Yolo Bypass floodplain during historic events to determine whether fish raised on a managed floodplain achieve a comparable growth benefit. An additional goal is to determine the protocols and design parameters for management of productive salmon habitat in an agricultural portion of the Yolo Bypass floodplain. The Yolo Bypass Restoration Team (YBRT) (Section 4.1.3) will apply the findings of the multi-year study as part of their rationale for developing criteria for habitat restoration actions in the Bypass. In addition, the project will provide information on best management practices for agricultural lands in the Bypass that may have a dual purpose of also serving as fish habitat during the winter and early spring months.

This three year pilot project is being implemented by UC Davis Center for Watershed Sciences, DWR and the NMFS Southwest Science Center, and funded by Reclamation and other partners. Potential implementation of a longer term project would be subject to future planning processes.

Between January and March 2012, DWR and UC Davis undertook the first year of investigations on the Knaggs Ranch Restoration Study. The first year of the study occurred on a 5 acre portion of the property, but it is likely that the study site may be enlarged in future years. The initial concept included a field in which a portion of the terrain consisted of rice (approximately 1-3 feet deep) and another somewhat smaller proportion of the terrain consisted of a fallow area (approximately 2-3 feet deep). Once constructed, the field ranged in depth from approximately 9 inches in the northwest corner to approximately 32 inches in the southeast corner. Juvenile hatchery fall run Chinook salmon were released into the constructed field, which consisted of four habitat types: long rice stubble, short rice stubble, disked and fallow. Long stubble and disked blocks were approximately 50 feet x 50 feet. The remainder of the field was largely short stubble, with a small portion (approximately 1/10 of the field) being left fallow. The perimeter was also disked.

The study site had a single inlet (which was screened prior to salmon introduction into the field) and a screened outlet. A fyke net with an approximate entrance diameter of 24 inches was affixed to the outlet screen. Fish congregations in the study site were monitored to determine their preferences for one habitat area over the other; however, complications during sampling and use of hatchery fish introduced potential sources of error. Invertebrates and zooplankton were also monitored to investigate potential differences in food sources in rice versus fallow terrains. In future years, this project will continue to investigate juvenile salmon habitat use in fallow and agricultural areas, as well as the ability of the aquatic food web in agricultural areas to support juvenile salmon growth. Although the acreage involved in Knaggs Ranch research study is small in scale, the knowledge gained from it will be directly applicable to the design of future seasonally inundated habitat restoration efforts on the Bypass floodplain, particularly in regard to modification and enhancement of habitat for juvenile salmonids rearing on the floodplain. This project is a good example of DWR and Reclamation working with willing landowners to meet the conditions of RPA Action I.6.1.

Other potential monitoring opportunities could be explored, including the lower portion of the Bypass where the Yolo Bypass Wildlife Area and some recently restored freshwater tidal habitat is located. Appendix C includes more detailed information on potential alternatives for further evaluation, including draft operational considerations as discussed in the Yolo Bypass Fisheries Enhancement Planning Team (YBFEPT) (Section 4.1.5) planning process.

3.2 Fish Passage Actions

The following text briefly describes potential actions for further evaluation to improve fish passage in the Yolo Bypass in accordance with NMFS RPA Action 1.7.

3.2.1 Physical Elements

Potential fish passage actions include physical elements associated with the existing Fremont Weir fish ladder, agricultural road crossings, experimental sturgeon ramps, Lisbon Weir improvements, and new fishways.

Remove baffles from Fremont Weir fish ladder

As a trial, DFG is working to remove the existing baffles from the fish ladder, transforming it into a clear-chute fishway. Funding will be made available to DFG so that performance of the modified fishway can be monitored by means of underwater cameras and monitoring of the passage of tagged fish. DFG will provide an annual report prior to the next water year detailing any observations of fish through the modified Fremont Weir fishway. This information will be reviewed by DFG, NMFS, DWR, and Reclamation to determine continuation of the modified fishway or reestablishment of the baffles. This is an initial action that will be implemented and monitored by DFG on an experimental basis beginning in 2012, and potentially annually until other fish passage improvements are completed.

Replace agricultural road crossings at Toe Drain and Tule Canal with fish-passage-friendly designs
The Yolo Bypass drains to its east side. Along the east side is a drainage channel running north-to-south, from just south of Fremont Weir down to Cache Slough. The drain channel north of Interstate 80 is called the Tule Canal and south of this point it is called the Toe Drain. There are three agricultural structures in the northern Tule Canal that impede flow and cause fish passage delays. These earthen structures would be modified to maintain land access and reduce fish passage delays. These improvements would maintain or improve their utility during the growing and harvest seasons. These earthen structures could be replaced with permanently installed structures such as rail car bridges or concrete box culverts, or could be replaced with removable, seasonally operable structures. It is expected that replacement of the existing structures would substantially reduce fish passage delays through the Tule Canal. Fish tagging and tracking studies may be used to quantify the extent of adult salmon and sturgeon passage impediments at the existing structures. Initial delays would be assessed based on data collected from tagged salmon and sturgeon prior to project modifications. Modification is also expected to reduce juvenile stranding after Fremont Weir overtops.

Experimental sturgeon ramps
An experimental sturgeon passage structure would be designed and installed along Fremont Weir to improve the ability of green sturgeon to pass. A range of fish passage designs will be evaluated during the planning and environmental compliance process, which will consider and compare the feasibility and potential performance of potential fish passage elements. The Denil fish ladder currently located at Fremont Weir, which is designed for anadromous salmonid passage, is inappropriate for sturgeon passage. Most recently in 2011 following a period when the ladder was operable, a rescue operation conducted by the Department of Fish and Game (DFG) rescued stranded green and white sturgeon. This observation is similar to what has been noted during fish rescues over the past few decades. Sturgeon, unlike salmon, rely more on sustained swim speeds rather than on bursts of speed to carry them over obstacles (Kynard et al. 2002). A ramp could be designed and installed to provide improved passage conditions for green sturgeon under a narrow range of Sacramento River water surface elevations. During design of the experimental ramp, a number of elevations would be examined to determine the length of increased duration of sturgeon passage. A design would be selected based on the goal of having the longest duration of increased passage window during natural overtopping patterns over the past two decades. The sturgeon ramp or ramps may extend from the top of the Fremont Weir to the opposite side of the splash basin. The ramp(s) could be made of earthen fill, concrete, or some other suitable material, depending on engineering constraints. An appropriate length for the ramp(s) along Fremont Weir would be determined based on an assessment of hydraulic constraints and the ramp's likely effectiveness in enhancing green sturgeon passage (e.g., the likely ability of green sturgeon to locate and use the ramps). This would be done in consultation with the U.S. Army Corps of Engineers (USACE) in order to ensure that adequate flood safety precautions would be taken and to ensure that the integrity of the weir would not be compromised.

The purpose of the ramp(s) would be to reduce stranding risks of green and white sturgeon during natural overtopping events at Fremont Weir. The turbulence caused by the spilling of Fremont Weir would be reduced within the footprint of such a ramp, creating conditions more suitable for fish passage. The ramp(s) would encourage sturgeon to exit the bypass through the laminar flows created by the ascending ramp when spill over the unramped portions of the weir would become an impediment to passage due to turbulent flows (Kynard et al. 2002; McClenathan 2003). If effective, the ramps would likely pass sturgeon when there is at least 2 to 3 feet of flow over the weir. Risk associated with this weir modification would be minimal, since there would be no reduction in flood conveyance and no foreseeable negative effects on other species.

Performance of the sturgeon ramp(s) would be measured primarily by the absence of sturgeon in the spring after overtopping of Fremont Weir. Specifically, the performance measures would be:

- Few or no green sturgeon stranded within the splash basin following flood events. In light of the rarity of green sturgeon, white sturgeon may be considered surrogates for evaluating the performance of experimental sturgeon ramps.
- Extension of passable conditions beyond the current window
- Minimization of migration delays
- No negative impacts to weir integrity (e.g., no scour directly downstream of the splash basin, no undercutting of the splash basin, no cracking due to the additional weight, etc.).

The sturgeon ramps would be difficult to monitor due to limited access to the area during flood conditions. Additionally, there are limited baseline passage data that would be used in assessing the effectiveness of the structures. During the first flood event directly following installation, flow over the ramped and unramped sections would be monitored for direct comparison (e.g., by video) to determine whether passage conditions have been extended by the ramp. When possible, sturgeon would be tagged with acoustic transmitters in or downstream of the bypass, and then tracked via an array of receivers to determine their migration route (i.e., the Sacramento River mainstem versus the Yolo Bypass) and their potential for migration delays due to the Fremont Weir. Additionally, receivers would identify tagged fish from other studies being conducted in the Central Valley that migrate through the Bypass. When conditions allow, site visits would be made during the descending hydrograph to determine whether the ramp is functioning in a way that allows passage. After the river has receded and the floodplain has become hydraulically disconnected, the splash basin would be surveyed (e.g., part of CDFG fish rescue incident planning) to determine how many green sturgeon (if any) are stranded in the pools created by the splash basin. After the river has receded and the floodplain has become hydraulically disconnected, the foot of the ramp would be inspected to ensure that there is no scour or undercutting at the downstream end of the splash basin that could threaten the weir's structural integrity.

Lisbon Weir improvements

Across the Toe Drain, five miles south of the Interstate 80 Causeway, is an agricultural impoundment structure called the Lisbon Weir. The main part of this weir is composed of a rock mound reinforced on the downstream side with sheet piling. Along the west side of the weir is a small bypass channel with tidally operated flap gates that allow upstream flow, but restrict downstream flows. Lisbon Weir helps with field irrigations north of the weir by providing higher and more stable water levels for upstream diversion pumps by holding in flows of tidal water.

The water elevation in the Toe Drain is affected by tidal actions as far north as I-80 and water surface elevation (WSE) fluctuates 0 to 4 feet a few hundred feet south of the weir (DFG 2008). Lisbon Weir blocks the channel and limits the range of tidal fluctuation upstream of the weir. The weir operates passively by impounding upstream inflows and tidal water at a minimum elevation that is equal to the weir crest elevation. At high tide, the weir is completely submerged, but at low tide the WSE can be 2.5 feet below the weir crest, and impede fish passage. Lisbon Weir is discussed by DFG in its Yolo Bypass Management Strategy and its Yolo Bypass Wildlife Area Land Management Plan.

Lisbon Weir could be modified to allow flow and fish passage, or prevent fish passage when upstream migration past Fremont Weir is not feasible. This project would redesign Lisbon Weir so the structure could be operated to allow unimpeded fish passage, reduced maintenance of the weir, and at the same time be managed to impound water for agriculture. This design would modify the crest of the weir with a passage slot and/or modification of its west end flap gates so they would remain open during periods critical for fish passage. Design would modify all or part of the weir with a fish passage slot or structure such as a bladder dam that could be operated to be flush with the channel invert at high tide, and at times when more rapid floodplain drainage is desired.

Fish tagging and tracking studies may be used to quantify the extent of fish passage impediments at the existing structures. Initial delays will be assessed from data collected from tagged salmon and sturgeon prior to project modifications. Replacement of and/or modifications to the structures would be expected to improve fish passage and decrease passage delays. Lisbon Weir actions analyzed in this planning and environmental compliance process could also address NMFS RPA Action I.6.4 and would be consistent with Appendix 2-C of the NMFS RPA.

Fremont Weir modifications

Modifications to the Fremont Weir could include:

- Construction of an S-shaped fishway (or alternative) that would connect with the weir at two points by means of gates that would allow fish passage at two different water elevations, extending the range of hydrologic conditions at which passage would be possible.

- Replacement of the existing fish ladder with one having a wider, roughened channel that would broaden the range of fish species and populations that could swim upstream through it.

- Addition of a channel to drain the western Fremont Weir, by means of a gated notch, back into the Sacramento River to prevent stranding.

- Resurface the apron so water drains to one of the above fish passage facilities and does not strand fish in disconnected pools.

- Potential risks associated with these fish passage actions include, but are not limited to:

- Ineffectiveness overall at protecting fish if no additional passage improvement is provided at Fremont Weir.

- Fish could remain in downstream splash pool, increasing passage delays.

Fish trapping and tagged and tracking studies could be used to quantify the extent of fish entrainment and/or passage delays at the existing structures. Initial entrainment and/or passage delays would be assessed from data collected from tagged salmon and sturgeon prior to project modifications. Replacement and/or modification of the structures would be expected to decrease fish stranding and improve fish passage to the Sacramento River, with decreased passage delays. Multi-species fish passage actions at Fremont Weir analyzed in this planning and environmental compliance process would be consistent with Appendix 2-C of the NMFS RPA.

Grading of downstream channels
Downstream channels would be graded to improve connectivity to the Tule Canal when water levels fall as inundations recede and guarantee the presence of exit points for fish that would otherwise be stranded when inundations recede. Actions to improve Tule Canal connectivity analyzed in this planning and environmental compliance process would be consistent with Appendix 2-C of the NMFS RPA.

Reduction of the creation of isolated pools
As appropriate, the creation of isolated pools could be prevented where fish are stranded when inundations recede, primarily by connecting the pools to main channels. Some natural features with the potential to hold fish may remain.

Modification of the Knights Landing Ridge Cut
The KLRC would be modified as it currently provides no exit path for upstream-migrating fish. Three potential options for modification are construction of a temporary weir at the outflow end of the existing channel to both allow the downstream passage of water and prevent the upstream passage of fish; realignment of the outflow point into the existing Cache Creek Settling Basin (CCSB), which already is equipped with a high wall weir that prevents the upstream passage of fish; and blocking passage further downstream of the junction of KLRC and the Bypass.

Please see Appendix C for more detailed information on these potential actions. In addition, potential options at other locations, such as Sacramento Weir will be evaluated during the planning and environmental compliance process. Also, information gained from experimental actions such as the Knaggs Ranch project may help inform evaluation of alternatives during the planning and environmental compliance process.

3.2.2 Operational Elements

Potential fish passage actions include operational elements associated with fish rescue, juvenile stranding, and timing of fish passage operations.

Fish rescue
Upon agreement on a Fish Rescue Plan between NMFS and DFG, funding will be made available to DFG for increased law enforcement and a fish rescue program following natural

Fremont Weir overtopping events. Such a program took place in spring 2011, and provides a reasonable estimate of what such an effort may cost on the Yolo Bypass. While DFG has tracked fish rescue and stranding around Fremont Weir and the Yolo Bypass, this information is not well cataloged and these observational rescues have not been assessed to evaluate the efficacy of fish rescues or prioritize remediation of fish stranding locations. A fish rescue program will be funded and coordinated with DFG to provide consistent and efficient fish salvage and to record detailed stranding data. To minimize mortalities below Fremont Weir, the program will fund efforts to catch and salvage adult salmonids and sturgeon stranded in the splash basin and associated scour ponds. These fish will be tagged to evaluate the effectiveness of the fish rescue plan. This effort will begin in water year 2013 at a level identified for funding by CDFG.

Juvenile stranding reduction

Stranding of juvenile salmonids is a regular occurrence when the Yolo Bypass is flooded (Sommer et al 2005). Juvenile salmonids have been observed in all regions and substrates of the Yolo Bypass, and while there is evidence that the majority of young fish do not become stranded, monitoring has documented high rates of fish stranding associated with engineered water control structures (Sommer et al 2005) and the effects on population level among covered salmonids that can be attributed to these mortalities remain unknown.

Under current conditions, fish stranding within the Bypass is caused by two main types of processes: geomorphic processes (i.e., the hydraulic scouring of the Bypass as a result of water flow) and mechanical earthmoving for land use purposes within the Bypass. Potential modifications to the Fremont Weir and the operation of weirs to increase seasonal inundation or fish passage could also increase the risks of fish stranding in the Bypass. Since juvenile fish stranding has been documented in this area and could increase or decrease depending on how fish passage and seasonal inundation projects are pursued within the Bypass, DWR and Reclamation intend to minimize juvenile fish stranding by implementing a number of measures. Reclamation and DWR will fund, develop, and implement a juvenile stranding reduction program with DFG to manage fish stranding by means of four approaches: 1) cataloging juvenile stranding locations, 2) estimation of the magnitude of stranding, 3) education of Bypass stakeholders on management practices that reduce stranding and 4) the strategic implementation of corrective actions as necessary. The first two approaches in the stranding reduction program will be undertaken in WY 2013 by CDFG, and these results will inform the second two approaches during the course of implementation.

Juvenile salmonid stranding dynamics may change over time. As near-term stranding reduction measures are taken, it may become apparent that certain areas are significant stranding “sinks.” At present these locations are not well identified, but they could become apparent as a catalog of stranding and fish rescues is developed. Long-term implementation of a stranding reduction program would include the strategic identification of fixed juvenile stranding locations based upon such criteria as: 1) the size of the wetted area of the Bypass at the time when connectivity is lost, 2) the proximity of the stranding location to migratory corridors (i.e., the west side tributary channel, the Tule Canal, the Toe Drain), and 3) the frequency with which fish are isolated in each particular location.

Although seasonally inundated floodplain habitat is somewhat less common in areas of the Central Valley outside of the bypasses, seasonally inundated off channel habitats still are frequent occurrences along tributaries in the Central Valley. In those cases in which these habitats are located on rivers with CVP/SWP dams, flow ramping rates are prescribed to reduce stranding opportunities (Table 2). If an operable facility is developed for management of seasonal inundation as part of this project, Reclamation and DWR propose that similar ramping rates be used there to reduce stranding risks unless the stranding reduction program demonstrates through monitoring results that these rates do not correspond with conditions favorable to reduced stranding.

Table 2. Example Flow Ramping Rate

Location	Flow ramping protocol	Citation
Nimbus Dam, American River	At flow levels <5,000 cfs, flow reductions shall not exceed more than 500 cfs/day and not more than 100 cfs/hour.	NMFS 2009

As part of the juvenile fish stranding reduction program, a catalog of stranding locations would be compiled to document their locations and serve as a guide for potential physical modifications to the Bypass. Most stranding appears to occur near water control structures (Sommer et al 2005), so it may be that adjustments and changes to the operation of these structures would significantly reduce stranding. In cases where significant stranding occurs within the working landscape of the Bypass, Reclamation and DWR would pursue education and cooperative partnerships with landowners to determine what physical modifications can be made to reduce juvenile stranding while maintaining the owners' land use. In discussions with many stakeholders, efficient drainage has emerged as a critical aspect of waterfowl and agricultural land uses, so physical modifications to reduce stranding may actually be beneficial to existing land uses.

See Appendix C for more detailed information.

Timing of operation for fish passage

Operational criteria for fish passage will be based on the timing of migration for the target species as well as on the influence of flow fluctuations allowing their entrance into the Bypass. The phenomenon is not entirely understood, but it appears that fluctuations in streamflow have some effect on the timing of Chinook salmon migration (Yoshiyama et al. 1998), although such flow associations are less clearly present for California Central Valley steelhead migration. Intuitively, one would expect spring-run Chinook salmon and winter steelhead to have adapted to take advantage of higher midwinter and spring flows. Green sturgeon have a similar response to high-flow pulses (Heublein et al. 2009). Based on existing evidence, it will be necessary to consider flow fluctuations during migration and to operate the fish-passage structure in such a way as to maximize passage under whatever the current hydrologic conditions happen to be.

Fish passage structures should limit the risk of reverse flows and sedimentation, either of which is likely to decrease the efficiency of fish passage. The invert elevation of a fish passage structure through Fremont Weir would alter the existing hydraulics. Deeper invert elevations would decrease channel slope and thereby increase the risk of reverse flows and sedimentation, while shallower notches would reduce those risks. However, shallower invert elevations would provide a shorter temporal window for passage. The invert elevation for fish-passage structures should provide passage over a much longer time period, with low risk of stranding.

Additionally, a deeper notch invert would require longer stretches of excavation to attain elevations providing optimal passage efficiencies through connectivity with Tule Canal. The longer this stretch of excavation, the greater the length of a fish passage structure, and design of efficient passage structures may be confounded by greater lengths. However, a shallower notch invert elevation would provide a shorter temporal window for passage. The invert elevation for fish passage structures should provide passage over a longer time period, with low risk of stranding. An invert elevation of 20 feet would nearly eliminate any risk of reverse flows, but would limit duration and frequency of fish passage events in March during water years not categorized as wet or above normal. Initial analysis suggests that a fish passage structure with an invert elevation of approximately 14 feet would introduce a moderate risk of reverse flows, since water surface elevations in the Tule Canal are sometimes higher than in the Sacramento River when the river is at a stage of 14 feet. However, an invert elevation of approximately 14 feet would greatly improve the passage windows in March and April, key migration periods for many of the targeted species. The depth of a fish passage structure's notch as well as its length are important design criteria, which will be weighed during the alternative description and evaluation process.

In general, the target species are present when the water surface elevation of the Sacramento River is moderate to high and amenable to fish passage. However, steelhead are present only when the Sacramento River water surface elevation is generally low, often when it is lower than that of the Tule Canal. Based on the existing hydrology, reliable fish passage through the Bypass for steelhead is unlikely. However, it is also unlikely that steelhead would rely on the Bypass as a migration corridor to the extent that winter-run Chinook salmon, spring-run Chinook salmon, and green sturgeon do under higher-flow conditions. Although fyke traps are inefficient at sampling steelhead, DWR fyke trap data do confirm the presence of steelhead in the Bypass in winter and spring. Putah Creek, a tributary to the Bypass, is classified by the National Marine Fisheries Service as critical habitat for California Central Valley steelhead. However, genetic information indicates that the majority of trout in lower Putah Creek belong to a resident population. However, it is reasonable to assume that during flood events, migratory cues might be present to attract anadromous steelhead. Therefore, impediments to fish passage in this area should be evaluated so that migratory conditions can be improved for steelhead between lower Putah Creek and the lower portion of the Bypass.

4. Planning and Environmental Compliance

The following sections briefly describe the planning, interagency coordination and environmental compliance efforts that DWR and Reclamation will pursue in accordance with NMFS RPA Actions 1.6.1 and 1.7.

4.1 Planning and Interagency Coordination

Because of the multiple existing land uses in the Yolo Bypass, including flood damage reduction, agriculture, waterfowl habitat, and recreation, implementation of actions in accordance with NMFS RPA Actions 1.6.1 and 1.7 will require a high level of planning and coordination with all stakeholders from agencies and the public.

4.1.1 Agency Authorities and Roles

Several entities have authority, vested by their legal responsibility for features in the potential project area, that may be applicable to this Implementation Plan, including: the U.S. Army Corps of Engineers (USACE), the Central Valley Flood Protection Board (CVFPB), the Sacramento Area Flood Control Agency (SAFCA), DWR, and Reclamation. This Implementation Plan focuses on the authorities of the flood control entities, DWR, and Reclamation, although there are several other entities that have various kinds of authority over the area whether it is jurisdictional or by virtue of ownership or other consideration.

Organizations devoted to promoting flood protection date back to California's early settlement. The earliest flood protection efforts were made by individual property owners; small groups of property owners; reclamation, drainage, levee maintenance and flood control districts; and local communities. Natural flood hydrology was exacerbated by the tremendous debris loads that hydraulic gold-mining unleashed on the system. In the late 1800s and early 1900's plans for levees and bypasses were created along with the Reclamation Board (now the Central Valley Flood Protection Board) to implement and regulate such plans.

In 1913, the California Legislature created the Sacramento-San Joaquin Drainage District to aid the State Engineer in analyzing the San Joaquin and Sacramento rivers and their tributaries and report recommendations to the Reclamation Board (now the CVFPB). The Drainage District can acquire, own, hold, use, and enjoy any and all properties necessary for the purposes of the district; its management and control are vested in the CVFPB. Over the next several decades USACE, in cooperation with state and local entities, upgraded existing flood protection features and built new additional weirs, levees, bypasses and reservoirs to create the Sacramento Flood Control System. The existing major flood control and water supply systems affecting the study area, including the Sacramento River Flood Control Project, Central Valley Project, and State Water Project; were built by various entities over time with distinct project purposes, and continue to be maintained by multiple entities, including DWR; Reclamation, levee and drainage districts; and other municipalities as further described below.

U.S. Army Corps of Engineers
The authority of the USACE with respect to this Implementation Plan is to regulate (permit or deny) any proposed change based on the potential of the proposed change to negatively affect flood control, navigation, or wetlands. The USACE has the ultimate authority to regulate the Sacramento Valley Flood Control System, as well as other federally authorized flood control systems throughout the United States. The USACE requires different processes to consider permission of projects that may affect waterways, etc., and the process to seek approval varies with the scope of the project in question. National Environmental Policy Act (NEPA) compliance must be completed for the USACE to make a permitting decision.

Central Valley Flood Protection Board
The authority of the CVFPB with respect to this Implementation Plan is to regulate (permit or deny) any proposed change based on the potential of the proposed change to negatively affect flood control. Many of the low-lying areas that tend to pass flows, and therefore pass, attract, or strand fish, are known to lie within, or might reasonably be expected to fall within, the CVFPB's jurisdictional area. The CVFPB is responsible for monitoring reclamation districts, and has the authority to authorize DWR to establish a maintenance area and essentially take responsibility of the levee. When a project proponent seeks to implement a project within the CVFPB's Designated Floodway, the proponent must apply to the CVFPB for an encroachment permit. A permit is required for any project or plan of work that: 1) is within federal flood control project levees and within a Board easement, or 2) may have an effect on the flood control functions of project levees, or 3) is within a Board designated floodway, or 4) is within regulated Central Valley streams listed in Table 8.1 in Title 23 of the California Code of Regulations (http://www.cvfpb.ca.gov/faq/index.cfm accessed August 29, 2011). California Environmental Quality Act (CEQA) compliance must be met prior to CVFPB consideration of granting an encroachment permit. It takes 50 to 60 days from receipt of completed applications for CVFPB to grant a permit if the board decides to grant the permit. The CVFPB, a politically appointed board with a staff of state employees, is the gateway for consideration by USACE of any proposed changes to the Sacramento Valley Flood Control System.

Sacramento Area Flood Control Agency
SAFCA was formed in 1989 by the City of Sacramento, the County of Sacramento, the County of Sutter, the American River Flood Control District, and Reclamation District 1000 through a Joint Exercise of Powers Agreement, in response to a record flood event in 1986, to provide the Sacramento region with increased flood protection along the American and Sacramento Rivers. Because the major flood damage reduction structures protecting Sacramento are part of a system of Federally and State of California authorized levees, reservoirs and bypasses (including the Yolo Bypass), improvements to this flood control system are typically cost-shared by SAFCA or other local entities with both the Federal government and the State of California in an evolving partnership framed by Federal and State laws. Because of SAFCA's high level of coordination with USACE and the CVFPB on flood damage reduction project planning efforts, including the Central Valley Flood Protection Plan (CVFPP), they are likely to be an interested party DWR and Reclamation will engage in planning efforts. Their interest is likely to focus on coordination of potential flood damage reduction benefits with the biological objectives described in this Implementation Plan.

Private and Public Land Ownership
Most lands that have the potential to be affected by RPA Action I.6.1 are privately owned. The lands underlying and near the Fremont Weir and Sacramento Weir are owned by the Sacramento San Joaquin Drainage district, which as discussed above, is essentially a real estate related subsidiary entity of the CVFPB. These lands are leased to DFG, which manages hunting activities on these properties. While the CVFPB is an independent agency from DWR [Water Code section 8550(b)], DWR and the CVFPB are closely related in that they utilize the same real estate group for purposes of obtaining temporary entry permits. However, these entities are distinct enough that they have different statutory responsibilities and employ different staff. The likelihood that the CVFPB will approve projects such as those that Action 1.6.1 requires DWR and Reclamation to implement "to the maximum extent of their authority, excluding condemnation authority," is unknown. The purpose of Action 1.6.1 is outside the mission statement of the politically-appointed CVFPB, so the extent to which the projects can be shown to be compatible with the CVFPB's mission will be critical to the projects' successful implementation.

California Department of Water Resources
DWR's authority with respect to this Implementation Plan is to propose changes to the physical system; to pursue opportunities for providing increased seasonal floodplain habitat with willing landowners; to complete environmental compliance documentation; and if all necessary conditions are met, to construct and manage the projects necessary to comply with RPA Actions I.6.1 and I.7. DWR has responsibilities in the management of both the State Water Project (SWP, a water storage and supply project which is addressed in the NMFS and USFWS Operation BOs) and the Sacramento River Flood Control Project (SRFCP, which is not addressed in the NMFS and USFWS Operation BOs). However, it is important to note that the SWP and the SRFCP are separate facilities with distinct purposes, authorizations, and stakeholders. Balancing multiple objectives and mandates can pose a significant challenge for agencies and can require significant additional time and coordination during planning efforts.

United States Bureau of Reclamation
Reclamation's authority with respect to RPA Actions I.6.1 and I.7 is to propose changes to the physical system; to pursue opportunities for providing increased seasonal floodplain inundation with willing landowners; complete environmental compliance documentation; and if all necessary conditions are met, to construct and manage the projects necessary to comply with RPA Actions I.6.1 and I.7. Reclamation does not manage the Sacramento Valley Flood Control System. It does manage several reservoirs for multiple uses including water storage and delivery, flood management, and recreation. Because the implementation of RPA Actions I.6.1 and I.7 are required to operate the CVP in a way that avoids jeopardizing listed species in compliance with the Endangered Species Act, the CVP authorizations (Rivers and Harbors Act of 1935, Rivers and Harbors Act of 1937, and Central Valley Project Improvement Act of 1992) serve as the applicable federal authorizations for Reclamation involvement in implementation of these actions.

Based on the interrelations of the aforementioned entities and their varying authorities, all planning efforts must incorporate a high level of coordination with flood control interests and with all other potentially affected local stakeholders, from early discussions through project permitting for successful implementation.

4.1.2 Funding

Several entities have authority, vested by their legal responsibility for features in the potential project area, that may be applicable to this Implementation Plan, including: the USACE, the CVFPB, DWR, and Reclamation. Funding is instrumental for each agency to carry out their requirements. There are several possible funding sources for projects associated with the actions addressed in this Implementation Plan. In many instances, within a single department or agency there are multiple programs with distinct purposes, staff resources, and funding sources. The State of California Ecosystem Restoration Plan (ERP) has funded, and continues to contribute to, purchase of real estate rights, execution of restoration planning, etc. DWR's Fish Restoration Program Agreement (FRPA) may provide some funding and technical assistance to Bypass projects as part of DWR's compliance with the USFWS and NMFS Operation BOs, and the DFG Longfin Smelt Incidental Take Permit (ITP). The authorities for Reclamation provide Reclamation with the opportunity to use Federal Appropriations authorized by Congress to implement RPA Actions I.6.1 and I.7, as previously described. Funding would be appropriated by Congress through annual appropriations in the Energy and Water Development Act.

4.1.3 Environmental Compliance Activities

Federal and state environmental compliance regulations (i.e., NEPA and CEQA) require analysis and public disclosure of the potential environmental impacts of planned actions before they can be implemented. Compliance with applicable environmental laws and regulations, including the Endangered Species Act (ESA), Fish and Wildlife Coordination Act, California Endangered Species Act (CESA), Clean Water Act (Sections 401, 402 and 404), Rivers and Harbors Act (Sections 10 and 14 [408]), National Historic Preservation Act (Section 106), and the California Fish and Game Code (Section 1602), must be documented. Planning efforts for these actions will have to address stakeholder needs, including but not limited to: flood damage reduction, agricultural operations, wildlife and waterfowl management, and recreation. Environmental compliance and planning efforts will include public scoping notifications and meetings, alternatives development, impact analysis, public review of environmental impact documentation, interagency coordination on regulatory issues, finalization of environmental compliance documentation, decision documents, permitting, real estate coordination, and construction planning.

The lead agencies for these planning efforts will be DWR in accordance with CEQA, and Reclamation in accordance with NEPA. Various legal entities have authority over areas and features associated with this Implementation Plan. Of primary concern are the flood control entities, landowners, DWR, and Reclamation. DFG may also play a pivotal role in implementation, by virtue of its ongoing involvement in BDCP, its ownership of a significant fraction of the Bypass, and the activities of the Wildlife Conservation Board, which functions as the real estate arm of DFG. The CVFPB may also have a significant role, as it owns the land on which the Fremont Weir is located. These agencies, along with other agencies, such as the USFWS, NMFS, the USACE, and potentially affected counties could be cooperating agencies engaged in planning efforts for these actions. The Delta Stewardship Council, Delta Conservancy, and the Delta Protection Commission are also agencies that DWR and Reclamation will coordinate with during planning efforts. All planning efforts must incorporate a high level of coordination with flood control interests and with all other potentially affected local stakeholders, from early discussions through project permitting for successful implementation.

DWR and Reclamation have established a core group of scientists and engineers to develop this Implementation Plan. The group's immediate responsibilities are to describe restoration and fish passage actions within the Yolo Bypass and to identify constraints that may bear upon their implementation. Actions are described on a preliminary basis in this Implementation Plan; further evaluation will be undertaken during the environmental compliance process while these actions are further refined. Once the Implementation Plan is submitted to NMFS, staff efforts will shift to interagency planning, stakeholder outreach, and environmental compliance.

By October 1, 2012, Reclamation and DWR will, jointly with NMFS, convene the YBRT. The YBRT will be responsible for the planning, environmental compliance, implementation, and monitoring of actions addressed in this Implementation Plan. Initially, the YBRT will meet on a semiannual basis, and then with increasing frequency as its capacity to effectively manage implementation of this Plan increases as a result of the interagency and stakeholder planning efforts and environmental compliance work. Reclamation and DWR will co-chair the YBRT and will work with cooperating agencies and stakeholders to call meetings and set agendas.

The YBRT will be responsible for coordinating interagency compliance with CESA, the DWR Environmental Stewardship Policy, and various state and local interests as they pertain to Bypass restoration activities. As the YBRT will direct activities and implement actions to maintain compliance with the ESA, the USFWS will be invited to participate in planning activities on the YBRT. Preliminary pre-consultation with USACE indicates that any changes to Sacramento River Flood Control Project structures (e.g. Fremont Weir, Sacramento Weir, Project levees) will probably require Section 408 permissions, which may complicate and lengthen the time needed for environmental compliance. Another major factor in permitting strategy and ultimate timeline from a "critical path" perspective is whether actions will require water rights adjustments of some kind (new water rights, or a change in point of diversion for example).

Because of the complex nature of planning efforts for these actions, Reclamation and DWR propose to begin planning, public involvement, and environmental compliance processes for all potential actions addressed in this Implementation Plan as an overall program by beginning preparation of an Environmental Impact Statement/Environmental Impact Report (EIS/EIR). This EIS/EIR will address some elements at a project-specific level, and some elements at a programmatic level, based on the level of project planning and site specific information available. Further site specific environmental compliance documentation will be completed as necessary as project planning progresses. If, during project planning and preparation of this EIS/EIR it becomes apparent that some elements have a significantly greater level of project planning information available, have independent utility, and can be analyzed and permitted separately from other more complex elements, then environmental compliance documentation for those elements will be completed as expeditiously as possible in accordance with NEPA, CEQA, and all other relevant environmental laws and regulations. Environmental compliance processes can vary greatly in duration, but based on preliminary information and given the complexity and multiple stakeholder interests involved, it is anticipated that environmental compliance for these actions will have to be completed over several years. Please see the following section on schedule for more information on milestones.

Lead agencies will be responsible for compliance monitoring during construction of any structures to ensure that all avoidance and minimization measures are incorporated. Once construction is completed, the responsibility of the YBRT will include monitoring the performance of structures and actions. The YBRT will monitor the various metrics described in the previous section and appendix on performance goals. This monitoring will also include a fish-passage monitoring program that will identify impediments to safe and timely passage during the defined fish-passage window.

DWR and Reclamation will also create the Yolo Bypass Adaptive Management Team (YBAMT), which will provide operational recommendations to the YBRT on measures that are to be taken to meet the performance measures described previously and to minimize potential adverse effects from Bypass operations on salmonids and green sturgeon. The YBAMT will be made up of biologists, hydrologists, and other staff with relevant expertise from Reclamation, DWR, DFG, USFWS, and NMFS. The YBAMT will:

- Provide recommendations for in-season management of Yolo Bypass operations, consistent with the implementation procedures provided in RPA Actions I.6.1 and I.7
- Annually review project operations and the data collected for the Yolo Bypass
- Track the implementation of RPA Actions I.6.1 and I.7
- Evaluate the effectiveness of implemented actions in meeting performance goals
- Identify data gaps and recommend studies to YBRT to measure the effectiveness of implemented actions
- Recommend future restoration actions intended to meet established performance goals.

The YBRT and YBAMT will coordinate annually with the Implementation Management Team (IMT) and at regular intervals with the Water Operations Management Team (WOMT) and Delta Operations for Salmon and Sturgeon (DOSS) Group during seasonal flooding to convey information on the effectiveness of implemented actions. YBAMT will work with the Interagency Ecological Program (IEP) and cooperating agencies to carry out the recommended monitoring and implement the necessary actions. The YBAMT shall complete annual written reports, including a summary of major actions taken during the year, an evaluation of their effectiveness, and recommendations for future actions. Every five years, the YBAMT will produce a summary report of the previous five years' operations, actions taken, and the effectiveness of those actions in achieving the performance goals. The YBAMT will use an adaptive management framework to help identify data gaps and recommend new actions or changes in operations within the Yolo Bypass in order to meet goals and objectives.

Monitoring and studies of current conditions and fish rescue efforts will provide data to improve the design of fish passage structures. Post-project fish rescue data will be analyzed to determine the efficiency of the facilities and of scour pond improvements with regard to keeping fish entrainments to a minimum.

4.1.4 Federal Planning Requirements

The plan formulation process will be consistent with the Economic and Environmental Principles and Guidelines Water and Land Resources Implementation Studies, March 10, 1983 (P&G), including economic analysis (incuding analysis of impacts to other land uses in the Bypass, including agriculture and waterfowl habitat) of benefits and cost ratios; maximization of benefits and identification of the National Economic Development (NED Plan) for alternatives being further considered. Efforts under the Federal plan formulation process will be coordinated with alternatives development for the environmental compliance documentation.

4.1.5 Coordination with Other Related Planning Efforts

Synergy with, independence from, or conflict with other major planning processes (Bay Delta Conservation Plan, Delta Vision, CVFPP, Delta Plan, USACE Delta Islands Levee Feasibility Study, etc.) could speed or complicate implementation. In some instances, regulatory responsibilities are clearly laid out. In other instances, political entities are relatively new, and their propensity to determine or challenge consistency of projects addressed in this Implementation Plan is unknown. DWR and Reclamation propose to integrate the planning efforts addressed in this Implementation Plan with those of ongoing stakeholder planning and outreach processes already occurring to ensure that project goals and objectives can be met without jeopardizing agricultural operations, flood damage reduction, managed wildlife areas including waterfowl habitat, or recreation.

Bay Delta Conservation Plan

The Bay Delta Conservation Plan (BDCP) includes a conservation measure specific to the Bypass, proposing the planning and implementation of actions that will enhance fish habitat by modifying hydrology to improve the timing, frequency, and duration of inundation, with the intent to create more and better spawning and rearing habitat, improve upstream and downstream fish passage, increase food web production and availability, reduce fish stranding and illegal fish harvest, and reduce the exposure of fish to predators. Preparation of the BDCP includes a stakeholder engagement process to discuss and coordinate issues related to the development of Conservation Measure 2, Yolo Bypass Fishery Enhancement. The YBFEPT includes local agricultural and waterfowl interest groups, landowners, Yolo County, flood protection agencies, state and federal agencies, and water contractors. The YBFEPT has significantly advanced development of the Yolo Bypass Fishery Enhancement conservation measure. Their local knowledge provides valuable input about how to make fishery restoration compatible with agriculture, waterfowl, flood protection, and other uses in the Yolo Bypass. The YBFEPT members are continuing to work toward development of operational criteria that would guide seasonal inundation, and they have identified several pilot projects that are in varying stages of development. One of the requirements expected to be in Conservation Measure 2 of the BDCP is the development of a Fishery Enhancement Plan to detail the specific actions to be implemented in order to achieve the biological objectives outlined in the BDCP. The YBFEPT will be tasked with development of this plan, including coordination and discussion about planning and environmental review, design, development of adaptive management, and permitting. The YBFEPT typically meets once a month.

There is a significant level of overlap between the work of the YBFEPT and that of DWR and Reclamation in developing a plan to implement RPA Actions I.6.1 and I.7. The YBFEPT has been engaged in extensive discussion of multiple scenarios for Bypass habitat restoration and characterization of the relationships between aquatic habitat restoration and ongoing waterfowl and agricultural operations on the Bypass. To ensure efficient use of interagency resources, the YBRT will work with the YBFEPT to qualitatively evaluate a suite of habitat restoration scenarios and further develop the timeline for addressing remaining constraints and environmental compliance activities. DWR and Reclamation propose to actively engage with the YBFEPT as part of stakeholder outreach efforts to solicit input on the actions addressed in this Implementation Plan. The YBFEPT is highly informed on the issues of concern, familiar with the technical information and modeling, and generally well-positioned to provide helpful insight to DWR and Reclamation. Coordination through the YBFEPT offers the best likelihood of success for achieving long-term increases in seasonal floodplain inundation. It is anticipated at this time that YBFEPT will continue to meet on a monthly basis for the foreseeable future through development of the Yolo Bypass Fishery Enhancement Plan.

A draft description of BDCP Conservation Measure 2 has been included in Appendix C. The draft proposes a smaller footprint of 7,000 to 10,000 acres of inundation to be achieved as early as November 10 if the water is available in the system, and extending inundation to no later than May 15 of a given water year. As technical discussions of the YBFEPT have progressed, support has grown for the theory that at this scale, the numbers of fish that would have access to seasonal floodplain habitat, and the physical and chemical characteristics of that habitat, may be more important than the number of acres that the modifications inundate.

Central Valley Flood Protection Plan

In 2012, DWR issued the Draft CVFPP, which strives to improve integrated flood management in the Central Valley and provide a multispecies and floodplain conservation strategy. The CVFPP, while programmatic, proposes the closer examination of expanding existing flood bypasses, creation of new flood bypasses, and seasonal floodplain restoration. It also explicitly calls for fish passage improvements to Fremont Weir. The most likely scenarios by which significant flood protection funding might be directed to the Yolo Bypass are relatively near term and for fish passage improvements only. DWR's Flood Program plans to develop regional plans in the next few years to supplement the CVFPP with more project-specific plans that will be developed with more involved local input. Additional funding may come from water user fees, public bonds, or private sources.

Ecosystem Restoration Program Plan

DFG has recently issued the *Ecosystem Restoration Program Plan* (*ERPP*), which prescribes additional recommendations (DFG 2011) for restoration within floodplain habitat. While the *ERPP* does not directly conflict with the NMFS Operation BO RPA Actions, it does add elements that will be incorporated during project planning. Therefore, the YBRT will coordinate with the ERP during planning and environmental compliance efforts. Potential ERPP activities relating to the activities in this Implementation Plan could include:

- Development of a Comprehensive Central Valley Adult Chinook Salmon Escapement Monitoring Plan
- Development Of A Spatially Explicit Ecosystem Model To Explore Physicochemical Drivers of Step Changes in POD Species and Distribution In The Sacramento-San Joaquin Delta And Suisun Bay

- Development of Best Management Practices to Reduce Methyl Mercury Exports and Concentrations from Seasonal Wetlands in the Yolo Wildlife Area
- Estimating the Abundance of Sacramento River Juvenile Winter Chinook Salmon with Comparisons to Adult Escapement
- Evaluation of Floodplain Rearing and Migration
- Fish Passage Improvement Program
- Lower Yolo bypass Collaborative Process
- Population Biology, Life History, Distribution, and Environmental Optima of Green Sturgeon
- Survival and Migratory Patterns of Juvenile Spring and Fall Run Chinook Salmon in the Sacramento River and Delta
- Yolo Natural Heritage Program

Fish Restoration Program
Through FRPA, DWR is working with DFG, USFWS, NMFS, and others to identify potential habitat restoration sites and actions that are required under the BOs and ITP. Some near-term actions in the Yolo Bypass have been identified in the FRPA Implementation Strategy as follows: Lower Putah Creek Re-Alignment and Floodplain Restoration, Lisbon Weir Improvements, Tule Canal Connectivity, Fremont Weir Fish Passage, and Increased Yolo Bypass Floodplain Inundation. FRPA would possibly provide some funding assistance and some technical assistance towards implementing these actions, as appropriate.

Lower Yolo Wetland Restoration Project
The State and Federal Contractors Water Agency (SFCWA) is working in conjunction with DWR to restore 3,795 acres of wetlands in the lower Yolo Bypass over the course of the 2012 and 2013 dry seasons. The proposed project site consists of the 3,423-acre Yolo Ranch and the 372-acre Flyway Farms properties. The proposed project is located in southern Yolo County, California, at the southern end of the Bypass floodway near the north end of the Cache Slough Complex (Figure 4). The site encompasses two contiguous parcels located along the historic wetland-upland edge of the Bypass. The properties are currently leased for agricultural uses (primarily cattle grazing) and duck hunting. The primary goals of the project are: 1) to enhance regional food web productivity in support of Delta smelt recovery, and 2) to provide rearing habitats for out-migrating salmonids utilizing the Bypass. Secondary project goals are: 1) to support a broad range of other aquatic and wetland-dependent species (e.g., Sacramento splittail), and 2) to provide ecosystem functions of the Delta freshwater tidal marsh-floodplain-seasonal wetland-lowland grassland interfaces.

The Lower Yolo Wetland Restoration Project includes modifications to approximately 1,560 acres of the 3,795-acre site. Restoration actions within the proposed project footprint include: 1) restoration of approximately 1,060 acres of intertidal wetlands through elimination and/or removal of existing water control structures, 2) enhancement of 30 acres of floodplain wetlands through the grading down of existing lands that are slightly above current intertidal elevations, and 3) construction of 100 acres of subtidal channels in an effort to connect restoration areas to existing intertidal areas. In total, roughly 1,380 acres would be permanently removed from agricultural use. The proposed project would be designed and constructed in such a way as to avoid any impediment to flood flows within the Yolo Bypass.

Although the Lower Yolo Wetland Restoration Project is situated in a tidal marsh setting, the NMFS Operation BO specifies that if the 8,000-acre tidal restoration targets provided in the USFWS Operation BO also provide suitable rearing habitat for salmonids, they may count for partial satisfaction of RPA Action I.6.1. The actions of this project would achieve this goal in a number of ways. First, the project plans to restore tidal wetlands that have been used for cattle grazing. This increase in wetted area would effectively increase the carrying capacity of the region. In addition to opening up additional wetted areas to juvenile salmonids, the intertidal marshes would produce large quantities of phytoplankton, zooplankton, and organic material (BDCP 2008). The project also plans to improve connectivity between newly restored areas and existing intertidal/tidal areas. This improved connectivity would provide more diverse habitat types and lessen the risk of juvenile fish stranding when the floodplain begins to recede. In addition to reducing costs and accelerating the time to implementation, a partnership with SFCWA affords DWR an opportunity to seek partial fulfillment of the 8,000-acre tidal restoration targets contained within the USFWS Operation BO (USFWS 2008) RPA. The planning and environmental compliance process for implementing RPA Actions I.6.1 and I.7 will be coordinated with planning and environmental compliance efforts for the Lower Yolo Wetland Restoration Project, and will be consistent with RPA Action I.6.2.

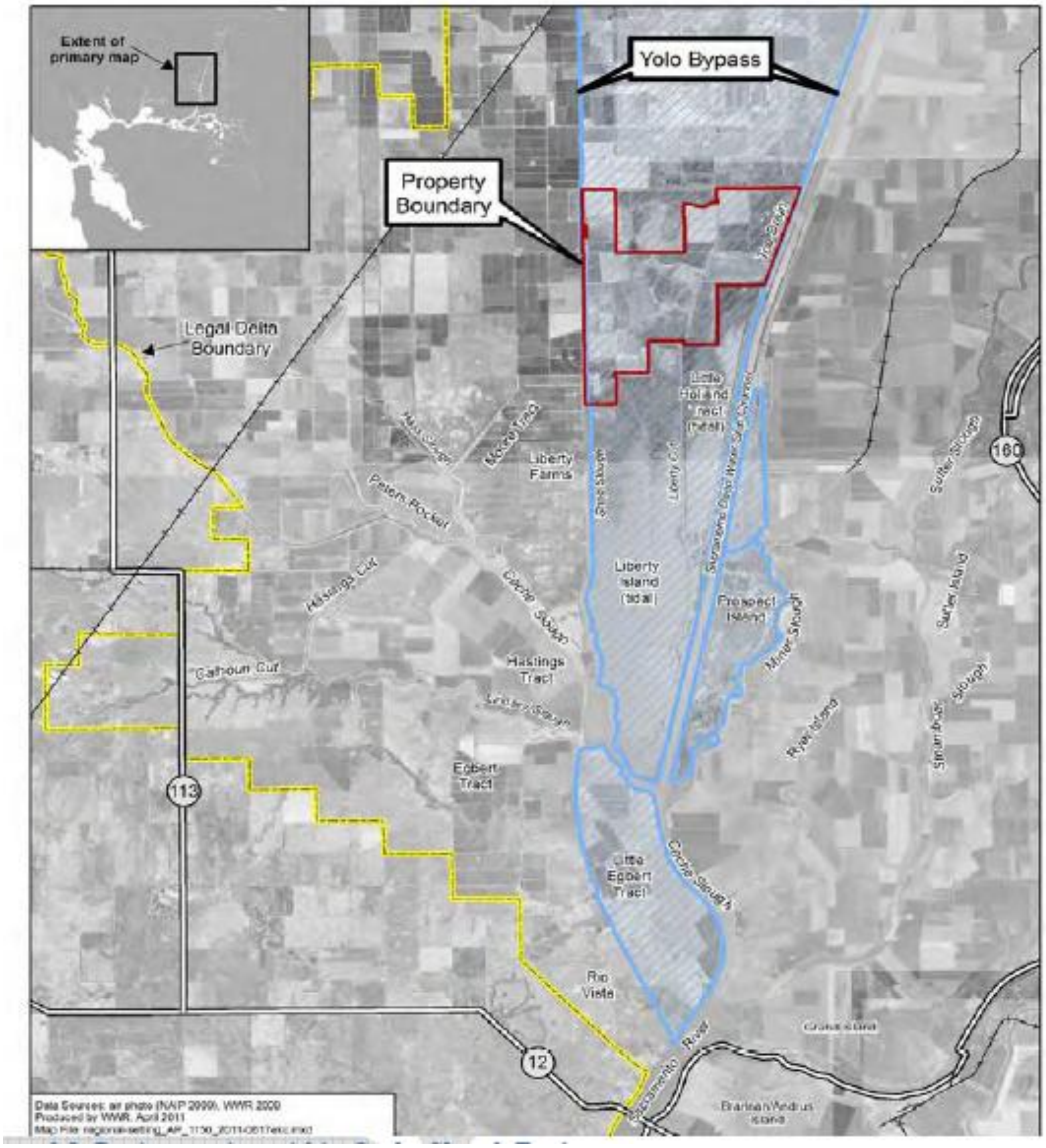


Figure 5. Lower Yolo Wetland Restoration Project

Lower Putah Creek Proposals

Proposals associated with Lower Putah Creek include improvements to provide floodplain habitat benefits for multiple species on existing public lands. DWR and USBR support DFG and the Yolo Basin Foundation efforts to improve Lower Putah Creek and respect the leadership of the respective landowners and land managers for these potential improvement projects. The planning and environmental compliance process for implementing RPA Actions I.6.1 and I.7 will be coordinated with planning and environmental compliance efforts for Lower Putah Creek and will be consistent with RPA Action I.6.3.

5. Key Milestones and Implementation Schedule

In accordance with the NMFS RPA, Reclamation and DWR are seeking NMFS concurrence with this Implementation Plan within 30 days of transmittal. Upon completion of this plan, DWR and Reclamation will initiate planning and environmental compliance activities for the implementation of actions in accordance with NMFS RPA Actions I.6.1 and I.7. Concurrently, some initial actions will be moving forward for initial implementation in 2012 and 2013. These actions include year 2 of the Knaggs Ranch Pilot Study, the fish rescue program, and fish passage monitoring, as described previously.

Specific planning and environmental compliance milestones and estimated timeframes are provided below, but are subject to change based on support of stakeholders and unforeseen circumstances. Key risks and uncertainties potentially associated with planning efforts for these actions include the risk that willing-seller conditions for flowage easements and agricultural structure improvements will not be available along the full length of the eastern Bypass during the project timeline, challenges to interagency coordination with entities with overlapping mandates, potential flood control and water rights permitting challenges, and funding issues. During the completion of these milestones, DWR and Reclamation will coordinate information from this planning and environmental compliance process with the YBFEPT and BDCP lead agencies. While DWR and Reclamation will earnestly work to meet these milestones, previously disclosed constraints or constraints not yet understood have the potential to impact these milestones.

• Contracting Process for Environmental Compliance	June 2012–December 2012
• Notice of Intent/Notice of Preparation	February 2013
• Public Scoping	March 2013
• Alternatives Formulation and Development/ Conceptual Engineering/Impact Analysis	April 2013 – September 2014
• Public Draft EIS/EIR	December 2014
• ESA and National Historic Preservation Act Consultation	December 2014 – November 2015
• Final Draft EIS/EIR	December 2015
• Record of Decision/Notice of Determination	2016
• Other Environmental Permit Efforts (i.e., Clean Water Act,	
• Rivers and Harbors Act, Clean Air Act)	2014 – 2016
• Real Estate Acquisition	2016 – 2017
• Design and Construction	2015 – 2019

6. Proposals to Refine the RPA Actions

DWR and Reclamation were required to submit the Implementation Plan to NMFS by December 31, 2011. DWR and Reclamation have been coordinating with NMFS and DFG on completion of this plan. However, submission of the plan was delayed for various reasons, including complexity of design, incorporation of new approaches regarding hydrology and fish migration timing constraints, and stakeholder involvement.

Currently, RPA Action I.6.1 requires that DWR and Reclamation provide *significantly increased acreage* of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from *December through April in the lower Sacramento River Basin,* on a return rate of approximately 1 to 3 years, depending on water year type. The initial performance measure is set at *17,000 to 20,000 acres.* RPA Action I.6.1 *requires that restoration of significant acreage be completed by December 31, 2013. If half of the total target acreage is not implemented by 2016, Reclamation and DWR will be required to re-initiate consultation.* (Italics added to highlight topics for which we offer additional clarification in this Implementation Plan and, in some cases, to highlight topics for which DWR and Reclamation wish to request modification of the measure.)

DWR and Reclamation request that the wording "significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes…" be interpreted as meaning "significantly increased seasonal floodplain rearing habitat availability with biologically appropriate durations and magnitudes…" The original wording and syntax of RPA Action I.6.1 could be interpreted as requiring flooding over significantly increased acreage outside the current Sacramento River Flood Control System levees in the lower Sacramento Valley. It is possible that the DWR FloodSAFE CVFPP will propose modifications to the Sacramento River Flood Control System that will involve the widening of existing bypasses or the creation of new bypasses. It is further possible that those types of projects, if proposed and implemented, would increase the availability of seasonal floodplain habitat. However, the funding source and the current flood protection regulatory impetus make it likely that CVFPP floodplain/bypass projects will focus on less-frequent, high-flow events rather than the types of high-frequency events described in RPA Action I.6.1.

As described above, DWR has responsibilities to manage both the SWP (a water storage and supply project, addressed in the NMFS Operation BO) and the SRFCP (not addressed in the NMFS Operation BO). These two projects are separate and distinct, as are their funding sources. As the Fremont Weir and Yolo Bypass are part of the SRFCP and not the SWP, RPA Action I.6.1 unreasonably assigns to the SWP responsibility for alterations to be made to the SRFCP. Neither the expansion of existing flood bypasses nor the setting back of levees along the mainstem Sacramento River is impossible, as some recent projects have proven (e.g., Three rivers Levee Improvement Authority Bear River Setback Levee), but preliminary DWR modeling investigations known as "Height Above River" analyses indicate that much of the natural floodplain is perched above typical sustained river levels. These analyses suggest that opportunities to work with the current landscape topography to create large amounts of frequently inundated seasonal floodplain habitat may be limited.

As discussed above in Section 1, this Implementation Plan focuses on restoration of floodplain rearing habitat within the Bypass to address RPA Action I.6.1. Technically, the areas of the Bypass that are neither permanently nor tidally inundated nor behind restricted-height levees (e.g., Little Egbert Tract, Prospect Island) already offer seasonal floodplain rearing habitat for fish. However, not all of that seasonal floodplain habitat is available during at least 1 in 3 years with a duration of inundation that appears to be biologically beneficial to native fish, so there is room for enhancement of less-frequently inundated areas to meet the performance measures of the NMFS Operation BO. The return rate frequency of specific areas of the Bypass has not been established, but Figure 6 illustrates areas that are more likely, and areas that are less likely to be inundated under current conditions.

As noted earlier, RPA Action I.6.1 requires that significant acreage be restored by December 31, 2013, and it specifies that unless half of the 17,000 to 20,000 acres of floodplain acreage restoration (i.e., 8,500 to 10,000 acres) is implemented by 2016, DWR and Reclamation will be required to re-initiate consultation. DWR and Reclamation do not anticipate re-initiating consultation for this purpose, as circumstances have changed given that future consultations will occur in accordance with the remanded NMFS BO. DWR and Reclamation will work diligently with their planning partners to meet the RPA Action I.6.1 requirements. However, the magnitude of the restoration and regulated nature of the associated structure establishes an implementation schedule that is not achievable within the timeframe required by RPA Action I.6.1. Based on the suite of current major planning processes and on DWR and Reclamation experiences with prior planning and environmental compliance processes of such magnitude and public interest, the previous section describes a more realistic timeline for undertaking the legal requirements for implementation as outlined above. Increased juvenile rearing habitat is likely to positively impact life history diversity and spatial distribution to a greater extent than abundance and population growth rate. The impact of a timeline increase of about two Chinook or steelhead generations and less than one-third of a green sturgeon generation is of a low magnitude.

DWR and Reclamation will work closely with partners, permitting agencies and stakeholders in planning and environmental compliance efforts. Some groundwork has been laid through meetings regarding Conservation Measure 2 of the BDCP by the YBFEPT, which DWR and Reclamation propose continuing. Coordination with these interested parties early on and throughout the planning process as technical material is developed will be aimed at fostering good working relationships and abbreviating the ultimate implementation timeline.

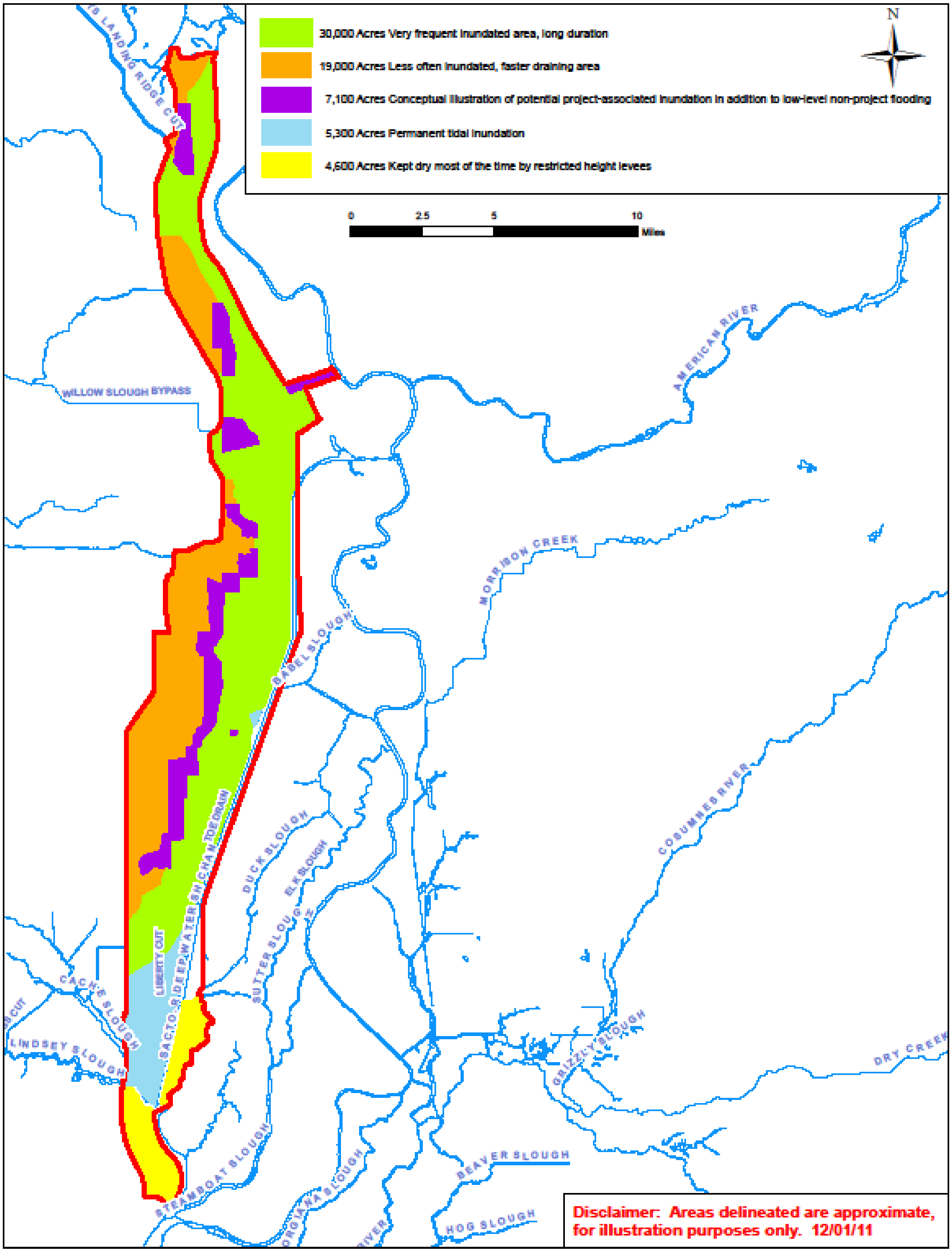


Figure 6. Comparison of Likelihood of Inundation for Areas in the Yolo Bypass

Appendix A
Performance Measures

1. Increased Seasonal Inundation Performance Measures

1.1 Habitat Attributes

The following is a review of the more critical habitat attributes associated with the Yolo Bypass (Bypass) floodplain and how they relate to the various juvenile fishes that utilize the floodplain. Where applicable, optimal conditions will be described, along with any associated risks inherent to each attribute. Performance measures for habitat attributes are described for each habitat attribute in relationship to the objectives they are being measured to meet. Performance measures associated with inundation on the Bypass are primarily directed toward juvenile life stages of salmonids, since these are known to benefit most from floodplain inundation (Jeffres et al. 2008, Sommer et al. 2001). Pre- and post-project comparisons will be made when prior data exist. measures for this section will consist of measurable indicators of habitat quality for the targeted species of this plan, as they relate to inundation of the Bypass. It will be critical that data related to each of these metrics be compiled seasonally for use in adaptive management to inform future decision making concerning notch operations for the purpose of achieving desired outcomes from restored, seasonally inundated habitat in the Bypass for juvenile and adult salmonids. A work team of biologists, engineers, and operators will be convened to review these data (e.g., DOSS) and make recommendations to a management team (e.g., WOMT). It is foreseeable that due to the stochastic nature of weather forecasting and weather observation, this team will not simply develop permanent inundation regimes, but will need to undertake scenario planning and modeling studies in order to make in-season recommendations to a management team concerning inundation area and duration. To achieve this, they should consider the following information.

1.1.1 Inundated Area and Inundation Duration

Inundation area is, as expected, directly related to flows into the Bypass. At flows greater than approximately 74,000 cfs in the Bypass, the flows have wetted the vast majority of the Bypass. At this point, additional flow mainly increases the depth of inundation. Below 74,000 cfs, however, the inundated area can be directly measured using aerial imagery, modeling, gauges (e.g., water elevation), or Acoustic Doppler Current Profilers (ADCP), although inundation and water levels also in some instances reflect landowners' water management operations or wetting directly by precipitation rather than due to inflows. Though the duration of inundation is in part related to the extent of the inundated area, it will also be influenced by the operation of facilities (e.g., gates open or gates closed). The same tools used to measure area (mentioned above) can also be used to measure duration.

Inundation area and inundation duration will seek to meet the criteria set forth in the Implementation Procedures and Rationale sections of Operation BO RPA Action 1.6.1.

However, preliminary work under BDCP suggests that the inundation area requirements in Operation BO RPA Action 1.6.1 may not be feasible in the Bypass. As described in Section 2 of the Implementation Plan, inundated acreage may be a less important measure than, for example, the proportion of fish that are given access to floodplain habitat of favorable characteristics for appropriate duration.

Studies conducted on Putah Creek, which flows into the Bypass, provide insight into stream salmonid densities. Putah Creek exhibits vastly differing habitat, both in terms of type and of quality, than the Bypass. The number of trout per mile is estimated to range from less than 100 in lower-quality areas to well over 1,600 trout per mile in higher-quality stretches (Weaver et al. 2009). It is important to note that fish stocking in this region was suspended in 2008, so any fish sampled in 2009 were either wild trout or holdovers. The majority were presumed to be of wild origin. Fish sampled ranged from 6 millimeters (6.4g or 0.01 lb) to 615 millimeters (3,402 g or 7.5 lb). In its most productive stretches, one can infer that Putah Creek is capable of sustaining roughly 190 fish per acre. This number would likely be significantly higher if it were limited strictly to juveniles. The 2010/2011 winter-run juvenile production estimate (JPE) is 332,012 individuals (NMFS preliminary data). At 11,000 acres of inundation (3,000 cfs), the entire winter-run juvenile population could take refuge on the Bypass and the density would still only be approximately 30 fish per acre, or roughly 16% of the density displayed in the Putah Creek example. This example is strictly and solely for comparative purposes, as the number of winter-run juveniles that will be drawn onto the floodplain is heavily dictated by the proportionality of flow diverted onto the floodplain from the Sacramento River. Similarly, Putah Creek density estimates are not intended to serve as predictors of Bypass floodplain density expectations; rather they are merely a point of comparison, as the two habitats differ significantly. For instance, the stretches of Putah Creek below Monticello Dam benefit from non-natural coldwater releases. Utilizing the highest densities displayed in Putah Creek and including a number of age classes provides a highly conservative comparison point. Simply put, if Putah Creek is capable of sustaining a population of 190 fish per acre year-round, then it is reasonable to assume that the Bypass could sustain 30 fish per acre for the duration of a few months. Sommer et al. (2005) showed that the Bypass yielded similar to significantly lower densities of fall-run juveniles when compared to Putah Creek (Table A.1).

Table A.1. Densities of Chinook Salmon Collected in Beach Seine Sampling of Contiguous Water Sources (not including isolated ponds) During Yolo Bypass Drainage Events in 1998–2000

1998	1999	2000
68 fish/acre	125 fish/acre	187 fish/acre

The comparison of salmonid stream densities to floodplain densities is not intended to quantify the amount of habitat necessary for salmonids to thrive. Rather, the comparison intends to describe the relative importance of area inundated.

1.1.2 Proportionality of Flow

The quantity of water entering the Yolo Bypass via Fremont Weir and other potential migration corridors from the Sacramento River affects the number of juvenile fishes that are entrained onto seasonally inundated Yolo Bypass habitats. Without specific information about individual behavior of fishes through the riverine habitats along the Fremont Weir, assumptions are required to understand the important linkage of Sacramento River flows with Sacramento River fishes. Information about the proportion of Sacramento River flows entering the Yolo Bypass can be combined with information about species of interests' passage along the Sacramento River to determine what proportion of a population may benefit (or be subject to risks) associated with specific operational criteria. Additional information will be gained via acoustic telemetry investigations and modeling to inform how orienting inundation structures maximizes passive juvenile fish entrainment onto the Yolo Bypass, but until more information is gained, the following simplifying assumptions are necessary:

- Fish species of interest are entrained onto seasonally inundated Bypass habitats in proportion to the fraction of Sacramento River flows entering the bypass.
- Fish species of interest pass Fremont Weir in a similar timing and quantity as when they pass Knights Landing.
- Fish densities in seasonally inundated habitats are never limited by carrying capacity of these habitats when entering at a density of fish equal to proportion of flow.

Using the assumptions above, quantification of fish migration timing and quantity, expressed as cumulative density functions, can be combined with the proportion of the fraction of Sacramento River flow entering the bypass to characterize how operations for seasonal inundation of Bypass floodplain habitats benefit species of interest. An example can be made using information from recent years of juvenile winter run Chinook salmon passage at Knights Landing rotary screw trap (KLRST), which is the fish monitoring location closest to the Fremont Weir (Figure A.1). This information provides some guidance and potential expectations about opportunities for fishery enhancement via floodplain inundation are gained from different timing of flooding. First, it is noted that the distribution of juvenile winter-run Chinook salmon past Knights Landing in dry years is similar to our average expectation for fish emigration. So, if the objective is to entrain fish over Fremont Weir depending on averaged information, dry years may entrain as many fish as expected based on "average" catch past the KLRST. This is useful to know since biologists and managers often only have water year type (WYT) information in retrospect, so it may be difficult for them to optimize a facility to entrain fish for looking ahead in real time WYT information. Also, it appears the distribution of winter-run Chinook salmon past Knights Landing in wet years is different than what may be expected in most water years. Thus, if the objective of a facility is to entrain fish over Fremont Weir depending on average information, more fish than expected may be entrained based on average catch past the Knights Landing Rotary Screw Trap. It is likely that use of the average distribution of migration to guide operations in entraining some proportion of winter-run Chinook salmon may serve as a reasonable expectation for the potential minimum entrainment exposure of winter-run Chinook salmon possible onto the bypass. This information, combined with information inferring density of fish in water or volume of water across Fremont Weir, provides an index for putting flow onto the bypass. A performance measure for juvenile fish entrained will be established, based on modeling, during the planning phase for a Fremont Weir juvenile fish passage notch. This performance measure will be used to evaluate monitoring results at the notch in order to assess performance. If monitoring demonstrates juvenile fish entrainment to be limiting the observed population benefits of restored seasonally inundated habitats, adaptive management will direct further project design, implementation, and operations toward increasing juvenile fish entrainment into restored seasonally inundated habitats.

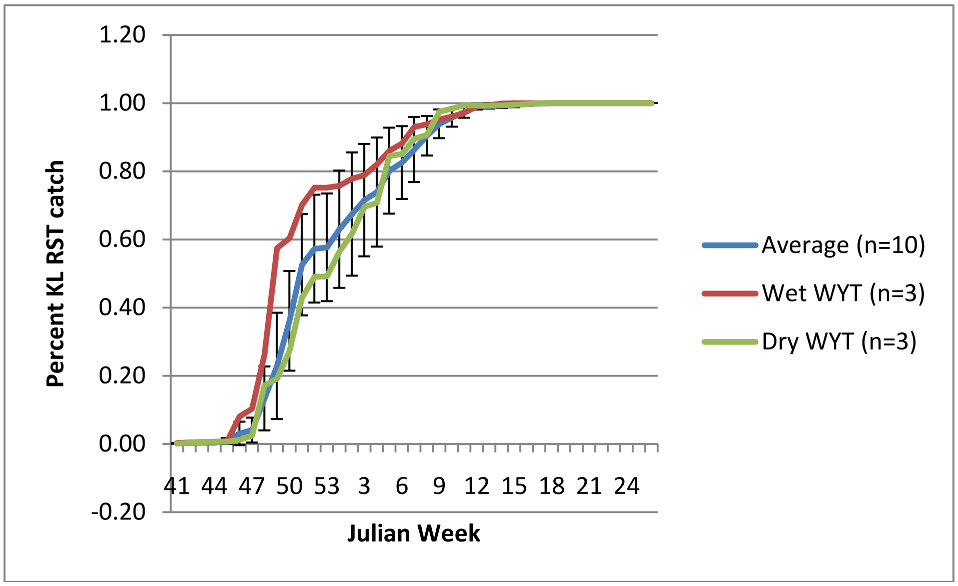


Figure A.1. Cumulative Density Curves of Juvenile Winter-Run Chinook Passing Knights Landing Rotary Screw Trap. The blue line represents the proportion of WRC passing Knights Landing weekly during ten years from 1997 through 2007 with 95% confidence intervals. The red line represents the proportion of WRC passing Knights Landing weekly during the three Wet WYT years between 1997 and 2007. The green line represents the proportion of WRC passing Knights Landing weekly during the three Dry WYT years between 1997 and 2007.

1.1.3 Inundation depth

Juvenile Chinook salmon typically utilize heterogeneous water depths as shallow as 0.1 ft (0.03 m) to as deep as 4.9 ft (1.5 m), though if given the opportunity they tend to prefer low-velocity areas with average depths of from 0.9 ft (0.27 m) to approximately 2.0 ft (0.61 m) (Raleigh et al. 1986). At first, age-0 Chinook utilize shallower regions in close proximity to eddies or shear velocity zones where food items are easily taken in drift (USFWS 1995). Over time, they gradually shift to slightly deeper habitat as they increase in size. Juvenile Chinook have been noted to display a number of behaviors in relationship to shallow depths. At night, juvenile Chinook show a tendency to abandon their daytime habitats in favor of shallow edgewaters (Moyle 2002; Everest and Chapman 1972), but they have also been shown to migrate in shallow depths at night by moving into swifter water (Blake and Horn 2006, Horn and Blake 2003, Perry 2010). Juvenile steelhead display many of the same depth preferences as juvenile Chinook salmon, but they tend to prefer slightly shallower, higher-velocity water (USFWS 1995). Since salmonids can utilize a wide range of depths, and considering that seasonally inundated habitats can be assumed to feature shallow edgewaters as well as deeper areas, restoration of seasonally inundated habitats may be increasingly important in ecological terms when the wetted surface area is maximized and the depth is allowed to remain heterogeneous within this area. Currently, there is ample heterogeneity on the Bypass to provide inundated habitats of diverse depths. These include areas in Tule Canal, various ponds, and isolated pools that are perennially wetted. Although these areas may not fall within the preferred depth range for juvenile salmonids, they remain essential components of the Bypass floodplain. In addition to being essential to adult passage through the floodplain, they provide habitat suitable to a variety of other fish rearing on the floodplain. Deeper habitat types serve as refugia from increased velocities, from predators, and even from escalating temperatures in late spring and early summer. In a laboratory setting, juvenile Chinook salmon have responded to the presence of predator models by seeking refuge in the deeper parts of their arena (Gregory 1993).

Variation in depth is important to serve the changing needs of fish that are rearing on the floodplain. A large expanse of heterogeneous, shallow (<1.5m) water supports the optimal depth habitat for juvenile salmonids and is associated with high primary and secondary productivity in seasonally inundated habitats. In contrast to deeper channels (>1.5m), shallow waters tend to move more slowly and allow for great thermal exchange, which enhances primary productivity and availability of drift-base prey (i.e., chironomids) for juvenile salmonids foraging in seasonally inundated habitats. Since floodplain-specific criteria for depth are not well founded, no performance measure for depth will initially be established. HEC RAS modeling documented in Tech Memo 2 suggests that at flows of at least 3,000 cfs, variable depths of flow occur, and that average depths in the Bypass are shallow. It is important to note that the average depth includes the Toe Drain, which would also experience higher flows than the surrounding floodplain. The greater mean depths for lower-magnitude flows can be attributed to the Toe Drain being a more significant contributor to the inundated surface area at these lower flows. At 3,000 cfs, approximately 11,000 acres of restored seasonally inundated habitats would be seasonally inundated, the vast majority of which would consist of shallow water. In the event that monitoring demonstrates that depth is a limiting factor for habitat occupancy in restored seasonally inundated habitats, adaptive management will be implemented and project design and implementation will take that condition into consideration.

Because the Bypass is essentially a large, flat floodplain, its mean depth is inversely related to its water flow (See Table A.2). While the flows included in Table A.2 only range from 1,000 to 10,000 cfs, this relationship probably continues beyond 10,000 cfs. It is unclear, however, whether or not this relationship would break down prior to full inundation, and a clearer understanding would require extensive modeling of the Bypass, which is currently unavailable. Preferred depths according to Section 1.1.1 seem to begin at depths that occur under flows of more than 2,000 cfs. Because of the topographic complexity of the Bypass, inundation depth as a metric will be measured as a function of flow, based on the most current available modeling.

1.1.4 Volitional Passage into Inundated Area

Volitional passage into the floodplain area is preferred over a "trap & haul" method. In the Northwest region, NMFS generally requires volitional passage to avoid risks associated with the handling and transport of migrant salmonids, in combination with the long term uncertainty of funding, maintenance, and operation of the trap and haul program. Trap and haul methods tend to operate intermittently, which truncates the migration period and likely adversely affects salmon population diversity (NMFS 2008). However, the notch used for floodplain won't be operated as a typical fish passage structure. More so, it will be operated similar to a gravity diversion facility with the intent of entraining salmonids from the mainstem Sacramento River. There may be cause to employ additional measures or add design features if volitional passage doesn't initially result in meeting performance goals. (National Marine Fisheries Service 2008).

1.1.5 Velocity

Age-0 Chinook salmon typically select areas with a water velocity ranging from 0–2.0 ft/sec (0–0.6 m/sec), preferring areas with velocities slower than 1.3 ft/sec (<0.4 m/sec) (Raleigh et al. 1986). Given the option, juvenile steelhead prefer somewhat swifter velocities, particularly as they approach age-1 status. Most age-1 steelhead shift to slightly deeper water with velocities ranging from 0.15– 0.3 m/sec on the bottom and 0.75–0.9 m/sec near the surface (Everest and Chapman 1972). As they increase in size, juvenile Chinook salmon begin to shift their habitat preference from slow habitats to deeper, faster-moving water (USFWS 1995; Everest and Chapman 1972). At night, however, these fish may return to low velocity edgewaters or pools (Moyle 2002). In order to accommodate these diel shifts in habitat use, it is important to ensure that juvenile salmonids be provided with a variety of velocities within restored seasonally inundated habitats. The presence of various channels and ponds (e.g., the Tule Canal) within the Bypass provides this sort of variation. Still, whether in river, stream, or floodplain habitat, juvenile Chinook salmon appear to congregate in greatest numbers in low-velocity areas (Sommer et al. 2005; Everest and Chapman 1972; Roper et al. 1994; Bradford and Higgins 2001). Due to the roughness and continuum of inundated aquatic microhabitats within the Bypass, velocities in inundated areas are inherently variable and ultimately slow to the point that they fall within a range utilized by rearing and foraging juvenile salmonids. Some areas within the Bypass may have higher velocities beyond the preferred range for juvenile salmonids as a result of scouring. However, during the period of inundation a significant portion of the Bypass is expected to fall within suitable velocity ranges for salmonids.

Velocities above the preferred range for salmonids are not necessarily detrimental. Sommer et al. (2004) found that densities of chironomids (a key food source for juvenile salmonids) on the Bypass were associated positively with flow. HEC-RAS modeling suggests that at flows of 6,000 cfs, variable velocities occur, and the mean velocity of the restored inundated habitat would be

1.3 ft/s. At 6,000 cfs, approximately 21,500 acres of floodplain would be inundated, the vast majority of which would consist of favorable, low-velocity shallow habitat. As described in the Implementation Plan, these considerations will be among the data gathered which a multidisciplinary operation team will use to adaptively manage associated habitat restoration projects to meet plan goals.

Table A.2: HEC-RAS Model Results for Depth, Area, Mean Velocity, and Travel Time from Different Flows at the Modified Fremont Weir (from BDCP Integration Team 2009)

Flow	Mean depth for the entire Yolo Bypass	Surface area (from GIS mapping)	Mean velocity	Travel time
(Q) cfs	(D) ft	(A) Acres	(V) ft/sec	(t) day
1,000	5.9	4,100	1.66	8.8
2,000	5.3	5,700	1.94	4.9
3,000	3.9	11,000	1.77	4.2
4,000	2.8	15,900	1.49	4.2
5,000	2.6	18,600	1.32	4.0
6,000	2.6	21,500	1.26	3.9
7,000	2.6	23,100	1.19	3.7
8,000	2.6	24,600	1.20	3.6
9,000	2.7	25,900	1.20	3.5
10,000	2.8	27,100	1.20	3.4

1.1.6 Temperature

As juvenile salmonids develop, they become more capable of tolerating a broader range of temperatures. As Chinook salmon and steelhead juveniles enter the lower mainstem Sacramento River and have the potential to become entrained onto the Bypass to utilize restored seasonally inundated habitats, their temperature tolerances will have increased to accommodate a much broader range, approximately 1°–24°C for Chinook salmon and 1°–25°C for steelhead (Myrick and Cech 2004). Water temperatures in the Central Valley rarely dip close to the lower range of salmonid tolerance, so the upper thermal limit is of greater concern to managers. The incipient upper lethal temperature (IULT) for salmonids is highly dependent upon the acclimation temperature of the fish, and an increase in acclimation temperature will ultimately yield an increased IULT (see Table A.3) (Brett 1952). At high, sublethal temperatures, there must also be sufficient prey available to offset the fish’s increased metabolism triggered by warmer temperatures.

Table A.3. Incipient Lethal Temperature Limits of Young Chinook Salmon (Brett 1952)

Acclimation temperature	Incipient lower lethal temperature	Incipient upper lethal temperature (IULT)
75.2°F (24°C)	45.3°F (7.4°C)	77.2°F (25.1°C)
68°F (20°C)	40.1°F (4.5°C)	77.2°F (25.1°C)
59°F (15°C)	36.5°F (2.5°C)	77°F (25.0°C)
50°F (10°C)	33.4°F (0.8°C)	75.7°F (24.3°C)
41°F (5°C)		70.7°F (21.5°C)

Even though juvenile salmonids are capable of surviving a wide range of temperatures, their growth and overall fitness are maximized at levels well below the limits of what they can actually tolerate. The optimal growth rate may also vary based upon the acclimation temperature of the individual fish. For example, lab studies using American River fall-run Chinook yielded maximum growth rates at a temperature range of 12.8°–15.6°C (Rich 1987). However, in another laboratory study, Marine and Cech (2004) reared fall-run Chinook at 13°–16°C, 17°–20°C, and 21°–24°C and reported a maximal growth rate of 3.3% weight gain per day at 17°–20°C (Marine and Cech 2004). Growth rates slowed at temperatures above and below approximately 17°–20°C. It is worth noting that although fish reared at 21°–24°C still grew, they were more vulnerable to predation by striped bass (*Morone saxatilis*). This may be useful information for managers, as it is not uncommon for water temperatures in the Bypass to climb above 20°C as the inundation season progresses, potentially making conditions less suitable for Chinook and more suitable for effective foraging by predators. Even in the deeper, cooler waters of the Toe Drain, temperatures typically approach IULT for salmonids by late April to early May (DWR preliminary data). As conditions become more favorable in this way to predators (i.e. centrarchids), the benefit of extending inundation for salmonids later into the year begins to diminish.

Although no studies have been conducted to determine IULTs on California Central Valley steelhead, studies on rainbow trout report IULTs of 22.8°–26°C (Bidgood and Berst 1969; Threader and Houston 1983). A technical report from the Feather River stated that juvenile steelhead had a critical thermal maximum of 30.8°C, a higher value than the maximum of 29.4°C that was measured on hatchery-reared juvenile Feather River steelhead acclimated to 16°C water (Myrick and Cech 2000). The optimal growth temperature for steelhead also has not been well studied, but Myrick and Cech (2004) advise that optimal growing temperatures are more than likely very similar to those for Chinook salmon, with one study (Myrick 1998) indicating that 19°C as a probable optimal temperature. Studies have shown that juvenile salmonids that reared on the Bypass floodplain exhibited higher growth rates and ultimately grew larger than those that remained in the main stem of the adjacent Sacramento River. Sommer et al. (2001) showed that mean length of rearing salmon increased more quickly in the Bypass, and stomach-content results indicated that juvenile salmon reared on the Bypass had greater feeding success of higher-quality prey items than their Sacramento River counterparts. Gut contents of Bypass fish showed increased levels of drift species (chironomids), whereas Sacramento River stomach-content analyses showed that zooplankton (lower in bioenergetic value) was the dominant prey item. The higher water temperatures associated with the shallower depths and slower velocities of Bypass waters likely provide the elements needed to increase primary productivity over that of the main stem of the Sacramento River, thus creating more numerous and diverse prey items for floodplain fishes. Research in other river systems has also shown that production of invertebrates on inundated floodplains can far exceed river production. Gladden and Smock (1990) estimated that annual invertebrate production on two Virginia floodplains exceeded river production by one to two orders of magnitude.

Water temperature on the Bypass is primarily a function of air temperature, which cannot be controlled, and of flow sources and rates, which can be influenced. At this time no water temperature performance goal is being proposed for restored seasonally inundated habitat. However, a performance goal for fish growth can be identified that is related to water temperature and food. As already noted, salmonids on the Bypass are noted as having a better condition (greater mean length) than fish that remain in the Sacramento River mainstem, and a performance measure for fish growth will be based on comparison between fish monitored downstream of a significant portion of the restored seasonally inundated habitat and those in fresh water in the Sacramento River. If growth and water temperatures do prove to be preferable for salmonids in restored Bypass habitats, we would anticipate that a group of these fish would be in better condition (i.e., greater mean length) than a similar group measured in the Sacramento River. Over time, the comparative condition of fish will be evaluated for a relationship with temperature to assess the benefits and risks of warmer temperatures vis-à-vis growing larger fish or potentially causing physiological stress to salmonids. If monitoring demonstrates temperature to be a limiting factor for fish growth or fish health in restored seasonally inundated habitats, adaptive management will be implemented to inform program design, implementation, and operation.

The most efficient way to monitor temperature is through the use of a continuous data logger. The incipient upper lethal temperature (the primary concern in shallow floodplain waters) ranges from 21.5° to 25.1°C for Chinook salmon, depending on acclimation temperature (Brett 1952). Temperatures should be kept below this upper limit during the migratory window when juvenile salmonids are using the Bypass. The range typically considered to be conducive to juvenile salmonid health in a riverine system is 13-18°C. [Marine, K. R. 1997. Effects of elevated water temperature on some aspects of the physiological and ecological performance of juvenile chinook salmon (Oncorhynchus tshawytscha); M.S. thesis, University of California, Davis. 63pp.; as cited in Moyle, P. B. 2002. Inland fishes of California. – Revised and expanded. University of California Press, Berkeley. Page 255.] Based on database records, measured temperatures in the low flow channel of the Bypass have been within the 13-18°C range from the second or third week of October through the third week of April, sometimes as late as mid-May. [Kevin Reece, personal communication]. Where food is highly available, as might be expected on the floodplain, quite high temperatures optimize growth. Laboratory study derived temperatures optimal for growth of approximately 17° to 20°C (Marine and Cech 2004).

1.1.7 Turbidity

Steelhead can handle a wide range of turbidities, from clear water that is typical of springs during low-flow periods to the turbid water associated with runoff conditions (Moyle 2002). Juvenile salmon are capable of tolerating turbidity as high as 1,000 ppm, but if given a choice, Chinook salmon will avoid overly turbid waters (Allen and Hassler 1986). Laboratory tests have shown that turbidity has an influence on where juvenile Chinook salmon position themselves in the water column as well as how they react to the presence of predators. In turbid conditions (roughly 23 NTU), Chinook juveniles were distributed randomly throughout the water column, but as conditions became increasingly more clear (<1 NTU) they began to associate with the bottom (Gregory 1993). In the presence of both bird and fish predator models, the Chinook shifted to deeper waters regardless of turbidity. However, in more turbid conditions their response to predators was less marked and of notably shorter duration, apparently due to the reduced perceived risk of predation in the turbid waters. Given the agricultural land practices that are prevalent on the Bypass, seasonally inundated habitats there are turbid. A performance goal for turbidity in restored seasonally inundated habitats is >23 NTU, which can be expected to provide habitat conditions that would allow fish to be distributed throughout the water column, reducing the amount of time they would need to spend on predator avoidance activity. If monitoring demonstrates that turbidity is not meeting suitable levels in restored seasonally inundated habitat areas, adaptive management will be implemented to inform program design, implementation, and operation.

Turbidity should be measured by continuous data loggers as well. In turbid conditions, Chinook juveniles are likely to have a reduced likelihood of predation. It follows that the maintenance of turbidity at 23 NTU or above would likely increase Chinook juvenile survival by reducing predation. However, there is some risk that at highly elevated turbidity levels, the juveniles' own sight feeding will be inhibited. As more data become available, results of turbidity monitoring will likely become increasingly relevant to the management of the bypass by the YBAMT.

1.1.8 Dissolved Oxygen

Reported optimal dissolved oxygen levels for juvenile Chinook salmon are greater than 9 mg/l at water temperatures below 50°F (10°C) and greater than 13 mg/l at water temperatures above 50°F (10°C). Juveniles can tolerate short-term exposure to 3 mg/l at temperatures below 41°F (5°C) (Raleigh et al. 1986). Allen and Hassler (1986) reported that juvenile Chinook avoided DO levels below 4.5 mg/L at temperatures of 61–77°F (16–25°C), and avoided DO levels below 3.0 mg/L at temperatures of 46–64°F (8–18°C). In cooler waters, steelhead can survive dissolved oxygen concentrations as low as 1.5–2.0 mg/l, but they require concentrations close to saturation for optimal growth (Moyle 2002). In a study conducted on the Chehalis River floodplain in Washington, researchers noted that the dissolved oxygen concentration had significant impacts on juvenile salmonid use of the floodplain. Specifically, dissolved oxygen levels served as cues to the fish as to when to emigrate off of the floodplain and back into the main river channel (Henning et al. 2006). Residence time of juvenile salmonids on the floodplain was positively correlated with dissolved oxygen concentration. Dissolved oxygen concentrations decreased in emergent wetlands throughout the season and approached lethal limits by May or June of each year. This was more of an influencing factor to emigration than were escalating water temperatures. Emigration patterns suggest that age-0 and age-1 Coho (the predominant salmonid in the study, although Chinook were also present) emigrated off of the floodplain as dissolved oxygen levels fell below 1.5 mg/l. However, if the outlet channel connecting the floodplain to the main river stem desiccated before dissolved oxygen concentrations fell below 1.5 mg/l, most of the fish remained on the floodplain and the number of strandings was substantially increased. In addition to the potential that dissolved oxygen will fall to lethal limits and the increased risk that fish will be stranded later in the season, prolonged low dissolved oxygen concentrations may also reduce the overall fitness of surviving juvenile salmonids. Juvenile Coho salmon show a marked decrease in food consumption and ultimately a loss of body mass as dissolved oxygen concentrations fell to 2 mg/l (Colt et al. 1979). It is likely that Chinook salmon exhibit a similar response. Although Coho salmon may not be good surrogates for Chinook and steelhead, which are the focus of this Action, this study does make a few interesting observations. First, DO may influence the movements, and the potentially stranding, of fish. Second, reduced DO impacts the growth of fish. Although no performance goal will initially be established for DO, rigorous monitoring of DO will be important. If monitoring demonstrates that DO is linked to stranding or reduced growth in restored seasonally inundated habitats, an appropriate performance goal will be established and adaptive management will be implemented to inform program design, implementation, and operation.

As with temperature and turbidity, dissolved oxygen (DO) could be measured via continuous data loggers. The relationship between DO and fish health is more clearly defined than for turbidity. Optimal DO for temperatures that are likely to occur in the Yolo Bypass is above 13 mg/l, with a minimum sustained concentration of 8 mg/l. Dissolved oxygen should be kept within optimal ranges as much as possible and kept above the minimum as long as possible during juvenile migration. Juveniles are likely to emigrate when levels drop too low, provided there is connectivity to downstream exits from the bypass. The prolongation of adequate DO levels during inundation makes it more likely that juvenile salmonids will benefit from the bypass inundation.

1.1.9 pH

The reported optimal pH range for Chinook salmon is 6.8–8.0, although they are known to tolerate a broader range of 5.5–9.0 (Raleigh et al. 1986). Rainbow trout (steelhead) have been documented to prefer a similar pH range of 7.0–8.0, with the ability to withstand an overall broader scale than Chinook, 5.8–9.6 (Moyle 2002). On the Bypass, pH levels (along with temperature) play an integral role in determining what form of nitrogen is present, and in what concentrations (see section 4.1.7). While inundated, pH levels in the Bypass range from neutral to mildly alkaline (+/- 7.0–<9.0), and may vary from day to day depending upon inputs from neighboring agricultural lands (i.e., pesticides and herbicides) (Smalling et al. 2005). However, these swings in pH are not unusually drastic and rarely climb to levels that are sufficiently alkaline to stimulate excess production of harmful NH_3. During inundation events, pH levels on the Bypass are not expected to deviate from the suitable range for salmonids. No performance goal is initially being established for pH. If monitoring demonstrates pH to be a limiting factor for survival in restored seasonally inundated habitats, adaptive management will be implemented to inform program design, implementation, and operation.

Measurement of pH should be done via continuous loggers as well. While pH can frequently vary in the Bypass, keeping the pH in the optimum range should be the goal and pH should not exceed tolerance limits, as defined in Section 1.1.6. It also seems that pH is tied to various other metrics (e.g., nitrogen, MeHg, etc.). As further data regarding these relationships becomes available, pH goals will be modified to help manage these other metrics.

1.1.10 Nitrogen (NH3, NH4, NO3)

In zero- or near-zero-salinity water, ammonia (NH_3) levels increase with increasing pH and temperature (see Table A.4) (U.S. EPA 1999). At low pH and temperature values, ammonia combines with water to produce an ammonium ion (NH_4^+) and a hydroxide ion (OH^-). The ammonium ion is nontoxic and therefore of little concern to organisms. If ammonia is introduced into pristine water (neutral pH or slightly acidic), it is converted to nitrate (NO_3^-) via nitrification and becomes harmless. However, as pH values climb above 9, un-ionized ammonia (NH3), which can be toxic to fish and other aquatic organisms, becomes the predominant species in water (Stumm and Morgan 1981). NH3 can cross cell membranes in fish more readily at higher pH values. The increased concentration that can enter the aquatic organism heightens the toxic effect of un-ionized ammonia (NRC 1979).

Table A.4. Percent Total Ammonia Present in the Toxic, Un-Ionized Form in a Zero-Salinity Solution (U.S. EPA 1987)

Temp (°C)	pH								
	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
5	0.013	0.040	0.12	0.39	1.2	3.8	11	28	56
10	0.019	0.059	0.19	0.59	1.8	5.6	16	37	65
15	0.027	0.087	0.27	0.86	2.7	8	21	46	73
20	0.040	0.13	0.40	1.2	3.8	11	28	56	80
25	0.057	0.18	0.57	1.8	5.4	15	36	64	85
30	0.080	0.25	0.80	2.5	7.5	20	45	72	89

Excess ammonia (NH3) levels may harm aquatic life. Juvenile salmonids are among the most susceptible fish species. Experiments have shown that the lethal concentration of NH3 for fish ranges from 0.2 mg/l (salmonids) to 2.0 mg/l (carp) (U.S. EPA 1999). Excess ammonia may accumulate in the organism and cause alterations of the metabolism or an increase in body pH. Additionally, fish may suffer a loss of equilibrium, hyperexcitability, increased respiratory activity and oxygen uptake, and increased heart rate. At extreme levels, convulsions, coma, and death may occur (NRC 1979). Even slightly elevated ammonia levels falling within the acceptable range may adversely impact aquatic life. Fish may experience reductions in hatching success and in growth rate and morphological development, along with injuries to gill tissue, liver, and kidneys (U.S. EPA 1999). In a laboratory study, the 24-hour median lethal concentration of un-ionized ammonia for Chinook salmon parr in freshwater was 0.36 mg NH3/l (Harader and Allen 1983). Chinook salmon were more sensitive to un-ionized ammonia in fresh water than were rainbow trout (steelhead) or Coho salmon (Buckley 1978). Other laboratory experiments have shown that exposure to un-ionized ammonia concentrations as low as 0.002 mg/l for six weeks causes hyperplasia of the gill lining in salmon fingerlings and may lead to bacterial gill disease (NRC 1979). Chronic ammonia exposure impacts are highly dependent on temperature and pH conditions, as harmful ammonia levels increase along with increased pH and temperature levels (U.S. EPA 1999).

However, in light of recent studies that indicate falling dissolved oxygen concentrations may play a larger role than rising temperatures in cueing juvenile salmonids into emigration from the floodplain (Henning et al. 2006), excess ammonia levels likely do not pose a significant threat to floodplain fishes. In abnormally warm years or under conditions in which the floodplain remains inundated longer into the season, it is plausible that un-ionized ammonia concentrations could climb into unhealthy ranges. Future baseline water quality monitoring will evaluate un-ionized ammonia concentration, but no performance goal is initially being established for this attribute. If implementation monitoring demonstrates un-ionized ammonia to be a limiting factor for survival in restored seasonally inundated habitats, adaptive management will be implemented to inform program design, implementation, and operation.

Nitrogen should also be measured using discrete sampling at regular intervals (e.g., weekly). Ammonia (NH3) is the primary concern, since NH3 has been shown to harm aquatic life, with high susceptibility of juvenile salmonids. Concentrations should be kept below the lethal concentrations for salmonids during inundation. As previously explained, pH in excess of 9 and elevated temperatures elevate NH3 concentrations. If the combination of pH and temperature cause NH3 to rise to near lethal concentrations, action should be taken by the YBAMT to reduce concentrations or move fish out of the bypass.

1.1.11 Pesticide levels

A number of pesticides are known to be present in the Bypass, and also to enter the system during high flows from neighboring watersheds with significant agricultural activity. Measurable levels have been found dissolved in surface waters as well as in bed- and suspended-sediment samples (Smalling et al. 2005). In particular, diazinon, an organophosphate present throughout the Bypass, is known to be extremely harmful to salmonids. Scholz et al. (2000) found that in addition to killing Chinook salmon and their potential prey items, diazinon exposure can cause genetic damage and disrupt behaviors that are responsible for reproduction, natal homing, and predator avoidance.

Pesticide concentrations found in water, sediments, and soils on the Bypass all have been orders of magnitude below levels known to cause acute or chronic toxicity to fish (Smalling et al. 2007). However, there is still the potential for these pesticides to harm the aquatic ecosystem. Some herbicides have been known to decrease primary productivity, thus reducing both the quantity and quality of food available to fish rearing on the floodplain (Edmunds et al. 1999).

Certain pesticides may also affect benthic macroinvertebrates that are considered as prey for fish within the Bypass. Finally, although the concentrations of individual pesticides were well below the acute toxicity levels for fish, there remains the possibility that exposure to a mixture of pesticides in the water, sediment, and potential prey could lead to sublethal or chronic harmful effects (Smalling et al. 2007). No performance measure is initially being established for pesticide levels. If monitoring demonstrates pesticides to be a limiting factor for survival in restored seasonally inundated habitats, adaptive management will be implemented to inform program design, implementation, and land use best management practices.

Pesticide levels will be measured following initial inundation and during periods of high input from agricultural sources, such as the Knights Landing Ridge Cut, to determine the potential for agricultural inputs of pesticides into the bypass. Samples should be taken at various distances from identifiable input sources to determine the range of influence within which pesticide concentrations are potentially harmful to fish. Sampling after initial flooding should be done at various locations throughout the length of the Bypass.

1.1.12 MeHg

Methylmercury is a neurotoxin that bioaccumulates and biomagnifies in the aquatic food web (Davis et al. 2003). Berntssen et al. (2003) showed that methylmercury can cause pathological damage and altered behavior in Atlantic salmon (*Salmo salar*). In a recent field study, juvenile

Chinook salmon reared on the Bypass floodplain displayed a more rapid accumulation of methylmercury than those reared in the Sacramento River. Additionally, the floodplain-reared fish showed higher methylmercury levels per weight at outmigration than the Sacramento River fish. However, given that juvenile Chinook salmon on the floodplain grow approximately three orders of magnitude larger over the course of their life, the observed levels of methylmercury bioaccumulation over their time spent rearing on the floodplain (1–12 weeks) likely represent only insignificant concentrations in the tissues of eventual adult fish (Henery et al. 2010). No performance goal is initially being established for methylmercury levels. To comply with the Regional Water Quality Control Board's total maximum daily load (TMDL) requirement to examine management practices to control total and methyl mercury, DWR is partnering with other regulated entities to examine the possible impacts that changes in Bypass floodplain management could have on methyl mercury production. This phased approach will potentially include field sampling to characterize processes that affect methyl mercury production and degradation in the Bypass. It is anticipated that this information will be used in a hydrodynamic and mercury process model. The model will provide information on the impacts to total and methylmercury production associated with potential changes in floodplain management practices in the Bypass.

Methylmercury will be measured by discrete sampling of soils and sampling for bioaccumulation. While bioaccumulation is more rapid on the floodplain, it is not as clear whether this is a function of the amount of MeHg on the floodplain or of higher feeding rates for fish on the floodplain. Frequency of sampling will likely depend on the YBAMT's data needs. Sampling are likely to be more intensive early in the inundation program and to taper off as more information becomes available. Sampling will also likely show the highest MeHg concentrations later in the season, as temperatures warm and fish exposure is the greatest. If monitoring demonstrates methylmercury to be a limiting factor for survival in restored seasonally inundated habitats, adaptive management will be implemented to inform program design, implementation, and best management practices.

1.2 Juvenile Fitness Metrics

1.2.1 Survival

The larger size exhibited by salmonids that rear in the floodplain leads to increased chances of survival, due to their increased swimming ability and the gape (mouth opening) limitations of potential predators. Juvenile survival can be measured using telemetry or catch at Chipps Island, relative to sampling data from stations upstream of the Bypass. Goals for increased survivability will be difficult to quantify; however, relative survival compared with fish survival in the Sacramento River mainstem is likely the best indicator of the benefits of the restored habitat. Telemetry and/or other tagging methods (i.e., PIT tags) will be used to measure these performance criteria. The survival of migrating salmonids is an important performance measure in evaluating whether the implementation of seasonally inundated habitat restoration is resulting in population impacts similar to those identified during the planning and modeling phases of this program. A performance measure for migration survival will be established based on modeling during the planning phase for a Fremont Weir juvenile fish passage notch. This performance measure will be used to evaluate monitoring results that will show migration survival in order to assess the effectiveness of implementation of the initial notch design. If monitoring demonstrates migration survival to be less in the Bypass than in the Sacramento River or less than was modeled during the planning phase, adaptive management will direct further project design, implementation, and operations towards attaining fish survival performance goals.

1.2.2 Growth

Growth benefits will be measured by comparing fish captured in the Bypass rotary screw traps (RSTR) with those captured within the Sacramento River. While increased growth rates are well documented in floodplains (Jeffres et al. 2008, Sommer et al. 2001), it will be important to ensure that existing floodplain benefits continue following any alteration to inundation regime. A performance measure for salmonid growth will be for salmonids on the floodplain to grow 30% larger than salmonids in the Sacramento River while traveling parallel paths to the vicinity of Rio Vista.

1.2.3 Residence time

Residence time of juvenile salmonids in the Bypass can be measured using a combination of RSTR data and telemetry. Telemetry is the most definitive way to establish residence time, provided there are enough receivers to capture data for when fish are leaving the bypass. Data from the RSTR located in the Toe Drain give another indicator of residence time, when compared with emigration data from the main stem above and below the Bypass. Inundation should provide for residence times that will provide high benefits without risk of exceeding lethal limits of temperature, DO, pH, etc., as well as considering ocean conditions.

1.2.4 Use of additional habitat

Measurement of additional habitat use will likely require a combination of techniques. Seining in areas that are more frequently inundated would give direct indication of the habitat use. Rotary screw traps could be seen to indicate more extensive usage of the Bypass if data were to indicate a substantial increase in catch, compared with historical data. Lastly, telemetry and a telemetry array could be used to determine just which areas within the bypass the fish are using and just when they are using these areas.

1.3 Juvenile Food-Web Metrics

1.3.1 Phytoplankton

Based on the study period from Sommer et al. (2004), phytoplankton biomass in the form of chlorophyll *a* typically is higher in the Yolo Bypass floodplain than in the Sacramento River when flows are low, as a result of warmer water temperature associated with shallower depth and a longer residence time. The greater abundance of phytoplankton biomass in the Bypass may help support the planktonic food web since phytoplankton is an important primary source of carbon (Sobczak et al. 2002). Lab experiments by Müller-Solger et al. (2002) corroborate this view. They found that higher concentrations of chlorophyll a on floodplain sites led to faster growth rates for the cladoceran *Daphnia magna*, as compared to the river sites included in that study. For these reasons, we expect that phytoplankton biomass will be higher in the Bypass than in the Sacramento River during the drain phase. To evaluate phytoplankton levels, chlorophyll a may be monitored using the spectrophotometric method as a proxy for phytoplankton since it is the primary photosynthetic pigment found in all green plants (Eaton et al. 2005).

Phytoplankton is an important part of the food web, but it is not expected to be a limiting factor, so high levels of resources are not proposed for monitoring phytoplankton levels or composition.

The initial metric for phytoplankton, that phytoplankton are more prevalent in the Bypass than in the Sacramento River, is unlikely to trigger special operations of increased seasonal floodplain habitat in the Bypass. The time it takes for phytoplankton biomass to reach elevated concentrations is currently not well quantified in the Bypass, but the duration operational criterion of at least 14 days set forth in Appendix B should be sufficient for phytoplankton biomass accumulation based on studies from other floodplains. For instance, Ahearn et al. (2006) revealed that the ponded water on the Cosumnes River floodplain began to show elevated concentrations of chlorophyll a after two days of disconnection from the river. In comparison, Hein et al. (2004) found that the maximum values of chlorophyll a were achieved after 3 and 10 days in the side-arm channels of the Danube in Austria. However, if monitoring demonstrates phytoplankton biomass as a limiting factor, then adaptive management will direct further project design, implementation, and operations towards attaining phytoplankton performance measures.

1.3.2 Drift Macroinvertebrates

Drift terrestrial and aquatic macroinvertebrates are typically more abundant in the Bypass than in the Sacramento River and their numbers are positively correlated with flow (Sommer et al. 2004). For the most part, the drift macroinvertebrates in the Bypass comprise various aquatic stages of dipterans, such as chironomids (Sommer et al. 2004). In particular, chironomid pupae and adults serve as the primary food source for juvenile Chinook salmon in the Bypass (Sommer et al. 2001). Because of this, the current duration criterion of at least 14 days for inundation is based on the amount of time it takes for dominant chironomid species in the Bypass to mature into the life stages that are used as a food source by the targeted species, suggested by the results from Benigno and Sommer (2008) (see Appendix A, Secion 1.1.1). However, there are some limitations to the usefulness of the Benigno and Sommer (2008) study that was used to develop the current duration criterion. First of all, Benigno and Sommer's (2008) observation that it took about 14 days for chironomids to reach the pupa stage was made under laboratory conditions and may not reflect the timing under actual field conditions in the Bypass. Second, Benigno and Sommer's (2008) field observations, in which they reported a huge abundance of chironomids (primarily *Hydrobaenus saetheri*) during the winter, may not reflect actual temporal patterns as the dominant macroinvertebrate taxa may change over time after floodplain inundation (Benigno and Sommer 2008; Grosholz and Gallo 2006). Lastly, different water years will have different hydrologic conditions that will lead to different levels of drift macroinvertebrate abundance. For example, Sommer et al. (2004) reported that Diptera were less abundant in a drier year than in wetter years. For these reasons, YBRT will need to monitor for drift macroinvertebrate abundance and composition at fixed locations in the Bypass and the adjacent Sacramento River in order to gain a better understanding of the chironomid life cycle in the Bypass.

Since drift macroinvertebrates are important to salmonids as forage, a drift macroinvertebrate performance goal requires that monitoring observe a peak in chironomid abundance prior to alteration of operations aimed at achieving other food web-related performance measures (i.e., phytoplankton). For this performance goal, drift macroinvertebrate abundance in the Bypass during the flood phase would need to be higher than in the adjacent Sacramento River. The sampling locations and sampling frequency for drift macroinvertebrates will be dependent on the data needs of the monitoring team and should be concurrent with zooplankton sampling (see Section 1.3.3). To assist with sampling design, Reclamation and DWR can refer to Standard Method 10500 from Eaton et al. (2005), a good reference on proper techniques and methods for sample collection and analysis of drift macroinvertebrates. As more data become available, a more definitive understanding of the chironomid lifecycle will be gained and manager's insights into maturation and timing for different water year types and seasons will be integrated into their considerations for determining inundation durations. Drift sampling may not be the ideal method for direct observation and capture of the earlier life stages of chironomids, since they can be either planktonic or benthic in nature (Walker 2001). Nevertheless, drift sampling can provide an estimate for when chironomids mature through observations of the presence of later life stages in the drift samples. In this way, drift sampling will allow for an evaluation of the current duration criterion, in response to which the operations can either be lengthened or shortened to maximize benefits to salmonids.

1.3.3 Zooplankton

Unlike drift macroinvertebrates, zooplankton abundance in the Yolo Bypass typically is not significantly different from that observed in the Sacramento River (Sommer et al. 2004). Even so, zooplankton are an important food source for juvenile Chinook salmon in the Yolo Bypass (Sommer et al. 2001). Zooplankton may stand to benefit from floodplain habitat conditions in ways that are not reflected in recent records of their abundance. For this reason, the initial zooplankton abundance performance goal will be that abundance in the Yolo Bypass should be at the same level as that of the Sacramento River during the drain phase since zooplankton abundance is inversely related to flow (Sommer et al. 2004).

To evaluate this initial performance measure, zooplankton composition, abundance, and biomass should be monitored at fixed locations in the Yolo Bypass and in the adjacent Sacramento River. Sampling will be concurrent with sampling for drift macroinvertebrates. To assist with sampling design, Reclamation and DWR will refer to Standard Method 10200 from Eaton et al. (2005), a good reference on proper techniques for sample collection and analysis of zooplankton.

1.3.4 Fish Diets

Monitoring for drift macroinvertebrates and zooplankton alone may not be sufficient to ensure benefits to salmonids in the Yolo Bypass. The mere fact that a drift macroinvertebrate or a zooplankton species is dominant does not necessarily mean they will be highly consumed by salmonids. For example, corixids were the dominant benthic invertebrate found on the Cosumnes River floodplain at the end of the flood season, but they were never found in fish guts (Grosholz and Gallo 2006). The gut contents of both juvenile Chinook salmon and California Central Valley steelhead in the Yolo Bypass should be examined using methods similar to those described in Sommer et al. (2001) in order to get a clear picture of the actual makeup of the salmonids' diets.

Determination of the frequency and location of sampling will be based on the timing and location of fish sampling done for the juvenile fitness metrics (see Appendix A, Section 1.2). For this metric, a significant portion of juvenile Chinook salmon and California Central Valley steelhead diets should be chironomids, when those invertebrates are abundant in the Bypass. If they are not, Reclamation and DWR may consider changing from the current inundation duration criterion, which is based primarily on the life cycle of chironomids (see Appendix A, Section 1.1.1). The current understanding is that juvenile Chinook salmon in the Bypass mainly consume Diptera (primarily chironomids), followed by zooplankton (mainly cladocerans and copepods) (Sommer et al. 2001). Little is currently known about the feeding behavior of California Central Valley steelhead in the Bypass, but chironomids and zooplankton have been found in the diets of post yearling steelhead in other systems such as the Mokelumne River (Merz 2002). As more data become available, Reclamation and DWR will gain a better understanding of the feeding behavior of salmonids and the availability of prey when salmonids are present.

2. Fish Passage Performance Measures

Performance measures associated with fish passage on the Bypass are primarily directed toward adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and green sturgeon, since these are known to utilize the floodplain for migration. Juvenile salmonid passage will be considered as well, but there are few fish-passage issues for juvenile salmonids aside from the potential for stranding. We will make pre-project/post-project comparisons where prior data exist. Mesaures for this section will consist of a combination of variables related to swimming ability for these species and life stages and various measures of a successful fish passage system.

Fish passage structures will be evaluated upon their completion to determine whether each structure has been constructed and is functioning according to the design metrics listed below. The following metrics are indicators of whether or not the constructed fish-passage system meets the design criteria.

2.1 Flow Attributes for Fish Passage

Most fish-passage structures in the Central Valley have been designed specifically to enable salmonid passage. However, due to variances in the size, behavior, and overall physiology of various fish species, most of these structures are largely ineffectual for the passage of other fish species (Daigle et al. 2005).

This is especially true for sturgeon, which are notorious for being among the most difficult native, riverine fishes for which to provide passage (USFWS 1995). This Section describes the components necessary for an effective, multi species fish passage structure capable of meeting the needs of anadromous salmonids (including winter-run and spring-run Chinook salmon and steelhead) and green sturgeon. It is expected that the passage structure will also allow passage by other fish species, but this report and the designs will be focused on the threatened and endangered species identified in RPA Action I.7.

2.1.1 Depth

Fish require a minimum depth of flow in order to reach their swimming potential (Dane 1978). Total submergence eliminates the risk of oxygen starvation for the fish, allows it to create maximum thrust, and lowers its risk of bodily injury through contact with the structure's substrate (Forest Practices Advisory Committee on Salmon in Watersheds 2001). As an example, steelhead often reject fishways that are undersized or too shallow or that cause the fish to be exposed (DFG 2010a). Specific depth requirements for salmonids in fish passage structures have been the subject of extensive study. The absolute minimum depth required for successful upstream passage of adult Chinook salmon and steelhead has been determined to be 0.79 feet (0.24 m) (Everest et al. 1985). However, this depth is for short bursts only, and would not be passable for any significant distance. Specific depth guidelines have been determined for the passage of many salmonid species at various types of structures, although there may be some variation between states and between regions, depending on how conservative each state or region's criteria are. For instance, Alaska requires that the depth be greater than 2.5 times the depth of a fish's caudal fin (Alaska Department of Fish and Game and Alaska Department of

Transportation 2001), while the California Department of Fish and Game (DFG) and the California Department of Transportation have prescribed a minimum depth of 1.0 foot (0.30 m) for adult anadromous salmonids at all culvert and road crossings (Caltrans 2007). Federally, the National Marine Fisheries Service (NMFS) states that the depth for the entrance of a salmonid-designed fishway should be at least 6 feet (1.83 m), depending upon site-specific downstream channel depths, while the minimum depths within a structure vary depending upon the specific structure type (NMFS 2008). If a fish passage structure is intended to be capable of passing multiple species, it is best to design it using a conservative depth criterion that will accommodate the needs of the animal with the greatest depth requirements. For example, salmon are capable of passing most structures that have a minimum depth of 0.5 foot (0.15 m), but that depth would make passage highly improbable for green sturgeon (*Acipenser medirostris*), and such a structure could in fact constitute a migration barrier. It is important to note that minimum depths for passage are largely distance-dependent, to a point. While fish may be capable of passing shallow humps or short-interval structures, it is unlikely that extremely shallow water navigation would be possible for an extended duration. In order to successfully pass sturgeon, a minimum depth requirement of roughly 3 feet (1 m) is recommended. Whenever possible, the aforementioned NMFS recommended depth of 6 feet should be targeted throughout the structure. Since sturgeon are a bottom-oriented fish, greater depths are desired in order to prevent passage structures from acting as barriers. Increased depths also allow salmonids a greater volume of water in which to navigate through the structure. However, in scenarios where only salmon passage need be provided, a passage structure may be operated with only 1 ft depth. Measuring the depth of the passage structure would require either a visit to the structure during operation to take manual readings from a staff gauge or the installation of a real-time gauge that could be accessed remotely via computer.

2.1.2 Velocity

As with depth, a velocity measure should take into account the most limiting species. Due to its large size and its swimming behavior, the green sturgeon is once again the species that is considered to have the most limiting passage requirements. Any passage structure should be designed to provide that high velocity areas are accompanied by slower velocity sections to allow sturgeon an opportunity to recover. Velocity measurements could either be taken with a current meter during site visits or with a remote gauge similar to, or combined with, a depth gauge.

The conservative approach should be used to assign maximum water velocity criteria within a structure. The United States Department of Transportation's Federal Highway Administration defines a successful fish crossing as one that ensures passage for the weakest-swimming fish species of concern (Hotchkiss and Frei 2007). It is important to note that fish may fail to pass a structure for a number of velocity-related reasons. A high-velocity zone may act as a barrier if it exceeds the fish's burst speed capabilities, while a continuous section of seemingly reasonable velocity may require that the fish maintain prolonged swimming speeds for a period beyond its natural ability (see Table A.5 below) (Hotchkiss and Frei 2007). Furthermore, even if fish are physically capable of specific swimming energies, that does not mean they will choose to expend their maximum swimming energy when confronted with an obstacle (Behlke et al. 1991). These criteria are not necessarily cumulative, and a fish that reaches the point of exhaustion in any manner will require a recovery period before it is able to proceed in continued movement.

Table A.5. Movement Type as it Relates to Muscle System Utilization (adapted from Bell 1991; Hotchkiss and Frei 2007)

Movement type (Hotchkiss)	Movement type (Bell)	Description	Muscle system	Period
Sustained	Cruising	Used for long periods of travel at low speeds	Red (purely aerobic)	Hours
Prolonged	Sustained	Short periods of travel at high speeds	Red and White	Minutes
Burst	Darting	Maximum swimming speed or jumping, inducing fatigue	White (purely anaerobic)	Seconds

Swimming and jumping capabilities vary greatly between species (see Figure A.2). These same capabilities may also vary between individuals within a given species as a result of the individuals' size, life stage, or condition, or simply because of the physical prowess of a given individual. This reinforces the importance of taking a conservative approach to velocity criteria. Sturgeon exhibit lower endurance at all velocities, compared with Chinook salmon and steelhead. However, overall speed and endurance does increase with length, so the swimming performance of a larger sturgeon may be comparable to that of a smaller salmonid (Peake et al. 1997).

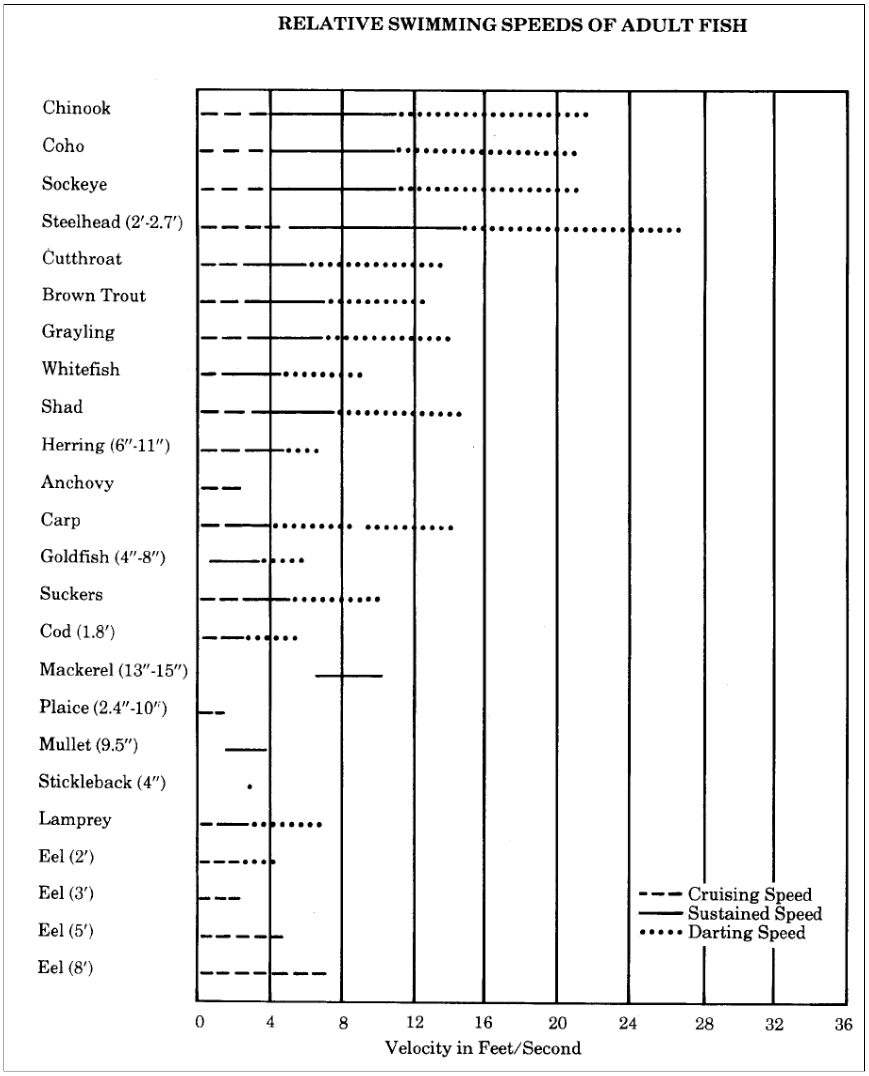


Figure A.2. Relative Swimming Speeds of Adult Fish (Bell 1991)

Chinook salmon and steelhead are strong swimmers (Figure A.2) capable of passing through a wide range of water velocities and under a number of different conditions. Still, these fish are not immune to exhaustion and can only maintain anaerobic activity for so long before they require a rest and recovery period (see Table A.6). It should be noted that the speeds listed in Table A.6 are intended to reflect conservative, real-world prolonged and burst speeds, and not the absolute maximum attainable speeds recorded by Bell (1991).

Table A.6. Salmonid Swimming Capabilities (DFG 2010b)

Species or life stage	Prolonged swimming mode		Burst swimming mode		
	Maximum swim speed	Time to exhaustion	Maximum swim speed	Time to exhaustion	Maximum leap speed
Adult anadromous salmonids	6.0 ft/sec	30 min	10.0 ft/sec	5.0 sec	15.0 ft/sec
Resident trout and juvenile steelhead trout <6”	4.0 ft/sec	30 min	5.0 ft/sec	5.0 sec	6.0 ft/sec
Juvenile salmonids <6”	1.5 ft/sec	30 min	3.0 ft/sec	5.0 ft/sec	4.0 ft/sec

Longer periods of enhanced activity will require longer resting periods than will momentary bursts. As stated in the California Department of Transportation’s “Fish Passage Design for Roadway Crossings” manual, DFG has established a set of velocity criteria for culverts of varying lengths (Table A.7) in order to ensure that water velocities do not reach speeds that will deter the passage of adult salmonids (Caltrans 2007). If velocities exceed the maximum speed for a given length of culvert, it is assumed that the majority of adult salmonids will not be able to maintain a burst swimming speed for that distance without requiring a velocity refuge where they can recover.

Table A.7. Culvert Length vs. Maximum Average Water Velocity for Adult Salmonids (Caltrans 2007)

Culvert length (ft)	Velocity (fps) – adult salmonids
<60	6
60–100	5
100–200	4
200–300	3
>300	2

Webber et al. (2007) suggest that areas of reduced velocities be interspersed if high velocity sections are necessary. The swimming behavior was typified by bursts of speed followed by protracted rest and recovery periods during which the sturgeon would orient on the bottom, facing into the current. Swimming behavior was dictated largely by the velocity of the water coming through the flume. White sturgeon exposed to lower velocities took the longest time to reach the upstream end of the flume, whereas fish exposed to higher velocities would use burst swimming to reach the upstream portion more quickly.

Passage was found to be significantly more efficient at medium to higher water velocities, with sturgeon passing successfully through velocities in excess of 8.27 feet/second (2.52 m/sec). This critical swimming velocity is higher than those of other sturgeon species. Previous work on shovelnose sturgeon (*Scaphirhynchus platorynchus*) found its critical swimming velocity to be 3.81 feet/second (1.16 m/sec) (Adams et al. 2003), and the burst swimming of lake sturgeon (*Acipenser fulvescens*) was measured at 5.25 feet/second (1.60 m/sec) (Peake et al. 1997). However, the white sturgeon observed by Webber et al. (2007) were considerably larger than those observed in the aforementioned studies. Peake et al. (1997) used lake sturgeon ranging from 106 to 132 cm in length, while Webber et al. (2007) used fish that ranged from 135 to 198 cm. It is widely accepted that green sturgeon have swimming capabilities comparable to those of other riverine sturgeon of the same size (i.e., white sturgeon) (Adams et al. 2003; DWR 2007). Webber et al. (2007) suggest that successful adult sturgeon passage structures should incorporate high-velocity sections ranging from 2.76 to 8.27 feet/second (0.84–2.52 m/sec) interspersed with segments of reduced velocities for rest and recovery. Flume studies conducted by White and Mefford (2002) confirm the usefulness of velocity refugia as resting points between swimming bursts. DWR (2007) found that slot water velocities of 1 to 3 feet/second (0.30–0.91 m/sec) at the entrance of a flume were most effective at attracting fish into the flume. Additionally, special care should be taken to design any ramps or baffles within the structures in a manner that reduces turbulence (Webber et al. 2007). Sturgeon passed more readily where hydraulic conditions were more stable and uniform. Given that sturgeon are considered weaker performers than salmonids, velocities within a structure should cater more to the needs of sturgeon in order to increase passage efficiency. Velocities through a modified Fremont Weir fish passage structure would be expected to provide the greatest passage efficiency at roughly 4 to 7 feet/sec.

2.1.3 Width

When designing a fish passage structure, it is important to consider the minimum width requirements of the various species that the structure is intended to pass. If a structure is perceived to be too narrow by up-migrating fish, they may avoid it altogether. Furthermore, a structure that is too narrow has the potential for impingement if the fish do not having sufficient room to maneuver within the structure. NMFS has included minimum width criteria in their "Guidelines for Salmonid Passage at Stream Crossings" manual (NMFS 2001). This manual describes a number of salmonid passage options, and each is assigned minimum width requirements (Table A.8). In addition, NMFS specifies that the entrance for fishways and similar structures must be 4 feet or more wide for salmonids (NMFS 2008).

Table A.8. Minimum Culvert Widths (for salmonids) for Various Road/Stream Crossing Methods (adapted from NMFS 2001)

Road/stream crossing method	Minimum culvert width
Active channel design	Equal to or greater than active channel width
Stream simulation design	Equal to or greater than bank-full channel width, and not less than 6 feet
Hydraulic design	3 feet

Clearly, these salmonid-specific guidelines can create barriers for sturgeon. A baffled system with minimum spacing requirements would not be large enough to accommodate a large sturgeon and could function as a deterrent to smaller individuals. Parsley et al. (2006) found that significantly greater numbers of adult white sturgeon at the Dalles Dam on the Columbia River ascended the east fishway, presumably due to the facts that the north fishway is narrower than the east fishway and that the orifices in the weirs in the east fishway are wider than those in the north fishway. This is not to suggest that basic salmonid criteria must be drastically modified in order to successfully pass sturgeon. Sturgeon were able to pass successfully through slots in fish passage flumes ranging from 1.42 to 2.92 feet (0.43–0.89 m) wide, with a minimum recommended width of 2 feet (0.61 m) (DWR 2007). However, to increase travel efficiency throughout the length of a structure, the minimum standards for slot widths simply will not suffice. Instead, a body length approach is recommended. A structure should be wide enough to allow a sturgeon to change direction 180° without colliding with the walls of the structure. Therefore, the width of the structure should be slightly greater than the length of the longest fish that is expected to utilize the structure. For a Fremont Weir passage structure, a minimum width of roughly 10 feet is recommended to accommodate a large adult sturgeon.

Limiting factors with regard to channel width relate primarily to the large size of green sturgeon. If a fish passage structure is slotted, it need not actually vary drastically from salmon requirements. The recommended absolute minimum width of 2 to 3 feet is easily attainable in most passage structures where baffles are present; however, slotted structures are not efficient for passing sturgeon. Therefore, the minimum width of 10 feet will be used. In addition, there should be enough width to provide adequate attraction flows. This will be an adaptive management process, and if the original design does not attract enough fish based on the operational metrics given below, the details of operation may need to be reassessed and the passage structure may require some retrofitting. Width need only be measured once after construction in order to ensure that the fish passage structure has met design requirements.

2.1.4 Other Considerations

Natural vs. formal fishways
DFG (2010A) states "Formal fishways are not the preferred fish passage solution at culverts and low dams. Solutions with diverse hydraulic conditions and passage corridors, such as stream simulation, roughened channels, and boulder weirs, are preferred over formal fishways because they provide passage for a broader range of species, often over a broader range of flows." In keeping with this approach, at least one unbaffled, roughened channel through the existing Fremont Weir is recommended. This channel would connect to Tule Pond via a natural, earthen channel of excavated soils. In an effort to maintain flows and to remove debris, the channel should slope at a degree slightly greater than the surrounding landscape. It is possible that in some locations, or over some operational conditions, one or more formal fishways will be required. In that event, the entrance and exit points of the channel should be flared open to lower velocities. At the entrance, a widened opening should make the structure more enticing for fish seeking to pass.

Roughened substrates
Roughened substrates may provide sturgeon with a means of recovery in a high-velocity setting before they proceed with burst or prolonged swimming. Roughened substrates also facilitated more successful passage in studies on shovelnose sturgeon, presumably because the variable substrate of the fishway provided more varied velocities, allowing the sturgeon a means of finding the least challenging hydraulic condition (White and Mefford 2002).

Straight trajectories
Studies (Webber et al. 2007, plus the UCD study) have found that sturgeon swimming bursts were most effective in straight trajectories. Any baffle slots and areas of fishways intended to facilitate sturgeon passage should be situated in alignment with each other. Webber et al. 2007 found that it was not uncommon for fish to collide with the second baffle in the flume under burst speeds where baffles were not so aligned. DWR (2007) found that fish injured by sharp

edges in the flume did not perform as well as uninjured fish. Walls, turns, or baffles should be angled to provide a non-perpendicular surface as a way to prevent collisions. Similarly, straight and horizontal flow paths were recommended, since vertical eddies confused fish in the flume, and as a result they often ended up in a downstream-facing orientation.

No overbank flow
It may be necessary to operate fish passage structures outside of the time that is negotiated in flowage easements. In order to avoid additional impacts to other land uses, fish passage flows will remain in bank during nonflood periods. This metric will be incorporated into the design of the fish passage system by determining the channel capacity via hydraulic modeling and then conducting field monitoring after construction to verify that flows do not exceed the capacity of the channels in the Fremont Weir Wildlife Area. In the event an inundation structure was being operated, this metric would not apply.

2.2 Adult Passage – Operational Metrics

The following metrics are measures of whether or not the fish passage structure is successful at passing adult migrants:

2.2.1 Number of passable days
The ultimate goal of constructing a fish passage structure is to ensure that there will be passable conditions beyond the historical conditions at the Fremont Weir, which is currently considered a passage impediment. Currently there is one small Denil fish ladder on the Fremont Weir. For the majority of the weir, passage is blocked once the Sacramento River has receded below the crest at 32.8 feet (NAVD88). It will likely take a combination of modeling and empirical data to measure an improvement in the number of passable days for salmonids and green sturgeon. Historic data may not be available for the number of passable days at Fremont Weir, but it may be possible to determine this from hydraulic modeling. Empirical data showing the passage condition of the fish-passage structure to be constructed under this plan can be collected by means of the installation of a combination of telemetry and a video or DIDSON monitoring system in the fish passage structure itself (depending on turbidity constraints).

In addition to the empirical data collection described above, Table A.9 shows the percentage of years during which passage can be provided for each species with a 14-foot invert elevation (i.e., an elevation of 14 feet at the bottom of the structure) on a monthly basis, which will serve as a best-case long-term metric for passable days. This represents the maximum depth of a passage structure. These percentages may change based on water year type and potential changes to invert elevation, following further analyses (e.g., too little slope to the structure possibly causing sedimentation issues). If further studies lead to changes in invert elevation, a similar metric will be developed for the selected design.

Table A.9. Percentage of Years During Which Passage would be Provided Based on a 14-foot Invert Elevation and Certain Passage Depths (based on all water years from 1985 to 2008)[1]

Month of passage	Percent exceedance			
	Winter run (1 foot depth=15 ft WSE)	Spring run (1 foot depth=15 ft WSE)	Steelhead (1 foot depth=15 ft WSE)	Sturgeon (3 foot depth=17 ft WSE)
Oct			25	
Nov	26		26	
Dec	70			
Jan	82	82		
Feb	86	86		71
Mar	88	88		73
Apr		71		46
May		49		36
June				
July				
Aug			80	
Sept			70	

[1]Values in this table represent the percentage of years that passage can be provided during months of peak migration for each of these fishes (WSE = water surface elevation)

2.2.2 Number of fish passing

Empirical counts of passing fish will be acquired by means of a combination of video monitoring within the fish passage structure and either acoustic receivers or PIT tag receivers, or both. Tagging efforts are being undertaken in a number of watersheds and involve nearly all of the targeted species and runs, with the objectives of gaining better understanding of migratory pathways, swimming behavior, and other life history characteristics. No historical data are available on the number of fish that actually pass or attempt to pass the Fremont Weir. This means that the collection of empirical data once the passage structure is built will provide an important baseline for future potential projects. In addition, an in-river tagging program should be undertaken below the outlet of the Yolo Bypass/Toe Drain for adult Chinook salmon and green sturgeon, with receivers placed within the Bypass to determine what proportion of fish pass Fremont Weir, for comparison with the number of fish that enter the Bypass, and to identify other potential passage impediments.

2.2.3 Passage efficiency

Passage efficiency will be assessed by comparing downstream fish counts to counts of those utilizing the ladder. This can be accomplished using a combination of video monitoring/Didson stations and radio telemetry. Video monitoring stations (or Didson units, if turbid conditions required them) could be placed at the base of the fish passage structure and further upstream near the top of the structure to assess how many fish are entering and how many are successfully passing through the structure. The telemetry program described above (see “Number of fish passing”) could also be used to assess how many fish were entering the ladder and successfully passing into the Sacramento River. Comparing historic data from fish rescues with data from future fish rescues or observations of fish stranded in the splash basin following inundation could also used in determining passage efficiency.

2.3 Juvenile Performance Measure

The following is a measure of whether or not juvenile salmonids can successfully migrate out of the Bypass.

2.3.1 Stranding

One of the largest concerns related to juvenile use of floodplain habitat in the Central Valley is the potential for juvenile stranding. The degree of stranding within the Bypass has not been extensively studied, though results from Sommer et al. (2005) seem to indicate that stranding typically is not a major risk in the Bypass. There are not yet sufficient data, however, to conclusively indicate that this is not an issue worthy of consideration. For this reason, we will measure stranding using a combination of beach seining and visual surveys. Seining will be conducted in remnant flooded areas (i.e., ponds) once waters have receded to the point that connectivity with flow channels is lost, using methods similar to those employed by Sommer et al. (2005). Visual surveys of previously flooded areas will be taken at regular, repeated intervals to document the spatial extent of potential stranding and the actual rate of mortality by desiccation as they relate to floodplain topography and proximity to flow channels and other features.

Appendix B

Technical Evaluation of Increased Seasonal Inundation and Fish Passage

1. Seasonal Inundation

1.1 Timing

Ephemeral floodplain habitat is important to the juvenile rearing life-stage of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. Juvenile Chinook salmon rearing in ephemeral floodplains have shown more rapid growth than those rearing in-stream in the Central Valley (Jeffres et al. 2008, Sommer et al. 2001). This is largely attributable to the abundance of food in the floodplain habitat, including chironomid larvae, macroinvertebrates, and zooplankton (Benigno and Sommer 2008, Jeffres et al. 2008, Sommer et al. 2001), and to increased primary productivity found in the slightly warmer, low velocity waters of the floodplain (Schemel et al. 2004). Because of the benefits of inundation to juvenile salmonid rearing, the timing of inundation should be based on a combination of their natural emigration timing and the hydrologic conditions to which these fish to have adapted.

Juvenile salmonid emigration timing is based on rotary screw trap data. The nearest trapping location to the Fremont Weir, which is the primary entrance point for downstream migration of juvenile salmon onto the Yolo Bypass (Bypass) floodplain, is at Knights Landing Rotary Screw Traps (KLRST) (Figure B-1). Two screw traps with 8-foot cones are operated in tandem at this location by the California Department of Fish and Game (Vincik pers. comm.). The traps are run continuously from October through June.

Juveniles are classified by length criteria that are widely used and were originally established by Fisher (1992). We acknowledge that size-based run identification brings with it some inherent error (Williams 2006). Because there are multiple Chinook runs, fast- or slow-growing individuals of other runs may overlap in size with winter-run. As a result, many juvenile salmon identified as winter-run or spring-run by means of the size-based criteria may actually be from a different run. The size-based criteria may be more accurate at locations upstream of the Delta, such as Knights Landing, but less reliable downstream in the Delta (Williams 2006). Nonetheless, these size-based criteria are highly relevant because they are the primary tool used to categorize Chinook salmon runs for management applications in the Central Valley.

Emigration generally subsides by mid-April. This subsidence coincides with fall-run releases from upstream hatcheries, which introduce larger hatchery fish that cannot be classified accurately by the length criteria (Vincik pers. comm.). In addition, due to the constant fractional marking of hatchery fish (rather than complete marking), hatchery fish cannot be distinguished from naturally spawned fish. Therefore, length criteria cannot be applied based on the origin of juveniles.

The water-year type is difficult to forecast prior to juvenile emigration. This makes management of Bypass inundation based on a pre-determined water-year type nearly impossible. In order to maintain adequate in-stream flows, reservoir storage, and ecological benefits from inundation on an annual basis, a team will be established to adaptively manage the inundation of the Bypass via Fremont Weir based on other variables (Section 4.1.3). The Yolo Bypass Adaptive Management Team will conduct its work in a manner similar to that of the WOMT workgroup, with the purpose of designating an appropriate timing for inundation for each year, as it relates to water-year type.

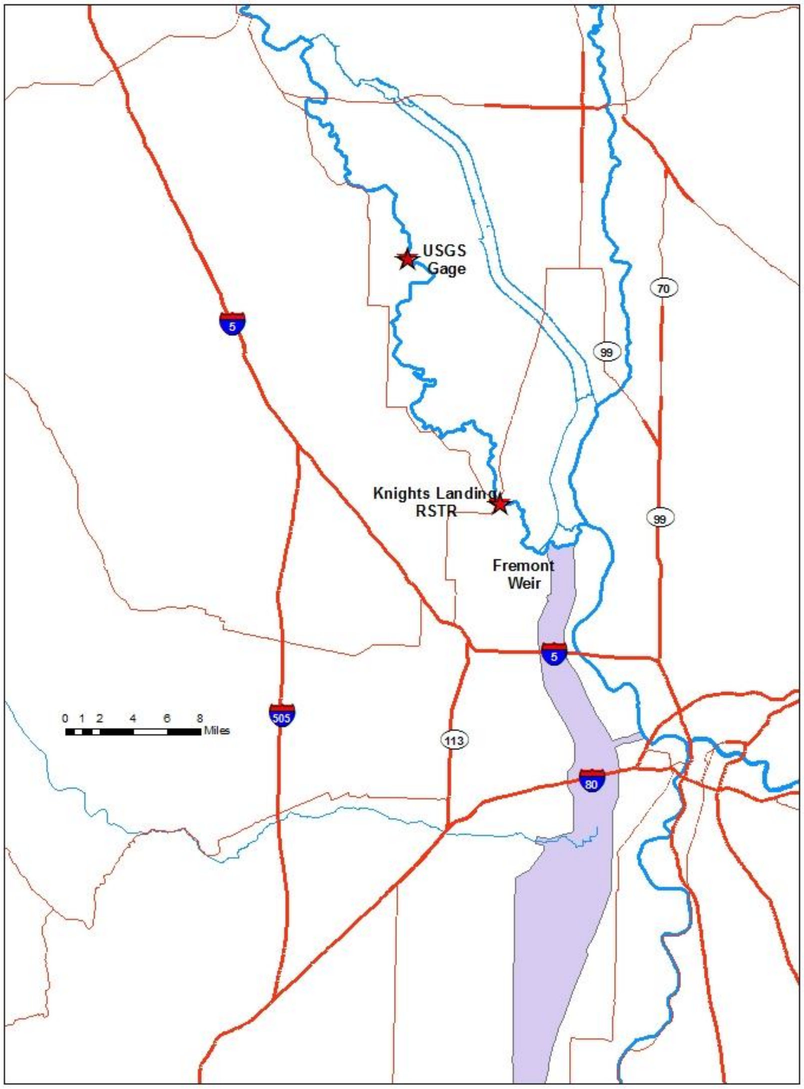


Figure B.1. Map Showing the Yolo Bypass in Purple, with the Locations of Knights Landing Rotary Screw Trap and USGS Gauge for the Sacramento River at Wilkins Slough

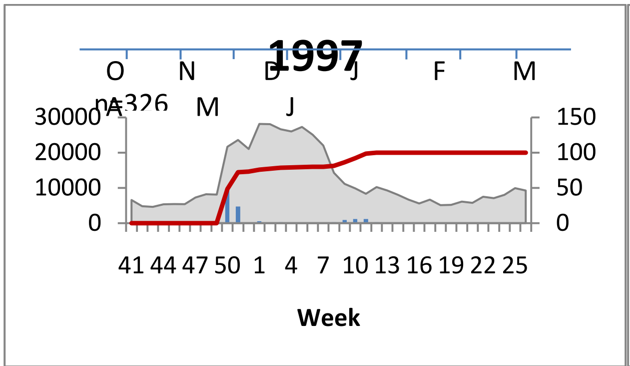
1.1.1 Winter-Run

Winter-run Chinook salmon are endemic to the Sacramento River Basin (Healey1994, Waples et al. 2004). Historically, they spawned upstream of what is now Lake Shasta Dam, relying on colder spring-fed streams during summer spawning and incubation periods (Fisher 1994). Since 1945, when they were excluded from waters upstream of Lake Shasta Dam, winter-run Chinook salmon have persisted in the main stem of the Sacramento River below the dam via coldwater releases during the summer spawning and incubation period (Yoshiyama et al. 1998). Fry emergence from the gravel takes place between July and October (Fisher 1994) and the juvenile winter-run Chinook salmon seem to exhibit a hybridization of stream and ocean life-history types (Healey 1994). Stream-type juveniles reside in-stream where they rear for a year or more, while ocean-type juveniles emigrate as sub-yearlings (Healey 1983). Screw trap data reported by NMFS (Pipal 2005) indicate that the majority of winter-run Chinook salmon migrate past

Knights Landing from December through January and continue to migrate through mid-April to early May.

Winter-run Chinook salmon begin to appear at Knights Landing around late November or early December (Pipal 2005). Recent studies have found that the early emigration pulses correlate strongly with the first flushing flow of over 15,000 cfs at the Sacramento River at Wilkins Slough gauge. Del Rosario and Redler (2010) also indicate that fish using the Bypass tend to migrate from the delta to the ocean later than those restricted to the main channel, perhaps because of the availability of additional nutrients for rearing in the Bypass. Emigrating at a larger size would increase the fish's chance of survival due to improved swimming ability and a size that would put them out of the range of gape-limited predators.

Based on these data, the maximum floodplain benefit for winter-run salmon growth would be achieved if inundation were to take place from late November through the end of April. Data also indicate that the availability of the floodplain for winter-run rearing is largely dependent on the timing of the 15,000 cfs threshold that seems to trigger the first major pulse of fish. This often occurs in late November or early December, and may occur as late as January (del Rosario and Redler 2010 [in review]). Late-season flooding during April and May would be less important in terms of passing winter-run Chinook salmon onto the floodplain, but winter-run may enjoy an increased residence time in the Bypass so late-season flooding could result in greater growth and improved chances of survival. The following figure (Figure B-2) shows weekly average flow data from Wilkins Slough (shaded) and winter-run data from the Knights Landing Rotary Screw Trap on a weekly basis (blue bars) and as a cumulative percentage (red line). Run classifications are based on length criteria prior to the April release of hatchery fish. These data are considered preliminary and are subject to revision; they are sufficient, however, to be used as a basis for run-timing conclusions.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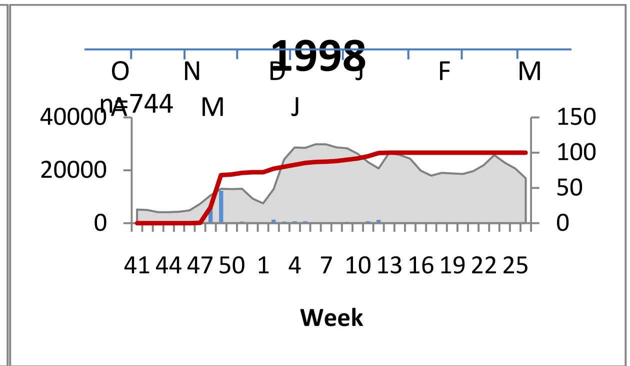
Week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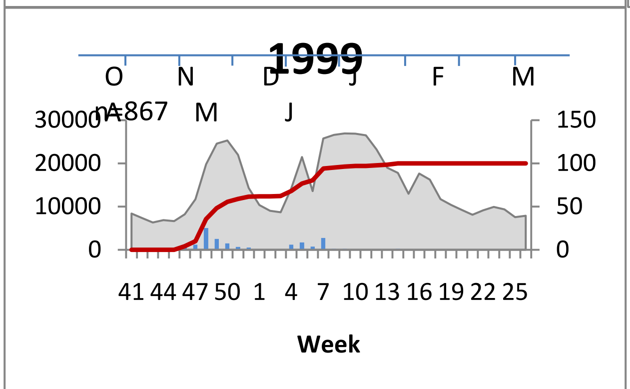
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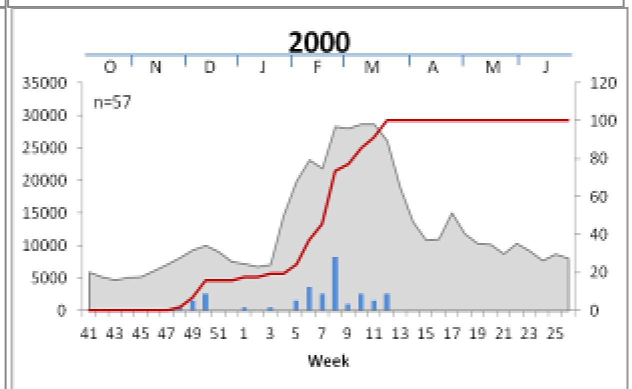
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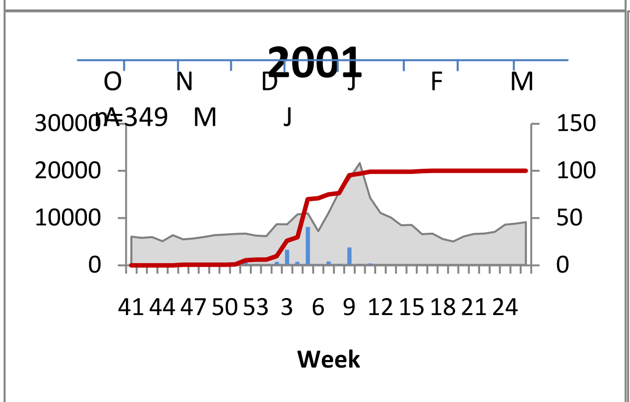
Week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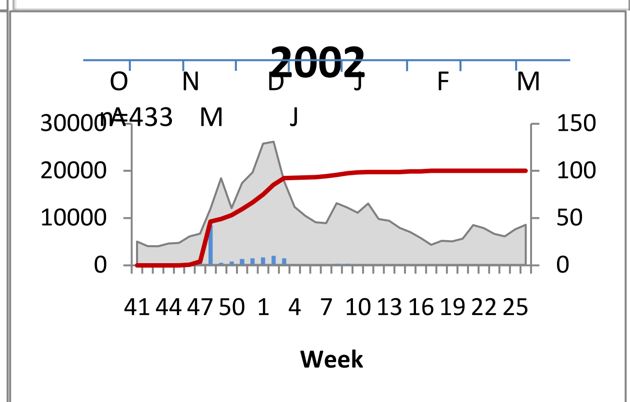
Week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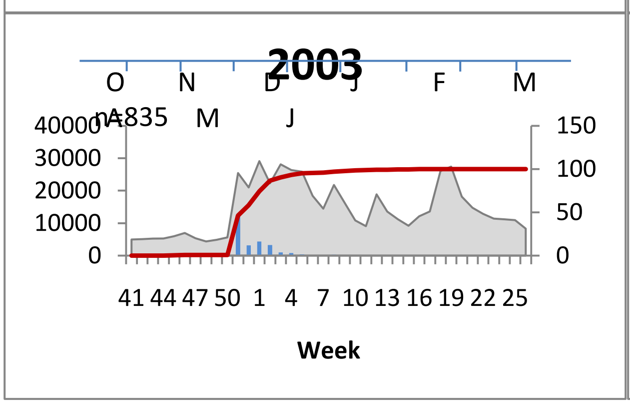
Week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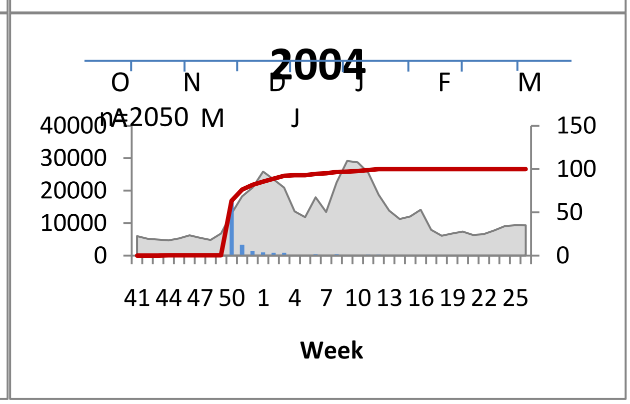
Week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Week

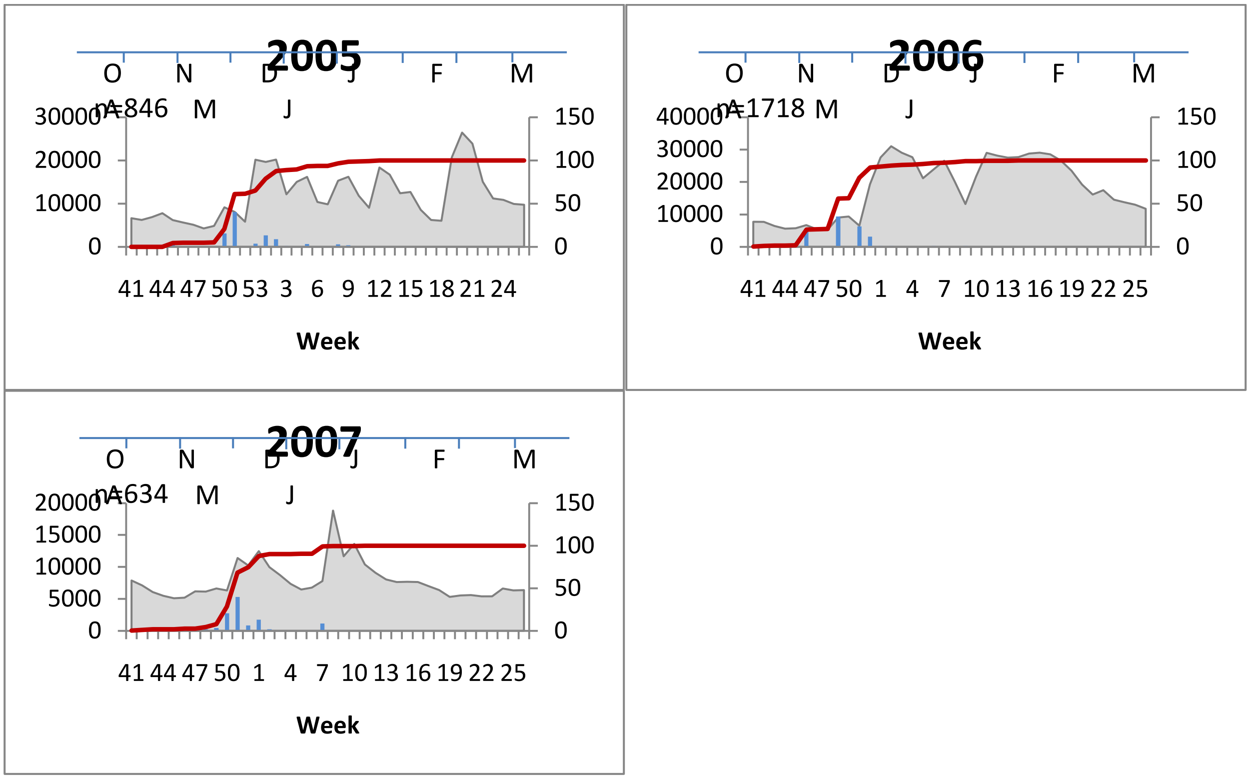


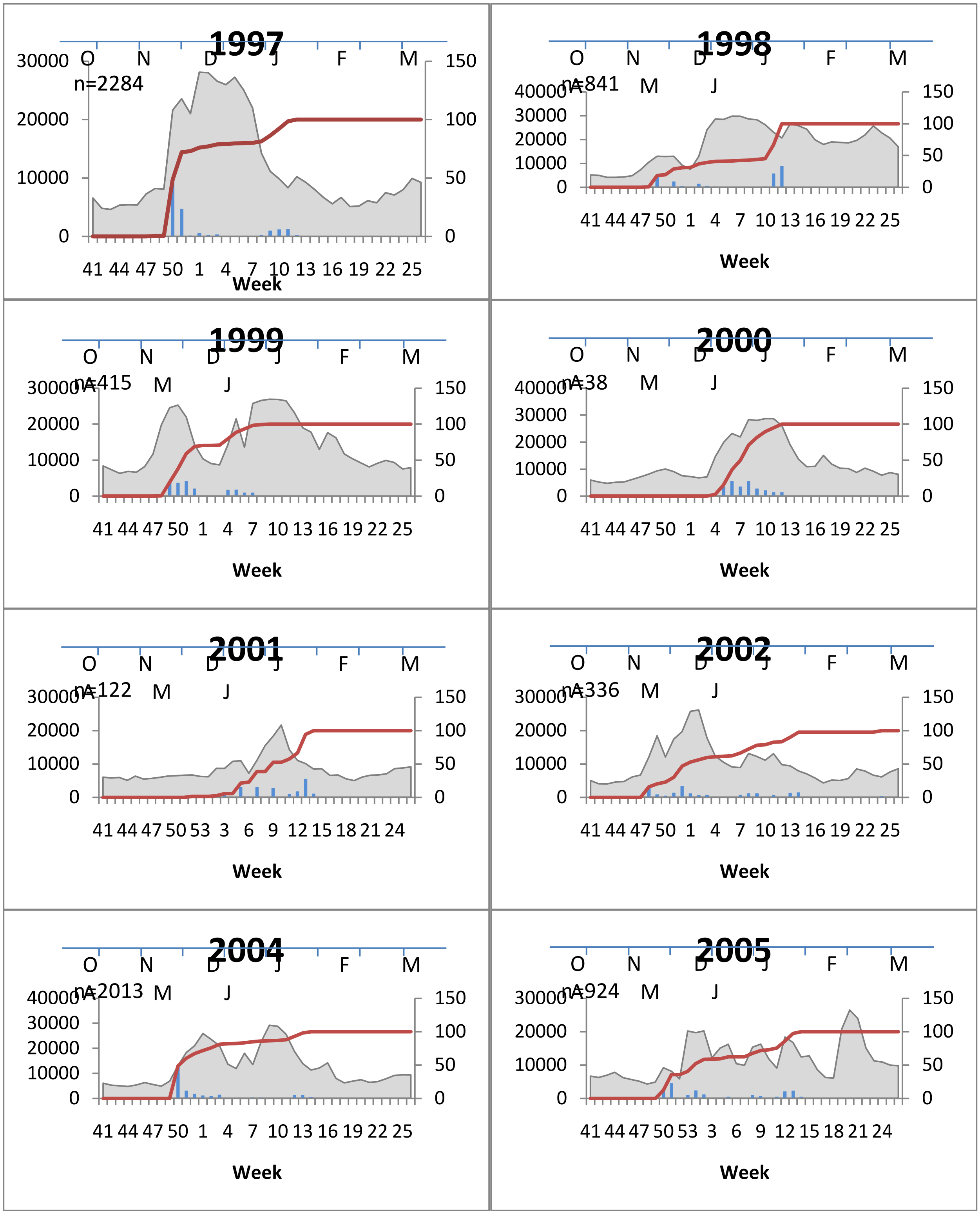
Figure B.2. Weekly Average Flow Data from Wilkins Slough (shaded) Showing Winter-Run Chinook Salmon Collected at Knights Landing Screw Trap (blue bars) and as a Cumulative Percentage

1.1.2 Spring-Run

Central Valley spring-run Chinook salmon historically spawned in a number of spring-fed and snowmelt-fed Sacramento River tributaries, primarily in the Sierra Nevada and Cascade ranges, with smaller dependent populations occurring in the Coast Range (Lindley et al. 2004). Similar to winter-run, the spring-run salmon relied on the cooler, high-elevation waters to survive the summer months. Unlike winter-run, this cold-water holding habitat was used by adult spring-run salmon that were maturing in-stream rather than by the egg and juvenile life stages. Though habitat for these fish has been reduced by more than 90% (Moyle et al. 2008), spring-run salmon persist in foothill habitats due to cold-water releases from numerous dams and in the few undammed tributaries remaining in Northern California. Central Valley spring-run Chinook salmon spawn from late August through early October, peaking in mid-September. Emergence takes place from November through March (Fisher 1994). Most Central Valley spring-run Chinook salmon express an ocean-type life history, emigrating as sub-yearlings (Waples et al. 2004). Knights Landing data from 1995 to 2004 reported by Pipal (2005) indicates that the majority of spring-run salmon pass the rotary screw traps from late November through December. More recent data through 2007 also supports this assumption (DFG *unpublished data*). The 2005 NMFS-reported data from Knights Landing also indicates a second pulse of spring-run salmon, peaking around sampling week 13 around early April. However, because this also coincides with the release of hatchery fish from Coleman National Fish Hatchery, which has taken place on week 13 (before 2000) and week 15 (after 2000) (Vincik *pers. comm.*), it appears that the second pulse seen in the Pipal (2005) data could be the result of misidentification based on the length criteria mistakenly applied to accelerated-growth hatchery juveniles. As stated within Pipal (2005), those fish that did not have a clipped adipose fin were considered to have been naturally spawned. With only constant fractional marking of hatchery fish, the unclipped portion of the fall-run could be easily misidentified as naturally spawned spring-run. Data from Pipal (2005) and data up to 2007 (DFG unpublished data) appear to indicate that spring-run salmon migrate beyond Knights Landing by no later than mid-May, and that the majority pass by the end of April.

In order to obtain maximal benefit to spring-run salmon, using this data, inundation would take place from late November and early December through mid-May. Based on professional opinion (Vincik personal communication), the emigration of naturally spawned fish is nearly complete by mid April (week 15), when hatchery releases are made. If one assumes that the final spring run to emigrate are already quite large, and do not need as much access to floodplain habitat, then inundation through April would be adequate to benefit the non-hatchery spring-run.

There is considerable overlap in the timing of emigration of juvenile winter-run and spring-run Chinook salmon, indicating that early inundation (late November into early December) may be more critical to the realization of benefits for both of these listed species than is extending the latter end of the hydrograph beyond the end of April. In addition, extending the hydrograph could lead to issues due to predation, while earlier inundation seems to favor native species (Sommer et al 2004). The following figure (Figure B-3) shows weekly average flow data from Wilkins Slough (shaded) and spring-run data from the Knights Landing Rotary Screw Trap on a weekly basis (blue bars) and as a cumulative percentage (red line). Run classifications are based on length criteria prior to the April release of hatchery fish. These data are considered preliminary and are subject to revision; they are sufficient, however, to be used as a basis for run-timing conclusions.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Week
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40000 30000 20000 10000 0
150 100 50 0
41 44 47 50 1 4 7 10 13 16 19 22 25
Week
1999
O N D J F M
n=415 A M J
30000 20000 10000 0
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41 44 47 50 1 4 7 10 13 16 19 22 25
Week
2000
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Week
2001
O N D J F M
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150 100 50 0
41 44 47 50 53 3 6 9 12 15 18 21 24
Week
2002
O N D J F M
n=336 A M J
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150 100 50 0
41 44 47 50 1 4 7 10 13 16 19 22 25
Week
2004
O N D J F M
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150 100 50 0
41 44 47 50 1 4 7 10 13 16 19 22 25
Week
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Week

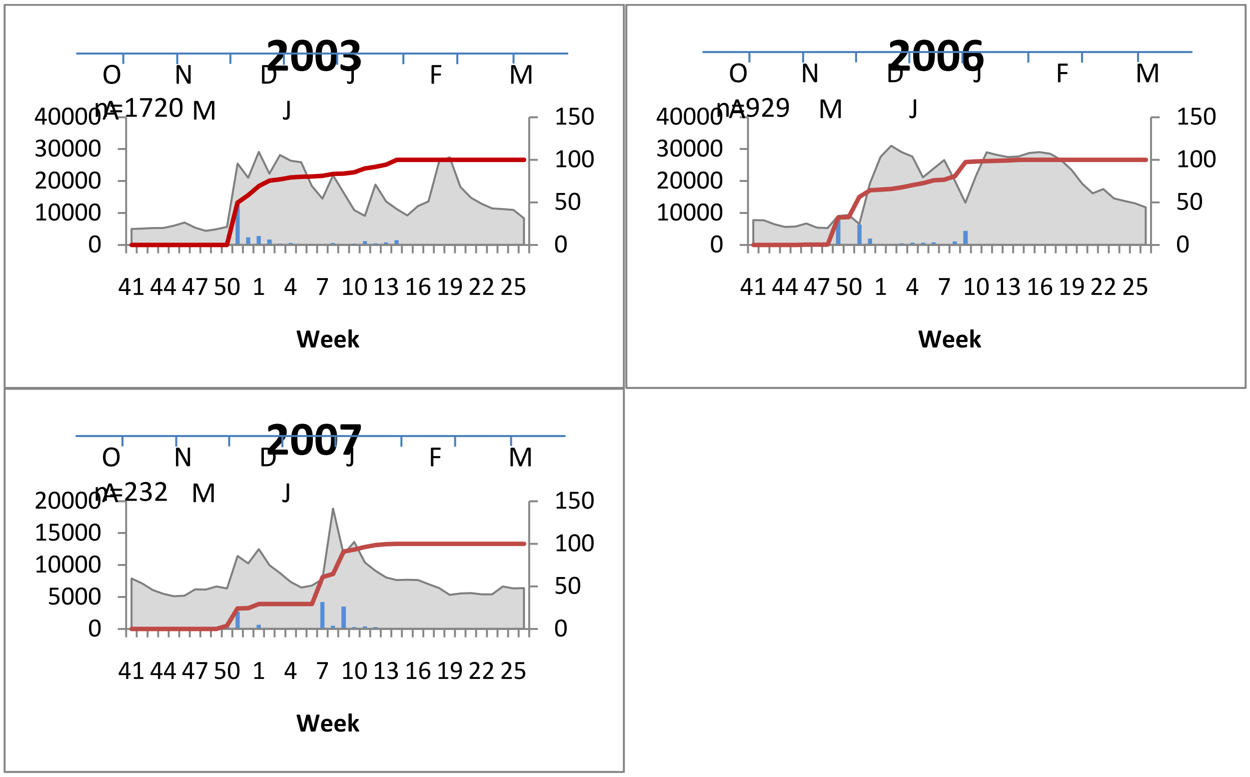
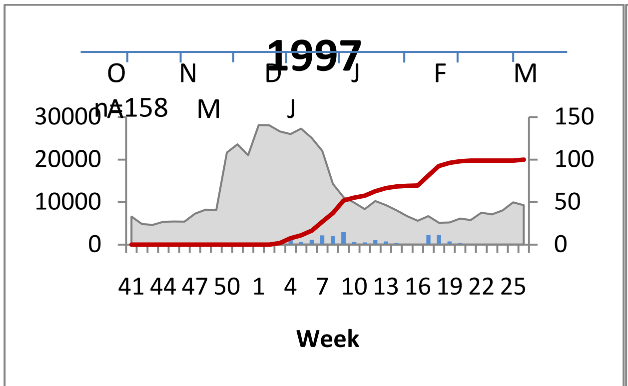


Figure B.3. Weekly Average Flow Data from Wilkins Slough (shaded) Showing Spring-Run Chinook Salmon Collected at Knights Landing Screw Trap (blue bars) and as a Cumulative Percentage (red line)

1.1.3 Steelhead

California Central Valley steelhead typically spawn in habitats similar to those of spring-run Chinook salmon. Of the two runs of steelhead (summer and winter, based on migration timing, gonad maturation, and spawning behavior), the Central Valley currently only supports a winter run (McEwan 2001). Winter-run steelhead typically migrate in fall, winter, and into early spring, and spawn relatively soon after they enter freshwater areas. Studies have indicated that extensive damming throughout the Central Valley has caused steelhead to lose perhaps more than 80% of their historic spawning habitat (Lindley et al. 2006, Yoshiyama et al. 1996). Juveniles generally spend from 1 to 3 years rearing in-stream prior to emigration. However, the genetic similarities and plasticity expressed by the resident and anadromous *O. mykiss* populations within the Central Valley make the identification of juveniles as one or the other difficult (Moyle et al. 2008). For purposes of this plan, we will assume that *O. mykiss* caught in the Knights Landing rotary screw trap are emigrating steelhead rather than resident rainbow trout. Knights Landing screw trap data indicate that the vast majority of juvenile steelhead passing Knights Landing are yearlings, not young-of-the-year (DFG *unpublished data*). Given the extensive time that they seem to spend rearing in or near their natal streams, steelhead are likely realizing less benefit to growth from the floodplain than are the Chinook salmon runs. Yearling data seems to indicate that the fish begin passing Knights Landing around late January and early February and end their passage near the end of May. The majority of fish generally pass Knights Landing by the end of April, with the emigration peaking in March (McEwan 2001, DFG unpublished data). Screw trap sampling in the Bypass confirms their presence in the Yolo (Sommer et al. 2001), but the magnitude of their use remains unclear. The benefits of floodplain rearing to juvenile steelhead are less clear than the benefits to Chinook salmon. Based on Knights landing data, the maximum beneficial inundation period that would benefit steelhead, if they use the floodplain to any great extent, would be from February through the end of May. The vast majority of fish seem to move through by the end of April (DFG *unpublished data*). However, the extensive rearing period of steelhead in fresh water seems to indicate that, historically at least, rearing has naturally taken place in mid- to high-elevation reaches where the water can maintain suitable temperatures (McEwan 2001). Due to their larger size at emigration and the later migration period, one could expect that emigrating steelhead would realize only minimal benefits to growth from the floodplain. This would also concur with Williams's (2006) observation that steelhead tend to move rapidly out of the delta beyond Chipps Island once emigration has begun. Given this information, it seems that inundation from the beginning of emigration through the mid-March peak, and a short while after, would allow the majority of steelhead to realize whatever potential benefit they might gain from the floodplain while minimizing potential negative effects from unsuitable temperatures. The following figure (Figure B-4) shows weekly average flow data from Wilkins Slough (shaded) and steelhead data from the Knights Landing Rotary Screw Trap on a weekly basis (blue bars) and as a cumulative percentage (red line). Run classifications are based on length criteria prior to the April release of hatchery fish. These data are considered preliminary and are subject to revision. These data include young-of-the-year and yearlings, due to the limited amount of data available.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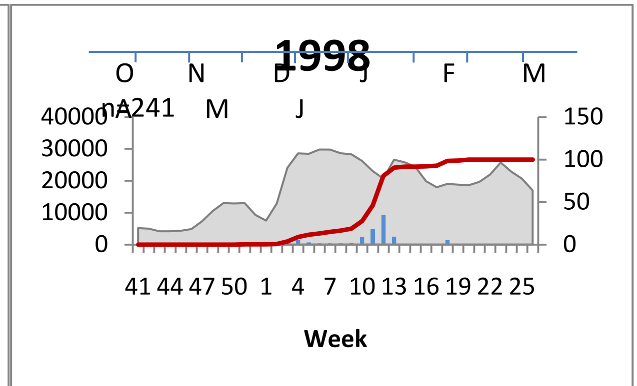
Week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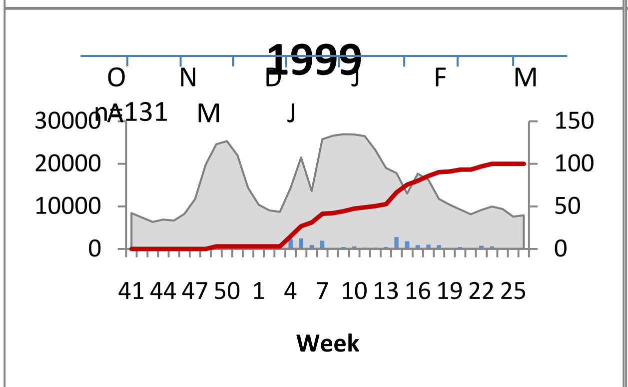
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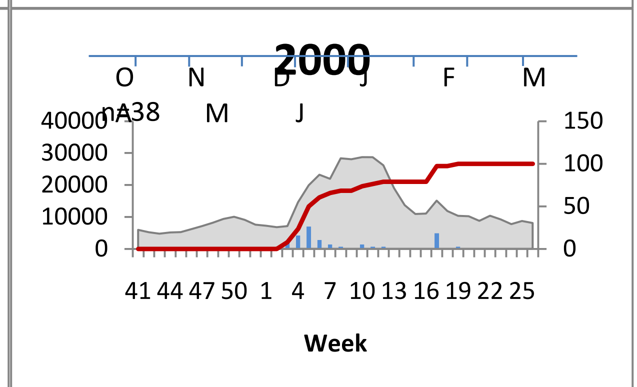
Week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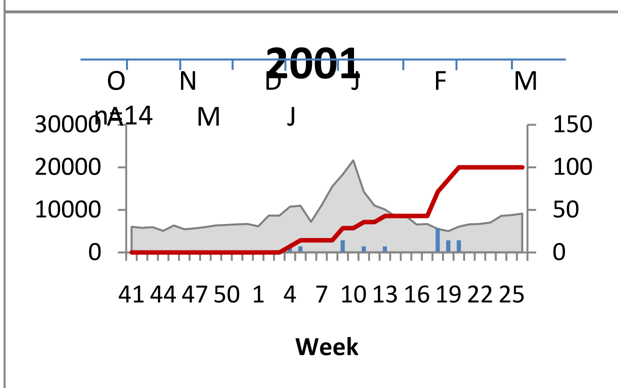
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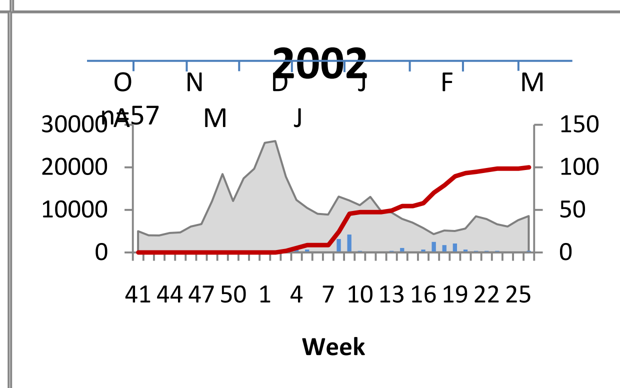
Week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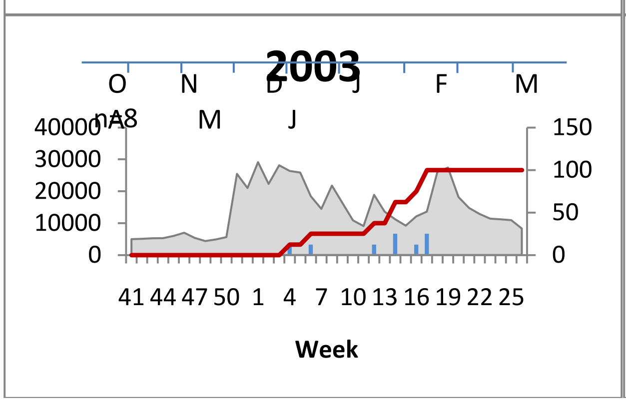
Week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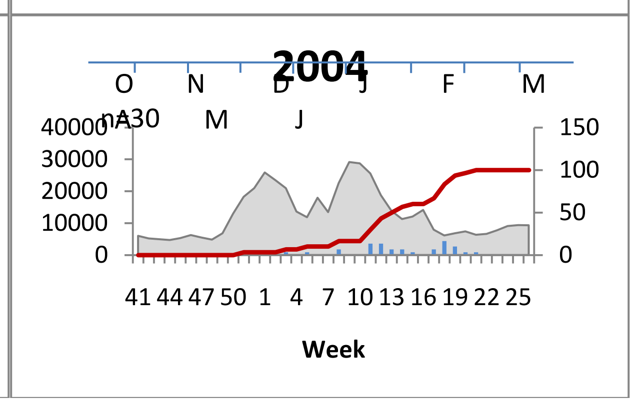
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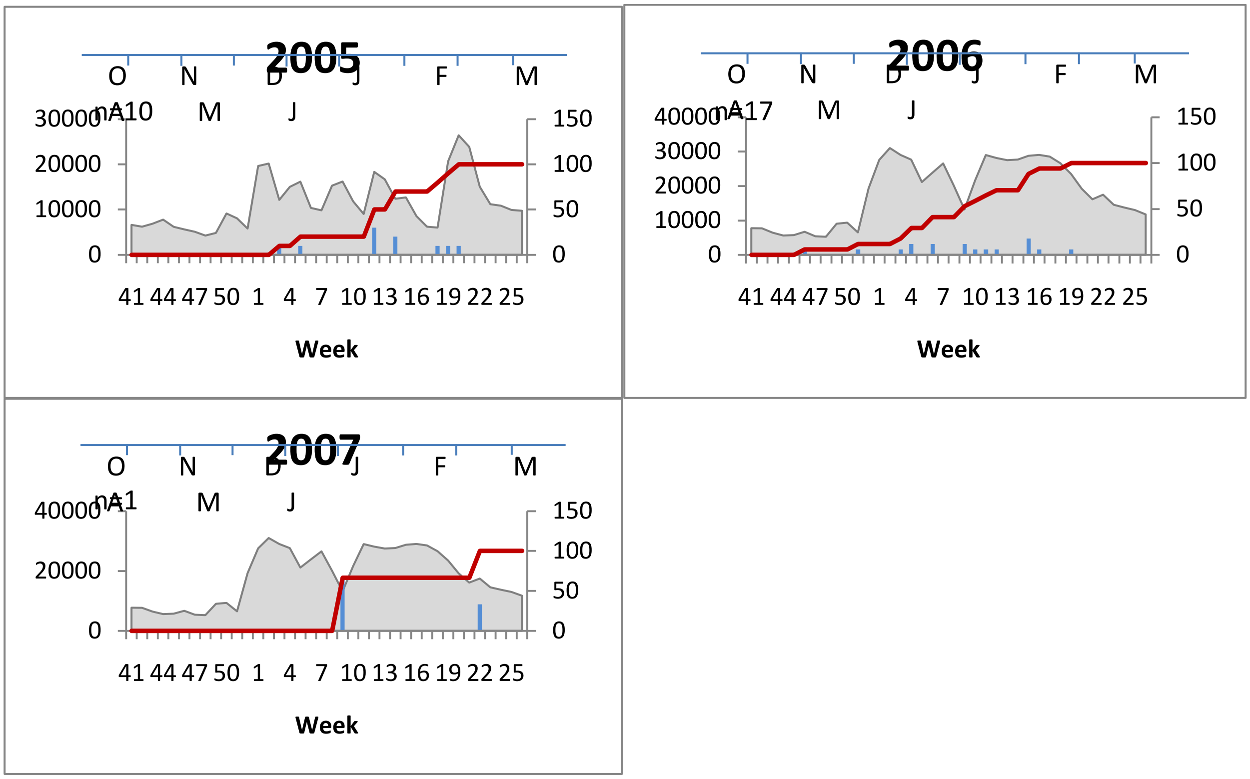

Figure B.4. Weekly Average Flow Data from Wilkins Slough (shaded) Showing Steelhead Collected at Knights Landing Screw Trap (blue bars) and as a Cumulative Percentage (red line)

1.2. Duration of Seasonal Inundation

1.2.1 Criterion

Inundation events provide a range of benefits to aquatic species that are related to the duration of the event. Generally, a longer event would allow for greater primary and secondary production, and as a result would provide greater benefits to fish species than a shorter event. Even short inundation events may provide some ecological benefits to many endangered and threatened fish species that use the Bypass (Sommer et al. 2004). Results from Benigno and Sommer (2008) suggest that it takes about 14 days for the dominant chironomid species (i.e., *Hydrobaenus saetheri*) in the Bypass to mature into the life stages that are used as a food source by the targeted fish species (Benigno and Sommer 2008). For this reason, any design will have to allow for inundation events that occur on an interval of every two out of three years and last for at least 14 days. Although detrimental effects of events of fewer than 7 days have not been quantified, we can presume that events of fewer than 7days present fewer benefits to threatened and endangered fish species than those events that last at least 7 days. Ecological benefits from flooding typically occur when floodwaters overbank Tule Canal, but the duration of overbanking of Tule Canal is not easily measured or predicted. For the purposes of this criterion, duration is defined as the time period when water from the Sacramento River is passively spilling into the Bypass. This criterion will be satisfied when the duration is at least 14 days. The time it takes for the water to drain out of the Bypass will not be used to satisfy the criterion, but would provide additional benefits as there would be more time for the targeted species to capitalize on the abundance of chironomids.

Furthermore, the draining period may be the most ecologically important time for the production of phytoplankton and zooplankton (see section on juvenile food web metrics). Currently, there is some uncertainty in how to determine the range of drainage times associated with an inundation event. For the purposes of estimation, it typically takes 11 days for water to drain below a water surface elevation of 9 feet (NAVD 88) in the Toe Drain at Lisbon Weir after flows fall below 6,000 cfs at the Woodland gauge (DWR 2011; USGS 2011). By the time the water surface falls below this stage, most water over the floodplain has drained back into Tule Canal or the Toe Drain.

1.2.2 Rationale

Recent studies in the Bypass have shown that chironomid pupae and adults are the dominant prey items found in young Chinook salmon (Sommer et al. 2001). Similarly, pupae were the dominant life stage of chironomids that were consumed by post-yearling steelhead (age 1+) in the lower Mokelumne River (Merz 2002). Researchers have observed that early instar chironomids were not consumed by steelhead, as they were too small to be either perceived or pursued (Power 1990). Based on these studies, it would be important to have flood events with a sufficient period of inundation to allow the larval chironomids to develop into pupae and adults in order to provide the life stages more readily utilized as prey by salmonids. Chironomids are a particularly important food source for juvenile Chinook salmon on seasonal floodplains during winter flood events when other food sources are not as readily available (Benigno and Sommer 2008; Sommer et al. 2001). Benigno and Sommer (2008) found that the primary source of chironomids in the Bypass (mainly *H. saetheri*) is from the emergence of inundated floodplain sediment. Partially mature larvae of this species form desiccation-resistant cocoons and are able to oversummer (aestivate) in dry floodplain sediments and then emerge to resume development once the sediment is rewetted by floodwaters (Cranston et al. 2007). Laboratory rehydration of Bypass sediments found second and third instar larvae 4 days after rewetting, fourth instar larvae after 7 days of inundation, and pupae after 14 days (Benigno and Sommer 2008).

Laboratory findings were confirmed by field sampling during a minor Bypass flood event. After 14 days of overbank flow in Tule Canal, emerging adult *H. saetheri*, with pupal exuviae attached, were abundant in floodwater drift (Benigno and Sommer 2008). The presence of pupal exuviae still attached to collected adults indicates that the adults were in the process of emerging from the floodwaters, as opposed to adults colonizing floodwaters from other sources. These results suggest that an inundation event of at least 14 days would allow chironomid larvae to develop into life stages that are used as a food source by the targeted fish species. Additionally, chironomid adults emerging from floodwaters will reproduce, which may help provide chironomid larvae for subsequent flood events.

1.2.3 Adaptive Management

There have been concerns that short flooding events may not substantially benefit the targeted species, due to our limited capability to control the rate at which water drains out of the floodplain. Short events, then, may not create substantial habitat for fish and may lead to potential strandings if the water drains out quickly (Bradford 1997; Sommer et al. 2005; Young et al. 2011). Despite these concerns, short flooding events have occurred historically and may have habitat benefits that outweigh their potential detrimental effects. For these reasons, Reclamation and DWR plan to cooperate with NMFS to determine whether the benefits from a short inundation event will outweigh the risks. As an initial management strategy, the Yolo Bypass Adaptive Management Team (YBAMT) (as described in Section 4 of the Implementation Plan) will aim to avoid short (and potentially detrimental) inundation events from Fremont Weir by forecasting events through the use of guidance plots from the California Data Exchange Center (http://cdec.water.ca.gov/guidance_plots/FRE_gp.html). Events can be forecast as far as 5 to 7 days in advance, giving YBAMT enough time to avoid flooding events shorter than 7 days when operating on the 14-day criterion. The current method used for forecasting, however, cannot reliably predict whether an event will last as long as 14 days. YBAMT should therefore develop a new forecasting method that has a higher rate of accuracy than the current method when used to predict events that last for at least 14 days. In addition, as the risks and benefits from short events are better quantified YBAMT will need to further evaluate the initial management strategy of avoiding short flooding events.

Moreover, YBAMT will have to review the 14-day criterion on a real-time basis to determine whether the current duration criterion should be shortened or extended, by reviewing current, ongoing, or special studies that are aimed at answering management questions. The 14-day criterion is primarily based on the life cycle of chironomids. However, the information used to develop the current duration criterion may not reflect temporal patterns, as the dominant chironomid taxa may change after floodplain inundation (Benigno and Sommer 2008; Grosholz and Gallo 2006). In addition, the field observations from Benigno and Sommer (2008) were based solely on tributary input. Different water-years will have different hydrologic conditions that will in turn lead to different levels of invertebrate drift abundance (Sommer et al. 2004). Lastly, Benigno and Sommer’s (2008) observation that it took about 14 days for chironomids to reach the pupa stage was made under laboratory conditions and may not reflet the timing under actual field conditions in the Bypass. As a result, YBAMT will be encouraged to review other metrics that they may want to incorporate into the duration criterion as new research and information become available. This will be particularly important since the study objective from Benigno and Sommer (2008) was not aimed at answering the question about the life cycle of chironomids.

1.3 Frequency

1.3.1 Criterion

The main point of entry for floodwaters into the Bypass is at the Fremont Weir. Fremont Weir is a passive structure. When the Sacramento River stage exceeds the crest elevation of Fremont Weir, approximately 32.8 feet (NAVD), Sacramento River floodwaters enter the Bypass. Overtopping events leading to at least 14 days of downstream floodplain inundation only occurred in approximately 10 out of 24 years in the years analyzed (DWR 2011a). One way to increase the frequency of these inundation events would be to create a gated channel or “notch” in the weir that would allow Sacramento River water to spill onto the Bypass at a lower Sacramento River stage (see Appendix C).

Even with a gated channel that allowed inflow from the Sacramento River at a lower stage, it would not always be possible to achieve floodplain inundation by gravity flow because the

Sacramento River stage is often lower than the existing range of floodplain elevations. There are limits on the frequency that the bypass can be inundated, given the physical relationship of land to water, and water management in upstream reservoirs. The timing of inundations will of necessity be based on the frequency of favorable hydrologic conditions. These conditions most commonly occur in years classified as below normal, above normal, and wet in the Sacramento Valley.

For the recording period from 1906 to 2010, below normal, above normal, and wet water years made up 66% of the water years, while critical and dry water years made up 34% (Table B.1; DWR 2011b). This is similar to the distribution of water years in which Fremont Weir does, or does not overtop**.** Based on past hydrological data, our targeted frequency will be approximately 2 out of 3 years when favorable hydrological conditions allow.

Table B.1. Occurrence of Water Year Types in the Sacramento Valley for Water Years 1906 to 2010 (DWR 2011b)

Year type	Number of occurrences	Percentage of occurrence
Critical	14	13.33
Dry	22	20.95
Below normal	19	18.10
Above normal	15	14.29
Wet	35	33.33

1.3.2 Adaptive Management

In the future, the YBAMT, responsible for providing recommendations on Yolo Bypass operations, should take into consideration the role climate change may have on the rate of occurrence for the different water year types. Currently, the wet water year is the most frequent water year type and the critical water year is the least frequent (Table B.1; DWR 2011a). Climate change may alter the patterns of precipitation and runoff in California (Dettinger and Cayan 1995; Singer 2007) and thus alter the frequency of the different water year types in the Sacramento Valley. To illustrate this point, Van Rheenen et al. (2004) found that the critical water year would become the most frequent water year type when comparing three different future scenario models (2010 to 2039, 2040 to 2069, and 2070 to 2098) to the 1995-to-2099 control run that was initialized to conditions from 1995. The future scenario models also reduced the occurrence of wet water years by approximately 10 to 20% (Van Rheenen et al. 2004). Because of climate change, YBAMT should look into new methods for predicting the frequency of floodplain inundation events in the Yolo Bypass. One possible alternative is to use the California Water Resources Simulation Model II (CalSim II), which has been used in recent studies to evaluate the impacts of climate change on the water supply in California (Brekke et al. 2004; USBR 2008; Vicuña 2006).

1.4. Hydrology of Inundation Flows

During development of this plan, technical reviewers have expressed concern that a rapid ramping rate could have the potential to lead to stranding for various fish species when flows would recede. A number of sources in the literature such as DWR 2007; Hunter 1992; Young et al. 2011 have discussed stranding in relationship to ramping rates. To address these concerns, the notch design should be able to extend the descending limb of a natural hydrograph, and thus slow down ramping rates. A notch lower than the existing weir elevation would afford an extension of the descending limb of the hydrograph when compared to current conditions and would allow salmonids more time to navigate to Tule Canal and out of the floodplain than they have under current conditions. However, few studies addressed the issue of suggested ramping rates for salmonids in floodplains. In one study, Sommer et al. (2005) observed that ramping rates of 1 cm/hr or less allowed juvenile Chinook salmon and other fish to emigrate off the floodplain during drainage, but the authors did not quantify suggested ramping rates for their study period from 1998 to 2000.

For a more quantitative estimate, YBAMT can refer to the ramping requirements (Table B.2) used in the Oroville facilities' relicensing (FERC Project No. 2100) for the low flow channel of the Feather River (DWR 2007). These ramping requirements were for periods outside of the flood control operations, or during the flood control operations if possible. However, the hydrologic characteristics of the floodplain differ from those of the Feather River. Monitoring of ramping rates in the Bypass floodplain can provide opportunities to define suggested ramping rates for salmonids there.

Table B.2. Lower Feather River Ramping Rates (from DWR 2007)

Releases to the Feather River low flow channel (cfs)	Rate of decreases (cfs)
5,000 to 3,501	1,000 per 24 hours
3,500 to 2,501	500 per 24 hours
2,500 to 600	300 per 24 hours

Furthermore, extension of the descending limb of a natural hydrograph could help salmonids avoid the impacts of a sharp drop in dissolved oxygen. Low dissolved oxygen levels often result from long periods of inundation in floodplain habitats (Henning et al. 2006, 2007; Mitsch and Gosselink 1993). Extension of the descending limb of a natural hydrograph would allow fish to cue on the declining dissolved oxygen levels and emigrate off the floodplain. For example, Henning et al. (2006, 2007) found that Coho salmon on the Chehalis River floodplain in Washington were able to emigrate off the floodplain if the enhanced emergent wetlands had control structures that contained an outlet for emigration when dissolved oxygen levels began to decline. Lastly, flows released from the notch design must be able to drain into a reliable emigration route so the salmonids can navigate away from the Bypass floodplain when necessary. The lack of a reliable emigration route could lead to fish stranding even if ramping rates were slowed down to better suit salmonids. Consequently, the proposed notch should have some defined channel downstream connecting it to Tule Canal. A defined channel would offer passage out of the Bypass floodplain and into the Sacramento–San Joaquin Delta.

1.5. Evaluation Criteria

1.5.1 Biological Criteria for Evaluating Floodplain Inundation Options

Water sources

The proposed option should provide the ability to deliver fish from all tributaries that supply fish during a natural spill into the Yolo Bypass and should provide source signatures that limit the straying of adult migrants from their natal spawning areas.

Water quality

The proposed option should avoid poor water quality (e.g., contaminants, temperature, dissolved oxygen) to the extent feasible. Source water should be of high quality. The floodplain area utilized in the proposed option should not have soil contaminant characteristics that are harmful to covered species. The proposed option should provide the ability to manage water quality in the floodplain habitat.

Juvenile capture

The proposed option should be effective in bringing juvenile fish onto the floodplain. The proposed option should passively bring fish onto the floodplain. The proposed option should not require intervention to bring fish onto the floodplain.

Habitat connectivity

The proposed option should provide floodplain habitat with connectivity to the entire floodplain footprint. The proposed option should provide floodplain habitat connectivity to the "deep fish-passage channel" to facilitate upstream adult fish passage.

Drainage connectivity

The proposed option should provide a floodplain habitat that adequately drains or maintains flow-through conditions, to limit stranding.

Habitat mosaic

The proposed area of floodplain inundation should be heterogeneous. The proposed option's food web productivity should be similar to the food web productivity of a natural spill over the Fremont Weir. The proposed option should provide adequate refugia. The duration of the proposed inundation footprint should be long enough to benefit Sacramento River winter-run Chinook salmon, spring-run Chinook salmon, and California Central Valley steelhead, if possible.

Predator exposure

The proposed option should address and minimize predation impacts. The proposed option should limit predation upon targeted species as they emigrate through systems such as canals and structures. The proposed option should avoid the creation of year-round refugia for predators. The proposed option should prevent or limit the potential for increased predator density, as compared to a natural spill over the Fremont Weir. The proposed option should avoid or limit human-created "bottlenecks" that may lead to an increased density of targeted species and predators. The proposed option should not unduly expose targeted species to predation.

2. Fish Passage

Unfortunately, literature on run-specific migration timing through the Sacramento–San Joaquin River Delta is sparse. Much of the data collected on migration timing for anadromous fish in California's Central Valley represents fish arrival in the upper watersheds (Hallock and Fisher 1985; Johnson et al. 2010); residence time in the delta prior to their arrival in natal streams is poorly documented. Data are available for the Columbia River in Oregon on migration rates for spring-run Chinook salmon. The data are collected to inform dam operations in the Columbia River Watershed (Keefer et al. 2004). Given the similarities between spring-run timing in the Columbia River and in the Sacramento River and the scarcity of regionally specific data, inferences can be drawn regarding migration rates based on the Oregon data to better estimate migration timing through the Bypass.

Perhaps even less well understood are the migration timing and presence of green sturgeon in the Bypass. At the very least, the recent stranding surveys show us that green sturgeon are migrating through the Bypass in spring (and probably late winter, too). However, with increased tagging efforts and use of the Vemco VR2 array (Heublein et al. 2009), some of this uncertainty will likely diminish with regard to this species. While currently available data indicate that fish passage can be improved, an adaptive system for management of the passage structure will be crucial as new, local migration data become available.

2.1 Winter Run

Data related to adult winter-run Chinook salmon usage of the Bypass are poorly documented and scientifically imprecise. However, more general information on run timing is available. Yoshiyama et al. (1998) cite winter-run migration as ranging from December through July with a peak in March. Similar timing is also noted by Myers et al. (1998), and this correlates well with data collected from 1970 to 1981 at Red Bluff Diversion Dam (RBDD) and analyzed by Hallock and Fisher (1985). This run timing information is useful, though it is important to note that Red Bluff Diversion Dam is approximately 256 river kilometers north of the Fremont Weir. This substantial distance means that the fish would be passing Fremont Weir quite awhile before the migration window shown by these data. Difficulties arise when one tries to determine the assumptions one must make in order to estimate the migration timing appropriate for winter-run Chinook salmon passage at Fremont Weir. No studies exist that quantify the migration rate of adult winter-run Chinook salmon through the Delta and the Sacramento River. While the winter run is temporally distinct from the spring run, the two runs share some similarities in migration strategy. Winter-run Chinook salmon enter the system immature, hold for several months in fresh water, and spawn months after they enter the river (Moyle 2002). Given that migration strategies are similar for the two runs, if one were to assume that winter-run migration rates are similar to those observed for spring-run Chinook salmon (roughly 10 to 30 km per day [Keifer et al. 2004]), that would place winter-run Chinook salmon in the vicinity of Fremont Weir approximately 1 to 3 weeks prior to their arrival at Red Bluff Diversion Dam. Given the small percentage of the fish that pass in June and later in the year (Hallock and Fisher 1985), this seems to indicate that the majority of winter-run salmon would have gone past Fremont Weir before mid-May. It would also indicate that the first winter-run Chinook salmon entering the system could be passing around mid-November. A fish-passage system for winter-run Chinook salmon based on these assumptions would have to be operable from February through April if it were to capture the peak of the winter-run migration (Hallock and Fisher 1985) and it would have to be operable between mid-November and the end of May, if possible, to ensure passage of nearly all adult winter-run Chinook salmon.

2.2 Spring Run

More data are available on spring-run Chinook salmon migration timing than on winter-run, but most of the available spring-run migration timing data are for natal streams rather than for the Delta or, more specifically, for the Fremont Weir locale. The California Department of Fish and Game (DFG 1998) estimates that, based on their dates of arrival in their natal habitats, spring-run Chinook salmon leave the ocean around January or February to begin their migration. Most sources note a general peak for migration in the natal tributaries around May or June (DFG 1998; NMFS 2009), with some sources asserting that spring-run migration extends through September (NMFS 2009; Yoshiyama et al. 1998), assertions that may be based in large part on the basin-wide scope of these spring-run migration times, which means that they include Feather River salmon that have been hybridized due to historical hatchery practices with fall-run salmon (Lindley et al. 2004; Williams 2006). It is highly probable that this has led to alterations from the fish's natural migration timing patterns.

Mill Creek data seem to indicate that spring-run migration timing is considerably earlier for tributaries north of the Fremont Weir. In 2006, 2008, and 2010, hydroacoustic and video monitoring were conducted in Mill Creek. The migration peak there occurred in mid to late April (April 24, April 14, and April 17, respectively), with most of the fish passing by the end of April (Johnson et al. 2006; Johnson et al. 2008; Johnson et al. 2010). Using the migration rates cited above from Keifer et al. (2004) and back-calculating from Mill Creek, these fish would likely also have peaked approximately 1 to 3 weeks earlier than this around Fremont Weir. Johnson et al. (2010) also observed that peak migration seemed to correspond with water year type, with dry years having an earlier peak in migration and wet years having a later peak, but more data are necessary before we can make any conclusive determination about this. Given what information we have, though, it appears that it would be beneficial to adaptively manage the fish-passage structure based on water year type, making modifications to operation as data become available. A fish passage system that targets the peak of spring-run Chinook salmon based on the data and assumptions described above would need to be operable from March through April. If it were possible (based on river flows), the provision of passage from January through the end of April would cover most of the spring run Chinook salmon migration period. For an added precaution, if flows allow, operations could be extended into mid to late May, ensuring the passage of nearly all adult spring-run fish. This would also add the flexibility of adaptively managing the fish passage system according to water year type if the data should continue to indicate later peaks in wet years.

2.3 Steelhead

Most of the available data and literature on adult steelhead migration are historical, but they are still useful as a basis for establishing appropriate timing windows and operational criteria for adult steelhead passage at Fremont Weir. The most pertinent historical run timing information available for steelhead may be that of Hallock (1957, 1989), which was collected by means of a large wire fyke net set very near the east side of Fremont Weir.

According to historical data from Hallock (1957, 1989), steelhead migration in the vicinity of Fremont Weir occurred primarily from August through November, with a peak around late September and early October. Busby et al. (1996) stated that steelhead migration generally encompasses the months from August through April. That study was a basin-wide assessment that included migration into the natal tributaries, so it probably covered a time span beyond the months when most migration occurs near the Fremont Weir. Any attempt to quantify migration peaks in those natal tributaries is further confounded by the lack of any means to distinguish the resident Oncorhynchus mykiss that are migrating up and down within the same tributary from the truly anadromous O. mykiss individuals that have migrated in from the sea.

Current data from Red Bluff Diversion Dam (McEwan 2001; Moyle et al. 2008) corroborates the assumption that run timing is similar today, when we consider that there is approximately 1 week's lag between steelhead arrival at Fremont Weir and their arrival at Red Bluff Diversion Dam (Hallock 1989). This amount of lag time is typical of the winter-run steelhead phenotype, the only phenotype currently known to exist within the Central Valley (McEwan 2001, Moyle et al. 2008).

Based on this information, it appears that most steelhead migrate during a time of year when the floodplain would not historically have been inundated (August through November), since fall is typically a low-flow period for the Sacramento River, with much smaller numbers migrating throughout the remainder of the year (McEwan 2001). Even with diversions that route water from the Sacramento River through the Yolo Bypass during this period (i.e., the Knights Landing Ridge Cut), one would expect the steelhead to key instead on the much greater flows of the Sacramento River mainstem.

All of this means that the stranding risk is lower for adult steelhead than for the other targeted species under this plan. However, if one were to operate a passage structure for steelhead during the migration window, it would need to accommodate flows that are present for the August-through-November period and to achieve connectivity with the Tule Canal, which would likely be the only passage during this low-flow period. It is feasible that a new fish-passage structure could allow passage in November during flood or high-flow conditions, but it is not feasible that such a structure could provide passage under summer and early fall low-flow conditions, when no floodplain passage may historically have been present.

Current researchers are using methods similar to those employed by Hallock (1957) to attempt to improve our understanding of steelhead migration in the Sacramento River Basin, working under a Comprehensive Monitoring Plan for Steelhead in the California Central Valley (Eilers et al. 2010). As new data from this monitoring plan become available, they should be taken into account when making management decisions for any fish-passage structure that is built as part of this plan.

2.4 Green Sturgeon

Of the species targeted under this plan, the green sturgeon's use of the Bypass is the least understood. The sampling methods that have been employed to date in the Yolo Bypass do not reliably capture green sturgeon (DWR, unpublished data). Furthermore, the green sturgeon population has remained relatively small, which makes sampling difficult. Green sturgeon have less commercial value than salmon or steelhead (Kelly et al. 2007), and as a result there are fewer avenues available for collecting data (e.g., commercial or recreational harvest data).

However, since their listing, some migration and habitat use data have been collected and analyzed, and further telemetry studies (such as those using the Vemco VR2 array) will likely yield data that will better inform the decisions that must be based on migration timing criteria. Tagging data presented by Heublein et al. (2009) seem to indicate that, based on data from fish tagged in 2005 and 2006, green sturgeon begin migrating around late February and into March. All 12 tagged fish passed receivers near Knights Landing, the station nearest to the Fremont Weir, between March and mid-May. Of the 12 fish, all but two seemed to migrate beyond Knights Landing by mid-April and five did not migrate upstream beyond the Red Bluff Diversion Dam (RBDD). Interestingly, the five fish that were not detected above the Red Bluff Diversion Dam appeared to begin their downstream migration earlier than the others, around the beginning of June. Data in Heublein et al. (2009) also appear to indicate that fish tend to take more time migrating upstream and then rapidly migrate back downstream once they turn back toward the ocean. This is likely facilitated by their ability to adjust quickly to differences in water salinity (Kelly et al. 2007).

Downstream migration generally takes place beginning in summer and continuing into the fall (data from Heublein et al. 2009). Studies conducted by the U.S. Fish and Wildlife Service (USFWS) from 2008 through 2010 in the upper Sacramento River indicate that spawn timing (back-calculated from egg development) is well within this migratory window (Poytress et al. 2009, 2010, 2011).

There has been some concern expressed that "spatial memory" (Lindley et al. 2011) may prompt green sturgeon to continue to use poor-quality habitat areas. Lindley et al. (2011) also note that this phenomenon could cause a substantial delay between habitat degradation and a response on the part of the sturgeon population as well. This adds further weight to the point that, if the Bypass does not provide appropriate habitat for green sturgeon, we must provide them with adequate passage out of the Bypass, since the fish may continue to enter the Bypass regardless of habitat quality.

According to the tracking data cited above, passage should be provided from February through April in order to cover the presumed migration peak and should then continue into early May to ensure that most upstream migrants are not delayed or stranded within the Bypass. Stranding events in the beginning of April, 2011, at Fremont Weir also support these assumptions about the migration timing window.

Given the timing of downstream migration for adult green sturgeon (which occurs during a period when the Bypass is less likely to be inundated due to lower river flows), it is unlikely that passage would need to be provided during those periods for out migrants. In addition, it is unlikely, given the speed with which these fish migrate downstream, that they would deviate much from the main channel before reaching Rio Vista (Seesholtz, personal communication), even if that meant they would be swimming higher in the water column during directional movement (Kelly et al. 2007).

2.5 Adult Upstream Fish Passage Improvements at Fremont Weir

A facility's ability to provide fish passage from the Bypass past Fremont Weir and into the Sacramento River using gravity flow is limited by the water surface elevation (WSE) of the Sacramento River at Fremont Weir and the elevations in Tule Canal south of Fremont Weir. The conditions at Fremont Weir can be atypical of most fish passage projects at weirs, which generally provide a migration corridor from the lower water surface elevations downstream to the higher elevations upstream. While these conditions are usually present at Fremont Weir, the reverse conditions can also occur, with a higher downstream WSE and a lower upstream WSE.

It is equally important to note the weir structure (Figure B.5 – light blue shading) ranges in width from 25 to 35 feet. However, the Weir's crest elevation is roughly equal to the upstream ground elevation, which combines with the weir to form a barrier ranging from 150 to 700 feet wide between the Sacramento River and the Fremont Weir Wildlife Area (Figure B.5 – dark blue shading). Figure B.5 highlights the weir and surrounding topography which block fish passage under most conditions.

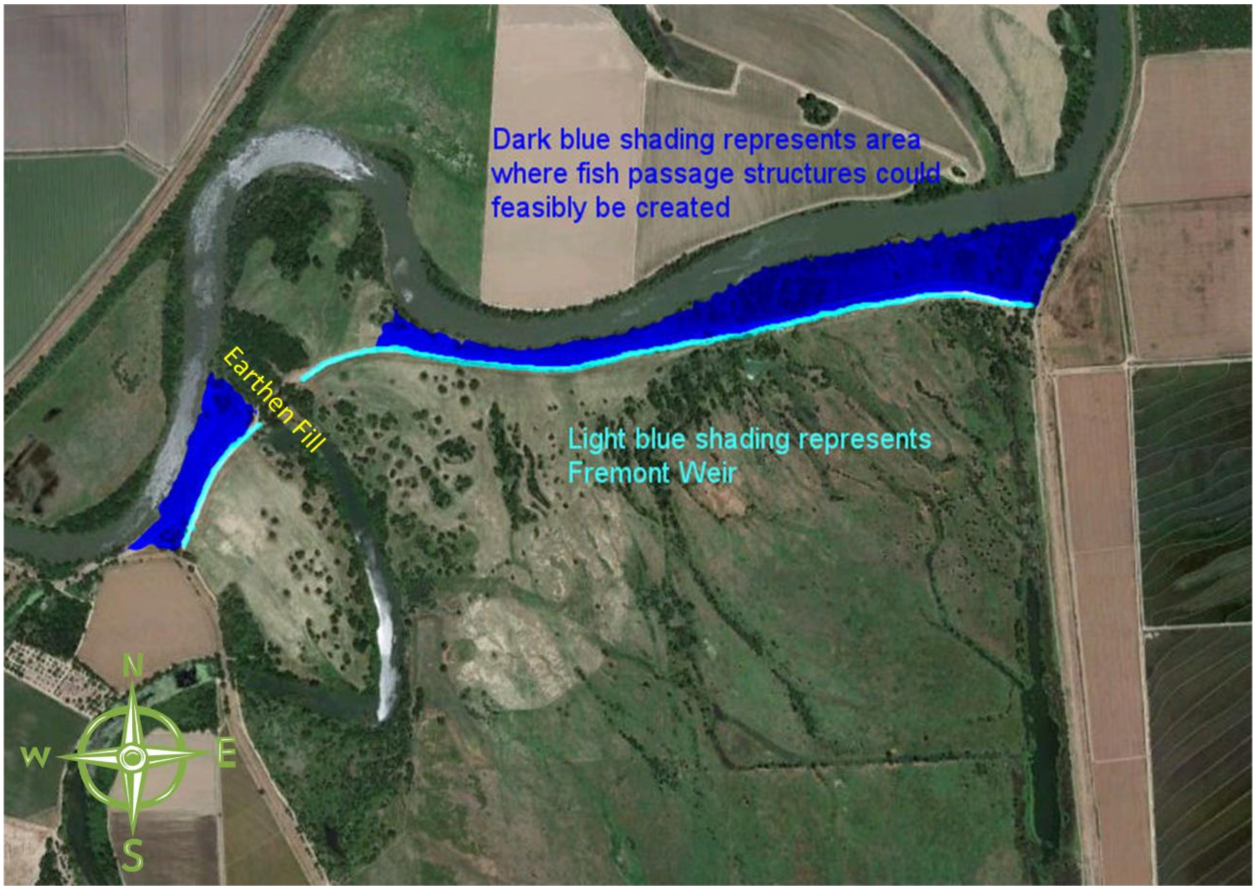

Figure B.5. Northern Section of Yolo Bypass Illustrating Fish Passage Constraints

It may not be feasible or biologically necessary to provide fish passage year round. Constructing a channel to pass fish when the Sacramento River stage is below 16 feet would most likely require extensive grading of the Tule Pond and Tule Canal. This intensive excavation would in turn lengthen the fish passage facility and perhaps reduce its effectiveness because the excavated area would create longer stretches of lower velocities during higher flow times, which would results in less keying for fishes downstream and more sedimentation. Increased sedimentation would also require increased maintenance of the facility. In contrast, designing facilities to pass fish at higher water surface elevations would result in greater passage efficiency by avoiding the aforementioned issues, but would reduce the frequency of times when fish passage would be available. Fremont Weir is approximately 1.8 miles long and is bisected at the western portion by earthen fill that is slightly higher than the weir. This relatively long weir will require multiple fish passage facilities to provide the most reliable fish passage. The eastern section of the weir would be the primary corridor for fish passage since it is just upstream of the Tule Canal, which holds water most of the time. Various scour channels extend south of Fremont Weir and continue east towards the Tule Canal, and they intermittently provide a migration corridor. Fish passage facilities could extend passage from these scoured channels through Fremont Weir at higher flows. These facilities would not need to be excavated as deep as a facility on the eastern edge of the weir. Based on Lidar imagery, we expect that fish can only migrate into the western portion of the weir, along the western edge, during high flows. The existing limited access to the western portion is due to the increased invert elevations of scoured channels when compared to channels on the eastern section of the Yolo Bypass. (Figure B.6).

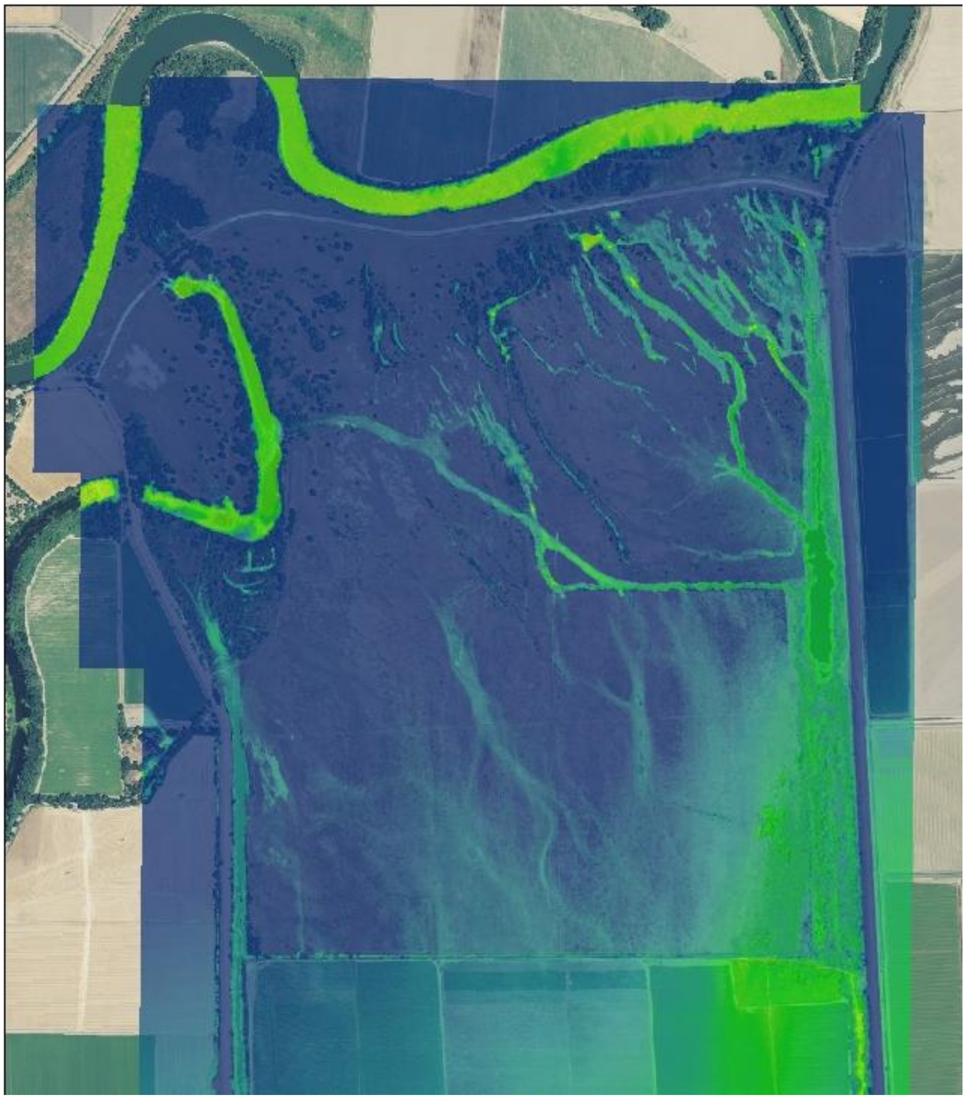

Figure B.6. DEM Based on 2005 Lidar Imagery Showing Scour Channels and Tule Canal Downstream of Fremont Weir

Irregularities in the splash basin and the section of earthen fill along the western side of the weir create stranded pools of water within the splash basin as floodwaters recede. The western portion of the splash basin is segregated by the earthen fill and becomes disconnected from the rest of the weir. Due to irregularities in the splash basin east of the earthen fill, isolated pools can also form at various places along this expanse. These isolated pools prevent fish from moving toward the current fish ladder from other sections of the weir. Even in areas where the current ladder is accessible, low attraction flows and the physical configuration may make passage through the ladder less desirable to target species (i.e., sturgeon). Once the water surface elevation drops below the downstream rim of the splash basin, these fish become stranded within the basin. Target species that have been witnessed in the splash basin include adult green sturgeon, adult Chinook salmon (run unknown), and steelhead smolts. Provision of reliable fish passage across the expanse of Fremont Weir will probably require multiple facilities. The reliability of passage may be further improved if structures were designed to take advantage of the existing scour channels downstream. And finally, any structure on the eastern portion of the weir should take advantage of the lower invert elevations and strive to provide passage at a greater frequency.

Appendix C
Potential Alternatives for Further Evaluation

1. Increased Seasonal Inundation

1.1 Introduction

Reclamation and DWR have evaluated potential options at a preliminary level. During the planning and environmental compliance process, these options, and a reasonable range of alternatives, will be further evaluated. The parameters selected for evaluation include the elevation and width of the inundation structure and the excavation of the associated downstream channel. This approach allowed us to compare the relative timing, frequency, and magnitude of expected floodplain inundations. This preliminary evaluation assumed that the notch through the Fremont Weir would be near the east side of the Yolo Bypass (Bypass) and would remain hydrologically connected to the Tule Canal so that when "flooding" of the Bypass would occur, up-migrating fish would have an opportunity to pass through the structure. The notch should not be set at an elevation that would create reverse flows or hydraulics that would delay up-migrating fish. The notch should be placed such that it will allow fish-passage structures to operate both in conjunction with the notch and independently of the notch. Detailed design options of the inundation structure will be further evaluated during the environmental compliance process, potentially including: gates and gate configurations, cross-section shapes, baffles, and multiple channels. The following sections describe the timing, frequency, and magnitude of potential configurations for the Eastern Fremont Weir option.

1.2 Preliminary Evaluation of Notch Configurations

An existing one-dimensional HEC-RAS (Hydrologic Engineering Center–River Analysis System) model was modified and used to evaluate the expected performance of inundation notches of various depths and widths. "Technical Study # 2: Evaluation of North Delta Migration Corridors: Yolo Bypass" (Tech Memo II), prepared for the Bay Delta Conservation Plan (BDCP), created a steady-state HEC-RAS model to evaluate the concept of lowering a section of Fremont Weir as a way to introduce flows into the Yolo Bypass more frequently and so improve the functioning of the Bypass as seasonal floodplain habitat. The authors of Tech Memo II chose 17.5 feet (NAVD 88) as their invert elevation in order to avoid major earth work and reduce potential backwater effects, and then performed a sensitivity analysis for channels with bottom widths of 225 feet and 450 feet. For the analysis described in this appendix, we altered the existing model to evaluate five different channel configurations:

- invert elevation of 14 feet, channel length of 1.8 miles, and channel slope of 0.036%
- invert elevation of 17.5 feet, channel length of 1.5 miles, and channel slope of 0.035%

- invert elevation of 20 feet, channel length of less than 1.5 miles, and channel slope of 0.065%
- invert elevation of 14 feet, channel length of 6 miles, and channel slope of 0.043%
- invert elevation of 17.5 feet, channel length of 6 miles, and channel slope of 0.054%

Each channel configuration was modeled with varying channel bottom widths of 225 feet, 600 feet, and 1,000 feet. All channel configurations had side slopes of approximately 2 feet (horizontal) to 1 foot (vertical).

In the modified hydraulic model, both the upstream channel (the notch) that allows Sacramento River water into the Bypass and the upstream boundary condition differ from those in the Tech Memo II model. Since the slope of Tule Canal and Toe Drain is relatively flat and the upstream stage is unknown, the upstream boundary condition was changed from a stage-flow rating curve to normal depth conditions, in which the new channel's slope was used to calculate an upstream stage. The variations in channel size in the model can be seen in Figure C.1. The hydraulic model uses a steady-state flow analysis with a downstream boundary condition of 4.1 feet (NAVD 88), which is the observed average stage of the tidally influenced Liberty Island gauge according to the Tech Memo II model. The Manning's n value for the model was left at 0.022 for in bank flow and 0.04 for out-of-bank flow.

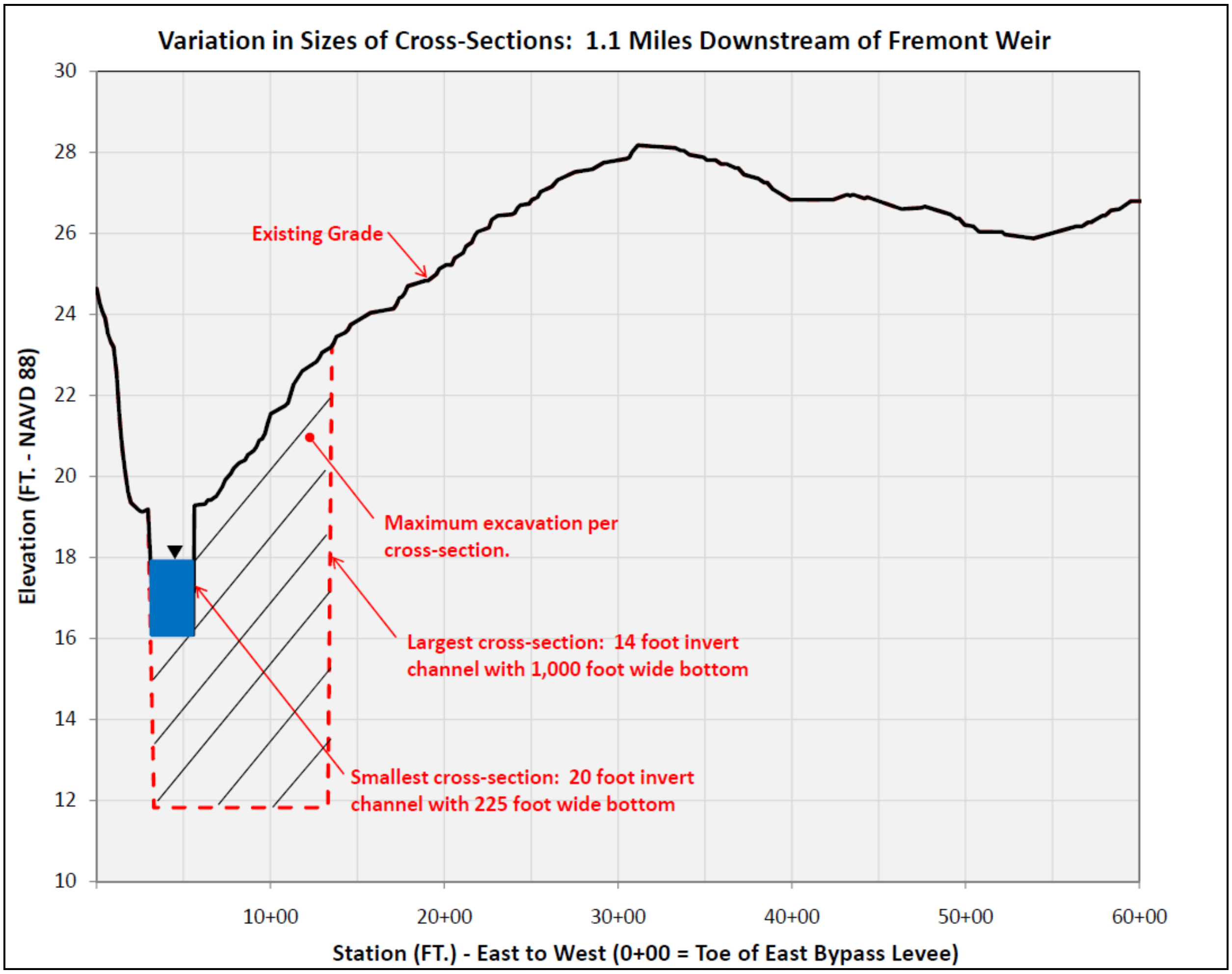

Figure C.1. Variations in Sizes of Cross-Sections 1.1 Miles Downstream from the Fremont Weir

The initial Tech Memo II HEC-RAS model was a coarse-level model, so the same limitations that applied to that model apply to subsequent runs of models based on it. No new survey data points were added to the model. To improve on the model, bathymetry data should be collected for the entire length of the Tule Canal and the Toe Drain and these data should be incorporated into the model. Additional topographic terrain data are also needed in the area between Fremont Weir and Sacramento Weir, per Tech Memo II. The model should also include elevation data for all locations where structures will alter or impede flow, including the Highway 80 Bridge, the Interstate 5 Bridge, railroad crossings, and earthen crossings over the Tule Canal. This model does not account for flows that enter the Bypass from tributaries such as the Knights Landing Ridge Cut, Cache Creek, Willow Slough, or Putah Creek. The flows from these tributaries would likely increase the magnitude and duration of inundation events. However, our approach in modeling was to compare the benefits of various configurations of only Sacramento River water. Newer two-dimensional hydraulic models can give a more accurate representation of floodplain conditions. These newer models do include the tributary flows and have given results for the amount of acreage that would be inundated that differ from those that were reported in Tech Memo II. Lastly, the model does not incorporate climate change into the scenarios. As mentioned in Appendix B, climate change is a variable that the Yolo Bypass Adaptive

Management Team (YBAMT) will incorporate into future management decisions. Due to climate change, future scenarios may be different than historical trends. Because of these discrepancies and relative inaccuracies, the number of acres that our model runs indicated would be inundated for floodplain habitat will not be included.

The model runs indicate that the Tule Canal is subject to backwater effects most likely from downstream structures and topography, and that the widening or deepening of the inundation channel that would connect Sacramento River and the Tule Canal would not reduce these backwater effects enough to significantly increase the probability of inundation events. Figure C.2 illustrates the stage that the Sacramento River would have to reach in order to allow certain flows through various inundation channel configurations. A flow of 3,000 cfs is almost completely out of bank in the northern region of the Yolo Bypass, and for this reason it was chosen as the base flow upon which to evaluate inundation channel configurations that would provide floodplain habitat. The wetted area inside the Tule Canal is not considered to be seasonal floodplain habitat based on the attributes developed. 6,000 cfs was chosen as the maximum flow allowed through the inundation channels. Figure C.3 shows the probability that a 14-day event (the biologically beneficial duration goal mentioned previously) will occur at least once a year, and will occur at least once a year in the months of November and December, for the modeled inundation channel configurations.

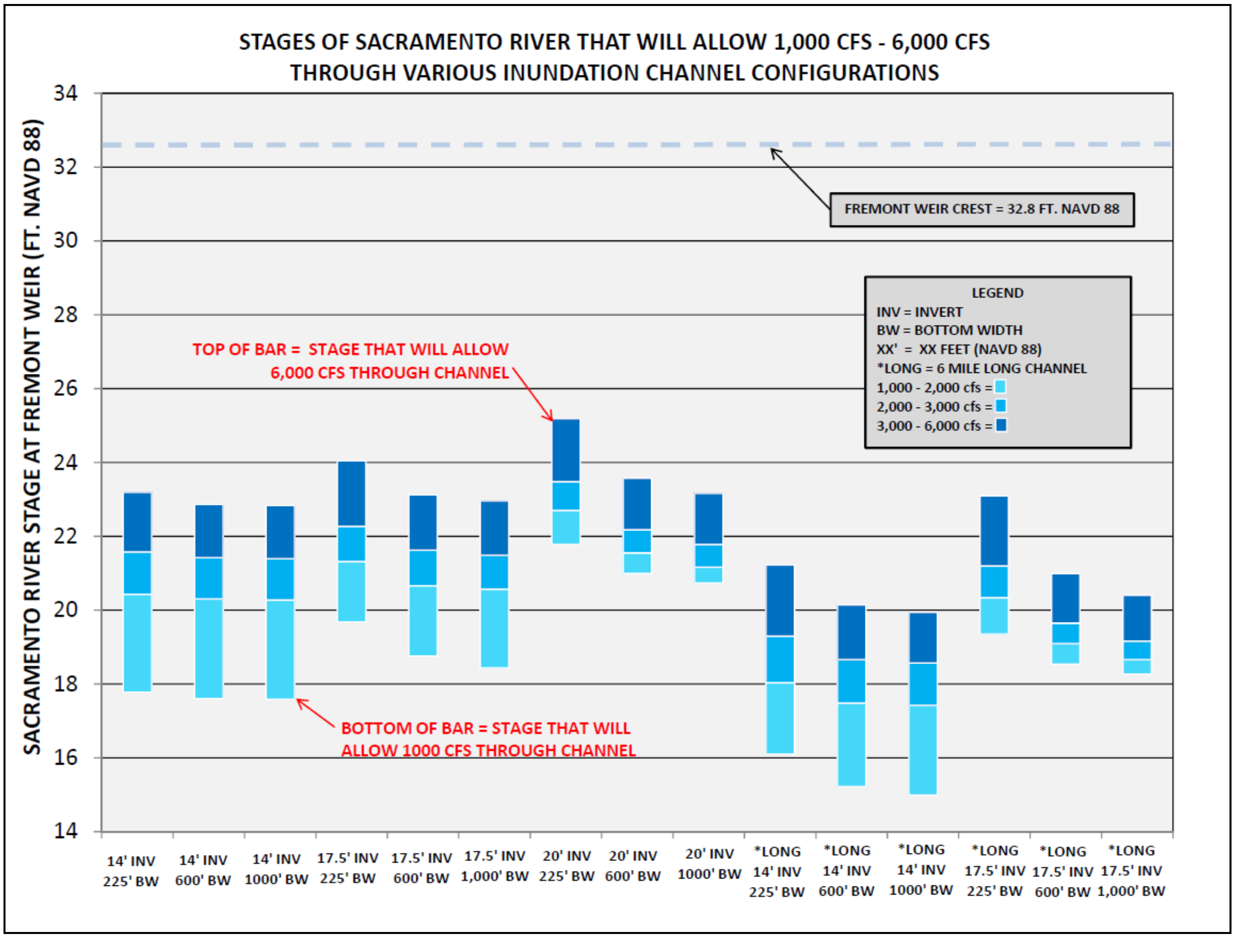

Figure C.2. Stages of the Sacramento River that would allow 1,000 cfs to 6,000 cfs to Pass Through for Various Inundation Channel Configurations

The probabilities illustrated in Figure C-3 are based on data collected by the DWR North Central District for water years 1985–2008. All channel configurations shown meet the two-out-of-three-year frequency criterion for 3,000 cfs. Two inundation channel configurations—invert elevation of 17.5 feet with a bottom width of 225 feet and invert elevation of 20 feet with a bottom width of 225 feet—failed to meet the two-out-of-three-year criteria at 6,000 cfs, with probabilities of 58 percent and 54 percent, respectively. Under the existing conditions, flows overtop Fremont Weir for 14 consecutive days at least once a year in 42 percent of years per stage data collected by DWR's Northern Central Regional Office, for water years 1985-2008. The frequency of events decreases when we isolate the data for the months of November and December in order to evaluate the possible benefits for juvenile winter-run Chinook salmon. Flows overtop Fremont Weir for 14 consecutive days in the months of November and December in 8 percent of years, under existing conditions. The improvement in the capability to provide floodplain habitat in November and December ranges from 21 percent to 38 percent for the various inundation channels modeled.

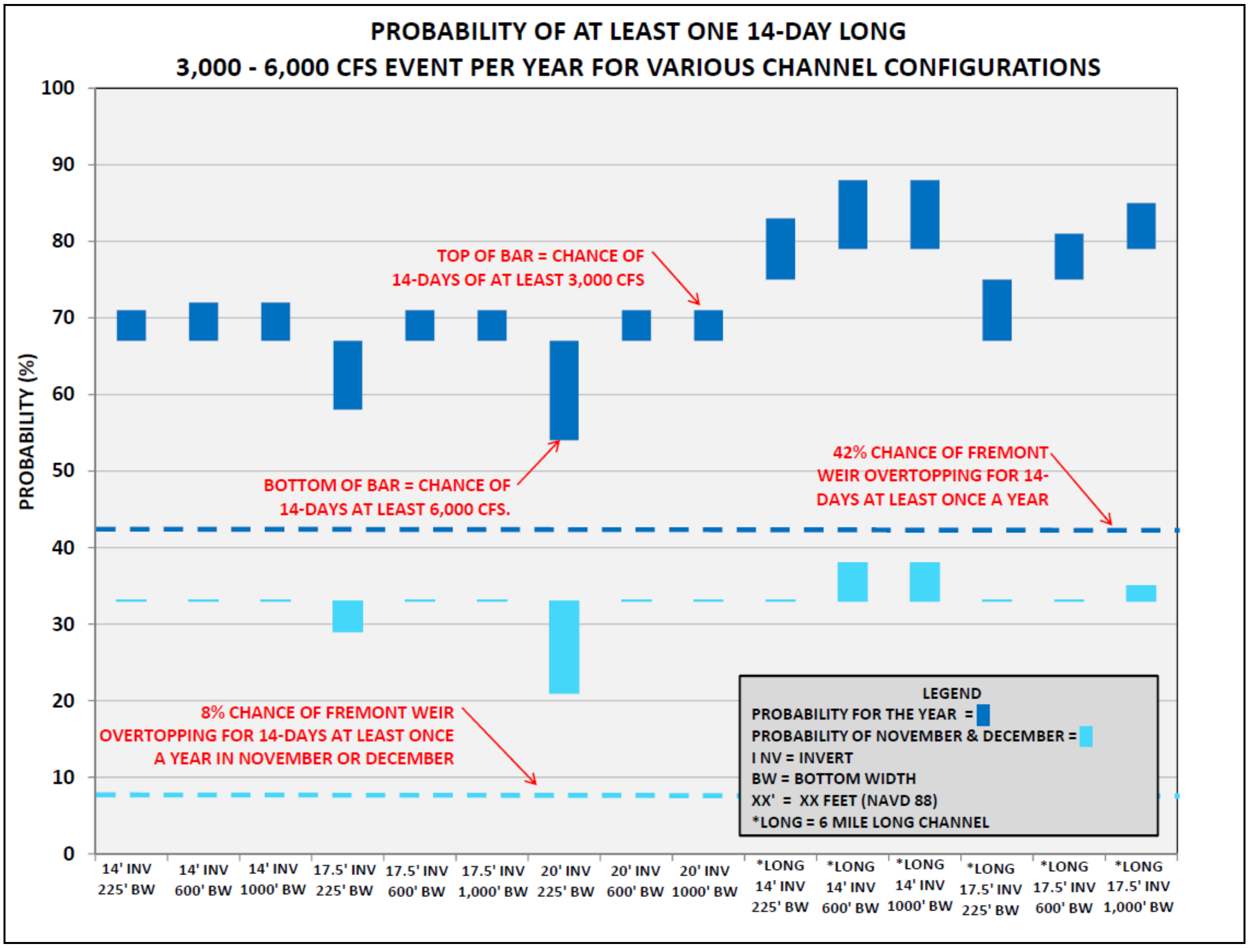

Figure C.3. Probability of at Least One 14-day-long 3,000 to 6,000 cfs Event per Year for Various Channel Configurations

Similarities in the model results indicate that a backwater effect in the Tule Canal and Toe Drain is not easily overcome. The backwater effect is the result of constrictions within the Tule Canal, such as narrow channel widths and high points in the channel, and the overall flat terrain of the Bypass. A series of ridges approximately 6 to 14 miles south of Fremont Weir cause the water flow to back up, as can be seen between miles 22 and 30 in Figure C-4. In order to ameliorate the backwater effect, the ridge in the Tule Canal would have to be removed or altered. Those alterations, however, would improve the conveyance of water flows through that section of the Tule Canal, which would decrease the potential for out-of-bank flows (i.e., floodplain habitat) in that region. Therefore, its possible minimal net gain in acres inundated would be achieved. Future modeling will describe the differences in acres inundated for these scenarios.

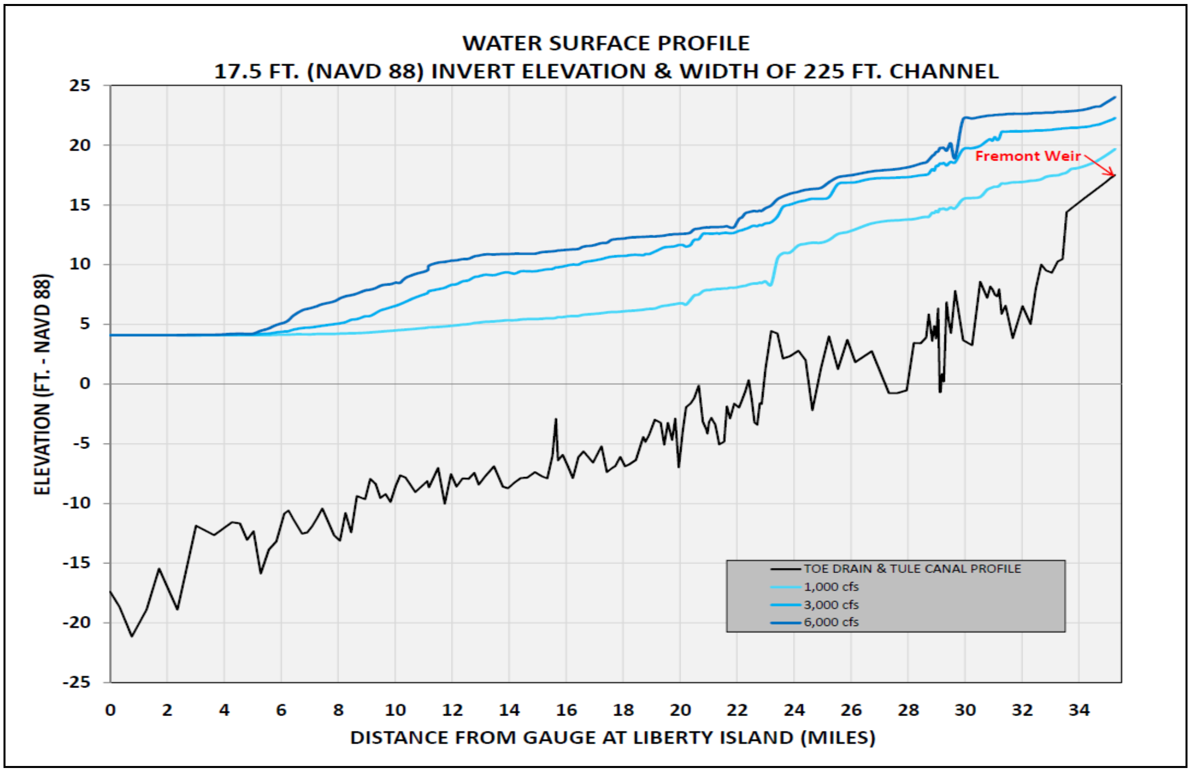

Figure C.4. Water Surface Profile (invert elevation 17.5 feet [NAVD 88] and channel width 225 feet)

Any deepening or widening of the inundation channels would increase the amount of earthwork cut that would have to be disposed of. Figure C-5 shows how much additional earthwork would be required for various channel configurations. The smallest footprint is the configuration for a channel with a 20-foot invert elevation and a bottom width of 225 feet. A deeper, wider channel would require additional expenditures associated with the excavation work.

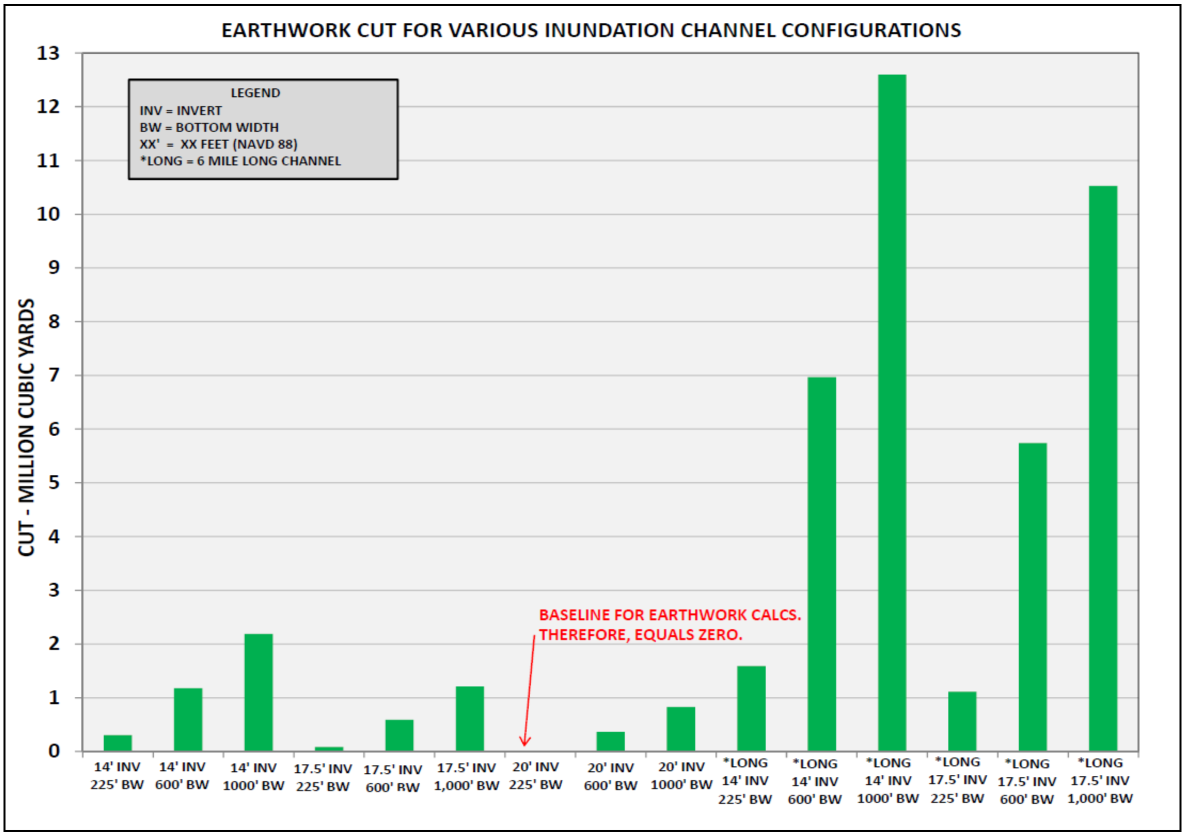

Figure C.5. Earthwork Cut for Various Inundation Channel Configurations

Based on this modeling, the two-out-of-three-year inundation criteria can be achieved with a notch configuration having an invert elevation of 17.5 feet and a bottom width of 225 feet. A wider notch at this elevation would allow more flow through the notch, but little improvement would be realized from expansion of the notch width beyond 600 feet because the channel capacity downstream would eventually prevent the additional flow from moving into the Yolo Bypass. Events that occur in November and December are perhaps more significant than others because they correlate strongly with the presence of winter-run and spring run Chinook juveniles at Fremont Weir. The frequency of inundation events that occur in November and December ranges from about 20% to 40% of years, depending on the specific configuration. The lower end of the frequency requires the least amount of earthwork. The higher end of the frequency range would require earthwork on the order of 7 to 12.5 million cubic yards. This amount of earthwork would improve the conveyance of flows but would diminish our efficiency in providing floodplain habitat at those flows. In one year out of three, the notch configuration with an invert elevation of 17.5 feet and a bottom width of 225 feet would provide a 14-day event at 6,000 cfs at the time when it would be most beneficial to winter-run and spring-run Chinook salmon. This would be a 400% improvement over existing conditions, based on our performance measures.

A notch configuration deeper than 17.5 feet and wider than 600 feet would be difficult to justify because of the high expense of the earthwork and the diminished benefits to targeted species. On the other end of the scale, a notch configuration higher than 17.5 feet or narrower than 225 feet might not meet the performance goals identified in this plan.

Of the options preliminarily evaluated, an elevation of 17.5 feet may be the most appropriate for the inundation notch. In comparison, the deeper notch (at an elevation of 14 feet) involves exorbitant costs for earth moving and construction, poses potential sedimentation issues due to the low gradient, and offers minimal gains in biological benefits. A shallower notch (at an elevation of 20 feet) would not meet the criteria we are using for inundation frequency and duration and would only minimally reduce costs. A range of notch depths will be further analyzed during the environmental compliance and planning process.

Based on preliminary data in Appendix A, the inundation period that would benefit both winter-run and spring-run juveniles is the November and December period. A potentially preferred notch depth—even at the minimum 225-foot bottom width—could provide this in 1 out of 3 years. As described previously, this would mean a 400% increase in availability of this habitat for winter-run and spring-run salmonids during these critical months. As shown in Sommer et al. (2001), based on fall-run studies, floodplain availability leads to increased growth of young salmon. It is logical to assume that this increase in growth would lead to an increase in survivability to adulthood. By providing inundation during a period correlating to the occurrence of both of these runs, as indicated by the data from the Knights Landing RSTR, the preferred notch depth would maximize the biological benefits of these less-frequent events.

More-frequent inundation events are likely to occur between November and April due to the larger window of time for inundation. The goal of achieving inundation in 2 out of 3 years for 14 days' duration during this period is not met at 6000 cfs, according to model results, when the bottom width is 225 feet. As previously described, there is a probability of approximately 58% that 6,000 cfs flows will occur. This criterion is met, however, at 3,000 cfs for the 14-day duration. In order to fulfill this measure in its entirety, we would need to expand the bottom width. According to model results, the bottom width necessary to accommodate this criterion would be no greater than 600 feet. The increased bottom width would increase the proportion of flow diverted into the Bypass and it is reasonable to assume that a greater proportion of fish would pass into the Bypass. However, the increased acreage would provide additional food-web benefits to the Bypass and the northern Delta.

According to the modeling conducted under the BDCP Draft Technical Memorandum: Technical Study 2, substantial increases in the area of inundation would be accomplished under the preferred notch depth scenario with a minimum bottom width of 225 feet and as little as 3,000 cfs flowing through the notch (river stage of 22.7 feet at Fremont Weir). At 3,000 cfs, 11,000 total acres within the Bypass would be inundated; at 6,000 cfs (river stage of 24.5 ft. at Fremont Weir), approximately 21,500 total acres would be inundated. With 3,000 cfs and 6,000 cfs flowing through the notch, the mean depth would be 3.9 feet and 2.6 feet, respectively. This negative correlation between cfs and inundation depth reflects the condition that lower flows are largely contained within the Tule Canal and Toe Drain, whereas moderate to high flows spread across the floodplain, creating shallower habitat. Both of the mean depths cited above fall within the useable habitat conditions specified in Appendix A. It is also likely that there will be a great deal of shallower habitat that falls within the preferred range throughout much of the Bypass due to topographical variability. In addition, most of the habitat is likely to be shallower than the mean as a result of the bias introduced by the deeper Tule Canal/Toe Drain. All of this means that, based on the magnitude of inundation, modeling indicates that the additional acreage would be suitable for juvenile Chinook salmonids even under the most conservative width conditions.

The target of a 14-day inundation duration to allow for development of food resources in the inundated area could be achieved under the 17.5 foot scenario and a minimum bottom width (225 feet) with only 3,000 cfs (river stage of 22.7 feet at Fremont Weir) in 2 out of 3 years between November and April, and could be achieved between November and December in 1 out of 3 years. This would be the minimum expected duration of inundation at a magnitude of 11,000 total inundated acres (net increase of 7,300 acres compared to zero flow through the notch) at these flows. With at least 14 days of inundation, though total realization of floodplain benefits would not be achieved, the degree to which the juvenile salmonids could utilize floodplain resources would be substantially increased over current conditions. While expanding the bottom width would increase the cross-sectional area of the channel and theoretically allow our target flows into the Bypass at lower river stages and increase our capability to inundate, the dimensions of Tule Canal cause flows to back-up and prevent a significant reduction in the river stage needed to allow target flows into the Bypass (Figure C.2). The duration of inundation could only be altered by a change in the rate at which water could exit the Bypass once the Sacramento River stage receded below this elevation.

1.3 Potential Locations

1.3.1 East Side Fremont Weir

The primary inundation notch could be located on the eastern end of the Fremont Weir. The notch should be adjacent to the fish passage structure, or near enough to it so that additional passage can be provided through the inundation notch. It should also be far enough to the east to allow it to be connected directly to the Tule Canal. This location would provide a high level of biological benefit, while also keeping the amount of disruption to the Bypass resulting from the necessary earthwork to a minimum. Reducing this disruption also reduces the risk of negative effects on other resources, such as oversummering invertebrate eggs and larvae in the floodplain soil, which would help create beneficial conditions for salmonid growth following inundation.

The biological benefits from selection of the east side of the weir as the location for the notch fall into two main categories: length of time required to realize benefits and provision of an emigration corridor via connectivity with the Tule Canal. The topography of the Bypass is such that inundation begins in the east at the Tule Canal and moving west across the Bypass. As one would expect, the floodplain dries up in the opposite direction, from west to east. Due to this hydrologic pattern it is reasonable to assume that by providing flows directly to the east, where inundation begins naturally, benefits could be made to be realized sooner. By providing water directly to the east side of the bypass, we would reduce travel time for water to reach the inundation area and increase the ability to provide shallow water habitat for an extended period of time along the margins of the Tule Canal/Toe Drain. This would lead to an extended period of beneficial shallow water habitat inundation, which might be provided with minimal consequences for other interests within the Bypass (e.g., agriculture).

One large concern expressed in the Operation Biological Opinion is the potential for stranding of juvenile salmonids within the floodplain. A notch on the eastern section of Fremont Weir would provide an emigration corridor for salmonids leaving the bypass. This location provides fish with a direct route out of the bypass through the Tule Canal/Toe Drain. As waters recede, the channels visible via aerial photography direct flows toward the east. Logically, this means that the juvenile salmonids are also being directed, with the water, toward the east end of the Bypass. Besides following the natural pattern of drying in the floodplain, this approach of using the natural topography within the Bypass is the most feasible way to connect ponds that pose a potential stranding risk to an emigration corridor (e.g., the Tule Canal).

The Bypass is approximately 42 miles long and has a slight downslope to the east and to the south. During a Fremont Weir overtopping event or when there are substantial flows from west side tributaries, the east side of the Bypass is the first area to flood and the last to drain. The west side of the Bypass has disconnected channels of various sizes that run only portions of its length and has various tributaries and diversions. Along the length of the east side levee is an excavated channel (Tule Canal/Toe Drain) that helps drain the Bypass and provides water for agricultural purposes. It has the lowest surface elevation in the Bypass for a given latitude. The channel's average low-water depth is in excess of 10 feet for most of its length and it naturally draws fish. The east side's channel is continuous, with minor impediments, from approximately 0.25 mile south of Fremont Weir to Cache Slough, the southern terminus of the Bypass. The east side channel also has the greatest amount of existing riparian habitat when compared to the other channels in the Bypass. The Sacramento Weir is located on the east side near the Bypass's midpoint.

The Fremont Weir (east side) notch option, intended to improve fish passage and floodplain inundation, would be located near the east side levee. Since this option is in line with the main drainage channel, it would offer the simplest and most direct migratory path and the best chance of maintaining connectivity and it would require the least amount of modification and excavation of the channel. Diagonal scour channels, created and maintained by Fremont Weir overtopping high flow events, help provide fish passage connectivity to the east side channel as the waters recede behind Fremont Weir during the descending hydrograph. A notch deeper than the base of Fremont Weir at this location would provide clear fish passage opportunities after the rest of the Bypass floodplain begins to drain. An east side notch would not improve the passage of fish isolated in the short western portion of Fremont Weir isolated by the earthen fill and oxbow, so additional considerations will be necessary to provide passage in that section of the weir.

1.3.2 Sacramento Weir

The Sacramento Weir notch option, intended to improve fish passage and floodplain inundation, would be along either a portion or the whole length of the current weir, which is approximately 0.25 mile long. This location would provide relatively easy access to the structure, a condition that would facilitate its construction and maintenance, but it has the potential to provide the least benefit, along with increased risks to fishes, due to its southern location. A road and a railroad pass over this site. This option would require the least amount of excavation, depending on notch invert elevation. The Sacramento Weir has a channel more than 1 mile long connecting it to the Bypass floodplain. Sacramento Weir is located 13 miles south of Fremont Weir, which is about one third of the 42-mile length of the Bypass. This option could provide water to inundate the floodplain south (downstream) of the site, and would provide adequate fish passage so long as it were the sole provider of water into the Bypass. Since this site is so far south, it may not be able to provide as much habitat as the other options. Under most hydrologic conditions, a significant number to the majority, up-migrating fish pass north of this site in the Bypass. The Sacramento Weir will do nothing to reduce fish passage delays or stranding for fish near Fremont Weir or to improve fish habitat north of this site. A notch or notches would still be needed in the Fremont Weir to significantly improve fish passage and to reduce stranding rates.

1.3.3 West Side Fremont Weir

The West side (Fremont Weir) notch option, intended to improve fish passage and floodplain inundation, would be located between the west side levee and where the weir is interrupted by earthen fill at the oxbow. The West side (Fremont Weir) notch option would not provide any additional benefit to fish over that provided by the Fremont Weir (east side) notch option but it could increase risks to fishes and would exponentially increase the costs of construction. This west section is only about 0.3 mile long and its floodplain is segregated from the rest of the Bypass by the oxbow (see Figures 2, 3 and 4). The oxbow approaches Fremont Weir near the west end of this section. The oxbow is effectively a large water fish trap, presumably populated with exotic fishes. Flood flows in this portion of the Yolo Bypass are only provided by Fremont Weir overtopping events. Flows from these events pass over the oxbow and flow out over the unimproved State Wildlife Area and across farm fields. There are no channels, whether manmade or scour, to connect the west side of the weir with the rest of the Bypass and allow unimpeded fish movements under low-flow conditions. Any connectivity would have to be built, possibly to an elevation with a greater difference from existing surface elevations than would be necessary if the notch were built on the east side. Any built channel on the west side would cross the State Wildlife Area and, potentially, farm fields. Cross channels and water demands from agriculture would constitute risks to the fishes. Fish stranding on the longer, 1.4-mile east side section of Fremont Weir or in the northern reaches of the east side channel would not be alleviated by an isolated west side notch. A small secondary fish-passage notch to the elevation of the stilling basin of Fremont Weir in this west side portion would be beneficial in that it would substantially increase the passage window for fishes at this location.

1.3.4 Potential Operations

The Yolo Bypass Fisheries Enhancement Planning Team (YBFEPT), as described in Section 4.1.5 of the Implementation Plan is coordinating discussions on a potential operational scenario for a notch at Fremont Weir that could be included in Conservation Measure 2 of the Bay Delta Conservation Plan (Table C-1). This potential operational scenario is currently in draft form, as the YBFEPT continues discussions including input from state, federal and local agencies representing water management, flood damage reduction, agriculture, waterfowl and other interests in the Yolo Bypass. This potential operational scenario will be further evaluated, along with a reasonable range of alternative operational scenarios by the Yolo Bypass Restoration Team (YBRT) (Section 4.1.3), in coordination with the YBFEPT, during planning and environmental compliance.

Potential Operation Pattern for Fremont Weir Gated Channel, or "Notch"

		Before Nov 10	Nov 10-Nov 30	Dec 1 - Feb 15	Feb 16 - Feb 28	March 1 - March 23	Mar 24-April 10	April 11-May 15	May 16 or Later
If Fremont Weir does not overtop that water year	**Operations Concept**	**No Fremont Weir operations** except for the minimum in-bank flow required to provide fish passage (**up to 500 cfs** if appropriate).	Initiate Fremont Weir **flows up to 6,000 cfs, only if harvest is complete or if western tribs are already flooding.**	Initiate Fremont Weir flows **up to 6,000 cfs.** A change in shallow water habitat distribution is anticipated (e.g. acres available at 0 to 1 foot depth and at 1 to 6 foot depth). As very shallow areas get deeper, new very shallow areas are created, variably offsetting the total amount available for dabbling and wading birds. These changes and tradeoffs will need to be analyzed and managed.			**No Fremont Weir notch operations except ramping down of flows initiated earlier** to in-bank fish passage flow levels of 1,000 cfs or less, by April 10, at a rate that does not increase fish stranding. When natural events drop to 6,000 cfs at the YBY gauge, flows go in-bank approximately 11 days later. Unless natural floods are dominating the system during this time, time-to-drainage should be much less than 11 days from the time notch flows drop to 1,000 cfs. More detail about flow ramping is desirable. It will need to be determined in the YBFEP.	No Fremont Weir notch operations except for in-bank fish passage flows up to 500 cfs (if appropriate).	**No Fremont Weir operations** except for the minimum in-bank flow required to provide fish passage (**up to 500 cfs** if appropriate).
						If a natural flood event, lasting for a 30-day duration, has not occurred within 5-7 years during March 1 - May 15, prescribe an inundation regime to meet or exceed a minimum duration of 30 days with small flooding footprint.			
	Estimated "notch" operation frequency for a portion of the period		0 to very few water years	6 to 25% of water years	8 to 14% of water years	11 to 19% of water years	8 to 11% of water years	No floodplain inundation flows through Fremont Weir "notch" past April 11 in years Fremont Weir does not overtop	
If Fremont Weir overtops that water year	**Operations Concept**		When upstream flows are available, capture juvenile salmonids in **up to 6,000 cfs** into the Bypass and operate to achieve **30 day duration.** Water availability in the river upstream will determine whether full 6,000 cfs flows are passed.	Provide continuity between events with flows **up to 6,000 cfs** to achieve **30 to 45+ day duration.**		After FW overtopping stops, extend small flooding footprint in low-yield areas with **up to 6,000 cfs notch flows to achieve at least 30 day duration,** then ramp down to in-bank fish passage flows up to 500 cfs if appropriate.			
						If a natural flood event, lasting for a 30-day duration, has not occurred within 5-7 years during March 1 - May 15, prescribe an inundation regime to meet or exceed a minimum duration of 30 days with small flooding footprint.			
	Estimated "notch" operation frequency for a portion of the period		11% of water years	64% of water years	58 to 61% of water years	61% of water years	53 to 56% of water years	19% of water years	
Total % water years with Potential with-Project for-floodplain habitat operation, by period		0%	11%	69 to 89%	67 to 75%	72 to 81%	61 to 67%	19%	0%
Historical % of water years with Fremont Weir overflow in these periods, for reference		0%	11%	61%	50%	47%	22%	17%	8%
Footprint Targets: (Conservation easements or fee title will be required for all inundation on agricultural land)		**Out-of-bank flows not created by project (zero or negligible)**	**Smaller Inundation** - First flush "notch" operations add **up to 10,000 acres** to existing inundation. Operations piggybacking on overflow events prolong **7,000 to 10,000 acres of inundation.**	**Larger Inundation** - First flush "notch" operations add to existing inundation. Following natural spill events (non-project flooding, including westside tributaries or Fremont Weir), operate the notch to prolong duration and provide continuity between events. Natural spill events range considerably. Operations would target **17,000 acres of inundation.** When appropriate flows are not available for a "larger inundation" operate the notch for "smaller inundation."	**Larger Inundation** - Following natural spill events (non-project flooding, including westside tributaries or Fremont Weir), operate the notch to prolong duration and provide continuity between events. Natural spill events range considerably. Operations would target **17,000 acres of inundation.** Ramp larger inundation flows down to the smaller acreage range by February 28. When appropriate flows are not available for a "bigger inundation" operate the notch for "smaller inundation."	**Smaller Prolonged Inundation** - Acreage of **7,000 to 10,000 acres**, with mitigation of impacts on agriculture.	**Smaller Prolonged Inundation** - Acreage of **7,000 to 10,000 acres**, with mitigation of impacts on agriculture.	**Smaller Prolonged Inundation** - Acreage of **7,000 to 10,000 acres**, with mitigation of impacts on agriculture.	**Out-of-bank flows not created by project (zero or negligible)**

Note: Frequency estimates are based on water years 1968-2003 as represented in CALSIM results PP and the Fremont Weir bar charts summarizing historic overtopping in the Sac River Flood Control System Fact Sheet. High and low ranges were estimated based on avoidance of very short flow events.

Note: Notch ops at river stage 17.5 or higher correspond to times when Westside tributaries are also typically contributing flow. Preliminary investigations suggest that very short Fremont Weir "notch" events are unlikely to be met with substantial sustained Westside tributary flow, particularly early in the water year. This may have limiting implications on operations to send more juvenile winter-run salmon into the Bypass more often in November, December, January.

2. Potential Fish Passage Actions

2.1 Remove Baffles

As a trial, the baffles will be removed from the Denil ladder to assess how well it functions as a clear chute "fishway." Anecdotal observations by a DWR biologist from just downstream of the ladder indicate that most salmonids either pass over the Fremont Weir during overtopping events or successfully negotiate the ladder on the descending limb of the hydrograph, as fewer salmonids than sturgeon seem to be stranded in the splash basin (a small pool at the foot of the weir). The baffles within the ladder, which obstruct the bottom of each ladder "rung" and restrict the width of the ladder, are believed to be a deterrent for green sturgeon. Due to the small size and location of the Denil fish ladder, it quickly becomes obstructed by debris. We expect that removal of the baffles will help multiple species of fish with varying swimming capabilities to ascend the ladder after an overtopping event and that it will also reduce the rate of obstruction to the ladder due to debris. Monitoring of how well the ladder performs as a clear chute "fishway" will be integrated into this action. An initial performance measure after removal of the baffles will be made by DWR, Reclamation, and cooperating agency (i.e., DFG) staff via direct observations and by DIDSON as well as by monitoring the passage of tagged fishes. The amount and types of fish observed passing through the ladder and the amount and types of fish being stranded in the splash basin after an overflow event will serve as an initial performance measure. The data collected will be used to identify criteria for fish ladder design and construction to maximize green sturgeon passage at the Fremont Weir fish ladder.

2.2 Potential Concept Proposal: Fish Passage at Fremont Weir

This concept was developed by a fish passage technical team during development of the plan to provide passage over the greatest range of flow conditions. However, passage efficiency of this concept has not been evaluated, and it may be that shorter alternatives that operate under a narrower range of flow conditions will provide greater passage efficiency and reliability of passage. This concept and other alternatives will be further developed and evaluated by a multi-agency fish passage technical team, which will be assembled following submission of this plan. This concept involves three facilities that would operate seasonally and greatly improve passage conditions at Fremont Weir. Each facility would be constructed as part of the Long-Term Actions for RPA Action I.7. There are four components to this concept:

- An S-shaped facility on the eastern section of Fremont Weir
- Replacement of the existing ladder with wider, roughened channel
- Addition of a channel that would drain the isolated western portion of Fremont Weir back into Sacramento River
- Excavation of channels downstream to improve connectivity between isolated areas

S-shaped facility

This component includes two channels that are operative depending on the magnitude of flow in the Sacramento River. The "high-flow" channel is of a sinuous shape, while the "low-flow" channel is more straight. Because of its sinuous shape, this component has been termed the "S-shaped facility." The S-shaped facility would operate over the greatest span of time. The facility is made up of a high-stage channel and a low-stage channel to provide passage over a wide range of river stages. At the weir, the invert elevations are 22 feet for the high-stage channel and 14 feet for the low-stage channel. The flow of water through the fishway could be manipulated by means of two gated notches. When the stage in the Sacramento River rises above 16 feet, the eastern gate (14- foot elevation), which controls flow into the low-stage channel, would be opened to allow a direct route of passage to the Sacramento River. At this stage in the river, there would be 2 feet of depth in the low-stage channel at the weir. As the stage in the Sacramento River continued to rise, at 24 feet (or, if flows threaten to exceed Tule Canal capacity or velocities are too high for fish passage),the eastern gate on the low-stage channel could be closed, and the western gate on the high stage channel would be opened to allow fish passage. As waters receded, operations could shift to the eastern gated notch when flows fall below the threat of exceeding Tule Canal capacity. The fishway channels will be roughened channels, constructed of rock and soil. This design allows fish passage to take place at moderate flows (<800 cfs) over a wide range of conditions. In this way, velocity (ft/sec) and volume (cfs) could be managed to maintain passage velocities without exceeding the capacity of the Tule Canal. Natural-shaped bends in the S-shaped facility would also provide resting pools for migrating fish (Figure C-6).

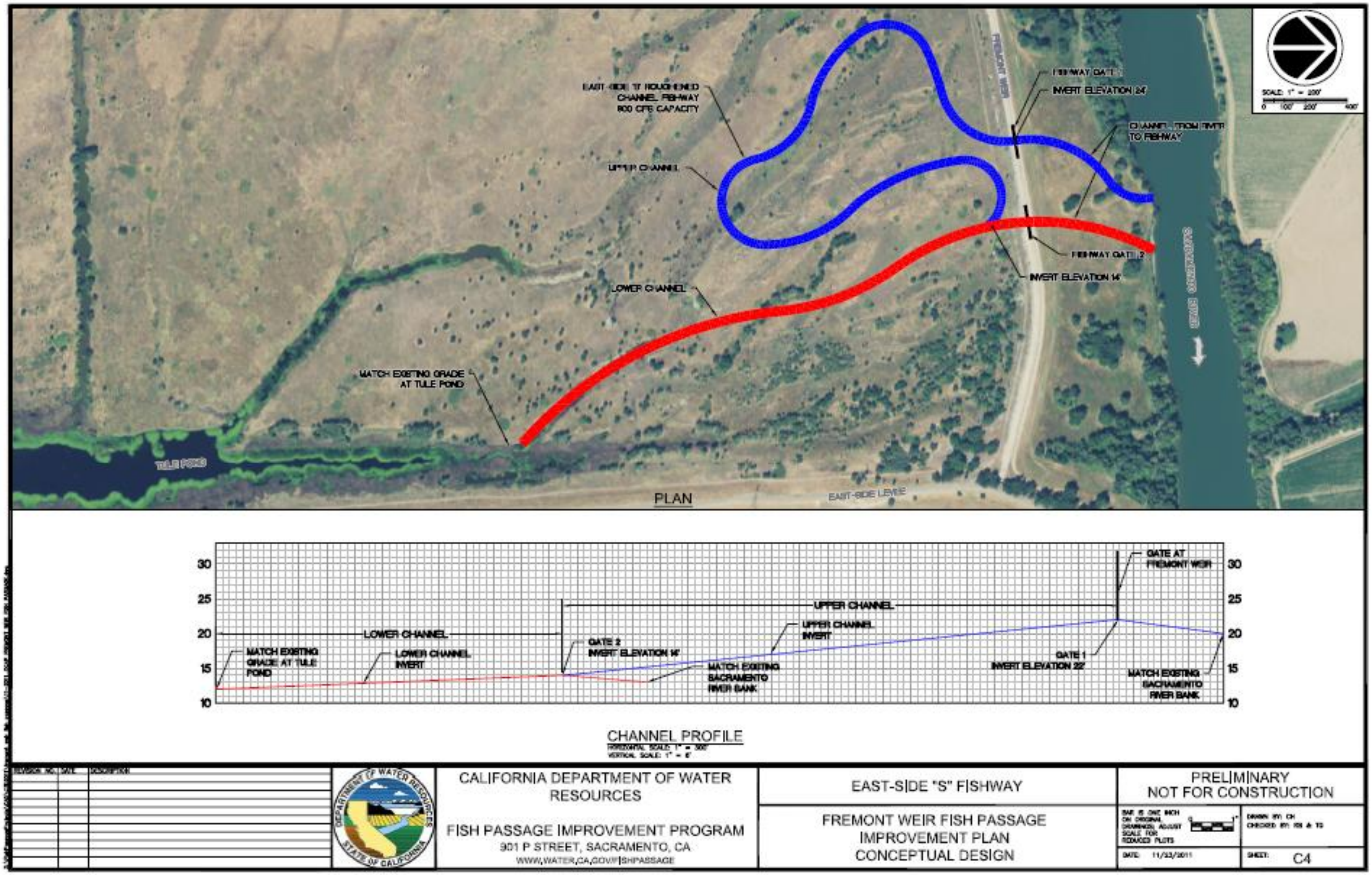

Figure C.6. Potential S-Shaped Fishway

Replace existing ladder

The second facility is a simple replacement for the existing fish ladder. The existing ladder is roughly 4 feet wide and operates under very limited conditions. It is more than likely that the channel's relatively narrow width limits passage to salmon and steelhead. Expansion of the ladder to a wider notch connected to a roughened channel would allow passage of salmon, steelhead, and sturgeon that are able to migrate as far as this section of Fremont Weir. Fish currently have access to this area after an overtopping event, so any gates on this structure should be opened when the area becomes inundated in order to allow easier passage out of the Bypass during floods and as flood waters recede. This concept would include widening the current fish ladder and replacing the ladder with a gated notch. A channel would then be constructed from the weir to the Sacramento River for connectivity with upstream waters, and a second, roughened channel would be constructed from the ladder downstream to the existing scour channel. The invert elevation of this structure would be the same as that of the current fish ladder, which is level with the bottom of the splash basin (Figure C.7).

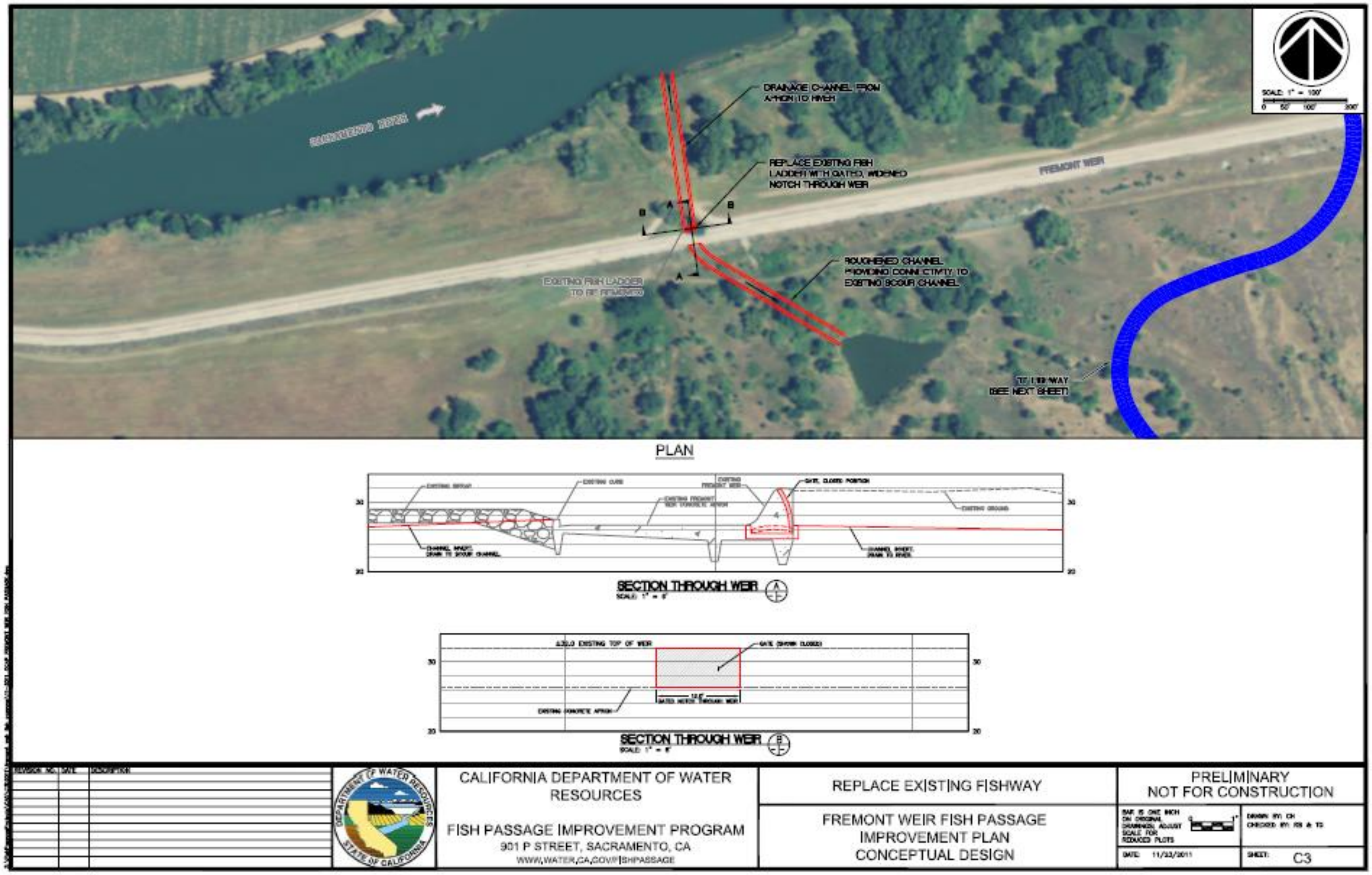

Figure C.7. Potential Modification to Existing Fishway

Add a channel to drain the western Fremont Weir

The simplest of the three structures would be intended to provide a migration gateway from the splash basin near the western margin of the weir to the river via a gated notch through the weir. A channel connecting this portion of the Fremont Weir to the Sacramento River would allow stranded fish to migrate back to the Sacramento River. As with the previous structure, the notch would be even with the splash basin and would connect to the weir near the section of earthen fill (figure 3).

The western portion of Fremont Weir traps fish after flood waters recede. Fish currently have access to this area after an overtopping event. Any gate on this structure would have to be opened when this area would become inundated in order to allow fish to move out of the Bypass later, when floodwaters recede.

Grade downstream channels

Graded downstream channels should be placed in line with existing scour channels that extend southeast from Fremont Weir. These scour channels are part of a network that eventually leads back to the Tule Canal. Some sections of the channels are either poorly defined or contain sediment deposits that isolate the water in pools as floodwaters recede. Careful evaluation of these channels will be necessary to determine where grading would improve connectivity back to the Tule Canal. It is important to note that there are large, isolated pools that occur along this channel network, which currently might allow fish to reside in between overtopping events. The water surface elevation of the Sacramento River is low in the summer months, so this period poses the greatest difficulty when we look for ways to provide fish passage. Fortunately, attempts at migration are also greatly reduced during the summer months. It is more feasible to provide fish passage in the winter and spring, when most of our target species migrate.

3. Stranding Improvements: Adult and Juvenile Passage Improvements below Fremont Weir

The stranding of fish in Central Valley floodplain habitats is a well-documented and potentially serious phenomenon. Specifically, the highly variable flow conditions characteristic of floodplains can lead to major stranding events and increased mortality rates for native fishes (Bradford 1997; Brown 2002). Water depths can fluctuate on a daily basis on the Bypass floodplain, with the potential to strand fish located in areas where conditions allow for the puddling of water or in areas with poor drainage (Whitener and Kennedy 1999). However, the risks of excessive mortality in only some years may be outweighed by the overall increased benefits that floodplains offer in most years (Sommer et al. 2001; Whitener and Kennedy 1999). Even with stranding, many believe that the production of native fishes on the floodplain exceeds their production in the river channel alone (Swenson et al. 2003). Major stranding events appear to be strongly associated with man-made structures, such as roads, fences, ponds, ditches, and levees (Swenson et al. 2003; Sommer et al. 2005). By identifying the features within the Bypass that serve as significant stranding sites, we can facilitate the modification or removal of problem areas in an effort to alleviate the potential for stranding. These passage improvements will allow the Bypass to continue to provide all of the benefits a floodplain offers to native fishes while effectively minimizing the associated risks. Figure 4 in the Plan shows the extent of a potential fish passage component at Fremont Weir.

As mentioned previously, ("Actions to Minimize Stranding or Migration Barriers for Juvenile Salmon"), the first step toward improving fish passage in the Bypass will be to develop and implement a juvenile stranding reduction program that will identify and catalog stranding locations. Once these potential stranding sinks have been identified, they will be corrected by means of one or more of the following options.

3.1 Grading (Main Channels Should Be Connected to the Tule Canal)

One of the principle causes of stranding on floodplains is inadequate drainage. Researchers on the Cosumnes River floodplain have shown that successful floodplain restoration should consider drainage patterns from the floodplain, with a specific emphasis on creating exit points for fish (Swenson et al. 2003). Currently, the Tule Canal and the Toe Drain along the eastern boundary of the Bypass together serve as the primary drainage channel. The grading of priority stranding sites so that they will drain either into an adjacent channel or directly into the Tule Canal or Toe Drain is an important step in ensuring proper drainage while keeping ponding-related stranding to a minimum. Additionally, if preliminary surveys of the Bypass indicate that any road crossings or agricultural impoundments impact the connectivity of wetted habitat, they will be modified or removed to improve or maintain connectivity.

3.2 Connecting/Filling Pools

An increase in connectivity between possible stranding sites and drainage canals would reduce the potential for stranding of both adult and juvenile fishes. When the flows across the Bypass begin to recede, fish within the various pools and ponds across the floodplain search for exit points, which must ultimately lead to the Toe Drain or Tule Canal. In areas of where connecting channels are limited or nonexistent, the pools and ponds become isolated as the rest of the floodplain desiccates. Man-made pools have been documented as significant stranding sites: research has shown that in the Bypass significantly more juvenile salmon have been stranded downstream of the concrete weir in scour ponds than in isolated earthen ponds (Sommer et al. 2005).

Once problematic pools are identified, the YBRT will have to determine whether remedial measures to fill them with earthen material or to connect them to the nearest drainage canal via a connecting channel are appropriate and beneficial to salmon and sturgeon populations. The size of each pool, as well as its proximity to the nearest migration corridor (i.e., the Tule Canal), will determine whether it will be more feasible to fill the pool or excavate a connecting channel. The filling of pools with earthen material may provide the additional benefit of reducing the number of predators on the floodplain. Perennial ponds tend to favor the production of non-native fishes over native species, and many of these will prey upon juvenile salmonids. The mortality of juvenile salmonids from predation can be extremely high in isolated perennial ponds; in one study, mortality approached 80% in 2 weeks (Jones & Stokes Associates 1999). Potential impacts on other aquatic and terrestrial species of all alternatives being evaluated for further consideration will be analyzed and discussed in the EIS/EIR.

3.3 Monitoring and Evaluation of Action

The juvenile stranding reduction program will monitor water levels on the floodplain during receding flows in an attempt to identify those portions of the Bypass that are prone to becoming isolated due to limited connectivity. Major stranding sites will be addressed first and the resulting isolated pools will subsequently be monitored to determine the level of risk associated with each pool. After the ponds are isolated, the ponds will be sampled to determine the number of stranded fish in order to establish a baseline. These ponds can be sampled after each inundation event to track stranding rates as well as to determine which ponds may need to be filled or modified in the future to minimize stranding. Continued monitoring of stranding sites on the floodplain will provide the YBRT with insight into the effectiveness of its stranding reduction actions and will highlight areas that may be in need of future correction.

3.4 Adult Entrainment Improvements: Potential Fish Passage Barrier for the Knights Landing Ridge Cut

3.4.1 Knights Landing Ridge Cut

The Colusa Basin Drain (Colusa Drain) is connected to the Bypass by an artificial overflow channel called the Knights Landing Ridge Cut (KLRC). The Colusa Drain has a 1,620-square-mile watershed that receives inputs from all Sacramento Valley west side creeks between Stony Creek and Knights Landing. The Colusa Drain channels the creeks' runoff and irrigation waters from west of the Sacramento River for nearly 70 miles between Stony Creek and Knights Landing. "Water from the Colusa Drain is released into the Sacramento River through the Knights Landing Outfall Gates. The gates were constructed in the 1930s to reduce flooding in the lower Colusa Basin from Sacramento River backwater as well as providing a drainage structure for the Colusa Drain when the Sacramento River is at lower stages" (DWR 2010). The gates maintain an upstream water elevation of 25 feet (USACE datum [DFG 2008]). Flows entering the Sacramento River through the gates are measured by DWR. This design, along with Wallace Weir at the mouth of KLRC, allows the retention of backwater along the length of the KLRC to help meet agricultural irrigation needs. To help maintain the desired elevation, a berm is constructed at the Yolo Bypass end of the KLRC. When flows on the Sacramento River increase water elevation to 25 feet at Knights Landing, the Colusa Drain gates are closed and all flows move through the KLRC, over Wallace Weir, and into the Yolo Bypass (DFG 2008).

Significant flows into the Yolo Bypass from the KLRC occur when there are large pulse flows in the fall from rice field drainage and when the gates are closed. Fish attracted to the Colusa Drain through the KLRC become entrained, since there are no outlets for the return of migratory fish to the Sacramento River. Salmonids are attracted and entrained by outflow from the KLRC as early as late September, when the Yolo Bypass is not yet flooded. Sturgeon may be attracted and entrained during the months from winter to spring.

3.4.2 Knights Landing Ridge Cut Modification

If the YBRT determines there is a need to prevent the reproductive loss of fish straying into Knights Landing Ridge Cut, entry into KLRC will be blocked and fish passage will be provided back to the Sacramento River. Two barrier approaches are described here. The YBRT may first consider the construction of a temporary barrier at KLRC, and may then consider the realignment of the KLRC outflow into the Yolo Bypass.

3.4.3 Temporary Barrier

Under the temporary barrier solution, the YBRT would decide to design and construct an Alaskan board weir, inflatable weir, or similar structure that would allow flows to pass but would prevent fish passage. This is a priority project for preventing the reproductive loss of fish straying into KLRC. A temporary barrier may be the preferred option because it may provide the quickest fix to entrainment at KLRC. Prevention of the straying of fish into KLRC is desirable, but without an exit connection to the Sacramento River and appropriate attraction flows to draw fish away from the barrier, we would still expect fish to remain near the barrier.

3.4.4 Key Risks and Uncertainties

Structure Placed at Wallace Weir

- Risk of inadequate maintenance leading to elevated water surface elevations and associated flood risk for agricultural lands within the Bypass
- Ineffective when KLRC flows are elevated.
- Fish remain downstream of the barrier, increasing passage delays.
- Overall ineffectiveness at protecting fish if no additional passage improvement is provided at Fremont Weir.

Outlfow Realignment: Diversion of KLRC Flood Flows into the Cache Creek Settling Basin

- Increased flood risk for the City of Woodland unless additional improvements are made outside the Bypass
- Ineffective when KLRC flows are elevated.
- Fish remain downstream of the barrier, increasing passage delays
- Overall ineffectiveness at protecting fish if no additional passage improvement is provided at Fremont Weir

3.4.5 Outflow Realignment

Realignment of the KLRC outflow into the Bypass has been proposed as a possible permanent alternative. This alternative would require the reengineering of the structures involved and would require a long implementation time line. For these reasons we are not currently considering this option.

Realignment modifications would divert the outfall from the KLRC into the Cache Creek Settling Basin via drain gates at the current outfall location. The structure could be used to regulate outfall from Cache Creek Settling Basin provides an effective fish passage barrier and would be effective in reducing KLRC entrainments while allowing increased outflows from the KLRC. Additional fish passage improvements, such as connectivity to the Sacramento River, would have to be made to guide fish away from the structure. This action would support other passage improvements at Fremont Weir, including west side options.

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