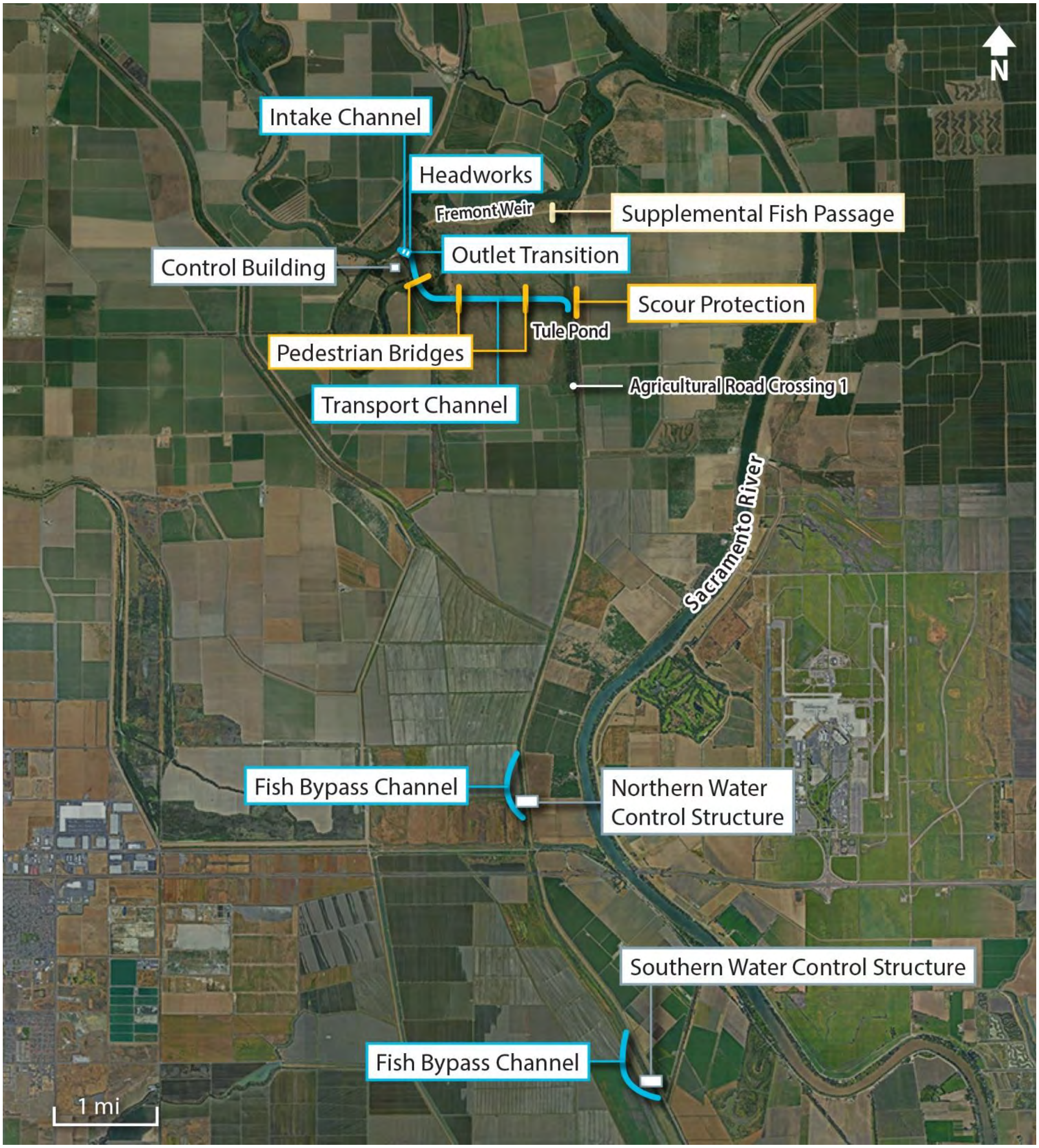

Figure 4-13. Alternative 4 Key Components

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

4.7.1 Facilities

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

Two bypass channels would be constructed, each as an open channel sized for 300 cfs with a 10-foot-bottom width and 3:1 side slopes. The channel near the northern water control structure would be approximately 2,500 feet long, whereas the channel near the southern water control structure would be 3,000 feet long. The channels would have no operable weir features.

4.7.1.1 Northern Water Control Structure

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

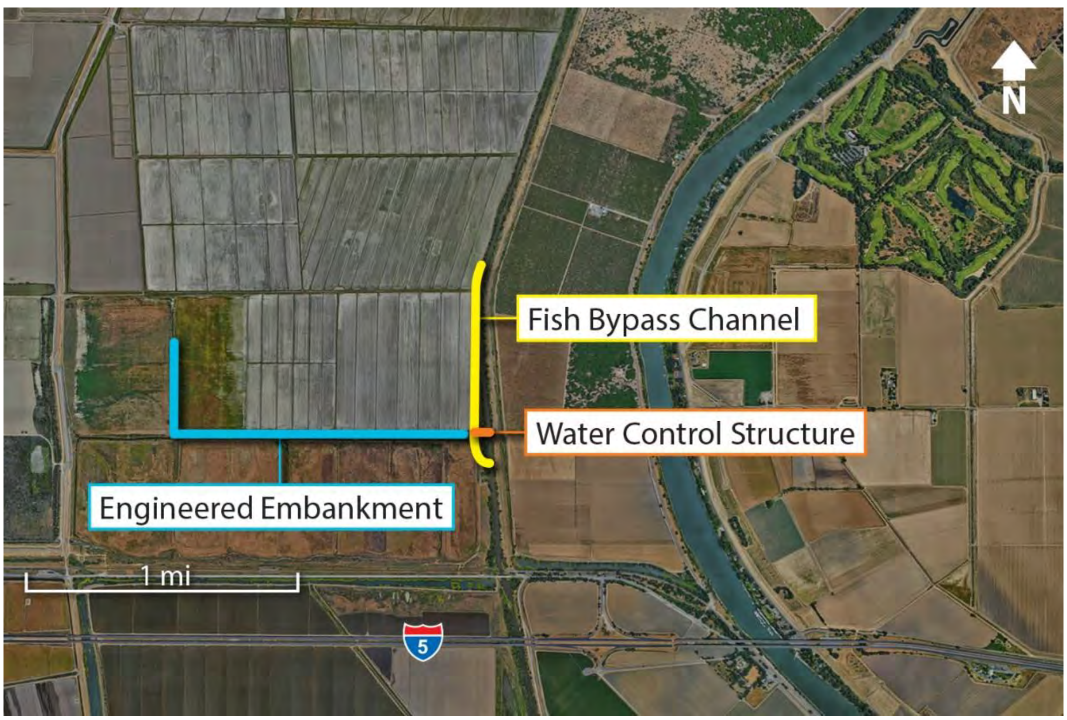

Figure 4-14. Northern Water Control Structure and Bypass Channel

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

When the gates are raised, they would block fish passage through Tule Canal. To reduce fish passage delays, a bypass channel would go around the water control structure, as shown on Figure 4-14. The bypass channel would be an open, trapezoidal channel with a 10-foot-bottom width and 3:1 side slopes. Berms (two to five feet in height) would be constructed on each side of the channel to maintain water levels in the bypass channel. The channel would include two areas where it would be constricted down to a five-foot-bottom width for 60 feet. This constriction would help slow the water and meet fish passage criteria. Figure 4-16 shows a cross-section schematic of the bypass channel next to Tule Canal. The channel would be approximately 2,500 feet long with no operable features in the bypass channel. It would convey up to 300 cfs. The bypass channel would include a box culvert adjacent to the water control structure to allow vehicular access across both facilities.

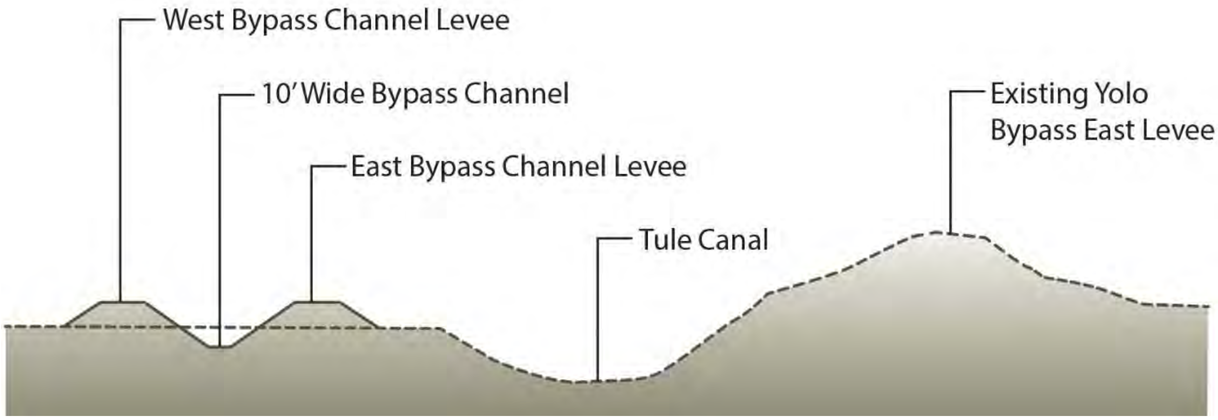

Figure 4-16. Cross-Section of Bypass Channel

An engineered, armored embankment would be added in the area of existing roads or berms west and north of the water control structure to maintain water levels north of the water control structure. This embankment would add two to six feet above the surrounding ground. The improvements would be about 12,000 linear feet, as shown on Figure 4-14. The embankment would be designed to have a top elevation of 23 feet inside the Yolo Bypass.

4.7.1.2 Southern Water Control Structure

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

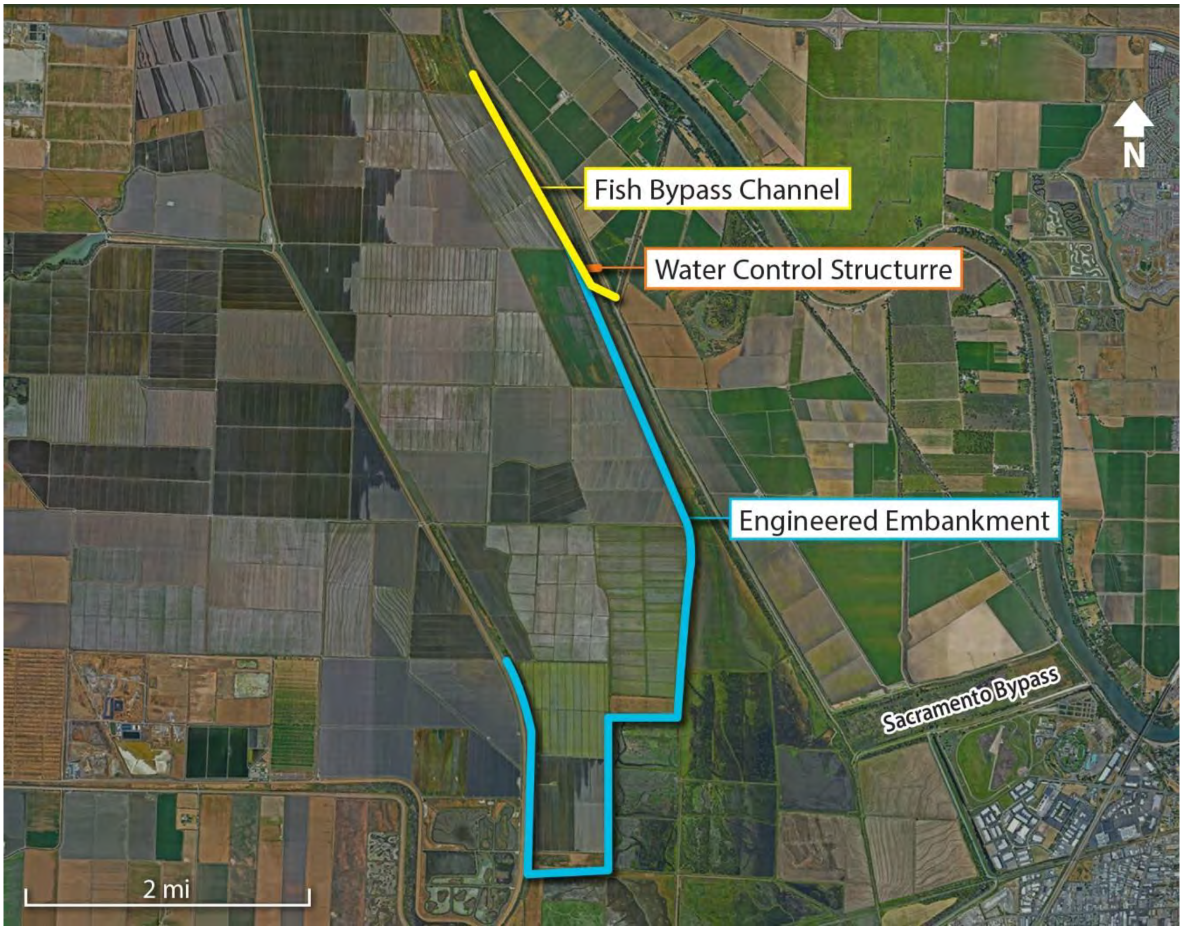

Figure 4-17. Southern Water Control Structure and Bypass Channel

When the gates are raised, they would block fish passage through Tule Canal. To reduce fish passage delays, a bypass channel would go around the water control structure, as shown on Figure 4-17. The bypass channel would be an open, trapezoidal channel with a 10-foot-bottom width and 3:1 side slopes. Berms would be constructed on each side of the channel to maintain water levels in the bypass channel. The cross-section would be similar to the northern channel, as shown on Figure 4-16. The channel would be roughly 4,000 feet long with no operable features in the bypass channel (but existing agricultural facilities would be maintained). The channel would convey up to 300 cfs. The bypass channel would include a box culvert adjacent to the water control structure to allow vehicular access across both facilities.

An engineered embankment (armored with rock) would be constructed along the alignments of existing roads or berms south then west of the water control structure to maintain water levels north of the water control structure. The existing berms would be degraded and rebuilt to meet the stability requirements to hold back water. The rebuilt embankments would be two to six feet above the existing grade on the surrounding property. The improvements would be about 42,500 linear feet, as shown on Figure 4-17. The embankment would be designed to have a top elevation of 19 feet inside the Yolo Bypass.

4.7.2 Construction Methods

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

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

4.7.2.1 Excavated Material

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

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

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

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

4.7.2.2 Construction Materials

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

4.7.2.3 Staging Areas and Access

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

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

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

4.7.2.4 Construction Equipment

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

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

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

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

4.7.2.5 Construction Schedule and Workers

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

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

4.7.3 Operations

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

Once Fremont Weir begins to overtop, the smaller gates would remain in their last position prior to the weir overtopping (generally both would be closed at this point). After the overtopping event is over, the smaller gates would open and close as needed to keep the flow through the gate below, but as close as possible to, 3,000 cfs. The notch would close when the river falls below an elevation of 16.1 feet. Gate operations to increase inundation could continue through March 7 or March 15 of each year, based on hydraulic conditions. The gates may remain partially open after March 7 or March 15 to provide fish passage. However, flows through the gates after March 7 or March 15 could not exceed 1,000 cfs (the capacity of Tule Canal) so that these flows do not inundate areas outside of the canal and affect landowners.

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

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

4.7.4 Inspection and Maintenance

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

4.7.4.1 Sediment Deposition

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

Reclamation or DWR would purchase land outside the bypass for the sediment removed during maintenance actions. This acquisition would be part of the land acquired for the construction effort, but the acquisition could be phased over time. The maintenance-related sediment removal would require 20 to 23 acres for 50 years of operation.

4.7.4.2 Water Control Structures

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

4.7.5 Monitoring and Adaptive Management

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

4.7.6 Alternative 4 Preliminary Costs

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

4.8 Alternative 5: Central Multiple Gated Notches

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

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

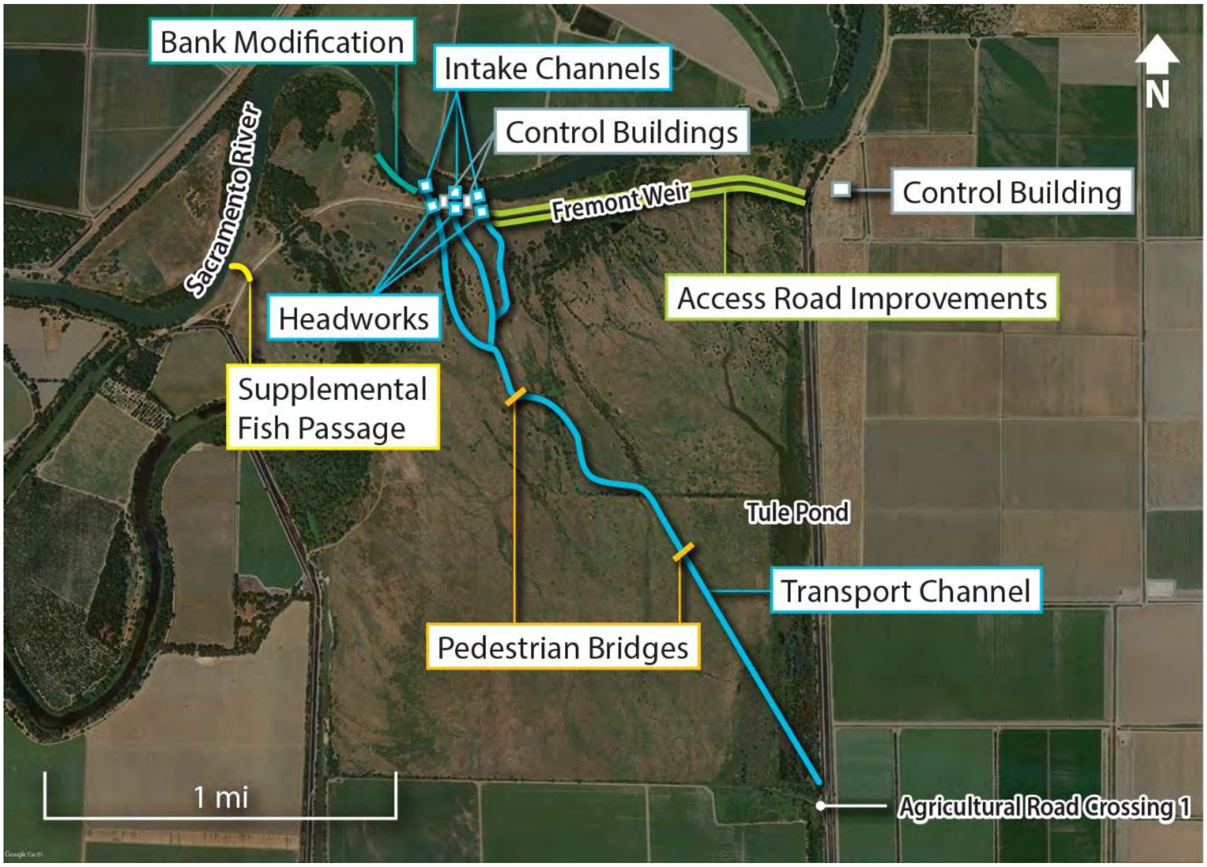

Figure 4-18. Alternative 5 Key Components

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

4.8.1 Facilities

4.8.1.1 Intake Channel

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

4.8.1.2 Headworks Structure

The approximately 100-foot-long headworks structure would house four bottom-hinge control gates with varying invert elevations, as shown on Figures 4-19 and 4-20. Gates A and B would be located on the west side of the structure (at the central notch location at the existing Fremont Weir), Gate C would be in the middle, and Gate D would be on the eastern side of the structure. The structure would be foundationally supported by multiple 24-inch square piles with the bottom of the pile at elevation of 75 feet below NAVD 88. The gate dimensions are as follows:

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

All box culverts include downstream bottom-hinged gates.

4.8.1.3 Control Buildings

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

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

4.8.1.4 Transport Channel

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

- Channel AB would connect A and B gate groups to the Tule Canal and would be a rock-lined compound trapezoidal channel 2,250 feet long with a left bench set three feet above the channel bed.

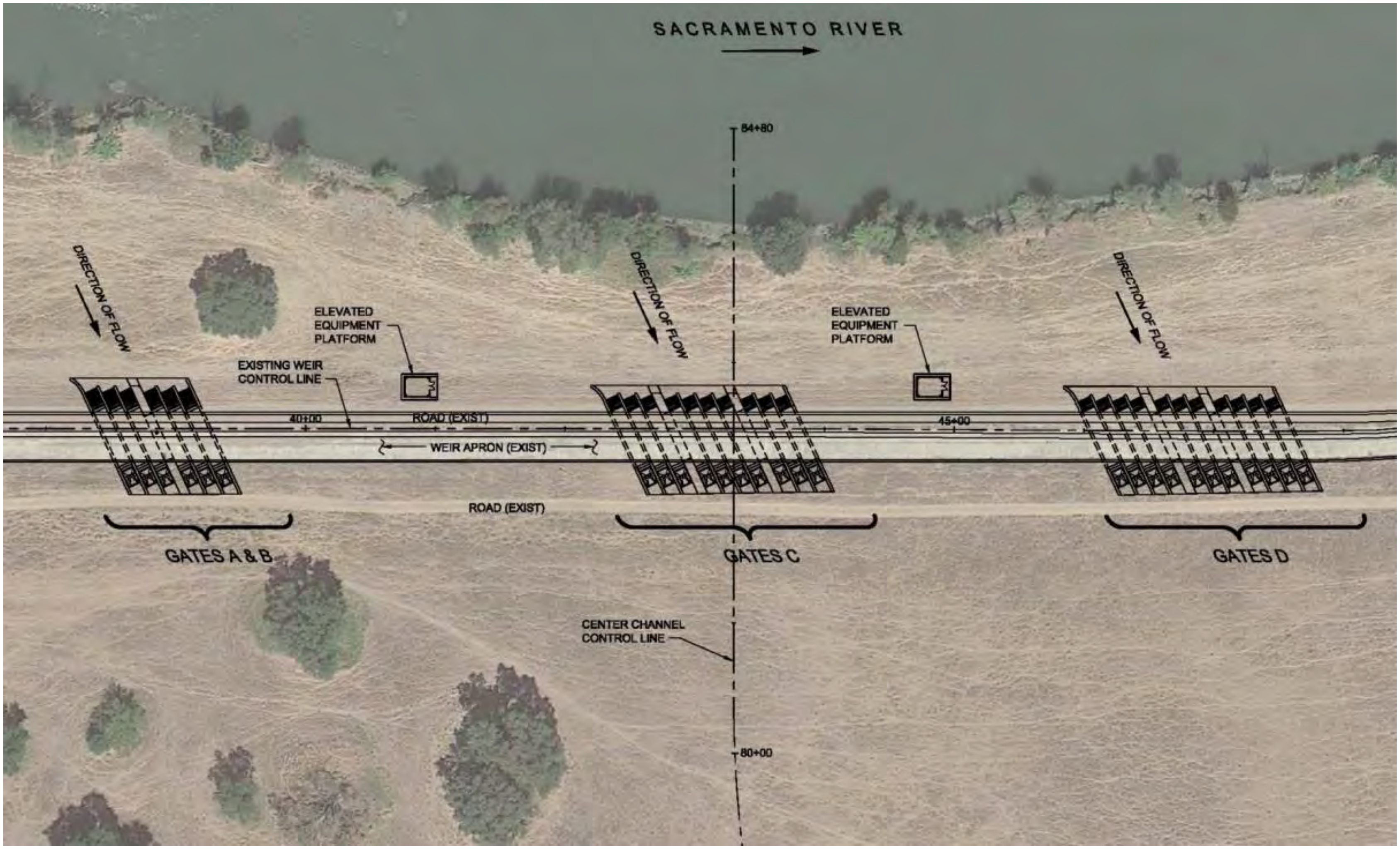

Figure 4-19. Alternative 5 Headworks (view from top looking down)

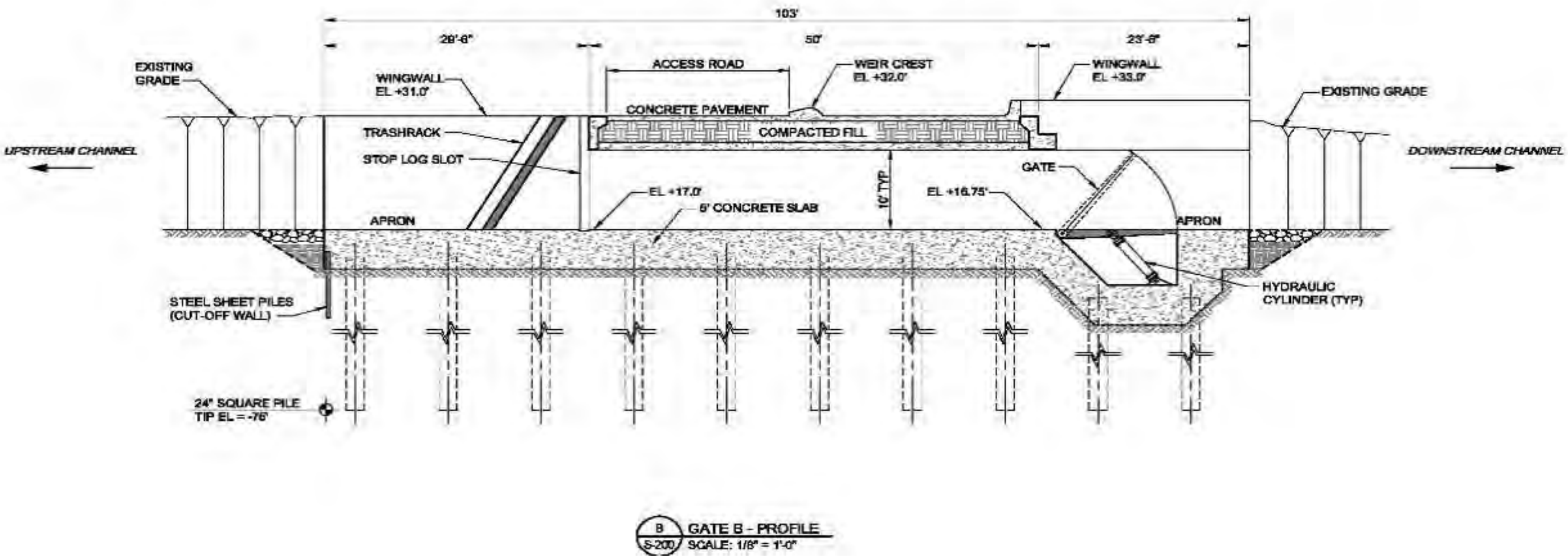

Figure 4-20. Alternative 5 Headworks (view from side of Gate Group B)[5]

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

- Channel C would connect the C gate group to the Tule Canal and would be a rock-lined trapezoidal channel 1,930 feet long that connects to Channel AB at its bench.
- Channel D would connect the D gate group to the Tule Canal and would be a rock-lined trapezoidal channel 1,400 feet long that connects to Channel C.

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

4.8.1.5 Access Structures

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

4.8.1.6 Supplemental Fish Passage Facility

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

4.8.1.7 Tule Canal Floodplain Improvements (Program Level)

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

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

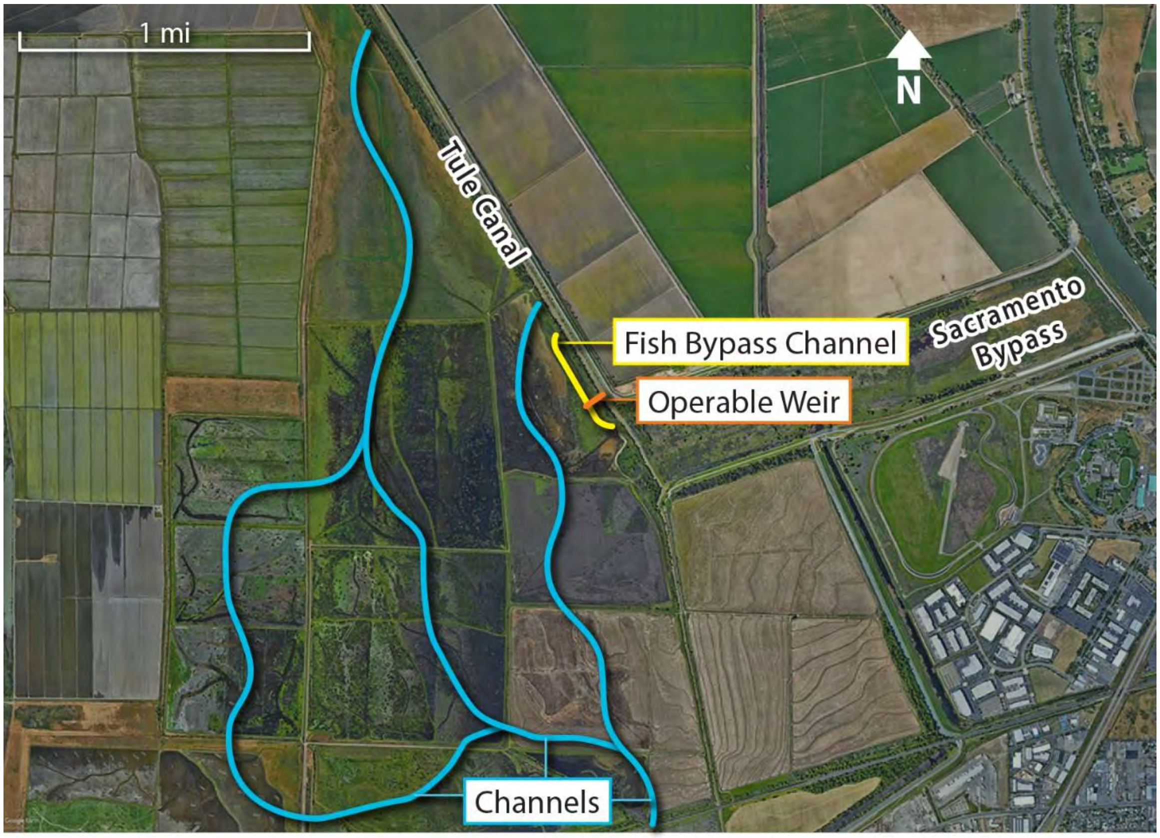

Figure 4-21. Tule Canal Floodplain Improvements (Program Level)

4.8.2 Construction Methods

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

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

4.8.2.1 Excavated Material

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

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

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

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

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

4.8.2.2 Construction Materials

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

4.8.2.3 Staging Areas and Access

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

4.8.2.4 Construction Equipment

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

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

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

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

4.8.2.5 Construction Schedule and Workers

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

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

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

4.8.3 Operations

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

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

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

Figure 4-22 shows the overlap in the gate operations, with the number in each box showing the number of gates open at each time. The line indicating "all gates" shows the flow added together from all gates operating at the same time. Gate operations to increase inundation could continue through March 15 of each year, based on hydraulic conditions. The gates may remain partially open after March 15 to provide fish passage. However, flows through the gates after March 15 could not exceed 1,000 cfs (the capacity of Tule Canal) so that these flows do not inundate areas outside of the canal.

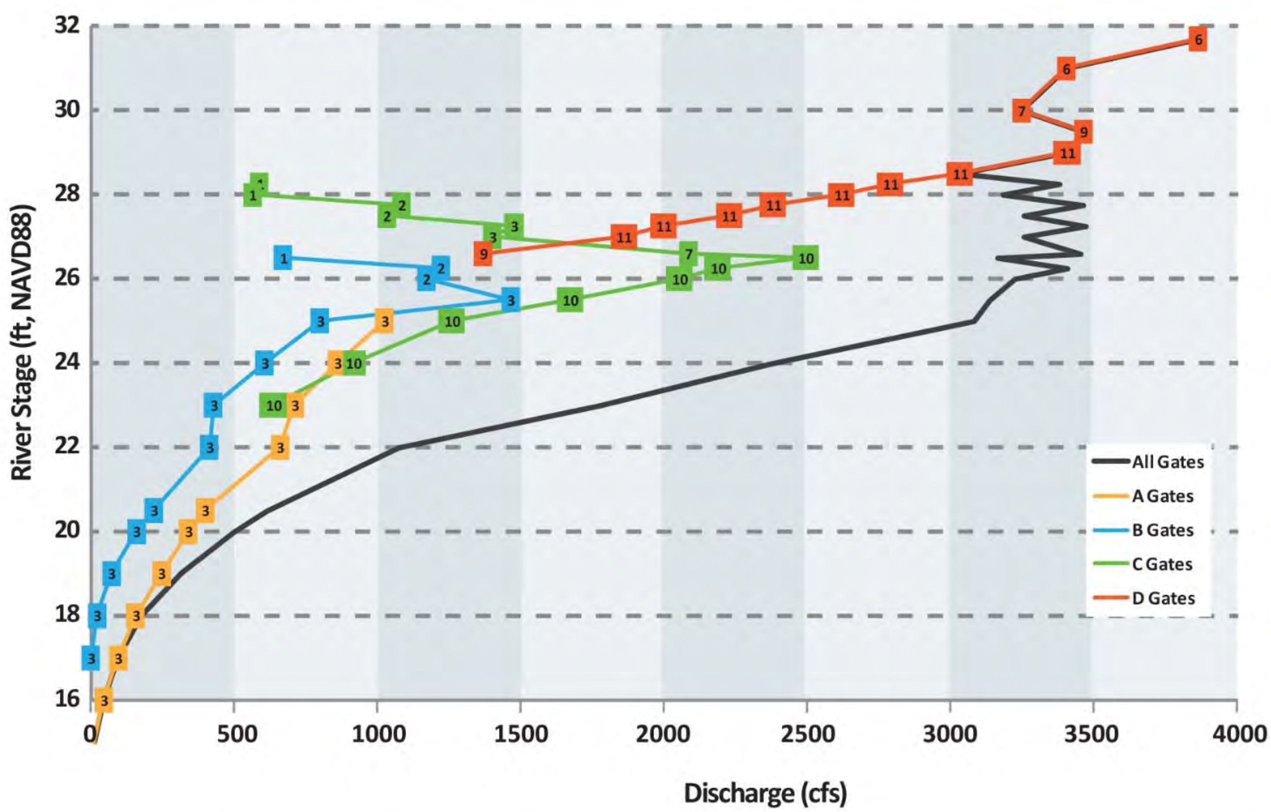

Figure 4-22. Alternative 5 Gate Operations

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

4.8.4 Inspection and Maintenance

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

Table 4-19. Maintenance Accessibility by River Elevation

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

4.8.4.1 Sediment Deposition

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

Reclamation or DWR would purchase land outside the bypass for the sediment removed during maintenance actions. This acquisition would be part of the land acquired for the construction effort, but the acquisition could be phased over time. The maintenance-related sediment removal would require 20 to 23 acres for 50 years of operation.

4.8.4.2 Vegetation Removal

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

4.8.5 Monitoring and Adaptive Management

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

4.8.6 Alternative 5 Preliminary Costs

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

4.9 Alternative 6: West Side Large Gated Notch

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

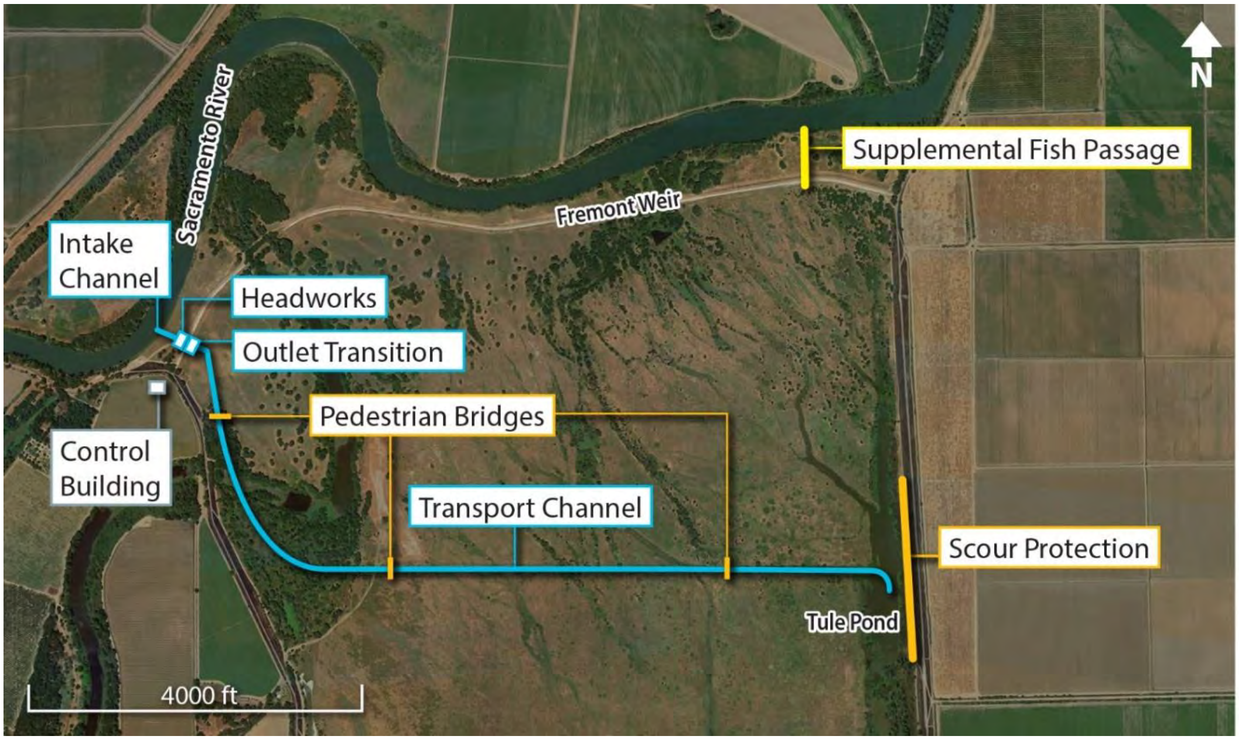

Figure 4-23. Alternative 6 Key Components

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

4.9.1 Facilities

4.9.1.1 Intake Channel

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

4.9.1.2 Headworks Structure

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

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

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

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

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

4.9.1.3 Control Building

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

4.9.1.4 Access Structures

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

View from river side of Fremont Weir

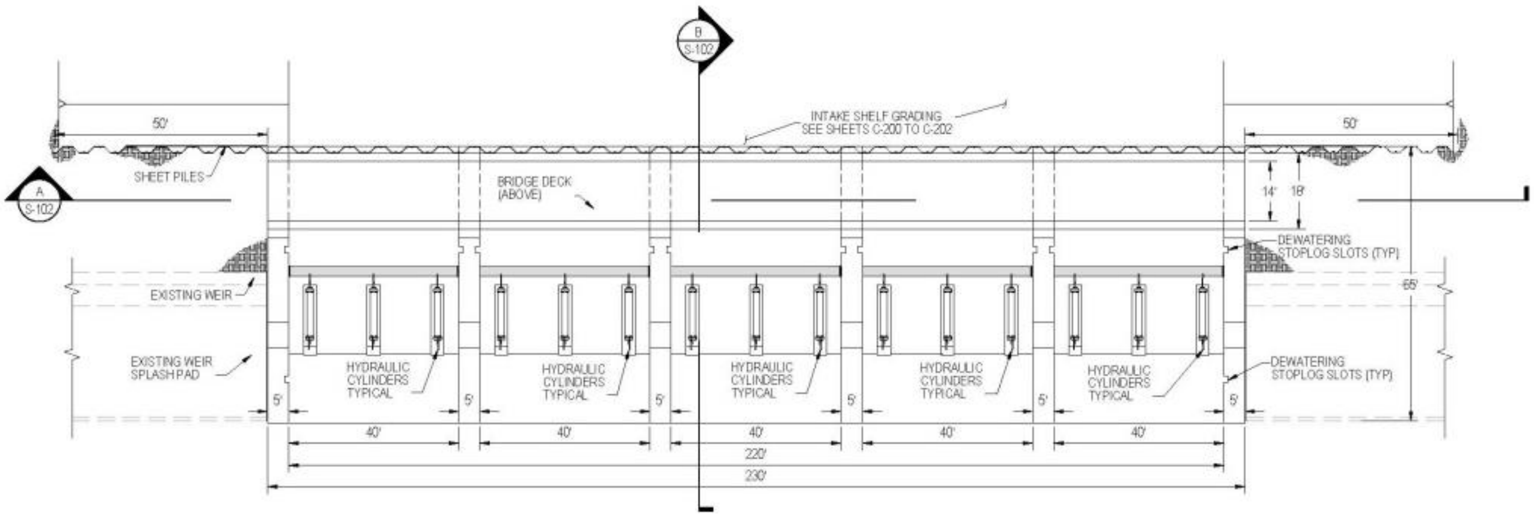

Figure 4-24. Alternative 6 Headworks Cross Section (view from river side)

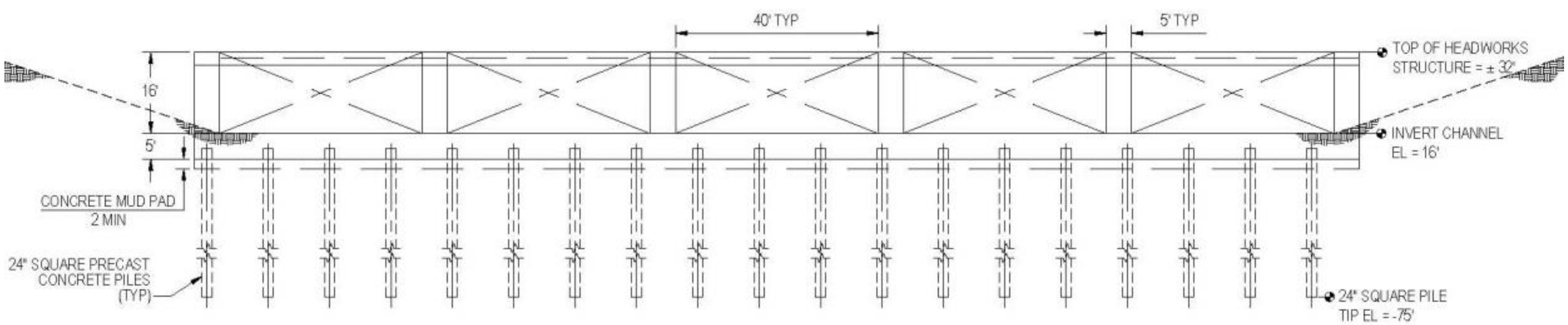

Figure 4-25. Alternative 6 Headworks (view from top of structure)

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

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

4.9.1.5 Outlet Transition

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

4.9.1.6 Transport Channel

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

4.9.1.7 Scour Protection

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

4.9.1.8 Supplemental Fish Passage Facility

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

4.9.2 Construction Methods

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

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

4.9.2.1 Excavated Material

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

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

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

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

4.9.2.2 Construction Materials

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

4.9.2.3 Staging Areas and Access

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

4.9.2.4 Construction Equipment

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

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

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

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

4.9.2.5 Construction Schedule and Workers

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

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

4.9.3 Operations

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

If the river continues to rise, the gates would stay open until the flow through the gates reaches 12,000 cfs. The flow through the gates would reach 12,000 cfs when the river elevation is about 29.8 feet; at this point, three of the gates would be programmed to start closing such that 12,000 cfs would not be exceeded. Gate closures would be controlled so that there is not a sudden reduction in flow. Two of the gates would remain fully open throughout operations.

Once Fremont Weir begins to overtop, the three gates being operated would remain in their last position prior to the weir overtopping (generally they would be closed at this point). After the overtopping event is over, the three operating gates would open and close as needed to keep the flow through the gate below, but as close as possible to, 12,000 cfs. All gates would be closed once river elevations fall below 16.1 feet. Gate operations to increase inundation could continue through March 15 of each year, based on hydraulic conditions. The gates may remain partially open after March 15 to provide fish passage. However, flows through the gates after March 15 could not exceed 1,000 cfs (the capacity of Tule Canal) so that these flows do not inundate areas outside of the canal and affect landowners.

4.9.4 Inspection and Maintenance

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

4.9.4.1 Sediment Deposition

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

Reclamation or DWR would purchase land outside the bypass for the sediment removed during maintenance actions. This acquisition would be part of the land acquired for the construction effort, but the acquisition could be phased over time. The maintenance-generated sediment removal would require 35 to 40 acres for 50 years of operation.

4.9.5 Monitoring and Adaptive Management

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

4.9.6 Alternative 6 Preliminary Costs

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

4.10 References

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

HDR, Inc. 2017. Draft Technical Memorandum: Assessment of Groundwater, Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project – Ten Percent Design. February 14, 2017.

Sacramento Metropolitan AQMD (Sacramento Metropolitan Air Quality Management District). 2016. *Guide to Air Quality Assessment in Sacramento County.* Site accessed June 26, 2017. http://www.airquality.org/Businesses/CEQA-Land-Use-Planning/CEQA-Guidance-Tools.

5 Evaluation and Comparison of Alternatives

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

5.1 Evaluation Factors

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

Table 5-1. Alternative Evaluation Factors

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

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

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

5.2 Alternatives Evaluation and Comparison

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

5.2.1 Effectiveness

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

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

Table 5-2. Effectiveness Evaluation Results

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

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

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

Source:

[1] DWR 2017a

[2] Hinkelman et al. 2017

[3] TUFLOW modeling results

[4] TUFLOW modeling results

[5] DWR 2017b

5.2.1.1 Access to Floodplain Habitat

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

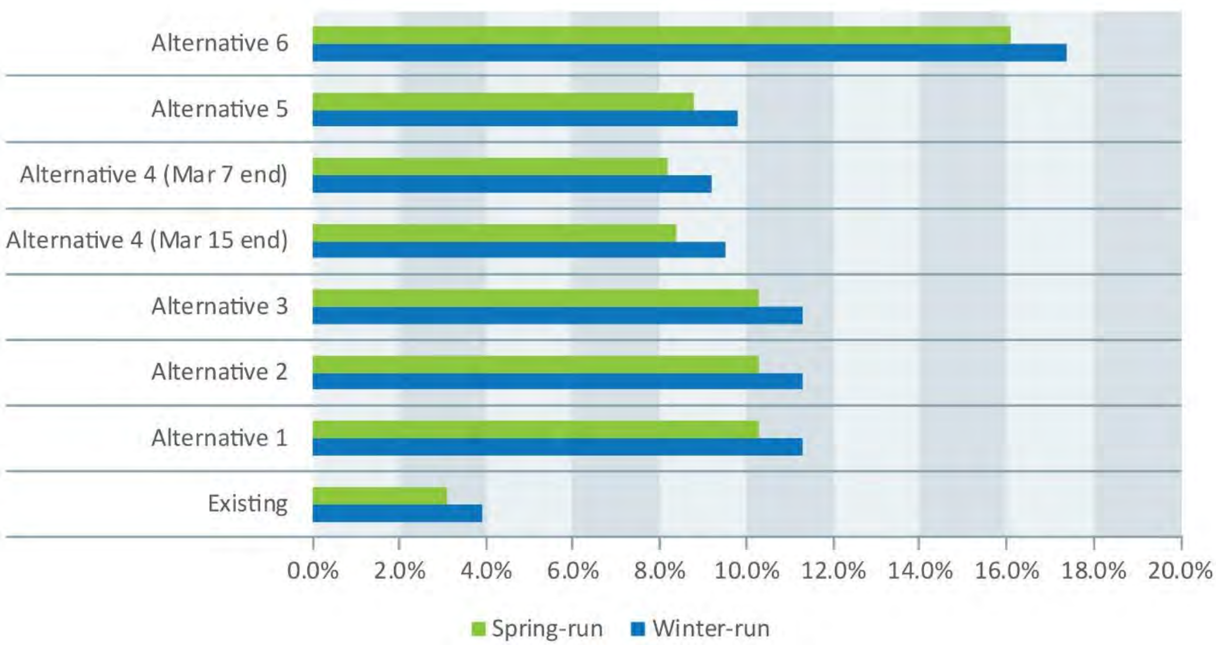

Figure 5-1. JEET Estimate of Juvenile Fish Entrainment

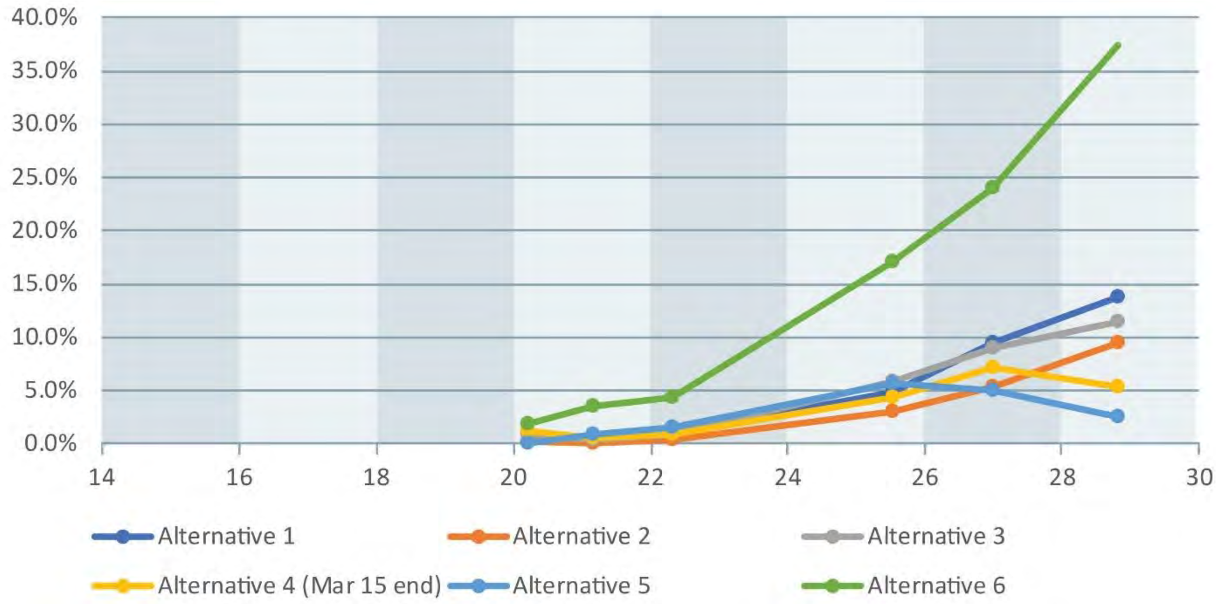

Figure 5-2. ELAM Model Estimate of Juvenile Fish Entrainment

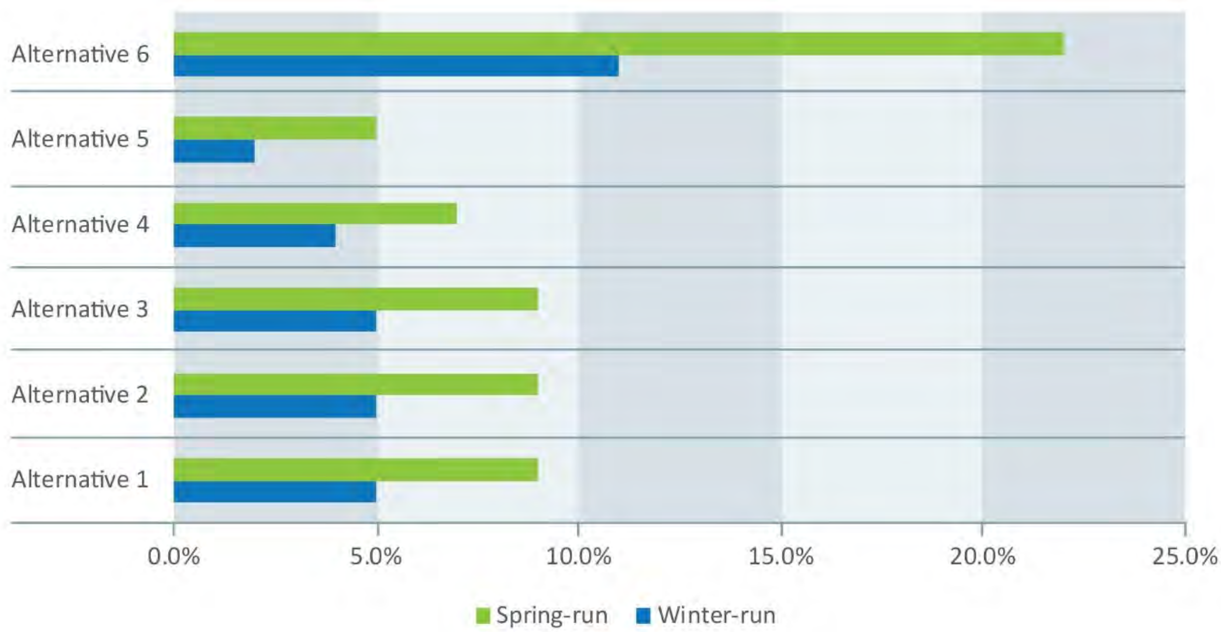

Figure 5-3. Critical Streakline Estimate of Juvenile Fish Entrainment

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

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

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

5.2.1.2 Seasonal Floodplain Fisheries Rearing Habitat

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

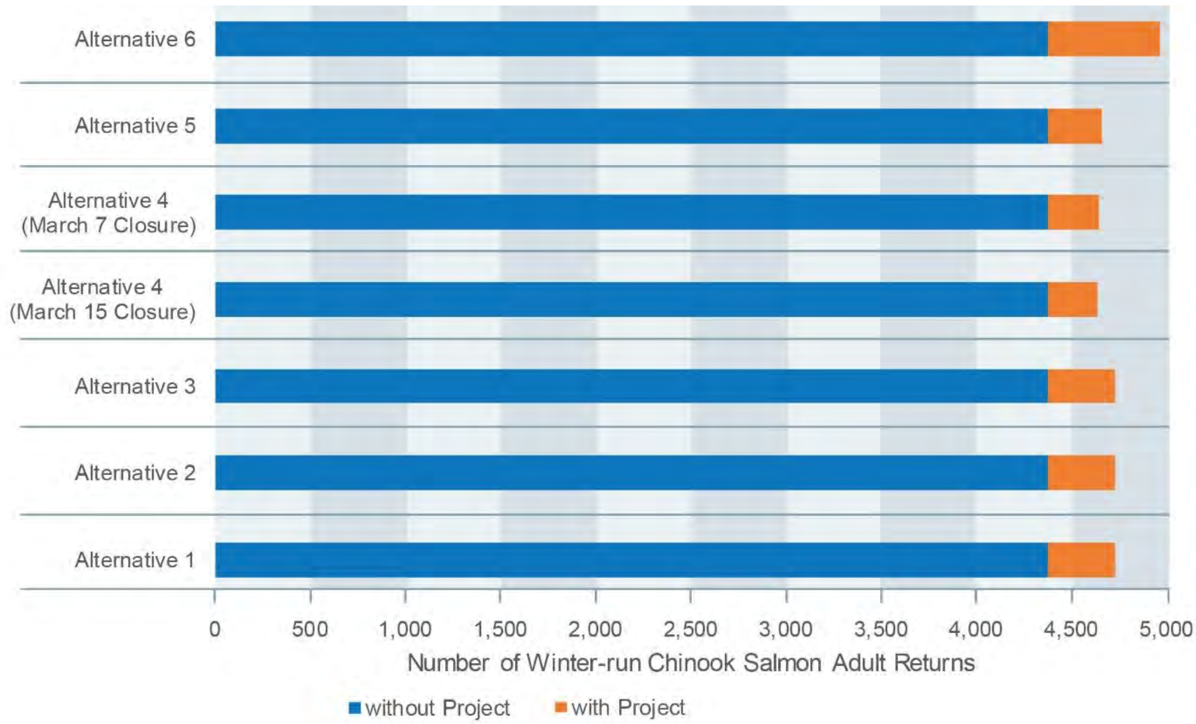

Figure 5-5. Average Change in Returns for Winter-Run Chinook Salmon

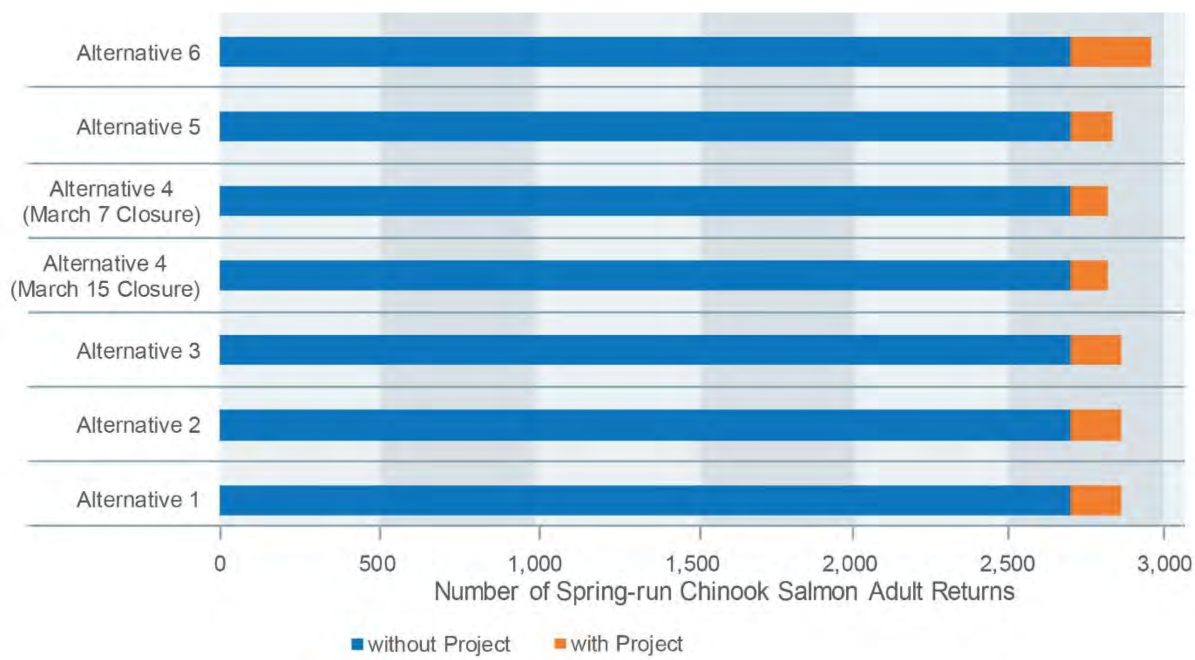

Figure 5-6. Average Change in Returns for Spring-Run Chinook Salmon

5.2.1.3 Area of Floodplain Habitat

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

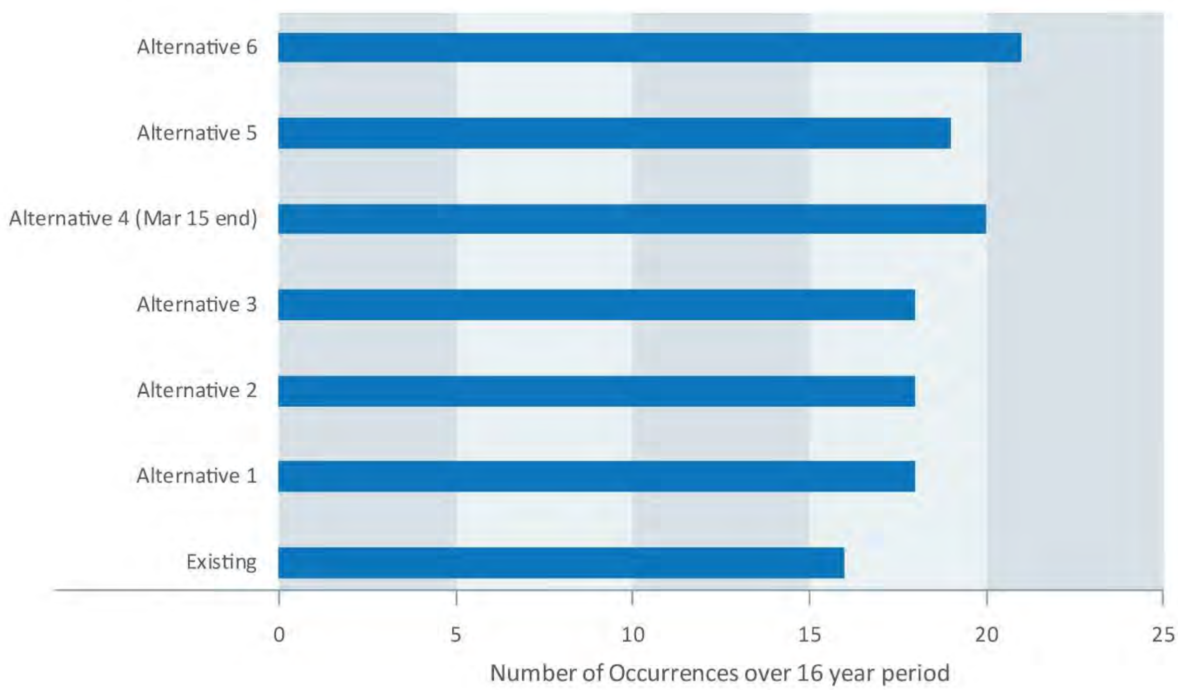

Figure 5-7. Number of Occurrences of 14 Consecutive Days with Greater than 10,000 Acres Inundated

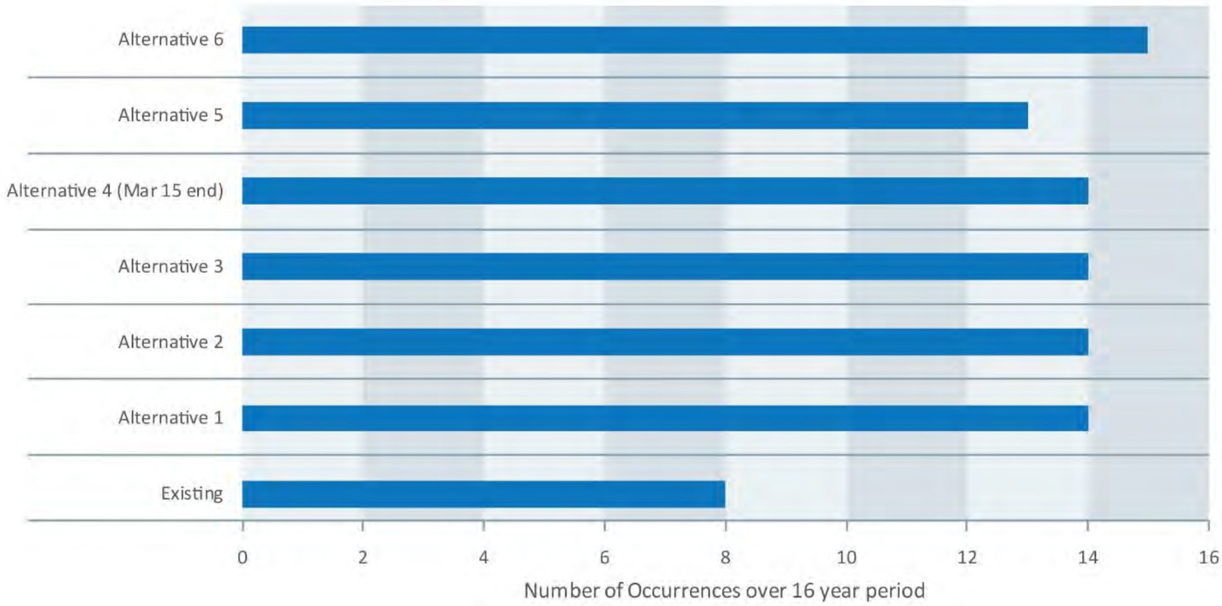

Figure 5-8. Number of Occurrences of 14 Consecutive Days with Greater than 20,000 Acres Inundated

5.2.1.4 Duration of Flooded Habitat

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

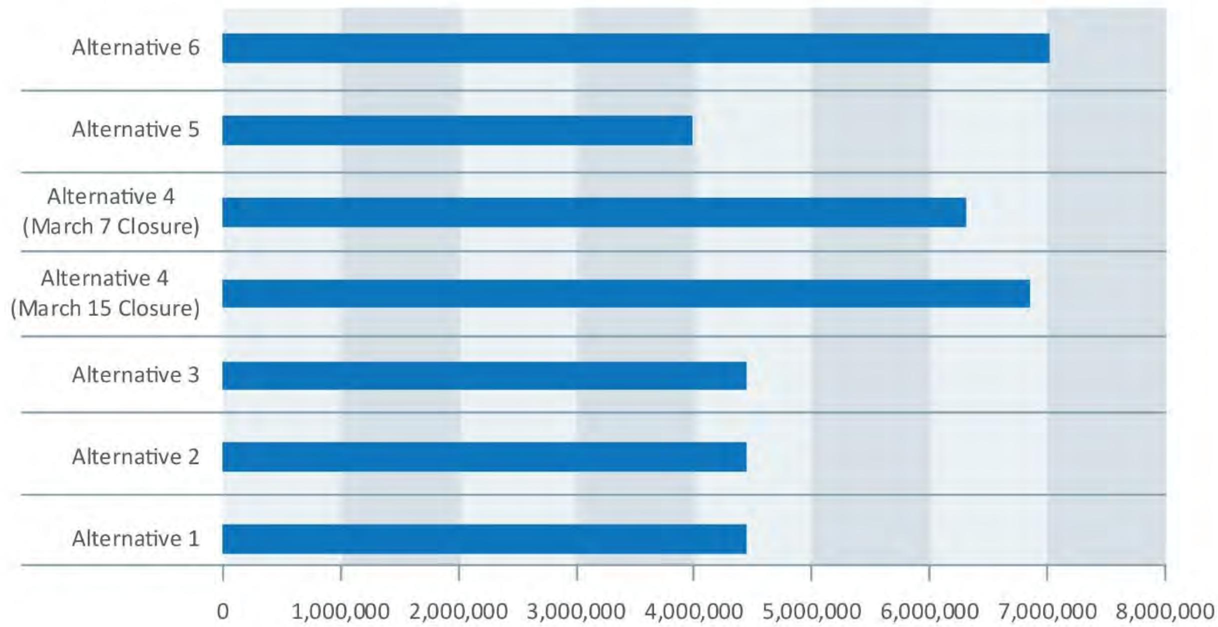

Figure 5-9. Increase in Wetted Acre-Days During the 16-Year Model Period

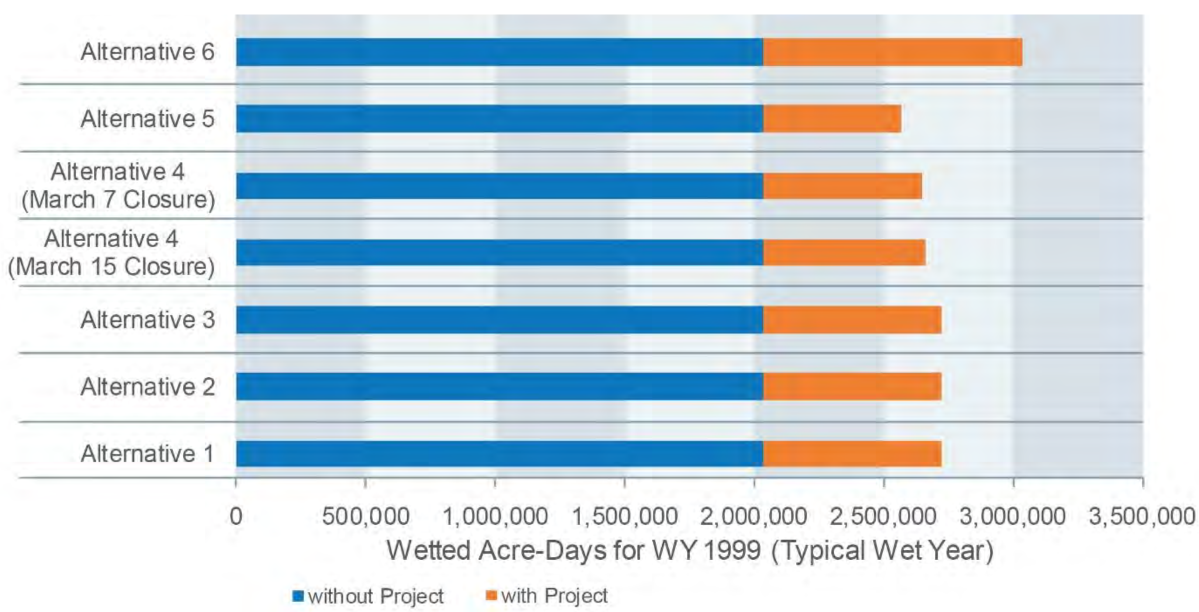

Figure 5-10. Increase in Wetted Acre-Days During a Wet Year

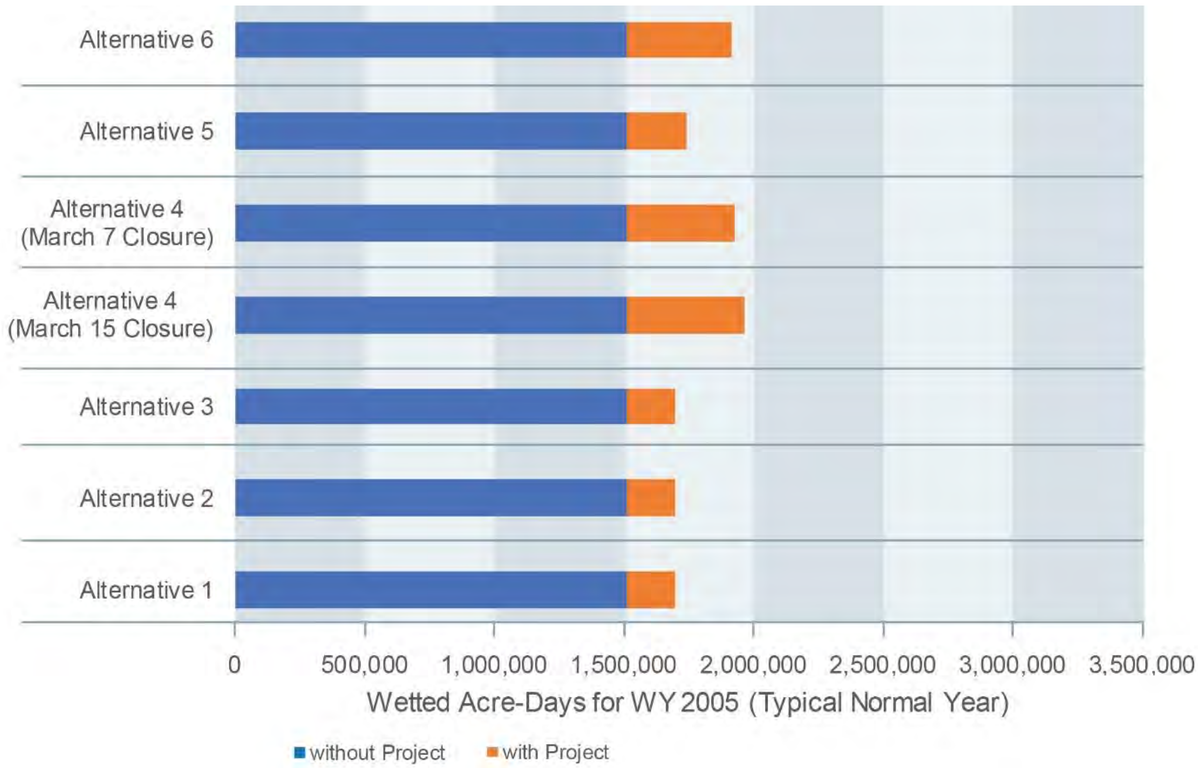

Figure 5-11. Increase in Wetted Acre-Days During a Normal Year

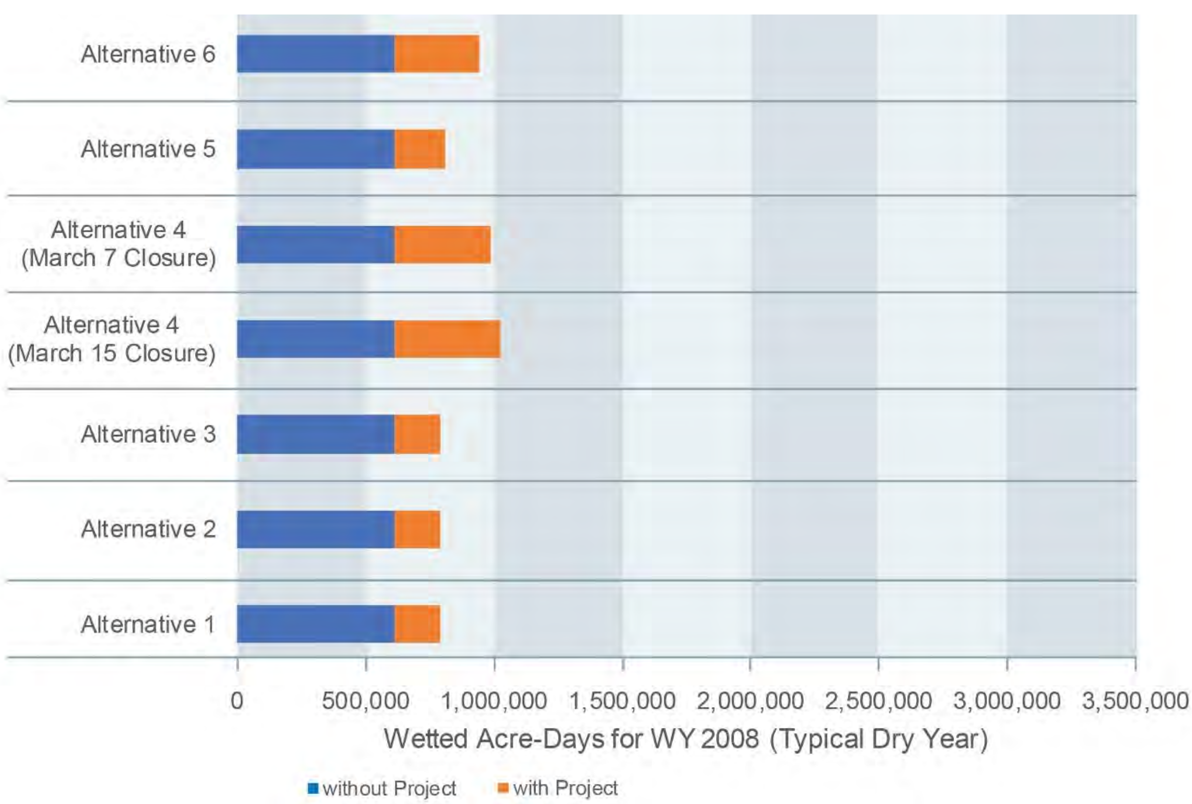

Figure 5-12. Increase in Wetted Acre-Days During a Dry Year

5.2.1.5 Food Production with an Ecosystem Approach

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

5.2.1.6 Adult Fish Passage

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

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

Figure 5-13 shows the average percent of the season that each alternative would meet depth and velocity passage criteria at Fremont Weir. Figure 5-14 provides additional detail about the timing of passage for adult sturgeon. Upstream passage would be available more time during February (when the gated notch is fully operational) but available for fewer days in March and April. Sturgeon that are unable to pass during these periods would either face passage delays at Fremont Weir or would turn around and travel to the Wallace Weir collection facility.

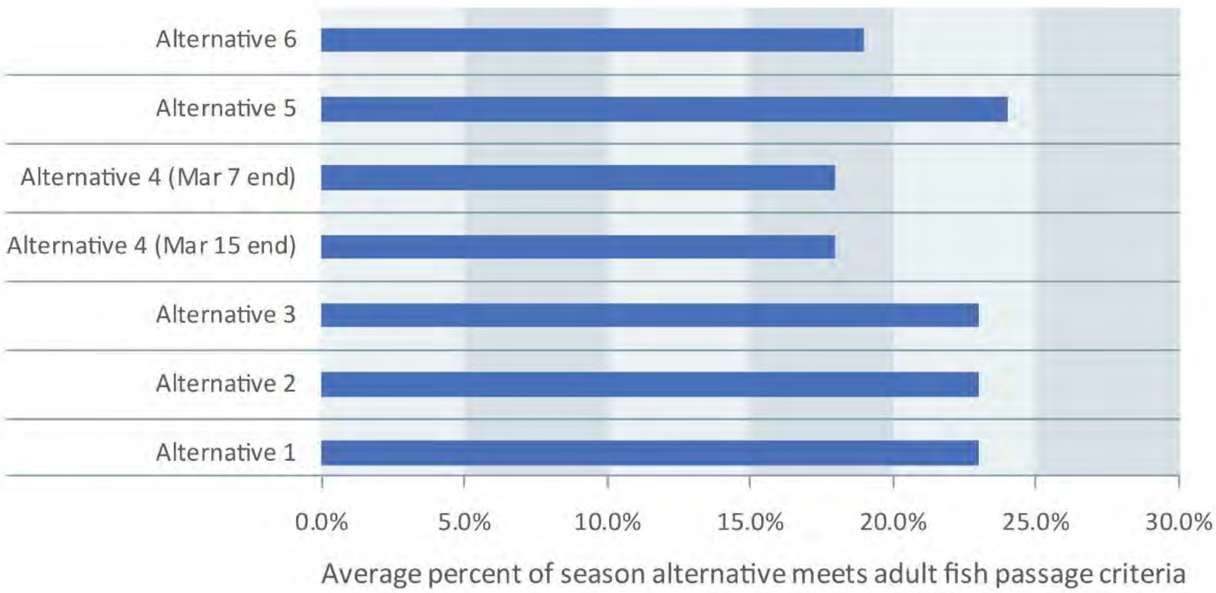

Figure 5-13. Average Fish Passage Availability at Fremont Weir

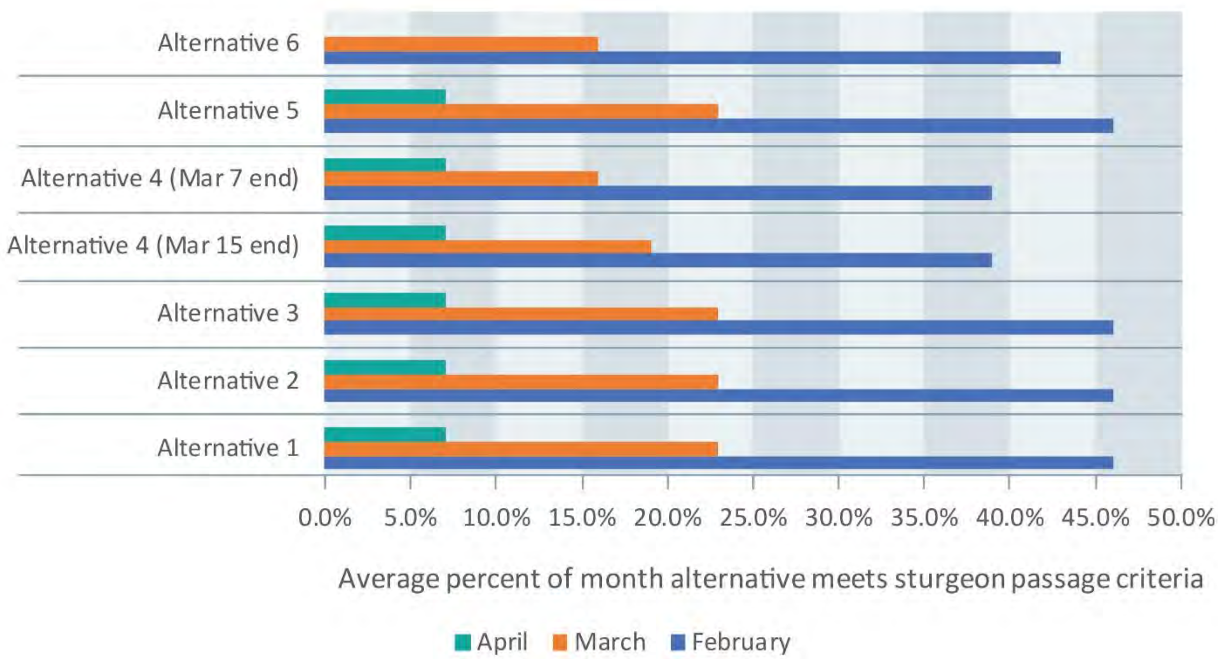

Figure 5-14. Average Timing of Adult Sturgeon Fish Passage

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

5.2.1.7 Juvenile Fish Passage

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

5.2.2 Completeness

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

5.2.3 Acceptability

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

5.2.3.1 Agricultural Impacts

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

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

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

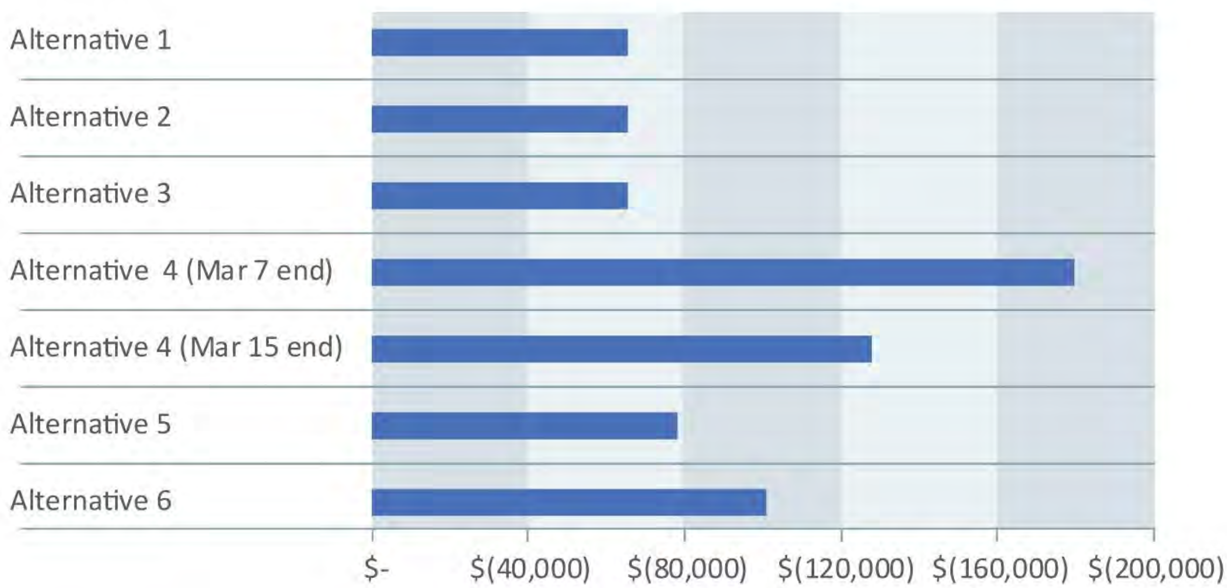

Figure 5-15. Change in Average Annual Agricultural Income

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

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

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

5.2.3.2 Recreation Impacts

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

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

This impact focuses on non-waterfowl recreation (because waterfowl is addressed separately). While non-waterfowl hunting activities could occur at the FWWA, YBWA, or the SBWA, this assessment focuses on the FWWA. The FWWA is likely to experience the greatest effects because of its location near Fremont Weir and because construction would occur within the area. The comparison of alternatives would follow the same patterns in the other wildlife areas.

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

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

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

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

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

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

Key: FWWA = Fremont Weir Wildlife Area

5.2.3.3 Waterfowl Impacts

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

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

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

- At FWWA, Alternative 1, 2, and 3 would decrease the inundation frequency by up to one week for the majority of the wildlife area, and Alternative 4 would decrease the inundation frequency by more than two weeks. As shown on Figure 5-16, the total area of inundation is similar between all action alternatives. Under Alternative 1, 2, 3, and 4, areas on the eastern portion of the wildlife area would experience an increase in the frequency of inundation (up to four additional weeks) compared to the No Action Alternative. Alternative 5 would result in an overall increase in inundation frequency by greater than four weeks in approximately 30 percent of the area within the FWWA. The remaining 70 percent of the lands within FWWA would largely experience a decreased inundation frequency up to two weeks. Under Alternative 6, most of the wildlife area would experience a decreased inundation frequency up to two weeks compared to the No Action Alternative. In contrast, Tule Pond and transport channel component areas would experience an increased inundation frequency of more than four weeks.

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

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

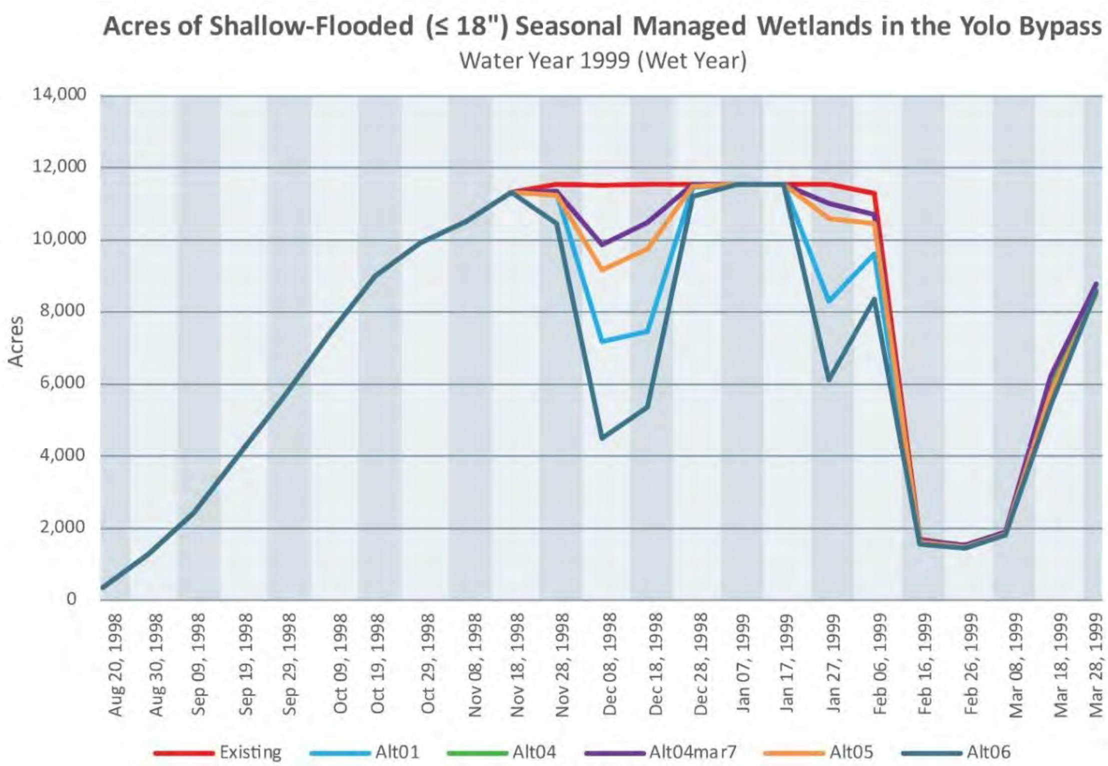

Figure 5-17. Change in Inundation of Managed Wetlands in a Wet Year

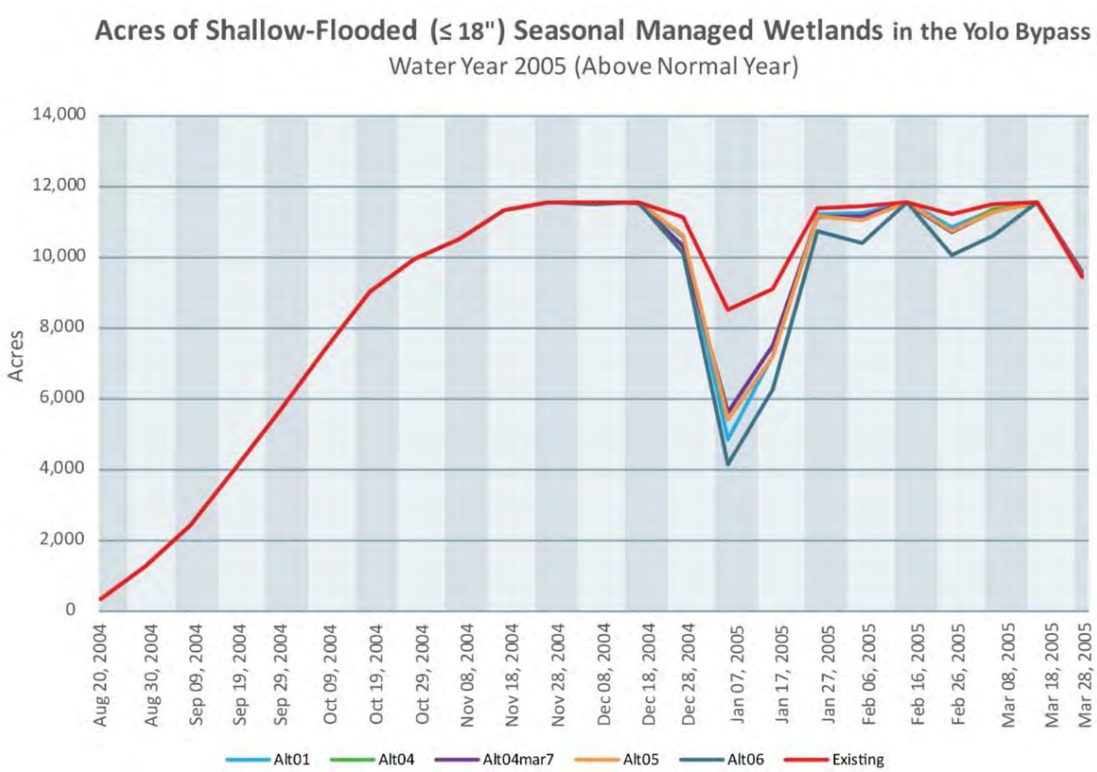

Figure 5-18. Change in Inundation of Managed Wetlands in an Above Normal Year

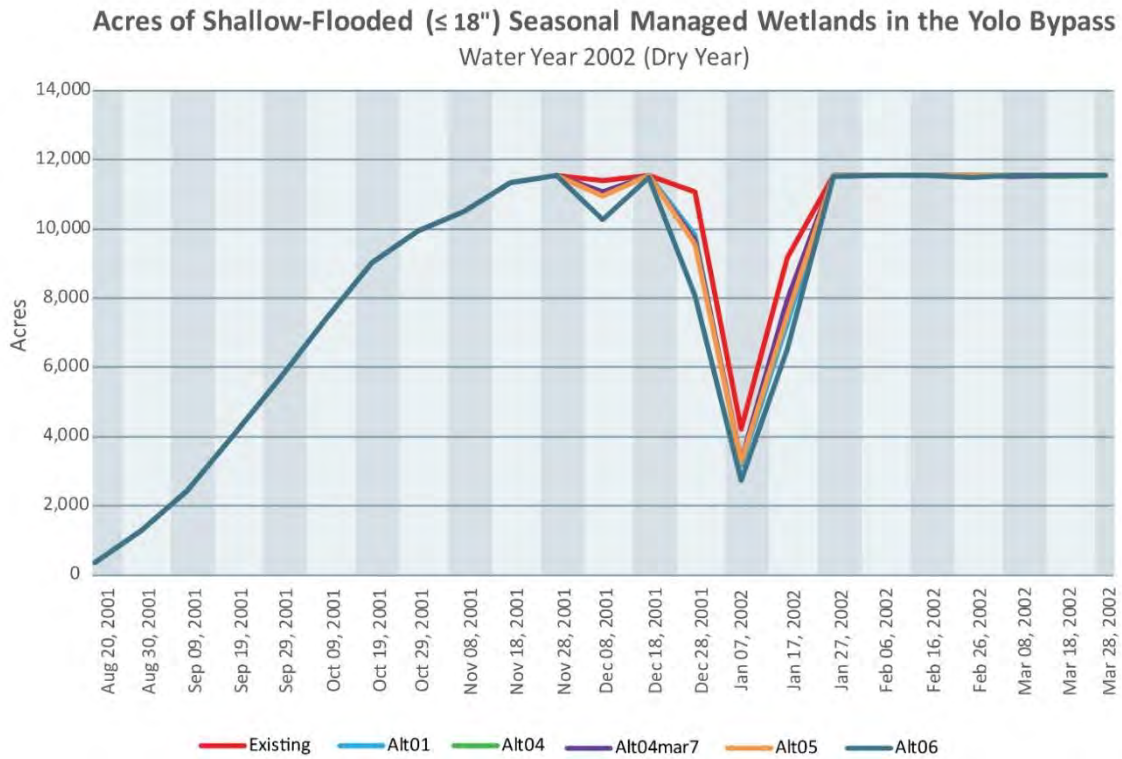

Figure 5-19. Change in Inundation of Managed Wetlands in a Dry Year

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

5.2.3.4 Education Impacts

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

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

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

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

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

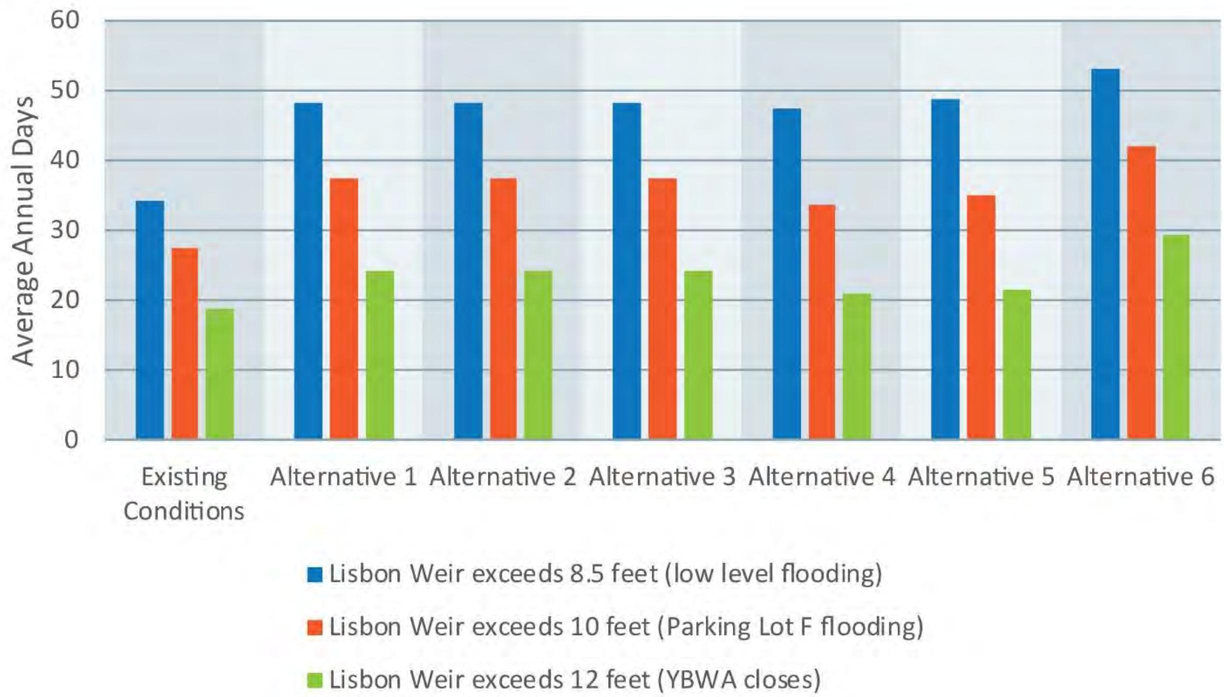

Figure 5-20. Average Annual Days with Potential Limitations on Educational Opportunities at the YBWA

5.2.3.5 Biological Impacts

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

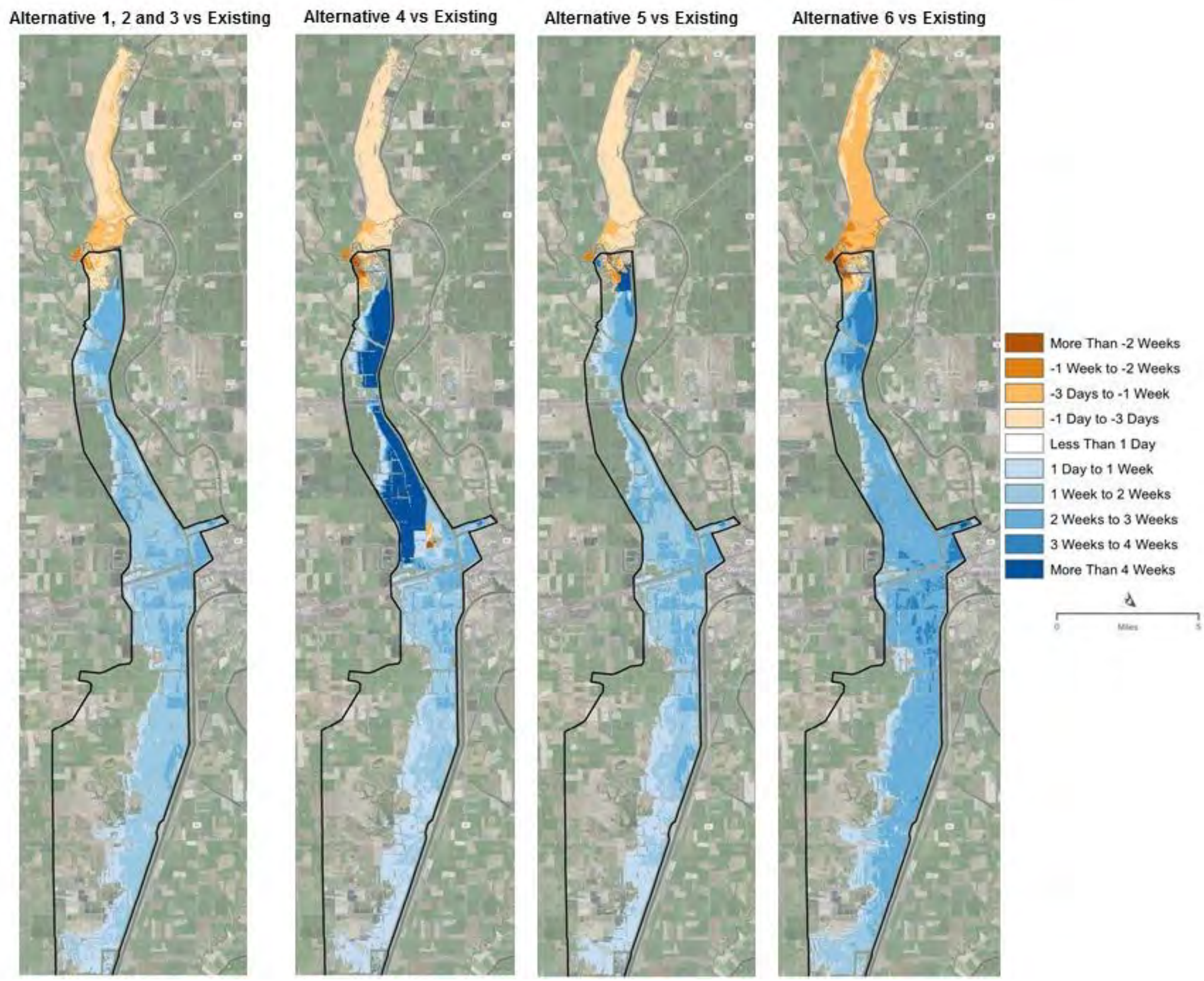

Figure 5-16. Changes in Wet Days for Land in the Yolo Bypass

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.2.3.6 Cultural Impacts

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

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

5.2.3.7 Flood Impacts

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

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

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

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

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

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

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

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

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

5.2.3.8 Water Supply Impacts

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

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

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

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

5.2.3.9 Compatibility with Related Programs

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

Table 5-11. Changes in Water Supplies

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

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

5.2.4 Efficiency

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

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

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

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

Source:

[1] HDR 2017

[2] ERA Economics 2017

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

Note: O&M = operations and maintenance

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 5-15. Projected Population and Housing Units

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

Source:

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

[2] California Department of Finance 2017

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

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

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

Table 5-16. Alternatives Efficiency Evaluation

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

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

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

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

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

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

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

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

5.3 Summary of Comparisons

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

Table 5-17. Alternative Evaluation Results

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

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

Legend

High Performance	Medium Performance	Neutral Performance or Minor Benefits	Poor Performance

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Appendix A Commonly Found Fish Species in the Yolo Bypass

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

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

Source: Modified from Sommer et al. 2001.

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

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

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

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

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

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

Source: California Native Plant Society 2016

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

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

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

Source: California Department of Fish and Wildlife 2016

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

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State of California
California Natural Resources Agency
Department of Water Resources

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

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

Technical Memorandum

May 2017

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

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Acronyms and Abbreviations

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

1. Introduction

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

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

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

2. Target Species

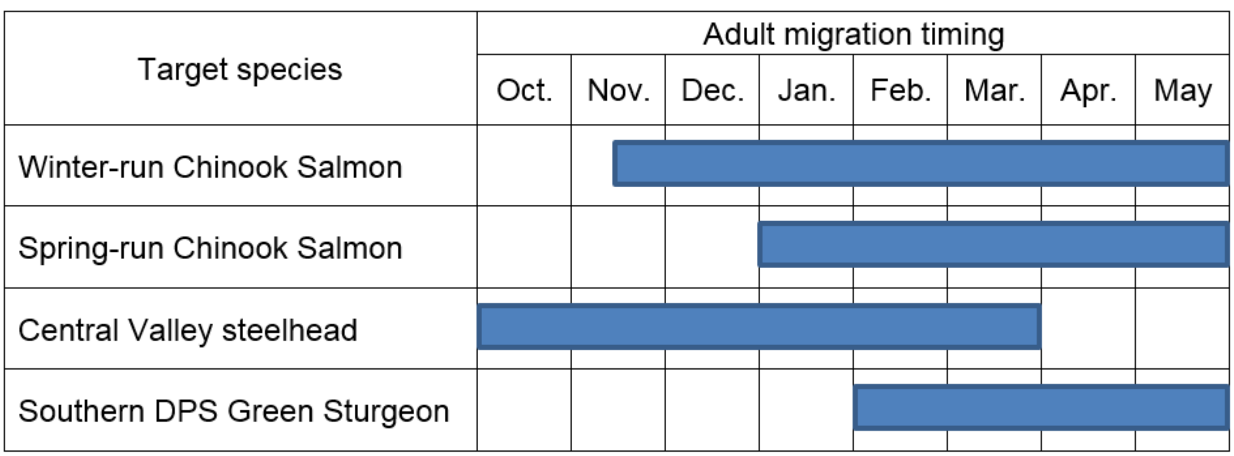
2.1 Chinook Salmon

2.1.1 Sacramento River Winter-run Chinook Salmon

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

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

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



*sourced from DWR and Reclamation 2012 and FETT 2015

2.1.2 Central Valley Spring-run Chinook Salmon

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

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

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

2.2 CA Central Valley steelhead DPS

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

2.3 Southern DPS North American Green Sturgeon

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

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

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

3. Passage Criteria

3.1 Timing

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

3.1 Depth

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

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

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

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

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

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

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

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

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

3.2 Velocity

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

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

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

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

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

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

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

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

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

3.3 Width

To provide efficient passage for salmonids and sturgeon, the minimum width of a structure should be considered to prevent potential passage delay or physical injury to the fish. A structure too narrow to pass fish will deter fish from moving upstream and may cause harm to the fish while maneuvering. NMFS (2011) guidelines for salmonid passage specify that fishway entrance widths should be a minimum of 4 ft wide and that pools should be a minimum of 6 ft wide (Table 2). However, as with other passage criteria, sturgeon differ from salmonids in body size and physiology. Therefore, larger bodied sturgeon will require additional area for unobstructed maneuvering in a passage structure than salmonids.

Swimming flume studies conducted with adult White Sturgeon found that fish were able to pass successfully through a flume measured at 6.9 ft wide (Webber et al. 2007, DWR 2007, Cocherell et al. 2011). Further trials found that sturgeon could pass through slotted widths between 1.42 and 2.92 ft wide, with recommended slot width no less than 2 ft (DWR 2007). Vertical slot passage was also observed within the Columbia

River at Dalles Dam, in which more adult White Sturgeon were found ascending the east fish ladder than the north fish ladder (Parsley et al. 2007). Preference was assumed due to lack of slots and greater width in the east fish ladder (30.0 ft) than the north fish ladder (24.0 ft). The east fish ladder also has greater cross-sectional areas for orifices than the north fish ladder, which may facilitate upstream passage (Parsley et al. 2007).

Although slot passage may provide some indication of minimum width, slot passage should not be used as a width criterion for efficient sturgeon passage through a fishway (Parsley et al. 2007, DWR and Reclamation 2012). Instead, DWR and Reclamation (2012) suggest using a body length approach, whereby the fishway is designed wide enough to allow for sturgeon to make a complete directional change. Therefore, it is recommended that a minimum width criterion of 10 ft be used when designing fish passage structures and project channels (Table 2; Moyle 2002, DWR and Reclamation 2012). This criterion is more conservative than the adapted guidelines from Turek et al (2016) that calculate a minimum width for Green and White Sturgeon as 5 and 5.5 ft, respectively.

4. Additional Design Considerations

Considerations for designing an effective passage structure for sturgeon goes beyond dimensions to include open bottom and open channel concepts and flow requirements. As benthic swimmers, sturgeon generate speed through body curvature. This behavior can limit passage success or lead to structure avoidance if a channel concept (e.g., fish ladder) includes submerged impediments or orifices designed for salmonid passage (Parsley et al. 2007, Dennis Cocherell, University of California Davis, personal communication, April 3, 2015). Therefore, orifices should be designed to accommodate sturgeon passage for dimensioning and velocity thresholds.

In addition to dimension criteria, fishway design preference should be open channel concepts, with limited use of tunnels and pressurized flow (NMFS 2011). If tunnels are constructed due to site requirements, pressure throughout the tunnel should be equal to the atmospheric pressure with transitions in pressures avoided. Fishways should also avoid hydraulic and lighting transitions (NMFS 2011) as well as light, sound, or partial barriers due to unknown effects on sturgeon (Parsley et al. 2007).

Turbulent flows also limit passage for sturgeon as well as salmonids by preventing fish from maintaining station and potentially causing disorientation or injury (DFW 2010, NMFS 2011). Studies conducted by Cheong et al. (2006) found that increased turbidity caused a delay in passage for White Sturgeon. In a similar study, Cocherell et al. (2011) found that White Sturgeon passage performance increased as turbulence and eddies decreased, indicating that non-turbulent flow improves passage success. Therefore, passage structures should avoid high velocity transitions and turbulent areas with designs favoring non-turbulent flow (NMFS 2011, Dennis Cocherell, University of California Davis, personal communication, April 3, 2015, Boyd Kynard, University of Massachusetts Amherst, personal communication, March 27, 2015).

The fish passage design considerations addressed in this memorandum provide guidance for early designing stages. These criteria are not universally applicable and should not replace site specific criteria dependent on local hydrology and other site specific considerations. As the design process develops sufficient information, engineers should incorporate the use of modeling (e.g., FishXing) to provide refined design considerations specific to the study site's hydraulic conditions and target species behavior and swimming performance.

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Appendix A

The following calculations for design considerations were adapted from Turek et al. (2016) with specific body morphology measurements sited. While these values were not adopted due to other considerations, they were helpful in providing some validation that the adopted criteria were appropriate for target species.

Green Sturgeon

Minimum Total Length = 130 cm (Moyle 2002)
Maximum Total Length = 284 cm (M. Manual, DWR, unpublished data)

Minimum Weir Opening Depth: 3.75 ft
Minimum Depth = 3 × Maximum Body Depth
Maximum Body Depth = 0.13 × Maximum Total Length
This value was rounded up by 0.25 ft.

Maximum Weir Opening Water Velocity: 12.75 ft/sec
Maximum Velocity = 3 × Minimum Total Length/Second
This value was rounded down by 0.25 ft.

Minimum Weir Opening Width: 5 ft
Minimum Width = 2 × Maximum Body Width
Maximum Body Width = 0.27 × Maximum Total Length
This value was rounded up by 0.25 ft.

White Sturgeon

Minimum Total Length = 82 cm (Moyle 2002)
Maximum Total Length = 305 cm (Moyle 2002)

Minimum Weir Opening Depth: 4 ft
Minimum Depth = 3 × Maximum Body Depth
Maximum Body Depth = 0.13 × Maximum Total Length
This value was rounded up by 0.25 ft.

Maximum Weir Opening Water Velocity: 8 ft/sec
Maximum Velocity = 3 × Minimum Total Length/Second
This value was rounded down by 0.25 ft.

Minimum Weir Opening Width: 5.5 ft
Minimum Width = 2 × Maximum Body Width
Maximum Body Width = 0.27 × Maximum Total Length
This value was rounded up by 0.25 ft.

Appendix B

Constructability and Construction Considerations

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Draft Technical Memorandum

Constructability and Construction Considerations

Yolo Bypass Salmonid Habitat Restoration & Fish Passage Project – Ten Percent Design

Yolo County, CA
September 19, 2017

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YOLO BYPASS SALMONID HABITAT RESTORATION & FISH PASSAGE PROJECT – TEN PERCENT DESIGN

CONSTRUCTABILITY AND CONSTRUCTION CONSIDERATIONS

SEPTEMBER 19, 2017

1 PURPOSE AND BACKGROUND

HDR assessed the potential construction period, and the associated equipment and personnel requirements to construct the key components of the six Environmental Impact Statement and Environmental Impact Report (EIS/EIR) alternatives selected through the plan formulation process. This technical memorandum (TM), which is intended to accompany Volume II –10% Design Drawings, describes the approach, assumptions, and results of the construction related evaluations.

The six project alternatives that were selected through the plan formulation process are listed below. The associated key project components are summarized in Table 1, the general alignments in the Yolo Bypass Fremont Weir State Wildlife Area are presented in Figure 1, the general location of the Tule Canal water control structures associated with Alternatives 4 and 5 are presented in Figure 2, and the 10 percent design drawings are contained in Volume II – 10% Design Drawings.

Six project alternatives have been developed:

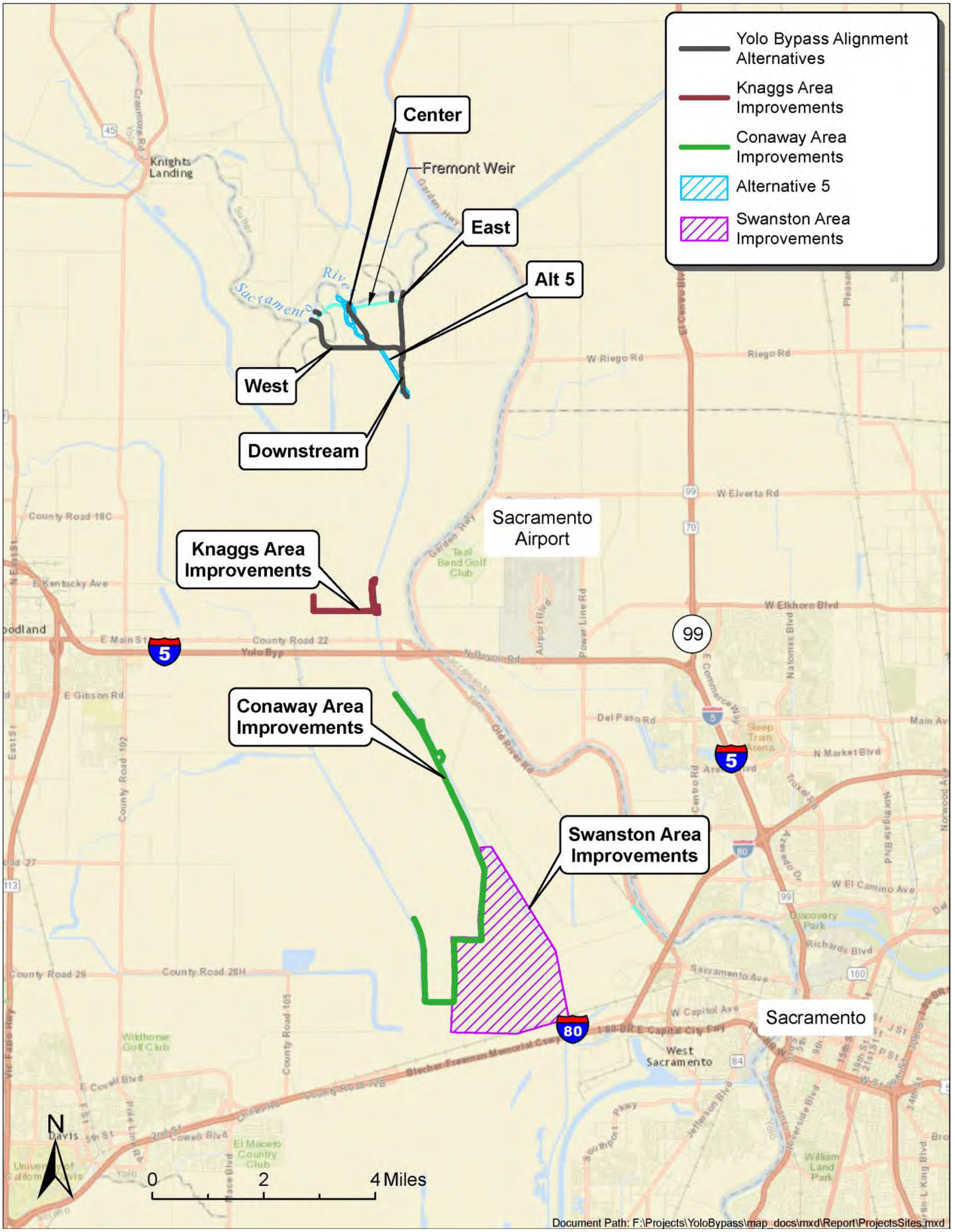
- Alternative 1 – East Channel, 6,000 cubic feet per second (cfs) Design Flow
- Alternative 2 – Central Channel, 6000 cfs Design Flow
- Alternative 3 – West Channel, 6,000 cfs Design Flow
- Alternative 4 – West Channel, 3,000 cfs Design Flow and Managed Floodplain
- Alternative 5 – Multiple Channels, 3,400 cfs Design Flow
- Alternative 6 – West Channel, 12,000 cfs Design Flow and Managed Floodplain

Table 1. Alternative Components

Components	Alt 1 East	Alt 2 Center	Alt 3 West	Alt 4 West	Alt 5 Multiple	Alt 6 West
Peak Design Flow (CFS)	**6,000**	**6,000**	**6,000**	**3,000**	**3,400**	**12,000**
East Channel (Intake Channel, Headworks, & Outlet Channel)	**X**					
Central Channel (Intake Channel, Headworks, & Outlet Channel)		**X**			**X**	
West Channel (Intake Channel, Headworks, & Outlet Channel)			**X**	**X**		**X**
Sacramento River Grading		**X**			**X**	
Supplemental Fish Passage West	**X**	**X**			**X**	
Supplemental Fish Passage East			**X**	**X**		**X**
Downstream Channel	**X**	**X**	**X**	**X**		**X**
Sacramento River Grading		**X**			**X**	
Ag Crossing 1	**X**	**X**	**X**	**X**	**X**	**X**
Knaggs Area Improvements				**X**		
Conaway Area Improvements				**X**		
Swanston Area Improvements					**X**	

Figure 1. Yolo Bypass Alternatives and Components

Figure 2. Yolo Bypass Alternatives and Components



2 KEY CONSTRUCTABLITY ISSUES

A few of the key constructability issues that may affect the cost and schedule for constructing the project alternatives are discussed in this section. They include flood regulatory agency requirements, air quality, protected species, high groundwater, and the Tule Canal operational requirements.

The allowable construction window will be driven by various schedule constraints and it is anticipated that the estimated allowable annual construction period will extend from April 15 to November 1, with potentially additional schedule restrictions on work in close proximity to the Sacramento River and Tule Canal. The allowable period was established reflecting the following anticipated regulatory requirements.

Flood Regulatory Agency Requirements

The Yolo Bypass is a critical element of the State Plan of Flood Control and is designed to flood. If all of the project features cannot be constructed in one construction season, provisions will need to be made to allow for the constructed project features to withstand being inundated during the flood season and to then prepare them for continuing the construction process the following season.

As such, the flood season construction window as dictated by the Central Valley Flood Projection Board (CVFPB) and the Army Corps of Engineers (USACE) is from April 15 through November 1, which is the typical construction window for working on a flood protection project.

Air Regulatory Agency Constraints

Additionally, the construction operations will likely have daily, monthly, and annual exceedence levels for air pollution limits that could limit the operational rates of equipment, which could also drive the construction schedule. At this time, the construction schedule is based upon a standard 10 hour work shift, anticipated equipment, staffing levels, and the associated production rates to determine if it is realistically possible to complete the project construction within a single season without consideration for limits of air pollution. This does not preclude the contractor from, or consider, performing extended or multiple shifts for the various project components, which could ultimately alter schedule and air pollution impacts.

National Marine Fisheries Service Constraints – Confirm Tule Canal or not

The National Marine Fisheries Service (NMFS) will likely further restrict work in close proximity to the Sacramento River and Tule Canal, roughly within 100 to 150 feet of the ordinary high water mark (OHWM), to the periods between July 1 and October 31.

Protected Species

Giant Gardner Snake habitat has been identified within the project area. As a result, major earthwork disturbance operations will be prohibited between November and April, when the snakes are typically hibernating underground.

Ground Water

The Yolo Bypass experiences relatively high groundwater levels, which vary significantly, spatially, and seasonally. Refer to the Assessment of Groundwater Impact on Project Excavation TM January 26, 2017, by HDR for more information. It is anticipated that some construction activities will require excavation below the groundwater. For limited areas, such as the headworks, groundwater may be controlled for construction purposes by excluding it from the site via installing a cutoff wall around the perimeter of the excavation with some limited groundwater pumping to remove leakage. It may also be possible to control groundwater locally in the vicinity of a limited excavation site by pumping alone. These methods will likely not be practical for very large excavation sites such as those required for constructing the channels. It is anticipated that the portion of the channels located near and below the groundwater levels will be constructed in the wet using excavators.

Tule Canal Operational Requirements

The Tule Canal serves as both an irrigation supply and a drainage facility. Flow in the Canal will need to be maintained during the construction period. Constructing the water control structures in the Tule Canal, for the Knaggs, Conaway, and Swanston areas will require provisions for maintaining flows in the canal as well as controlling groundwater for excavation. The flows that will need to be maintained in the canal during construction are estimated to be roughly 1,000 cfs.

3 CONSTRUCTION SEQUENCE AND PERIOD

Based upon estimated equipment numbers, crew sizes, and production rates, it is anticipated that all project components could be constructed in a single season for all of alternatives except for Alternative 5. The construction period for Alternative 5 is estimated to be 2 years due to the complexity of and the number of gates that need to be installed for the headworks. However, for all of the alternatives higher than anticipated ground water levels, inclement weather, cultural discoveries, and protected species observances may impact constructability and adversely extend the construction schedule into the following season. Refer to **Table 9** through **Table 22** for a detailed breakdown of the baseline project sequencing by component.

It is anticipated that the outlet channel grading will begin at the downstream end and progress upstream towards the headworks structure. There are three reasons for supporting this sequence. First, with construction starting in spring when groundwater levels are highest, it is known from the project's groundwater assessment that groundwater levels decrease with increasing distance from the Sacramento River. Second, is to avoid potential interruptions to the construction of the headworks foundation. Third, if for some reason channel construction extends beyond one season, having the channel already constructed downstream may facilitate draining the site in the spring for continued excavation.

Roughly 60 to 80 percent of the channel excavations are assumed to be performed in dry, unsaturated soil conditions by scrapers and dozers. The remaining 40 to 20 percent is assumed to be performed in wet, saturated soil conditions by hydraulic excavators and haul trucks. As the channel inverts are anticipated to be below river stage for the Sacramento River or groundwater levels, it is anticipated that much of the wet excavation may be performed underwater, which makes grading the channels a considerable constructability challenge. Additionally, the significant portion of the revetment prescribed for the habitat shelf is also anticipated to be placed in the wet, further complicating the construction.

The headworks is the most complex component of the project, and the activities associated with its completion will likely be the critical path of the overall construction schedule. Completing the headworks in one season is possible, but may be challenging. Care will be needed in scheduling the design and ordering of long lead items, such as the gates and mechanical and electrical facilities. Like other project components, work on the headworks can move independently from the other activities for the most part.

It is estimated that it will take approximately 12 to 15 weeks, depending on the alternative, to construct the headworks structure to a point at which it is ready for the installation of the gates and mechanical equipment. It is estimated to take upwards of and additional 3 to 5 weeks for the gate installation, mechanical and electrical installation, and testing. If unforeseen constructability challenges occur and the contractor is not able to meet a single season schedule that the temporary measures such as the cofferdam installed for dewatering of the headworks structure would remain in place through the flood season, and would result in the completion of the construction of the headworks structure during the following construction season.

Equipment and mobilization staging areas are assumed to be identified within construction easements. Spoiling sites have not been identified at this time, but are assumed to be located within an approximately 1-mile radius of the project site. Refer to the Access Roads, Haul Routes, and Spoils Sites Draft Technical Memorandum for additional information.

4 PERSONNEL AND EQUIPMENT

The number of construction personnel and equipment required by week were estimated for each alternative. The number of personnel is summarized by key project component of each alternative in **Table 2** through **Table 8**. In general, rock haul and placement, and earthwork excavation and haul require the greatest number of personnel, which will peak in the months of July and August. The estimations assume a standard 10-hour shift work day and 6-day work week. However as noted above, this does not preclude the contractor from utilizing multiple shifts and extended hours of operations in which to expedite efforts. Additionally, on large construction projects it is very common that the equipment maintenance and up-keep operations are handled during the night shift.

A detailed breakdown of estimated construction personnel and equipment is provided in Table 8 through Table 20. The estimate is broken down into cost codes based on the cost estimating guide developed by the USACE, Engineering and Design Civil Works Cost Engineering, ER 1110-2-1302, June 30, 2016. The tables present the construction activities, a description of the associated personnel and equipment needs, and the duration of the activity.

Table 2. Alternative 1, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	31	18	18	18	8	12	32	35	36	36	28	27	56	84	84	84	56	56	31	0	0	4	4	4	0	0	0	0
2	Headworks Structure	0	0	50	7	7	7	23	23	23	16	16	43	30	3	19	19	3	30	3	3	5	25	25	25	29	23	52	0
3	Bridges, Buildings, & Operating Equipment	17	20	20	10	19	10	9	0	0	0	0	0	0	5	13	9	7	5	0	0	0	0	0	0	0	0	8	5
4	Supplemental Fish Passage, West	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
	Total per Week:	**89**	**66**	**135**	**57**	**55**	**86**	**155**	**98**	**126**	**105**	**102**	**119**	**144**	**163**	**202**	**191**	**134**	**182**	**73**	**14**	**9**	**55**	**39**	**31**	**29**	**23**	**68**	**10**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: **202**

Table 3. Alternative 2, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	53	18	18	18	24	24	68	64	64	64	40	56	112	112	112	112	112	112	84	56	53	0	4	4	0	0	0	0
2	Headworks Structure	0	0	50	7	7	7	23	23	23	16	16	16	43	30	19	19	3	3	30	3	5	19	25	25	29	29	52	0
3	Bridges, Buildings, & Operating Equipment	17	20	20	10	19	10	9	0	0	0	0	0	0	0	5	13	9	7	7	5	0	0	0	0	0	0	8	5
4	Supplemental Fish Passage, West	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
	Total per Week:	**111**	**66**	**135**	**57**	**71**	**98**	**191**	**127**	**154**	**133**	**114**	**121**	**213**	**213**	**222**	**223**	**192**	**213**	**160**	**75**	**62**	**45**	**39**	**31**	**29**	**29**	**68**	**10**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: **223**

Table 4. Alternative 3, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	53	18	18	18	24	24	68	68	68	68	68	120	120	176	112	112	112	112	140	165	56	56	4	4	0	0	0	0
2	Headworks Structure	0	0	50	7	7	7	23	23	23	16	16	16	43	30	19	19	3	3	30	3	5	19	25	25	29	29	52	0
3	Bridges, Buildings, & Operating Equipment	17	20	20	10	19	10	9	0	0	0	0	0	0	0	5	13	9	7	7	5	0	0	0	0	0	0	8	5
4	Supplemental Fish Passage, East	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
	Total per Week:	**111**	**66**	**135**	**57**	**71**	**98**	**191**	**131**	**158**	**137**	**142**	**185**	**221**	**277**	**222**	**223**	**192**	**213**	**216**	**184**	**65**	**101**	**39**	**31**	**29**	**29**	**68**	**10**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: 277

Table 5. Alternative 4, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	53	18	18	18	24	24	68	68	68	68	68	120	120	176	112	112	112	112	140	165	56	56	4	4	0	0	0	0
2	Headworks Structure	0	0	50	7	7	7	23	23	23	16	16	16	43	30	19	19	3	3	30	3	5	19	25	25	29	29	52	0
3	Bridges, Buildings, & Operating Equipment	17	20	20	10	19	10	9	0	0	0	0	0	0	0	5	13	9	7	7	5	0	0	0	0	0	0	8	5
4	Supplemental Fish Passage, East	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
7	Knaggs Area	26	19	24	26	44	46	65	43	39	59	19	23	9	11	9	11	13	13	4	8	8	10	2	0	0	0	0	0
6	Conoway Area	30	28	33	36	44	46	101	79	75	95	82	75	73	75	73	75	77	77	68	20	32	15	2	0	0	0	0	0
	Total per Week:	**167**	**113**	**192**	**119**	**159**	**190**	**357**	**253**	**272**	**291**	**243**	**283**	**303**	**363**	**304**	**309**	**282**	**303**	**288**	**212**	**105**	**126**	**43**	**31**	**29**	**29**	**68**	**10**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: 363

Table 6. Alternative 5, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week – Year 1																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	95	90	40	100	100	100	100	184	168	168	172	172	168	168	168	168	168	84	4	0	0	0	95	0	0	0	0	0
2	Headworks Structure	0	0	103	10	83	63	10	10	83	63	42	10	83	63	42	57	57	57	3	3	3	3	57	57	103	0	0	0
3	Bridges, Buildings, & Operating Equipment	53	40	40	10	19	19	9	9	9	0	0	0	0	0	0	0	0	4	13	9	7	7	4	0	0	13	0	0
4	Supplemental Fish Passage, West	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
6	Swanston Area	50	64	64	64	82	84	83	42	39	59	86	87	84	88	94	94	94	92	51	51	13	44	16	4	0	0	0	0
	Total per Week:	**221**	**213**	**285**	**197**	**296**	**296**	**261**	**253**	**338**	**316**	**330**	**290**	**358**	**334**	**334**	**342**	**331**	**272**	**82**	**70**	**23**	**67**	**174**	**61**	**103**	**13**	**8**	**5**

* Estimated Beginning of the Construction is April 15th

Year 1 Weekly Maximum: 358

#	Project Major Components	Estimated Number of Personnel per Week – Year 2														
		April*		May					June				July			
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
2	Headworks Structure	4	43	43	43	43	43	43	43	43	47	23	4	0	0	0
	Total per Week:	**4**	**43**	**43**	**43**	**43**	**43**	**43**	**43**	**43**	**47**	**23**	**4**	**0**	**0**	**0**

* Estimated Beginning of the Construction is April 15th

Year 2 Weekly Maximum: 47

Table 7. Alternative 6, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Intake and Outlet Channels	76	27	27	27	32	32	36	32	32	32	288	288	288	288	288	288	288	288	288	316	284	112	116	80	0	0	0	0
2	Headworks Structure	0	77	14	14	23	23	49	49	42	69	30	30	19	19	19	3	30	30	5	19	19	19	31	31	35	35	19	79
3	Bridges, Buildings, & Operating Equipment	20	30	30	10	19	10	9	0	0	0	0	0	5	13	9	7	7	5	0	0	0	0	0	0	0	0	8	8
4	Supplemental Fish Passage, East	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5
5	Downstream Reach	18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0
6	Agricultural Crossing 1	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0
	Total per Week:	**137**	**162**	**118**	**73**	**95**	**122**	**185**	**121**	**141**	**154**	**376**	**367**	**370**	**391**	**402**	**377**	**393**	**414**	**332**	**346**	**307**	**157**	**157**	**113**	**35**	**35**	**35**	**92**

* Estimated Beginning of the Construction is April 15th

Weekly Maximum: 414

Table 8. Alternative 2 & 5 River Grading Site, Estimated Number of Construction Personnel by Week

#	Project Major Components	Estimated Number of Personnel per Week																											
		Year 1																											
		April*		May					June				July				August					September				October			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	**River Repair**	15	9	35	19	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	63	28	32	4	15	0	0	0
	Total per Week:	**15**	**9**	**35**	**19**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**63**	**28**	**32**	**4**	**15**	**0**	**0**	**0**
	Year 1 Weekly Maximum:	**63**																											

* Estimated Beginning of the Construction is April 15th

Table 9. Alternative 1, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations[2]																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	5																											5
2	Fremont Weir Concrete Demo[5]	450	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	12		10	10																									
3	Levee O&M Road Regrading (6" AB)	119,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	4																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	31																		31									
6	Clearing and Grubbing[6]	61	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	16		18	18	18																								
7	Excavation (Wet Conditions)[7]	61,810	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	35							20	20	20	20	20	20																
8	Excavation/Grading (Dry Conditions)[8]	118,960	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	34					8	8	8	8	8	8																		
9	Earthen Backfill[12]	8,950	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	9						4	4																					
10	Riprap - Class 2	24,940	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	25														28	28	28	28	28										
11	Riprap - Class 3	9,420	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	10																	28	28										
12	RSP Bedding Material	36,150	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	2	2,000	19													56	56	56	56												
13	Erosion Control Seeding	31	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	16																						4	4	4				
11 - Levees and Floodwalls																																				
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2								7				7																
15	Soil Cement Bentonite Cutoff Wall	84,480	SF	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (1) 2.5 CY Hydraulic Excavator (1) 16 CY 3 Axle Dump Truck (1) Flash Mixer (1) Slurry Pump (1) Pickup Truck Conventional (5)	7,000	1	7,000	13									8	8	8																	
dway Control and Diversion Structures																																				
16	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			50																								50	
17	Construction Site Dewatering (Temporary Cofferdam)	21,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	18				7	7	7																						
18	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	120							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
		6,130	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 19 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	Excavation (Wet Conditions)[7] 1,800	1	1,800	4							20																					
20	Sheet Pile Wall	7,790	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	7								7	7																			
21	Headworks Structure Concrete Piles	5,040	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	28								13	13	13	13	13																
22	Headworks Structure	3,080	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	18												27	27					27										
23	Headworks Channel Transition	1,330	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	10															16	16												
24	Hinged Bottom Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24																						6	6	6	6			
s, Railroads, and Bridges																																				
25	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2														5				5										
26	Pedestrian Bridge Concrete Piles	320	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	2															13													
27	Pedestrian Bridge Concrete Abutments and Wingwalls	24	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1																9												
28	Pedestrian Bridge Span Installation	1,040	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	3																	7											
19 - Buildings, Grounds, and Utilities																																				
29	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	9						9																					
30	CMU Building and Earthwork Pad Construction[10]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
31	Concrete Duct Bank	190	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	4					9																							
20 -Permanent Operating Equipment[11]																																				
32	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																					2						2	
33	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
34	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
35	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
36	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
37	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																									4	4		
								Estimated Total Number of Construction Workers:	48	38	88	35	34	29	64	58	59	52	44	70	86	92	116	112	66	91	34	3	5	29	29	29	29	23	60	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Assumption: 30 days for CMU building construction.
11 Assumption: 30 days for permanent equipment installation
12 Excavated material assumed to be reused for backfill (including construction of working surface for Soil Cement Bentonite Cutoff Wall), hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed

Table 10. Alternative 2, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days
02 - Relocations								
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
2	Fremont Weir Demo	420	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	11
3	Levee O&M Road Regrading (6" AB)	119,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	4
4	Temporary Electrical Power	5,280	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	4
09 - Channels and Canals								
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
6	Clearing and Grubbing[6]	70	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	18
7	Excavation (Wet Conditions)[7]	93,610	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	2	3,600	27
8	Excavation/Grading (Dry Conditions)[8]	372,680	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	3	10,500	36
9	Earthen Backfill[10]	1,010	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	2
10	Riprap - Class 2	87,580	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	2	2,000	44
11	Riprap - Class 3	1,530	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	2
12	RSP Bedding Material	81,050	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	2	2,000	41
13	Erosion Control Seeding	13	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	7
15 - Floodway Control and Diversion Structures								
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
15	Construction Site Dewatering (Temporary Cofferdam)	21,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	18
16	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	120
17	Excavation (Wet Conditions)	6,460	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	4
18	Sheet Pile Wall	7,940	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	7
19	Headworks Structure Concrete Piles	5,600	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	32
20	Headworks Structure	3,140	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	18
21	Headworks Channel Transition	1,370	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	10
22	Hinged Bottom Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24
08 - Roads, Railroads, and Bridges								
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
24	Pedestrian Bridge Concrete Piles	640	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	4
25	Pedestrian Bridge Concrete Abutments and Wingwalls	48	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1
26	Pedestrian Bridge Span Installation	2,720	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	7
19 - Buildings, Grounds, and Utilities								
27	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)				
28	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30
29	Concrete Duct Bank	1,350	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	23
20 -Permanent Operating Equipment[12]								
30	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
30	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30
31	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30
32	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30
33	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30
34	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12

Estimated Duration, Weeks[4]

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																												
1	5																											5
2		10	10																									
3																											8	
4	3																											
09 - Channels and Canals																												
5	53																				53							
6		18	18	18																								
7							40	40	40	40	40																	
8					24	24	24	24	24	24																		
9							4																					
10													56	56	56	56	56	56	56	56								
11																			28									
12												56	56	56	56	56	56	56										
13																							4	4				
15 - Floodway Control and Diversion Structures																												
14			50																								50	
15				7	7	7																						
16							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
17							20																					
18								7	7																			
19								13	13	13	13	13	13															
20													27	27					27									
21															16	16												
22																							6	6	6	6		
08 - Roads, Railroads, and Bridges																												
23															5					5								
24																13												
25																	9											
26																		7	7									
19 - Buildings, Grounds, and Utilities																												
27	9						9																					
28		10	10	10	10	10																						
29					9																							
20 -Permanent Operating Equipment[12]																												
30																					2						2	
30																						4	4	4	4	4		
31																						4	4	4	4	4		
32																						4	4	4	4	4		
33																						4	4	4	4	4		
34																									4	4		
Estimated Total Number of Construction Workers:	70	38	88	35	50	41	100	87	87	80	56	72	155	142	136	144	124	122	121	64	58	19	29	29	29	29	60	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 11. Alternative 3, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	5																											5
2	Fremont Weir Demo	470	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	12		10	10																									
3	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	53																			53								
6	Clearing and Grubbing[6]	88	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	23		18	18	18																								
7	Excavation (Wet Conditions)[7]	161,750	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	2	3,600	45							40	40	40	40	40	40	40	40														
8	Excavation/Grading (Dry Conditions)[8]	581,540	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	3	10,500	56					24	24	24	24	24	24	24	24	24	24														
9	Earthen Backfill[10]	27,510	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	28							4	4	4	4	4																	
10	Riprap - Class 2	98,070	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	2	2,000	50														56	56	56	56	56	56	56	56	56						
11	Riprap - Class 3	3,600	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	4																			28									
12	RSP Bedding Material	109,330	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	2	2,000	55												56	56	56	56	56	56	56	56	56								
13	Erosion Control Seeding	18	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	10																							4	4				
15 - Floodway Control and Diversion Structures																																				
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			50																										50	
15	Construction Site Dewatering (Temporary Cofferdam)	21,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	18				7	7	7																						
16	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	120							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
17	Excavation (Wet Conditions)	6,460	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	4							20																					
18	Sheet Pile Wall	7,940	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	7								7	7																			
19	Headworks Structure Concrete Piles	5,600	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	32								13	13	13	13	13	13															
20	Headworks Structure	3,080	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	18													27	27					27									
21	Headworks Channel Transition	1,370	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	10															16	16												
22	Hinged Bottom Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24																							6	6	6	6		
08 - Roads, Railroads, and Bridges																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2															5					5								
24	Pedestrian Bridge Concrete Piles	640	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	4																13												
25	Pedestrian Bridge Concrete Abutments and Wingwalls	48	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1																	9											
26	Pedestrian Bridge Span Installation	2,930	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	8																		7	7									
19 - Buildings, Grounds, and Utilities																																				
27	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
28	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
29	Concrete Duct Bank	120	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	2					9																							
20 -Permanent Operating Equipment[12]																																				
30	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																					2						2	
30	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
31	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
32	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
33	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30																						4	4	4	4	4		
34	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																									4	4		
								Estimated Total Number of Construction Workers:	70	38	88	35	50	41	100	91	91	84	84	136	163	206	136	144	124	122	177	173	61	75	29	29	29	29	60	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 12. Alternative 4, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days
02 - Relocations								
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
2	Fremont Weir Demo	470	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	12
3	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1
09 - Channels and Canals								
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
6	Clearing and Grubbing[6]	88	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	23
7	Excavation (Wet Conditions)[7]	161,750	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	2	3,600	45
8	Excavation/Grading (Dry Conditions)[8]	581,540	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	3	10,500	56
9	Earthen Backfill[10]	27,510	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	28
10	Riprap - Class 2	98,070	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	2	2,000	50
11	Riprap - Class 3	3,600	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	4
12	RSP Bedding Material	109,330	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	2	2,000	55
13	Erosion Control Seeding	18	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	10
15 - Floodway Control and Diversion Structures								
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
15	Construction Site Dewatering (Temporary Cofferdam)	21,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	18
16	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	120
17	Excavation (Wet Conditions)	6,460	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	4
18	Sheet Pile Wall	7,940	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	7
19	Headworks Structure Concrete Piles	5,600	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	32
20	Headworks Structure	3,080	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	18
21	Headworks Channel Transition	1,370	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	10
22	Hinged Bottom Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24
08 - Roads, Railroads, and Bridges								
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
24	Pedestrian Bridge Concrete Piles	640	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	4
25	Pedestrian Bridge Concrete Abutments and Wingwalls	48	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1
26	Pedestrian Bridge Span Installation	2,930	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	8
19 - Buildings, Grounds, and Utilities								
27	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)				
28	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30
29	Concrete Duct Bank	120	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	2
20 -Permanent Operating Equipment[12]								
30	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
30	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30
31	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30
32	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30
33	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	30
34	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12

Estimated Duration, Weeks[4]

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																												
1	5																											5
2		10	10																									
3																											8	
4	3																											
09 - Channels and Canals																												
5	53																			53								
6		18	18	18																								
7							40	40	40	40	40	40	40	40														
8					24	24	24	24	24	24	24	24	24															
9							4	4	4	4	4																	
10														56	56	56	56	56	56	56	56	56						
11																			28									
12												56	56	56	56	56	56	56	56	56								
13																							4	4				
15 - Floodway Control and Diversion Structures																												
14			50																								50	
15				7	7	7																						
16							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
17							20																					
18								7	7																			
19								13	13	13	13	13	13															
20													27	27					27									
21															16	16												
22																							6	6	6	6		
08 - Roads, Railroads, and Bridges																												
23															5					5								
24																13												
25																	9											
26																		7	7									
19 - Buildings, Grounds, and Utilities																												
27	9						9																					
28		10	10	10	10	10																						
29					9																							
20 -Permanent Operating Equipment[12]																												
30																					2						2	
30																						4	4	4	4	4		
31																						4	4	4	4	4		
32																						4	4	4	4	4		
33																						4	4	4	4	4		
34																									4	4		
Estimated Total Number of Construction Workers:	70	38	88	35	50	41	100	91	91	84	84	136	163	206	136	144	124	122	177	173	61	75	29	29	29	29	60	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
12 Assumption: 30 days for CMU building construction.
13 Assumption: 30 days for permanent equipment installation

Table 13. Alternative 5, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days
02 - Relocations								
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
2	Fremont Weir Demo	1,610	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	3	120	14
3	Levee O&M Road Regrading (6" AB)	119,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	4
4	Temporary Electrical Power	5,280	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	4
09 - Channels and Canals								
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
6	Clearing and Grubbing[6]	110	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	10	20	6
7	Excavation (Wet Conditions)[7]	148,830	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	3	5,400	28
8	Excavation/Grading (Dry Conditions)[8]	600,290	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	5	17,500	35
9	Riprap - Class 2	163,254	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	3	3,000	55
10	RSP Bedding Material	174,806	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	3	3,000	59
11	Erosion Control Seeding	31	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	17
15 - Floodway Control and Diversion Structures								
12	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
13	Construction Site Dewatering (Temporary Cofferdam)	1	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	3	3,600	1
14	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	186
15	Excavation (Wet Conditions)	28,710	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	16
16	Sheet Pile Wall	26,840	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	23
17	Headworks Structure Concrete Piles	26,400	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	3	540	49
18	Headworks Structure	11,040	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	6	360	31
19	Hinged Bottom Gates	27	EA	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	0.1	4	0.5	54
08 - Roads, Railroads, and Bridges								
20	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
21	Pedestrian Bridge Concrete Piles	320	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	2
22	Pedestrian Bridge Concrete Abutments and Wingwalls	24	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1
23	Pedestrian Bridge Span Installation	1,600	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	5
19 - Buildings, Grounds, and Utilities								
24	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)				
25	CMU Building and Earthwork Pad Construction[10]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30
26	Concrete Duct Bank	1,350	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	23
20 -Permanent Operating Equipment[11]								
27	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
27	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	1	-	60
28	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	1	-	60
29	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	1	-	60
30	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	1	-	60
31	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	1	-	12

Estimated Duration, Weeks[4]

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28		29	30	31	32	33	34	35	36	37	38	39	40	41
02 - Relocations																																										
1	11																									5																
2	30	30	30																																							
3																										8																
4	3																																									
09 - Channels and Canals																																										
5	95																						95																			
6		90																																								
7				60	60	60	60	60																					END OF THE													
8			40	40	40	40	40	40																																		
9									84	84	84	84	84	84	84	84	84	84																								
10								84	84	84	84	84	84	84	84	84	84																									
11											4	4							4																							
15 - Floodway Control and Diversion Structures																																										
12			103																						103					2											2	
13					21	21			21	21			21	21																												
14				3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3							3	3	3	3	3	3	3	3	3	3		
15					20				20				20																CONSTRUCTION													
16				7			7	7				7																														
17					39	39			39	39	39		39	39	39																											
18																54	54	54					54	54																		
19																															24	24	24	24	24	24	24	24	24			
08 - Roads, Railroads, and Bridges																																										
20																		4					4																			
21																			13										SEASON													
22																				9																						
23																					7	7																				
19 - Buildings, Grounds, and Utilities																																										
24	9								9																																	
25		10	10	10	10	10																																				
26					9	9	9	9																																		
20 -Permanent Operating Equipment[11]																																										
27																														2											2	
27																															4	4	4	4	4	4	4	4	4	4		
28																															4	4	4	4	4	4	4	4	4	4		
29																															4	4	4	4	4	4	4	4	4	4		
30																															4	4	4	4	4	4	4	4	4	4		
31																																							4	4		
Estimated Total Number of Construction Workers:	148	130	183	120	202	182	119	203	260	231	214	182	251	231	210	225	225	145	20	12	10	10	156	57	103	13	0	0	0	4	43	43	43	43	43	43	43	43	47	23	4	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Assumption: 30 days for CMU building construction.
11 Assumption 60 days for permanent equipment installation

Table 14. Alternative 6, Intake Channel, Headworks, & Outlet Channel: Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	8																											8
2	Fremont Weir Demo	920	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	2	80	12		20	20																									
3	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	76																							76				
6	Clearing and Grubbing[6]	109	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	3	6	19		27	27	27																								
7	Excavation (Wet Conditions)[7]	350,390	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	3	5,400	65											60	60	60	60	60	60	60	60	60	60	60							
8	Excavation/Grading (Dry Conditions)[8]	1,270,140	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	4	14,000	91					32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32								
9	Earthen Backfill[10]	2,200	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	3							4																					
10	Riprap - Class 2	313,940	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	4	4,000	79											112	112	112	##	##	##	##	##	##	##	##	##	##	##				
11	Riprap - Class 3	11,460	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	12																				28	28							
12	RSP Bedding Material	197,000	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	3	3,000	66											84	84	84	84	84	84	84	84	84	84	84							
13	Erosion Control Seeding	13	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	7																							4	4				
15 - Floodway Control and Diversion Structures																																				
14	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2		77																										77
15	Construction Site Dewatering (Temporary Cofferdam)	29,900	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	2	2,400	13			14	14																								
16	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	138					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
17	Excavation (Wet Conditions)	12,750	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	8					20	20																						
18	Sheet Pile Wall	10,220	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	9							7	7																				
19	Headworks Structure Concrete Piles	11,440	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	3	540	22							39	39	39	39																		
20	Headworks Structure	4,480	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	3	180	25										27	27	27					27	27										
21	Headworks Channel Transition	2,310	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	2	140	17													16	16	16													
22	Hinged Bottom Gates	5	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	2	0.3	20																							12	12	12	12		
08 - Roads, Railroads, and Bridges																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2													5					5										
24	Pedestrian Bridge Concrete Piles	640	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	4														13														
25	Pedestrian Bridge Concrete Abutments and Wingwalls	48	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1															9													
26	Pedestrian Bridge Span Installation	2,480	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	7																7	7											
19 - Buildings, Grounds, and Utilities																																				
27	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
28	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
29	Concrete Duct Bank	120	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	2					9																							
20 -Permanent Operating Equipment[12]																																				
30	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																			2									2
30	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	50																				4	4	4	4	4	4	4	4	
31	CMU Building Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	50																				4	4	4	4	4	4	4	4	
32	Electrical Control Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	50																				4	4	4	4	4	4	4	4	
33	Electrical Power Equipment CMU Building	-	-	Pickup Truck Conventional (3)	-	-	-	50																				4	4	4	4	4	4	4	4	
34	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																									4	4		
								Estimated Total Number of Construction Workers:	96	134	71	51	74	65	94	81	74	101	318	318	312	320	316	298	325	323	293	335	303	131	147	111	35	35	27	87

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 50 days for permanent equipment installation

Table 15. Downstream Reach, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	2																							2				
2	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																							8					
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	13																					13						
5	Clearing and Grubbing[6]	42	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	21		9	9	9	9																							
6	Excavation (Wet Conditions)[7]	73,850	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	42						20	20	20	20	20	20	20																
7	Earthen Backfill[10]	10,550	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	11							4	4																				
8	Riprap - Class 2	32,500	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	33														28	28	28	28	28	28									
9	RSP Bedding Material	32,470	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	1	1,000	33													28	28	28	28	28	28										
10	Erosion Control Seeding	28	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	15																				4	4							
11 - Levees and Floodwalls																																				
11	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2									7				7															
12	Soil Cement Bentonite Cutoff Wall	94,500	SF	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (1) 2.5 CY Hydraulic Excavator (1) 16 CY 3 Axle Dump Truck (1) Flash Mixer (1) Slurry Pump (1) Pickup Truck Conventional (5)	7,000	1	7,000	14										8	8	8																
	Estimated Total Number of Construction Workers:								18	9	9	9	9	27	32	32	28	27	28	28	35	56	56	56	56	56	28	4	4	13	8	2	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill (including construction of working surface for Soil Cement Bentonite Cutoff Wall), hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed

Table 16. Supplemental Fish Passage East, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days
02 - Relocations								
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
2	Fremont Weir Demo	180	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	5
3	Levee O&M Road Regrading (6" AB)	119,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	4
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1
09 - Channels and Canals								
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
6	Clearing and Grubbing[6]	2	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	1
7	Excavation/Grading (Dry Conditions)[8]	2,080	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	1
8	Excavation (Wet Conditions)[7]	520	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	1
9	Riprap - Class 3	1,520	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	2
10	RSP Bedding Material	1,190	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	1	1,000	2
11	Erosion Control Seeding	1	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	1
15 - Floodway Control and Diversion Structures								
12	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
13	Excavation/Grading (Dry Conditions)[8]	940	CY	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	3,500	1	3,500	1
14	Sheet Pile Wall	1,730	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2
15	Headworks Structure	130	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	3
16	Headworks Channel Transition	130	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	2
17	Hinged Bottom Gates	1	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	8
20 -Permanent Operating Equipment[11]								
18	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
19	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30

#	Estimated Duration, Weeks[4]																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	5																											5
2		10																										
3																											8	
4	3																											
5			18						18																			
6				9																								
7					8																							
8						20																						
9							28																					
10							28																					
11								4																				
12									18						18													
13										8																		
14											7																	
15												9																
16													8															
17													6	6														
18																2			2									
19																	4	4										
Estimated Total Number of Construction Workers:	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 10 days for permanent equipment installation

Table 17. Supplemental Fish Passage West, Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4] 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	5																											5
2	Fremont Weir Demo	180	CY	3.5 CY Hydraulic Excavator (1) 3.5 CY Front End Loader Wheel (1) 0.8 CY Loader/Backhoe, Wheel (1) 4000 gallon Water Truck (1) 16 CY 3 Axle Dump Truck (1) Pickup Truck Conventional (6)	40	1	40	5		10																										
3	Levee O&M Road Regrading (6" AB)	89,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																											8	
4	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
5	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2			18						18																			
6	Clearing and Grubbing[6]	2	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	1				9																								
7	Excavation/Grading (Dry Conditions)[8]	1,830	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	1					8																							
8	Excavation (Wet Conditions)[7]	460	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	1						20																						
9	Riprap - Class 3	1,070	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	2							28																					
10	RSP Bedding Material	850	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) Pickup Truck Conventional (5) 16 CY 3 Axle Dump Trucks (23)	1,000	1	1,000	1							28																					
11	Erosion Control Seeding	1	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	1								4																				
15 - Floodway Control and Diversion Structures																																				
12	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2									18						18													
13	Excavation/Grading (Dry Conditions)[8]	940	CY	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	3,500	1	3,500	1										8																		
14	Sheet Pile Wall	1,730	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2											7																	
15	Headworks Structure	130	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	3												9																
16	Headworks Channel Transition	130	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	2													8															
17	Hinged Bottom Gates	1	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	8													6	6														
20 -Permanent Operating Equipment[11]																																				
18	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																2			2									
19	Mechanical Hydraulic Cylinders & Housing	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	10																	4	4										
								Estimated Total Number of Construction Workers:	8	10	18	9	8	20	56	4	36	8	7	9	14	6	18	2	4	4	2	0	0	0	0	0	0	0	8	5

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 10 days for permanent equipment installation

Table 18. Agricultural Crossing 1, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days
02 - Relocations								
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
2	Levee O&M Road Regrading (6" AB)	10,400	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	1
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1
09 - Channels and Canals								
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
5	Clearing and Grubbing[6]	3	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	2
6	Excavation (Wet Conditions)[7]	150	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	1
7	Erosion Control Seeding	2	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	2
11 - Levees and Floodwalls								
8	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (3) Temp. Mobile Office Building (1)	-	-	-	2
9	Reinforced AG Berm	2,120	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	3
15 - Floodway Control and Diversion Structures								
10	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
11	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	42
12	Excavation (Wet Conditions)	5,140	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	3
13	Concrete Turnout Structure	1	EA	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	1	1	1	1
14	36-inch RCP	680	LF	25 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (1) Pickup Truck Conventional (4)	90	1	90	8
15	Trashrack	3	EA	Flatbed Truck (1) Pickup Truck Conventional (2)	3	1	3	1
16	Screw Gate	3	EA	Flatbed Truck (1) Pickup Truck Conventional (2)	3	1	3	1
17	Outlet Fish Screen	1	EA	Flatbed Truck (1) Pickup Truck Conventional (2)	1	1	1	1
18	Concrete Emergency Spillway	19	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	70	1	70	1
19	Concrete Connection Vault	1	EA	40 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (3)	1	1	1	1
08 - Roads, Railroads, and Bridges								
20	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2
21	Rail Car Bridge Concete Piles	480	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	3
22	Rail Car Bridge Concrete Abutments and Wingwalls	58	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1
23	Rail Car Bridge Span Installation	1,000	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	3

Estimated Duration, Weeks[4]

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	2																						2					
2																						8						
3	3																											
4	10					10																						
5		9																										
6			20																									
7				4	4																							
8							3		3																			
9								4																				
10										18								18										
11											3	3	3	3	3	3	3											
12											20																	
13												9																
14													6	6														
15															3													
16															3													
17															3													
18																9												
19																9												
20																	5					5						
21																		13										
22																			9									
23																				7								
Estimated Total Number of Construction Workers:	15	9	20	4	4	10	3	4	3	18	23	12	9	9	12	21	8	31	9	7	0	13	2	0	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed

Table 19. Knaggs Area, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	2																						2					
2	Levee O&M Road Regrading (6" AB)	104,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	3																						8						
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	12											12																
5	Clearing and Grubbing[6]	17	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	1	2	9		9	9																									
6	Excavation/Grading (Dry Conditions)[8]	54,870	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	16				8	8	8																						
7	Riprap - Class 2	20,210	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	21							28	28	28	28																		
8	Erosion Control Seeding	3	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	2											4																	
11 - Levees and Floodwalls																																				
9	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (3) Temp. Mobile Office Building (1)	-	-	-	2			5								5																	
10	Berm/Levee Fill	72,330	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	2	2,000	37				8	8	8	8	8	8	8																		
15 - Floodway Control and Diversion Structures																																				
11	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2					9													9										
12	Construction Site Dewatering (Temporary Cofferdam)	9,300	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	8								7																				
13	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	54									3	3	3	3	3	3	3	3	3											
14	Excavation (Wet Conditions)[11]	25,960	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	15						20	20			20																		
15	Sheet Pile Wall	1,840	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2											7																	
16	Culvert Headwall	110	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	60	1	60	2												8																
17	Precast Box Culvert 10'x8' 30'	30	LF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (4)	100	1	100	1													6															
18	Water Control Structure	280	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	4														8														
19	Inflatable Obermeyer Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24															6	6	6											
19 - Buildings, Grounds, and Utilities																																				
20	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
21	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
22	Concrete Duct Bank	40	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1					9																							
20 -Permanent Operating Equipment[12]																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																2						2						
24	Power, Electrical, & Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																	4	4	4	4	4							
25	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																				4	4							
								Estimated Total Number of Construction Workers:	26	19	24	26	44	46	65	43	39	59	19	23	9	11	9	11	13	13	4	8	8	10	2	0	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 20. Conaway Area, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (2) Temp. Mobile Office Building (1)	-	-	-	2	2																						2					
2	Levee O&M Road Regrading (6" AB)	218,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	6																						8						
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	16																				16							
5	Clearing and Grubbing[6]	67	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	2	4	17		18	18	18																								
6	Excavation/Grading (Dry Conditions)[8]	133,580	CY	300 HP Dozers (1) 21 CY Scrapers (4) 12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (7)	3,500	1	3,500	39					8	8	8	8	8	8	8																	
7	Riprap - Class 2	153,590	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	2	2,000	77							56	56	56	56	56	56	56	56	56	56	56	56	56									
8	Erosion Control Seeding	24	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	13																				4								
11 - Levees and Floodwalls																																				
9	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (3) Temp. Mobile Office Building (1)	-	-	-	2			5																			5						
10	Berm/Levee Fill	213,520	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	2	2,000	107				8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8							
15 - Floodway Control and Diversion Structures																																				
11	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2					9													9										
12	Construction Site Dewatering (Temporary Cofferdam)	93,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	78								7																				
13	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	54									3	3	3	3	3	3	3	3	3											
14	Excavation (Wet Conditions)	25,960	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	15						20	20			20																		
15	Sheet Pile Wall	1,840	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2											7																	
16	Culvert Headwall	110	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	60	1	60	2												8																
17	Precast Box Culvert 10'x8' 30'	30	LF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (4)	100	1	100	1													6															
18	Water Control Structure	280	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	4														8														
19	Inflatable Obermeyer Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24															6	6	6											
19 - Buildings, Grounds, and Utilities																																				
20	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
21	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
22	Concrete Duct Bank	40	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1					9																							
20 -Permanent Operating Equipment[12]																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																2						2						
24	Power, Electrical, & Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																	4	4	4	4	4							
25	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																				4	4							
	Estimated Total Number of Construction Workers:								30	28	33	36	44	46	101	79	75	95	82	75	73	75	73	75	77	77	68	20	32	15	2	0	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 21. Swanston Area, Detailed Weekly Estimate of Construction Activities, Personnel, Equipment, and Duration

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
02 - Relocations																																				
1	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (2) Temp. Mobile Office Building (1)	-	-	-	2	2																							2				
2	Levee O&M Road Regrading (6" AB)	221,000	SF	12' Blade Grader (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (1) 16 CY 3 Axle Dump Truck (5)	39,400	1	39,400	6																							8					
3	Temporary Electrical Power	100	LF	Flatbed Truck (1) Pickup Truck Conventional (2)	1,500	1	1,500	1	3																											
09 - Channels and Canals																																				
4	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2	36																					36						
5	Clearing and Grubbing[6]	503	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	2	6	12	42		54	54	54	54	54	54																					
6	Excavation (Wet Conditions)[7]	213,710	CY	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	1,800	2	3,600	60											40	40	40	40	40	40	40	40	40	40								
7	Excavation/Grading (Dry Conditions)[8]	854,860	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	3,500	4	14,000	62								32	32	32	32	32	32	32	32	32	32	32										
8	Erosion Control Seeding	46	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	25																					4							
11 - Levees and Floodwalls																																				
9	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (3) Temp. Mobile Office Building (1)	-	-	-	2								3					3															
10	Berm/Levee Fill	21,070	CY	300 HP Dozer 4000 gallon Water Truck 10 TN Smooth Roller Pickup Truck Conventional (3)	1,000	1	1,000	22									4	4	4	4																
15 - Floodway Control and Diversion Structures																																				
11	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2					9													9										
12	Construction Site Dewatering (Temporary Cofferdam)	93,000	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer (1) Pickup Truck Conventional (6)	1,200	1	1,200	78								7																				
13	Construction Site Dewatering (Pumping)	-	-	6" Dia. Pump Engine Drive (1) Pickup Truck Conventional (3)	-	-	-	54									3	3	3	3	3	3	3	3	3											
14	Excavation (Wet Conditions)	25,960	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	1,800	1	1,800	15						20	20			20																		
15	Sheet Pile Wall	1,840	SF	Flatbed Truck (1) 75 TN Crane Crawler Pile Hammer Pickup Truck Conventional (6)	1,200	1	1,200	2											7																	
16	Culvert Headwall	110	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	60	1	60	2												8																
17	Precast Box Culvert 10'x8' 30'	30	LF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (4)	100	1	100	1													6															
18	Water Control Structure	280	CY	2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (6)	70	1	70	4														8														
19	Inflatable Obermeyer Gates	3	EA	90 TN Truck-mounted Hydraulic Crane Haul Truck Oversize Transport Pickup Truck Conventional (4)	0.1	1	0.1	24															6	6	6											
08 - Roads, Railroads, and Bridges																																				
20	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2														5							5							
21	Rail Car Bridge Concete Piles	2400	LF	40 TN Truck-mounted Hydraulic Crane 100 FT Auger Track-mounted Drill Rig Concrete Pump Boom Truck Mounted Concrete Mixer Truck (3) 0.8 CY Backhoe Loader (1) 24 TN Truck End Dump (2) Pickup Truck Conventional (8)	180	1	180	14															13	13	13											
22	Rail Car Bridge Concrete Abutments and Wingwalls	290	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	5																		9										
23	Rail Car Bridge Span Installation	4500	SF	90 TN Truck-mounted Hydraulic Crane (1) Flatbed Truck (2) Pickup Truck Conventional (5)	390	1	390	12																			7	7								
19 - Buildings, Grounds, and Utilities																																				
20	Mobilization and Demobilization[9]			Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)					9						9																					
21	CMU Building and Earthwork Pad Construction[11]	1	EA	165 HP Dozer (1) Scrapper (1) Motor Grader (1) Compactor (1) 4000 gallon Water Truck (1) 10 TN Smooth Roller (1) Pickup Truck Conventional (7) Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Extended Boom Pallet Loader (1) Concrete Mixer Truck (1)	-	-	-	30		10	10	10	10	10																						
22	Concrete Duct Bank	40	CY	Concrete Pump Boom Truck Mounted (1) 2.5" Dia. Concrete Vibrator (1) Concrete Mixer Truck (2) Pickup Truck Conventional (7)	60	1	60	1					9																							
20 -Permanent Operating Equipment[12]																																				
23	Mobilization and Demobilization[9]	-	-	Flatbed Truck (1 per piece of equipment) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1)	-	-	-	2																		2						2				
24	Power, Electrical, & Mechanical Equipment	-	-	Extended Boom Pallet Loader Pickup Truck Conventional (3)	-	-	-	30																			4	4	4	4	4					
25	Communication Equipment	-	-	Pickup Truck Conventional (3)	-	-	-	12																						4	4					
								Estimated Total Number of Construction Workers:	50	64	64	64	82	84	83	42	39	59	86	87	84	88	94	94	94	92	51	51	13	44	16	4	0	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site
6 Includes off haul of material to disposal site (estimated 80 CY/AC)
7 Includes off haul of material to the spoil site (within 1 mile radius) by dump trucks
8 Includes off haul of material to the spoil site (within 1 mile radius) by scrapers
9 The number of flatbed truck drivers required to bring equipment associated with a given task
10 Excavated material assumed to be reused for backfill, hauling cost is included under excavation, 20% shrinkage factor has be applied to the volume needed
11 Assumption: 30 days for CMU building construction.
12 Assumption: 30 days for permanent equipment installation

Table 22. Alternative 2 & 5 River Grading Site: Detailed Weekly Estimate of Construction Activities

#	Activity	Quantity	Unit	Crew / Equipment[1] (Number of Equipment)	Crew Daily Output	Crew/ Equipment Quantity[3]	Total Daily Output	Estimated Duration, Days	Estimated Duration, Weeks[4,9]																											
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
09 - Channels and Canals																																				
1	Mobilization and Demobilization[8]	-	-	Flatbed Truck (1 per piece of equipment not on barge) Extended Boom Pallet Loader (1) Pickup Truck Conventional (1) Temp. Mobile Office Building (1) Barges (4) (Including 1 Excavator or 1 Clamshell Crane, and 1 Sounding Boat) Tug Boat (2)	-	-	-	2	15																								15			
2	Clearing and Grubbing[5]	4	AC	1.5 CY Front End Loader Crawler (1) Trailer Mounted Brush Chipper Chainsaw (1) 4000 gallon Water Truck (1) Pickup Truck Conventional (6) 16 CY 3 Axle Dump Truck (1)	1	1	1	4		9																										
3	Excavation (From Bank)[6]	6,652	CY	4.5 CY Hydraulic Excavator (1) 300 HP Dozer (2) 3.5 CY Front End Loader, Wheel (2) 16 CY 3 Axle Dump Truck (9) Pickup Truck Conventional (7)	700	1	700	10			20																		20							
4	Excavation/Dredging (From Barge)[7]	44,177	CY	Clamn Shell Bucket (1) Barge Mounted Excavator (1) Tug Boat (1) Barge (2) Sounding Boat (1) Pickup Truck Conventional (4)	400	1	400	111			15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15							
5	Riprap - Graded Stone 'C'	17,546	TN	2.5 CY Hydraulic Excavators (2) 300 HP Dozer Crawler (1) 16 CY 3 Axle Dump Truck (23) Pickup Truck Conventional (5)	1,000	1	1,000	18																					28	28	28					
6	Erosion Control Seeding	31	AC	0.8 CY Front End Loader Wheel (1) Pickup Truck Conventional (4)	2	1	2	16				4																			4	4				
								Estimated Total Number of Construction Workers:	15	9	35	19	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	63	28	32	4	15	0	0	0

1 Assumed equipment and crew size
2 USA CE Civil Works Work Breakdown Structure Number
3 Number of generic crews outlined in the column "Crew / Equipment1 (Number of Equipment)"
4 Number in the cell represent estimated maximum number of crew members for a given task in a given week
5 Includes off haul of material to disposal site (estimated 80 CY/AC)
6 Includes off haul of material to the spoil site (within 1 mile radius) by dump truck
7 Includes spoiling material onto and then 2nd handling and off haul of material to the upland spoil site.
8 The number of flatbed truck drivers required to bring equipment associated with a given task

Appendix C
Adaptive Management Biological Objectives

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RECLAMATION
Managing Water in the West

Adaptive Management Biological Objectives

September 2017

U.S. Department of the Interior
Bureau of Reclamation

September 2017

1 Introduction

The goal of maintenance and management of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Project) sites is to promote the long-term improvements of the Proposed Action area in providing functions and services associated with Valley Lowland floodplain habitat. The approach to adaptive management of the site is to conduct annual site visits and monitor select characteristics to determine the benefits of the project and ongoing trends in physical and biological processes. Unexpected trends in the biological or physical characteristics of the project's sites will require examination to determine if they are risking the goals and objectives of the Proposed Action. The Adaptive Management Plan describes how the Proposed Action will incorporate focused monitoring efforts and proposed potential management responses.

2 Adaptive Management in the Yolo Bypass Salmonid Habitat and Fish Passage Project

Adaptive management is an iterative process (Figure 1) that promotes improved decision making and adjustments to management activities as uncertainty in outcomes from these activities become more well understood. Scientific understanding advances through careful monitoring to help adjust policies or operations through annual and biannual learning exercises. This framework aims to achieve more effective decisions that enhance benefits and moderate risks. The success of adaptive management will be measured in how well the process meets environmental, social, and economic goals; increases scientific knowledge, and reduces barriers among participants and agencies (Department of the Interior [DOI] 2009).

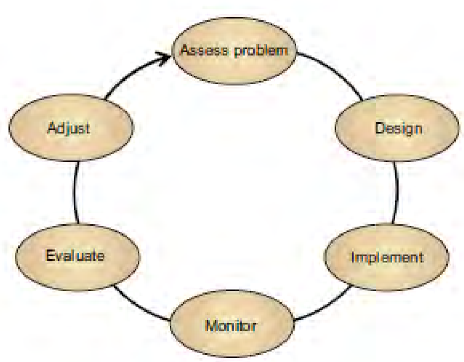

Figure 1. Diagram of the adaptive management process (DOI 2009)

During the Environmental Impact Statement/Environmental Impact Report (EIS/EIR) process for the Project, considerable effort has gone into describing problems and potential alternative solutions to address limiting factors associated with poor access to floodplains and poor fish passage on the Yolo Bypass. Upon a Record of Decision/Notice of Determination regarding a

Project to implement, this adaptive management plan will be used to guide monitoring, evaluation, and potential adjustments and management responses. Utilizing existing technical teams (i.e., Interagency Ecological Program Yolo Bypass Project Work Team, Fisheries Engineering Technical Team) to ensure compliance monitoring associate with the Project meets the requirements for measuring Restoration Objectives, implementing agencies will provide an opportunity to stakeholders and agencies to review the monitoring plan. Annually, these monitoring efforts will report to these technical teams and the Biological Opinion's Implementation Management Team their findings. Utilizing existing teams (i.e., Fishery Agency Strategy Team) these findings will be integrated into our existing understanding to determine how the Project's operations and facilities may require intervention to achieve Restoration Objectives. Finally, adjustments will be considered through an Adaptive Management Team, supported by the DOI Bureau of Reclamation (Reclamation) and Department of Water Resources (DWR).

3 Governance Framework

The Project will be adaptively managed to ensure that biological goals and objectives are met and in turn will address impacts and the uncertainties of future impacts. Adaptive Management governance is discussed in a separate document which outlines a framework for a structured decision-making process to reduce uncertainty and increase effectiveness of habitat restoration and fish passage.

Decisions on adaptive management will be divided into three categories based on level of impacts and appropriate level of involvement. These categories will, as appropriate, help landowners, stakeholders, and the public provide input into minimizing economic impacts and accomplishing the goals and objectives of the project. Reclamation and DWR will retain decision-making authority on the project and adaptive management actions.

4 Conceptual Models of Salmonids and Central Valley Floodplains

Two recent conceptual models are useful for considering adaptive management of Valley Lowland floodplains are the Salmon and Sturgeon Assessment of Indicators by Life State conceptual model (Windell et al 2017) and a conceptual model regarding floodplain function (Opperman 2012). Similarities of these models include ecological outcomes for Chinook salmon and food web contribution, but differ in the structure of linkages between hydrology and environmental attributes and habitat conditions. Thus, we modified these models to simplify the likely processes affected by the Proposed Action and maintained the ecological responses likely to be observed.

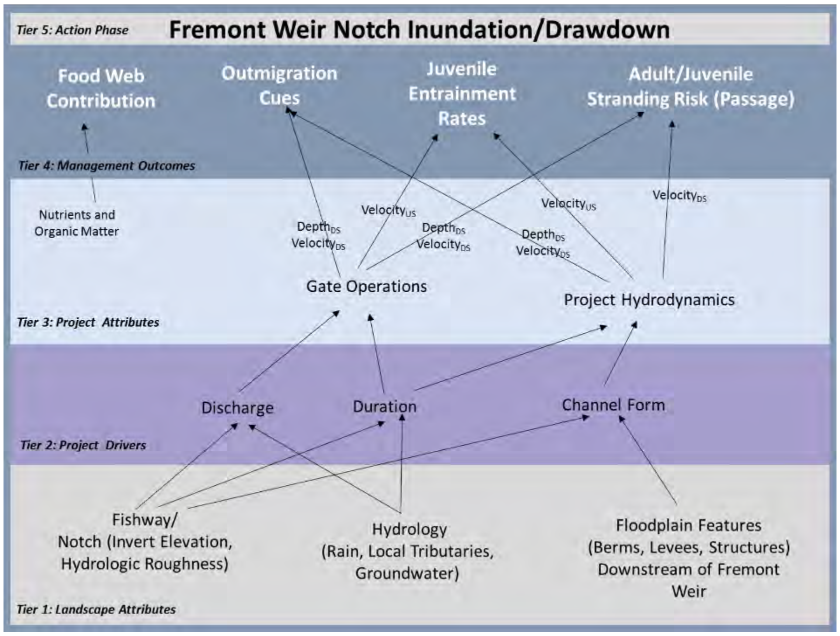

Figure 2. Fremont Weir Notch Flood Up/Drawdown Operation Conceptual Model

Fremont Weir notch operation in the initial phase of the Project's operational action primarily focuses on increased connectivity between the Sacramento River and Yolo bypass to improve adult fish passage and juvenile salmon entrainment (Figure 2). Also, Fremont Weir notch operation during the drawdown phase of the Project's operational action primarily focuses on passage benefits related to reducing adult and juvenile stranding risks while creating fish outmigration cues. As the Fremont Weir notch opens and closes, it connects the Sacramento River and Yolo Bypass landscape leading to nutrient exchange priming the floodplain and subsequently the Sacramento-San Joaquin Delta (Delta) food webs.

Inundation of a notch and fishways in Fremont Weir are directly affected by the elevation of these facilities. The notch's design and hydrology (e.g., rain, local tributaries, and groundwater) are key landscape attributes leading to the discharge rate and duration of inundation. The channel form of the notch and fishway facilities are also critical to flow-related project attributes and biological outcomes, that can be measured biological and physically and are representative of the effectiveness of a notch and fishway's design to contribute to the success of the Project.

Gate operations and project hydrodynamics (roughness/secondary circulation) are project attributes that are affected by the project drivers, and directly impact the benefits of the Project to juvenile and adult Endangered Species Act (ESA) listed species. Salmonids and sturgeon are affected by the Project through the key processes of being entrained onto the Yolo Bypass through the notch and cued to outmigrate into Cache Slough's tidal wetlands. Entrainment rates through a notch are dependent on the upstream (riverside) velocities, accelerations and turbulence characteristics created through gate operations and project hydrodynamics. Depending on the daily discharge and duration of potential notch flows, gate operation in a notch may be modified following the adaptive management process to affect the entrainment rate.

The success of juvenile outmigration or increased juvenile stranding are controlled by discharge and duration of notch flows control gate operations. Discharge also directly affects the project hydrodynamics (roughness/ secondary circulation). These project attributes influence downstream velocity and water depths on the inundated floodplain's channel forms. While many floodplain attributes and fish characteristics cue outmigration (i.e., temperature, dissolved oxygen [DO], and physiology), the Project does not actively control these. Localized hydrodynamics (i.e., velocities) are a project attribute that may be managed to reduce stranding of juvenile fish trying to migrate off a receding floodplain. The risk of adult stranding in the Fremont Weir fishways or on the Yolo Bypass is dependent on the downstream velocity and water depths created by gate operations and project hydrodynamics. The Yolo Bypass's floodplain features contain many channel form features including berms, water control structures, canals, agricultural crossings, and rice checks, which all impact the project hydrodynamics at a localized scale. This can result in some level of localized stranding risk. Depending on the daily discharge and duration of potential notch flows, gate operations in a notch may be modified following the adaptive management process to affect juvenile and adult migration on the Yolo Bypass. To improve outmigration and reduce stranding, modification of channel forms may also be considered through the adaptive management process. Ultimately, drawdown has an important impact on juvenile salmon migration timing and survival, as well as adult salmon passage condition, passage rate, and passage survival.

The connection between the Sacramento River and Yolo Bypass via a Fremont Weir notch is important to nutrient availability. This connection imports allochthonous riverine nutrients and organic matter to the broad floodplain of the Yolo Bypass. Primary productivity is stimulated by temperatures and DO concentrations, which are not actively controlled by the Project.

Yolo Bypass inundation is the Project's operational action focused on improving juvenile salmonid growth, survival, and increased life history diversity in the lower Sacramento River (Figure 3). Also, inundation of the Yolo Bypass is a major contributor of secondary production to the Delta food web. As the Yolo Bypass floodplain is inundated via the Fremont Weir, additional flows from western tributaries (Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek) play a pivotal role in the extent and duration of inundation.

The notch and human-built floodplain features provide habitat connectivity. The volume and duration of flows through a Fremont Weir notch are directly affected by the elevation of these facilities. The notch's design and hydrology and key landscape attributes affect gate operations and project hydrodynamics. These Project attributes influence outmigration cue and residence times that result in biological outcomes that can be measured biologically and physically and are representative of the effectiveness of a notch's design to contribute to the success of the Project.

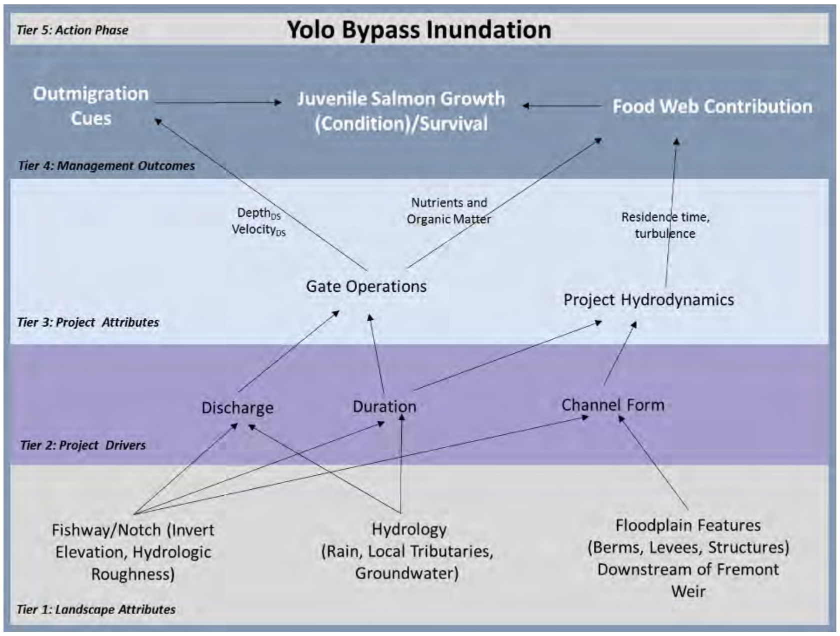

Figure 3. Yolo Bypass Inundation Conceptual Model

Floodplain features are likely to be quite influential in affecting project hydrodynamics and the residence times of water. The Project attribute stimulates secondary production. Hydrology (i.e., rain events) may influence turbidity, which affects light availability. Hydrologic events may also transport nutrients and organic matter. Light and nutrient availability impacts primary productivity and vegetation growth. Increases in primary productivity and vegetation growth allow for increases in secondary productivity (i.e., food web contribution), which effects salmon survival and migration. While the majority of these drivers are not Project attributes, features on the floodplain may be modified following the adaptive management process to affect growth, survival, and life history diversity of juvenile salmonid benefiting from the Project.

5 Restoration Objectives:

While it is not anticipated that major modification of the Proposed Action's facilities or project sites will be needed, an objective of this plan is to guide monitoring and to identify the thresholds that may comprise the Proposed Action's objectives. This section summarizes the Proposed Action's Objectives that were initially described in the Implementation Plan. Then, expected outcomes are described related to the objectives. Further synthesis of published baseline data and technical reports, which are part of this EIS/EIR are required to inform metrics by which progress towards meeting the objective will be measured, as well as thresholds for undertaking a management response if objectives are not being met.

5.1 Food Web Contribution

Objective: Enhance food web productivity and export into Cache Slough in support of native ESA-listed fish recovery.

Expected Outcome: The increased duration and frequency of floodplain inundation will increase terrestrial exchange on the site. This productivity exchange will increase the export of primary and secondary productivity from the Yolo Bypass.

Monitoring Category: Physical Process and Hydrology

> **Metric:** Elevation and topography. Hydrology measured with level-loggers in various locations along channel cross sections.
>
> **Goal:** A notched Fremont Weir will supply flows to increase terrestrial-aquatic exchange within the Action Area.
>
> **Intervention Threshold**: If floodplain inundation area changes for 2 or more years in a row from excessive sedimentation of Action Area. Also, an obstruction such as a large tree blocks the notch site.
>
> **Potential Management Response:** Work with Land Owners on appropriate actions to take, but not limited to, removal of obstruction or grading or dredging. Any non-agricultural work will be limited to work windows outside of the period of sensitive and ESA-listed species. A log of action location, and cause will be reported as part of an Annual Report. Equipment may include long-reach excavator, barge-mounted dragline, or backhoe

Monitoring Category: Food Web

> **Metrics:** Chlorophyll a, Phytoplankton, zooplankton, benthic macroinvertebrates.
>
> **Goal:** Food web contributions from the Action Area are higher than the Sacramento River entering the North Delta. Food web contributions from the various habitat components with the Action Area are maximized to the extent possible.
>
> **Intervention Threshold:** Food web components in floodplains and the Toe Drain are lower in concentration than those found in the lower Sacramento River entering the Delta.
>
> **Potential Management Response:** Increase water quality monitoring to determine conditions that may be leading to lower productivity. Modify the floodplain to increase residence times or other water quality characteristics favorable to increased productivity. Prior to any modifications to Project features, information describing the proposed work, the elevation of existing landforms, expected response, and on-site inspection results for protected species.

5.2 Salmonid Entrainment

Objective: Provide juvenile entrainment rates at least 90 percent the proportion of flow entrained through the Fremont Weir.

Expected Outcome: The Action Area will provide a greater than 0.9:1.0 ratio between juvenile entrainment rates and flow entrainment rates.

Monitoring Category: Fish

Metric: Chinook salmon entrainment

Goal: Measure entrainment.

Intervention Threshold: Results from five-year special study of juvenile entrainment does not support expected outcome being met.

Potential Management Response: Improve upstream bank channel. Develop model for behavioral guidance structures to improve entrainment and implement if likely to provide desired objective.

5.3 Salmonid Rearing

Objective: Provide rearing habitats for a diverse range of life histories of juvenile salmonids.

Expected Outcome: The Action Area will provide an increase occupied habitat for rearing and outmigrating salmonids compared to the prior conditions during a similar water year type.

Monitoring Category: Fish

Metric: Chinook salmon presence

Goal: Observe Chinook salmon at southern Yolo Bypass screw trap site

Intervention Threshold: Duration of juvenile Chinook salmon presence at south Yolo Bypass screw trap site is shorter than during years with operation of the Fremont Weir notch than without operation.

Potential Management Response: Lengthen period of Fremont Weir notch operation between first and last operational dates during the Fremont Weir notch operation period.

Monitoring Category: Fish

Metric: Variance in size of juvenile Chinook salmon.

Goal: Measure Chinook salmon at southern Yolo Bypass screw trap site.

Intervention Threshold: Range of sizes of juvenile Chinook salmon at the south Yolo Bypass screw trap site is narrower during years with operation of the Fremont Weir notch than without operation.

Potential Management Response: Lengthen period of Fremont Weir Notch operation earlier and/or later during the Fremont Weir notch operation period.

Monitoring Category: Water Quality

Metric: DO, temperature, pH.

Goal: Maintain suitable water quality conditions for rearing salmonids.

Intervention Threshold: If juvenile Chinook salmon are present within the site and water quality conditions are unsuitable, consider potential management response. No threshold for intervention is appropriate if juvenile Chinook salmon are not found within the site.

Potential Management Response: Reduce inundation flows to move juvenile Chinook salmon off of floodplain habitat and maintain migration flows in Tule Canal to move fish into Cache Slough.

5.4 Adult Fish Passage

Objective: Provide volitional passage to adult salmon and sturgeon so that they remain in good condition passing through the Yolo Bypass to spawning grounds.

Expected Outcome: The Project will improve passage of adult salmon and sturgeon by reducing delays and minimizing straying.

Monitoring Category: Fish

Metric: Percent of salmon escapement captured at Wallace Weir.

Goal: Measure number of adult salmon and sturgeon straying to Wallace Weir during fish rescue operations.

Intervention Threshold: More than 1 percent of salmon evolutionarily significant unit (ESU) or green sturgeon annual escapement stray to Wallace Weir during project operations.

Potential Management Response: Operate Fremont Weir fish passage structures to increase volitional passage window following end of overtopping. Re-operate Knights Landing Ridge Cut to reduce Wallace Weir attractions flows. Evaluate if creating a connection to the Sacramento River from Wallace Weir may reduce impact of Wallace Weir stranding on ESU escapement.

Monitoring Category: Fish

Metric: Percent of salmon escapement stranded/rescued in Yolo Bypass.

Goal: Measure number of ESA-listed fish stranded and rescued in Yolo Bypass.

Intervention Threshold: More than 1 percent of salmon ESU or green sturgeon adult annual escapement or juvenile production estimate are stranded in Yolo Bypass.

Potential Management Response: For adult salmon, re-operate Fremont Weir fish passage facilities when sufficient depths are expected over a sufficient duration. Regrade Fremont Weir apron so it drains towards fish passage structures. Improve coordinated operations of the primary, modified adult, and tertiary fish passage structures. Evaluation potential for low-flow salmon fish ladder in Sacramento Weir to reduce adult stranding. For juvenile salmon, improve connectivity between stranding areas, fill in stranding locations.

Monitoring Category: Physical processes and hydrology

Metric: Length of time Fremont Weir notch is passable by adult salmon and sturgeon.

Goal: Measure velocity and depth in fish passage channel during fish passage period.

Intervention Threshold: Volitional passage conditions through the fish passage structure are unsuitable within 36 hours following cessation of natural and project-operated overtopping.

Potential Management Response: Extend operation to slightly less conservative conditions to improve passage. Alternately, roughen the fish passage channel.

6 References

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