Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project

Draft
Technical Summary Report

SAN JOAQUIN RIVER
RESTORATION PROGRAM

Mission Statements

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

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

U.S. Department of the Interior
Bureau of Reclamation

November 2018

Contents

Chapter 1 Introduction 1-1
1.1 Reach 4B, Eastside Bypass, and Mariposa Bypass 1-1
1.2 Settlement Requirements 1-2
1.3 Project Area 1-3
1.4 Purpose of this Report 1-4

Chapter 2 Alternatives 2-1
2.1 No Action Alternative 2-1
2.2 Action Alternatives Summary 2-2
2.3 Alternative 1 – Main Channel Restoration 2-3
2.3.1 Flow Routing 2-3
2.3.2 Construction Actions 2-3
2.3.3 Operations 2-6
2.4 Alternative 2 – Bypass Restoration 2-6
2.4.1 Flow Routing 2-6
2.4.2 Construction Actions 2-7
2.4.3 Operations 2-12
2.5 Alternative 3 – Bypass All Pulse Flows 2-13
2.5.1 Flow Routing 2-13
2.5.2 Construction Actions 2-13
2.5.3 Operations 2-16

Chapter 3 Hydrology and Flood Operations 3-1
3.1 Setting 3-1
3.1.1 Hydrology 3-1
3.1.2 Flood Management Structures 3-2
3.1.3 Levees 3-3
3.1.4 Subsidence 3-3
3.1.5 Flood Management Operations and Conditions 3-4
3.2 Alternative Comparison 3-4
3.2.1 Flood Flows 3-4
3.2.2 Straying Pathways 3-7
3.2.3 Subsidence 3-7

Chapter 4 River Geomorphology and Sedimentation 4-1
4.1 Setting 4-1
4.1.1 River Geomorphology and Sediment Transport 4-1
4.1.2 Subsidence 4-4
4.2 Alternative Comparison 4-6
4.2.1 Sediment Transport 4-6

Chapter 5 Vegetation and Soils 5-1
5.1 Setting 5-1
5.1.1 Regional Setting 5-1
5.1.2 Reach 4B/ESB Project Habitat 5-1
5.1.3 Invasive Plants 5-5
5.1.4 Soils 5-6
5.2 Alternative Comparison 5-9
5.2.1 Direct Effects to Vegetation 5-9
5.2.2 Revegetation 5-9
5.2.3 Invasive Species 5-10
Chapter 6 Groundwater 6-1
6.1 Setting 6-1
6.1.1 Regional Groundwater Conditions 6-1
6.1.2 Local Hydrogeology 6-2
6.1.3 Local Groundwater Levels 6-3
6.1.4 Local Land Subsidence 6-4
6.1.5 Local Groundwater Quality 6-4
6.1.6 Seepage Management Project along San Joaquin River 6-4
6.2 Alternative Comparison 6-5
6.2.1 Changes to Groundwater/Surface Water Interaction 6-5
6.2.2 Changes to Groundwater Levels 6-9
6.2.3 Subsidence 6-10
Chapter 7 Fisheries and Wildlife 7-1
7.1 Setting 7-1
7.1.1 Historical Setting 7-1
7.1.2 Reach 4B/ESB Project Habitat 7-1
7.1.3 Fish Species 7-2
7.1.4 Birds 7-6
7.2 Alternative Comparison 7-8
7.2.1 Construction-Related Effects on Fish 7-8
7.2.2 Effects on Wildlife 7-8
7.2.3 Water Temperature 7-9
7.2.4 Flow Conditions for Fish 7-14
7.2.5 Fish Habitat 7-18
7.2.6 Predation 7-22
Chapter 8 Cultural Resources 8-1
8.1 Setting 8-1
8.1.1 Regional Setting 8-1
8.1.2 Reach 4B/ESB Project Area 8-1
8.2 Alternative Comparison 8-3
8.2.1 Effects to Cultural Resources 8-3
8.2.2 Effects to Historic Resources 8-4

Chapter 9 Implementation Considerations 9-1
9.1 Levee Stability Work 9-1
9.2 Cost 9-2
9.3 Public Access 9-2
Chapter 10 Summary and Conclusions 10-1
10.1 Alternative Comparison and Key Conclusions 10-1
10.2 Next Steps 10-3
Chapter 11 References 11-1

Tables

Table 2-1. Reach 4B/ESB Project EIS Alternatives and Key Elements 2-2
Table 2-2. San Joaquin River Proposed Levee Alignment for Alternative 1 2-5
Table 4-1. Average Slope and Average Diameter of Bed Material 4-2
Table 4-2. Infrastructure within the Reach 4B/ESB Project Area and Affected Geomorphic Processes 4-3
Table 4-3. Subsidence rates in the SRH-1D V4.0 one dimensional model 4-9
Table 5-1. Project Area Habitat Types 5-2
Table 5-2. Prevalent Non-Native Invasive Species in the Project Area 5-5
Table 5-3. Affected Habitat (acres) by Alternative 5-9
Table 6-1. Root Zones Values by Crop Type 6-5
Table 7-1. Fish species with historic or current presence within the Reach 4B/ESB Project study area .**Error! Bookmark not defined.**
Table 7-2. Alternative 1 Inundated Acres and Suitable Habitat at Different Restoration Flows (cfs) 7-19
Table 7-3. Alternative 2 Inundated Acres and Suitable Habitat at Different Restoration Flows (cfs) 7-21
Table 7-4. Alternative 3 Inundated Acres and Suitable Habitat at Different Restoration Flows (cfs) 7-22
Table 8-1. Potentially Affected Resource in the Reach 4B/ESB Project Area 8-3
Table 9-1. Levee Stability Improvements in Each Alternative 9-1
Table 9-2. Preliminary Alternative Cost Estimates 9-2
Table 10-1. Key Alternative Tradeoffs 10-2

Figures

Figure 1-1. Reach 4B/ESB Project Area 1-1
Figure 1-2. Site Conditions within Reach 4B1 1-5
Figure 1-3. Site Conditions within the Flood Bypass System 1-6
Figure 2-1. Alternative 1 – Flow Routing for Main Channel Restoration 2-3
Figure 2-2. Key Construction Actions in Alternative 1 2-4
Figure 2-3. Alternative 2A – Flow Routing for Main Restored Channel in Middle Eastside Bypass, Mariposa Bypass, and Reach 4B2 2-7
Figure 2-4. Alternative 2B – Flow Routing for Main Restored Channel in Middle Eastside Bypass and Lower Eastside Bypass 2-7
Figure 2-5. Key Construction Actions in Alternative 2A 2-8
Figure 2-6. Key Construction Actions in Alternative 2B 2-9
Figure 2-7. Alternative 3 – Flows below 475 cfs in San Joaquin River with Middle and Lower Eastside Bypass as High Flow Floodplain 2-13
Figure 2-8. Key Construction Actions in Alternative 3 2-14
Figure 3-1. Inflow from East Side Creeks into Middle and Lower Eastside Bypass 3-2
Figure 3-2. Project and Nonproject Levees with the Reach 4B/ESB Project Area 3-3
Figure 3-3. Flood Flows in a Normal-Wet Year (1932) 3-5
Figure 3-4. Flood Flows in a Wet Year (1938) 3-6
Figure 4-1. Measured Subsidence Rate between December 2011 and December 2016 4-5
Figure 4-2. Conceptual diagram of effects of subsidence on sedimentation in Reach 4B/ESBP Project area 4-6

Figure 4-3. Sediment Erosion and Deposition 4-7
Figure 4-4. Subsidence Changes to Bypass Channel 4-8
Figure 4-5. Subsidence Effects to Levee Freeboard under the No Action Alternative 4-8
Figure 4-6. Sediment Deposition in Reach 4B1 for Alternative 1 4-9
Figure 4-7. Sediment Deposition in the Bypass System for Alternative 2 4-11
Figure 4-8. Sediment Deposition in the Bypass System for Alternative 3 4-12
Figure 5-1. Vegetation in Reach 4B1 5-2
Figure 5-2. Vegetation in Middle Eastside Bypass within the Merced National Wildlife Refuge 5-2
Figure 5-3. Habitats of the Project Area 5-4
Figure 5-4. Soil Characteristics in the Reach 4B Area 5-7
Figure 5-5. Soil Salinity in the Reach 4B Project Area 5-8
Figure 6-1. Predevelopment and Post development hydrogeology in San Joaquin Valley 6-2
Figure 6-2. Schematic Representation of Changes in Groundwater Levels, Under Losing and Gaining Conditions, due to Increased Streamflow 6-3
Figure 6-3. Land Parcels along Reach 3 and Reach 4A Prioritized by Allowable Flow in the San Joaquin River 6-5
Figure 6-4. Monthly Losses in Reach 4B1 under Alternative 1 6-6
Figure 6-5. Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on April 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1 6-7
Figure 6-6. Monthly Losses in the Middle Eastside Bypass under Alternative 2 6-8
Figure 6-7. Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on April 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2 6-9
Figure 7-1. Salmon Life Cycle 7-6
Figure 7-2. Surface Water and Groundwater Temperatures in Reach 4B in a Wet Year 7-11
Figure 7-3. Surface Water and Groundwater Temperatures in Reach 4B in a Dry Year 7-11
Figure 7-4. Surface Water and Groundwater Temperatures in the Eastside Bypass in a Wet Year 7-13
Figure 7-5. Surface Water and Groundwater Temperatures in the Eastside Bypass in a Dry Year 7-13
Figure 9-1. State Land Area in Reach 4B under Public Trust Doctrine 9-3

List of Abbreviations and Acronyms

1D	One dimensional
2D	Two dimensional
bgs	below ground surface
C2VSIM	California Central Valley Groundwater-Surface Water Simulation Model
CACMP	Common Assumptions Common Modeling Package
Cal-IPC	California Invasive Plant Council
CCIC	Central California Information Center
CDFA	California Department of Food and Agriculture
cfs	cubic feet per second
CRHR	California Register of Historical Resources
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
gpm	gallons per minute
LSJLD	Lower San Joaquin Levee District
LWM	large woody materials
MAF	million acre-feet
mm	millimeters
NHPA	National Historic Preservation Act
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NWR	National Wildlife Refuge
O&M	operations and maintenance
PA	Programmatic Agreement
PEIS/R	Program Environmental Impact Statement/Report
Reach 4B/ESB Project	Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project
Reclamation	United States Department of the Interior, Bureau of Reclamation
RM	river mile
Settlement	Stipulation of Settlement
SHPO	State Historic Preservation Officer
SJRRP	San Joaquin River Restoration Program
SLC	California State Lands Commission
USACE	United States Army Corps of Engineers

Note to Readers:

This report was prepared by the San Joaquin River Restoration Program Team to document technical studies completed as part of the Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements. Studies in this area started in 2009; this Technical Summary Report documents key technical findings and summarizes the work that led to these findings. The report describes the differences between the routes for high flows through this area and compares these routes. Finally, it identifies potential near-term actions (in addition to the Eastside Bypass Improvements Project) that could provide benefits regardless of the high flow alternative selected. The San Joaquin River Restoration Program Team is not requesting formal comments on this draft document, but comments received will be considered to the extent possible.

Chapter 1 Introduction

Reach 4B1 of the San Joaquin River was once part of a meandering, braided river system that supported a historic salmonid fishery. Over time, changes to the river system reduced the water that entered this part of the river system. Upstream headgates now divert water into the flood bypasses and around this part of the river; the only water in this reach is from agricultural returns.

The San Joaquin River Restoration Program (SJRRP) was established in 2006 to restore flows and fish to the San Joaquin River by implementing the Stipulation of Settlement (Settlement) in *Natural Resources Defense Council, et al., v. Kirk Rodgers, et al*. The Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project (Reach 4B/ESB Project) is a project under the SJRRP that proposes to implement channel and structural modifications in the area of Reach 4B of the San Joaquin River. The United States Department of the Interior, Bureau of Reclamation (Reclamation) has prepared this report to document ongoing technical investigations for this project.

1.1 Reach 4B, Eastside Bypass, and Mariposa Bypass

The Reach 4B/ESB Project focuses on the area of Reach 4B of the San Joaquin River and the flood bypass system. Reach 4B of the San Joaquin River is a 32.5-mile stretch that begins at the Sand Slough Control Structure (River Mile [RM] 168.5) and extends to the confluence of the Eastside Bypass and San Joaquin River (RM 136). Reach 4B has been further divided into two subreaches: Reach 4B1 from the Sand Slough Control Structure to the Mariposa Bypass, the historical channel and flood conveyance pathway of the San Joaquin River; and Reach 4B2 from the Mariposa Bypass to the confluence of the Eastside Bypass and the San Joaquin River (see Figure 1-1).

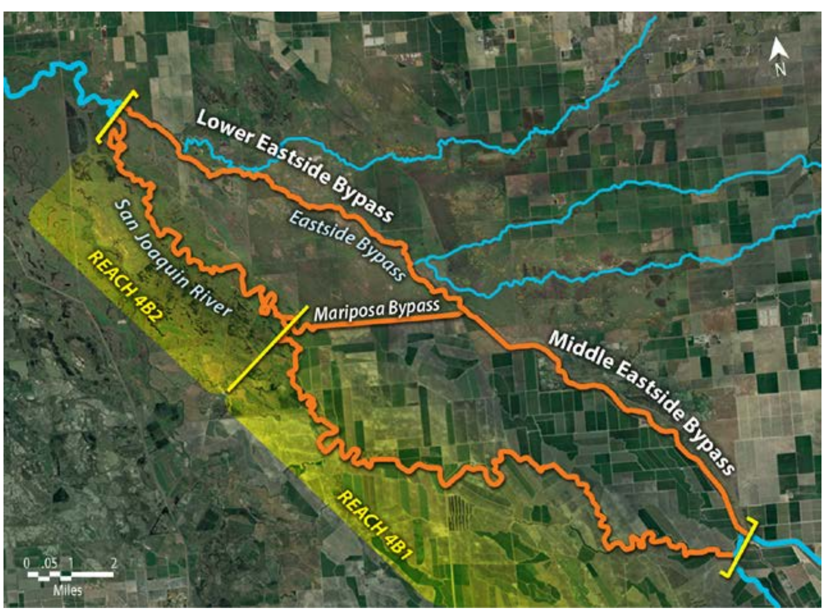


Figure 1-1. Reach 4B/ESB Project Area

The Reach 4B/ESB Project also includes actions within the Eastside and Mariposa bypasses. The Eastside and Mariposa bypasses, in operation since the 1960s, are flood control channels that convey flood flows and reduce flooding to surrounding lands. The portions of the Eastside Bypass within the Project area include the Middle Eastside Bypass, which begins at the Sand Slough Control Structure and ends at Eastside Bypass Control Structure, and the Lower Eastside Bypass, which begins at the Eastside Bypass Control Structure and ends at the confluence with the San Joaquin River. The Mariposa Bypass conveys flows from the end of the Middle Eastside Bypass to the San Joaquin River at the upstream terminus of Reach 4B2. Figures 1-2 and 1-3 show the features within the project area.

Currently, Reach 4A, the section of river directly upstream of Reach 4B, is dry in most months because all flows in the San Joaquin River are diverted at Sack Dam to the Arroyo Canal. Any flows reaching the Sand Slough Control Structure are diverted to the Eastside Bypass via the Sand Slough Control Structure, leaving Reach 4B1 dry, with the exception of agricultural returns.

Other than some ponding in low-lying areas, the bypasses generally remain dry until they are required to convey flood releases during the flood period. The flood season for the Lower San Joaquin Levee District (LSJLD) typically lasts from November 15 to June 15 of each water year, with rainfall contributing to higher flows during the early part of the flood season, and snowmelt contributing to flows at the later part of the flood season. Part of the Merced National Wildlife Refuge (NWR) is within the Middle Eastside Bypass, and this area is wet for longer periods because the NWR uses a part of the bypass system to convey water supplies.

1.2 Settlement Requirements

The Reach 4B/ESB Project is a high-priority SJRRP project with key elements in Paragraph 11(a) and 11(b) of the Settlement. Phase 1 improvements refer to the improvements specified in Paragraph 11(a) of the Settlement, whereas Phase 2 improvements refer to the improvements specified in Paragraph 11(b). Specifically, in regards to Reach 4B and the Eastside Bypass, Paragraph 11(a) of the Settlement stipulates:

- Modifications in San Joaquin River channel capacity to the extent necessary to ensure conveyance of at least 475 cubic feet per second (cfs) through Reach 4B

San Joaquin River Restoration Program

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit, known as *NRDC, et al., v. Kirk Rodgers, et al.*, challenging the renewal of long-term water service contracts between the United States and the Central Valley Project (CVP) Friant Division contractors. On September 13, 2006, after more than 18 years of litigation, the Settling Parties, including NRDC, Friant Water Authority (FWA), and the United States Departments of the Interior and Commerce, agreed on the terms and conditions of the Settlement subsequently approved by the United States Eastern District Court of California on October 23, 2006. The San Joaquin River Restoration Settlement Act (Act), included in Public Law 111-11 and signed into law on March 30, 2009, authorizes and directs the Secretary of the Interior (Secretary) to implement the Settlement. The Settlement establishes two primary goals:

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

The Settlement and the Act authorize and direct specific physical and operational actions that potentially could affect environmental conditions directly or indirectly in the Central Valley. Areas potentially affected by Settlement actions include the San Joaquin River and associated flood bypass system, tributaries to the San Joaquin River, the Sacramento-San Joaquin Delta, and water service areas of the CVP and State Water Project (SWP), including the Friant Division. Settlement Paragraphs 11 through 16 describe the physical and operational actions. The SJRRP is implementing the Settlement consistent with the Act.

- Modifications at the Reach 4B Headgate on the San Joaquin River channel to ensure fish passage and enable flow routing of between 500 cfs and 4,500 cfs into Reach 4B, consistent with any determination made in Paragraph 11(b)(1)
- Modifications to the Sand Slough Control Structure to ensure fish passage
- Modifications to structures in the Eastside and Mariposa bypass channels to the extent needed to provide anadromous fish passage on an interim basis until completion of the Phase 2 improvements
- Modifications in the Eastside and Mariposa bypass channels to establish a suitable low-flow channel if the Secretary, in consultation with the Regional Administrator (RA), determines such modifications are necessary to support anadromous fish migration through these channels

Paragraph 11(b)(1) of the Settlement includes additional language on long-term flows in Reach 4B of the San Joaquin River:

- Modifications in the San Joaquin River channel capacity (incorporating new floodplain and related riparian habitat) to ensure conveyance of at least 4,500 cfs through Reach 4B unless the Secretary of the Interior, in consultation with the RA and with the concurrence of the National Marine Fisheries Service and United States Fish and Wildlife Service, determines that such modifications would not substantially enhance achievement of the Restoration Goal

The San Joaquin River Settlement Act contains the following language requiring a report on the long-term flows in Section 10009(f)(2):

- Secretary of the Interior shall submit a report to Congress on whether to expand the channel conveyance to 4,500 cfs in Reach 4B of the San Joaquin River or use an alternative route for pulse flows.
- Secretary of the Interior shall make the high-flow routing determination prior to undertaking "any substantial construction work" to increase capacity in Reach 4B of the San Joaquin River.

1.3 Project Area

The current conditions in the Project area present several challenges to fish rearing and passage. Figures 1-2 and 1-3 show major features in the San Joaquin River and bypass system, respectively. Challenges associated with these features include:

- *San Joaquin River* – Reach 4B1 of the San Joaquin River has been disconnected hydraulically from other river reaches for approximately 40 years, is poorly defined, contains dense vegetation, and, in some segments, is filled with sediment and other debris. The current channel capacity of Reach 4B1 is unknown and could be zero in some locations. There is currently no available floodplain-rearing habitat. Several agricultural diversions and returns occur throughout this reach that may entrain or create water quality issues for fish. Downstream from the Mariposa Bypass, Reach 4B2 is confined by San Joaquin River Flood Control Project levees, and regularly conveys agricultural return flows, runoff, and flood flows conveyed through the Mariposa Bypass.
- *Eastside and Mariposa Bypasses* – The bypasses were designed to carry flood flows from the San Joaquin River and Kings River basins. The bypasses were not designed to facilitate fish migration, but the Eastside Bypass Improvements Project[1] proposes to remove existing barriers to fish passage. The bypasses are maintained and operated by LSJLD.

[1] DWR and Reclamation are implementing the Eastside Bypass Improvements Project, which will address fish passage and levee stability in the Eastside Bypass to allow fish and flow to pass through this reach in the near term.

- *Reach 4B Headgate* (RM 168.5) – The Reach 4B Headgates remain closed under current operations and have not been operated for several decades. They were designed to convey 1,500 cfs into the San Joaquin River channel. When the gates are closed, this structure is a complete barrier to flow and fish. Downstream of the gates is a concrete energy dissipation structure with an elevation gradient that would be an impediment to upstream and downstream migration.
- *Sand Slough Control Structure* (RM 168.5) – The Sand Slough Control Structure regulates flow between Reach 4A of the San Joaquin River and the Eastside Bypass. The gateless structure would not create fish passage issues.
- *Mariposa Bypass Control Structure* – The concrete structure has 14 bays (six open in the middle and four gated on either side). This structure, in cooperation with the Eastside Bypass Control Structure, directs flows from the Middle Eastside Bypass into the Mariposa or Lower Eastside Bypass. The hydraulic drop through the structure and downstream deep pool could injure and disorient downstream-moving fish and harbor predators.
- *Mariposa Bypass Drop Structure* – This structure dissipates energy from flows before they enter the main stem San Joaquin River channel near RM 147.6. The structure consists of a concrete wall spanning the channel and two concrete walls framing the downstream channel banks. The channel-spanning wall is over 6 feet tall on the upstream side and well over 15 feet on the downstream side. The drop height and downstream pool depths would not allow upstream fish passage at low flows.
- *Eastside Bypass Control Structure* – The six-gated Eastside Bypass Control Structure directs flows to either the Lower Eastside Bypass or the Mariposa Bypass. The structure impedes fish passage, but a rock ramp is proposed for fish passage as part of the Eastside Bypass Improvements Project.

1.4 Purpose of this Report

Technical studies on the Project area (including Reach 4B of the San Joaquin River, the Middle Eastside Bypass, Lower Eastside Bypass, and Mariposa Bypass) have been ongoing since the 2009. This Technical Summary Report documents key technical findings and summarizes the work that led to these findings. The report describes the differences between the routes for high flows through this area and compares these routes. Finally, it identifies potential near-term actions (in addition to the Eastside Bypass Improvements Project) that could provide benefits regardless of the high flow alternative selected.

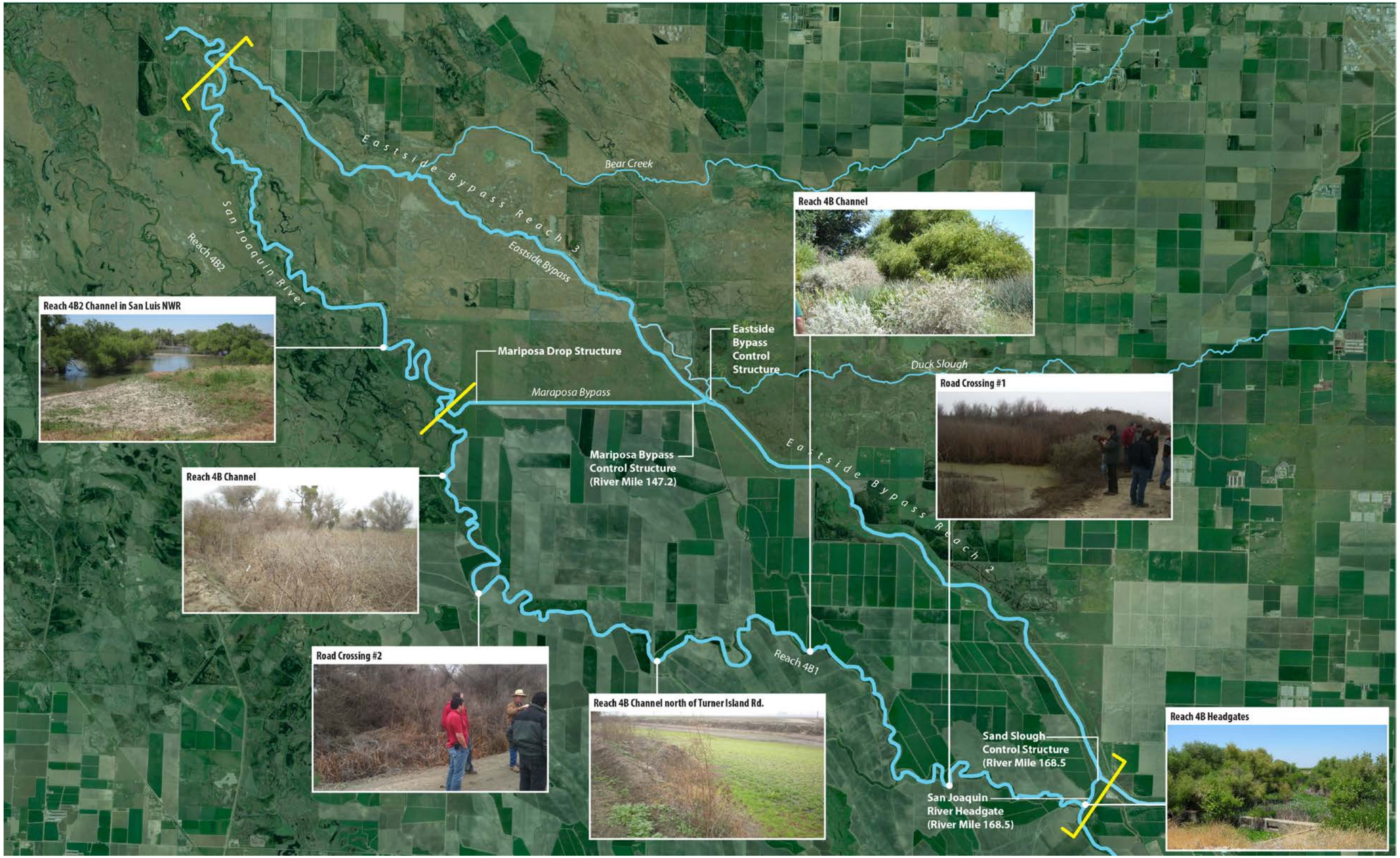


Figure 1-2. Site Conditions within Reach 4B1

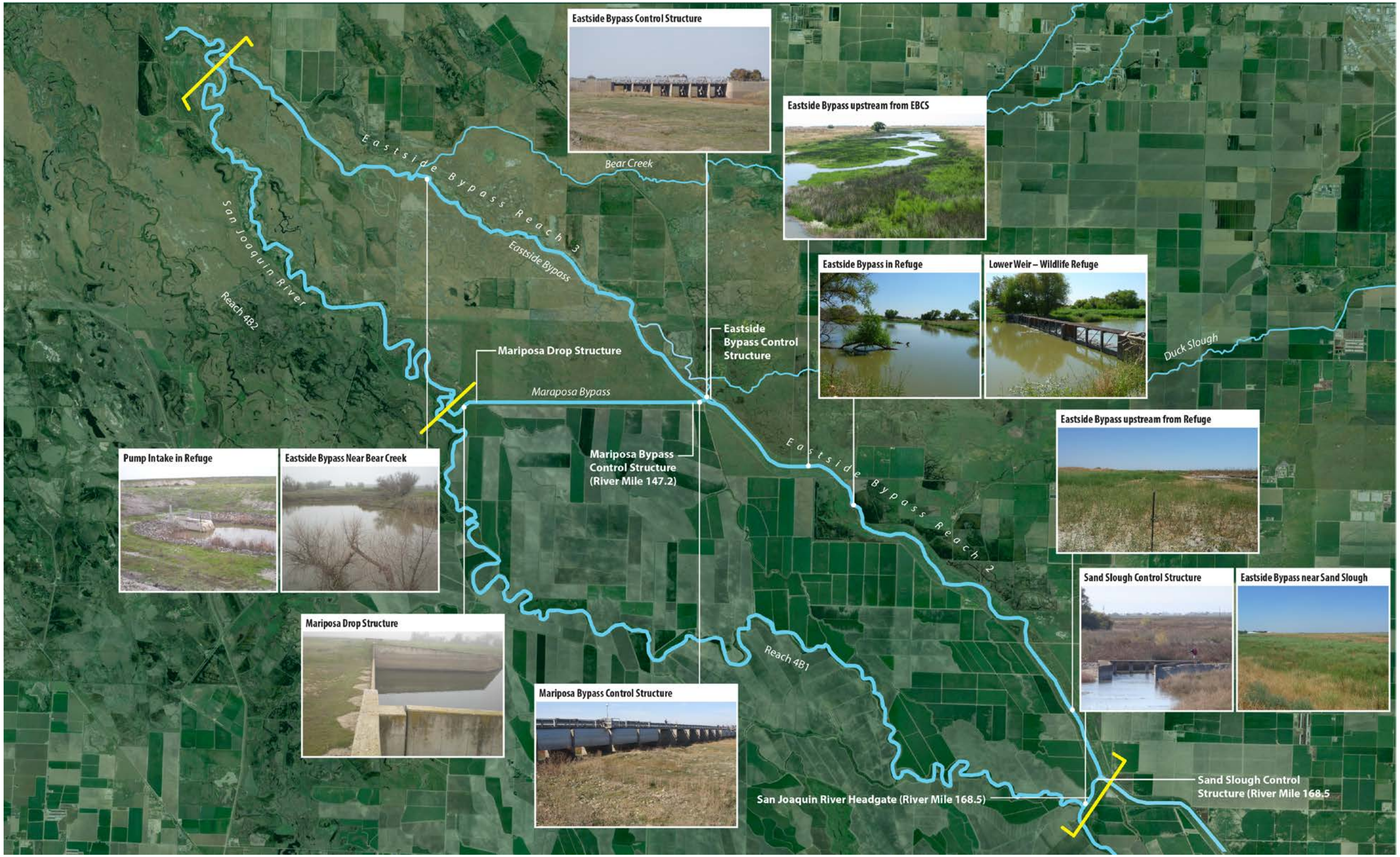


Figure 1-3. Site Conditions within the Flood Bypass System

Chapter 2 Alternatives

This chapter summarizes the alternatives under consideration for the Reach 4B/ESB Project.

2.1 No Action Alternative

The No Action Alternative represents the condition that would be expected to occur if the Reach 4B/ESB Project were not implemented. Under this condition, the Reach 4B/ESB Project would not be implemented, and no impacts associated with construction would occur. However, other components of the Settlement would still be implemented because they were selected in the SJRRP Program EIS/R Record of Decision (SJRRP 2012) or subsequent environmental documentation. This includes the Settlement components that have been implemented or are in the process of being implemented:

- Improvements in the Middle Eastside Bypass to allow fish passage and Restoration Flows (the Eastside Bypass Improvements Project)
- Reoperation of Friant Dam and downstream flow control structures to route Restoration Flows
- Recapture of Restoration Flows in the Restoration Area
- Recapture of Restoration Flows at existing Central Valley Project and State Water Project facilities in the Sacramento-San Joaquin Delta or private diversion facilities on the Lower San Joaquin River
- Associated monitoring and mitigation actions
- Projects to reduce groundwater seepage
- A bypass facility around Mendota Pool (part of the Reach 2B Project)

If the Reach 4B/ESB Project were not implemented, Restoration Flows would continue to be released from Friant Dam. These flows would make their way into the Eastside Bypass. As part of another SJRRP effort, DWR and Reclamation are currently implementing the Eastside Bypass Improvements Project to accommodate Restoration Flows and provide fish passage through this reach. This project is designed to ultimately allow Restoration Flows up to 2,500 cubic feet per second (cfs) into the Middle Eastside Bypass, in conjunction with other projects upstream to allow these flows to pass to this point in the system. The Eastside Bypass Improvements Project includes levee improvements to increase capacity and fish passage improvements (removal of the weirs in the Merced NWR and development of an alternate water supply, addition of fish passage culverts at Dan McNamara Road, and development of a rock ramp to allow fish passage at the Eastside Bypass Control Structure). The No Action Alternative would not fully satisfy the Paragraph 11(a) or 11(b)(1) Settlement requirements related to Reach 4B of the San Joaquin River and the Eastside and Mariposa bypasses (see Section 1.2 for a list of the requirements).

Restoration Flows into the Eastside and Mariposa bypasses are currently limited to avoid channel capacity and seepage concerns. The SJRRP has addressed seepage-related concerns in the Middle Eastside Bypass and Lower Eastside Bypass, but the Restoration Flows into this reach are limited by channel capacity concerns to about 300 cfs. The other projects implemented under the No Action Alternative would provide a capacity of about 2,500 cfs.

2.2 Action Alternatives Summary

Table 2-1 summarizes key elements of each alternative. These alternatives will be described in more detail in the following sections.

Table 2-1. Reach 4B/ESB Project EIS Alternatives and Key Elements

Channel/ Structure	Alternative 1 Main Channel Restoration	Alternative 2 Bypass Restoration	Alternative 3 Bypass All Pulse Flows
Flows through the San Joaquin River	Up to 4,500 cfs (all Restoration Flows)	At least 475 cfs of Flood Flows	At least 475 cfs of Restoration Flows
Flows through the Bypass System	Flood Flows	All flows up to capacity	All Flood Flows and Restoration Flows greater than Reach 4B1 capacity
Fish Route Under Most Flow Conditions	San Joaquin River (SJR)	2A: Middle Eastside Bypass, Mariposa Bypass, and SJR Reach 4B2 2B: Middle Eastside Bypass and Lower Eastside Bypass	SJR Reach 4B1 or Middle and Lower Eastside Bypass
Habitat Restoration	SJR	Bypass and SJR Reach 4B2	SJR and Bypass
Floodplain Habitat Grading	SJR	Bypass	SJR and Bypass
Channel Slope Grading	No change	Change channel slope in bypasses	No change
Reach 4B Headgates	Remove Headgate and install radial gates	Simple gate (replacement in-kind)	Construct gates and roughened channel fishway
Mariposa Bypass Control Structure	No change	2A: Notch center bays 2B: No change	No change
Mariposa Drop Structure	No change	2A: Remove Drop Structure 2B: No change	No change
Eastside Bypass Control Structure	No change	No change	No change
Sand Slough Control Structure	Remove and replace with Obermeyer-style gate; fish passage	Remove and regrade Channel	Remove and replace with Obermeyer-style gate; fish passage
Reach 4B1 Levee Alignments	B, C, or D	A	A
Middle Eastside Bypass Levee Improvements	Existing	Setback and Improvements to existing levees	Improvements to existing levees
Lower Eastside Bypass Improvements	Existing	2B: Improvements to existing levees and habitat improvements	Improvements to existing levees and habitat improvements
Mariposa Bypass Levee Improvements	Existing	2A: Levee setback and seepage improvements	Existing
Reach 4B2 Levee Improvements	Seepage berms and/or slurry walls	2A: Seepage berms and/or slurry walls	Seepage berms and/or slurry walls

2.3 Alternative 1 – Main Channel Restoration

Under Alternative 1, Main Channel Restoration, the San Joaquin River would function as the main route for fish and flows. In addition to the actions described below, Alternative 1 would incorporate requirements from the SJRRP Program Environmental Impact Statement/Report (PEIS/R), including Channel Capacity Management, Physical Monitoring and Management Plan, and the Conservation Strategy.

2.3.1 Flow Routing

The San Joaquin River would have a capacity of 4,500 cfs and would receive all Restoration Flows. The LSJLD would operate Flood Flows for flood protection and could choose to route 4,500 cfs of Flood Flows into the Middle Eastside Bypass or Reach 4B1. During Restoration Flows, adult salmon would migrate upstream and juvenile salmon downstream along the San Joaquin River. The river would provide both in-channel habitat and access to wide, frequently inundated floodplains bounded by setback levees. During periods with Flood Flows, fish could be washed into, or could migrate up into, the bypass. Due to the infrequency of such events (approximately one year in five for varying durations), this alternative would not prevent Chinook Salmon and other target fish species from entering the bypass system during such flows. Figure 2-1 presents the flow routing for Alternative 1.

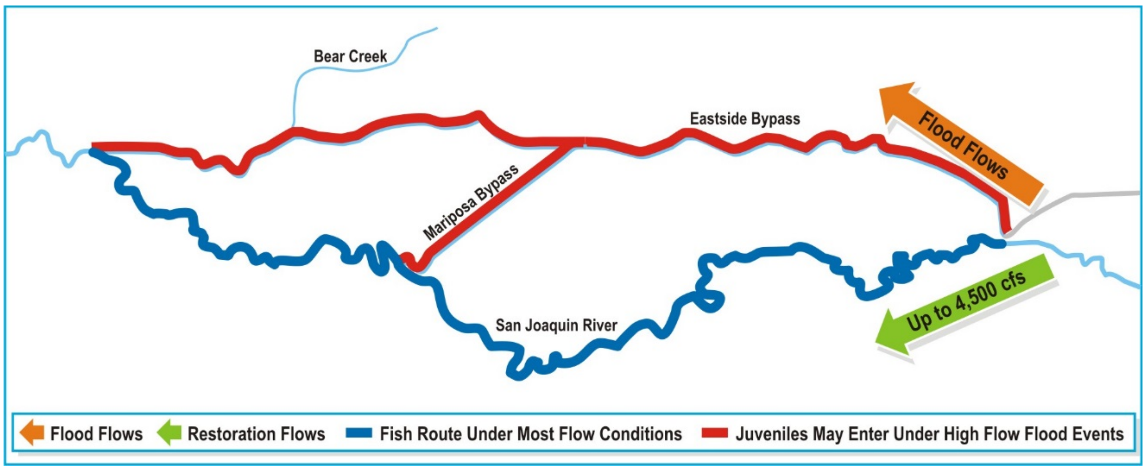


Figure 2-1. Alternative 1 – Flow Routing for Main Channel Restoration

2.3.2 Construction Actions

Figure 2-2 shows the construction actions included in Alternative 1. Construction would focus on moving flow and fish through Reach 4B of the San Joaquin River by removing impediments and developing floodplain habitat.

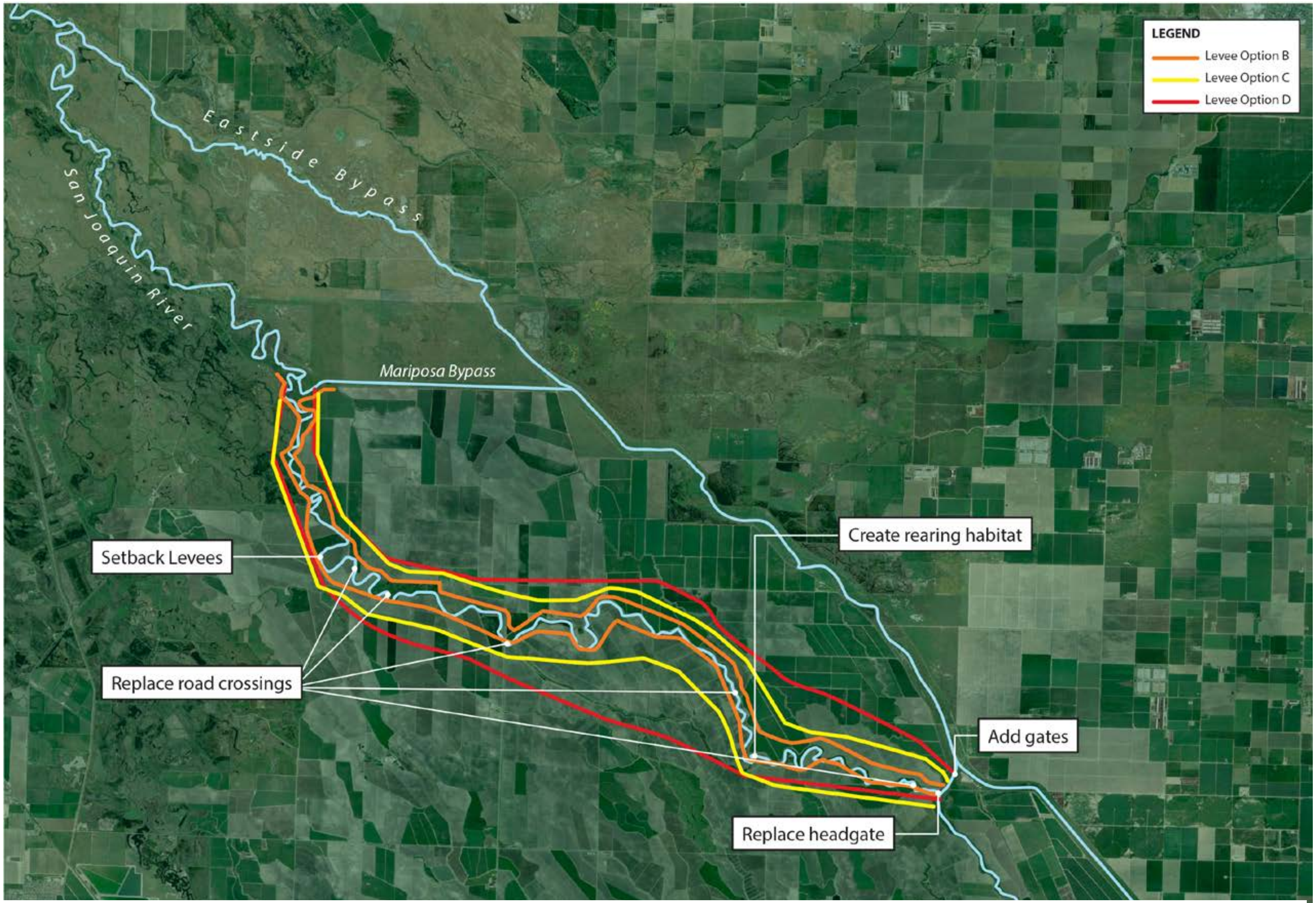


Figure 2-2. Key Construction Actions in Alternative 1

Levee Improvements

Alternative 1 would include new levees within Reach 4B1 that would be wider than the existing channel banks to fully convey Restoration Flows. The levees would have a seepage berm to improve levee stability, where necessary. Table 2-2 shows a summary of the proposed Reach 4B1 levee alignments. Alternative 1 has three sub-alternatives to reflect these different alignments: Alternative 1A (Levee Alignment B), Alternative 1B (Levee Alignment C), and Alternative 1C (Levee Alignment D).

Table 2-2. San Joaquin River Proposed Levee Alignment for Alternative 1

Proposed Levee Alignment	Levee Length Left/Right in feet	Maximum Capacity	Approx. Width Between Levees (in feet)
Alignment B	77,800/76,400	4,500 cfs	1,300-2,000
Alignment C	72,800/66,300	4,500 cfs	3,500-5,500
Alignment D	70,200/65,100	4,500 cfs	5,000-11,000 at widest part

Reach 4B2 would not have new levees or levee setbacks but would require levee improvements. The low-flow channel in Reach 4B2 is adjacent to the levees, which could cause levee stability concerns. Seepage berms or slurry walls likely would be needed to accommodate full Restoration Flows.

Channel and Habitat Modifications

Because all the proposed setback levee alignments provide sufficient flow conveyance, in-channel vegetation would be left in place except for any very dense areas that would be flow or fish impediments within the low-flow channel, which would be cleared. Over time, the presence of flows would kill non-riparian vegetation in the active channel and support a natural transition to riparian species. Native riparian vegetation along the channel banks and between the banks and the levees would be preserved and enhanced. Large woody vegetation growing in the existing levees would be preserved where practical by leaving these portions of the levee intact and removing less vegetated sections to allow flow to reach the floodplain. Obstruction to upstream and downstream fish migration would be removed.

For Alternative 1, additional habitat enhancement would be undertaken. Native riparian vegetation along the channel banks and between the banks and the levees would be preserved and enhanced. Additional riparian vegetation would be planted to provide shade and a riparian corridor where the existing condition was degraded. Large woody materials (LWM) habitat elements would be added to the channel where existing cover is lacking to provide additional cover and complexity. Where used, LWM structures would be anchored or keyed into the banks. The San Joaquin River channel would provide in-channel rearing and refugia habitat, and the area within the levee setbacks would provide floodplain rearing habitat.

Reach 4B Headgates/Sand Slough Control Structure

The Headgates at the upstream end of Reach 4B would be removed and replaced with a new control structure to allow all flows from Reach 4A to enter Reach 4B. The design capacity at the downstream end of Reach 4A is 4,500 cfs; therefore, all flow from Reach 4A would be able to enter Reach 4B. During flood events, the LSJLD may need to be able to restrict flows entering Reach 4B1. The existing structure would be replaced with new, fish-friendly radial gates.

The Sand Slough Control Structure would be removed and replaced with a new Obermeyer-style gate to regulate the water depths at the bifurcation of Reach 4B1 from the Middle Eastside Bypass Sand Slough Control Structure

Road Crossings

Reach 4B1 has two public road crossings (Washington Road/Indiana Road and Turner Island Road) that would create a potential barrier to fish passage with Restoration Flows in this area. These road crossings would be replaced with new bridges over the active channel that connect to causeways through the floodplain areas.

Reach 4B1 has four private river crossings. The first (Crossing #0) connects to a privately-owned park area in the center of the river channel. For the higher flows in this alternative, the park would become inundated; thus, this crossing would not be maintained. The other three crossings (Crossings #1 to #3) would be replaced with low-flow crossings that become inundated at 1,500 cfs.

Seepage Improvements

The SJRRP includes a constraint that the material adverse effects due to groundwater seepage must be reduced or avoided. All proposed levee alignments include levee construction to reduce or avoid seepage based on site-specific groundwater information. In Reach 4B1, seepage actions could include:

- Easements and license agreements: Involves purchasing easements (permanent encumbrance) or license agreements (short-term) on areas affected by seepage. The landowners would still own the property and could decide whether to plant the field (understanding that yields would be lower because of seepage), leave the field idle, or implement an independent solution.
- Interceptor drains: Includes installing perforated pipe and pumps to intercept and drain water that has seeped from the river and/or from adjacent fields. Pumps would be spaced at regular intervals to pump the drainage water into the river or bypass system or local irrigation canals.

2.3.3 Operations

Restoration Flows up to 4,500 cfs would be directed into the San Joaquin River by raising the gates on the proposed new Sand Slough Control Structure. The LSJLD would control Flood Flows as under existing conditions though the overall flood capacity of the system would be increased due to the setback levees along the San Joaquin River. The LSJLD would choose whether or not to route Flood Flows into Reach 4B1.

2.4 Alternative 2 – Bypass Restoration

Under Alternative 2, all Restoration and Flood flows would be routed down the Eastside Bypass, which would be made slightly steeper by regrading the low-flow channel. The levees in the Middle Eastside Bypass would also be set back to allow increased riparian and floodplain habitat. In addition to the actions described below, Alternative 2 would incorporate requirements from the SJRRP PEIS/R, including Channel Capacity Management, Physical Monitoring and Management Plan, and the Conservation Strategy.

2.4.1 Flow Routing

Restoration Flows would be routed into the Middle Eastside Bypass. Alternative 2 includes two variations (Alternatives 2A and 2B) for how Restoration Flows would be routed at the Mariposa Bypass/Lower Eastside Bypass intersection.

Alternative 2A would route Restoration Flows into the Mariposa Bypass and into Reach 4B2 (see Figure 2-3). Adult salmon migrating upstream would enter the San Joaquin River Reach 4B2, be directed up the Mariposa Bypass Channel over modified or removed structures that allow fish passage, and pass up the Middle Eastside Bypass before rejoining the San Joaquin River channel at the junction of Reach 4B1 and Reach 4A (at the existing Sand Slough Control Structure). Juvenile salmon migrating downstream would enter the system from the San Joaquin River Reach 4A or the Upper Eastside Bypass and move downstream through the Middle Eastside Bypass, Mariposa Bypass, and San Joaquin River Reach 4B2. This pathway would be restored to provide rearing habitat and barriers to migration would be removed or modified.

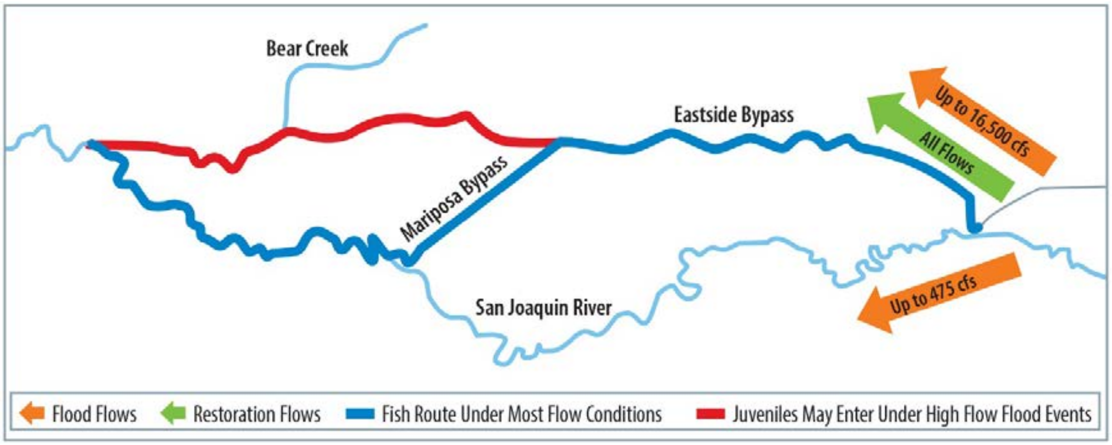


Figure 2-3. Alternative 2A – Flow Routing for Main Restored Channel in Middle Eastside Bypass, Mariposa Bypass, and Reach 4B2

Alternative 2B would route Restoration Flows into the Lower Eastside Bypass (see Figure 2-4), and juvenile fish would follow this path. Adult salmon migrating upstream would swim through the Lower Eastside Bypass into the Middle Eastside Bypass before joining the San Joaquin River at the existing Sand Slough Control Structure.

Under both variations, the LSJLD would operate Flood Flows and split flows between the Mariposa Bypass and Lower Eastside Bypass according to the LSJLD Operations and Maintenance (O&M) Manual. During high flood flow periods, flows may also pass through Reach 4B1. Reach 4B1 of the San Joaquin River would be modified to convey up to 475 cfs without setback levees.

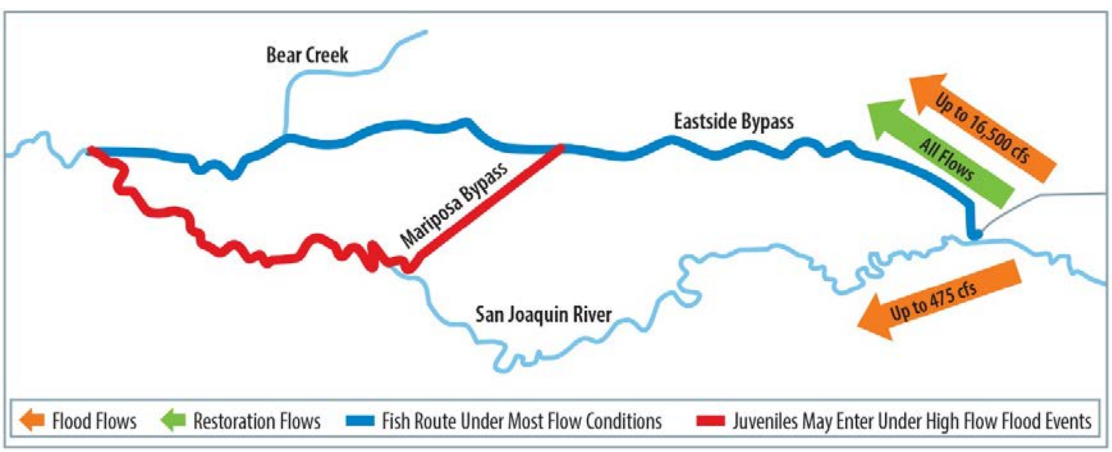


Figure 2-4. Alternative 2B – Flow Routing for Main Restored Channel in Middle Eastside Bypass and Lower Eastside Bypass

2.4.2 Construction Actions

Figures 2-5 and 2-6 show the construction actions included in Alternatives 2A and 2B, respectively. Both alternatives would regrade the low flow channel in the Middle Eastside Bypass to have a more sustainable pattern of sediment deposition in the long-term, and they would include levee setbacks to accommodate habitat creation in this area.

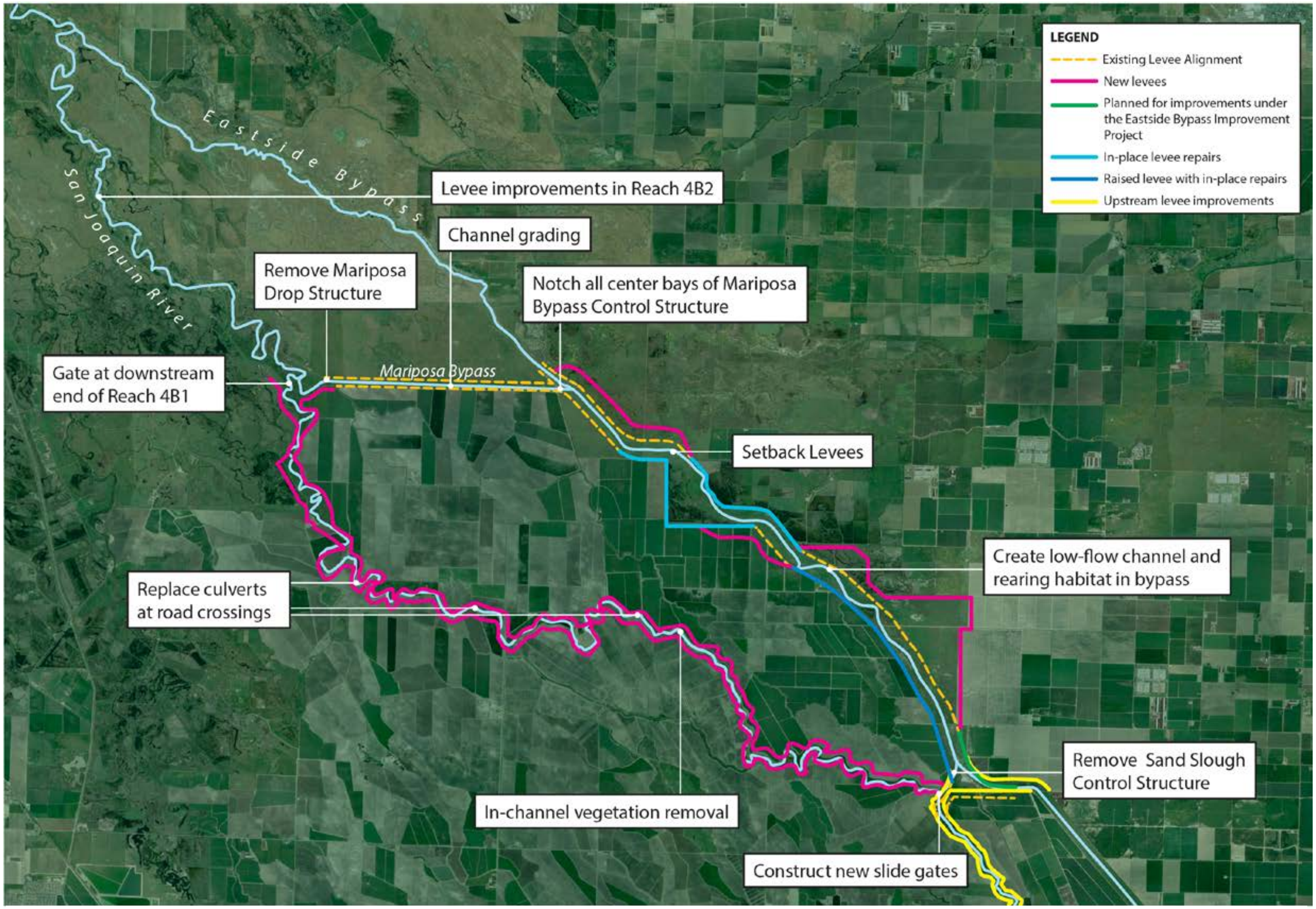


Figure 2-5. Key Construction Actions in Alternative 2A

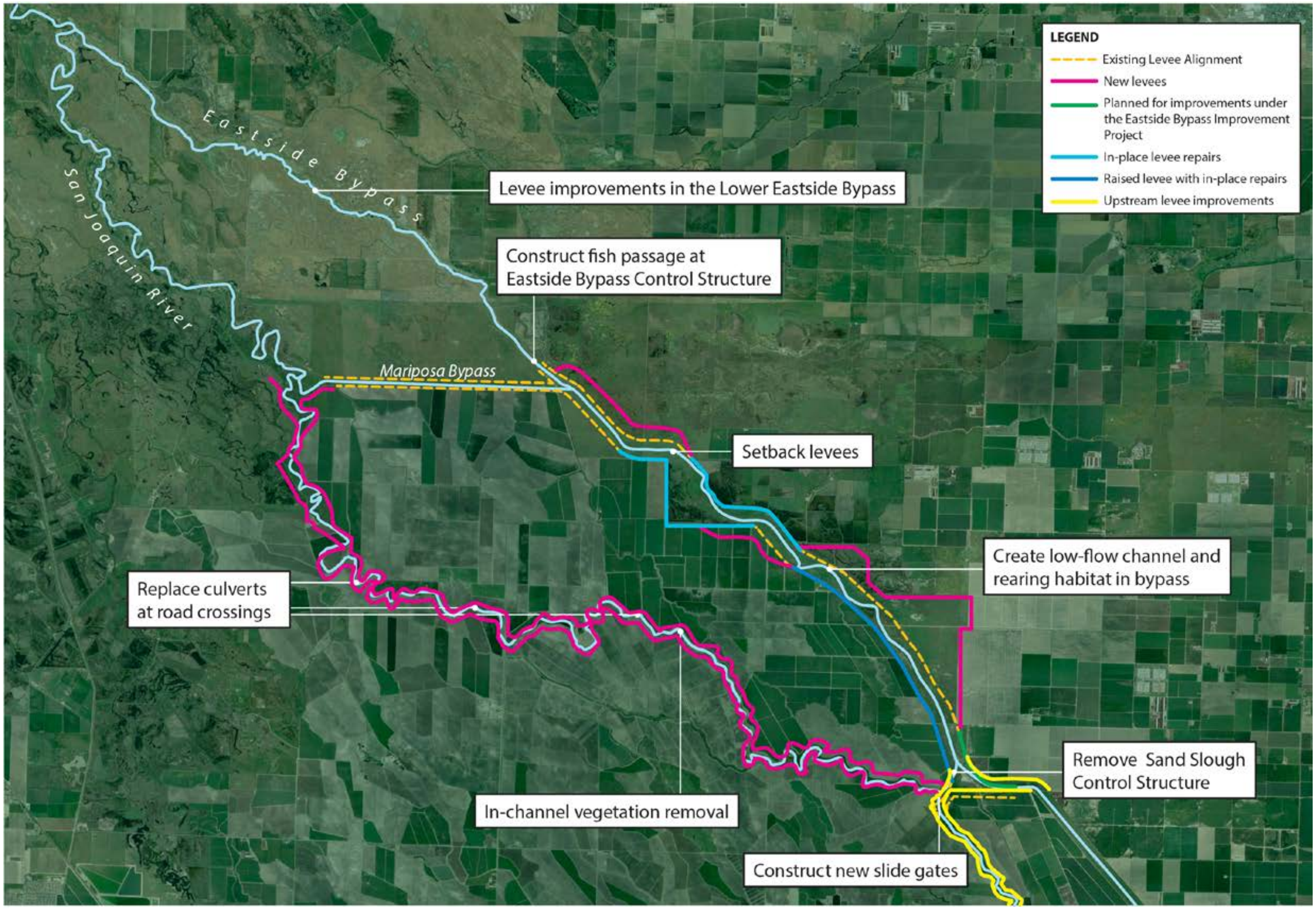


Figure 2-6. Key Construction Actions in Alternative 2B

Levees

San Joaquin River

Alternative 2 would raise and widen levees along the existing levee alignment in Reach 4B1 to contain up to 475 cfs. The low-flow channel in Reach 4B2 is adjacent to the levees, which could cause levee stability concerns. Seepage berms or slurry walls likely would be needed to accommodate full Restoration Flows.

Middle Eastside Bypass

Alternative 2 would modify the levees in Middle Eastside Bypass to maintain flood capacity and operational flexibility while allowing increased vegetation growth. Levee improvements could include a new setback levee with seepage berm, a raised levee with seepage berm, or in-place repairs that install a seepage berm adjacent to existing levees. The levee setbacks are included to accommodate increases in vegetation associated with the habitat restoration included in Alternative 2. The in-place repairs and levee raises are included to minimize flood risk and increase levee stability in this area.

Upstream Levee Improvements

Alternative 2 would set back levees for most of the Middle Eastside Bypass except for the portion at the upstream end near Sand Slough. Because this reach has a constriction, it has the potential to cause upstream water levels to increase at high flows. Hydraulic modeling indicated that the water levels could increase into the Upper Eastside Bypass and Reach 4A by small amounts. Alternative 2 includes levee raises in these areas to accommodate these flow increase. The maximum levee raises would be less than 0.5 feet, so Alternative 2 would add material to the levee crown without increasing the levee width.

Mariposa Bypass (Alternative 2A)

Alternative 2A would include a levee setback on the north side of the Mariposa Bypass. These levee setbacks would accommodate increased vegetation in the Mariposa Bypass without affecting flood capacity. Revegetation efforts in the Mariposa Bypass would not be able to proceed until these levee setbacks are completed.

Lower Eastside Bypass (Alternative 2B)

Alternative 2B would include levee improvements, including stability berms, slurry walls, or levee raises, to accommodate full Restoration Flows.

Channel and Habitat Improvements

San Joaquin River

Alternative 2 includes in-channel vegetation removal for an estimated 8.5 miles of channel to increase capacity, and a combination of vegetation and sediment removal would be carried out over an additional 3.5 miles of channel that are more constricted.

Eastside Bypass and Mariposa Bypass (Alternative 2A)

Under this concept, all Restoration and Flood flows up to 16,500 cfs would be routed through the Eastside and Mariposa bypasses. Thus, under this alternative, all necessary features for adult and juvenile Chinook Salmon and for all life stages of other target species supported by the Restoration Flows must be provided within the bypass system.

Under existing conditions, the Mariposa Bypass Control Structure is six feet higher than the Eastside Bypass Control Structure when both structures are open. Water must be backed up at the Eastside Bypass (either because of high flows or the gates are closed) before water can be forced into the Mariposa Bypass. Additionally, the Mariposa Bypass is very flat with an 8-foot drop at the downstream end (the Mariposa Bypass Drop Structure). Major elements of Alternative 2A include the removal of the Mariposa Bypass Drop

Structure for fish passage and sediment transport and the notching of the Mariposa Bypass Control Structure. These actions would allow the channel through the bypass to be regraded to gradually lose elevation over the length of the bypasses. The resulting low-flow channel would be deeper and somewhat more defined than the existing channel, which is very flat and shallow.

Under Alternative 2A, the existing channel in the Middle Eastside Bypass and Mariposa Bypass would be enhanced to provide a channel suitable for both fish passage and rearing of Chinook Salmon and other target fish species. Channel enhancement actions would include establishing a riparian corridor of 50 to 75 feet on either side around the channel to provide shade, cover, and inputs of nutrients and woody debris. Establishing a riparian corridor in the bypasses is expected to take some time (10 to 15 years to provide significant shade along the channel) and would be challenging due to the highly erodible, sandy soils. LWM habitat elements would be introduced into the channel to where bank stabilization is needed to improve rearing and shelter for target fish species. LWM would need to be anchored or keyed into the banks to minimize movement during Flood Flows.

The setback levees in the southeastern portion of the Eastside Bypass would include portions of the Merced NWR within the bypass. The existing levees would be removed, and secondary channels would be constructed to connect to the refuge areas.

Eastside Bypass (Alternative 2B)

Under this concept, all Restoration and Flood flows up to 16,500 cfs would be routed through the Middle and Lower Eastside Bypass. Thus, under this alternative, all necessary features for adult and juvenile Chinook Salmon and for all life stages of other target species supported by the Restoration Flows must be provided within the bypass system.

Alternative 2B would accomplish similar grade changes to Alternative 2A, but the new low-flow channel in the Middle Eastside Bypass would connect to the rock ramp being constructed at the Eastside Bypass Control Structure. This elevation change would allow the low-flow channel in the Middle Eastside Bypass to be regraded to gradually lose elevation over the length of the bypass. The resulting channel would be deeper and somewhat more defined than the existing channel, which is very flat and shallow. The low-flow channel modifications in the Middle Eastside Bypass (including size and dimensions) would be similar to those described above for Alternative 2A, but the slope of the new channel would be somewhat less steep. The setback levees in the southeastern portion of the Eastside Bypass would include portions of the Merced NWR within the bypass. The existing levees would be removed, and secondary channels would be constructed to connect to the refuge areas.

The Lower Eastside Bypass has a deeper, narrower low-flow channel than the Middle Eastside Bypass. This channel would not require modification to convey Restoration Flows.

Reach 4B Headgates/Sand Slough Control Structure

A new headgate would be constructed at the upstream end of Reach 4B to divert all Restoration Flows into the Eastside Bypass but allow limited flow during very large floods (up to 475 cfs). The existing slide gates at the headworks structure are not functional, so they would be demolished and removed. A small section of the concrete floor slab, approximately 3 feet wide below the existing gates, would be removed to facilitate the installation of the new gates. New slide gates of the same dimensions as the existing gates would be installed and new concrete placed to create a transition to the new gates.

The Sand Slough Control Structure would no longer be necessary under this alternative. To provide the required invert elevation of the channel, and associated flow routing, the existing structure would be demolished and removed.

Road Crossings

In the San Joaquin River channel, Crossing #0 currently connects the southern levee road to a privately-owned park area in the center of the river channel, whereas Crossings #1 through 3 are private crossings that provide access across the river channel. With the restoration of the river channel and the addition of the flows on this alternative, these crossings would need to be replaced to prevent a backwater/seepage problem at these locations and upstream. Road crossings in the bypass system would not require improvements.

Reach 4B1 Backwater Modifications (Alternative 2A)

During typical operations under Alternative 2A, both Restoration and Flood Flows would be in the bypass system. Restoration Flows coming down the Mariposa Bypass into Reach 4B2 could back flow into Reach 4B1. This condition currently occurs during flood conditions, but it could occur more frequently with Alternative 2A. To avoid seepage-related impacts from this backwater condition, Alternative 2A would include either a new gate structure at the downstream end of Reach 4B1 or additional seepage easements.

Mariposa Bypass Control Structure (Alternative 2A)

Alternative 2A includes notching the existing Mariposa Bypass Control Structure to lower the channel invert elevation in four of the center bays for the 4,500 cfs flows to enter the Mariposa Bypass. The structure's current configuration allows fish passage at flows above approximately 4,500 cfs; therefore, improving passage at low flows should allow fish passage at a full range of flows.

Mariposa Drop Structure (Alternative 2A)

Alternative 2A includes demolition and removal of the existing Mariposa Bypass Drop Structure to remove a fish passage barrier and facilitate the regrading of this channel. With the improvements to the bypass channel system from regrading, the Mariposa Bypass Drop Structure should no longer be required to retain sediment and prevent channel erosion.

Seepage Improvements

As part of the No Action Alternative, Reclamation has implemented seepage measures along the Eastside Bypass to allow Restoration Flows before the Reach 4B/ESB Project is implemented. Reclamation started these projects before the rest of the Reach 4B/ESB Project because the seepage constraints within this reach were the limiting factor to releasing Restoration Flows, as required in the Settlement and analyzed in the PEIS/R. These seepage projects were designed to accommodate full Restoration Flows up to 4,500 cfs so that subsequent seepage projects would not be necessary on the same parcel when Restoration Flows increase. These seepage actions in the Eastside Bypass are currently complete. Alternatives that route flows through the Eastside Bypass would not require additional seepage measures.

For Reach 4B1, seepage easements, license agreements, or interceptor lines would address seepage concerns (as discussed in Alternative 1).

2.4.3 Operations

All Flood Flows would be directed into the Middle Eastside Bypass and operated according to the LSJLD O&M manual (LSJLD 1967). At the downstream end of the Middle Eastside Bypass, the O&M manual indicates that the first 8,500 cfs would be sent down the Mariposa Bypass by restricting flow through the Eastside Bypass Control Structure. Higher flows would pass into the Lower Eastside Bypass. The O&M manual also indicates that LSJLD can modify operations to minimize the loss of life and property. The typical operations route the first 2,500 cfs of flows in the Middle Eastside Bypass into the Lower Eastside Bypass, then flows are split with approximately 30 percent of flows to the Mariposa Bypass. If Bear, Owens, or Deadmans Creek are flooding, the LSJLD may close the gates at the Eastside Bypass Control Structure and route more flow to the Mariposa Bypass. Reach 4B1 could also support flows up to 475 cfs.

2.5 Alternative 3 – Bypass All Pulse Flows

Alternative 3 would restore Reach 4B1 as a low-flow channel, but pulse flows would be directed into the bypass system. In addition to the actions described below, Alternative 3 would incorporate requirements from the SJRRP PEIS/R, including Channel Capacity Management, Physical Monitoring and Management Plan, and the Conservation Strategy.

2.5.1 Flow Routing

Restoration Flows first would be routed down the San Joaquin River Reach 4B1 up to the capacity of this reach. The capacity could vary, from a minimum of 475 cfs to a maximum of approximately 1,500 cfs, depending on the geomorphology and biological benefits associated with different flow splits. Smaller flows into Reach 4B1 (close to 475 cfs) could increase operations and maintenance because they cause a higher rate of sedimentation in the upstream reaches of 4B1; on the other hand, larger flows (close to 1,500 cfs) could cause increased erosion in Reach 4B1. While the split flow quantities may vary, the minimum capacity of 475 cfs is included in this alternative.

Some levee improvements would be conducted in the San Joaquin River channel, and some flow obstructions would be removed to bring its capacity up to 475 cfs. Restoration Flows greater than 475 cfs would be routed through the Bypass system, through the Middle Eastside Bypass to the Lower Eastside Bypass. Under this alternative, during flows up to 475 cfs, adult and juvenile salmon would migrate through the San Joaquin River channel. The river channel would provide in-channel rearing and migration needs but would not have significant areas of inundated floodplain. For flows greater than 475 cfs, adults migrating upstream and juveniles migrating downstream could split and pass down either the river or the bypass system. The bypass system would function as a floodplain. Fish passage barriers would be removed from both the San Joaquin River channel and the bypass system. Figure 2-7 presents the routing for flow and fish for Alternative 3.

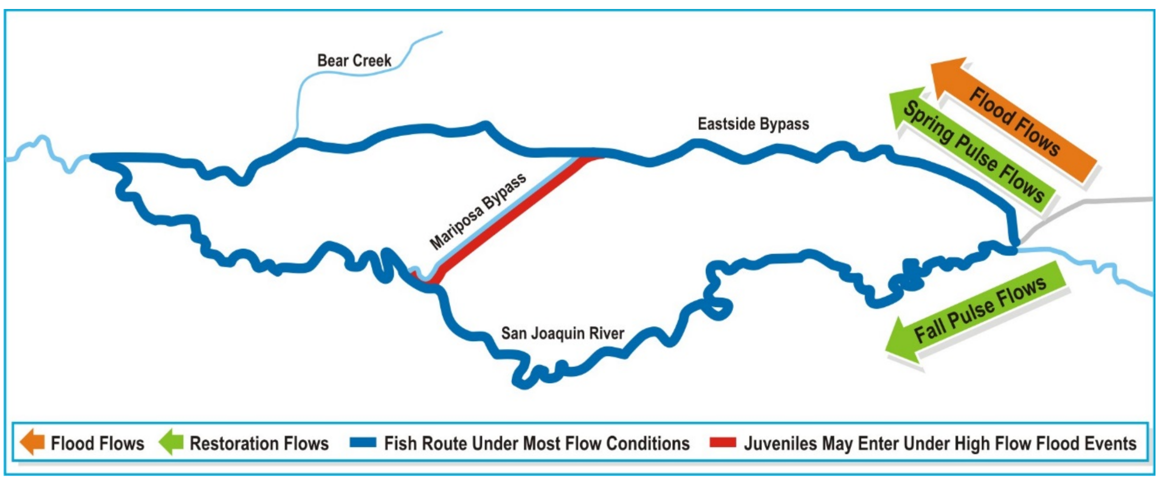


Figure 2-7. Alternative 3 – Flows below 475 cfs in San Joaquin River with Middle and Lower Eastside Bypass as High Flow Floodplain

2.5.2 Construction Actions

Figure 2-8 shows the construction actions included in Alternative 3. Alternative 3 construction is focused on removing impediments to fish passage and improving levee stability, but levee setbacks are not proposed.

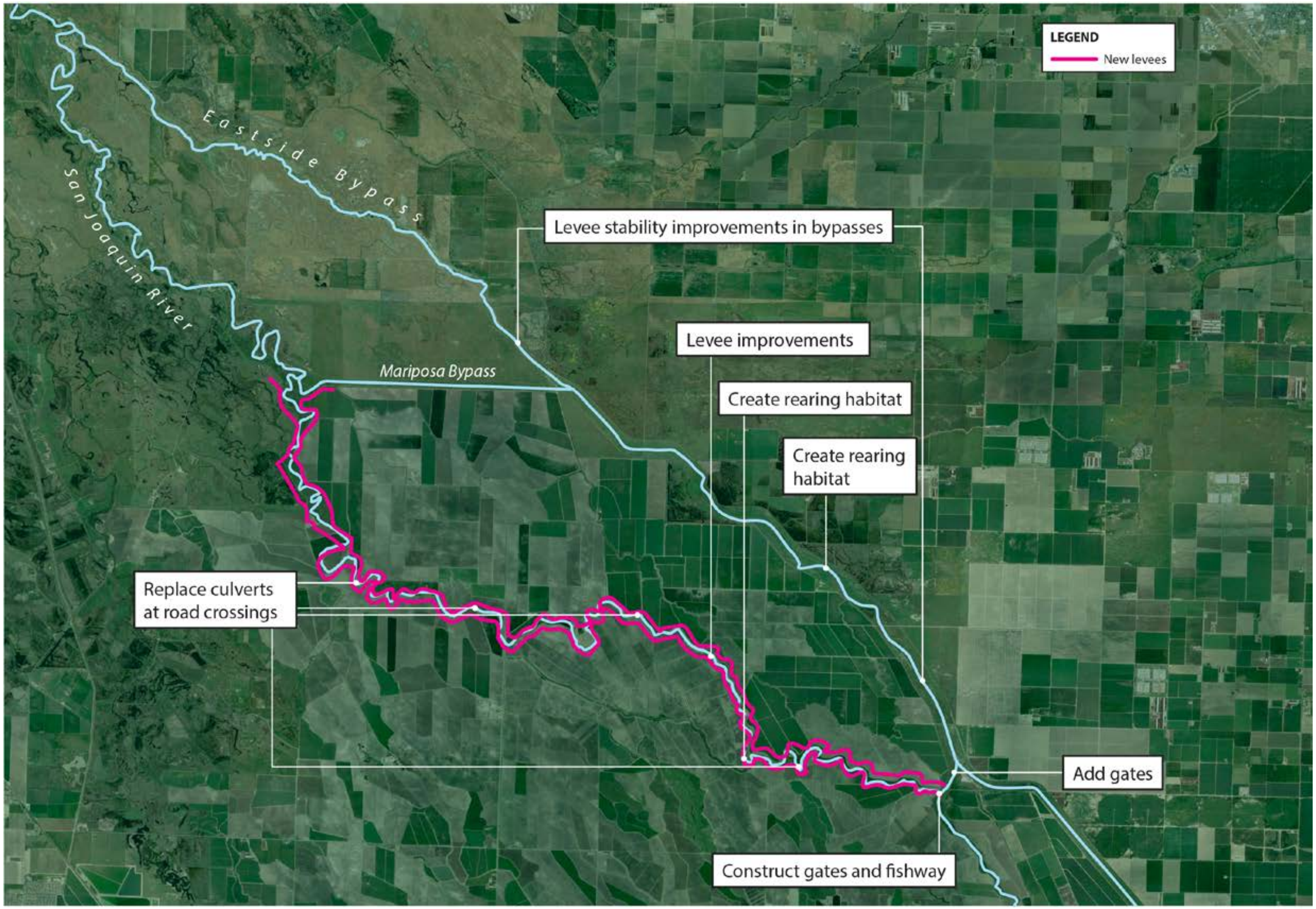


Figure 2-8. Key Construction Actions in Alternative 3

Levees

San Joaquin River

The existing levees in Reach 4B1 would be expanded along the same alignment (similar to Alternative 2). In Reach 4B2, the low flow channel is adjacent to the levees, which could cause levee stability concerns. Seepage berms or slurry walls likely would be needed to accommodate full Restoration Flows.

Middle Eastside Bypass

No levee setbacks are included in this alternative, but improvements to the existing levee would be necessary to minimize flood risk. The full length of the east and west levees in the Middle Eastside Bypass would have in-place repairs, which consist of seepage berms on the outside of the existing levees or slurry walls.

Lower Eastside Bypass

Alternative 3 would include levee improvements, including stability berms, slurry walls, or levee raises, to accommodate full Restoration Flows.

Channel and Habitat Improvements

Channel improvements for restoration and fish migration would take place in both the San Joaquin River and the bypass channels.

San Joaquin River

Under Alternative 3, vegetation and sediment removal in Reach 4B1 would be the same as in Alternative 2. Alternative 3, however, would include habitat enhancement within the Reach 4B channel. Native riparian vegetation along the channel banks and between the banks and the levees would be preserved and enhanced. In reaches where channel capacity allows, additional riparian vegetation would be planted to provide shade and a riparian corridor. LWM habitat elements would be added to the channel in sparsely vegetated reaches where existing shelter and complexity is a limiting factor on fish migration and rearing. Where used, LWM structures would be anchored or keyed into the banks. The San Joaquin River channel would provide in-channel rearing and refugia habitat but not floodplain rearing habitat to avoid significant out-of-bank flows under this alternative.

Eastside Bypass

Under this alternative, all Restoration Flows greater than 475 cfs would be routed through the bypass system. These flows would be routed through the Middle Eastside Bypass into the Lower Eastside Bypass. Vegetation management practices would be modified to allow vegetation that is beneficial to habitat to recruit and persist while maintaining the conveyance capacity of the bypass system.

Reach 4B Headgates/Sand Slough Control Structure

A new headgate would be constructed at the upstream end of Reach 4B to allow Restoration Flows up to 475 cfs into Reach 4B1. For this alternative, the existing slide gates at the San Joaquin River, Reach 4B1 headworks structure would be demolished and removed because the existing gates are not functional. New gates would be installed, similar to that described for Alternative 2. This alternative differs from Alternative 2 in that fish would be present and allowed to pass through the structure and into Reach 4B1 of the San Joaquin River. When flows upstream of this structure are up to approximately 1,150 cfs, the Headgates could pass the design flow (475 cfs) with sufficiently low velocity (under 6 feet per second) to serve as a fish passage. At flows over 1,150 cfs on the upstream side, the velocities through the gates require an alternative passage facility. Because these higher flows would be encountered regularly during the spring and fall seasons, an alternate passage would be required. To provide passage of fish over a large flow range, a roughened channel fishway is proposed. This fishway would be constructed from the upstream side of the Headgate structure to the downstream side of the structure in Reach 4B1.

To accomplish this flow routing, the existing control structure at Sand Slough would be removed and replaced with a new Obermeyer-style gate to regulate the water depths at the bifurcation of Reach 4B1 from the Middle Eastside Bypass.

Road Crossings

In the San Joaquin River channel, Crossing #0 currently connects the southern levee road to a privately-owned park area in the center of the river channel, whereas Crossings #1 through 3 are private crossings that provide access across the river channel. With the restoration of the river channel and the addition of the flows on this alternative, these crossings would need to be replaced to prevent a backwatering/seepage problem at these locations and upstream. Road crossings in the bypass system would not require improvements.

Seepage Improvements

As discussed for Alternative 2, Reclamation has implemented seepage measures in the Eastside Bypass, and additional measures are not necessary. Alternative 3 would include seepage easements, license agreements, or interceptor lines in Reach 4B.

2.5.3 Operations

For Restoration Flows below 475 cfs, all flows would be directed down the San Joaquin River. When Restoration Flows reach 475 cfs, the Sand Slough Control Structure would direct flows above 475 cfs into the Eastside Bypass. The LSJLD would continue to operate Flood Flows in the Bypass system to provide flood protection.

Chapter 3 Hydrology and Flood Operations

Reach 4B of the San Joaquin River has not received any flow through the Reach 4B headgates in many years. Flows from upstream reaches, including Reach 4A and the Upper Eastside Bypass, flow into the Middle Eastside Bypass. This chapter describes existing hydrology and flood operations, and how they would change in the future under each alternative.

3.1 Setting

3.1.1 Hydrology

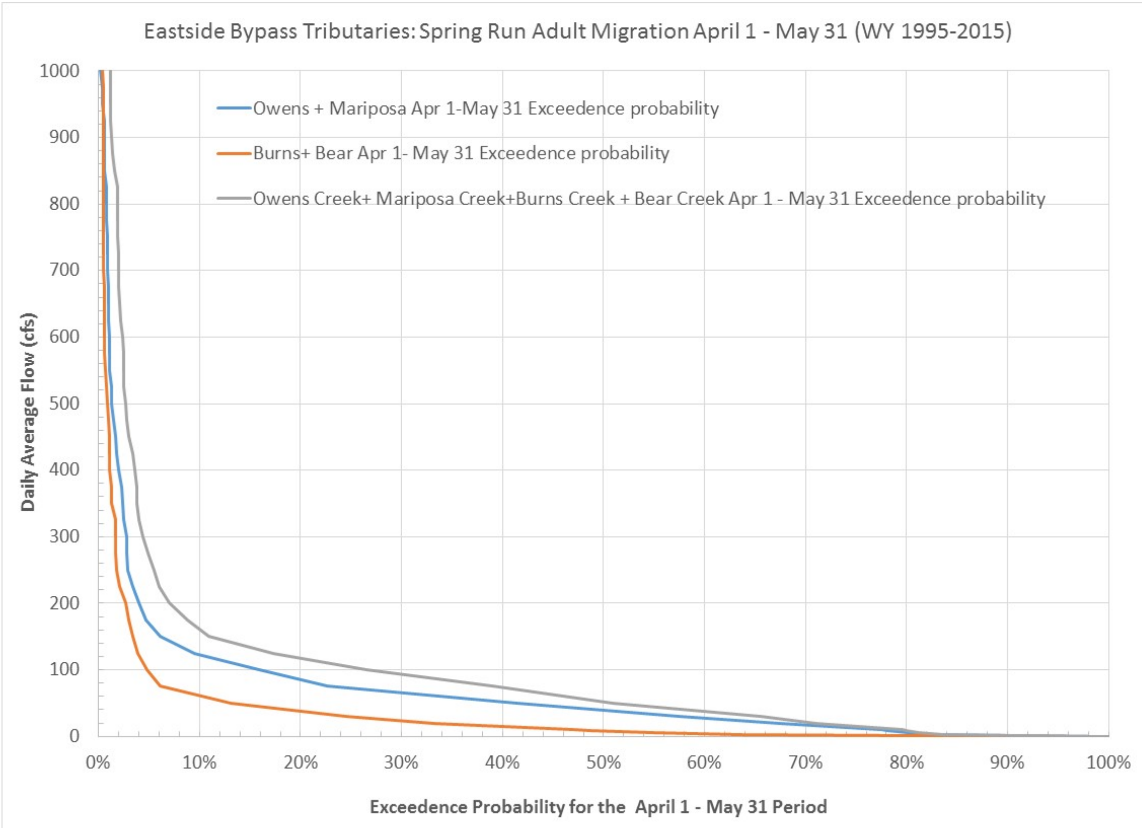
Flow in the San Joaquin River originates in the Sierra Nevada and is stored in Millerton Lake. Flows released from Millerton Lake are either Restoration Flows or Flood Flows. The SJRRP releases Restoration Flows on a schedule determined by the Restoration Administrator to meet the Restoration Goal. If Reclamation (the Millerton Lake operator) identifies the need for Flood Flow releases that exceed the recommended Restoration Flows, then the entire release is designated as a Flood Flow. Restoration Flows and Flood Flows will not be released from Millerton at the same time, and Flood Flows will be managed by the LSJLD, not the SJRRP.

Millerton releases travel through the San Joaquin River Reaches 1 and 2A until they reach the confluence with the Chowchilla Bypass. At this point, the LSJLD operates to put the first 1,200 cfs of Flood Flows into Reach 2B and the remaining flows into the Chowchilla Bypass. Flows in Reach 2B continue into Reaches 3 and 4A. Flows in the Chowchilla Bypass continue into the Eastside Bypass.

Flow enters the Reach 4B/ESB Project area from several sources:

- Reach 4A of the San Joaquin River
- Upper Eastside Bypass
- East side creeks

Flow routes that include the Middle and Lower Eastside Bypass would involve inflow from several smaller East side creeks, including the Fresno River, Berenda Slough, Ash Slough, Chowchilla River, Bear Creek, and others. These creeks flow from the foothills of the Sierras westward, and intercept (and are intercepted by) the Chowchilla, Middle and Lower Eastside Bypass flood control facilities. Most of these tributary creeks have minimal storage facilities; however, all are impaired to a large degree by canals, ponds, culverts, and other structures. Additionally, most are rainfall-dominated, meaning their runoff patterns are extremely flashy and directly correlated with rainfall events. The total tributary inflow of these drainages can be substantial in comparison to the Restoration Flows. Figure 3-1 shows an exceedance plot of the flows into the Bypass system during the spring, when Restoration Flows would be in the Reach 4B Project area.



Source: United States Army Corps of Engineers 2016

Figure 3-1. Inflow from East Side Creeks into Middle and Lower Eastside Bypass

3.1.2 Flood Management Structures

Figure 1-1 shows the flood management structures within the Reach 4B/ESB Project area, including:

- *Sand Slough Control Structure/San Joaquin River Headgates*: these structures control flow from Reach 4A of the San Joaquin River to divert it either into Reach 4B1 or through the Sand Slough Connector Channel into the Eastside Bypass. Currently, all water from Reach 4A flows over the Sand Slough Control Structure into the Eastside Bypass. Reach 4B1 does not receive flow from upstream and only contains local water from runoff and agricultural return flows.
- *Eastside Bypass*: the Eastside Bypass extends from the confluence of the Fresno River and the Chowchilla Bypass to the San Joaquin River at the head of Reach 5. The Eastside Bypass is subdivided into three reaches; the Middle and Lower Eastside bypasses are within the Reach 4B/ESB Project area (see Figure 1-1). Figure 1-3 shows more about the features within the bypass system. The Middle Eastside Bypass has a design channel capacity of 16,500 cfs. The Lower Eastside Bypass has a design channel capacity of 12,000 cfs from the Mariposa Bypass to the Owens Creek confluence, 13,500 cfs from the Owens Creek confluence to the Bear Creek confluence, and 18,500 cfs from the Bear Creek confluence to the confluence with the San Joaquin River (Reclamation 2016).
- *Eastside Bypass Control Structure*: this structure is between the Middle and Lower Eastside Bypass and controls the split of water between the Lower Eastside Bypass and Mariposa Bypass.
- *Mariposa Bypass*: this bypass conveys up to 8,500 cfs of Flood Flows from the Middle Eastside Bypass to Reach 4B2 of the San Joaquin River.

- *Mariposa Bypass Control Structure and Drop Structure*: the control structure is at the upstream end of the Mariposa Bypass and works with the Eastside Bypass Control Structure to split flows between the Lower Eastside Bypass and the Mariposa Bypass. The Mariposa Drop Structure is a grade control structure at the downstream end of the Mariposa Bypass.

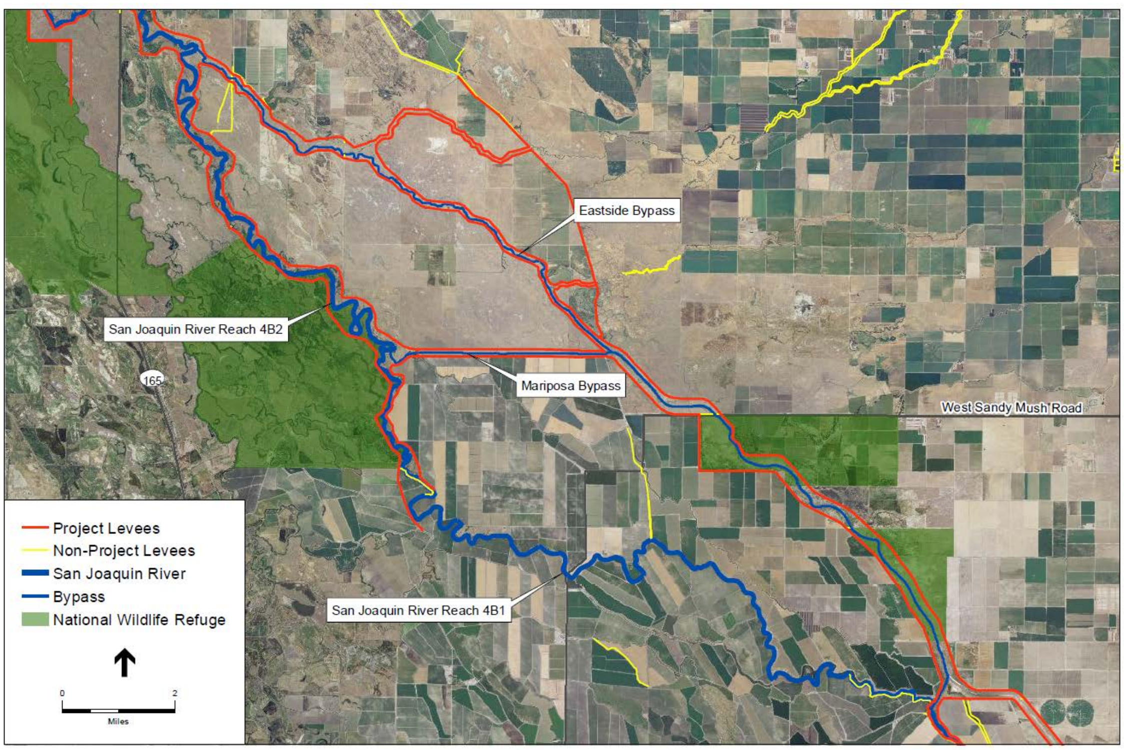
3.1.3 Levees

There are two classes of levees along the San Joaquin River and associated flood bypass channels:

- *Project levees*: Levees constructed as part of the Lower San Joaquin River Flood Control Project; and
- *Nonproject levees*: Levees constructed by individual landowners to protect site-specific properties and thus not associated with the San Joaquin River Flood Control Project.

A combination of project and nonproject levees exists within the Reach 4B/ESB Project area (Figure 3-2). Project levees run along both sides of the Eastside Bypass, Mariposa Bypass, Reach 4B2, and approximately two miles of the downstream-most portion of Reach 4B1. Nonproject levees run along both sides of the remaining portion of Reach 4B1.

The LSJLD is responsible for O&M of project levees within the Reach 4B/ESB Project area. The Lower San Joaquin River Flood Control Project Operation and Maintenance Manual provides guidance for project levees O&M (LSJLD 1967).



Source: USDA 2012; USFWS 2012

Figure 3-2. Project and Nonproject Levees with the Reach 4B/ESB Project Area

3.1.4 Subsidence

The Project area has historically experienced substantial subsidence (see Chapter 4, River Geomorphology and Sedimentation). Subsidence is a gradual sinking of the land surfaced caused by changes in subsurface geology associated with declining groundwater levels. Most of the subsidence observed in the Reach

4B/ESB Project area occurred by the late 1970s, but subsidence in the valley has continued and is expected to continue into the future. Approximately 1 to 6 feet of subsidence has been observed along the Lower San Joaquin River Flood Control Project between the 1920s and 1960s (USACE 2002). However, rates of 0.2 to 0.88 feet have been observed for the period of 2008 and 2012 (DWR 2013). The subsidence rate between 2015 and 2016 has been reported to be between 0.15 and 0.3 feet per year (SJRRP 2016), a trend that continued through at least 2016, when up to 1 feet of subsidence per year was observed in the Project area (Farr et al. 2017). The zone of greatest subsidence has occurred just upstream of the Reach 4B/ESB Project area.

Subsidence appears to have had a substantial effect on the profile of the river channel. Upstream of Reach 4B, subsidence appears to have steepened the slope of the San Joaquin River channel and Flood Control Project facilities. The steeper slope upstream of the Project area creates more erosion, which increases sediment loads into the Reach 4B/ESB Project area. At the same time, less subsidence within the Reach 4B/ESB Project area has resulted in a more gradual slope. Flows slow down when they enter the Reach 4B/ESB Project area, which increases deposition of sediment. The result of ongoing subsidence within Reach 4B is therefore expected to result in a reduction of freeboard (the distance between the top of the water surface in the bypass and the top of levee) (Reclamation 2016).

3.1.5 Flood Management Operations and Conditions

Based on discussions with the LSJLD, flood flows generally route as follows:

- *Chowchilla Bypass*: The LSJLD operates to put the first 1,200 cfs of flood flows from the San Joaquin River into Reach 2B, if there are no flood flows from the Kings River system. The remaining floods from the San Joaquin River go into the Chowchilla Bypass. If the Kings River is flooding, the LSJLD follows Section 5200 of the O&M Manual that includes a second operational mode stating that the first 5,500 cfs of flood flow should be routed to the Chowchilla Bypass. Due to levee and seepage issues in Reach 2B, and in cases when the Kings River is flowing and takes up the available Reach 3 capacity, the LSJLD has been routing all flows to the Chowchilla Bypass. After construction of the Reach 2B project and the increase in capacity of Reach 2B up to 4,500 cfs, it is expected that the LSJLD may change to operate in accordance with the first operational mode, which would put the first 2,500 cfs of flood flow in Reach 2B of the San Joaquin River (if the Kings River is not flooding).
- *Eastside Bypass*: LSJLD operates such that the first 2,500 cfs of flows in the Middle Eastside Bypass are routed into the Lower Eastside Bypass, then flows are split with approximately 30 percent of flows to the Mariposa Bypass. If Bear, Owens, or Deadmans Creek are flooding, the LSJLD may close the gates at the Eastside Bypass Control Structure and route more flow to the Mariposa Bypass.
- *Reach 4B1*: While Reach 4B1 has a design capacity of 1,500 cfs in the flood control manual, the capacity of this reach is effectively zero because road crossings and vegetation restrict the channel.

In cases where flood flows exceed all channel capacities, the O&M Manual directs the LSJLD to operate in a manner to reduce loss of life and property.

3.2 Alternative Comparison

This section highlights several key issues and how each alternative would function related to these issues.

3.2.1 Flood Flows

Friant Dam typically releases flood flows during wetter years (normal-wet and wet years), although short periods of flood releases can occur during other years. When flood releases over the planned Restoration Flows are necessary, all releases from Friant Dam will be flood flows. The LSJLD would decide how to route these flows, and they may not be routed into Reach 4B1, even if capacity were available. In this condition, all flow would move through the bypass system. Figure 3-3 shows how often this would occur during an example normal-wet year (1932), based on Riverware model results. Under these hydrologic conditions, Friant would release flood flows for about three weeks in February and two weeks in March. During these periods (shaded blue in the figure), the Reach 4B1 headgates would be closed and the only flow in the reach would be from local inflow. Figure 3-4 shows similar information for an example wet year (1938). The figures only show the periods that Friant would make flood releases, but flows into Reach 4B1 would also be limited at times that Kings River flood flows are entering Mendota Pool and routing additional Friant releases into the Chowchilla Bypass. Appendix A includes more detailed information about potential flow routing and the modeling effort to identify timing of flows in Reach 4B1.

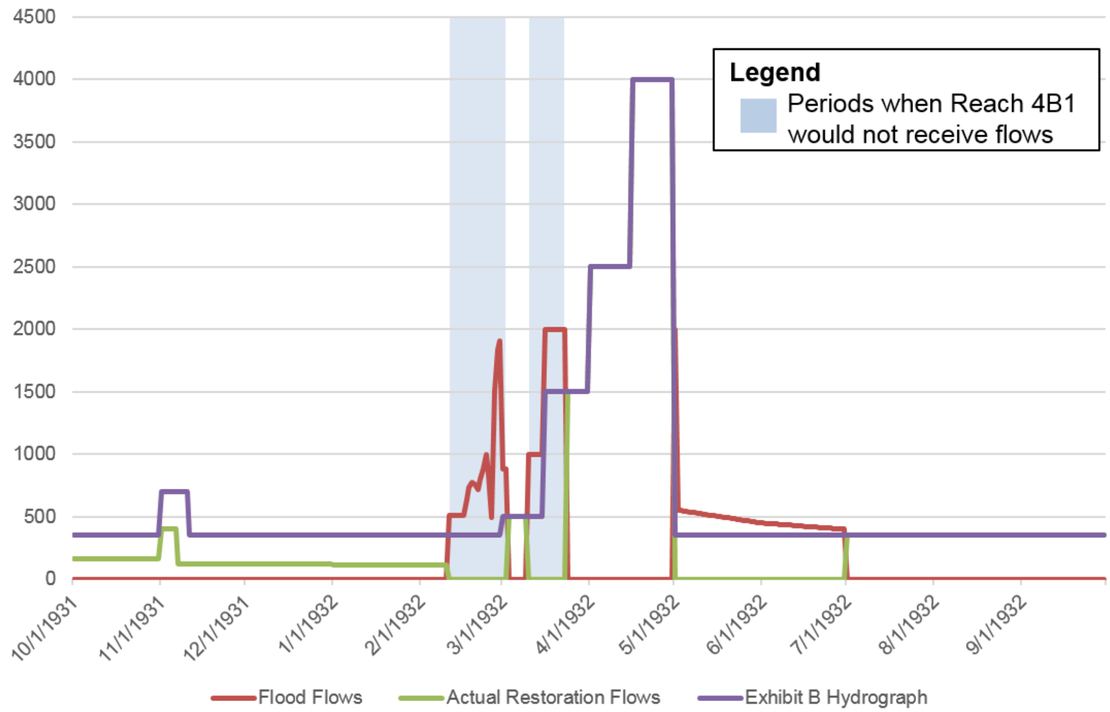


Figure 3-3. Flood Flows in a Normal-Wet Year (1932)

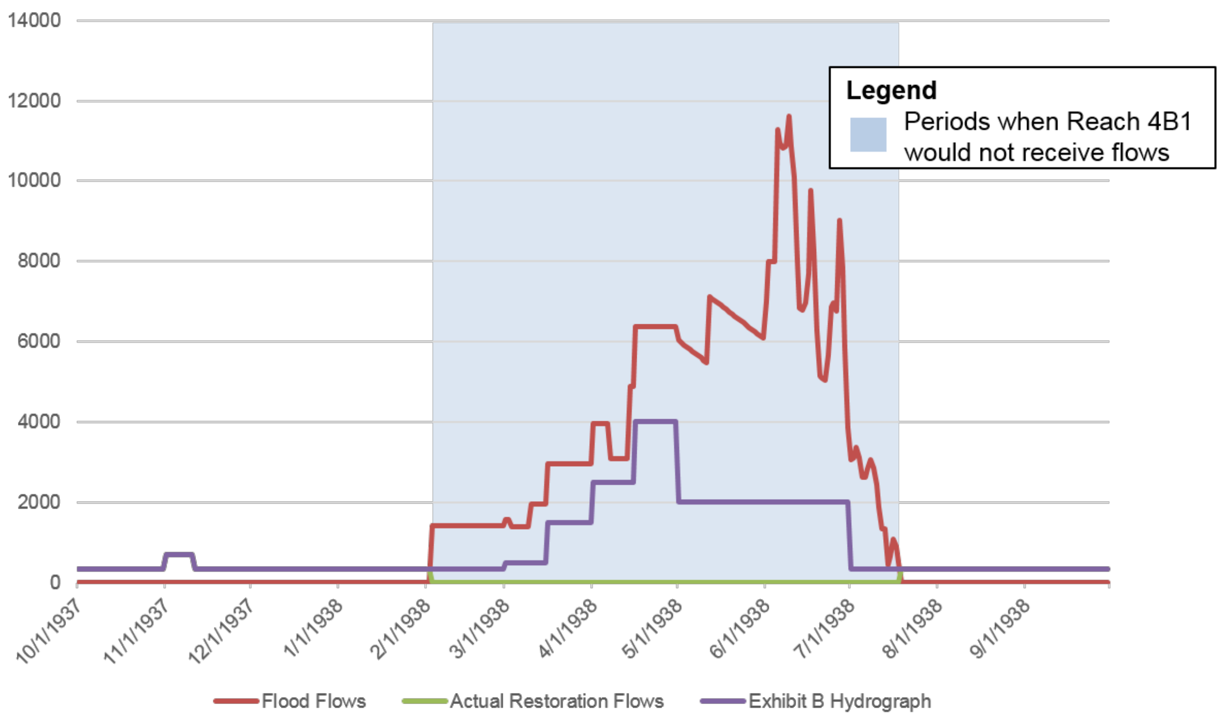


Figure 3-4. Flood Flows in a Wet Year (1938)

No Action Alternative

The No Action Alternative includes actions that would accommodate flows up to 2,500 cfs in the Middle and Lower Eastside bypasses. These actions would keep all Restoration Flows together in these waterways. The LSJLD would operate Flood Flows so that flows from the Middle Eastside Bypass are divided between the Lower Eastside Bypass (which receives the first 2,500 cfs) and the Mariposa Bypass. Generally, Restoration and Flood flows would follow the same path through the Reach 4B/ESB Project area.

Alternative 1 – Main Channel Restoration

Alternative 1 would route all Restoration Flows into Reach 4B1 of the San Joaquin River. The LSJLD may route Flood Flows into either Reach 4B1 or the Middle Eastside Bypass. If the LSJLD routes Flood Flows into the Eastside Bypass, then Reach 4B1 would not receive any flow during wetter periods. This operation could affect riparian vegetation and in-channel and floodplain habitat because it would not receive water during wet periods. Fish may be confused if they migrated out to the ocean through Reach 4B1, but the channel was not open when they returned as adults. Additionally, the operation could reduce sediment flushing flows in the river channel.

Alternative 2 – Bypass Restoration

Alternative 2 would route all Restoration and Flood flows into the bypass system. Alternative 2 also includes the restoration of 475 cfs of conveyance capacity in Reach 4B1, but that would only be used during high flow flood events in the bypass system (at the discretion of LSJLD). Generally, Restoration and Flood flows would follow the same path through the Reach 4B/ESB Project area.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 would split flows between Reach 4B1 and the bypass system. Similar to Alternative 1, flows may not enter Reach 4B1 when Friant Dam is releasing Flood Flows. Under this operation, all flow would enter the bypass system and no flow would enter Reach 4B1 during wetter periods. This operation could create concerns for vegetation, fish migration, and flushing flows similar to Alternative 1.

3.2.2 Straying Pathways

Several small East side creeks enter the Middle and Lower Eastside bypasses, including Owens Creek, Duck Slough, and Deadmans Slough. These creeks have little flow for much of the time but are flashy and can contribute more substantial flows during rainfall events. These waterways could prevent false pathways that encourage adult fish to stray into a waterway tbat does not have rearing potential

No Action Alternative

The No Action Alternative would convey Restoration Flows through the Middle and Lower Eastside bypasses. Upstream migrating adults would need to pass the small creeks and could migrate up a false pathway during a storm event.

Alternative 1 – Main Channel Restoration

Alternative 1 would route all Restoration Flows into Reach 4B1 of the San Joaquin River. Upstream migrating adult fish would not need to pass the East side creeks; therefore, these creeks would not be a straying concern. However, if the LSJLD routes Flood Flows into the bypass system, the creeks could cause a straying concern during these periods.

Alternative 2 – Bypass Restoration

Alternative 2 would route all Restoration and Flood flows into the bypass system. Upstream migrating fish would all be in the bypass system and would have to pass the false pathways created by the East side creeks. Some fish that stray may not return to the river to continue upstream, reducing spawning success.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 would split flows between Reach 4B1 and the bypass system. Upstream migrating fish within the bypass system would have to pass the false pathways created by the East side creeks.

3.2.3 Subsidence

Subsidence is an issue discussed in more detail in Chapters 4 (River Geomorphology and Sedimentation) and 6 (Groundwater). However, as described above, the differential subsidence within the bypass system is expected to reduce capacity for flood control, which would cause a need for flood management actions to address this reduced capacity. The action alternatives include levee improvements to make sure that the reduced capacity could safely convey Restoration Flows, but the alternatives do not include improvements to maintain flood capacity in the bypasses. The alternatives that convey water through the bypasses (Alternatives 2 and 3) may have an opportunity for cooperation with flood control agencies to improve the bypass system for both flood management and restoration actions.

THIS PAGE LEFT BLANK INTENTIONALLY.

Chapter 4 River Geomorphology and Sedimentation

This chapter describes existing river geomorphology and sedimentation in the Reach 4B Project area, and how they would change in the future under each alternative.

4.1 Setting

4.1.1 River Geomorphology and Sediment Transport

The most significant effect of dams and storage reservoirs on the geomorphology of a watershed is on sediment supply because they serve as impediments to sediment transport downstream. Due to the slowing of river velocity in the reservoir that forms behind a dam, river carrying capacity decreases and the sediment load drops out of the water column and onto the channel bottom. Although the water and some of its fine sediment may be released on the downstream side of the dam, the majority of the sediment load, particularly the coarse materials, remains on the upstream side. This sediment accumulation may be so marked that over time it can significantly decrease the storage volume of the reservoir itself.

Under unaltered conditions, geomorphic fluvial processes, including sediment transport, occur on a relatively consistent basis along the length of a river, and flow energy in the river channel is dissipated gradually. Bridges and culverts constrict the natural channel and disrupt these processes, which also alter channel form. This may occur at either high or low flows, depending on the size of the structure. The function and operation of the existing water supply and flood control infrastructure also affect fluvial processes. Such infrastructure includes diversion structures, bypasses and bypass diversions, other hydraulic control structures, off-stream flood control dams, levees, and canals. These structures divert base flows and/or flood flows and thereby significantly alter fluvial processes. The processes most affected are sediment transport, local incision and deposition, and channel migration.

The sediment load of the San Joaquin River and its tributaries originates from the erosion of soil and rock units of the Sierra Nevada Province. In upstream reaches of the San Joaquin River, the sediment load generally comprises large boulders, cobbles of diameters greater than or equal to 4 inches, fine sand, and less commonly, intermediate-size gravels (Southern California Edison 2003). The sediment load of the San Joaquin River becomes finer with distance downstream. The San Joaquin Valley floor is divided into several geomorphic land types, including dissected uplands, low alluvial fans and plains, river floodplains and channels, and overflow lands and lake bottoms. The alluvial plains cover most of the valley floor and make up some of the intensely developed agricultural lands in the Central Valley.

The upstream portion of Reach 4 of the San Joaquin River contains a meandering, sand-bedded channel with a gradient that decreases relative to Reach 3. River morphology in the upstream portion of Reach 4 once included an extensive flood basin that continued through Reach 5 and changes from the moderately confined configuration of Reaches 2 and 3 to the extensive flood basin geometry that characterizes Reaches 4 and 5. Beginning in Reach 4A, the channel is confined by smaller levees rather than by the bank-full channel and floodplains. The width between the levees varies between 200 and 700 feet. Many large anabranching[2] sloughs originated in Reach 4; these sloughs probably conveyed summer and winter base flows in the past. Currently, these channels carry agricultural return flows and runoff. These sloughs include Sand Slough, which originates near the Sand Slough Control Structure and terminates near the end of the Mariposa Bypass, and the Pick Anderson Bypass, which originates and terminates in Reach 4B1 and has been heavily channelized to convey agricultural flows.

Numerous other side channels exist near Reaches 4 and 5 that do not carry any significant return flows or runoff. Channel migration and avulsion were probably historically slower and less frequent than in Reaches 2 and 3 because of the low sediment supply and dissipation of stream energy as floodwaters spilled out into the flood basin.

Reach 4B1 of the San Joaquin River extends from the Sand Slough Control Structure to the return of the Mariposa Bypass. This reach has had very little flowing water since the construction of the Reach 4B Headgates. Currently, the capacity of the river is severely limited by vegetation in the channel and adjacent land use. The average channel slope is very low in Reach 4B1 at 0.00022. The median bed material size is 0.55 millimeters (mm), which is typical for a sand-bed river, as shown in Table 4-1.

Table 4-1. Average Slope and Average Diameter of Bed Material

Subreach	Average Bed Slope	Average Bed Material Diameter (D_{50})
4B1	0.00022	0.55
4B2	0.00017	0.56
Eastside Bypass	0.00020	***
Mariposa Bypass	0.00019	***

Source: (Mussetter 2002a and 2002b, Reclamation 2011a)
**** = mostly native soil material*

Reach 4B2 extends from Mariposa Bypass at the upstream end to the return of the Eastside Bypass into the San Joaquin River at the downstream end. This reach is bordered on the south side by the San Luis NWR. Levees bound the river, but the width between the levees is generally more than 1,000 feet. The channel capacity in this reach of the San Joaquin River has been estimated to be greater than 10,000 cfs (Mussetter 2002b). The river slope is very low in Reach 4B2 at approximately 0.00017, and the median bed material size is 0.56 mm.

Soils in Reach 4B of the San Joaquin River are characterized as clay loam, clay, and some loam, with minor amounts of sandier soils, and have moderate soil erosion potential. The absence of flows through Reach 4B1 has prevented channel scour from removing the fine sediments. The bypass system contains manmade channels and converted sloughs. Throughout most of the bypass system, there is a channel that is best defined in the Mariposa Bypass. Sand scoured from the Eastside Bypass Reach 1 is deposited in the Eastside Bypass Reach 3. Soils in the bypass system are characterized as loam, clay loam, and clay, with some sandy loam and sand, have a moderate erosion potential and a moderate to high shrink-swell potential.

Structures in the Reach 4B/ESB Project area, including the Sand Slough Control Structure, the Reach 4B Headgates, the Eastside and Mariposa Bypass Control structures, the Mariposa Drop Structure, and the Chowchilla Bypass upstream, have affected geomorphic processes, including the disruption of local incision and deposition patterns due to backwater effects and the rerouting of sediment load. Prior to dam construction, Reach 4 of the San Joaquin River likely was subject to sediment deprivation relative to the

[2] An anabranching river reach is a river reach that divides into multiple channels from the main channel or stem of the watercourse and rejoins the main stem downstream.

upstream reaches. The lack of extensive floodplains and a lower frequency of exposed sand bars within the channel indicate that Reach 4 of the San Joaquin River was previously capable of transporting most sediment that was supplied to the reach. Since construction of the Chowchilla Bypass and diversion of the majority of river flows there, sediment deprivation has increased.

Currently, the river sediment load is typically low by the time flows arrive at the Reach 4B/ESB Project area. The San Joaquin River Headgates diverts all flows into the Eastside Bypass, preventing sediment from moving downstream into the Reach 4B1 channel. A sand bed is present within approximately the first mile of the Eastside Bypass below the Sand Slough Control Structure where deposition of sand occurs during high flows. Table 4-2 includes information on the existing infrastructure within the Reach 4B/ESB Project area and the affected geomorphic processes.

Table 4-2. Infrastructure within the Reach 4B/ESB Project Area and Affected Geomorphic Processes

			Affected Geomorphic Processes					
Reach	Infrastructure	Description	Sediment Transport Short Term	Sediment Transport Long Term	Sediment Transport High Flows	Sediment Transport Low Flows	Local Incision/ Deposition	Channel Migration/ Avulsion
Diversion Structures								
Bypass Diversion Structures								
4B	Mariposa Bypass Bifurcation Structure	Diverts flood flows from the Eastside Bypass/Mariposa Bypass confluence back to SJR	x	x	x	x	x	
Bypasses								
4B	Mariposa Bypass	Conveys water from the Mariposa Bypass Bifurcation Structure back to SJR	x	x	x	x		
4B	Eastside Bypass	Conveys water from the Chowchilla Bypass to the Mariposa Bypass Bifurcation Structure and back to SJR	x	x	x	x		
Other Hydraulic Control Structures								
4B	Sand Slough Control Structure	Low head control structure in Sand Slough between SJR and Eastside Bypass	x			x	x	
Eastside Bypass	Eastside Bypass Control Structures	Low head grade control structures within the Eastside Bypass	x	x	x	x		
Mariposa Bypass	Mariposa Bypass Control Structures	Low head grade control structures within the Mariposa Bypass	x	x	x	x	x	
4B	Reach 4B Headgates	Low head control structure within the main stem SJR that controls flows into Reach 4B	x	x	x	x	x	

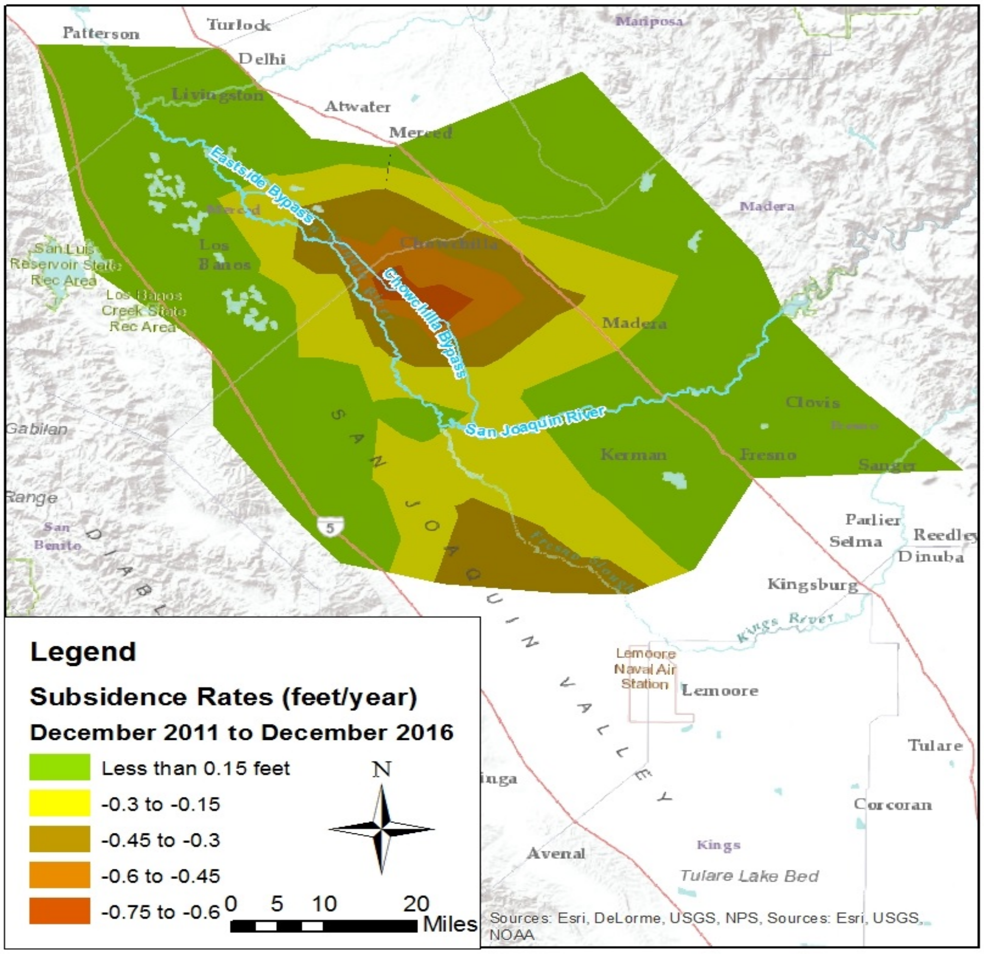
Reach	Infrastructure	Description	Affected Geomorphic Processes					
			Sediment Transport Short Term	Sediment Transport Long Term	Sediment Transport High Flows	Sediment Transport Low Flows	Local Incision/ Deposition	Channel Migration/ Avulsion
Levees								
4B2, Eastside Bypass, Mariposa Bypass	Project Levees	Line 4B2 and the Eastside and Mariposa bypasses						x
4B1	Non-project levees	Line 4B1						x

Source: Reclamation 2011b

Key: DMC = Delta-Mendota Canal; SJR = San Joaquin River

4.1.2 Subsidence

As discussed in Chapter 3, Hydrology and Flood Operations, the Reach 4B/ESB Project area has historically experienced substantial subsidence. The primary cause for subsidence in the San Joaquin Valley has been attributed to (1) deep aquifer system compaction due to lowering of groundwater levels due sustained groundwater overdraft and; (2) hydro-compaction of moisture-deficient deposits above the water table (U.S. Geological Services [USGS] undated). From the 1920s until the mid-1960s, groundwater use in the San Joaquin Valley increased rapidly, causing land subsidence throughout the west and southern portions of the valley. From 1920 to 1970, almost 5,200 square miles of irrigated land in the San Joaquin River Watershed showed at least 1 foot and as much as 28 feet of land subsidence in northwest Fresno County (CALFED 2000). Approximately 1 to 6 feet of subsidence has been observed along the Lower San Joaquin River Flood Control Project between the 1920s and 1960s (USACE 2002). Following the construction of the California Aqueduct in the 1960s, delivery of surface water conveyed by the aqueduct reduced the irrigators' need to extract groundwater, thus, reducing the rate of subsidence in the valley. During the recent drought conditions, subsidence in and around the Project area has increased. rate ranges from 0.45 feet/year at the upstream end of Reach 4B from 2011 to 2016 (Reclamation 2016).



(Source: Reclamation 2016)

Figure 4-1. Measured Subsidence Rate between December 2011 and December 2016

The effects of subsidence on the profile of the river channel may be a significant contributing factor to the deposition challenges within the bypasses. Figure 4-2 is a conceptual diagram showing the effects of subsidence on the profile of the Reach 4B river channel and the Eastside Bypass channel. As shown in Figure 4-2, upstream of Reach 4B, subsidence appears to have steepened the slope of the San Joaquin River channel and Flood Control Project facilities. The steeper slope creates more erosion, which increases sediment loads into the Reach 4B/ESB Project area. At the same time, differential subsidence within the Reach 4B/ESB Project area has resulted in a more gradual slope. Flows slow down when they enter the Reach 4B/ESB Project area, which increases deposition of sediment.

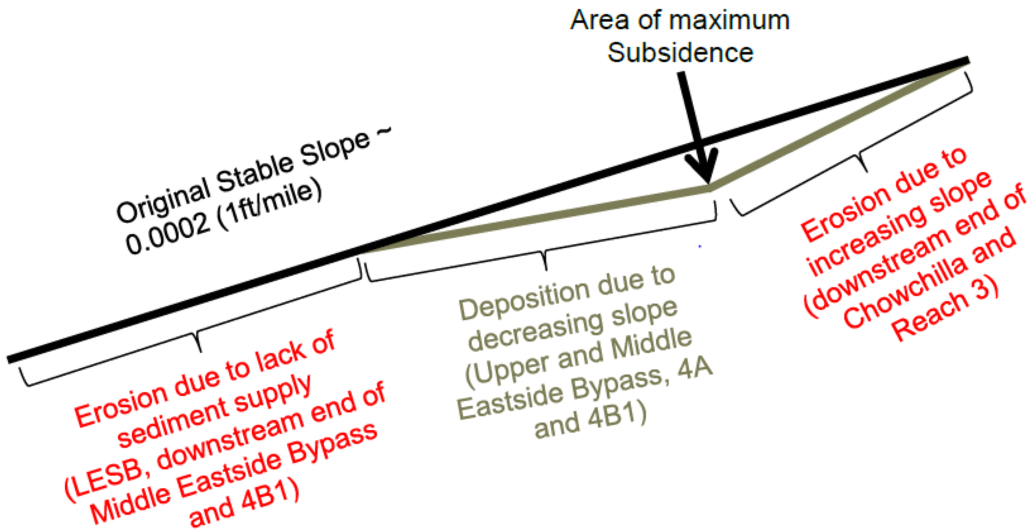


Figure 4-2. Conceptual diagram of effects of subsidence on sedimentation in Reach 4B/ESB Project area

4.2 Alternative Comparison

This section highlights several key issues and how each alternative would function related to these issues.

4.2.1 Sediment Transport

Sediment transport occurs on a relatively consistent basis along the length of a river. Increased flows and realignment of flood control levees under the alternatives could affect sediment transport and potentially increase sedimentation or erosion along the Reach 4B/ESB reaches. Subsidence also effects sediment transport and channel morphology. As discussed previously, the upper portion of both the Middle Eastside Bypass and Reach 4B1 are depositional reaches because of the subsidence that has already occurred in these reaches. The sedimentation in these reaches would continue and accelerate if subsidence continues.

Several models have been used to characterize the hydraulics in the Reach 4B/ESB Project area:

- One-dimensional (1D) model using HEC-RAS 4.1
- Two-dimensional (2D) model using SRH-2D (a hydraulic model developed by Reclamation)

Sediment transport modeling was completed using SRH-1D (a one dimensional model), using daily flow information from Riverware. The sediment transport modeling shows that the No Action Alternative has substantial deposition in the Middle Eastside Bypass near Sand Slough Control Structure, which is consistent with field observations. Figure 4-3 shows the sediment erosion and deposition in Reach 4B1 and the Eastside Bypass (erosion is negative and deposition is positive). The subreaches of each system are in order from upstream to downstream and show how conditions change throughout each channel. Alternative 1 would have limited erosion and deposition in Reach 4B1. Alternative 2 would still have substantial deposition in the Middle Eastside Bypass, but it would be less than the existing conditions. Appendix B has more details about the modeling efforts and results.

Figure 4-3. Sediment Erosion and Deposition

No Action Alternative

Under the No Action Alternative, the Reach 4B/ESB Project would not be implemented and none of the project features would be implemented. However, other proposed projects under the SJRRP would be implemented, including seepage measures along the Eastside and Mariposa bypasses, habitat restoration in other river reaches, augmentation of river flows, and reintroduction of salmon.

The No Action Alternative would route a greater volume of flows through the Eastside and Mariposa bypasses in comparison to existing conditions. Deposition would continue in the upstream area of the Middle Eastside Bypass, and the increased flows would increase this deposition. The majority of the sand-sized sediment that enters the Middle Eastside Bypass would deposit in this upstream area, which would cause a lack of sediment supply in the remainder of the reach. Elevated sediment deposition rates would require an increase in the frequency of sediment removal actions in comparison to existing conditions.

Over time, deposition on the area just downstream of Sand Slough Control Structure would start to accumulate on the channel bed (see Figure 4-4). The channel may become perched, where the bypass channel is at a higher elevation than surrounding ground. It will also raise the bed compared to the levees, which would reduce available freeboard on the levees. Figure 4-5 shows how the levee subsidence and channel bed subsidence would change in the No Action Alternative in the Middle Eastside Bypass. While the modeling indicates that the ground surface (including levees) would decline by 8.8 feet between 2015 and 2040, the water surface would only decline by 6.6 feet.

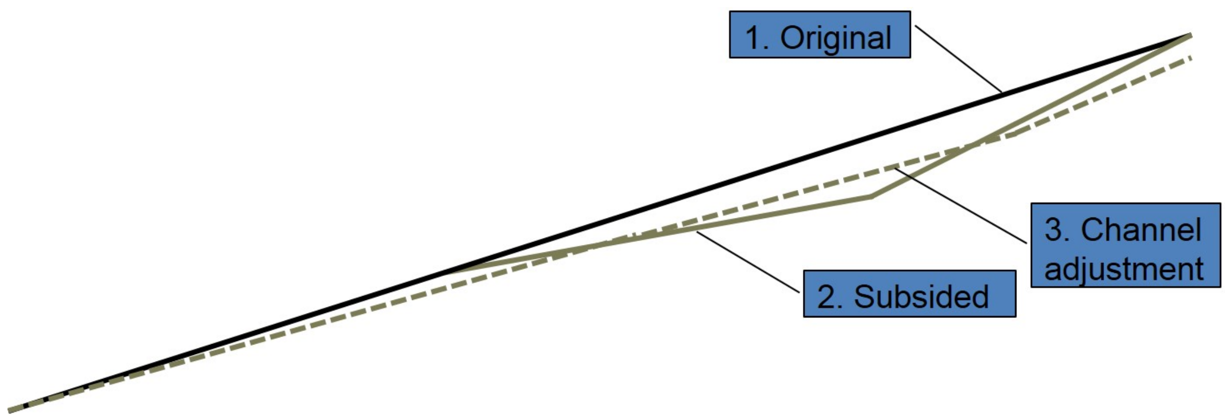


Figure 4-4. Subsidence Changes to Bypass Channel

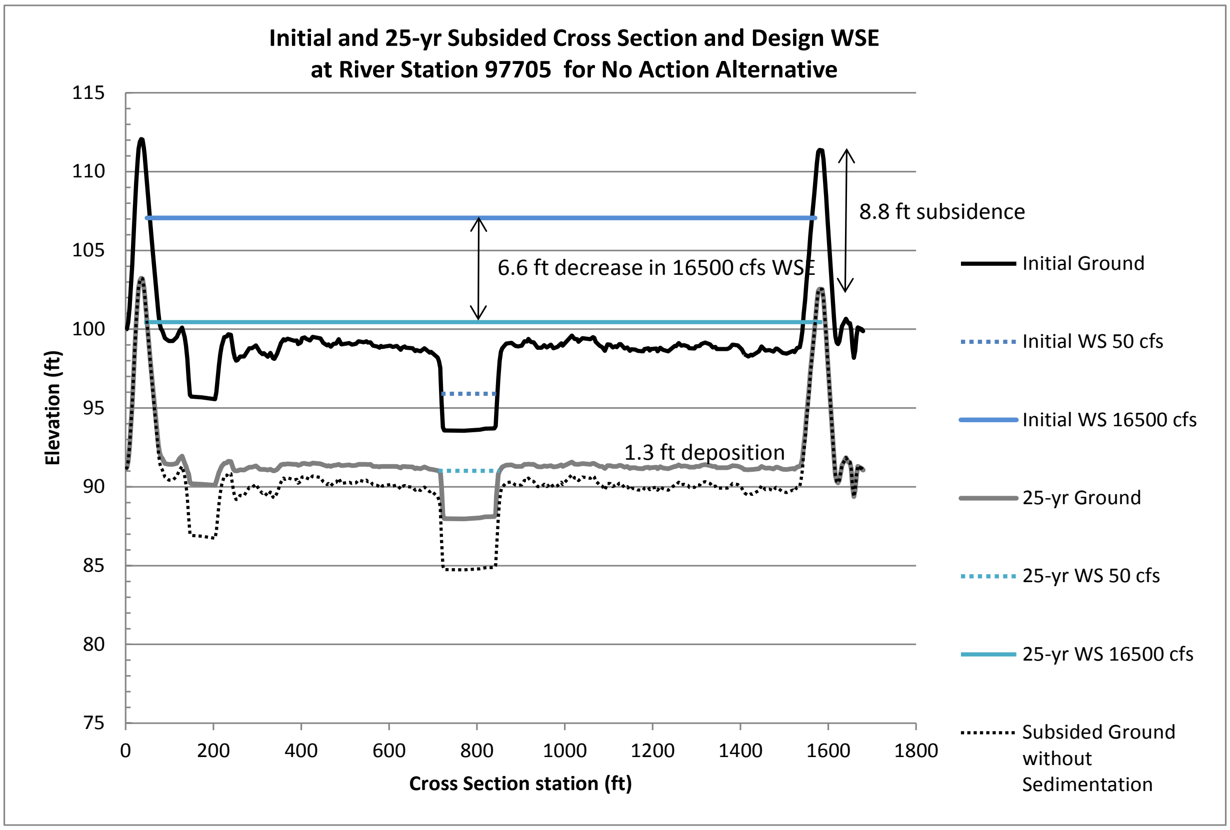


Figure 4-5. Subsidence Effects to Levee Freeboard under the No Action Alternative

Alternative 1 – Main Channel Restoration

Under Alternative 1, proposed in-river facilities such as control structures, bridges, and other in-channel obstructions, that would be introduced or modified under this alternative could result in increased erosion or sediment transport. Erosion or sedimentation would occur immediately upstream or downstream of the proposed facilities due to increased scour, increased backwater conditions and sedimentation, or other potential effects. Replacement of the Reach 4B Headgates, Sand Slough Control Structure, and bridge crossings and locations of construction access routes and staging areas would be designed to minimize the erosion and sedimentation issues described above.

The SRH-1D model was used to simulate the erosion and deposition under the alternative conditions. Two subsidence conditions were modeled: one with no additional subsidence occurring in the reaches and one with continued subsidence at rates summarized in Table 4-3. Appendix B documents the modeling results from the SRH-1D V4.0 one dimensional sediment transport model.

Table 4-3. Subsidence rates in the SRH-1D one dimensional model

Location	Subsidence Rate (feet/yr)
Sack Dam	-0.4
Sand Slough Control Structure	-0.4
End of Reach 4B1	-0.05

Source: Reclamation 2016

Under Alternative 1, there would be increased flows through Reach 4B1. The lower portion of Reach 4A and the first 5 to 7 miles of Reach 4B1 would be depositional. Simulated sediment load under Alternative 1 shows very little sediment is transported out of the upper five to seven miles of Reach 4B1. Approximately 80 percent of the sediment load entering Reach 4B1 deposits along the first five to seven miles of the reach (see Figure 4-6). Deposition in this area would occur at a rate of approximately 17 to 22 tons per mile over the modeled 50-year timeframe (0.4 to 0.5 feet of deposition) within the channel, and at a rate of approximately 36 to 229 tons per mile over 50 years (0.1 to 0.4 feet of deposition) on the floodplain. Because of the deposition at the start of Reach 4B1 the sediment load in the downstream end of the reach would be lower and lead to increased erosion (see Figure 4-6). In the lower seven to twenty-five miles of Reach 4B1, deposition rates would range from approximately neutral to erosional, with increasing vertical erosion toward the downstream end of the reach. Specifically, from approximately 17 miles downstream of the Headgates to the end of Reach 4B1, the channel would experience vertical erosion rates of approximately 49 to 51 tons per mile over 50 years, (approximately 1.3 to 1.5 feet of vertical erosion), whereas the floodplain would experience a net deposition of about 11 to 67 tons per miles over 50 years (less than 0.1 feet of deposition).

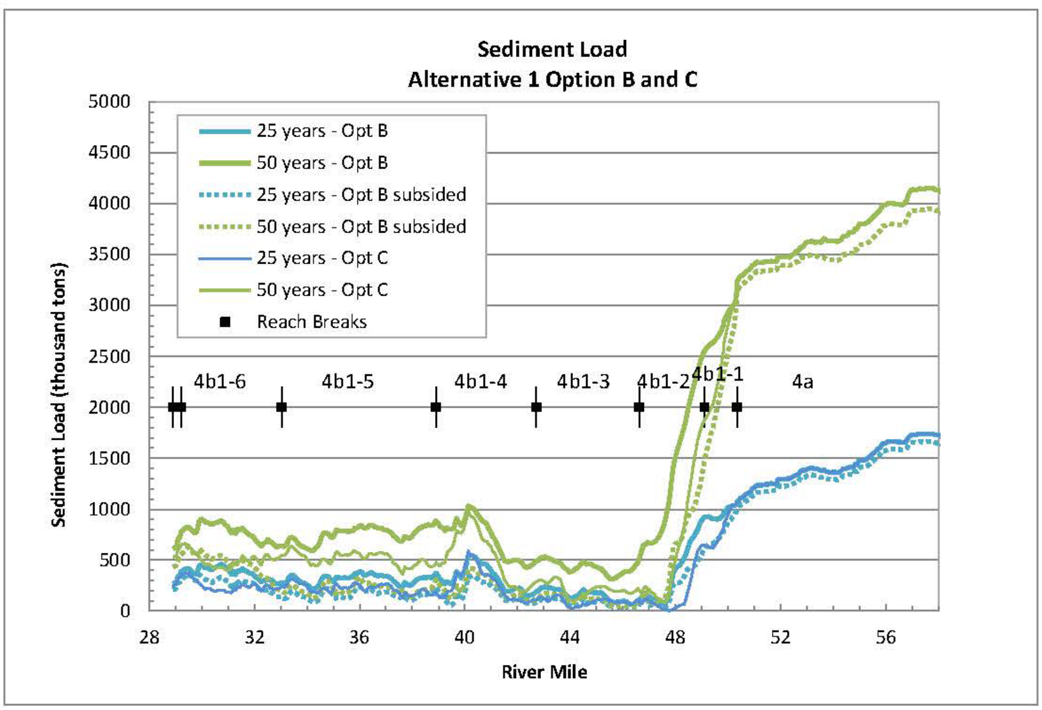


Figure 4-6. Sediment Deposition in Reach 4B1 for Alternative 1

If the rate of subsidence in the Reach 4B/ESB Project area continues as summarized in Table 4-3, at the end of 25 years the slope in the lower portion of Reach 4A and the upper seven miles of Reach 4B1 would be practically zero (see Figure 9-21 in Appendix B). Consequently, there would be almost no sediment transported out of the upper five to seven miles of Reach 4B1. Subsidence would have little effect on the levee freeboard in Reach 4B1 under Alternative 1. There are two main reasons for this: (1) the increase in flow depth for a given amount of subsidence is proportional to the original flow depth. The flow depth in Reach 4B1 at the design flow of 4,500 cfs is significantly less than the flow depth in the Middle Eastside Bypass at a flow of 16,500 cfs. (2) There is overall channel erosion in the lower 7 to 25 miles of Reach 4B1 which would increase conveyance area of Reach 4B1.

Alternative 2 – Bypass Restoration

Under Alternative 2, levee improvements and setbacks, removal of the existing Mariposa Bypass Drop Structure, channel grading, construction of a new headgate at the upstream end of Reach 4B1, removal and demolition of the Sand Slough Control Structure, and notching of the Mariposa Bypass Control Structure could result in increased erosion or deposition.

Reach 4A and the upper mile of the Middle Eastside Bypass would still be depositional under Alternative 2. There would be less deposition under Alternative 2 in comparison to existing conditions or the No Action Alternative as the slope in Middle Eastside Bypass would be increased due to channel grading, notching the Mariposa Bypass Control Structure, and lowering the Mariposa Bypass Drop Structure. As shown in Figure 4-7, the first one mile of the Middle Eastside Bypass would experience deposition, but these depositional actions are expected to cause vertical erosion in miles 2 to 3 of the Middle Eastside Bypass. Model results indicate that the Middle Eastside Bypass would experience vertical channel erosion at rates of up to 73 tons per mile over 50 years (approximately 1.4 feet of erosion over 50 years), whereas the floodplain would experience deposition of up to 166 tons per mile over 50 years (0.5 feet of deposition over 50 years). While the Middle Eastside Bypass slope would increase under Alternative 2, the sediment transport analysis concluded that the channel bed profile would remain stable. Erosion is expected to subside along the Eastside Bypass once riparian vegetation becomes established. Downstream, along Reach 4B2 of the San Joaquin River, more substantial sedimentation would occur. Channel deposition would reach 179 tons per mile over 50 years, resulting in a net accretion of about 4.1 feet of sediment within the channel over 50 years. Floodplains along this reach would remain near to neutral, showing erosion of 178 tons per mile over 50 years (0.8 feet of erosion).

If the rate of subsidence in the Reach 4B/ESB Project area continues as summarized in Table 4-3, at the end of 25 years the end of upper end of Middle Eastside Bypass would have subsided 9 feet and downstream end would have subsided 2 feet (see Figure 9-26 in Appendix B). Consequently, slope in the Middle Eastside Bypass would reduce. The most severe reductions in levee freeboard would occur upstream of Chamberlain Road and freeboard reduction greater than 2.5 feet would occur upstream of El Nido Road. This reduction in freeboard would be excess of the freeboard reduction due to increases in vegetation roughness.

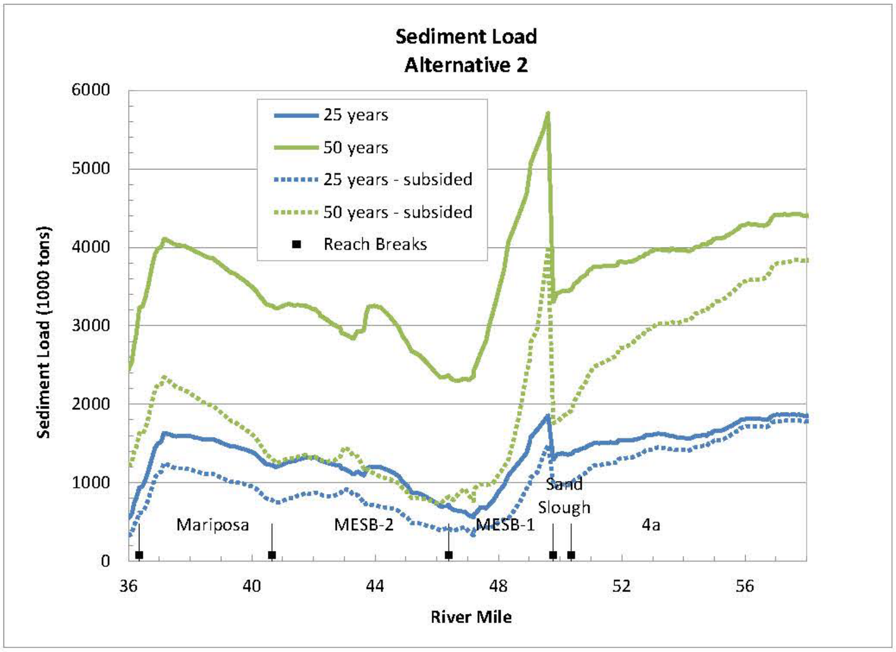


Figure 4-7. Sediment Deposition in the Bypass System for Alternative 2

Alternative 3 – Bypass All Pulse Flows

Under Alternative 3, control structures, bridges, and other in-channel obstructions that would be introduced or modified could result in erosion or sedimentation immediately upstream or downstream of the proposed facilities. Regrading to fill borrow areas and ponds within portions of the Eastside Bypass, modification of vegetation practices, modifications within the existing channels of the Middle Eastside Bypass, removal and replacement of gates for fish passage at the Sand Slough Control Structure, and structural improvements associated with the Eastside Bypass Control Structure and road crossings would be designed to avoid the erosion and sedimentation issues.

Significant deposition in the upper 4 miles of Reach 4B1 is expected due to the low bed slopes in this reach and because the relatively low flows are not sufficient to mobilize sediment through the reach (see Figure 4-8). It is likely that the deposition in the upper portion of Reach 4B1 would continue and Reach 4B1 may not be able to convey the high sediment concentrations that would occur during high flows in Reach 4A under Alternative 3. Model results indicated that under Alternative 3 flow conditions, the upper five to seven miles of Reach 4B1 would experience deposition at a rate of approximately 43 to 69 tons per mile over 50 years (equivalent to 0.8- to 2.0-foot increase in channel elevation over 50 years). Downstream areas along Reach 4B1 would remain near neutral to minimally erosional, with in channel erosion rates of up to 15 tons per mile over 50 years (up to 0.5 feet of vertical erosion) and floodplain deposition of up to 4 tons per mile over 50 years (0.5 feet of deposition or vertical erosion). Along the Eastside Bypass, erosion would be anticipated to occur at rates generally similar to those identified for the Eastside Bypass under Alternative 2, up to 73 tons per mile over 50 years of vertical channel erosion (1.4 feet of erosion over 50 years).

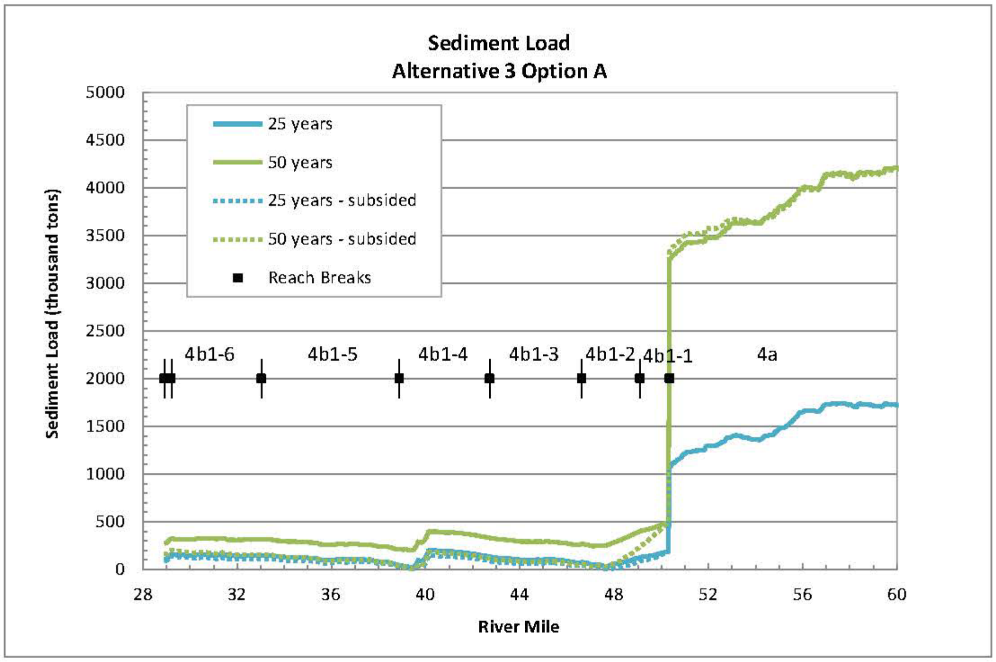


Figure 4-8. Sediment Deposition in the Bypass System for Alternative 3

If the rate of subsidence in the Reach 4B/ESB Project area continues as summarized in Table 4-3, slope in the Middle Eastside Bypass would reduce similar to Alternative 2 (see Figure 9-32 in Appendix B).

Chapter 5 Vegetation and Soils

Riparian vegetation provides rearing habitat for outmigrating juvenile salmonids. It provides food and cover for these fish. This section describes existing vegetation and the potential for future vegetation under the different alternatives.

5.1 Setting

5.1.1 Regional Setting

The Reach 4B/ESB Project area is located in the Great Valley ecological region, San Joaquin Basin subsection (Miles and Goudey 1997). The Great Valley ecological region contains the alluvial plains of the Sacramento and San Joaquin Valleys, where the river systems have deposited sediment as they slow in the flatter valley areas. Much of the natural habitat has been modified in this region. The San Joaquin Basin subsection is on nearly level floodplains and basin floors. It is between alluvial fans from the Coast Ranges on the west and alluvial fans from the Sierra Nevada of the east. The subsection elevation ranges from approximately 60 to 100 feet.

5.1.2 Reach 4B/ESB Project Habitat

Reach 4B1 does not receive river flows, but typically has ponded water from runoff, agricultural drainage, and water management actions. Water availability has created a substantial amount of vegetation, with reedy species (like cattails) in the channel and shrubs and trees along the borders (see Figure 5-1).

Figure 5-1. Vegetation in Reach 4B1

The Middle Eastside Bypass receives flood flows in the winter. During other parts of the year, the Merced NWR uses a portion of the channel for water delivery. The NWR flows keep a portion of the channel wet for most of the year. Upstream and downstream of this area, the channel primarily consists of annual grassland. In the wetted area, the channel has grasses interspersed with trees (see Figure 5-2).

Figure 5-2. Vegetation in Middle Eastside Bypass within the Merced National Wildlife Refuge

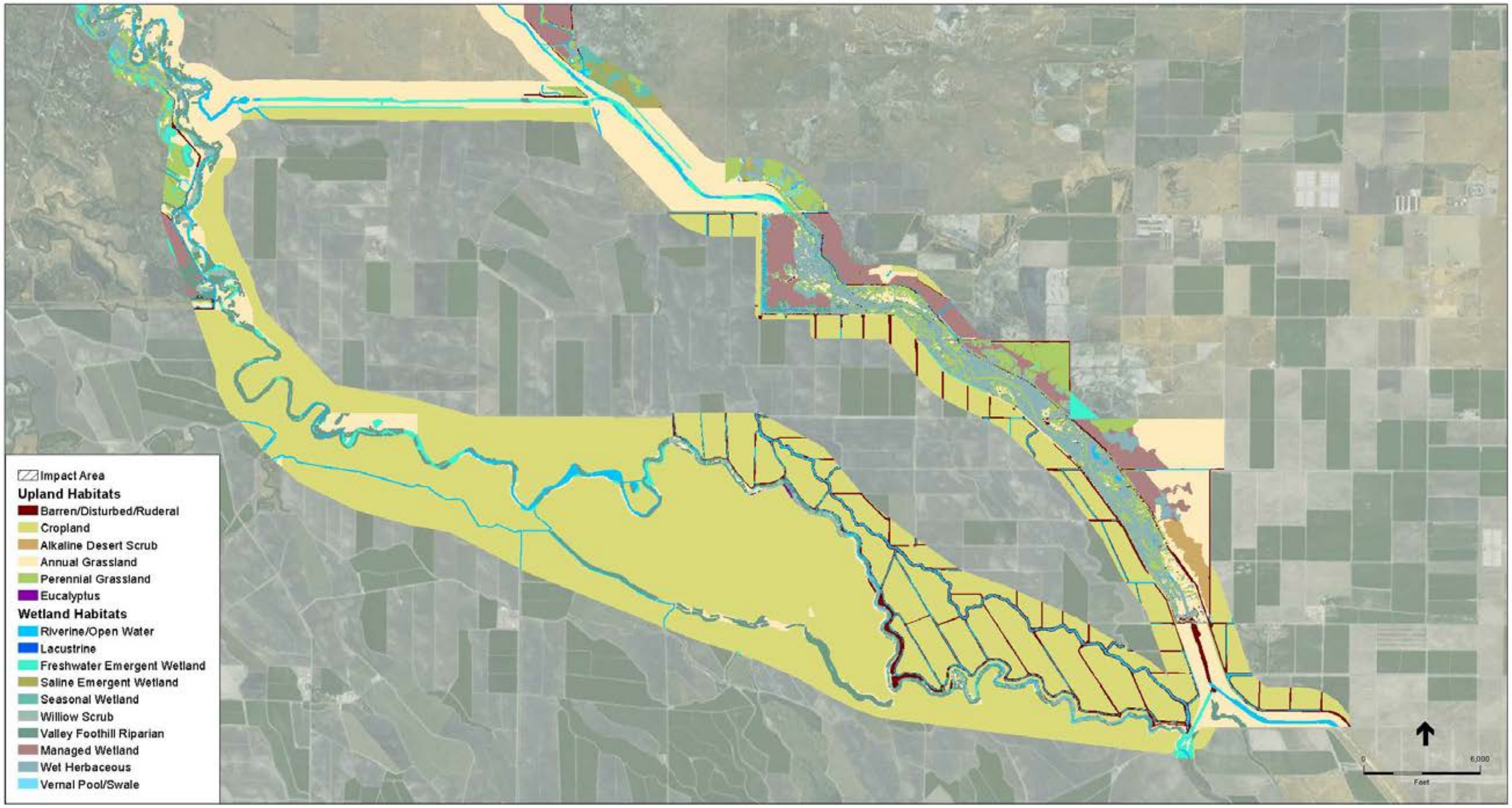
A total of 16 habitat types occur within the Project area. Acreages by habitat types mapped in the Project area are provided in **Table 5-1.** Terrestrial habitat types mapped in the Project area are described below. Aquatic habitat types are described in "Section 6.1.2 Wetlands and Waters of the U.S." A map of habitat types is shown in **Figure 5-3.** Appendix C includes more details of the habitat and vegetation within the Project area.

Table 5-1. Project Area Habitat Types

Habitat Type	Habitat Description	Acres
Upland		
Cropland	Land where crops are grown.	10,573
Annual Grassland	Grassland with a lifecycle of one year.	5,062
Perennial Grassland	Grassland with plants that live longer than one year (including alkaline soils that support species).	1,247
Barren/Disturbed	Areas that are sparsely vegetated because of unfavorable natural conditions (such as hydrology) or physical disturbance.	504
Alkali Desert Scrub	Areas with low to moderately high shrubs on alkaline soils.	93
Eucalyptus	Area planted with eucalyptus trees.	3

Habitat Type	Habitat Description	Acres
Aquatic		
Wet Herbaceous	Annual and perennial vegetation in areas with a high water table or subject to frequent flooding.	989
Managed Wetland	Areas managed for inundation during extended portions of the year (such as refuge areas and duck clubs).	752
Freshwater Emergent Wetland	Habitat along the margins of riverine habitat.	753
Valley Foothill Riparian	Narrow bands of habitat along Reach 4B2 that include trees and shrubs.	702
Riverine	Open water areas that occur within a defined channel of a stream.	658
Saline Emergent Wetland	Saline soils that remain inundated or saturated for extended periods.	125
Willow Scrub/Riparian Scrub	Areas with California rose and willows.	71
Seasonal Wetland	Ephemeral wetlands that remain flooded for extended portions of the year.	39
Vernal Pool/Vernal Swale	Areas distinguished by a unique host of species adapted to the extreme conditions created by the cycles of inundation and drying.	7
Lacustrine	Inland depressions or dammed riverine channels containing standing water.	0.2
TOTAL		21,578

SOURCES: Reclamation 2012, USFWS 2008, DWR 2011, Environmental Science Associates 2016



Source: Reclamation 2012; USFWS 2008; DWR 2011; ESA 2016

Figure 5-3. Habitats of the Project Area

5.1.3 Invasive Plants

Invasive plants that are introduced to a region and spread throughout the environment may have a large impact on the new environment (Davis and Thompson 2000). The California Invasive Plant Council (Cal-IPC) categorizes non-native invasive plant species and maintains a list of species that have been designated as invasive in California. Section 6.1.3 of the SJRRP PEIS/R (Reclamation 2011) provides detailed information on the distribution and abundance of invasive plant species in the Project area. For the predominant species, accounts of their ecology are provided in Appendix C. Non-native invasive species known to occur in the Project area and their associated Cal-IPC category and California Department of Food and Agriculture (CDFA) rating are identified in **Table 5-2.**

Table 5-2. Prevalent Non-Native Invasive Species in the Project Area

Scientific Name	Common Name	Cal IPC Category[1]	CDFA Rating[2]
Terrestrial Species			
Brassica nigra	black mustard	moderate	--
Bromus diandrus	ripgut brome	moderate	--
Bromus madritensis subsp. *rubens*	foxtail brome	high	--
Centaurea solstitialis	yellow starthistle	high	C
Cirsium vulgare	bull thistle	moderate	C
Conium maculatum	poison hemlock	moderate	--
Cynodon dactylon	Bermuda grass	moderate	C
Festuca perennis	ryegrass	moderate	--
Hirschfeldia incana	short-pod mustard	moderate	--
Hordeum marinum ssp. *gussoneanum*	Mediterranean barley	moderate	--
Hordeum murinum ssp. *leporinum*	common foxtail	moderate	--
Lepidium latifolium	perennial pepperweed	high	B
Phalaris aquatica	harding grass	moderate	--
Ricinus communis	castor bean	limited	--
Sesbania punicea	red sesbania	high, red alert	B
Tamarix sp.	salt cedar	high	B
Aquatic Species			
Eichhornia crassipes	water hyacinth	high, red alert	C

Source: Cal-IPC 2006, CDFA 2010, USDA 2017

Notes:

[1] California Invasive Plant Council Inventory Categories:

- High – Have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically.
- Moderate – Have substantial and apparent, but generally not severe, ecological impacts on physical processes, plant and animal communities, and vegetation structure. Reproductive biology and other attributes are conducive to moderate to high rates of dispersal, but establishment generally depends on ecological disturbance. Ecological amplitude and distribution range from limited to widespread.
- Limited – Invasive but ecological impacts are minor on a Statewide level, or not enough information was available to justify higher rating. Reproductive biology and other attributes result in low to moderate rates of invasiveness. Ecological amplitude and distribution are limited, but these species may be locally persistent and problematic.
- Red Alert – Plants with the potential to spread explosively; infestations currently small and localized.

[2] California Department of Food and Agriculture Rating (CDFA):

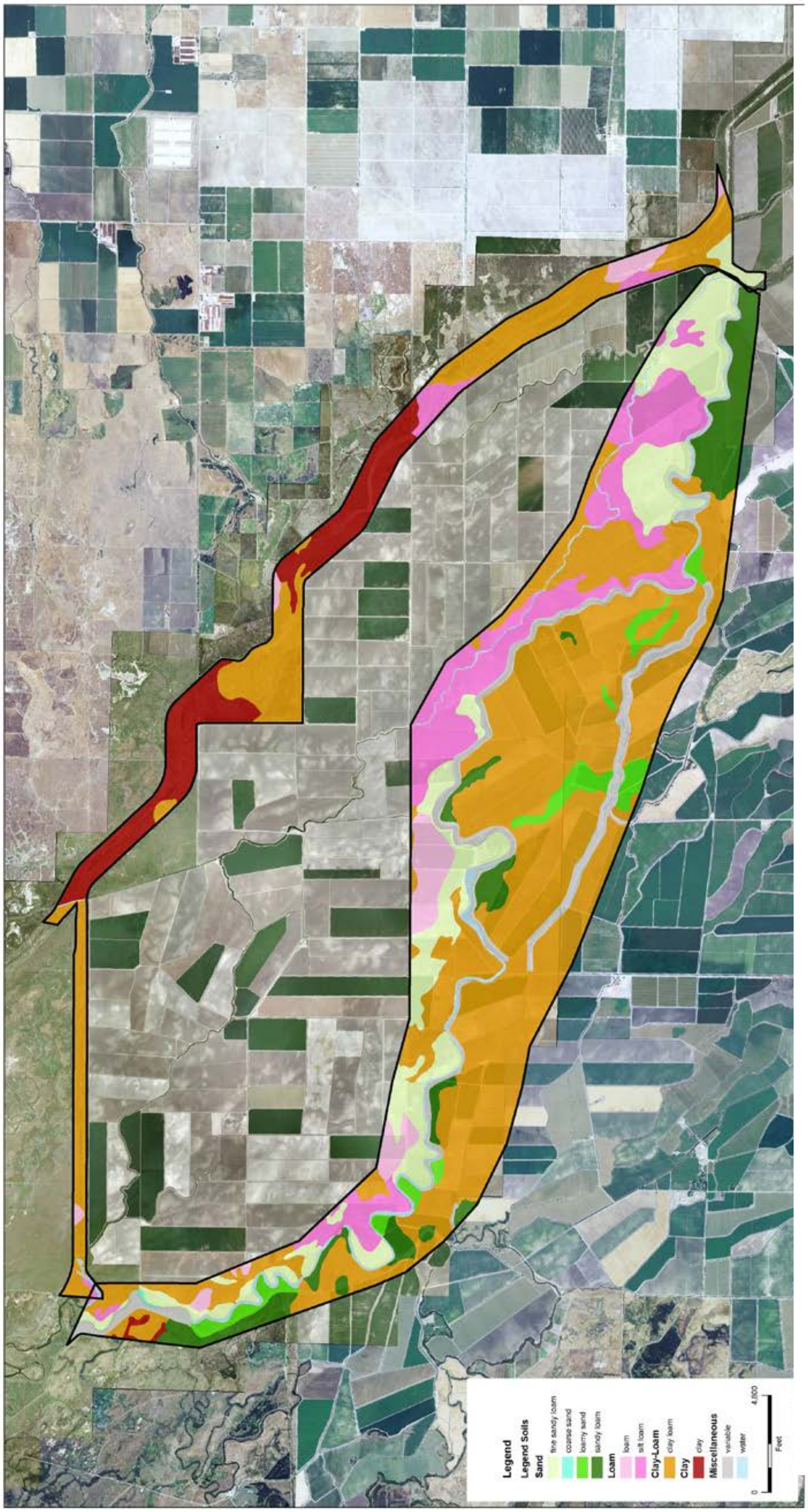
- B – A pest of known economic or environmental detriment, and if present in California, it is of limited distribution. B-rated pests are eligible to enter the State if the receiving county has agreed to accept them. If found in the State, they are subject to State-endorsed holding action and eradication only to provide for containment, as when found in a nursery. At the discretion of the individual county agricultural commissioner, they are subject to eradication, containment, suppression, control, or other holding action.

- C – A pest of known economic or environmental detriment, and if present in California, it is usually widespread. C-rated organisms are eligible to enter the State as long as the commodities with which they are associated conform to pest cleanliness standards when found in nursery stock shipments. If found in the State, they are subject to regulations designed to retard spread or to suppress at the discretion of the individual county agricultural commissioner. There is no State-enforced action other than providing for pest cleanliness.

5.1.4 Soils

Soils within a floodplain exhibit many different properties, and these properties can have substantial influence on the location and composition of riparian plant communities. In general, portions of the floodplain that are along the edge of the river are dominated by heavy textured soils (high sand content). Areas further away and topographically higher than the river channel have more complex soil layers. The higher floodplain soils are most often fine textured (higher silt content) with complex stratification as a result of deposition over time. Upper floodplain soils are often composed of nutrient rich sediments that support late seral riparian communities. Soil structure and texture also affect moisture holding capacity. Heavy textured soils are generally well drained and have a smaller capillary fringe as compared to fine textured soils. Fine sediments generally hold moisture longer, enabling upper floodplain species to endure summer drought conditions. Riparian species occupying the higher floodplain are generally less tolerant of long duration flooding, but are more tolerant of drought conditions. Riparian species established in the more frequently activated portion of the floodplain are adapted to more frequent and longer duration winter and spring flooding, but require higher groundwater levels as they are intolerant of drought conditions. Because floodplain soils develop over time as various sediments are deposited, there may also be thin lenses of gravel, sand, silt or clay, and each of these can affect plant growth. These lenses often explain poor plant establishment or dominance of shrubs in soils that typically support vigorous riparian growth.

Analysis of soil conditions within Reach 4B1, the Middle Eastside Bypass, and the Mariposa Bypass utilized the most recent soil surveys available: Merced County, Western Part and Merced Area (Natural Resources Conservation Service [NRCS] 2012). Additionally, Reclamation completed analysis of soil conditions in 2018 (Appendix D). Two primary soil parameters were assessed for riparian recruitment purposes: soil salinity and soil texture. Previously analyzed soils and vegetation data showed strong associations between riparian vegetation and soils that had low to free salinity levels and textures ranging from sand to loams. High salinity levels and soils with clay had very low association with the presence of riparian vegetation (Stillwater Sciences 2003). Figures 5-4 and 5-5 show the soil texture and salinity, respectively.


Legend
Legend Soils
Sand
fine sandy loam
coarse sand
loamy sand
sandy loam
Loam
loam
silt loam
Clay-Loam
clay loam
Clay
clay
Miscellaneous
variable
water
0
4,000
Feet

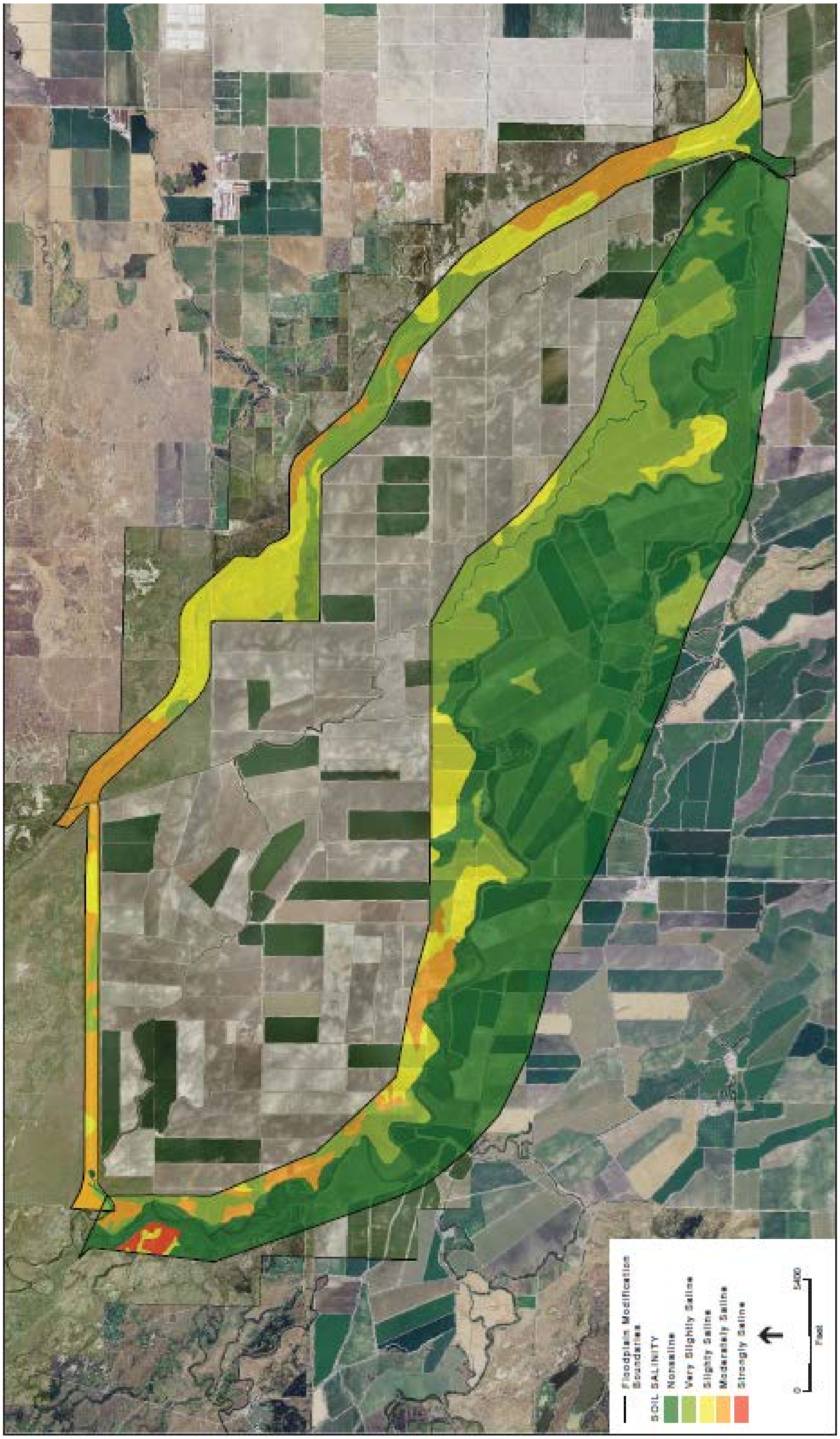


Figure 5-5. Soil Salinity in the Reach 4B Project Area

5.2 Alternative Comparison

This section highlights several key issues and how each alternative would function related to these issues.

5.2.1 Direct Effects to Vegetation

Construction of new levees and floodplains (or improvements to existing facilities) would have direct impacts on the existing habitats. Table 5-3 shows the acres of affected habitat under each alternative.

Table 5-3. Affected Habitat (acres) by Alternative

		Alternative 1 Main Channel Restoration			Alternative 2 Bypass Restoration		Alternative 3 Bypass All Pulse Flows
Habitat Type	**Existing Acres**	**1A**	**1B**	**1C**	**2A**	**2B**	**3**
Cropland	10,554	1,893	4,822	8,516	425	425	293
Annual Grassland	5,040	375	443	480	2,088	2,088	399
Perennial Grassland	1,247	8	62	62	609	609	23
Wet Herbaceous	989	11	11	11	410	410	14
Managed Wetland	745		45	45	398	398	15
Freshwater Emergent Wetland	744	162	187	187	370	317	175
Valley Foothill Riparian	702	234	262	341	296	296	235
Riverine/Open Water	658	127	149	218	317	308	122
Barren/Disturbed/Ruderal	502	115	179	258	199	199	104
Saline Emergent Wetland	123		3	3	65	65	9
Alkali Desert Scrub	93				92	92	1
Willow Scrub/Riparian Scrub	71	68	71	71	68	68	68
Seasonal Wetland	39		3	3	13	13	2
Vernal Pool/Vernal Swale	7				2	2	
Eucalyptus	3	3	3	3	2	2	2
Lacustrine	0.2	0.2	0.2	0.2	0.2	0.2	0.2
TOTAL	21,517.2	2,996.2	6,240.2	10,198.2	5,354.2	5,292.2	1,462.2

In addition to the construction-related changes, the inundation pattern within the Eastside Bypass would change under all action alternatives given the inability of the Refuge to operate two weirs and a portable pump due to the presence of Restoration Flows. An analysis performed by Reclamation, in coordination with the Refuge, sought to determine the approximate acreage of wetlands affected by the change in flow conditions (see Appendix E).

5.2.2 Revegetation

Existing vegetation is different in Reach 4B1 and the Middle Eastside Bypass. The existing vegetation is generally controlled by water availability, soil texture, and soil salinity. In the future, Restoration Flows will provide a more consistent water source, so the soil conditions will affect the types of vegetation that persist.

The action alternatives include a revegetation component to help accelerate riparian vegetation growth. In the long-term, floodplain habitat would not receive water year-round, and would depend on shallow groundwater as a water source. As discussed in Chapter 4, the groundwater levels in both the river and bypass systems are shallow enough to support vegetation. In the short-term, however, the root systems would not reach the groundwater, and revegetated areas would require irrigation.

No Action Alternative

The No Action Alternative would convey Restoration Flows through the Middle and Lower Eastside bypasses. The No Action Alternative does not include planting efforts in the Project area. The vegetation within the NWR would likely stay the same as the existing vegetation because this area current receives water on a regular basis. The areas upstream and downstream from the NWR could transition from annual grassland to become more similar to the NWR area (with perennial grasses and some trees or shrubs).

Alternative 1 – Main Channel Restoration

Alternative 1 would route all Restoration Flows into Reach 4B1 of the San Joaquin River and would revegetate areas of the river channel. The soil textures and low soil salinity could support a broad range of vegetation, including woody species. Vegetation may be easier to establish than in the Eastside Bypass.

Alternative 2 – Bypass Restoration

Alternative 2 would route all Restoration and Flood flows into the bypass system and focus revegetation in the Middle Eastside Bypass. Soil textures and moderate soil salinity may make it more difficult to establish a woody riparian corridor. Grasses and some trees would likely grow in the long term, as seen in the existing wetted portion of the bypass in the NWR.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 would split flows between Reach 4B1 and the bypass system and focus revegetation in Reach 4B1. Alternative 3 would not include floodplain habitat in Reach 4B1, but the channel would include riparian vegetation. Periodic flow in the bypass system would make it more difficult to sustain vegetation.

5.2.3 Invasive Species

The SJRRP is routing new flows through the Project area under all alternatives. The restoration efforts could facilitate the dispersal and establishment of invasive plants by transporting invasive plant propagules into the Project area, creating bare ground for them to establish, altering hydrology in a manner that is advantageous to invasive plant species, and eliminating competing native vegetation. As part of the SJRRP, PEIS/R Conservation Measure INV-1 requires implementation of an invasive plant monitoring and management plan to control or eradicate invasive plant infestations. This effort would apply to all alternatives, and would control the spread of invasive species.

Chapter 6 Groundwater

This chapter describes existing groundwater conditions in the Reach 4B Project area, and how they would change in the future under each alternative.

6.1 Setting

6.1.1 Regional Groundwater Conditions

The San Joaquin Valley Groundwater Basin extends from just north of Stockton in San Joaquin County to south of Bakersfield in Kern County. The Reach 4B/ESB Project area includes the Merced and Delta-Mendota subbasins as defined by the DWR.

The aquifer system in the San Joaquin Valley Groundwater Basin is mostly composed of unconsolidated alluvial and lacustrine sediments derived from parent materials of the Coast Ranges and the Sierra Nevada Mountains. The San Joaquin Valley fill reaches a thickness of about 28,000 feet in the southwestern corner (Page 1986). A significant hydrogeologic feature in the basin is the Corcoran Clay. This clay layer divides the aquifer system into two distinct zones, an upper unconfined to semi-confined aquifer and a lower confined aquifer below the confining unit (Corcoran Clay unit).

Under predevelopment conditions, groundwater flow in the San Joaquin Valley was from the valley flanks toward the axis of the valley and then north toward the Sacramento-San Joaquin Delta (Delta) (United States Department of the Interior, Bureau of Reclamation [Reclamation] 1997). Most of the water moves laterally, but a small amount leaked upward through the intervening confining unit (Planert and Williams 1995). However, since the 1920s, there have been substantial changes to flow patterns in the valley due to groundwater pumping and recharge from imported irrigation water. Upward vertical flow to discharge areas from the deep confined part of the aquifer system was impeded partially by the confining clay beds, particularly the Corcoran Clay. Extensive groundwater pumping and irrigation (with imported surface water) have modified local groundwater flow patterns and, in some areas, groundwater depressions are evident. Flows largely occur from areas of recharge toward areas of lower groundwater levels caused by groundwater pumping (Bertoldi et al. 1991).

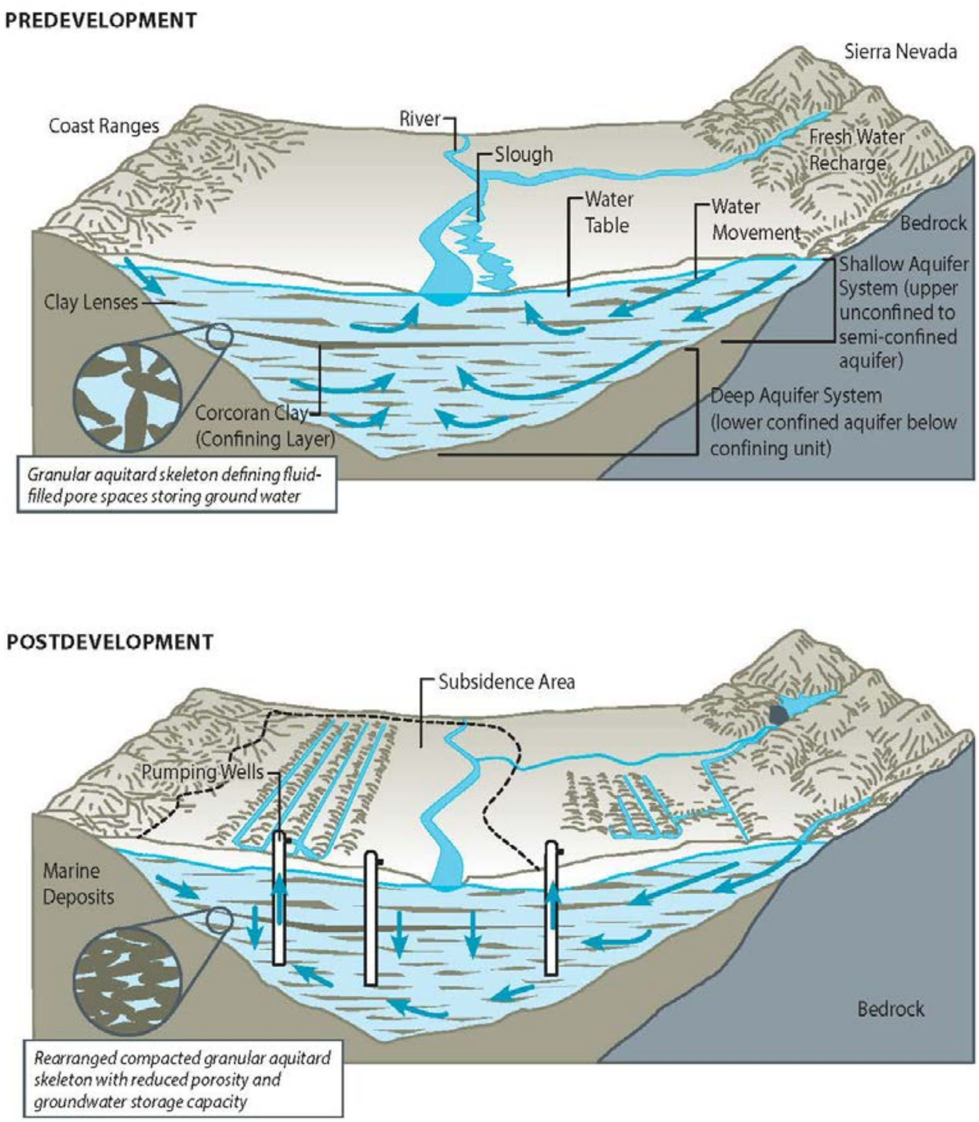


Figure 6-1. Predevelopment and Post development hydrogeology in San Joaquin Valley

6.1.2 Local Hydrogeology

As discussed in previous chapters, Reach 4B of the San Joaquin River has not received flows in many years. As shown in Figure 6-2, flowing unlined waterways typically interact with the surrounding groundwater aquifers and are either losing or gaining in nature. In a losing stream, water flows through the riverbed, out of the stream, and into the groundwater system. In a gaining stream, water flows from the groundwater into the surface water system. Since Reach 4B has not received flows in many years, stream conditions along this reach were estimated using groundwater levels from monitoring wells along Reach 4B.

In a “losing” stream condition, the water level in the stream is higher than the groundwater level under and adjacent to the stream. In a “gaining” system, the water level in the surface water is lower than the adjacent groundwater level. Depending on groundwater and stream levels, portions of the same stream system may be gaining while other portions are losing. The gaining/losing condition can also change at different times based on changes in either the groundwater level, the surface water level, or both.

Many hydrologic and hydrogeologic cross-sections along Reach 4B and the Eastside Bypass were developed as part of the groundwater analysis conducted for the Reach 4B/ESB Project (see Appendix F for more information). Hydrogeologic transects along Reach 4B and the Middle Eastside Bypass (see Appendix F, Figures F-2 through F-5) show that there is not a consistent pattern of gaining and/or losing conditions along Reach 4B and the Middle Eastside Bypass. In general, the Reach 4B is more of a gaining stream than the Middle Eastside Bypass because groundwater levels are typically lower than the channel bed elevation and are generally sloping away from the river.

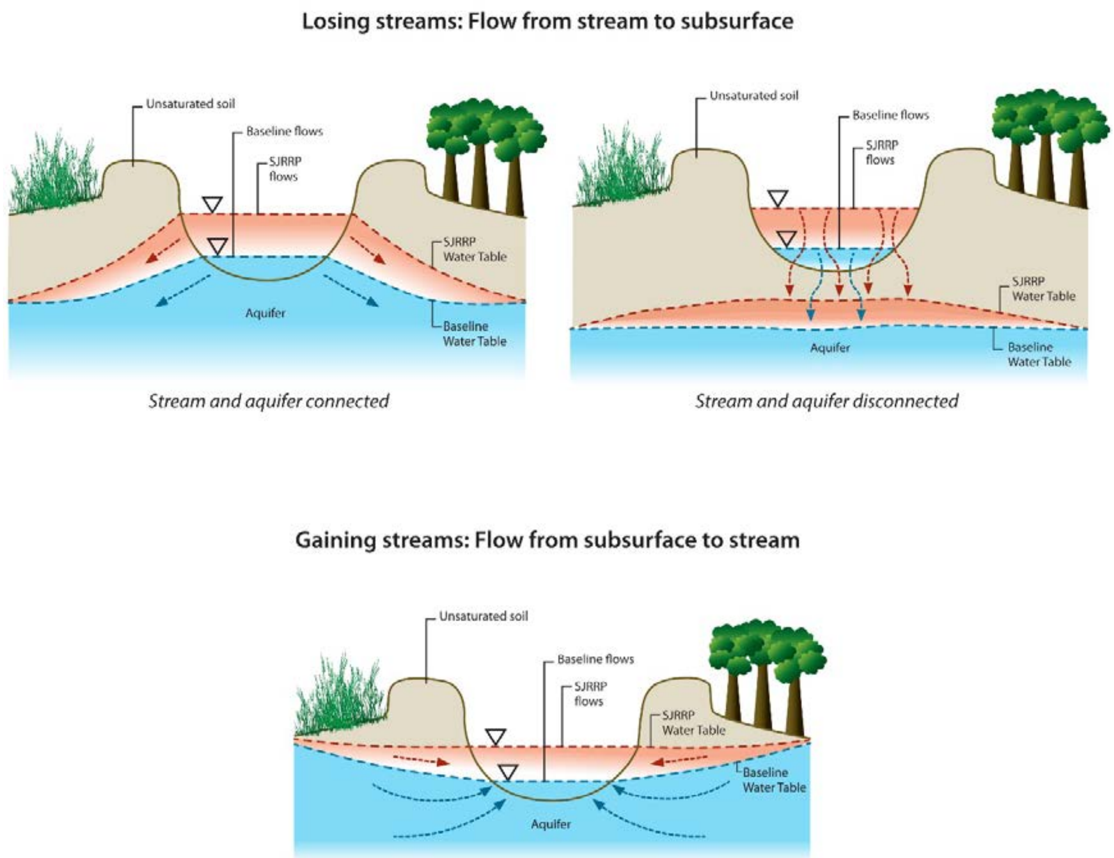


Figure 6-2. Schematic Representation of Changes in Groundwater Levels, Under Losing and Gaining Conditions, due to Increased Streamflow

6.1.3 Local Groundwater Levels

The left bank of Reach 4B overlies the Delta-Mendota groundwater subbasin and the right bank of Reach 4B and the Eastside Bypass overlies the Merced groundwater subbasin. DWR estimated the total storage of the Merced subbasins to be approximately 21.1 million acre-feet (MAF) to a depth of approximately 300 feet and 47.6 MAF to the base of fresh water (DWR 2004) DWR estimates the storage in the Delta-Mendota subbasin to be approximately 30.4 MAF to a depth of approximately 300 feet and 81.8 MAF to the base of fresh water (DWR 2006).

Groundwater levels in the San Joaquin Valley declined heavily from 1920 through the 1960s. Groundwater levels in the southeastern and eastern portions of the valley were less affected due to the availability of surface water for irrigation (USGS undated). Hydrologic transects along Reach 4B and the Middle Eastside Bypass (see Appendix F) show that groundwater levels tend to fluctuate during the year, likely due to agricultural activities. Groundwater levels have also shown a general decline during this period, likely due to the drought conditions. Groundwater monitoring suggests that groundwater levels tend to fluctuate around the elevation of the stream bed around Reach 4B, suggesting that Reach 4B may alternate between gaining and losing conditions. Monitoring indicates a similar trend in the Middle Eastside Bypass. Groundwater levels along the Middle Eastside Bypass may tend to be a bit lower below the riverbed in this area, contributing to a potential losing condition. However, this trend is not consistent among all the monitoring wells and not through the entire data record.

As mentioned previously, the data indicate seasonal fluctuation of groundwater levels within the Project area, likely due to agricultural practices. In addition to the seasonal variations, a general declining trend between 2011 through 2015 can be seen in the data, likely attributed to drought conditions. In general, groundwater levels along the Middle Eastside Bypass are a bit shallower than along Reach 4B (in the shallow aquifer within the Project area). Since restoration flow are not expected to affect the deep aquifer within the Project area, groundwater levels in the deep aquifer were not analyzed.

6.1.4 Local Land Subsidence

Subsidence in the Project area was discussed in detail in Chapter 4, River Geomorphology and Sedimentation. Groundwater-related subsidence in the San Joaquin Valley is primarily attributed to aquifer system compaction due to the lowering of groundwater levels by sustained groundwater overdraft and hydro-compaction of moisture-deficient deposits above the water table. Reclamation has been tracking recent subsidence in the area since 2011. In the upstream end of Reach 4B, subsidence rates average about 0.45 feet/year from 2011 to 2016 (Reclamation 2016).

6.1.5 Local Groundwater Quality

Since 2012 Reclamation has conducted water quality monitoring in the area near Reaches 3, 4A, and 4B to inform potential seepage management decisions (Reclamation 2012, 2013). There are several sampling locations, including both surface water and groundwater, that are local to the Reach 4B/ESB Project area. Results from these sampling events are summarized in Appendix F. Since these results are only grab samples taken during Restoration Flow periods, this information is not sufficient to determine long-term groundwater quality trends in Reach 4B with Restoration Flows. However, results show that groundwater quality typically improves during higher flow periods.

6.1.6 Seepage Management along San Joaquin River

As discussed in the Seepage Management Plan (Reclamation 2017), seepage related effects due to Restoration Flow could occur under both gaining and losing stream conditions. Reclamation is working on implementing seepage projects along Reach 3, Reach 4A and Reach 4B to reduce seepage related impacts. Figure 6-3 identifies parcels along Reach 3 and Reach 4A of the San Joaquin River and the flow thresholds at which seepage issues may occur. As of May 2018, Reclamation has implemented seepage projects on each of the parcels in the “0 – 300 cfs” category, allowing up to 300 cfs of flow in Reach 4A to pass into the Middle Eastside Bypass. Reclamation is continuing to work with landowners in Reaches 3 and 4A to implement seepage projects to allow for increased flow through the San Joaquin River and Eastside Bypass.

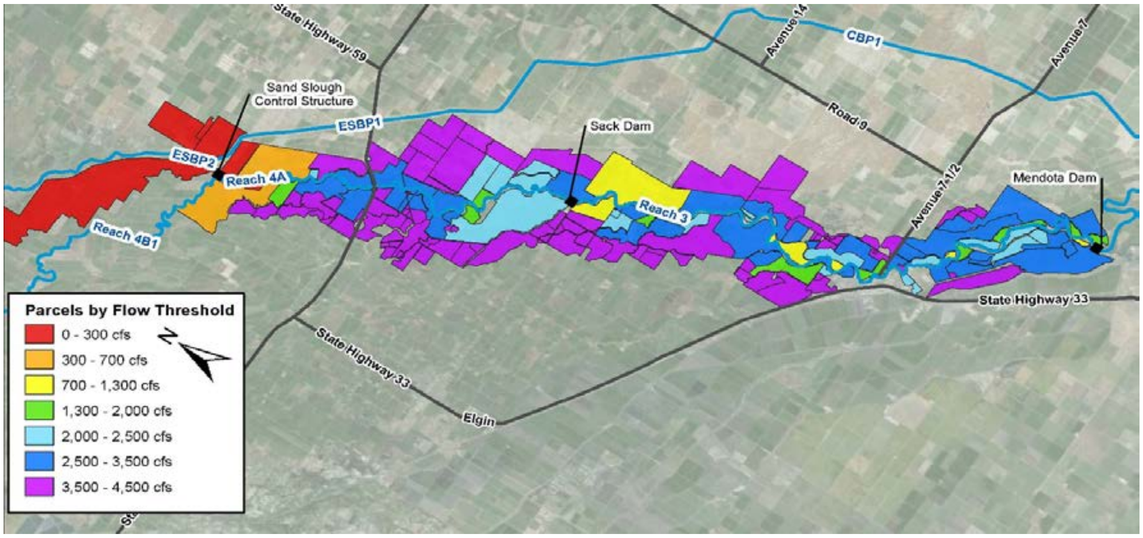


Figure 6-3. Land Parcels along Reach 3 and Reach 4A Prioritized by Allowable Flow in the San Joaquin River

Restoration Flow and seepage projects would operate to maintain groundwater levels below thresholds set forth in the Seepage Management Plan (Reclamation 2017). Thresholds represent surface or groundwater elevations that may risk adverse impacts due to groundwater seepage. Thresholds are set based on one of two methods: agricultural practices and historical groundwater levels. Agricultural practices threshold is set based on effective root zone of crops and a capillary fringe buffer. Table 6-1 below summarizes the root zones established in the Seepage Management Plan. The historical thresholds method makes use of long-term historical groundwater level measurements as well as more recent data without Restoration or Flood flows as a corollary to historical conditions. The threshold is ultimately set as the shallower of the two methods.

Table 6-1. Root Zones Values by Crop Type

Crop	Root Zone Depth from Seepage Management Plan
Sugar beet, lima beans	4 feet
Assumed annual crop, cotton, tomatoes, melon, pistachio, corn, palms, grain (wheat, barley)	5 feet
Alfalfa, grapes, pomegranates, safflower	6 feet
Almonds	6 feet

Source: Seepage Management Plan (Reclamation 2017)

6.2 Alternative Comparison

This section highlights several key issues and how each alternative would function related to these issues.

6.2.1 Changes to Groundwater/Surface Water Interaction

Reach 4B1 and the Middle Eastside Bypass are gaining at times and losing at other times, so increasing the Restoration Flows into these systems could change patterns. A gaining waterway could be helpful in maintaining Settlement flow targets and water temperatures (when the groundwater is cooler than the surface water).

No Action Alternative

Under the No Action Alternative, Restoration Flows up to 2,500 cfs would enter the Middle and Lower Eastside bypasses. Additionally, return flows from seepage management projects could be added to the bypass system. As discussed in Section 6.1.1, the Middle Eastside Bypass is generally a losing stream; therefore, the flow increase in the Eastside Bypass would increase the amount of water the seeps out of the bypass and into shallow groundwater, increasing the recharge to the groundwater table.

Alternative 1 – Main Channel Restoration

Alternative 1 would add Restoration Flows to Reach 4B, which currently only has water from agricultural drainage and local runoff. Adding flows to this reach would change the local hydrogeology. As compared to the No Action Alternative, the increase in flow in Reach 4B1 could cause additional seepage of water from the river to the groundwater system in areas where Reach 4B1 is a losing stream. The increase in flow could also cause less gain of groundwater into the river in areas where Reach 4B1 is gaining.

The SJRRPGW groundwater model was used to simulate conditions to better characterize the interaction between surface water and groundwater (see Appendix F for more details). The model simulates changes in the groundwater system and groundwater/surface water interaction. The model calculated the gain and/or loss between the surface water system and the groundwater system. The model results show that the gains and losses vary spatially and temporally along Reach 4B1 and the Middle Eastside Bypass. Some segments of Reach 4B1 and the Middle Eastside Bypass are calculated to be gaining and others are losing. Portions of these areas switch between gaining and losing conditions even within the same month. Figure 6-4 shows the percent of flow in Reach 4B that would be lost to seepage by month in each year type for Alternative 1. In general, the percent of water lost to seepage is higher during the summer, fall, and early winter months (when Restoration Flows are lower).

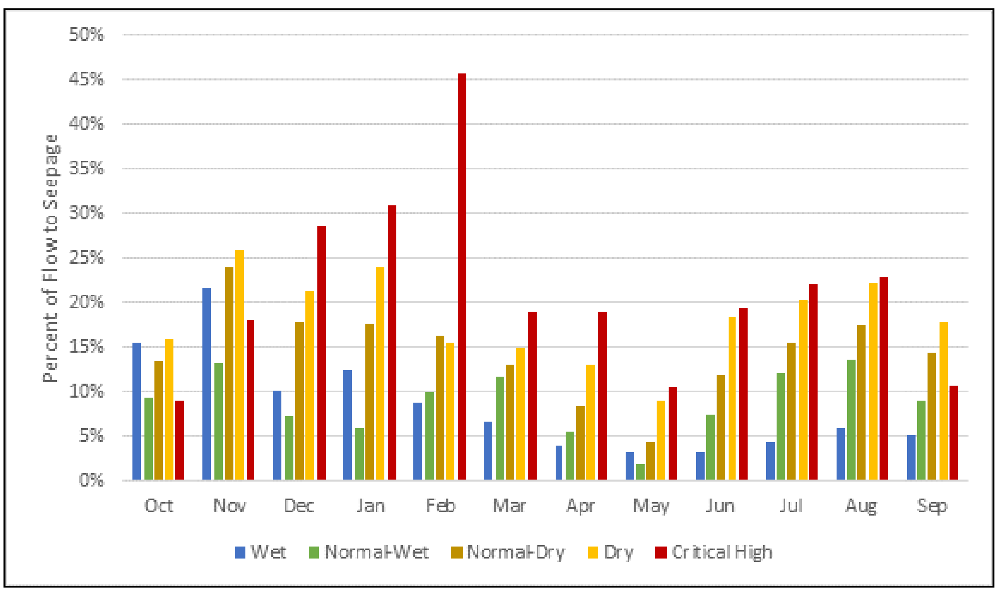


Figure 6-4. Monthly Losses in Reach 4B1 under Alternative 1

Figure 6-5 shows the spatial distribution of gains and losses in Reach 4B and the Middle Eastside Bypass for the month of April during a wet year. The figure demonstrates some segments of Reach 4B1 are gaining and some are losing. The magnitude of net gains and losses also vary spatially. Figures D-20 through D-31 in Appendix F demonstrates the spatial variability of groundwater gains and losses along Reach 4B1 and the Middle Eastside Bypass during the remaining month in 1983 i.e. wet hydrologic conditions. Overall Reach 4B1 has a higher rate of seepage loss than the Middle Eastside Bypass.

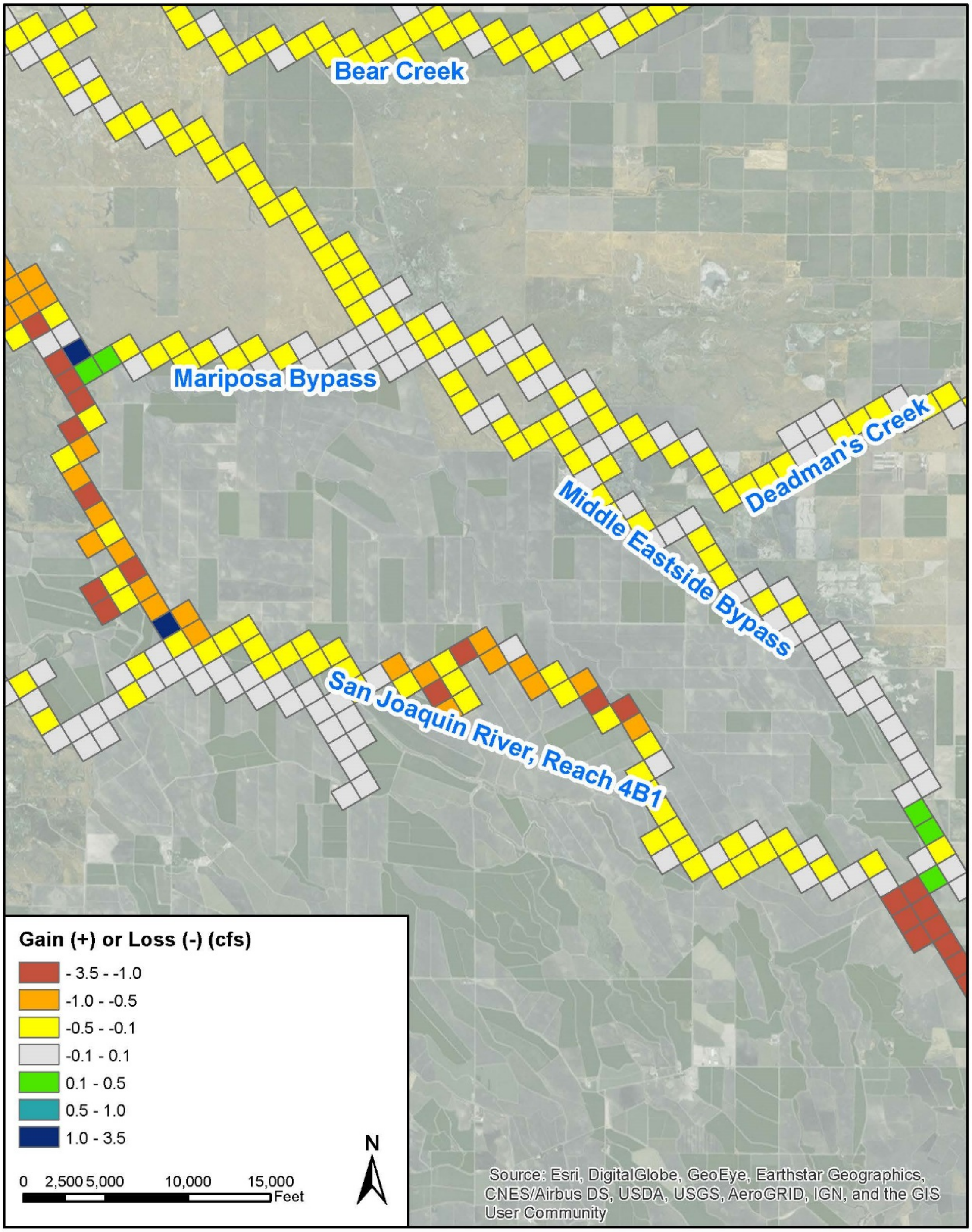


Figure 6-5. Simulated Average Monthly Gains/Losses along Reach 4B1 and the Middle Eastside Bypass, based on April 1983 (Wet Year Type) Hydrologic Conditions under Alternative 1

Under Alternative 1, the San Joaquin River would have a capacity of 4,500 cfs and would receive all Restoration Flow. The routing of Restoration Flow down Reach 4B1 rather than down the Middle Eastside Bypass would result in additional groundwater recharge within the Reach 4B/ESB Project area, as compared to the No Action Alternative, there would be a net increase in groundwater volume resulting from this recharge.

Alternative 2 – Bypass Restoration

Alternative 2 would have increased Restoration Flow in the Mariposa and Middle Eastside bypasses. Adding flows to this reach would change the local hydrogeology. As compared to the No Action Alternative, the increase in flow in the Middle Eastside Bypass could cause additional seepage of water from the bypass to the groundwater system in areas where Middle Eastside Bypass is a losing stream. The increase in flow could also cause less gain of groundwater into the river in areas where Middle Eastside Bypass is gaining.

The SJRRPGW groundwater model was used to simulate conditions to better characterize the interaction between surface water and groundwater. The model simulates groundwater conditions based on the Restoration and Flood Flows in Reach 4B1 and the Middle Eastside Bypass. Similar to results under Alternative 1 flows, the model found that groundwater flows into and out of the river would vary spatially and temporally, with some segments of Reach 4B1 and the Middle Eastside Bypass switching from gaining to losing streams within the same month. The Middle Eastside Bypass is mostly a losing reach, Figure 6-6 shows the average monthly variability of gains and losses in the Middle Eastside Bypass. The summer, fall, and early winter months (when Restoration Flows are lower) are where the most losses, on average, are calculated to occur.

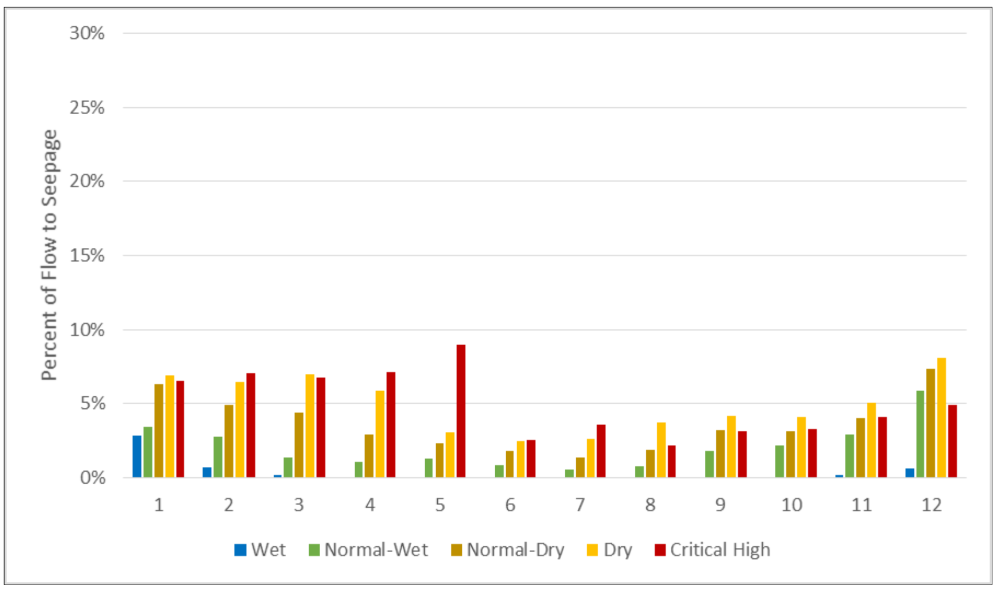


Figure 6-6. Monthly Losses in the Middle Eastside Bypass under Alternative 2

Figure 6-7 shows the show the spatial variability of groundwater flows within Reach 4B1 and the Middle Eastside Bypass for the month of April under wet hydrologic conditions. Figures D-34 through D-45 show the spatial variability of groundwater flows for the remaining months under wet hydrologic conditions. During this period, all Restoration Flow would be routed through the Middle Eastside Bypass (ranges from 45 to 5,600 cfs). The Middle Eastside Bypass is mostly a losing a stream during the wet year. The figures show the distribution of areas with gain and/or loss is not uniform across the entire length and time.

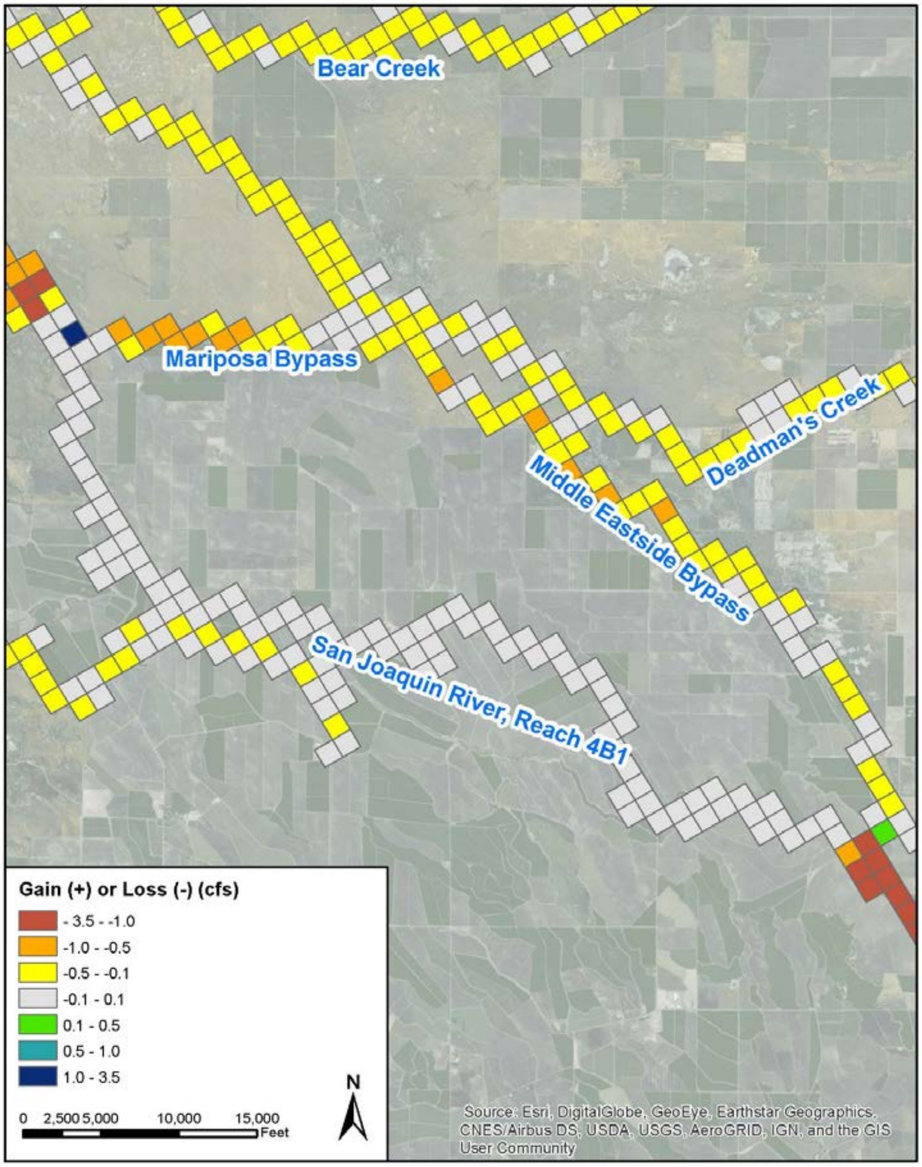


Figure 6-7. Simulated Average Monthly Gains/Losses from Reach 4B1 and the Middle Eastside Bypass, based on April 1983 (Wet Year Type) Hydrologic Conditions under Alternative 2

The routing of Restoration Flow down the Middle Eastside Bypass would result in increased groundwater recharge around the bypass system, and there would be a net increase in groundwater volume.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 was not simulated using the SJRRPGW groundwater model. Since flow routing under Alternative 3 is very similar to routing under Alternatives 1 and 2, results from these simulations were used to qualitatively analyze impacts under this alternative.

6.2.2 Changes to Groundwater Levels

Adding Restoration Flows to the Reach 4B/ESB Project area would affect shallow groundwater levels, which could affect agricultural and environmental resources in the area.

No Action Alternative

The No Action Alternative includes improvements that would accommodate Restoration Flows of up to 2,500 cfs in the Eastside Bypass. As discussed above, the Middle Eastside Bypass is generally a losing stream; therefore, the flow increase in the Eastside Bypass would likely increase shallow groundwater levels adjacent to the bypass. The No Action Alternative includes a cutoff wall for levee stability and seepage reduction in the upstream portion of the Middle Eastside Bypass. Because this area is typically a losing reach, the cutoff wall would reduce groundwater levels. These areas are currently affected by seepage-related effects, so a reduction in groundwater levels in the shallow aquifer would not be adverse.

In addition to the channel modification, early implementation actions would include the replacement of a groundwater well near the Merced NWR. The new groundwater well near the refuge would have a capacity of 1,500 gallons per minute (gpm) and would be screened at less than 400 feet below ground surface (bgs), in the shallow aquifer. Increased groundwater pumping in the shallow aquifer, combined with the increased groundwater recharge, is not expected to have an adverse impact on shallow groundwater levels.

Alternative 1 – Main Channel Restoration

Under Alternative 1, Restoration Flows would be introduced into Reach 4B1. Because the Reach 4B1 channel is mostly a losing stream, the increased flows would cause an increase in seepage from the river into the groundwater. This seepage could increase the shallow groundwater levels in the areas surrounding the Reach 4B1 channel. Areas of the river that may have been gaining under the No Action Alternative would gain less water with Alternative 1 because of the higher river levels. Higher river levels could change the slope of the groundwater such that that water either moves into the river more slowly or starts moving out of the river. This reduction in groundwater flow from the shallow aquifer to the stream would result in higher groundwater levels surrounding the Reach 4B1 channel. Alternative 1 includes seepage actions (either realty actions, a seepage berm, or a slurry wall) throughout Reach 4B1 to prevent impacts to neighboring landowners associated with the higher groundwater levels.

Alternative 2 – Bypass Restoration

Under Alternative 2, Restoration Flows would be introduced into the Middle Eastside Bypass. Because the Middle Eastside Bypass channel is mostly a losing stream, the increased flows would cause an increase in seepage from the river into the groundwater. This seepage could increase the shallow groundwater levels in the areas surrounding the Middle Eastside Bypass channel. Areas of the bypass that may have been gaining under the No Action Alternative would gain less water with Alternative 2 because of the higher river levels. Higher surface water levels could change the slope of the groundwater such that that water either moves into the bypass more slowly or starts moving out of the river. This reduction in groundwater flow from the shallow aquifer to the stream would result in higher groundwater levels surrounding the Middle Eastside Bypass channel.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 would increase flows into both the Reach 4B and Eastside Bypass channels. Similar to Alternatives 1 and 2, these increased flows would increase shallow groundwater levels near the channels.

6.2.3 Subsidence

Subsidence in the Project area was discussed in detail in Chapter 4, River Geomorphology and Sedimentation. Increased Restoration Flows under Alternatives 1, 2 and 3 would all result in increased groundwater levels in the Project area. A net increase in shallow groundwater levels under the alternatives could potentially reduce hydro-compaction related subsidence in the Project area but would not be expected to reverse subsidence.

Chapter 7 Fisheries and Wildlife

Fisheries restoration is one of the main goals of the SJRRP, and restoration actions need to consider the potential benefits or impacts to other wildlife in the Project area. This section describes existing wildlife and the potential future conditions for fisheries and wildlife under the different alternatives.

7.1 Setting

7.1.1 Historical Setting

Typical of Central Valley rivers and a semiarid climate, the natural or "unimpaired" flow regime of the San Joaquin River historically varied greatly in the magnitude, timing, duration, and frequency of streamflows, both interannually and seasonally (SJRRP 2011a). Streamflow variability created conditions that partially helped create and sustain multiple salmonid life history strategies and life history phases of numerous other resident and anadromous native fish and other aquatic species.

The San Joaquin River originates in the Sierra Nevada at an elevation greater than 13,000 feet above mean sea level (SJRRP 2011a). It rapidly descends and exits mountainous terrain in the area now occupied by Friant Dam. The San Joaquin River downstream from Friant Dam consists of a deeply incised channel that discharges to the valley floor near Gravelly Ford. Before the influx of settlers in the 1860s, and subsequent agricultural development, the San Joaquin River and its main tributaries meandered across alluvial fans, deposits of river sediments resulting from a decrease in velocity, along the main axis of the San Joaquin Valley floor in their natural state.

In the San Joaquin Valley downstream from Mendota, in the present area of the Reach 4B/ESB Project study area, the San Joaquin River was a meandering sand-bedded channel with numerous anabranching sloughs with base flows being conveyed by both the San Joaquin River channel and the sloughs (McBain and Trush 2002). Narrow riparian levees provided moderate confinement of the river on both banks, with large areas of tule marsh flood basins being present past the riparian levees (The Bay Institute 1998, McBain and Trush 2002). Oxbow lakes and off-channel ponds within the flood basins were likely present (McBain and Trush 2002). The flood basins extended for miles on both sides of the San Joaquin River in Reach 4B (McBain and Trush 2002). Channel migration and avulsion were likely very slow and infrequent due to the low sediment supply, as a result of deposition in upstream reaches, and low stream energy as high flows spilled over the narrow riparian levees into the flood basins (McBain and Trush 2002). With the limited channel confinement provided by the riparian levees, overbank inundation of the flood basins probably occurred most years and was of long duration, on the order of months (McBain and Trush 2002). The prolonged inundation of sloughs and flood basins likely provided high flow refugia and rearing habitat for juvenile salmonids and other native fishes (McBain and Trush 2002).

7.1.2 Reach 4B/ESB Project Habitat

Reach 4B

The Reach 4B1 channel no longer receives flow from upstream reaches and has become poorly defined and filled with dense vegetation. In addition, Reach 4B1 is confined by anthropogenically-modified narrow levees. Reach 4B2 begins at the confluence of the Mariposa Bypass, where flood flows in the bypass system rejoin the main stem of the San Joaquin River, and this reach extends to the confluence of the Eastside Bypass.

Reach 4B2 contains wider floodplains and a more sinuous channel, including side channels and oxbows, because of a wider levee configuration than Reach 4B1. Additionally, it contains vast areas of grasslands and riparian vegetation stands.

Eastside Bypass and Mariposa Bypass

The Eastside and Mariposa bypasses typically only convey flood flows, typically for periods during November 15 to June 15. Apart from the flood flows, the bypass system has water in some areas because it conveys water for the Merced NWR and has ponding in low-lying areas. The bypass system is not hydraulically connected upstream and downstream outside of flood periods.

NWR System

The Reach 4B/ESB Project area includes portions of the San Luis NWR Complex. Portions of the Merced NWR, a component of the overall San Luis NWR Complex, are within the Middle Eastside Bypass. Portions of the San Luis NWR are also within Reach 4B2. The San Luis NWR Complex and the Grasslands area are components of the most important remaining wetland complexes in western North America. They provide habitat for millions of water birds, including waterfowl, shorebirds, and wading/diving birds.

The primary goal of wetland management is to produce a variety of high quality habitats for migratory birds and other wetland-dependent wildlife. These include mudflats for foraging shorebirds, shallow wetlands with moist soil food plants for waterfowl and wading birds, open water interspersed with emergent vegetation for resting and thermal cover, cattail/bulrush stands for nesting and roosting, summer wetlands for resident birds and other water-dependent wildlife, and deeper water habitats for diving ducks, grebes, cormorants, pelicans, and lesser sandhill crane.

Because of the importance of the San Luis NWR Complex to wintering waterfowl, and the need of providing food for the hundreds of thousands of waterfowl and shorebirds that use the refuge units each winter, seasonal marshes make up the dominant wetland type (85-90 percent). Individual seasonal wetlands are dewatered on a staggered basis from late February through May to germinate moist soil plants and provide mudflat foraging habitat for shorebirds through the spring. They are irrigated one to three times in the spring and summer, depending on management objective; and then flooded on a staggered basis from early September through late November. The timing of drawdown, number of irrigations, duration of irrigations, soil type, and other conditions determine the resulting composition of moist soil plant species and robustness of growth and seed production.

Semi-permanent wetlands are typically kept inundated from November through August to provide summer water for locally breeding waterbirds. Permanent wetlands usually have a lower density of breeding birds, but have greater numbers of cormorants, pelicans, western and Clark's grebes, and molting ducks than seasonal or semi-permanent wetlands. Productivity of permanent wetlands declines after the first two or three years of inundation and the numbers of most species using those ponds decrease. Therefore, they are drained about once every three to five years to oxidize the soils/sediments to re-stimulate productivity, and to eliminate populations of carp and bullheads, whose presence reduce growth of submerged aquatic vegetation.

7.1.3 Fish Species

Fish communities in the San Joaquin Reach 4B/ESB Project study area have changed markedly in the last 150 years (SJRRP 2011b). Native fish assemblages were adapted to widely fluctuating riverine conditions, ranging from large winter and spring floods to low summer flows, and had migratory access to extensive upstream habitats. These environmental conditions resulted in a broad diversity of fish species, including anadromous species. Fishes that may have historically occurred, as well as those that currently inhabit the Reach 4B/ESB Project area, are listed in Table 7-1. Table 7-1 also includes fish in other reaches for informational purposes because the reconnected river may cause fish that are upstream or downstream to be periodically present (or recolonize) the Reach 4B/ESB Project Area. Appendix G includes descriptions of these species.

Table 7-1. Fish species with historic or current presence within or near the Reach 4B/ESB Project area

Category	Species	Scientific Name	Federal/State Status[2]	Current Presence in Project Area
Native Anadromous	Central Valley Spring-run Chinook Salmon[3]	*Oncorhynchus tshawytscha*	T/T	Yes; Periodic[3,4], reintroduction as a Nonessential Experimental Population
	Central Valley Fall-run Chinook Salmon[5]	*Oncorhynchus tshawytscha*	SC/ SSC	Yes; Periodic[4]
	California Central Valley steelhead	*Oncorhynchus mykiss*	T/SSC	No; Rainbow trout observed in Reach 1 (likely hatchery released). Only anecdotal evidence of historic presence in Restoration Area.
	North American Green Sturgeon	*Acipenser medirostris*	T/SSC	No; Only anecdotal evidence of historic presence in Restoration Area
	White Sturgeon	*Acipenser transmontanus*	--/SSC	Yes[6]; Observed by DIDSON in Reach 5
	River Lamprey	*Lampetra ayersii*	--/SSC	Unknown; have not been observed in Restoration Area during surveys
	Pacific Lamprey	*Entosphenus tridentata*	--/SSC	Yes; observed in Reaches 1 and 2
Native Resident	Sacramento Hitch	*Lavinia exilicauda exilicauda*	--/SSC	Observed in Reach 2,3, and 5
	Sacramento Blackfish	*Orthodon microlepidotus*		Yes
	Sacramento Splittail	*Pogonichthys macrolepidotus*	--/SSC	Yes; Periodic
	Sacramento Perch	*Archoplites interruptus*	--/SSC	No
	Hardhead	*Mylopharodon conocephalus*	--/SSC	Yes; Observed in Reach 1
	Sacramento Pikeminnow	*Ptychocheilus grandis*		Yes; Observed in Reaches 1 and 2
	Sacramento Sucker	*Catostomus occidentalis occidentalis*		Yes
	Tule Perch	*Hysterocarpus traski*		Yes; Observed in Reaches 2,3, and 5
	Prickly Sculpin	*Cottus asper*		Yes
	Riffle Sculpin	*Cottus gulosus*	--/SSC	Yes

Category	Species	Scientific Name	Federal/State Status[2]	Current Presence in Project Area
	Threespine Stickleback	*Gasterosteus aculeatus*		Yes
Native Resident Lamprey	Kern Brook Lamprey	*Lampetra hubbsi*	--/SSC	Yes; Observed in Reaches 1 and 2
Non-native Invasive Anadromous	Striped Bass	*Morone saxatilis*		Yes
Non-native Invasive Resident	Black Bullhead	*Ameiurus melas*		Yes
	Brown Bullhead	*Ameiurus nebulosus*		Yes
	Channel Catfish	*Ictalurus punctatus*		Yes
	White Catfish	*Ameirurus catus*		Yes
	Bigscale Logperch	*Percina macrolepida*		Yes
	Fathead Minnow	*Pimephelas promelas*		Yes
	Inland Silverside	*Menidia beryllina*		Yes
	Red Shiner	*Cyprinella lutrensis*		Yes
	Golden Shiner	*Notemigonus crysoleucas*		Yes
	Goldfish	*Carassius auratus*		
	Western Mosquitofish	*Gambusia affinis*		Yes
	Common Carp	*Cyprinus carpio*		Yes
	Shimofuri Goby	*Tridentiger bifasciatus*		Yes
	Black Crappie	*Pomoxis nigromaculatus*		Yes
	White Crappie	*Pomoxis annularis*		Yes
	Bluegill	*Lepomis macrochirus*		Yes
	Green Sunfish	*Lepomis cyanellus*		Yes
	Pumpkinseed	*Lepomis gibbosus*		No; observed in Reach 5
	Redear Sunfish	*Lepomis microlophus*		Yes
	Warmouth	*Lepomis gulosus*		Yes
	Large Scale Loach	*Paramisgurnus dabryanus*		No; observed in Reach 2
	Spotted Bass	*Micropterus punctulatus*		Yes
	Largemouth Bass	*Micropterus salmoides*		Yes
	Threadfin Shad	*Dorosoma petenense*		Yes

[1] Current fish presence information in Reach 4B is from San Joaquin River fish assemblage monitoring conducted during 2012 to 2018 (SJRRP 2014, 2017, personal communication). Current presence in Reach 4B is indicated as yes or no with

Category	Species	Scientific Name	Federal/State Status[2]	Current Presence in Project Area

current presence in other reaches in the Restoration Area included to reflect that fishes that are present in other reaches of the Restoration Area may be present in Reach 4B in the future when connectivity is improved.

[2] SC = Federal Species of Concern, SSC = California Species of Special Concern, T = Federally or State Threatened

[3] CV Spring-run Chinook Salmon are a focus of SJRRP reintroduction activities. Current presence of CV spring-run Chinook Salmon juveniles and adults are from hatchery reared and released individuals.

[4] Periodic is mentioned here to reflect that Reach 4B is/will be primarily a migratory corridor for Chinook Salmon with adults passing through on their upstream migration and juveniles on their downstream migration. Chinook Salmon are not expected to be present in Reach 4B year round. Additionally, current presence in Reach 4B is largely based on human intervention in the form of release of hatchery fish (spring-run Chinook Salmon) and trap and haul of fall-run Chinook Salmon.

[5] Fall-run Chinook Salmon are present in the Restoration Area primarily due to trap and haul of fall-run Chinook Salmon adults (SJRRP 2012).

[6] CDFG report card data 2009 indicated a White Sturgeon was captured in Reach 4B.

Due to the numerous fish barriers present in the Reach 4B/ESB Project area and lack of adequate flows, native anadromous fish species historically present in the Restoration Area cannot access the Reach 4B/ESB Project area and reaches upstream except in the wettest years. Therefore, all anadromous salmonids effectively have been extirpated from the Restoration Area because rare and inconsistent access has not allowed viable populations to persist. Furthermore, extreme habitat degradation and unsuitably high-water temperatures has made aquatic habitat in the Restoration Area unsuitable for most life stages of native anadromous fish species. Appendix G includes a detailed description of the stressors in the Restoration Area. Since there is only anecdotal evidence of the historical use of the San Joaquin River by North American green sturgeon (Beamesderfer et al. 2002, Jackson and Van Eenennaam 2013) this species is not further discussed in this document. In order for native anadromous fish to return to the Restoration Area, they need adequate flows, removal of fish passage barriers, suitable temperatures, and available aquatic habitat throughout the river area.

Figure 7-1 shows the life cycle for salmon, with the stages in gray that would not occur in the Reach 4B/ESB Project area. The Reach 4B/ESB Project must provide upstream migration habitat, including holding or refuge habitat, for adult salmon to allow them to move upstream without expending large amounts of energy. Additionally, the Reach 4B/ESB Project must provide juvenile salmon with downstream migration habitat, including feeding and holding habitat to support rearing of downstream migrants (transient rearing) and floodplain habitat. Spawning is anticipated to occur in upstream reaches and would not occur in the Reach 4B/ESB Project area.

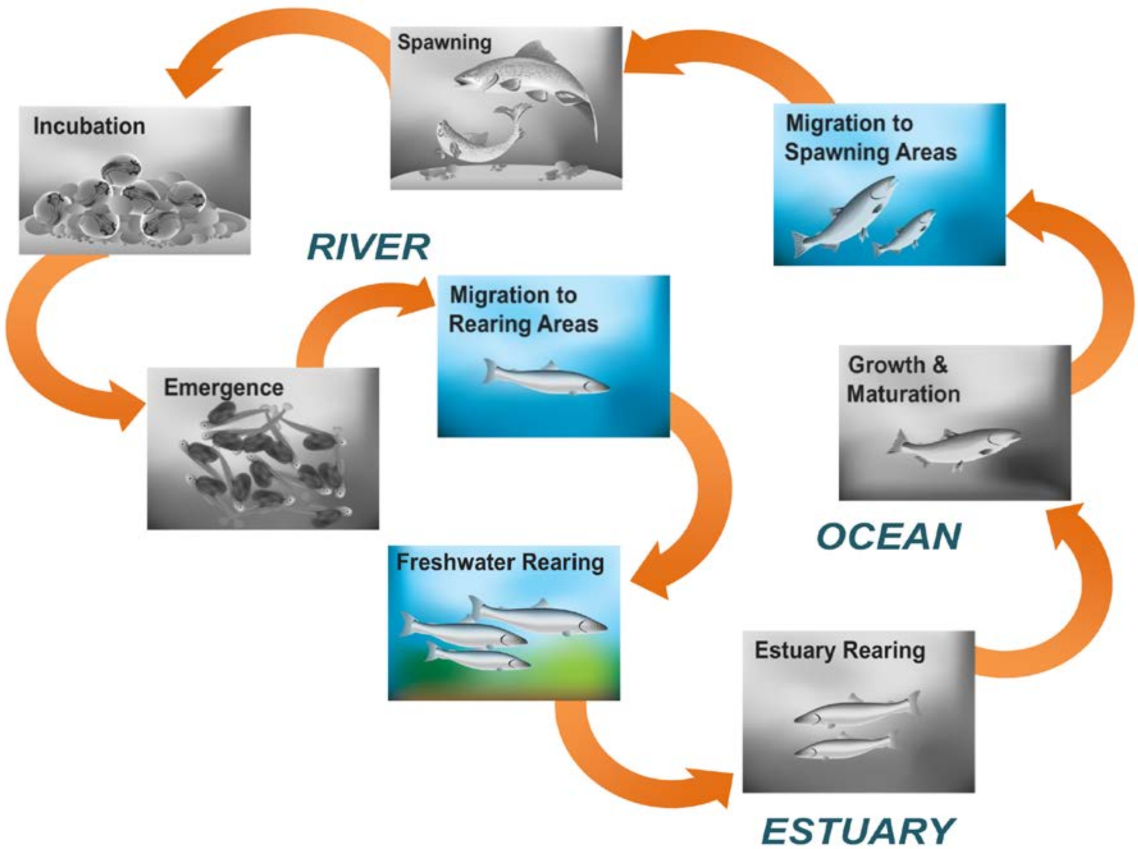


Figure 7-1. Salmon Life Cycle

7.1.4 Birds

Waterfowl

The refuge units, including the Merced NWR, form a major migration and wintering use area for Pacific Flyway waterfowl. Annual peak numbers of ducks and geese recorded at San Luis NWR, Merced NWR, and the Grasslands WMA have ranged from 800,000 to 1,400,000 during the past 10 winters (Service Midwinter Waterfowl Survey data). This represents about 25 percent of the waterfowl population wintering in the Central Valley of California. Thirty-two species of waterfowl have been recorded using the area. The most common ducks wintering on or near the refuges include northern pintail (*Anas acuta*), green-winged teal (*Anas crecca*), mallard (*Anas platyrhynchos*), northern shoveler (*Anas clypeata*), gadwall (*Anas strepera*), ring-necked duck (*Aythya collaris*), American wigeon (*Anas americana*), wood duck (*Aix sponsa*), and cinnamon teal (*Anas cyanoptera*). Diving duck species such as canvasback (*Aythya valisineria*), redhead (*Aythya americana*), common goldeneye (*Bucephala clangula*), and bufflehead (*Bucephala albeola*) are present in smaller numbers. The most common geese include Ross' goose (*Chen rossii*), lesser snow goose (*Chen caerulescens*), and greater white-fronted goose (*Anser albifrons*). Various subspecies of Canada and cackling geese; including the Aleutian cackling goose (*Branta hutchinsii leucopareia*), cackling goose (*B. h. minima*) and western Canada goose (*Branta canadensis moffitti*), are present in smaller numbers. Tundra swans (*Cygnus columbianus*) are seen on a regular basis. Species seen infrequently, or as accidentals, include trumpeter swan (*Cygnus buccinator*), brant (*Branta bernicla*), blue-winged teal (*Anas discors*), Eurasian wigeon (*Anas penelope*), and hooded merganser (*Lophodytes cucullatus*).

Species distribution varies throughout the area based on habitat attributes of the different refuge units. Fee-title and easement refuge lands east of the San Joaquin River (East Grasslands) are characterized by extensive floodplain grasslands interspersed with managed wetlands. The majority of the geese in the "Grasslands", especially Ross' and lesser snow geese use this area, as well as pintail, American wigeon, and other ducks. Greatest use of the East unit of the Grasslands WMA occurs in January – March following late winter rainfall and green-up of the annual grasses.

Waterfowl also use the area during the breeding season. Twelve species of duck and one goose species have been recorded as nesting on refuge lands. The most common nesting species are mallards, gadwall, and cinnamon teal. Wood ducks are becoming more common as a nesting species due to nest boxes being put out as a part of the statewide California Wood Duck Program.

Shorebirds

The Grasslands, representing about a third of California's remaining wetland habitat, is one of the most important shorebird habitats on the west coast of the United States. This area has been designated as one of only 22 international shorebird reserves in the world. Populations of shorebirds are present on the refuges and easement lands throughout the year, with the highest numbers occurring during the non-breeding season. Approximately 25 species of shorebirds make use of the "Grasslands" throughout the year. Large scale shorebird censuses in the area have documented 200,000 individuals (mainly Western Sandpipers [*Calidris mauri*], long-billed dowitchers [*Limnodromus scolopaceus*], dunlins [*Calidris alpine*], and least sandpipers [*Calidris minutilla*]) during the spring, and up to 14,000 shorebirds (mainly long-billed dowitchers [*Limnodromus scolopaceus*], least sandpipers [*Calidris minutilla*], and black-necked stilts [*Himantopus mexicanus*]) during the autumn (Shuford et al. 1998). The difference in shorebird numbers between the spring and fall is due to the migratory route that many species follow. Many species tend to follow more coastal routes during the fall, and more inland routes during the spring. Populations of killdeer (*Charadrius vociferous*), black-necked stilts (*Himantopus mexicanus*), and American avocets (*Recurvirostra Americana*), breed annually in the San Luis NWR Complex. Seasonal wetlands are managed to provide mud flat and shallow water habitat for foraging shorebirds. Irrigated pastures, alfalfa fields, and, to a lesser extent, native uplands are also used by longer billed species for foraging, such as long-billed curlew (*Numenius americanus*), whimbrel (*Numenius phaeopus*), and marbled godwit (*Limosa fedoa*). These habitats support large numbers of aquatic invertebrates and other insects used by shorebirds to replenish nutrient reserves lost during long migrations.

Wading/Diving Birds

Numerous species of wading and diving birds make use of the wetland, riparian, and upland habitats found on San Luis NWR, Merced NWR, and the Grasslands WMA. Great blue herons (*Ardea herodias*), great egrets (*Ardea alba*), and double crested cormorants (*Phalacrocorax auritus*) have established several rookeries in riparian areas on refuge and easement lands. Rookeries begin to develop in late February and young are usually fledged by July. Within wetland units, snowy egrets (*Egretta thula*), cattle egrets (*Bubulcus ibis*), and black-crowned night herons (*Nycticorax nycticorax*) establish roosting and breeding colonies in robust emergent vegetation. While large flocks of white-faced ibis (*Plegadis chihi*) are common during winter months in the Grasslands, breeding colonies have only been documented once in the past 20 years. In 1991 a colony of approximately 5,000 adults was established on the Kesterson unit of San Luis NWR. More solitary wading species such as, Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), American bittern (*Botaurus lentiginosus*), least bittern (*Ixobrychus exilis*), common moorhen, and American coot are common year-round and breed annually in permanent wetlands throughout the refuges and easement lands. Pied-billed grebes (*Podilymbus podiceps*) are a common year-round species in seasonal and permanent wetlands throughout the Grasslands. Western and Clark's grebes are common during the spring and often breed in permanent wetlands when open water and emergent vegetation are interspersed at suitable levels. Large numbers of American white pelicans (*Pelecanus erythrorhynchos*) make use of wetlands during winter months for foraging and roosting, however this species does not breed in the Central Valley.

7.2 Alternative Comparison

This section highlights several key issues and how each alternative would function related to these issues.

7.2.1 Construction-Related Effects on Fish

The No Action Alternative would allow access for fish into the Middle and Lower Eastside Bypass by improving levee conditions and removing fish passage barriers. Construction activities within the bypass system (associated with Alternatives 2A, 2B, and 3) could directly affect fish in the waterway or cause water quality conditions that would affect fish. Limiting the construction season to July 15 to November 1 and implementing Best Management Practices during construction would reduce potential effects. None of the action alternatives would cause adverse effects on fish in the bypass system.

7.2.2 Effects on Wildlife

Changes to available habitat for each alternative are analyzed in Chapter 5, "Vegetation and Soils." The presence of the Merced NWR within the Middle Eastside Bypass also creates the potential for effects to the waterfowl, shore birds, and wading/diving ducks that rely on the managed seasonal wetlands in this area.

No Action Alternative

The No Action Alternative includes the Eastside Bypass Improvements Project, which will make changes within the Merced NWR (including removal of existing water supply weirs, construction of a new well, and levee stability actions). This project was designed to avoid potential effects to managed seasonal wetlands in the NWR complex. The new groundwater well would offset water supply changes associated with removal of the existing weirs. The levee stability actions are focused on slurry walls because seepage berms would have a larger footprint and affect more wetland areas. The changes to the managed seasonal wetland areas would be small.

Alternative 1 – Main Channel Restoration

Alternative 1 would focus restoration actions within the Reach 4B1 channel and would have limited effects on managed seasonal wetlands. The restored areas would provide increased habitat for wildlife within the Project area.

Alternative 2 – Bypass Restoration

Alternative 2 would set back the Middle Eastside Bypass levees to increase floodplain habitat and increase vegetation within the bypass. The restored areas would provide increased habitat for wildlife within the Project area. In some areas, the new levees would incorporate Merced NWR managed seasonal wetlands into the floodplain habitat. Construction activities associated with Alternative 2 could temporarily disrupt wildlife movement. The new setback levees would be constructed near managed seasonal wetlands that are wintering habitat for waterfowl and shorebird species. The proximity of the new levees to managed seasonal wetlands could interfere substantially with the movement of waterfowl and shorebirds. Managed wetland near the new levees would be used less for landing and take-off by waterfowl and shorebird bird species, reducing the effective habitat area.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 would increase available habitat in the Reach 4B1 channel and the Eastside Bypass, but the improvements in both channels would be smaller than under Alternatives 1 and 2 (because Alternative 3 does not incorporate setback levees). Alternative 3 would not incorporate additional construction within the Merced NWR beyond what is included in the No Action Alternative.

7.2.3 Water Temperature

Because salmonids are the most temperature intolerant of the special-status fish species that could occur in the Project area, the impact of changes in water temperature was evaluated for salmonids in the life stages expected to occur within the Project area (juveniles and adults).

The temperature of water released from Friant Dam generally ranges from 48 to 58°F (8.9 to 14.4°C), and water temperatures are expected to be suitable for juvenile Chinook Salmon rearing and over summer holding of adult spring-run Chinook Salmon except in the downstream reaches (Reaches 2B to 5) as water temperatures increase. However, during recent drought years the temperature of water released from Friant Dam during the fall can be greater than 70°F (21.1°C). In 2014, maximum daily water temperature at the San Joaquin below Friant Dam CDEC gage (SJF) exceeded 70°F for 41 days, primarily in September and October. Similarly, in 2015 the maximum daily water temperature at SJF exceeded 70°F for 38 days, primarily in September and October. Maximum daily water temperatures which exceed 70°F in the San Joaquin River below Friant Dam only occur in critical dry water years, particularly during droughts when there are successive critical dry years. Between 1901 and 2017 there were 22 critically dry years in the San Joaquin Valley resulting in approximately 19% of years being critically dry. However, there were only six times in that same time period when successive years of critically dry years occurred. Unsuitably high water temperatures in downstream reaches of the Restoration Area and exaggerated fluctuations in water temperature result from a combination of factors, including seasonally high air temperatures (May through September), low flow releases, groundwater pumping that has eliminated the inflow of cool groundwater throughout the Restoration Area, absence of extensive gallery riparian forests that historically provided shade, warm agricultural runoff, and warm flood flows from the Kings River through the James Bypass (SJRRP 2010a).

Water temperatures that exceed 70°F (21.1°C) are considered deleterious to juvenile Chinook Salmon growth and maturation as well as successful migration of adult salmon. The juvenile Chinook Salmon growth rate and smoltification index (index of changes to adapt to saltwater) have been observed to increase with increasing water temperatures up to 68°F (20°C) (Marine 1997, Cech and Myrick 1999, Myrick and Cech 2002, Marine and Cech 2004) and decline at temperatures above 68°F (20°C) (Marine 1997, Marine and Cech 2004).

Juvenile fall-run and spring-run Chinook Salmon emigrate during November through June in most Central Valley rivers where they exist, including San Joaquin River tributary populations (Cramer Fish Sciences 2012). Water temperature modeling suggests that water temperatures in the Reach 4B/ESB Project area under existing conditions (which includes some Restoration Flows) would reach critical to lethal levels for juvenile salmon in most years around mid-May and by early May in dry years and by mid-July in wet years (SJRRP 2012a). These results suggest that Reach 4B/ESB water temperatures during May and June may be unfavorable for juvenile salmonid migration, depending on flows.

Upstream migration of spring-run Chinook Salmon in the Feather River Basin has been observed to occur during March through May (Massa et al. 2010, Massa et al. 2009). The upstream migration timing of spring-run Chinook Salmon in the San Joaquin River is expected to be similar to the migration timing in the Feather River (SJRRP 2010b). HEC-5Q temperature modeling results suggest water temperatures within Reach 4B2 and the bypass system exceed the tolerance levels of juvenile salmonids and adult spring-run Chinook Salmon in late spring and summer. Results indicate that water temperatures in Reach 4B2 and the bypass reach stressful levels for adult Chinook Salmon migration in mid-April during dry years and late May in wet years (SJRRP 2012a). The results suggest that Reach 4B water temperatures are likely unfavorable for spring-run Chinook Salmon during the latter portion of their run timing, depending on flow levels.

Water temperature monitoring during fall 2012 in Reach 4B2 and the Eastside Bypass found consistent pool stratification and bottom temperatures below 68°F (20°C) (Butler 2013), indicating suitable habitat for migrating fall-run Chinook Salmon in the Reach 4B/ESB Project area. In the Eastside Bypass during late October, pool bottom temperatures remained near 59°F (15°C) even when pool surface temperatures approached 70°F (21.1°C) (Butler 2013). In Reach 4B2, pool bottom temperatures ranged from 61 to 66°F (16.1 to 18.9°C) during October. However, when flow occurred, it disrupted the stratification in these pools and caused them to mix and become relatively homogenous in water temperature (Butler 2013). In addition, during July, no pools with water temperatures less than 70°F (21.1°C) at any depth were present in Reach 4B2 and the Eastside Bypass (Butler 2013).

Spring-run Chinook Salmon holding in upper watershed locations prefer water temperatures below 60°F (15.6°C) although salmon can tolerate temperatures up to 65°F (18.3°C) before they experience an increased susceptibility to disease (Reclamation 2009). Substantial spring-run Chinook Salmon pre-spawn mortality was observed in Butte Creek in 2 years when the average daily water temperature exceeded 66°F (18.9°C) for greater than 11 and 16 days (Ward et al. 2006). It appears that at least some of the pre-spawn mortality was a result of the pathogens columnaris (*Flavobacterium columnare*) and Ich (*Ichthyophthirius multiphilis*) (Ward et al. 2006). Stressful water temperatures can increase the susceptibility of salmon to disease as well as increase the transmission of pathogens between salmon. Therefore, observed water temperatures in Reach 4B2 and the Eastside Bypass during July indicate that the Reach 4B/ESB Project area does not have water temperatures suitable for spring-run adult holding.

No Action Alternative

The No Action Alternative would accommodate increased Restoration Flows in the Middle Eastside Bypass compared to existing conditions. These increased flows could cause the temperatures to stay below lethal levels longer in the spring, but modeling indicates that water temperatures in the Project area reach critical to lethal levels for spring-run Chinook Salmon during the late spring, resulting in adverse effects to upstream migrating adults as well as rearing and downstream migrating juveniles. Because no habitat restoration would occur under the No Action Alternative that would off-set the water warming effects (e.g., increased vegetative cover and shading), conditions for Spring-run Chinook Salmon would continue to be unsuitable for recovery for part of the spring migration season, and therefore no change from the existing conditions is expected.

Alternative 1 – Main Channel Restoration

In Alternative 1, simulated water temperature from HEC-5Q model results in Reach 4B (RM 146) would exceed 70°F by mid-April in most years and by late May in wet years (SJRRP 2012a). Water temperatures in the lower San Joaquin River likely would be unsuitable for juvenile Chinook Salmon for the last two or more months of their emigration period under Alternative 1 (SJRRP 2012a). Additionally, water temperatures under Alternative 1 possibly would block passage of migrating adult Chinook Salmon during the second half of their migration period due to water temperatures above 70°F (21.1°C) (SJRRP 2012a).

Localized areas of thermal refugia with cooler temperatures, from either pool stratification or groundwater contribution, could be helpful in providing respite for fish during the hottest part of the day and allowing them to continue migration at night (Sedell et al. 1990). A study found that pool stratification in the San Joaquin River could result in cooler bottom temperatures; however, the temperature stratification was lost when flow occurred (Butler 2013). Under Alternative 1, Restoration Flows would provide year-round flows (except in critical low years), so stratification is not likely to provide thermal refugia (Butler 2013).

Groundwater contributions could help reduce temperatures if the groundwater temperatures are cooler and the groundwater is moving into the river channel. Figure 7-2 shows surface water temperatures (observed during 2011 at San Joaquin River near Washington Rd [CDEC Station Id: SWA] gauge and modeled) during a wet year compared to the 68°F (20°C) threshold. The figure also highlights the spring period for fish from the beginning of March through the end of May. In wet years, the surface water temperatures generally stay below the threshold until late May and then begin to climb. Figure 7-2 also shows temperatures in two wells on the San Joaquin River. Temperatures in these wells are consistently below the temperature threshold, with temperatures between 65°F and 68°F (18.3 to 20°C) year-round.

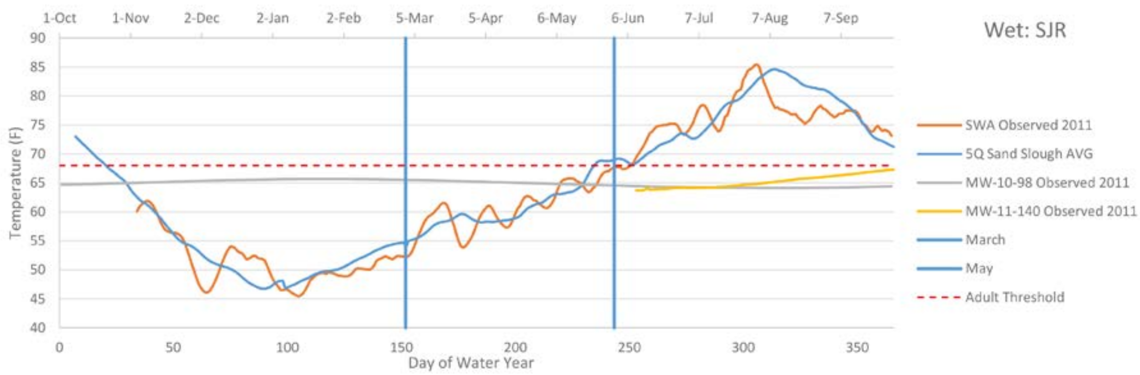


Figure 7-2. Surface Water and Groundwater Temperatures in Reach 4B in a Wet Year

Figure 7-3 shows similar data for a dry year (2013). In a dry year, temperatures rise above the threshold earlier in the year (typically in late April). The observed temperatures in the groundwater wells stay below the 68ºF (20°C) threshold year-round. If the groundwater could contribute to surface water flows in a substantive quantity, the groundwater temperatures could help reduce surface water temperatures.

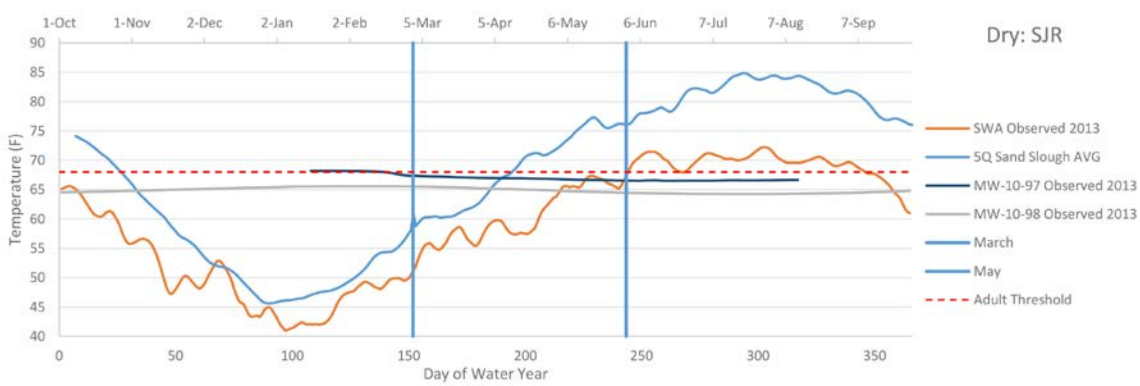


Figure 7-3. Surface Water and Groundwater Temperatures in Reach 4B in a Dry Year

Chapter 6, "Groundwater," analyzes how groundwater and surface water interact under Alternative 1. The groundwater modeling indicates that Reach 4B1 has periods and areas where the river may be gaining (receiving water from the groundwater system) or losing (sending water to the groundwater system). The conditions vary spatially and temporally, but the overall trend is that Reach 4B1 loses water, on average, in all months.

There are, sometimes, areas where Reach 4B1 could gain water from the shallow groundwater, but these trends would be further disrupted by seepage measures. To avoid seepage-related impacts to the agricultural uses surrounding Reach 4B1, seepage easements or interceptor lines would be implemented along the levees. If landowners choose to have a seepage easement, they would also likely install a private interceptor line. Interceptor lines would collect water seeping out of the river, but they would also collect water that is moving toward the river. This water may be used on the parcels or discharged into the river, but pumping the water is likely to warm it before discharge. As a result, gaining areas in Reach 4B1 would not be likely to contribute cool water to create thermal refugia.

Even though modeling identified high temperatures for salmonids in spring and summer, habitat restoration under Alternative 1 would result in the addition of habitat features beneficial for minimizing the increase in and possibly reducing water temperatures within the reach. Additional riparian and in-stream vegetation would result in reduced light penetration and solar heating.

Although there is still debate about the effect of riparian vegetation on water temperature in streams and rivers, studies have generally found that riparian vegetation moderates water temperature and can reduce water temperature, particularly daily maximum (Moore et al. 2005). However, most studies were conducted on small streams (4th order or smaller) and were examining the stream temperature response to forest harvesting (Moore et al. 2005). In Wisconsin, streams flowing through segments vegetated with riparian trees decreased in maximum daily average temperature (0.48°C [0.86°F]/km) and maximum weekly average temperature (0.30°C[0.54°F]/km) (Cross et al. 2013). In the same study, modeling of maximum weekly average temperature suggested that stream temperatures in equilibrium with their environmental conditions ranging from 23.2 to 28.3°C (73.8 to 82.9°F) at 0% shading could be reduced to 18.8 to 23.5°C (65.8 to 74.3°F) at 75% shading (Cross et al. 2013).

Fewer studies have researched the influence of riparian vegetation on water temperature dynamics in rivers. Modeling of water temperature in the Willamette River in Oregon suggested that restoring riparian vegetation to system potential along 60 miles of river could result in a maximum reduction of 0.419°C in the 7-day moving average of the daily maximum (Rounds 2007). In addition to riparian shading, stream morphology can affect the thermal regime, particularly for larger streams and rivers (Poole and Berman 2001). Narrow, deeper channels would not absorb as much heat as wider, shallower channels given the same climatic conditions (Poole and Berman 2001). Likewise, increased flow velocity, which is related to discharge, would reduce heat absorption for a given length of the channel (Poole and Berman 2001). In larger rivers and streams buffering processes can be more important than insulating processes (riparian microclimate) with the most important buffering process being hyporheic exchange between the alluvial aquifer and the stream channel (Poole and Berman 2001). Stream sinuosity and river features such as side and flood channels, floodplains, and backwaters have a large influence on the amount of hyporheic flow (Poole and Berman 2001). Flow regulation and channelization both negatively impact hyporheic flow through reduction in flow and altering the morphology of the channel and alluvial aquifer (Poole and Berman 2001). In addition, channelization by levees decreases flood water subsurface storage in the shallow groundwater which reduces shallow groundwater discharge during low flow periods (Poole and Berman 2001). Overall, the literature suggests that habitat restoration including riparian restoration to increase the amount of shading in combination with improved stream morphology and increased Restoration Flows would likely have water temperature benefits within Reach 4B of the San Joaquin River.

Alternative 1 water temperature modeling predicts high water temperatures during late spring that would be expected to exceed the tolerance levels of juvenile salmonids and adult spring-run Chinook Salmon. However, all habitat restoration measures under Alternative 1 would provide water temperature benefits (water cooling effects) compared to the No Action Alternative. Riparian restoration was not incorporated into the water temperature modeling results. Even with the habitat restoration performed in Alternative 1 water temperatures may still reach stressful levels in mid to late spring, particularly in dry and critical years which could have adverse effects on anadromous salmonids still present in the reach. The habitat restoration should improve conditions for fish that are using the area when water temperatures are less than stressful.

Alternative 2 – Bypass Restoration

Simulated water temperature from HEC-5Q model results in Reach 4B (RM 146) would exceed 70°F (21.1°C) by mid-April in most years and by late May in wet years under Alternative 2 (SJRRP 2012a). Based on temperature modeling results under Alternative 2, temperatures in the lower San Joaquin River likely would be unsuitable for juvenile Chinook Salmon for the last 2 or more months of their emigration period. Additionally, water temperatures in the lower San Joaquin River under Alternative 2 possibly would block passage of migrating adult Chinook Salmon during the second half of their migration period due to water temperatures above 70°F (21.1°C; EPA 2001).

As discussed for Alternative 1, localized areas of thermal refugia with cooler temperatures, either from pool stratification or groundwater contribution, could be helpful for fish. Pool stratification is not likely to provide a benefit in the Project area, but groundwater contributions could help reduce temperatures if the groundwater temperatures are cooler and the groundwater is moving into the channel. Figure 7-4 shows surface water temperatures in the Eastside Bypass (observed during 2011 and modeled) during a wet year compared to the 68°F threshold. The figure also highlights the spring period for fish from the beginning of March through the end of May. In wet years, the surface water temperatures generally stay below the threshold until late May and then begin to climb. Figure 7-4 also shows temperatures in two wells near the Eastside Bypass. Temperatures in these wells are consistently below the temperature threshold, with temperatures between 65°F and 68°F year-round.

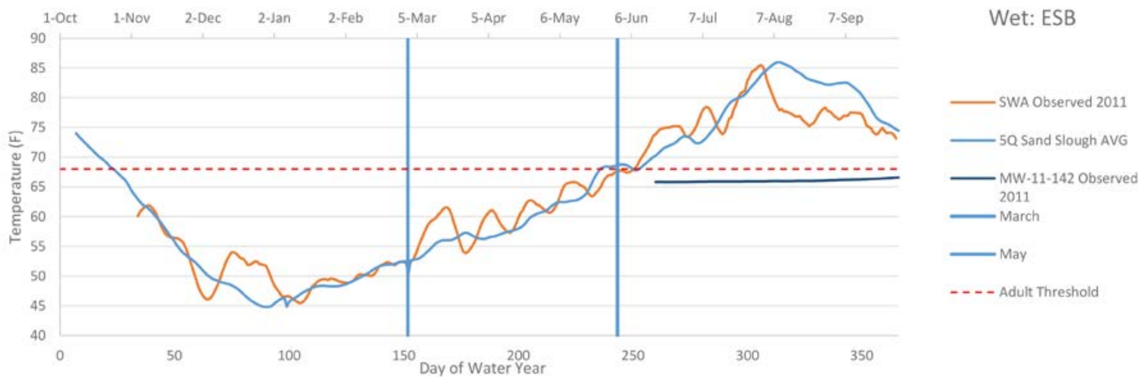


Figure 7-4. Surface Water and Groundwater Temperatures in the Eastside Bypass in a Wet Year

Figure 7-5 shows similar data for a dry year (2013). In a dry year, temperatures rise above the threshold earlier in the year (typically in late April). The observed temperatures in the groundwater wells stay below the 68°F threshold year-round. If the groundwater could contribute to surface water flows in a substantive quantity, the groundwater temperatures could help reduce surface water temperatures.

Figure 7-5. Surface Water and Groundwater Temperatures in the Eastside Bypass in a Dry Year

Chapter 6, "Groundwater," indicates that while the Eastside Bypass occasionally has a small area where the river may be gaining (receiving water from the groundwater system), it is much more commonly a losing reach (sending water to the groundwater system). On average, the Eastside Bypass loses water to the shallow groundwater system in all months and all year-types.

Even though modeling identified high temperatures for salmonids in spring and summer, habitat restoration under Alternative 2 would result in the addition of habitat features beneficial for cooler water temperatures. Additional riparian and in-stream vegetation would result in reduced light penetration and solar heating. However, soil maps of the Eastside Bypass indicate that there are areas that would likely not be able to support riparian gallery trees that would reduce the potential increase in shading in these areas. The shrubs and grasses that would likely grow in the Eastside Bypass would provide some opportunity for reduced light penetration and solar heating.

Alternative 2 water temperature modeling predicts high water temperatures during late spring that would be expected to exceed the tolerance levels of juvenile salmonids and adult spring-run Chinook Salmon. However, all habitat restoration measures under Alternative 2 would provide water temperature benefits (water cooling effects) compared to the No Action Alternative. Riparian restoration was not incorporated into the water temperature modeling results. Even with the habitat restoration performed in Alternative 2, water temperatures may still reach stressful levels in mid to late spring (particularly in dry and critical years), which could have adverse effects on anadromous salmonids still present in the reach. The riparian restoration should improve water temperature conditions for fish and may delay the onset of stressful water temperatures in the spring.

Alternative 3 – Bypass All Pulse Flows

Simulated water temperature from HEC-5Q model results in Reach 4B (RM 146) would exceed 70° F (21.1°C) by mid-April in most years under Alternative 3 (SJRRP 2012a). Therefore, negative impacts to juvenile and adult Chinook Salmon, as described for Alternative 1, would also be expected under Alternative 3. Similar to Alternative 1, habitat restoration would result in the addition of habitat features beneficial for cooler water temperatures.

As discussed in Alternatives 1 and 2, both Reach 4B1 and the Eastside Bypass are generally losing reaches for surface water. In Reach 4B1 and the Eastside Bypass, surface water is generally being lost to the groundwater such that the potential for thermal refugia to be present is limited because of cooler groundwater contributing to the surface water at certain locations. However, Reach 4B1 generally loses more surface water to groundwater than does the Eastside Bypass.

Unlike the previous alternatives, Alternative 3 would direct flows down two different pathways, the main stem route and the bypass route. Splitting flows may exacerbate water temperature problems by reducing the volume of water flowing in each route and increasing the warming potential of the water in the system. The flow splitting may be particularly problematic for water temperature when the flow split is resulting in only a small volume of water flowing down the bypass. The low flow in the bypass has a high potential to increase in water temperature substantially. Shallow streams with low flow can increase in water temperature quickly (Moore et al. 2005). However, if there is low flow in the bypass then there is also reduced potential for use by special status fish species. Under Alternative 3, water temperatures would still be expected to exceed the tolerance levels of juvenile salmonids and adult spring-run Chinook Salmon in late spring and summer.

While restoration actions could provide temperature benefits (water cooling effects), splitting Restoration Flows along with habitat restoration would have more uncertainty about whether there would be water temperature benefits compared to the No Action Alternative. Splitting the flows could increase water temperature while habitat restoration actions would reduce water temperature; these two actions could result in little effective change compared to the No Action Alternative.

7.2.4 Flow Conditions for Fish

Passage for San Joaquin River adult spring-run Chinook Salmon and other anadromous fish has been completely blocked in the Restoration Area since the 1950s when the river was dewatered below Sack Dam (except during uncontrolled flood flow releases in wet years). Under existing conditions, the stream reaches that are presently accessible to spring-run Chinook Salmon often lack the summer habitat and flow conditions needed to sustain juveniles through their freshwater rearing period. These conditions can be exacerbated by reservoir operations and water diversions that reduce summer flows and can be particularly severe in drought years. Reduced flows as a result of anthropogenic alterations can adversely affect survival and productivity of native anadromous populations as well as reduce the quality and quantity of available habitat. Likewise, low flow rates limit and degrade available habitat for resident native riverine fish species and likely have reduced their survival and production in the Reach 4B/ESB Project area. Low flows due to flow regulation can have a significant impact on the habitat amount and quality available for lamprey larvae, limiting their abundance (Ojutkangas et al. 1995). The SJRRP has started releasing Restoration Flows under existing conditions, but flows are currently limited to about 300 cfs. Projects under the No Action Alternative, including seepage projects, channel capacity projects, and the Eastside Bypass Improvements Project, would accommodate increased Restoration Flows up to 2,500 cfs. The actual Restoration Flows in a given year would vary based on time of year and hydrologic conditions.

No Action Alternative

Under the No Action Alternative, adult salmon migrating upstream would enter the bypass system through the Lower Eastside Bypass through a modified Eastside Bypass Control Structure to allow fish passage and would pass up the Middle Eastside Bypass before rejoining the San Joaquin River channel at the junction of Reach 4B1 and Reach 4A. Juvenile anadromous fish migrating downstream would enter the system from the San Joaquin River Reach 4A or the Upper Eastside Bypass and move downstream through the Middle Eastside Bypass and Lower Eastside Bypass.

During this period, adult fish could enter into Bear Creek or Owens Creek, which are tributaries to the Lower Eastside Bypass. Bear and Owens creeks typically discharge into the Eastside Canal but there are control structures in the Eastside Canal that allow higher flows to continue down the creeks into the Lower Eastside Bypass (San Joaquin River Flood Control Project Agency 2015). These control structures may be fish passage barriers when flows are being released out of them. If Bear or Owens creeks are flowing into the Lower Eastside Bypass, adult spring-run Chinook Salmon may stray into the creeks and experience reduced reproductive success due to delays or possible failure in reaching spawning areas. However, historical flow gauge data for Bear and Owens creeks shows they only flow during January through May during the wettest years (CDEC gages MCK - Bear Creek at McKee Rd and OWQ - Owens Creek below Owens Dam). Straying spring-run Chinook Salmon should have time to reorient and return to the main stem San Joaquin River prior to spawning in the fall and before Bear and Owens creeks' flows recede. However, straying could cost these individuals metabolically (in terms of energy) and delay spawning enough to reduce their reproductive success. Straying into Bear or Owens creek could result in increased likelihood of exposure to elevated water temperatures due to the delay if the strays return back to the San Joaquin River to continue their upstream migration.

Straying occurs in all anadromous salmonid populations and is a critical evolutionary feature of salmonid behavior (Keefer and Caudill 2014). Rates of straying vary among Pacific salmon species, life history types, and populations (Westley et al. 2013). Among hatchery populations of Chinook Salmon in the Pacific Northwest, stream-type (spring-run) strayed at a mean rate of 4.7% while ocean type (fall-run) had a mean stray rate of 15.8% (Westley et al. 2013). While Chinook Salmon generally stray at higher rates than other Pacific salmon species (Westley et al. 2013) it is still a relatively small percent of a given Chinook Salmon population that may stray and therefore would not be expected to have deleterious population level effects (Keefer and Caudill 2014). In addition, temporary straying into non-natal tributaries and other exploratory or searching movements by Chinook Salmon is common (Keefer et al. 2008). In the Columbia River system, a mean of 14% (range 2-44%) of spring-summer Chinook Salmon temporarily strayed into non-natal tributaries (Keefer et al. 2008). Most temporary straying was of short duration (<1 day) but also occurred for several weeks (Keefer et al. 2008). In addition to temporary straying, Chinook Salmon in the Columbia River have been documented to "overshoot", migrate 3 to over 250 km upstream of the confluence with their natal tributary before returning to migrate up the natal tributary (Keefer et al. 2008). Reproductive success of Chinook Salmon displaying temporary straying and overshooting was not evaluated in the Keefer et al. (2008) study but these fish, including ones that migrated substantial distances past their natal tributary, were tracked to their natal tributary to presumably spawn. The literature suggests that only a small percent of upstream migrating Chinook Salmon would enter into Bear or Owens creeks if they are accessible and some of the fish that enter would be temporary strays. In addition, Chinook Salmon are able to migrate substantial distances past their natal tributaries without apparent impact to their ability to arrive at their natal spawning grounds. Overall, the probability appears to be low that the accessibility of Bear or Owens creeks would have negative population level effects on San Joaquin River spring-run Chinook Salmon.

The Eastside Bypass Improvements Project would be implemented as part of the No Action Alternative. The Eastside Bypass Improvements Project would modify or remove fish passage barriers within the Eastside Bypass to allow for unrestricted fish passage through the Eastside Bypass during most flow conditions. The removal or modification of all passage limitations for adult and juvenile anadromous fish species along this route would benefit fish that migrate into upper reaches on the San Joaquin River where spawning and rearing habitat is more abundant and water temperatures are more favorable. And while the risk for adult spring-run Chinook Salmon individuals who stray into Bear and Owens creeks (when adults have access to the Lower Eastside Bypass) could be a concern, it does not negate the benefits for connectivity to the entire San Joaquin salmonid population. Likewise, increased flow connectivity would provide greater habitat availability for resident native fish species.

Alternative 1 – Main Channel Restoration

Alternative 1 would route Restoration Flows through Reach 4B1 of the San Joaquin River instead of through the bypass. Reach 4B1 of the San Joaquin River would have a capacity of 4,500 cfs with all fish passage barriers removed or modified and would receive all Restoration Flows. The LSJLD would continue to manage flood flows.

Previously dewatered habitat in Reach 4B1 would receive Restoration Flows and provide habitat connectivity for all life stages of anadromous fish species. For Restoration Flows up to 4,500 cfs, adult anadromous fish species would migrate upstream and juveniles downstream along the San Joaquin River. The river would provide both in-channel habitat and access to relatively wide, frequently inundated floodplains bounded by setback levees. During flood flows, the flows would be routed at the discretion of LSJLD and fish could use the main channel, bypass, or both depending on how flows are routed. The habitat restoration in combination with Restoration Flows would substantially increase the available habitat for resident fish species, thereby providing greater production potential.

Alternative 2A – Bypass Restoration through Reach 4B2

Alternative 2A would route all Restoration Flows down the Middle Eastside Bypass, into the Mariposa Bypass, and then into Reach 4B2. Flood flows would be routed at the discretion of the LSJLD from the Middle Eastside Bypass into the Mariposa and Lower Eastside bypasses.

Adult salmon migrating upstream would enter the San Joaquin River Reach 4B2, be directed up the Mariposa Bypass Channel over modified or removed structures that allow fish passage, and pass up the Middle Eastside Bypass before rejoining the San Joaquin River channel at the junction of Reach 4B1 and Reach 4A. Juvenile anadromous fish migrating downstream would enter the system from the San Joaquin River Reach 4A or the Upper Eastside Bypass and move downstream through the Middle Eastside Bypass, Mariposa Bypass, and San Joaquin River Reach 4B2.

During flood flow events, flows would enter the Lower Eastside Bypass (at the discretion of LSJLD) and potentially divert migrating adult salmon to Bear or Owens creeks or tributary streams. Straying impacts would be the same as described for the No Action Alternative.

Alternative 2A would provide habitat connectivity only for Reach 4B2 via the Mariposa Bypass and Eastside Bypass to connect with Reach 4A for all special-status fish species. All passage limitations for adult and juvenile anadromous fish species along this route would be removed or modified. While the risk for adult spring-run Chinook Salmon individuals who stray into Bear and Owens creeks (when adults have access to the Lower Eastside Bypass) could be a concern, it does not negate the benefits for connectivity to the entire San Joaquin salmonid population. Likewise, increased Restoration Flows capacity would provide greater habitat availability and connectivity for resident fish species.

Alternative 2B – Bypass Restoration through the Lower Eastside Bypass

Alternative 2B would route Restoration Flows down the Middle and Lower Eastside bypasses and connect to the San Joaquin River at the bottom of Reach 4B2. Flood flows would be routed at the discretion of the LSJLD. Adult and juvenile anadromous fish would be able to traverse freely the entire length of the Project area through the Middle and Lower Eastside bypass. The risks for straying into Bear or Owens creeks would be the same as described for the No Action Alternative.

During flood flow events, flows would enter the Mariposa Bypass (at the discretion of LSJLD) and potentially attract migrating adult salmon into Reach 4B2. These fish would then be blocked from entering Reach 4B1 (via a new structure that would block any potential back water effects from the Mariposa Bypass) and would re-connect to upstream habitats via the Mariposa Bypass into the Middle Eastside Bypass.

Alternative 2B would provide habitat connectivity for the entire length of the Reach 4B/ESB Project area via the bypass channel for all special-status fish species. All passage limitations for adult and juvenile anadromous fish species would be removed in the No Action Alternative. Although there may be an increased straying risk for adult spring-run Chinook Salmon into Bear or Owens creeks, adults should have plenty of time to return to the main stem San Joaquin River and continue their upstream migration to natal spawning grounds. Likewise, increased Restoration Flow capacity would provide greater habitat availability and connectivity for resident fish species.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 would route Restoration Flows down the San Joaquin River Reach 4B1 up to the capacity of this reach. The capacity could vary, from a minimum of 475 cfs to a maximum of approximately 1,500 cfs, depending on the geomorphology and biological benefits associated with different flow splits. Smaller flows into Reach 4B1 (close to 475 cfs) could increase operations and maintenance because they cause a higher rate of sedimentation in the upstream reaches of 4B1. On the other hand, larger flows (close to 1,500 cfs) could cause increased erosion in Reach 4B1 (Reclamation 2016). While the split flow quantities may vary, the minimum capacity of 475 cfs is included in this alternative description. Additional water along with removal and modification of fish barriers would provide habitat connectivity for all life stages of anadromous fish species. Adult and juvenile anadromous fish would be able to traverse freely the entire length of the Reach 4B/ESB Project area. Under this alternative, during flows up to 475 cfs, adult and juvenile anadromous fish would migrate through the San Joaquin River channel. For flows greater than 475 cfs, adults migrating upstream and juveniles migrating downstream could split and pass down either the river or the Middle and Lower Eastside bypasses. Compared to the No Action Alternative, the magnitude of Restoration Flow allowed in the Middle Eastside Bypass in Alternative 3 would increase from 2,500 to 4,500 cfs. During periods with Flood Flows, fish may also pass through the Mariposa Bypass and Reach 4B2 with Flood Flow routing determined by LSJLD.

During periods when Restoration or Flood flows are in the bypasses, flows would enter the Lower Eastside Bypass and potentially cause migrating adult salmon to stray into Bear or Owens creeks. The straying concerns would be the same as described for the No Action Alternative.

Increased Restoration Flow capacity would increase available habitat during periods of elevated flows and provide habitat connectivity throughout the length of the Reach 4B/ESB Project area for resident native riverine fish species. The Restoration Flows in conjunction with removal and modification of fish barriers in Reach 4B1 would make the entire length of the Reach 4B/ESB Project area available for resident fish species. Increased Restoration Flow capacity would greatly increase the available habitat for resident fish species during periods of elevated flows, thereby providing greater production potential and feeding success.

Alternative 3 would provide habitat connectivity and increased habitat availability for the entire length of the Reach 4B/ESB Project area for all special-status fish species. All passage limitations for adult and juvenile anadromous fish species would be removed in Reach 4B1. While the risk for adult spring-run Chinook Salmon individuals who stray into Bear and Owens creeks (when adults have access to the Lower Eastside Bypass) could be a concern, it does not negate the benefits for connectivity to the entire San Joaquin salmonid population. Likewise, increased Restoration Flows capacity would provide greater habitat availability and connectivity for resident fish species.

7.2.5 Fish Habitat

In the Reach 4B/ESB Project area, physical barriers, reaches with poor water quality or no surface flow, and the presence of false migration pathways have reduced habitat connectivity. Habitat complexity is reduced, with limited side channel habitat or instream habitat structure and highly altered (and highly reduced) riparian vegetation. Bypasses receive water sporadically, as necessary for flood control. Most aquatic habitat in the bypasses is therefore temporary, and its duration depends on flood flows; the bypasses are largely devoid of aquatic and riparian habitat because of efforts to maintain hydraulic conveyance for flood flows. Reach 4B1 has been perennially dry for more than 40 years, except when agricultural return flows are put through the channel, leaving standing water in many locations. Thus, the Reach 4B1 channel is poorly defined with dense vegetation and other fill material.

Reduced channel migration in the Reach 4B/ESB Project area due to construction of levees has resulted in the loss of suitable conditions for sensitive fish species (listed under ESA or California Endangered Species Act), including the elimination of off-channel habitats, reduction in the number of complex side channels, and the decrease in instream habitat complexity including LWM. Agricultural conversion has also directly reduced the amount of floodplains as well as the construction of levees and dikes, which have further isolated historic floodplains from the channel. It is likely that the loss of floodplain habitats has substantially reduced food resources and refuge from predators for all juvenile fish.

No Action Alternative

The No Action Alternative would, in combination with Restoration Flows, provide flow connectivity through the Project area by removing fish passage barriers in and routing fish through the Lower and Middle Eastside bypasses. Even though Restoration Flows would inundate previously dewatered habitat and provide a wetted channel along the entire length of the Reach 4B/ESB Project area, levees would remain in place. Flows would be confined within the channel between the levees in the Eastside Bypass, providing limited shallow water rearing and feeding habitat for anadromous and resident fish. Also, no riparian vegetation enhancement would occur, providing little refuge or food production for anadromous and resident fish.

The removal of fish passage barriers and input of Restoration Flows down the Middle and Lower Eastside bypasses would create additional main stem and floodplain habitat suitable for juvenile and adult native anadromous and riverine species. The relatively wide channel (compared to the main channel in Reach 4B1) present in the bypass would increase the amount of shallow-water flooded habitat available to native fish species that use this type of habitat such as Chinook Salmon, Sacramento Splittail, and lamprey species.

Outside of the Merced NWR area, the Eastside Bypass has limited aquatic and riparian cover, and no riparian vegetation enhancement would occur under the No Action Alternative. Riparian vegetation and LWM are the primary sources of overhead and instream cover and food production for juvenile salmonids (Steward and Bjornn 1987). Likewise, larval and juvenile Sacramento splittail require submerged beds of aquatic vegetation in shallow areas for feeding and refuge from predators (Moyle 2002).

In summary, all passage limitations for adult and juvenile anadromous fish species would be removed or modified, as part of other planned SJRRP actions. Likewise, increased Restoration Flow capacity and barrier removal or modification would provide greater habitat availability and connectivity for anadromous and resident fish species.

Alternative 1 – Main Channel Restoration

Under Alternative 1, the San Joaquin River would function as the primary route for fish and flows. No improvements would occur in the Eastside and Mariposa bypasses beyond those of the Eastside Bypass Improvement Project that would allow fish passage through the Lower and Middle Eastside bypasses. The river would provide both in-channel habitat and access to relatively wide, frequently inundated floodplains bounded by setback levees. One channel width is considered the minimum acceptable levee setback to allow for riparian shading and natural bank erosion processes and minimize levee maintenance (Larsen et al. 2006). The narrowest setback alignment (levee alignment B under Alternative 1A) would incorporate approximately one channel width on each side of the channel, and the other alternatives have wider floodplain areas. Table 7-2 shows the inundated acres and hydraulically suitable habitat under Alternative 1. The inundated acres and suitable habitat include areas in both Reach 4B1 and 4B2. To meet the SJRRP population targets for spring-run and fall-run Chinook Salmon, SJRRP investigations identified the need for 54 acres of suitable habitat in Reach 4B1 and 19 acres in Reach 4B2 (SJRRP 2012b)[3].

Table 7-2. Alternative 1 Inundated Acres and Suitable Habitat at Different Restoration Flows (cfs)

Alternative		50	150	475	700	1,200	2,200	3,655	4,500
1A	Total inundated area (acres)	403	587	1,322	1,832	2,885	3,735	4,153	4,214
	Hydraulically suitable juvenile salmon habitat (acres)[1]	158	209	419	617	1,060	1,630	1,906	1,832
	High value habitat (acres)[2]	93	101	175	275	522	826	1,182	1,162
1B	Total inundated area (acres)	430	624	2,076	2,846	4,181	6,327	7,234	7,370
	Hydraulically suitable juvenile salmon habitat (acres)[1]	169	223	606	959	1,615	2,613	3,355	3,557
	High value habitat (acres)[2]	98	107	198	370	794	1,398	1,783	1,929
1C	Total inundated area (acres)	445	681	2,752	4,240	6,156	8,415	10,163	10,775

[3] The investigation of minimum habitat needed also considered cover when identifying suitable habitat, which has not been factored in to the hydraulically suitable habitat area in Table 7-2.

	Hydraulically suitable juvenile salmon habitat (acres)[1]	172	232	727	1,298	2,227	3,599	4,692	5,165
	High value habitat (acres)[2]	95	108	199	439	943	1,904	2,636	3,054

Source: Reclamation 2016 [1] Hydraulically suitable habitat is total HSI of the hydraulic condition with values between 0.01 and 1.0. [2] High value habitat is total HSI of the hydraulic condition with values between 0.67 and 1.0.

Under Alternative 1, the San Joaquin River channel would provide floodplain-rearing habitat for juvenile salmonids and lamprey species. Juvenile salmonids rear on seasonally inundated floodplains when available. Sommer et al. (2001) found higher growth and survival rates of Chinook Salmon juveniles reared on the Yolo Bypass compared with those in the main stem Sacramento River. Jeffres et al. (2008) observed similar results on the Cosumnes River floodplain. Drifting invertebrates, the primary prey of juvenile salmonids, were more abundant on the inundated Yolo Bypass floodplain than in the adjacent Sacramento River (Sommer et al. 2001). Likewise, these low-velocity, depositional rearing areas would provide feeding areas for lamprey ammocoetes such as Pacific lamprey that feed by filtering organic matter from the substrate.

Alternative 1 would provide suitable habitat for deep-bodied fishes, such as Sacramento splittail. Sacramento splittail require shallow floodplains for successful rearing and spawning. Feeding in flooded riparian areas before spawning may contribute to spawning success and survival of splittail adults after spawning (Moyle et al. 2004). Splittail appear to concentrate their reproductive effort in wet years when potential success is greatly enhanced by the availability of inundated floodplain habitat (Meng and Moyle 1995, Sommer et al. 1997).

Under Alternative 1, the San Joaquin River channel would provide in-channel rearing and refugia habitat for juvenile salmonids through revegetation efforts and addition of LWM. As fry, Chinook Salmon in near-shore areas rely on overhanging vegetation, LWM, and other bank cover to reduce the risk of predation. Steward and Bjornn (1987) found that the amount of LWM was among the most important factors influencing density of juvenile Chinook Salmon and steelhead in experimental pools. LWM also contributes to invertebrate food sources and micro-habitat complexity for juvenile salmonids. When juvenile Chinook Salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991).

Increased flows and channel construction would create more pool habitat in the main stem channel required for benthic feeding for adult hardhead. Larvae and post-larvae hardhead would benefit from increased shallow-water habitat and vegetative cover as they occupy river edges or flooded habitat before seeking deeper low-velocity habitat as they increase in size (Moyle 2002).

Alternative 1 would create habitat conditions beneficial for all sensitive fish species. Anadromous fish species would have unimpeded passage along the length of the Reach 4B/ESB Project area. The amount of suitable habitat for juvenile salmonid rearing would greatly increase with the creation of floodplain habitat, the addition of LWM, and the restoration of riparian vegetation. Likewise, suitable habitat for rearing of lamprey species as well as rearing and spawning of deep-bodied fish would increase. Finally, main stem pool habitat would increase, providing suitable benthic habitat for hardhead foraging.

Alternative 2 – Bypass Restoration

Alternative 2 would route all Restoration Flows down the Middle Eastside Bypass and into the Mariposa Bypass (Alternative 2A) or the Middle Eastside Bypass into the Lower Eastside Bypass (Alternative 2B). The levees in the Middle Eastside Bypass also would be set back to allow increased riparian and floodplain habitat. All initial channel improvements for habitat creation would be focused in the bypass system though some channel clearing would be undertaken in the San Joaquin River channel to increase conveyance.

Under Alternative 2, the existing channel in the Middle Eastside would be enhanced to provide a channel suitable for both fish passage and rearing of Chinook Salmon and other target fish species. Channel enhancement actions would include establishing a riparian corridor of 50 to 75 feet (in locations where the soil is conducive to riparian trees) on either side around the channel to provide shade, cover, and inputs of nutrients and woody debris. Establishing a riparian corridor in the bypasses is expected to take some time (10 to 15 years to provide significant shade along the channel) and would be challenging due to the highly erodible, sandy soils. In locations where riparian trees cannot establish, grasses and shrubs may be planted or passively establish. Grasses and shrubs generally provide less shade and therefore less water temperature moderation than riparian trees. However, water flowing through dense stands of tules may experience more shading and water temperature moderation. Grasses, shrubs, and tules growing on floodplains provide cover for native fish when they become inundated. However, if floodplain water velocities are sufficiently high to flatten down the grasses, then grasses lose their function as cover. LWM would be introduced into the channel to improve rearing and shelter for target fish species. LWM would need to be anchored or keyed into the banks to minimize wood movement during Flood Flows.

Table 7-3 shows the inundated acres and hydraulically suitable habitat under Alternative 2. For Alternative 2A, the inundated areas and suitable habitat include areas in the Middle Eastside Bypass, Mariposa Bypass, and Reach 4B2. The inundated areas and suitable habitat in Alternative 2B include the Middle Eastside Bypass and Lower Eastside Bypass. To meet SJRRP population targets for spring-run and fall-run Chinook Salmon, SJRRP investigations identified the need for 54 acres of suitable habitat in Reach 4B1 (or the bypass system) and 19 acres in Reach 4B2 (SJRRP 2012b).

Table 7-3. Alternative 2 Inundated Acres and Suitable Habitat at Different Restoration Flows (cfs)

Alternative		50	150	475	700	1,200	2,200	3,655	4,500
2A	Total inundated area (acres)	266	451	660	842	1,304	2,322	3,690	3,978
	Hydraulically suitable juvenile salmon habitat (acres)[1]	143	316	198	248	386	838	1,490	1,601
	High value habitat (acres)[2]	51	93	91	111	165	423	771	863
2B	Total inundated area (acres)	241	323	445	527	795	1,510	2,347	2,732
	Hydraulically suitable juvenile salmon habitat (acres)[1]	135	276	126	147	222	560	947	1,044
	High value habitat (acres)[2]	44	77	55	65	86	290	509	504

Source: Reclamation 2016 [1] Hydraulically suitable habitat is total HSI of the hydraulic condition with values between 0.01 and 1.0.
[2] High value habitat is total HSI of the hydraulic condition with values between 0.67 and 1.0.

Alternative 2 would create habitat conditions beneficial for all special-status species. Anadromous fish species would have unimpeded passage through the Reach 4B/ESB Project area via this route. The amount of suitable habitat for juvenile salmonid rearing would increase with the creation of floodplain habitat and the restoration of riparian vegetation. Likewise, suitable habitat for rearing of lamprey species and rearing and spawning of deep-bodied fish would increase. Finally, Eastside Bypass pool habitat would increase, providing suitable benthic habitat for hardhead foraging.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 would route Restoration Flows of up to 475 cfs down the San Joaquin River. Some minor levee improvements would be conducted in the San Joaquin River channel, and extensive in-channel vegetation and sediment removal would occur to bring its capacity up to 475 cfs. Restoration Flows greater than 475 cfs would be split between river and the bypass with 475 cfs routed down the river and the additional flow routed down the Middle Eastside Bypass to the Lower Eastside Bypass. Reach 4B1 would function as the main river channel and the Eastside Bypass would function as the floodplain under Alternative 3.

The existing channel in Reach 4B1 of the San Joaquin River would be enhanced to provide a channel suitable for both fish passage and rearing of Chinook Salmon and other target fish species. All fish passage barriers would be modified or removed in Reach 4B1 to allow unimpeded passage for adult and juvenile anadromous fish. Native riparian vegetation along the channel banks and between the banks and the levees would be preserved where channel capacity allows. LWM habitat elements would be added to the channel in sparsely vegetated areas where existing shelter and complexity is a limiting factor on fish migration and rearing. The San Joaquin River channel would provide in-channel rearing habitat but little floodplain rearing under Alternative 3.

Table 7-4 shows the inundated acres and hydraulically suitable habitat under Alternative 3. The inundated areas and suitable habitat include areas in Reach 4B1 and Reach 4B2. To meet the SJRRP population targets for spring-run and fall-run Chinook Salmon, SJRRP investigations identified the need for 54 acres of suitable habitat in Reach 4B1 and 19 acres in Reach 4B2 (SJRRP 2012b).

Table 7-4. Alternative 3 Inundated Acres and Suitable Habitat at Different Restoration Flows (cfs)

	50	150	475	700	1,200	2,200	3,655	4,500
Total inundated area (acres)	412	577	783	886	1,066	1,373	1,706	1,760
Hydraulically suitable juvenile salmon habitat (acres)[1]	165	212	232	258	318	419	533	561
High value habitat (acres)[2]	98	102	108	116	148	196	252	282

Source: Reclamation 2016 [1] Hydraulically suitable habitat is total HSI of the hydraulic condition with values between 0.01 and 1.0. [2] High value habitat is total HSI of the hydraulic condition with values between 0.67 and 1.0.

Alternative 3 would increase the availability of beneficial habitat for all special-status species. Anadromous fish species would have unimpeded passage along the length of the Reach 4B/ESB Project area. The amount of suitable habitat for juvenile salmonid rearing would increase during high flow events in the Eastside Bypass, with the inundation of floodplain habitat and the restoration of riparian vegetation. However, during low flows when all of the water is routed down Reach 4B1 there may be little quality juvenile rearing habitat present due to the confined nature of this reach. Likewise, suitable habitat for rearing of lamprey species and rearing and spawning of deep-bodied fish would increase. Finally, San Joaquin River pool habitat would increase, providing suitable benthic habitat for hardhead foraging.

7.2.6 Predation

During fish assemblage monitoring in the Restoration Area native fishes were more frequently encountered in the upstream reaches while non-native fishes were more frequently encountered in downstream reaches (SJRRP 2014, 2017). The Reach 4B/ESB Project area is dominated by many fish species that are known to prey on juvenile salmonids and other native fish species. These predators include non-native largemouth bass, spotted bass, warmouth, and striped bass.

High predation rates on migratory fish, including juvenile salmonids, are known to occur below small Central Valley dams and diversions where striped bass and other non-native predators congregate. Adult striped bass often hold near screened diversions and manmade structures, feeding on small fish, including salmon that concentrate near them (Sabal et al 2016).

No Action Alternative

With existing conditions, when Restoration Flows are routed down the Eastside Bypass the fish passage barriers would likely serve as predator congregation locations. The No Action Alternative would result in the removal of fish passage barriers in and route Restoration Flows through the Lower and Middle Eastside Bypass to allow unimpeded movement of adult and juvenile fish through Reach 4B when flows are sufficient. Additionally, fish passage barrier removal in the bypass would substantially reduce the suitability of the former structure locations for predator congregation. However, the barrier removal or modification would also improve the access for non-native predators into the Lower and Middle Eastside Bypass, particularly striped bass as they move regularly between marine, estuary, and freshwater environments. The Lower and Middle Eastside Bypass contain generally poor fish habitat as they are managed for flood flow conveyance with wildlife habitat also managed for in the section of the bypass in the Merced NWR. The bypass does contain some shallow floodplain habitat that would likely provide some refuge from predators when flows are sufficient to exit from the low flow channel, especially in the Merced NWR where there is some riparian vegetation for cover. However, with the majority of the Middle and Lower Eastside Bypass being in a highly altered state, a levee confined channel that is largely devoid of riparian vegetation, the conditions may favor non-native predators over native fish species. The overall habitat quality in the Middle and Lower Eastside Bypass would not change in the No Action Alternative.

Predator congregation areas may be reduced by removal of fish passage barriers in the Middle and Lower Eastside Bypass but their removal would also improve access to the area for predators, particularly striped bass. In addition, the poor habitat quality of the Middle and Lower Eastside Bypass may favor non-native predators over native fish.

Alternative 1 – Main Channel Restoration

Because all fish barriers would be modified or removed under Alternative 1 in Reach 4B1, striped bass, the primary anadromous predator in the Central Valley, would have access to Reach 4B1 in addition to the Lower and Middle Eastside Bypass. Since striped bass move regularly between salt and fresh water, and usually spend much of their life cycle in estuaries, fish passage in Reach 4B1 likely would increase the abundance of striped bass. In addition, other non-native predators, such as largemouth bass, likely would colonize Reach 4B1.

Increased seasonal inundation of floodplain habitat created in Reach 4B1 through habitat restoration likely would create additional suitable habitat for bass and sunfish species; however, restoration of native vegetation and additions of LWM likely would counteract the increased predator presence (Gregory and Levings 1996). Bass and sunfish prefer warm, low-velocity habitat in rivers. These quiet water habitats provide preferred habitat for predatory fish species and could increase their populations. Habitat restoration would substantially increase the amount of cover available to native fish in the form of riparian vegetation, shallow floodplains, and LWM, providing refuge from potential increased predator abundance.

Additional potential magnitude of Restoration Flows along with habitat restoration likely would reduce the amount of in-channel habitat that is suitable for predator species in the Reach 4B/ESB Project area. Channel construction and modification of fish barriers in Reach 4B1 would increase connectivity of in-channel habitat and reduce the presence of isolated stretches of warm water habitat. This higher velocity, riverine habitat likely would be less suitable for bass and sunfish predator species, providing a safer migration corridor for native juvenile fish.

The removal or modification of barriers under Alternative 1 would allow predators, such as striped bass and black bass, to access Reach 4B1 when Reach 4B1 likely supports few if any predators currently. The removal or modification of barriers would likely also remove potential predator hotspots. However, increased connectivity of in-channel habitat would provide habitat less suitable for bass and sunfish predators, providing a safer migration corridor for juvenile fish. In addition, the habitat restoration activities, such as creation of seasonal floodplains, revegetation, and addition of LWM, likely would create habitat that is more favorable to native fish than non-native predators and provide cover for native fish to minimize predation. Finally, increased floodplain inundation events likely would have a net neutral effect on predation rates, with increased bass and sunfish habitat balanced by increased native fish habitat as well as hiding cover for native fish.

Alternative 2 – Bypass Restoration

Predators, including non-native striped bass and black bass and native pikeminnow, have been documented to congregate below dams and other water diversion and control structures and can result in predation hotspots (Sabal et al. 2016). Habitat restoration in Alternative 2 likely would have a net benefit on native fish predation rates. Although the removal or modification of barriers would increase the access of predators, such as striped bass in the Reach 4B/ESB Project area, removal of manmade structures would provide fewer areas for predators to congregate, eliminating many predator "hotspots." Increased connectivity of in-channel habitat would provide habitat less suitable for bass and sunfish predators, providing a safer migration corridor for juvenile fish. Finally, increased floodplain inundation events likely would have a neutral effect on predation rates, with increased bass and sunfish habitat balanced by increased hiding cover, provided by riparian/wetland vegetation and LWM, and shallow floodplain habitat for native fish.

Alternative 3 – Bypass All Pulse Flows

The removal or modification of barriers under Alternative 3 would increase the access of predators, such as striped bass, in Reach 4B1. Alternative 3 also includes a more complex control structure at the Reach 4B Headgates/Sand Slough Control structure than the other alternatives. Under Alternative 3, there is a complex Headgate structure with multiple fish passage facilities, and a large structure at the Sand Slough Control Structure. Alternatives with additional facilities with flow constrictions, include drops or pools where fish can become disoriented and/or predators can accumulate, and create holding areas for passage, all allow for increased predator-prey interactions (i.e., predator hotspots) and would result in increased predation compared to alternatives with fewer structures (Sabal et al. 2016).

Habitat restoration would likely decrease native fish predation rates through increased cover provided by riparian vegetation, LWM, and shallow floodplain habitat. Increased floodplain inundation events would likely have a net neutral effect on predation rates, with increased bass and sunfish habitat balanced by increased hiding cover and food production for native fish.

Chapter 8 Cultural Resources

Cultural resources may be defined as any building, structure, object, or location of past human activity, occupation, or use that may be identified through documentary evidence, oral history, inventory survey, or subsurface investigation. They may include archaeological sites, traditional cultural properties or tribal cultural resources, or structures within the built environment. This chapter describes cultural resources in the Reach 4B/ESB Project area, and how they could be affected by each alternative.

8.1 Setting

8.1.1 Regional Setting

The Project area is in the Central Valley Region of California, bounded by the Siskiyou Mountains to the north, the Tehachapi Mountains to the south, the Coast Ranges to the west, and the Sierra Nevada and Cascade ranges to the east. Appendix H includes a full discussion of this setting in the prehistoric and historic periods.

8.1.2 Reach 4B/ESB Project Area

Reclamation has characterized the Reach 4B/ESB Project area through archival and records searches, use of previous surveys, and project-specific surveys.

Archival and Records Searches

Reclamation completed archival and records searches for the Reach 4B/ESB Project at the Central California Information Center (CCIC), California State University, Stanislaus. Full copies of all cultural resource records and cover pages for all cultural resource reports associated with the Study Area were obtained for a one-mile radius surrounding the San Joaquin River and a half-mile radius for the Eastside Bypass and Mariposa Bypass (Byrd et al. 2009:3-5). The *Cultural Resources Sensitivity Study and Research Design for the San Joaquin River Restoration Program, Fresno, Madera, Merced, and Stanislaus Counties, California* includes the compiled findings from the archival and records searches (Byrd et al. 2009). This report is available for archaeologists, and the results are considered in this chapter (in a summary form).

Previous Survey Coverage

Sixteen prior cultural resource studies have been carried out within a one-mile radius of Reach 4B of the San Joaquin River and within a half-mile radius of the Eastside Bypass and Mariposa Bypass canals. Of those, 12 encompassed portions of the Study Area.

Previously Recorded Cultural Resources

Fifteen cultural resources (ten prehistoric, two multi-component, and three historic period) have been previously recorded within a one-mile radius of Reach 4B of the San Joaquin River and a half-mile radius of the Eastside Bypass and Mariposa Bypass canals (Byrd et al. 2009:40). Of those, ten were found to intersect the Study Area. Only one of those ten resources, the Stevinson/East Side Canal (P-24-000580), was evaluated and determined not eligible for listing in the National Register of Historic Places (NRHP) and/or the California Register of Historical Resources (CRHR), a determination that received concurrence from the

SHPO in 1998 (JRP 1998 as cited in Jones and Stokes 2002; Kreutzberg 1998 as cited in Jones and Stokes 2002).

Known Ethnographic Resources

Native American ethnographic resources within the Study Area were identified in a report prepared for the SJRRP PEIS/R (Davis-King 2009). The report presented confidential maps of approximate Native American resource locations and described Native American contact and consultation efforts. Two Native American village sites, *malim/cheneche* and *hah-no-mah,* were noted within the Study Area (Davis-King 2009). The location of *malim/cheneche* was uncertain, but believed to be east of the river near the northernmost extent of Reach 4B1; *hah-no-mah* was reported approximately one-half mile south of the river near Salt Slough. *Malim* may correspond to CA-MER-40, a prehistoric site that was first recorded in 1960. *Hah-no-mah* does not appear to have been recorded as an archaeological resource.

Historic Period Land Use Features

In addition to the cultural resources noted above, a number of historic period architectural or land use features were identified through an examination of historic period USGS topographic maps (Byrd et al. 2009). Several of these features were later recorded through an inventory survey of the Study Area; they have been given temporary (PL-SJRRP-FEAT-02, -05, and -06) or permanent (P-24-000580 and P-24-001962) designations. The majority of these features have not been identified through inventory survey, however, either because they no longer exist or because they lay within areas that have yet to be examined. These features include structures such as canals, ditches, roads, levees, and buildings but overwhelmingly consist of water conveyance features such as the Salt Slough Ditch, Pick Anderson Bypass, Pozo Drain, Loop Ditch, Middle Ditch, Eastside Bypass, Orchard ditch, Island Canal C, and Mariposa Bypass (Byrd et al. 2009).

Archaeological and Built Environment Inventory Surveys

A cultural resource inventory survey was conducted within the Study Area between May and November 2012 (Schneider et al. 2017). A total of 4,968 acres, including 1,276 acres within the Merced NWR and the San Luis NWR, were subject to inventory survey. Approximately 1,579 acres for which access permissions were available could not be surveyed because they were inundated or covered by dense vegetation. Within those areas that were inspected, six prehistoric archaeological sites and 24 isolated artifacts (23 prehistoric, one historic period) were newly discovered. One previously recorded prehistoric site (CA-MER-413) was relocated and re-recorded. In addition, portions of five historic period land use features were found to abut or intersect the Study Area. These features included two canals, two bypasses, and one ditch system. Two of these features (P-24-000580 and P-24-001962) had been previously recorded and three (PL-SJRRP-FEAT-02, -05, and -06) had been previously identified through map research. All of these cultural resources are detailed in a supporting cultural resources report (Schneider et al. 2017).

Reclamation led a *Historical Resources Inventory and Evaluation* effort for the Eastside Bypass Improvements Project (Norby and Wee 2017). The inventory and evaluation found that the Eastside Bypass within the Project area meets the significance criteria under the National Register of Historic Places (NRHP) and the California Register of Historic Resources (CRHR), if the historic integrity of other sections is sufficient to meet the criteria. Therefore, the analysis below considers the Eastside Bypass/Levee and associated features as a potentially historic significant district.

8.2 Alternative Comparison

This section highlights several key issues and how each alternative would function related to these issues.

8.2.1 Effects to Cultural Resources

Construction and O&M activities could affect known and unknown cultural resources in the Project area. Implementation of Best Management Practices (BMPs) would minimize potential effects. Table 8-1 shows cultural resources within the Project area that could be affected by each alternative. The BMPs and other requirements will be identified through a Programmatic Agreement (PA). The PA is being developed for the SJRRP by Reclamation, the State Historic Preservation Officer (SHPO), and consulting parties, including Native American tribes, for compliance with Section 106 of the National Historic Preservation Act (NHPA). The PA will provide a framework for conducting the Section 106 process, including mitigation and review protocols, for the Reach 4B/ESB Project and for the SJRRP as a whole.

Table 8-1. Potentially Affected Resource in the Reach 4B/ESB Project Area

Identified Cultural Resources	Alt 1A	Alt 1B	Alt 1C	Alt 2A	Alt 2B	Alt 3
PL-SJRRP-FEAT-02	X	X	X	X	X	
PL-SJRRP-FEAT-04				X	X	
PL-SJRRP-FEAT-05		X	X			
PL-SJRRP-FEAT-06				X	X	
PL-SJRRP-A-001				X	X	
PL-SJRRP-A-003				X		
PL-SJRRP-A-004					X	
PL-SJRRP-A-005					X	
PL-SJRRP-A-006			X			
PL-SJRRP-A-007			X			
P-24-001757				X	X	
P-24-001763	X	X	X	X	X	X
CA-MER-10				X	X	
CA-MER-11				X	X	
CA-MER-39/H				X		
CA-MER-40	X	X	X	X	X	X
CA-MER-409	X	X	X	X	X	X
CA-MER-410	X	X	X	X	X	X
CA-MER-412/H	X	X	X			X
CA-MER-478				X		
CA-MER-482				X	X	

No Action Alternative

The Reach 4B/ESB Project would not include construction or O&M under the No Action Alternative, so it would not affect cultural resources.

Alternative 1 – Main Channel Restoration

Alternative 1 could affect known and unknown resources in Reaches 4B1 and 4B2 and new floodplain habitat surrounding Reach 4B1. Impacts could occur to known resources that have not been evaluated for listing in the NRHP and/or the CRHR (see Table 8-1) or to unknown cultural resources in areas that have not been subject to prior cultural resource inventory. Alluvial deposits near the river also are considered sensitive for buried cultural resources (Byrd et al. 2009), and unknown cultural deposits not observable through surface inspection may exist the within the Alternative 1 footprint.

Alternative 1 O&M activities could induce water movement or wave activity that could affect cultural resources. O&M could also change biochemical conditions in an area that would adversely affect resources (Ware 1989). Proposed actions that may result in inundation, erosion, sedimentation, and/or periodic exposure of cultural resources would include Reach 4B1 levee construction and modifications; channel habitat modifications involving the removal of existing levees to allow flow to reach the floodplain; floodplain habitat modifications or grading of the floodplain; and modifications to existing road crossings. Periodic sediment and in-channel vegetation removal also may be required near the Sand Slough Control Structure once it is installed to ensure correct operation. Reach 4B1 levee construction and modifications in particular have the potential to increase the total area that is subject to flooding and water conveyance, while road crossing and weir modifications would likely change flooding patterns.

Alternative 2 – Bypass Restoration

Alternative 2 could affect known and unknown resources in the Middle Eastside Bypass, Mariposa Bypass, and Reach 4B2 (Alternative 2A) or the Middle Eastside Bypass and Lower Eastside Bypass (Alternative 2B). Alternative 2 could also affect resources within the area where levees would be set back to create floodplain habitat. Impacts could occur to known resources that have not been evaluated for listing in the NRHP and/or the CRHR (see Table 8-1) or to unknown cultural resources in areas that have not been subject to prior cultural resource inventory. As discussed in Alternative 1, alluvial deposits near the river are considered sensitive for buried cultural resources (Byrd et al. 2009), and unknown cultural deposits not observable through surface inspection may exist the within the Alternative 2 footprint. The types of impacts from O&M activities would be the same as described for Alternative 1, but the effects would be on known and unknown resources in the bypass system.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 could affect known and unknown resources in the Reach 4B1, Reach 4B2, Middle Eastside Bypass, and Lower Eastside Bypass. Alternative 3 does not involve setback levees in these channels; therefore, the impacts to known and unknown resources could be less than in Alternatives 1 and 2. Impacts could occur to known resources that have not been evaluated for listing in the NRHP and/or the CRHR (see Table 8-1) or to unknown cultural resources in areas that have not been subject to prior cultural resource inventory. As discussed in Alternative 1, alluvial deposits near the river are considered sensitive for buried cultural resources (Byrd et al. 2009), and unknown cultural deposits not observable through surface inspection may exist the within the Alternative 3 footprint. The types of impacts from O&M activities would be the same as described for Alternative 1, but the effects would be on known and unknown resources in the bypass system.

8.2.2 Effects to Historic Resources

Within the Project area, only one resource, the Stevinson/East Side Canal (P-24-000580), has been previously evaluated for listing in the NRHP and/or the CRHR. The resource was found not eligible for listing in either register. As discussed in Section 8.1.2, The Eastside Bypass/Levee (P-24-001962) is assumed to be eligible for listing in this evaluation.

No Action Alternative

The Reach 4B/ESB Project would not include construction or O&M under the No Action Alternative, so it would not affect cultural resources.

Alternative 1 – Main Channel Restoration

Alternative 1 would focus actions within the Reach 4B1 and 4B2 channels, and would therefore not affect these historic resources.

Alternative 2 – Bypass Restoration

Alternative 2 could affect the Stevinson/East Side Canal and the Eastside Bypass/Levee. Alternative 2 includes a setback levee in the Eastside Bypass, which would include moving portions of the existing levee that make up this resource. Implementation of a PA will allow for identification and treatment of historic properties.

Alternative 3 – Bypass All Pulse Flows

Alternative 3 would include activities in the area of the Stevinson/East Side Canal and Eastside Bypass/Levee, but it would work within the existing footprint of the bypass system. It would not affect the Stevinson/East Side Canal, and it would only make stability improvements to the Eastside Bypass/Levee (and would not develop setback levees). Implementation of a PA will allow for identification and treatment of historic properties.

THIS PAGE LEFT BLANK INTENTIONALLY.

Chapter 9 Implementation Considerations

The previous chapters have described environmental benefits and impacts that help understand the tradeoffs between the action alternatives. This chapter describes other implementation considerations that are relevant to decision-makers.

9.1 Levee Stability Work

Chapter 2 provided information on all of the levee work that needs to be completed to improve levee stability and channel capacity. Each reach in the Project area is at a different phase of study, and additional investigation may change the required components. Each reach would need the following levee work:

- Reach 4B1: existing levees would need to be replaced.
- Reach 4B2: the low-flow channel is adjacent to levees, so the levees would likely require seepage berms or slurry walls. The detailed study on this reach is not yet complete to identify the areas that need improvement, but the analysis assumes that the entire reach will require improvements.
- Middle Eastside Bypass: most areas would require improvements or replacement, as defined in Alternative 2.
- Lower Eastside Bypass: preliminary investigations indicate improvements would be necessary just downstream of the Eastside Bypass Control Structure, but the downstream portions would not require improvements. The detailed study on this area is not yet complete.
- Mariposa Bypass: Alternative 2A includes a setback levee on one side of the Mariposa Bypass and improvements to the opposite levee. Subsequent investigations are considering whether the setback levee is necessary, and it may be possible to remove this component as the levee studies move forward.

These improvements are a major contributor to the cost estimates for the alternatives. Table 9-1 shows which levee improvements are included in each alternative. Table 9-1 shows how the levee stability work required in Alternative 2 could change if Reach 4B1 improvements are delayed. The Settlement requires improvements in Reach 4B1 to convey at least 475 cfs, but phasing these construction actions could help make the Reach 4B/ESB project more affordable.

Table 9-1. Levee Stability Improvements in Each Alternative

Alternative #	Alternative Name	4B1	4B2	MESB	LESB	Mariposa
1A	Main Channel Restoration, Levee Option B	X	X			
1B	Main Channel Restoration, Levee Option C	X	X			
1C	Main Channel Restoration, Levee Option D	X	X			
2A	Bypass Restoration through Reach 4B2 (With 4B1 Improvements)	X	X	X		X
2A	Bypass Restoration through reach 4B2 (Without 4B1 Improvements)		X	X		X

Alternative #	Alternative Name	4B1	4B2	MESB	LESB	Mariposa
2B	Bypass Restoration through the Lower Eastside Bypass (With 4B1 Improvements)	X	X	X	X	
2B	Bypass Restoration through the Lower Eastside Bypass (Without 4B1 Improvements)			X	X	
3	Bypass All Pulse Flows	X	X	X	X	

Key:
MESB = Middle Eastside Bypass
LESB = Lower Eastside Bypass

9.2 Cost

Table 9-2 shows preliminary cost estimates for the action alternatives. These cost estimates are based on initial information and will change as the alternatives move forward in the design process. Similar to the levee improvement table, the estimates for Alternative 2 show costs with and without Reach 4B1 improvements because phasing construction could make the project more affordable.

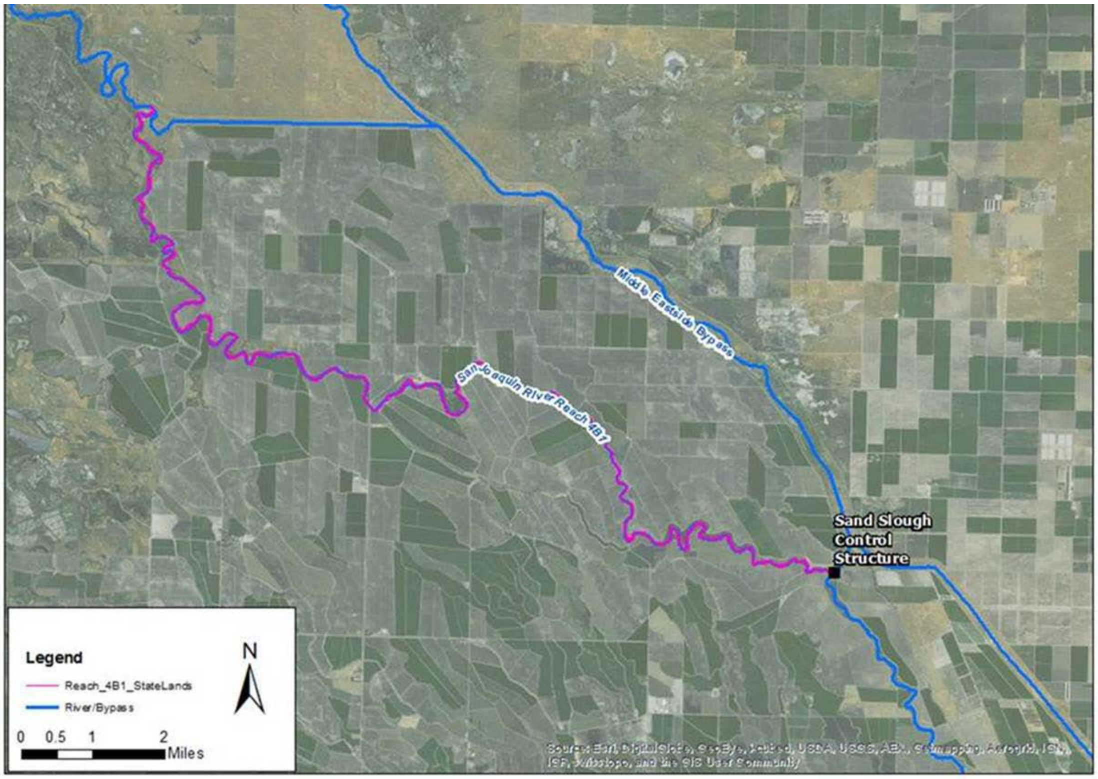
Table 9-2. Preliminary Alternative Cost Estimates

Alternative #	Alternative Name	Likely Cost ($ million)
1A	Main Channel Restoration, Levee Option B	$660
1B	Main Channel Restoration, Levee Option C	$682
1C	Main Channel Restoration, Levee Option D	$717
2A	Bypass Restoration through Reach 4B2 (With 4B1 Improvements)	$679
2A	Bypass Restoration through reach 4B2 (Without 4B1 Improvements)	$468
2B	Bypass Restoration through the Lower Eastside Bypass (With 4B1 Improvements)	$678
2B	Bypass Restoration through the Lower Eastside Bypass (Without 4B1 Improvements)	$467
3	Bypass All Pulse Flows	$826

9.3 Public Access

Figure 9-1 shows that within the Reach 4B/ESB Project area, the Reach 4B1 portion is considered State Sovereign and Public Trust Land. These areas are portions of navigable waterways the State of California has the responsibility to protect for the use and benefit of the public. The land below low water line is considered Sovereign Land and the land between low water and high water points is considered Public Trust Land. The low water line is considered the elevation in the streambed that water covers for most of the year, usually occurring during the Fall season in a normal water year. The high-water line is the elevation of the streambed where erosion occurs and there is often a change in the vegetation line.

Reach 4B1 would fall under the common law Public Trust Doctrine, which protects sovereign lands, including those submerged under navigable waterways, for the benefit and use by the public. While the waterways and immediate shoreline would be subject to the Public Trust Doctrine, the lands surrounding the Reach 4B1 portion of the Project area may be under private ownership and would not be required to grant public access. Any current public use of the river is limited to floating or boating use from existing public access points when rules governing the area permit boating activities (California State Lands Commission [SLC] 2015).



Reach 4B1 and Eastside Bypass Landowners

Subject to Revision

Source: SLC 2014

Figure 9-1. State Land Area in Reach 4B under Public Trust Doctrine

The alternatives that route Restoration Flows through Reach 4B1 (Alternatives 1 and 3) would provide opportunities for water-based recreation on the Public Trust lands. Although there may be an increase in boating opportunities like kayaking and floating in isolated sections of Reach 4B1 and Public Trust requires recreational use of the waterway, all public access would be limited to any existing access points. Public Trust requirements do not apply to the land surrounding the river, so local signage and instructions would indicate limits of public access to the river.

Alternative 2 would route flows through the Eastside Bypass. The Eastside Bypass does not have Public Trust lands that would allow recreational use. Although there has been some stakeholder interest in improving public access in this area, the bypass system does not incorporate public access at this time.

THIS PAGE LEFT BLANK INTENTIONALLY.

Chapter 10 Summary and Conclusions

The potential alternatives for the Reach 4B/ESB Project each have benefits and drawbacks. This section summarizes key conclusions and discusses next steps.

10.1 Alternative Comparison and Key Conclusions

Each resource analyzed in this document provides information about how the alternatives would function as part of the SJRRP. The sections below summarize key conclusions for each section.

Hydrology and Flood Operations

- The LSJLD may not choose to route Flood Flows into the Reach 4B1 channel, which would reduce flows during wetter periods for Alternatives 1 and 3. This operation could cause confusion for migrating fish and affect habitat because it would not have a consistent water source.
- Alternatives that route Restoration Flows through the Lower Eastside Bypass (No Action Alternative, Alternative 2B, Alternative 3) could create a straying concern with Owens Creek, Duck Slough, and Deadmans Slough.
- Differential subsidence (with more subsidence at the upstream end of the Reach 4B/ESB Project area than the downstream end) will reduce the capacity of the bypass system for flood management. Alternative 2 improves the bypass levees and may have an opportunity for cooperation with flood control agencies to improve the system for both flood management and restoration actions.

River Geomorphology and Sedimentation

- The No Action Alternative would have a decrease in freeboard in the Middle Eastside Bypass because of differential subsidence. This decreased freeboard will reduce the capacity for floods. All action alternatives would improve this condition and alternatives in the river channel would be more stable in the long term.
- The upstream end of Reach 4B1 and the Middle Eastside Bypass would have a substantial amount of sediment deposition because of current and projected future subsidence. The Middle Eastside Bypass would experience more sedimentation for alternatives that route Restoration Flows through the Bypass (Alternatives 2 and 3).

Vegetation and Soils

- Shallow groundwater levels in both the river and bypass channels are adequate to support new vegetation in the long-run, but revegetation efforts would require irrigation to establish the plants.
- Soil conditions in the Reach 4B1 channel would support a broader range of vegetation (for Alternatives 1 and 3) than in the bypass channel (Alternative 2). The bypass channel would primarily support grasses and shrubs, with some larger trees.

Groundwater

- Shallow groundwater levels would rise in the Reach 4B1 channel (under Alternatives 1 and 3) and the Eastside Bypass channel (under Alternative 2). The action alternatives include measures to avoid seepage impacts to neighboring landowners.

- Groundwater modeling indicates that both the Reach 4B1 channel and Middle Eastside Bypass channel would sometimes gain water from the shallow groundwater aquifer and sometimes lose water to shallow groundwater. The most common condition is for both channels to be losing. Reach 4B1 has more conductive soil conditions, so it loses more water to the groundwater over time. Alternative 1, therefore, may have trouble maintaining Settlement flow targets within Reach 4B1.

Fisheries and Wildlife

- Construction of setback levees in the Middle Eastside Bypass (under Alternative 2) would reduce the availability of managed seasonal wetlands for waterfowl and shorebirds.
- Water temperature would be critical to the success of any of the action alternatives. Groundwater temperatures are cooler than river temperatures during critical periods; however, groundwater modeling indicates that both Reach 4B1 and the Middle Eastside Bypass are typically losing streams. The groundwater is not moving into the river channels and would not be able to help with temperature management in either channel.
- Alternative 1D would result in the most-high value habitat for fish, and Alternative 3 would result in the least amount of high value habitat. All action alternatives, however, would substantially exceed the amount needed to maintain the desired SJRRP fish populations.
- Alternative 3 could create a predator concern with the new Reach 4B headgate structure and fish passage facility.

Cultural Resources

- All alternatives have the potential to affect known and unknown resources. The potential impacts would be reduced through development of a Programmatic Agreement between Reclamation, the State Historic Preservation Officer, and consulting parties, including Native American tribes, for compliance with section 106 of the National Historic Preservation Act.

Implementation Considerations

- Alternatives 1 and 3 would have a main channel on Public Trust land in Reach 4B1, but Alternative 2 would have a main channel in the bypass system (which does not have Public Trust land). Providing public access in the bypass system could disrupt waterfowl and hunting uses.

These conclusions highlight multiple tradeoffs between the alternatives. Often, the element that makes an alternative perform well for one resource can cause concerns for others. Table 10-1 summarizes which alternatives perform better (green) or less well (yellow) for each topic. These colors represent a comparison of performance between the alternatives based on the analysis in the sections above.

Table 10-1. Key Alternative Tradeoffs

Resource Area	Topic	Alt 1	Alt 2A	Alt 2B	Alt 3
Hydrology and Flood Flows	Keep flood flows together				
	Potential for straying				
	Cooperation opportunities with flood agencies				
Geomorphology and Sediment	Maintain freeboard				
	Sediment management				

Vegetation and Soils	Water supply for vegetation				
	Soils support broad range of plants				
Groundwater	Seepage management				
	Ability to maintain Restoration Flows				
Fisheries and Wildlife	Managed seasonal wetland effects				
	Water temperature and thermal refugia				
	Suitable habitat				
	Predator concerns				
Cultural resources	Potential to affect known and unknown resources				
Other Implementation Concerns	Potential public access conflicts				

Legend

Higher Performance	Lower Performance

10.2 Next Steps

The SJRRP released the *Funding Constrained Framework for Implementation* in May 2018 (SJRRP 2018). This effort reflects a more limited funding stream than previously anticipated and identifies the investments for this funding into the future. This framework identifies that the SJRRP will complete the activities included in the No Action Alternative (including the Eastside Bypass Improvements Project) but will delay additional work within the Reach 4B/ESB Project area until after 2024.

The SJRRP is not planning to select and implement Alternative 1, 2, or 3 for the high flow routing decision for the Reach 4B/ESB Project in the near term. Other actions, however, could improve conditions within the near term. The evaluation results identified a number of smaller projects that could provide benefits before a long-term project is implemented:

- Middle Eastside Bypass low-flow channel modifications: The sediment transport evaluation (see Chapter 4) identified that a steeper low-flow channel in Alternative 2 would assist in sediment transport through the reach. Modifying the channel in the near-term could avoid maintenance required for sediment removal, and help maintain a properly-sized low-flow channel for fish passage.
- Off-channel habitat restoration: An SJRRP study released juvenile salmon in a variety of locations, including the Cinnamon Slough area of the Merced NWR. The salmon in the NWR grew well in this study. The levee setbacks proposed in Alternative 2 would allow this area to be used for both waterfowl and fish rearing, but these setbacks will not occur in the near-term. There may be opportunities with the NWR or private landowners to look for small areas of off-channel habitat in the interim period.
- Characterize levee requirements: As discussed in Chapter 9, the levee improvements needed for levee stability and seepage in Reach 4B2, the Mariposa Bypass, and the Lower Eastside Bypass are not fully characterized. Studies to consider these areas would be beneficial, and near-term actions could include levee stability actions in areas where improvements are necessary.

THIS PAGE LEFT BLANK INTENTIONALLY.

Chapter 11 References

Beamesderfer, R. C. P., and M. A. H. Webb. 2002. *Green sturgeon status review information. S. P. Cramer & Associates.* Gresham, Oregon. Prepared for State Water Contractors. April 26.

Boles, G. 1988. *Water temperature effects on Chinook salmon (Oncorhynchus tshawytscha) with emphasis on the Sacramento River:* A literature review. California Department of Water Resources, Northern District. 42 pp.

Butler, N. L. 2013. *Thermal conditions in riverine pools from the Eastside Bypass/Reach 4 to Reach 5.* Prepared for the San Joaquin River Restoration Program, Sacramento, California. 143 p.

Byrd, B. F., Wee, S., and Costello, J. 2009. Cultural Resources Sensitivity Study and Research Design for the San Joaquin River Restoration Program, Fresno, Madera, Merced, and Stanislaus Counties, California. Far Western Anthropological Research Group, Inc., Davis, California. Report prepared for MWH Environmental Permitting, Sacramento, California on behalf of the US Bureau of Reclamation, Mid-Pacific Region, Sacramento, California.

CALFED. 2000. Final Programmatic Environmental Impact Statement/Environmental Impact Report. pp. 5.4-1 to 5.4-14. Available at: http://calwater.ca.gov/calfed/library/Archive_EIS.html

California Department of Food and Agriculture (CDFA). 2010. *Noxious Weed Pest Ratings.* Available from: http://www.cdfa.ca.gov/phpps/ipc/weedinfo/winfo_list-pestrating.htm

California Department of Water Resources (DWR). 2004. California's Groundwater: Bulletin 118, Update 2003. Individual description for the Merced Subbasin. February 27. Available at: http://www.water.ca.gov/groundwater/bulletin118/basindescriptions/5-22.04.pdf

_____. 2006. California's Groundwater: Bulletin 118, Update 2003. Individual description for the Delta-Mendota Subbasin. January 20. Available at: http://www.water.ca.gov/groundwater/bulletin118/basindescriptions/5-22.07.pdf

_____. 2011. *Final Geomorphology Technical Memoranda and Maps.* South NULE Geomorphic Assessments. Prepared by Kleinfelder West, Inc. January.

_____. 2013. Evaluation of the Effect of Subsidence on Flow Capacity in the Chowchilla and Eastside Bypasses. South Central Region Office.

California State Lands Commission (SLC). 2014. Reach 4B1 State Lands Record of Survey. Filed with Merced County, Book 53 of Surveys, pages 7-30. May 24.

_____. 2015. The Public Trust Doctrine Webpage. Accessed on June 15, 2017. Available from: http://www.slc.ca.gov/About/Public_Trust.html.

Cal-IPC. 2006. *California Invasive Plant Inventory.* Cal-IPC Publication 2006-02. California Invasive Plant Council: Berkeley, CA. Available online at: www.cal-ipc.org. Accessed in 2006.

Cech, J. J. and C. A. Myrick. 1999. *Steelhead and Chinook salmon bioenergetics: temperature, ration, and genetic effects.* Davis, CA: University of California Water Resources Center, 1999.

Cramer Fish Sciences. 2012. *Juvenile salmonid out-migration monitoring at Caswell Memorial State Park in the lower Stanislaus River, California: 2010-2011 Biannual Report.* Prepared for U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program. 48 pp.

Cross, B.K., M.A. Bozek, and M.G. Mitro. 2013. *Influence of riparian vegetation on trout stream temperatures in central Wisconsin*. North American Journal of Fisheries Management 33: 682-692.

Davis, M.A., and K. Thompson. 2000. *Eight Ways to Be a Colonizer, Two Ways to Be an Invader: A Proposed Nomenclature Scheme for Invasion Ecology.* Bulletin of the Ecological Society of America 81: 226-230.

Davis-King, S. 2009. Native American Ethnographic Information in Support of the Program Environmental Impact Statement/Report for the San Joaquin River Restoration Program, Fresno, Madera, and Merced Counties, California. Davis-King & Associates. Volume 1 & 2. Submitted to Far Western Anthropological Research Group, Inc. for the US Bureau of Reclamation, Mid-Pacific Region, Sacramento, California Environmental Science Associates (ESA). 2016. *Reconnaissance Biological Surveys of the San Joaquin River Restoration Reach 4B Eastside Bypass Refuge Alignment.* December 9, 2016.

Farr, T. G., C. E. Jones, and Z. Liu. 2017. Progress Report: Subsidence in California, March 2015 – September 2016. Jet Propulsion Laboratory, California Institute of Technology. Pasadena, CA. Accessed on June 10, 2017. Available at: http://www.water.ca.gov/waterconditions/docs/2017/JPL%20subsidence%20report%20final%20for%20public%20dec%202016.pdf.

Healey, M.C. 1991. *The life history of Chinook salmon. Pages 311–393 in C.* Groot and L Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, Canada.

Jackson, Z.J. and J.P. Van Eenennaam. 2013. 2012. *San Joaquin River sturgeon spawning survey*. Stockton Fish and Wildlife Office, Anadromous Fish Restoration Program, U.S. Fish and Wildlife Service, Lodi, California.

Jeffres, C.A., J.J. Opperman, P.B. Moyle. 2008. *Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California River.* Environmental Biology of Fishes 83:449–458.

Johnson, S.L. 2004. *Factors influencing stream temperatures in small streams: substrate effects and a shading experiment*. Canadian Journal of Fisheries and Aquatic Sciences 61: 913-923.

Jones and Stokes Associates, Inc. 2002. Supplemental Cultural Resources Survey Report for East Bear Creek Unit Water Delivery Project, San Luis National Wildlife Refuge, Merced County, California. Study ME-4707 on file at the Central California Information Center, California State University, Stanislaus, Turlock, California.

Keefer, M.L. and C.C. Caudill. 2014. *Homing and straying by anadromous salmonids: a review of mechanisms and rates*. Reviews in Fish Biology and Fisheries 24: 333-368.

Keefer, M.L., C.C. Caudill, C.A. Peery, and C.T. Boggs. 2008. *Non-direct homing behaviours by adult Chinook salmon in a large, multi-stock river system*. Journal of Fish Biology 72: 27-44.

Larsen, E.W., E.H. Girvetz, and A.K. Fremier. 2006. *Assessing the effects of alternative setback channel constraint scenarios employing a river meander migration model*. Environmental Management 37:880-897.

Lindley, S.T., R. Schick, B.P. May, J.J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R.B. MacFarlane, C. Swanson, and J.G. Williams. 2004. *Population structure of threatened and endangered Chinook salmon ESUs in California's Central Valley Basin.* Technical Memorandum NOAA-TM-NMFS-SWFSC-360. National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, California.

Lower San Joaquin Levee District. 1967. Lower San Joaquin River Flood Control Project Operation and Maintenance Manual for Levees, Irrigation and Drainage Structures, Channels and Miscellaneous Facilities, Part I, II, and III. Amended in 1978.

Marine, K. R. 1997. *Effects of elevated water temperature on some aspects of the physiological and ecological performance of juvenile Chinook salmon (Onchorhynchus tshawytscha):* Implications for management of California's Central Valley salmon stocks. Master's thesis. University of California, Davis.

Marine, K. R. and J. J. Cech. 2004*. Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon.* North American Journal of Fisheries Management 24:198-210.

Massa, D. J. Bergman, B. Kreb. 2010. *Lower Yuba River Accord Monitoring and Evaluation Plan2009-2010 Annual Escapement Survey Report*. Prepared for the Lower Yuba River Accord River Planning Team by the Pacific States Marine Fisheries Commission. 26p.

Massa, D., J. Bergman, C. Campos, C. Purdy. 2009*. Lower Yuba River Accord Monitoring and Evaluation Plan 2008 Annual Escapement Survey Report*. Prepared for the Lower Yuba River Accord River Planning Team by the Pacific States Marine Fisheries Commission. 2008 Annual Report. 30p.

McBain and Trush (eds.). 2002. *San Joaquin River Restoration Study Background Report*. Prepared for Friant Water Users Authority, Lindsay, CA and the Natural Resources Defense Council, San Francisco, CA.

Meng, L., and P.B. Moyle. 1995. *Status of splittail in the Sacramento-San Joaquin Estuary.* Transactions of the American Fisheries Society 124: 538–549.

Miles, S,R. and C.B. Goudey. 1997. *Ecological Subregions of California: Section and Subsection Descriptions*. USDA Forest Service, Pacific Southwest Region Publication R5-EM-TP-005. San Francisco, CA.

Moore, R.D., D.L. Spittlehouse, and A. Story. 2005*. Riparian microclimate and stream temperature response to forest harvesting: a review*. Journal of the American Water Resources Association 41: 813-834.

Moyle, P.B. 2002. *Inland fishes of California: revised and expanded.* University of California Press, Berkeley.

Moyle, P.B., R.D. Baxter, T. Sommer, T.C. Foin, and S.A. Matern. 2004. *Biology and population dynamics of Sacramento Splittail (Pogonichthys macrolepidotus) in the San Francisco Estuary: a review.* San Francisco Estuary and Watershed Science [online serial] 2(2):1-47.

Mussetter Engineering, Inc. 2002a. Hydraulic and Sediment Continuity Modeling of the San Joaquin River From Friant Dam to Mendota Dam. Prepared for the United States Department of the Interior, Bureau of Reclamation, Contract No. 98-CP- 20-20060.

_____. 2002b. "Hydraulic and Sediment-continuity Modeling of the San Joaquin River from Mendota Dam to the Merced River," U.S. Bureau of Reclamation, Contract No. 99-CP-20-2080.

Myrick, C.A. and J.J. Cech. 2002. *Growth of American River fall-run Chinook Salmon in California's Central Valley: temperature and ration effects.* California Fish and Game 88: 35-44.

Natural Resources Conservation Service (NRCS). 2012. Soil Survey Geographic (SSURGO) Database. Merced County, Western Part and Merced Area

Norby, H. and Wee, S. 2017. Eastside Bypass Improvements Project, Merced County, Historical Resources Inventory & Evaluation Report. December 22, 2017.

Ojutkangas , E., K. Aronen, and E. Laukkanen. 1995. *Distribution and abundance of river lamprey (Lampetra fluviatilis) ammocoetes in the regulated River Perhonjoki. Regulated Rivers:* Research and Management 10:239–245.

Poole, G.C. and C.H. Berman. 2001. *An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation.* Environmental Management 27: 787-802.

Rounds, S.A. 2007. Temperature effects of point sources, riparian shading, and dam operations on the Willamette River, Oregon. United States Geological Survey Scientific Investigations Report 2007-5185.

Sabal, M., Hayes, S., Merz, J. and Setka, J., 2016. *Habitat Alterations and a Nonnative Predator, the Striped Bass, Increase Native Chinook Salmon Mortality in the Central Valley, California.* North American Journal of Fisheries Management, 36(2), pp.309-320.

San Joaquin River Flood Control Project Agency. 2015. *Upper San Joaquin River regional flood management plan*. Prepared for the California Department of Water Resources, Sacramento, California.

San Joaquin River Restoration Program (SJRRP). 2010a. *Conceptual models of stressors and limiting factors for San Joaquin River Chinook salmon.* Exhibit A of fisheries management plan. November 2010.

_____. 2010b. *Fisheries management plan: a framework for adaptive management in the San Joaquin River Restoration Program.* San Joaquin River Restoration Program. November 2010.

_____. 2011a. Programmatic biological assessment. San Joaquin River Restoration Program. November 2011.

_____. 2011b. *San Joaquin River Restoration Program. Appendix B. 2011 Draft Annual Technical Report*. Fish passage evaluation. Task 1, evaluation of partial fish passage barriers. July 2011.

_____. 2012a. *San Joaquin River Restoration Program Environmental Impact Statement/Report.* Available from: https://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=2940. Accessed on March 27, 2017.

_____. 2012b. *Minimum Floodplain Habitat Area for Spring and Fall-Run Chinook Salmon.* Available from: http://www.restoresjr.net/download/program-documents/program-docs-2012/20121127_MinimumRearingHabitat.pdf. Accessed on March 27, 2017.

_____. 2014. 2013-2014 *Fish Assemblage Inventory and Monitoring.* 2014 Mid-Year Technical Report. Prepared for SJRRP by USFWS, Stockton, CA.

_____. 2017. *Fish Assemblage Inventory and Monitoring 2013-2014. Draft Final Monitoring and Analysis Plan Report.* Prepared for San Joaquin River Restoration Program by U.S. Bureau of Reclamation, Technical Service Center, Denver, Colorado and USFWS, Lodi Fish and Wildlife Office, Lodi, California.

San Joaquin River Restoration Program (SJRRP). 2016. Subsidence Mapping 2016. Accessed on August 10, 2017. Available at: http://www.restoresjr.net/wp-content/uploads/SubsidenceMappingDecember2016.pdf.

San Joaquin River Restoration Program. 2018. *Funding Constrained Framework for Implementation.* Available from: http://www.restoresjr.net/?wpfb_dl=2163. Accessed on June 11, 2018.

Schneider, T., S. Lane, and J. Holson. 2017. Cultural Resources Survey and Inventory for the San Joaquin River Restoration Program Reach 4B1, Eastside Bypass Reach 2, and Eastside Bypass Reach 3 Merced County, California. Prepared by Pacific Legacy, Inc. for the US Bureau of Reclamation, Mid-Pacific Region.

Sedell, J.R., Reeves, G.H., Hauer, F.R., Stanford, J.A. and Hawkins, C.P. 1990. *Role of refugia in recovery from disturbances:* modern fragmented and disconnected river systems. Environmental Management, 14(5), pp.711-724.Seesholtz, A.M., M.J. Manuel and J.P. Van Eenennaam. 2015. First documented spawning and associated habitat conditions for green sturgeon in the Feather River, California. Environmental Biology of Fishes 98(3): 905-912.

Shuford, W. D., G. W., Page, and J. E. Kjelmyr. 1998. Patterns and dynamics of shorebird use of California's Central Valley. The Condor 100: 227-244.

Sommer, T., R. Baxter, and B. Herbold. 1997. *Resilience of splittail in the Sacramento-San Joaquin estuary.* Transactions of the American Fisheries Society 126: 961–976.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. *Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival.* Canadian Journal of Fisheries and Aquatic Sciences 58: 325-333.

Southern California Edison (SCE). 2003. Draft Technical Study Reports for the Big Creek Hydroelectric Projects (FERC Project Nos. 67, 120, 2085, and 2175).

Steward, C.R., and T.C. Bjornn. 1987. *The distribution of chinook salmon juveniles in pools at three discharges.* In: Proceedings of the Annual Conference Western Association of the Fish and Wildlife Agencies 67:364-374.

Stillwater Sciences. 2003. Restoration Objectives for the San Joaquin River. Berkeley, CA.

The Bay Institute of San Francisco. 1998. *From the Sierra to the sea: The ecological history of the San Francisco Bay-Delta watershed.* Copyright 1998 The Bay Institute of San Francisco.

United States Army Corps of Engineers (USACE). 2002. Sacramento and San Joaquin River Basins Comprehensive Study, California. Appendix A: Technical Studies, United States Army Corps of Engineers and State of California Reclamation Board. December.

——. 2013. National Levee Database. Accessed on: January 5, 2013. Available at: http://nld.usace.army.mil.

——. 2016. Data on Burns, Bear, Owens, and Mariposa Creeks from 1995 – 2015. Accessed from: http://www.spk-wc.usace.army.mil/plots/california.html.

U.S. Department of Agriculture (USDA). 2017. *Introduced, Invasive, and Noxious Plants. Plants Database. U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS).* Accessed March 2017. Available at: https://plants.usda.gov/java/noxious?rptType=State&statefips=06.

United States Department of the Interior, Bureau of Reclamation (Reclamation). 2009. *Supplemental Water Temperature Modeling of the Effects of the Long-Term Operations of the Central Valley Project in the Lower American River, in Consideration of Various Future Climate Change Scenarios.* Modeling Results Submitted to NMFS via e-mail.

United States Department of the Interior, Bureau of Reclamation (Reclamation). 2011a. Geomorphology, Sediment Transport, and Vegetation Assessment Appendix. April 2011

_____. 2011b. San Joaquin River Restoration Program Draft PEIS/R. April 2011.

_____. 2012. *Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project First Administrative Draft Survey Results Technical Memorandum.* December 2012.

_____. 2012. Water Quality Monitoring for San Joaquin River Seepage Management Projects, Water Quality Assessment and Quality Assurance Summary, Sample Collection: December 2012.

_____. 2013. Water Quality Monitoring for San Joaquin River Seepage Management Projects, Water Quality Assessment and Quality Assurance Summary, Sample Collection: May 2013.

_____. 2016. San Joaquin River Restoration Program Subsidence Mapping. Available at: http://www.restoresjr.net/wp-content/uploads/SubsidenceMappingDecember2016.pdf

_____. 2016. *Hydrology, Hydraulic, and Sediment Studies for Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project, Technical Report No. SRH-2016-13.* Prepared for San Joaquin River Restoration Project, Mid-Pacific Region, US Bureau of Reclamation, by the Technical Service Center, Denver, CO.

______. 2017. San Joaquin River Restoration Program Seepage Management Plan. Available at: http://www.restoresjr.net/monitoring-data/groundwater-monitoring/

United States Environmental Protection Agency (EPA). 2001. *Issue Paper 5: Summary of technical literature examining the effects of temperature on salmonids.* Region 10, Seattle, WA. EPA 910-D-01-005. 113pp. Available at: http://yosemite.epa.gov/R10/water.nsf.

United States Fish and Wildlife Service (USFWS). 2008. *Invasive Species.* Resource Mapping and Spatial Analysis.

United States Geological Survey (USGS). undated. San Joaquin Valley, California Largest human alteration of the Earth's surface. Available at: https://pubs.usgs.gov/circ/circ1182/pdf/06SanJoaquinValley.pdf

Ward, P.D., T.R. McReynolds, and C.E. Garman. 2006. *Butte Creek Spring-Run Chinook Salmon, Oncorhynchus tshawytscha, Pre-spawn Mortality Evaluation 2004. Calif. Dept. of Fish and Game, Inland Fisheries Admin. Report No.2006-1. 49 pp.*

Ware, J. A. 1989. Archeological Inundation Studies: Manual for Reservoir Managers. Prepared for Department of the Army, US Army Corps of Engineers, Washington, D.C.

Westley, P.A.H, T.P. Quinn, and A.H. Dittman. 2013. *Rates of straying by hatchery-produced Pacific salmon (Oncorhynchus* spp.*) and steelhead (Oncorhynchus mykiss) differ among species, life history type, and populations*. Canadian Journal of Fisheries and Aquatic Sciences 70: 735-746.

THIS PAGE LEFT BLANK INTENTIONALLY.