**Technical Memorandum**

# Channel Capacity Report
# 2017 Restoration Year

SAN JOAQUIN RIVER
RESTORATION PROGRAM

# Table of Contents

## Tables



## Figures

## Appendices

# List of Abbreviations and Acronyms

| | |
|---|---|
| CBBS | Chowchilla Bypass Bifurcation Structure |
| CCAG | Channel Capacity Advisory Group |
| CDEC | California Data Exchange Center |
| CFS | Cubic feet per second |
| CPT | Cone Penetration Test (Cone Penetrometer Test) |
| CVFPP | Central Valley Flood Protection Plan |
| CVFED | Central Valley Floodplain Evaluation and Delineation |
| CVFPB | Central Valley Flood Protection Board |
| Delta | Sacramento-San Joaquin Delta |
| DEM | Digital Elevation Model |
| DMC | Delta-Mendota Canal |
| DTM | Digital Terrain Model |
| DWR | Department of Water Resources |
| FSRP | Flood System Repair Project |
| GAR | Geotechnical Assessment Report |
| GDR | Geotechnical Data Report |
| GOR | Geotechnical Overview Report |
| GCR | Geotechnical Conditions Report |
| LMAs | Local Maintaining Agencies |
| LSJLD | Lower San Joaquin Levee District |
| LSJRFC Project | Lower San Joaquin River Flood Control Project |
| MNWR | Merced National Wildlife Refuge |
| NRDC | Natural Resources Defense Council |
| NOD | Notice of Determination |
| NULE | Non-Urban Levee Evaluation |
| O&M | Operations and Maintenance |
| PEIS/R | Program Environmental Impact Statement/Environmental Impact Report |
| RACER | Remedial Alternatives and Cost Estimates Report |
| Reclamation | Bureau of Reclamation |
| Restoration Area | San Joaquin River Restoration Program Restoration Area |
| RFMP | Regional Flood Management Plan |
| RM | River mile |
| ROD | Record of Decision |
| SJLE Project | San Joaquin Levee Evaluation Project |
| SJRRP | San Joaquin River Restoration Program |
| SPFC | State Plan of Flood Control |
| WSE | Water surface elevation |
| WSP | Water surface profile |
| ULE | Urban Levee Evaluation |
| USACE | U.S. Army Corps of Engineers |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| USJR | Upper San Joaquin River |

# Definitions

**San Joaquin River Restoration Program (SJRRP):** The SJRRP (also known as Program) was established in late 2006 to restore and maintain fish populations in good condition in the mainstem of the San Joaquin River (SJR) below Friant Dam to the confluence of the Merced River, while reducing or avoiding adverse water supply impacts.

**Settlement:** In 2006, the SJRRP was established to implement the Stipulation of Settlement in *NRDC, et al., v. Kirk Rodgers, et al*.

**Program Environmental Impact Statement/Environmental Impact Report (PEIS/R):** The Bureau of Reclamation (Reclamation), as the federal lead agency under the National Environmental Policy Act (NEPA) and the California Department of Water Resources (DWR), the state lead agency under the California Environmental Quality Act (CEQA), jointly prepared a Program Environmental Impact Statement/Report (PEIS/R) and signed a Record of Decision and Notice of Determination (ROD and NOD), respectively, in 2012 to implement the Settlement.

**Channel Capacity Advisory Group:** The Channel Capacity Advisory Group provides focused input to Reclamation's determination of "then-existing channel capacity" within the Restoration Area.

**Then-existing channel capacity:** The channel capacity within the Restoration Area that correspond to flows that would not significantly increase flood risk from Restoration Flows in the Restoration Area. This annual report will recommend updating then-existing channel capacity based on recently completed evaluations.

**In-channel capacity:** The channel capacity at which the water surface elevation is maintained at or below the elevation of the outside ground (i.e., along the landside levee toe).

# 1.0 Executive Summary

## Background

The San Joaquin River Restoration Program (SJRRP) was established in late 2006 to implement a Stipulation of Settlement (Settlement) in *NRDC, et al., v. Kirk Rodgers, et al.* The U.S. Department of the Interior, Bureau of Reclamation, the Federal lead agency under the National Environmental Policy Act, and the California Department of Water Resources (DWR), the State lead agency under the California Environmental Quality Act, prepared a joint Program Environmental Impact Statement/Report (PEIS/R) to support implementation of the Settlement.

The Settlement calls for releases of Restoration Flows, which were initiated in 2014 and are specific volumes of water to be released from Friant Dam during different water year types, according to Exhibit B of the Settlement. Federal authorization for implementing the Settlement is provided in the San Joaquin River Restoration Settlement Act (Act) (Public Law 111-11). Reclamation signed the Record of Decision (ROD)/Notice of Determination (NOD) on September 28, 2012. Both the PEIS/R and the ROD committed to establishing a Channel Capacity Advisory Group (CCAG) to determine and update estimates of then-existing channel capacities as needed and to maintain Restoration Flows at or below estimates of then-existing channel capacities. Then-existing channel capacities in the Restoration Area (leveed reaches within the San Joaquin River between Friant Dam and the confluence of the Merced River and the flood control bypass) correspond to flows that would not significantly increase flood risk from Restoration Flows. This Channel Capacity Report is for the 2017 Restoration Year and is the fourth report in a series of reports prepared annually. The 2017 Report, prepared in coordination with the CCAG, fulfills the commitments in the ROD/NOD.

The primary objective of this report is to provide the CCAG and the public a summary of the prior Restoration Year's data, methods, and estimated channel capacities; and recommendations for monitoring and management actions for the following year. Identifying then-existing channel capacity is critically important to ensure the release of Restoration Flows would not significantly increase flood risk in the Restoration Area. This report only considers flood risks associated with levee failure when estimating then-existing channel capacity; all other potential material impacts, including agricultural seepage, are addressed in other analyses but are also summarized in this report.

## CCAG Roles and Responsibilities

The CCAG is comprised of members from the Bureau of Reclamation (Convener), California Department of Water Resources (DWR, Co-convener), U.S. Army Corps of Engineers (USACE), Lower San Joaquin Levee District (LSJLD), and the Central Valley Flood Protection Board (CVFPB). The role of the CCAG is to: (1) provide independent review of Reclamation's estimates of then-existing channel capacity as needed; (2) provide independent review of

Channel Capacity Reports; (3) participate in CCAG meetings; (4) provide independent and timely review of data; and (5) provide input and guidance on monitoring and management actions.

## Study Area

This Channel Capacity Report focuses on the portion of the Restoration Area where levees exist along channels to control flows. The leveed reaches on the San Joaquin River start at Gravelly Ford (River Mile 226.9) and continue to the Merced River confluence (River Mile 118.2). The study area also includes the Eastside Bypass from the Sand Slough Connector Channel to the confluence with the San Joaquin River and the Mariposa Bypass.

## Findings and Recommendations

Then-existing channel capacities are defined as flows that would correspond to the appropriate levee slope stability and underseepage Factors of Safety based on USACE criteria for levees. The application of the criteria requires the collection and evaluation of data at locations throughout the Restoration Area. Until adequate data are available to apply the USACE criteria, the release of Restoration Flows would be limited to those that would remain in-channel (the water surface elevation in the river remains below the levees). Two studies were completed for the 2016 Report and will continue to provide the best information to inform channel capacities for the 2017 Report: the *San Joaquin River In-channel Capacity Analysis* (Tetra Tech, 2015b) and the Priority 1 Levee Assessment.

A summary of the current and recommended then-existing channel capacity for the San Joaquin River and flood bypasses are described in Table ES-1 below. In addition to consideration of then-existing channel capacities, the release of Restoration Flows would also be limited by agricultural seepage. The table also identifies limitations in Restoration Flows based on agricultural seepage. Details of how these seepage limits are determined and limit Restoration Flows are in the *Seepage Management Plan*.

**Table ES-1.**
**Current and Recommended Then-existing Channel Capacity**

| Reach | Current Then-existing Channel Capacity (cfs) | Recommended Then-existing Channel Capacity (cfs)[1] |
|---|---|---|
| Reach 2A | 6,000 | 6,000[2] |
| Reach 2B | 1,120 | 1,120[3] |
| Reach 3 | 2,860 | 2,860[4] |
| Reach 4A | 2,840 | 2,840[5] |
| Reach 4B1 | Not Analyzed | Not Analyzed |
| Reach 4B2 | 930 | 930 |
| Reach 5 | 2,350 | 2,350 |
| Middle Eastside Bypass | 580 | 580[6] |
| Lower Eastside Bypass | 2,890 | 2,890 |
| Mariposa Bypass | 350 | 350 |

[1] Then-existing channel capacity shown in this table is based on levee stability only and does not consider Restoration Flow limitations related to agricultural seepage.
[2] Capacity not assessed for flows greater than 6,000 cfs. Restoration Flows are limited to approximately 2,140 cfs due to agricultural seepage.
[3] Restoration Flows are limited to approximately 1,300 cfs due to agricultural seepage.
[4] Restoration Flows are limited to approximately 900 cfs due to agricultural seepage.
[5] Restoration Flows are anticipated to be limited to approximately 300 cfs due to agricultural seepage.
[6] The recommended then-existing channel capacity reflects the typical board setting at the weirs that allows for flow diversions within the Merced National Wildlife Refuge. If all of the boards are removed from the weirs, the capacity could increase to 1,070 cfs. If all of the boards are placed in the weirs, Restoration Flows could not be put into the bypass without exceeding USACE criteria. Restoration Flows are anticipated to not be limited in this reach due to agricultural seepage.

# Current Channel Capacity Studies and Related Work Completed

The following technical studies and related work have been completed for this year's report that relate to channel capacities and were specifically evaluated to determine the recommended then-existing channel capacities in this report.

## In-channel Capacity Study

The *San Joaquin River In-channel Capacity Analysis* (Tetra Tech, 2015b) was performed to determine in-channel capacity of the San Joaquin River and the Eastside and Mariposa bypasses between Friant Dam and the confluence with the Merced River. The study incorporates ground subsidence in significantly impacted areas of Reach 3, Reach 4A, and the Eastside Bypass and geotechnical conditions of the levees in Reach 2A, Reach 4A, and the Middle Eastside Bypass. The in-channel flow capacity of each reach was determined to be the highest flow rate through the reach where the water-surface elevation is at or below the outside ground elevation for any part of the reach. Results for each reach are summarized in Table ES-2. The in-channel capacity in reaches that did not previously have geotechnical data inform the 2017 then-existing channel capacities provided in Table ES-1.

**Table ES-2.**
**Summary of In-channel Capacity for Each Side of Levee by River Reach**

| Reach | Levee Side | In-channel Capacity[1] (cfs) |
|---|---|---|
| | | |
| Reach 2A | Left | 2,430 |
| Reach 2A | Right | 1,630 |
| | | |
| Reach 2B (Entire Reach) | Left | 0 |
| Reach 2B (Entire Reach) | Right | 0 |
| Reach 2B (Excluding Mendota Pool)[2] | Left | 1,120 |
| Reach 2B (Excluding Mendota Pool)[2] | Right | 1,550 |
| | | |
| Reach 3 | Left | 3,960 |
| Reach 3 | Right | 2,860 |
| | | |
| Reach 4A (Inside geotechnical study area)[3] | Left | 980 |
| Reach 4A (Inside geotechnical study area)[3] | Right | 1,340 |
| Reach 4A (Outside geotechnical study area ) | Left | 2840 |
| Reach 4A (Outside geotechnical study area ) | Right | 2840 |
| | | |
| Reach 4B2 | Left | 1,370 |
| Reach 4B2 | Right | 930[4] |
| | | |
| Reach 5 | Left | 2,350 |
| Reach 5 | Right | 2,500 |
| | | |
| Middle Eastside Bypass (Eastside Bypass Reach 2) (Boards Out condition)[5] | Left | 10[6] |
| Middle Eastside Bypass (Eastside Bypass Reach 2) (Boards Out condition)[5] | Right | 340[6] |
| | | |
| Lower Eastside Bypass (Eastside Bypass Reach 3) | Left | 2,970 |
| Lower Eastside Bypass (Eastside Bypass Reach 3) | Right | 2,890 |
| | | |
| Mariposa Bypass | Left | 650 |
| Mariposa Bypass | Right | 350 |

[1] Capacity based on outside ground elevations.
[2] Portion of reach above influence of Mendota Pool (about River Mile 209.5).
[3] Includes the length of levee that was analyzed under the SJLE Project and is included in the Geotechnical Conditions Report (GCR). In-channel capacity results are superseded by the geotechnical assessment in the GCR.
[4] Capacity excludes localized deep depressions, which would reduce capacity to 50 cfs.
[5] Capacity assumes the refuge is not diverting flows and the weirs are not operating ("Boards Out").
[6] In-channel capacity is essentially 0 cfs when the refuge is diverting flow and the weirs are operating ("Typical Boards" and "Boards In").

## Priority 1 Levee Geotechnical Assessment

Levee evaluations along the San Joaquin River and flood bypasses are being conducted by DWR to assist the SJRRP assess flood risks due to levee seepage and stability associated with the release of Restoration Flows for the SJRRP. The evaluations were performed under DWR's San Joaquin Levee Evaluation Project (SJLE Project) and included the exploration and evaluation of existing levees within the Restoration Area that will be used to convey future Restoration Flows. The evaluation would allow the SJRRP to identify the maximum flow that can be conveyed on the levees without exceeding USACE criteria for levee underseepage and slope stability.

In identifying the priorities of the SJLE Project, DWR classified levee segments in the Restoration Area in one of three categories representing an increasing priority for the need to complete the geotechnical evaluation and analyses. Priority 1 levees are located in Reach 2A (14.9 miles) (Gravelly Ford Study Area); the Middle Eastside Bypass (from Sand Slough to the Eastside Bypass Control Structure) (20.6 miles), and the lowest 4.1 miles of Reach 4A (Middle Eastside Bypass Study Area).

The result of the SJLE Project evaluations was a maximum water surface elevation in 26 levee reaches within the Reach 2A, Reach 4A, and Middle Eastside Bypass that can be conveyed by the existing levees without exceeding USACE criteria. A hydraulic analysis to establish a maximum flow capacity in these levee reaches was then performed on the results of the SJLE Project analysis.

The geotechnical assessments, evaluations and identified maximum water surface elevation for the identified reaches are summarized in Geotechnical Conditions Reports (GCR). Table ES-3 summarizes the maximum water surface elevation and respective allowable flows of at least 6,000 cfs that can be put into each reach of the levees within the Gravelly Ford Study Area (Reach 2A).

**Table ES-3.**
**Maximum Allowable Flows on Levees for the Gravelly Ford Study Area**

| GCR Reach | GCR Station (ft) | Representative Model Cross Section | GCR Reference Elevation (ft) | Capacity (cfs) |
|---|---|---|---|---|
| **Gravelly Ford Study Area (Reach 2A)** | | | | |
| A | 11418+00 | 526981 | 176.0 | >6,000 cfs |
| B | 11560+00 | 541706 | 182.5 | >6,000 cfs |
| C | 11644+00 | 549708 | 185.3 | >6,000 cfs |
| D | 11708+00 | 555801 | 189.7 | >6,000 cfs |
| E[1] | | | | |
| F | 11647+00 | 521166 | 173.3 | >6,000 cfs |
| G | 11742+00 | 532395 | 178.7 | >6,000 cfs |
| H | 11830+00 | 538908 | 182.6 | >6,000 cfs |

[1] Reach E was not evaluated due to the low height of the levee.

Table ES-4 summarizes the maximum water surface elevation and the respective allowable flows that can be put into each reach with the Middle Eastside Bypass Study Area (Reach 4A, Middle and Upper Eastside Bypass). This study area has been adjusted for subsidence and shows that five reaches have an allowable flow capacity of less than 4,500 cfs. Table ES-4 also shows the capacity of the Middle Eastside Bypass Study Area assuming conditions at the weirs within the Merced National Wildlife Refuge. If the weirs are not operating, it is known as the "Boards Out" condition, and the capacity of the reach is about 1,070 cfs. If the weirs are operating in their typical configuration, known as the "Typical Condition", the capacity is reduced to 580 cfs. However, occasionally, all of the boards are placed into the weirs. This is known as the "Boards In" condition, which essentially reduces the capacity of the reach to 0 cfs.

**Table ES-4.**
**Maximum Allowable Flows on Levees for the Middle Eastside Bypass Study Area**

| GCR Reach | GCR Station (ft) | Representative Model Cross Section | Post-Subsidence | | |
|---|---|---|---|---|---|
| | | | GCR Reference Elevation (ft) [post-subsidence] | Capacity (cfs) | |
| | | | | Typical Boards | Boards Out |
| **Eastside Bypass Study Area (Reach 4A and Middle Eastside Bypass)** | | | | | |
| A | 102000 | 60106 | 99.4 | >4,500 | >4,500 |
| B | 106500 | 64035 | 105.5 | >4,500 | >4,500 |
| C | 111000 | 69622 | 98.2 | 3,290 | 3,290 |
| D | 116400 | 73247 | 100.9 | >4,500 | >4,500 |
| E | 136100 | 93015 | 103.2 | >4,500 | >4,500 |
| F | 144600 | 101445 | 102.6 | >4,500 | >4,500 |
| G | 152300 | 107371 | 111.4 | >4,500 | >4,500 |
| H | 155500 | 108228 | 109.2 | >4,500 | >4,500 |
| I | 157000 | 109849 | 108.6 | >4,500 | >4,500 |
| J | 106000 | 61699 | 96.3 | 4,150 | 4,150 |
| K | 111830 | 67946 | 100.2 | >4,500 | >4,500 |
| L | 116800 | 72501 | 99.6 | 2,600 | 2,600 |
| M | 126500 | 82690 | 105.6 | >4,500 | >4,500 |
| N | 134500 | 90952 | 102.3 | >4,500 | >4,500 |
| O | 140500 | 96995 | 99.2 | 580[1] | 1,070 |
| P | 152500 | 109849 | 104.3 | >4,500 | >4,500 |
| Q | 937400 | 269381 | 109.7 | >4,500 | >4,500 |
| R | 926300 | 270685 | 107.3 | >4,500 | >4,500 |

[1] If all of boards are placed in the weirs at the refuge, the capacity of this reach is essentially 0 cfs.

# Future Program Actions with the Potential to Impact Then-existing Channel Capacity

Throughout Settlement implementation, the maximum downstream extent and rate of Restoration Flows to be released would be limited to then-existing channel capacities. As channel or structure modifications are completed with additional environmental compliance, Restoration Flow releases would be correspondingly increased in accordance with then-existing channel capacities and with the release schedule. If the release of water from Friant Dam is required for flood control purposes, concurrent Restoration Flows would be reduced by an amount equivalent to the required flood control release. If flood control releases from Friant exceed the concurrent scheduled Restoration Flows, no additional releases above those required for flood control would be made for SJRRP purposes. Until sufficient data are available to determine the levee seepage and stability Factors of Safety, Reclamation would limit initial Restoration Flow releases to those flows which would remain in-channel. When sufficient data are available to determine the Factors of Safety, Reclamation would limit the release of Restoration Flows to those flows which would maintain standard USACE levee performance criteria at all times.

This report, similar to the previous years' Reports, describes both the future Program studies and monitoring and non-program actions with the potential to inform then-existing channel capacity. The future Program technical studies include continued implementation of the SJLE Project (includes geotechnical exploration and analysis), continued study and updates to the Reach 2A Morphology Study (as needed), continued subsidence monitoring and study, as well as a vegetation study (as needed). The Program monitoring activities also continue to include: gage monitoring, water surface profile surveys, aerial and topographic surveys, and vegetation surveys.

There are other entities that are active in the Restoration Area and whose programs may help inform or impact then-existing channel capacity. The SJRRP will need to closely coordinate and collaborate with these entities by sharing data and coordinating specific actions along the river that can inform or impact channel capacity. These entities and activities include the LSJLD's operation and maintenance of the bypass system and river channel, the U.S. Fish & Wildlife Service operation of weirs within the boundaries of the Merced National Wildlife Refuge (MNWR) along the Middle Eastside Bypass, and DWR efforts such as the Non-Urban Levee Evaluations, the Regional Flood Management Planning effort and the Flood System Repair Project. The SJRRP would continue to coordinate with these non-Program efforts and actions, and the CCAG will consider the effect of these actions in future Channel Capacity Reports.

# 2.0 Introduction

The San Joaquin River Restoration Program (SJRRP) was established in late 2006 to implement a Stipulation of Settlement (Settlement) in *NRDC, et al., v. Kirk Rodgers, et al*. The U.S. Department of the Interior, Bureau of Reclamation (Reclamation), the Federal lead agency under the National Environmental Policy Act (NEPA), and the California Department of Water Resources (DWR), the State lead agency under the California Environmental Quality Act (CEQA), prepared a joint Program Environmental Impact Statement/Report (PEIS/R) to support implementation of the Settlement. The Settlement calls for releases of Restoration Flows, which were initiated in 2014 and are specific volumes of water to be released from Friant Dam during different water year types, according to Exhibit B of the Settlement. Federal authorization for implementing the Settlement is provided in the San Joaquin River Restoration Settlement Act (Act) (Public Law 111-11). Reclamation signed the Record of Decision (ROD)/Notice of Determination (NOD) on September 28, 2012. Both the PEIS/R and the ROD/NOD committed to establishing a Channel Capacity Advisory Group (CCAG) to determine and update estimates of then-existing channel capacities as needed and to maintain Restoration Flows at or below estimates of then-existing channel capacities. Then-existing channel capacities in the Restoration Area (the San Joaquin River between Friant Dam and the confluence of the Merced River) correspond to flows that would not significantly increase flood risk from Restoration Flows. Sections of the PEIS/R applicable to the CCAG are included in Appendix A of this report.

This Channel Capacity Report for the 2017 Restoration Year (2017 Report) is the fourth in the series of annual reports required to fulfill the commitments in the ROD/NOD. The 2014, 2015, and 2016 Channel Capacity Reports can be found at the SJRRP website. The previous report can be found under the following link:

http://www.restoresjr.net/wp-content/uploads/Channel_Capacity_Report_2016.pdf.

The 2014 and 2015 Reports were the first reports to recommend then-existing channel capacities. The capacities in these reports were based on limited information regarding levee stability and subsidence. The 2016 Report recommended then-existing channel capacities based on geotechnical data in portions of Reach 2A, Reach 4A, and the Middle Eastside Bypass. The 2016 Report also considered subsidence in those reaches where capacity has likely changed as a result of subsidence. The 2017 Report does not recommend updating then-existing channel capacity due to the lack of additional geotechnical and topographic data. Therefore, this report will include the studies used to directly support then-existing channel capacities for the previous 2016 Report and Restoration Year. The report also describes several data collection and study efforts that are expected to be completed in 2017 that will be used to inform subsequent reports.

The 2017 Report was available for a 60-day public review and comment period beginning on September 19, 2016 to November 18, 2016. No written comments were received.

## 2.1 Objective

This Channel Capacity Report is required by the SJRRP PEIS/R and the corresponding ROD/NOD. The primary objective of the report is to provide the CCAG and the public a summary of the prior year's data, methods, and estimated channel capacities and the following year's monitoring and management actions. In doing so, it will present data, evaluations, estimates of then-existing channel capacity, and management actions to address levee stability, hydraulics, and sediment transport within the system in accordance with levee performance standards. Identifying then-existing channel capacity is critically important to ensure the release of Restoration Flows in 2017 would not significantly increase flood risk in the Restoration Area. This report only considers flood risks associated with levee failure when estimating then-existing channel capacity. All other potential material impacts, including agricultural seepage, are addressed in other analyses.

This report shall be prepared annually in coordination with the CCAG. The purpose of the CCAG is to provide independent review of estimated then-existing channel capacities, monitoring results, and management actions to address vegetation and sediment transport within the systems as developed by the Bureau of Reclamation (Reclamation).

## 2.2 CCAG Roles and Responsibilities

The CCAG is comprised of the following organizations:

- Bureau of Reclamation (Convener)
- CA Department of Water Resources (Co-convener)
- U.S. Army Corps of Engineers (USACE)
- Lower San Joaquin Levee District (LSJLD)
- Central Valley Flood Protection Board (CVFPB)

Each organization shall designate a primary and secondary member. The roles and responsibilities of the CCAG members are as follows:

- **Provide independent review of Reclamation's estimates of then-existing channel capacity as needed**: Provide an independent review of Reclamation's estimated then-existing channel capacities, monitoring results, and management actions to address levee stability, hydraulics, and sediment transport within the system estimated by Reclamation in accordance with standard USACE levee performance criteria.
- **Provide independent review of Channel Capacity Reports**: Annually or in the event Reclamation proposes increasing the upper limit of releases for Restoration Flows, Reclamation will release a public report detailing the new upper limits of releases and data and methods used to develop the new upper limits of releases. The CCAG provides input during the development of these public reports.

- **Participate in Channel Capacity Advisory Group meetings:** Reclamation organizes working meetings for the CCAG to review progress made in developing the annual reports. These meetings are an opportunity for the CCAG to comment on content as it is developed. CCAG members attend and participate in working meetings.
- **Provide independent and timely review of data**: The CCAG provides a timely review of data, analytical methodology, and results used to estimate the then-existing channel capacities.
- **Provide input and guidance on monitoring and management actions**: Reclamation provides occasional updates on on-going erosion monitoring and management results – including monitoring of potential erosion sites – to the CCAG. The CCAG provides comments on information provided through these updates.

## 2.3 Channel Capacity Technical Factors

There are several factors that can impact and limit channel capacity. The following is a summary of the factors that could be considered when evaluating and recommending then-existing channel capacities, as well as determining potential future improvements and other management actions of the SJRRP.

- **Levee Integrity** - Channel capacity may be limited if the levee is not constructed to design criteria (e.g., insufficient slope stability Factor of Safety or underseepage Factor of Safety) or if there is insufficient data to assess levee performance. In addition, observations (e.g., boils, sloughing, seepage, etc.) made of the performance of a levee during historical flow releases can also provide information on levee integrity and stability. These factors may result in recommendations to increase or decrease channel capacity.
- **Erosion** - Stream bank erosion that encroaches on the levee prism or has a significant potential to encroach on the levee prism increases the potential for levee failure. Therefore, channel capacity may be limited if erosion is present that could result in levee failure during a flow release.
- **Duration and Timing of Flow Releases –**The duration and timing of flow releases may cause water to be against a levee for a period of time which could result in the levee becoming saturated. As the levee becomes saturated, seepage through and sloughing of the soil can occur, which could result in the loss of foundation stability and ultimately potential levee failure.
- **Sediment Transport** - Sedimentation or scouring may change the geometry of the channel and increase or decrease channel capacity.
- **Subsidence** - Ground subsidence may change the geometry of the channel and increase or decrease channel capacity. Subsidence may also reduce freeboard, thus increasing the potential for overtopping during flow releases.

- **Vegetation** - In-channel vegetation may impact flow and stage and is measured by channel roughness in a hydraulic analysis. Changes in in-channel vegetation can increase or decrease channel capacity.
- **Operation and Maintenance** - Levee operation and maintenance (O&M) programs are necessary to assess changed conditions that could impact channel capacity and to provide flood fight capability in case of levee failure. Channel capacity may be limited if there are inadequate O&M resources to monitor conditions that could affect channel capacity.
- **Constructed Improvements** - Levee construction may improve levee integrity or channel geometry and increase channel capacity.
- **Additional Factors** - Other future conditions (i.e., climate change, structures, land encroachments, etc.) not listed above, or those recommended by the CCAG will also be a consideration in evaluating channel capacity.

The above factors, as well as others, are being considered as part of the current or future SJRRP studies and monitoring to determine then-existing channel capacity.

## 2.4 PEIS/R Approach to Minimizing Flood Risk

As outlined in the PEIS/R, Reclamation will minimize flood risk from Restoration Flows throughout the Settlement implementation process by undertaking three integrated measures: (1) establish a CCAG and determine and update the estimates of then-existing channel capacities as needed; (2) maintain Restoration Flows below estimates of then-existing channel capacities; and (3) closely monitor erosion and perform maintenance and/or reduce Restoration Flows as necessary to avoid erosion-related impacts. The CCAG was established in coordination with the Department of Water Resources (DWR) and prior to the release of Restoration Flows for the 2014 Restoration Year. Reclamation is to prepare an annual report, which would include data and methods used to develop estimates of then-existing channel capacities. A draft report is provided to the CCAG for its review and comment for a period of 60 days. In the event that comments or recommendations are received from the CCAG within 60 days, Reclamation would be required to consider and respond to such comments and prepare a final report for distribution to the CCAG within 60 days of the close of the draft report review period. Reclamation will not increase Restoration Flows above the previously determined then-existing channel capacities until 10 days after the final report is prepared and distributed to the CCAG. Draft reports include the data, methods, and estimated channel capacities; flow limits and any maintenance activities; and monitoring efforts and management actions. Draft and final reports will be made available to the public concurrent with their distribution to the CCAG. This report is the fourth in the series of annual Channel Capacity Reports.

Reclamation will convene the CCAG as required until 2030, but may stop earlier, provided that then-existing channel capacities are determined to equal or exceed the maximum proposed Restoration Flows throughout the Restoration Area. If after 2030 then-existing channel capacities decrease such that full Restoration Flows cannot be conveyed, the CCAG would be reconvened and function as described above until such time that the then-existing channel capacities are determined to equal or exceed the full Restoration Flows.

# 3.0 Study Area

The San Joaquin River originates from the Sierra Nevada Mountains and carries snowmelt from mountain meadows to the valley floor before turning north and becoming the backbone of tributaries draining into the San Joaquin Valley. It is California's second longest river and discharges to the Sacramento-San Joaquin Delta (Delta) and, ultimately, to the Pacific Ocean through San Francisco Bay.

In 1942, Reclamation completed construction of Friant Dam on the San Joaquin River. With the completion of Friant-Kern Canal in 1951 and Madera Canal in 1945, Friant Dam diverted San Joaquin River water supplies to over 1 million acres of highly productive farmland along the eastern portion of the San Joaquin Valley. In 1959, construction of the Lower San Joaquin River Flood Control Project (LSJRFC Project) began. The LSJRFC Project was completed in 1967 and provides flood protection along the San Joaquin River and tributaries in Merced, Madera, and Fresno counties. The LSJRFC Project includes 108 river miles (RMs), 191 miles of levees, and protects over 300,000 acres. An additional 67 miles of non-Project levees also provide flood projection along the San Joaquin River.

The study area starts from the Friant Dam and ends at the confluence of the San Joaquin River with the Merced River. The Channel Capacity Report will focus on the portion of the study area where levees exist along channels to control flows. The leveed reaches on the San Joaquin River start at Gravelly Ford (RM 226.9) and continue to the Merced River confluence (RM 118.2). The study area also includes the Eastside Bypass from the Sand Slough Connector Channel to the confluence with the San Joaquin River and the Mariposa Bypass. The study area is shown in Figure 3-1.

The study area reaches are shown in Figure 3-2 and are describe below. Currently SJRRP flows pass through Reaches 1 through 4A, through the Sand Slough Connector Channel and into the Eastside Bypass, where they travel through Eastside Bypass before entering Reach 5 of the San Joaquin River. Since Reach 1 does not have levees, it is not the focus of the analyses included in this report and is not discussed further. The flood capacities of each of the reaches within the study area, as part of the overall flood control system are shown in Figure 3-3 (DWR, 1985).

## 3.1 Reach 2

Reach 2 marks the beginning of the LSJRFC Project levees and therefore the start of this report's study area. Reach 2 begins at Gravelly Ford and extends approximately 24 miles downstream to the Mendota Pool, continuing the boundary between Fresno and Madera counties. This reach is a meandering, low-gradient channel. Reach 2 is subdivided at the Chowchilla Bypass Bifurcation Structure (CBBS) into two subreaches. Both Reach 2A and Reach 2B were dry in most months prior to the SJRRP. Reach 2A is subject to extensive seepage losses. Reach 2B is a sandy channel with limited conveyance capacity. Reach 2A has a flood design capacity of 8,000 cubic feet per second (cfs) while Reach 2B has a flood design capacity of 2,500 cfs. In Reach 2B, seepage problems are reported to occur at discharges in excess of 1,300 cfs (McBain & Trush, 2002). The levees in Reach 2B are not part of the LSJRFC Project. As part of the SJRRP, setback levees are anticipated to be constructed in Reach 2B to increase its capacity to at least 4,500 cfs.

## 3.2 Reach 3

Reach 3 begins at Mendota Dam and extends approximately 23 miles downstream to Sack Dam. Reach 3 conveys flows of up to 800 cfs from the Mendota Pool for diversion to the Arroyo Canal at Sack Dam, maintaining year-round flow in a meandering channel with a sandy bed. This reach continues along the boundary between Fresno and Madera counties. The sandy channel meanders through a predominantly agricultural area, and diversion structures are common in this reach. Reach 3 has a flood design capacity of 4,500 cfs. The levees in Reach 3 are also not part of the LSJRFC Project. Flood flows from the Kings River are conveyed to Reach 3 via Fresno Slough and Mendota Dam.

## 3.3 Reach 4

Reach 4 is approximately 46 miles long, and is subdivided into three distinct subreaches. Reach 4A begins at Sack Dam and extends to the Sand Slough Control Structure. Other than short 1-2 mile levee segments at the downstream end, levees in Reach 4A are not part of the LSJRFC Project (Figure 3-3). This subreach is dry in most months except under flood conditions and SJRRP flows. Reach 4B1 begins at the Sand Slough Control Structure and continues to the confluence of the San Joaquin River and the Mariposa Bypass. Only the lower 2 miles of Reach 4B1 levees just upstream of the Mariposa Bypass are part of the LSJRFC Project. All flows reaching the Sand Slough Control Structure are diverted to the flood bypass system via the Sand Slough Connector Channel, leaving Reach 4B1 perennially dry for more than 40 years, with the exception of agricultural return flows. Reach 4B1 has a flood design capacity of 1,500 cfs, but the current channel capacity is unknown and could be zero in some locations (SJRRP, 2011). As part of the SJRRP, setback levees may be constructed in Reach 4B1 to increase its capacity to at least 475 cfs and possibly up to 4,500 cfs, depending on the alternative. Reach 4B2 begins at the confluence of the Mariposa Bypass, where flood flows in the bypass system rejoin the mainstem San Joaquin River. Reach 4B2 extends to the confluence of the Eastside Bypass. The levees in this reach are all part of the LSJRFC Project. Reach 4B2 has a capacity of 10,000 cfs.

## 3.4 Reach 5

Reach 5 of the San Joaquin River extends approximately 18 miles from the confluence of the Eastside Bypass downstream to the Merced River confluence. This reach receives flows from Mud and Salt sloughs, and channels that run through both agricultural and wildlife management areas. Much of Reach 5 includes levees that are within the LSJRFC Project. Reach 5 is the end of the study area and has a flood design capacity of 26,000 cfs.

## 3.5 Eastside Bypass and Mariposa Bypass

The Middle Eastside Bypass (Reach 2) extends from Sand Slough Connector Channel to the Eastside Bypass Control Structure. Flood flows from Reach 4A of the San Joaquin River and the Upper Eastside Bypass (Reach 1) and the Chowchilla Bypass can be diverted into the bypass at the head of this reach. The Merced National Wildlife Refuge (MNWR) is in the middle of this reach of the bypass and diverts some flows to its Refuge by using two weirs. The Lower Eastside Bypass (Reach 3) extends from the head of the Mariposa Bypass to the head of Reach 5, and receives flows from Deadman, Owens, and Bear creeks. The Mariposa Bypass extends from the Mariposa Bypass Control Structure to the head of Reach 4B2. A drop structure is located near the downstream end of the Mariposa Bypass that dissipates energy from flows before they enter the mainstem San Joaquin River. The flood design flow for the Middle Eastside Bypass (Reach 2) is 16,500 cfs; the Lower Eastside Bypass (Reach 3) is between 8,000 cfs at its upstream end and 18,500 cfs just downstream of its confluence with Bear Creek; and 8,500 cfs for the Mariposa Bypass. As part of the SJRRP, the Middle and Lower Eastside bypasses may be used for Restoration Flows, but its overall design flood capacity will not be increased.

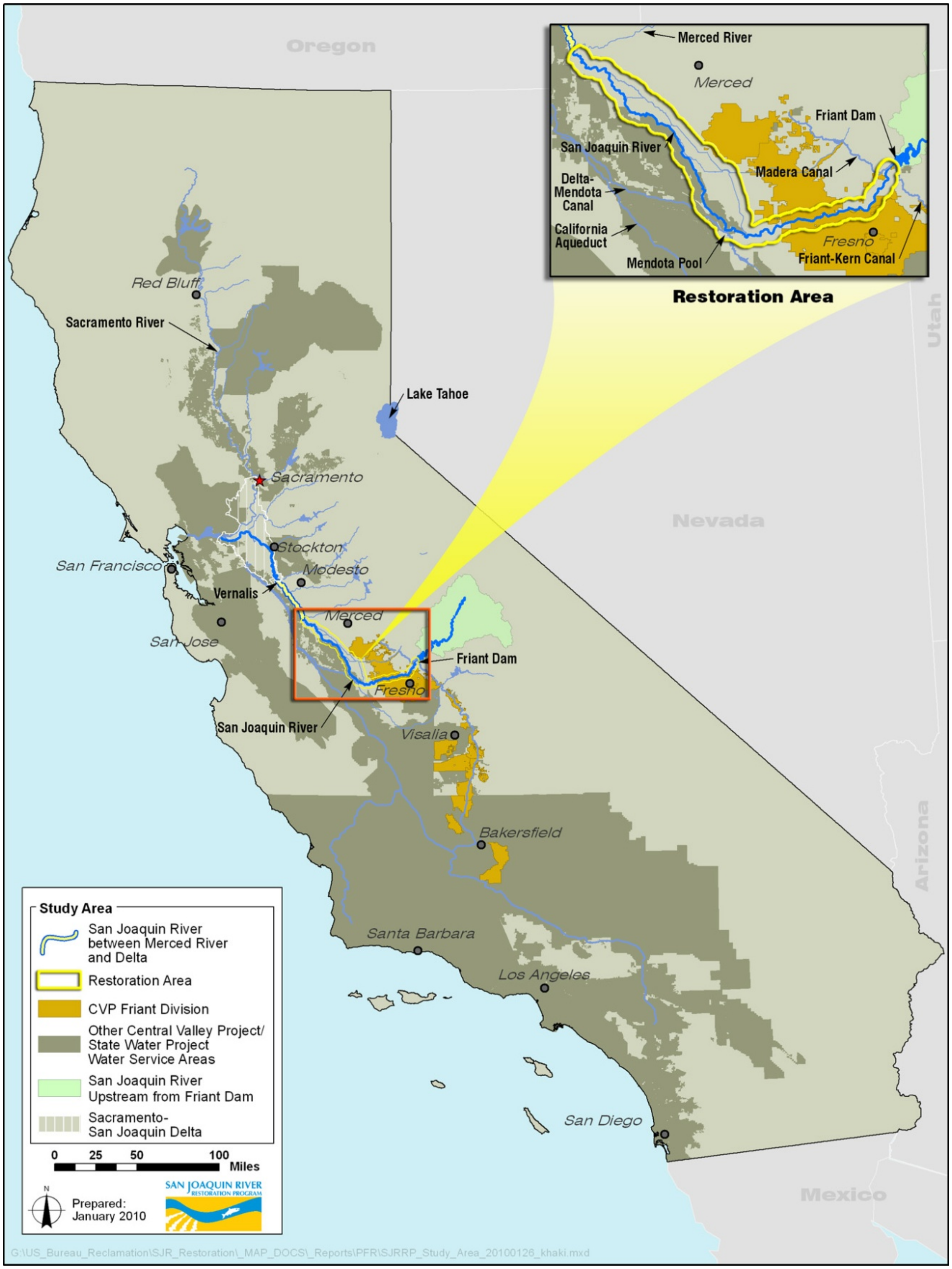


**Figure 3-1.**

**San Joaquin River Restoration Program Location**

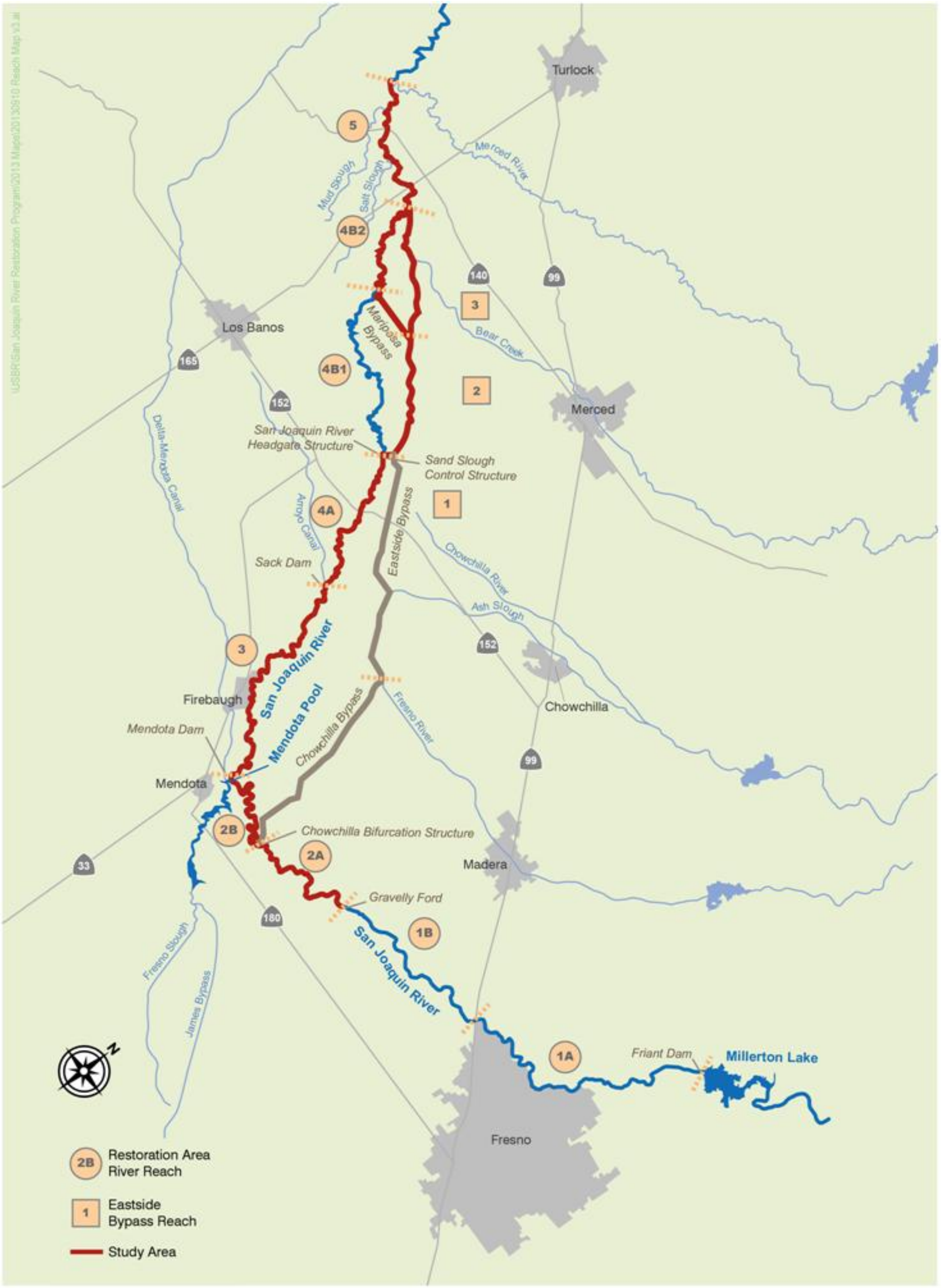


**Figure 3-2.**

**San Joaquin River Reaches and Flood Bypass System**

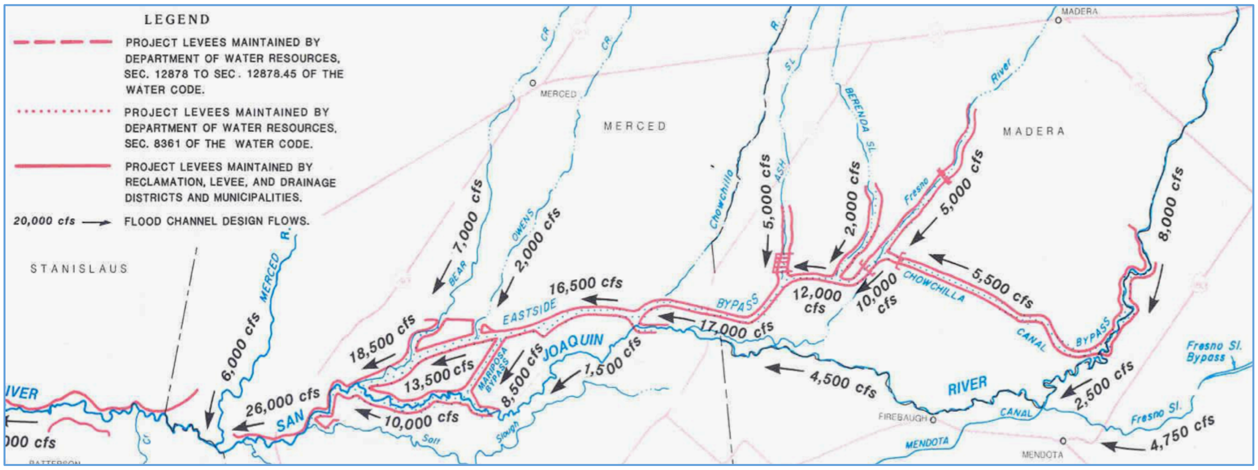


**Figure 3-3.**

**Flood Channel Design Flows**

# 4.0 Then-existing Channel Capacity Criteria

Then-existing channel capacities, as defined for this report, consider levee stability and seepage, but not other factors like agricultural seepage. This section presents the levee evaluation criteria described in the PEIS/R for determining then-existing channel capacity and briefly describes the process that will be used to collect data and perform analyses to determine levee conditions to further refine then-existing channel capacity estimates.

## 4.1 PEIS/R Levee Criteria

An objective of the SJRRP is to minimize increases in flood risk due to the release of Restoration Flows. To achieve this objective, the PEIS/R included the levee design criteria developed by USACE in *Design and Construction of Levees Engineering and Design Manual (Manual No. 1110-2-1913)* (USACE, 2000), *Engineering Manual: Slope Stability (Manual No. 1110-2-1902)* (USACE, 2003), and *Design Guidance for Levee Underseepage (Engineering Technical Letter No. 1110-2-569)* (USACE, 2005). The levee design criteria and guidelines are to be applied throughout the Restoration Area.

The levee criteria are included in the PEIS/R to reduce the risk of levee failure to less-than-significant-levels by meeting levee slope stability and underseepage Factors of Safety. The PEIS/R states that Restoration Flows should not cause the levee slope stability Factor of Safety to be below 1.4, or the underseepage Factor of Safety to be reduced below the value corresponding to an exit gradient at the (landside) toe of the levee of 0.5. The levee slope stability Factor of Safety is defined as the ratio of available shear strength of the top stratum of the levee slope to the necessary shear strength to keep the slope stable (USACE, 2003). The application of the levee slope stability Factor of Safety of 1.4 is required for federally authorized flood control projects. The underseepage Factor of Safety is defined as a ratio of the critical hydraulic gradient to the actual exit gradient of seepage on the levee. USACE design guidance recommends that the allowable underseepage Factor of Safety used in evaluations and/or design of seepage control measures should correspond to an exit gradient at the toe of the levee of 0.5 (in general this would provide a Factor of Safety of 1.6), but states that deviation from recommended design guidance is acceptable when based and documented on sound engineering judgment and experience (USACE, 2005). The SJRRP will continue to coordinate with DWR, CVFPB, and USACE to ensure appropriate methods and criteria are used in all levee evaluations and design.

Until adequate data are available to determine these Factors of Safety, Reclamation would limit the release of Restoration Flows to those that would remain in-channel. In-channel flows are flows that maintain a water surface elevation at or below the elevation of the landside levee toe (i.e., the base of the levee). When sufficient data is available to determine the levee slope stability and underseepage Factors of Safety, Reclamation would limit Restoration Flows to levels that would correspond to the appropriate levee slope stability Factor of Safety of 1.4 or higher and an underseepage Factor of Safety corresponding to an exit gradient at the toe of the levee of 0.5 or lower at all times. Implementing this measure would reduce the risk of levee failure due to underseepage, through-seepage, and associated levee stability issues to less-than-significant levels.

In addition, systematic levee condition monitoring would be implemented as described in more detail in PEIS/R Appendix D, *Physical Monitoring and Management Plan*. Observation of levee erosion, seepage, boils, impaired emergency levee access, or other indications of increased flood risk identified through ongoing monitoring at potential erosion sites would indicate that the minimum Factors of Safety are not met and would trigger immediate reductions in Restoration Flows at the site. Such observations would supersede channel capacity estimates, and Restoration Flows would be reduced in areas where these conditions occur.

## 4.2 Future Evaluation Process

The SJRRP will continue to complete and update the studies necessary to determine then-existing channel capacity. This includes assessing channel capacity due to changes in the channel as a result of vegetation and subsidence, as well as collecting and assessing the necessary geotechnical data to determine the appropriate levee slope stability and underseepage Factors of Safety. To address the levee stability task, the San Joaquin Levee Evaluation Project (SJLE Project) was initiated by DWR. The SJLE Project includes collecting geotechnical data along the river and flood bypasses, evaluating the levee geotechnical performance at various water surface elevations, and identifying levees and appropriate actions to improve levee performance. The goal of this evaluation is to gain adequate information on the levees to determine the levee slope stability and underseepage Factors of Safety. This will provide Reclamation with the necessary information to make decisions on Restoration Flow releases that will reduce the risk of levee failure. Details of the initial phase of results of the SJLE Project, as well as other studies and monitoring that may be used to inform channel capacities are summarized in Section 7 "Completed Channel Capacity Studies and Related Work" and Section 10 "Future Program Studies and Monitoring with the Potential to Inform Then-existing Channel Capacity."

# 5.0 Data and Analytical Tools

The following sections describe the data and analytical tools used to determine then-existing channel capacity. The sections provide an overview of the restoration hydrograph and hydraulic, sediment transport modeling and levee assessment tools. Several of the tools are in the process of being updated to incorporate additional data that has been collected since their initial development. This section also includes a summary of the overall strategy Reclamation and DWR developed for the coordination and application of the hydraulic and sediment modeling tools.

## 5.1 Restoration Hydrograph

The SJRRP flow hydrograph involves a spring and a fall pulse with base flow releases of 350 cfs from Friant Dam in the summer and winter months in most year types. These hydrographs are provided in Exhibit B of the Settlement and the Restoration Flow hydrograph at Friant Dam is summarized in Figure 5-1. Spring flow pulses range from 1,500 cfs maximum release in a critical-high year type, to a 4,000 cfs release in a wet year type. The Restoration Administrator, an independent individual called for in the Settlement, makes recommendations to the Secretary of the Interior on how best to shape the hydrograph to meet the Restoration Goal of the Settlement. The Restoration Administrator has the flexibility to adjust the hydrographs, consistent with the Settlement, including releasing buffer flows of up to 10 percent, mobilizing gravel with an up to 8,000 cfs pulse, and flexibly scheduling the spring pulse volume within a period defined as 28 days in advance of the Settlement Exhibit B hydrographs (i.e., beginning on February 1 with 500 cfs), and 28 days later than the Exhibit B hydrographs (ending on May 28 at 4,000 cfs). The fall pulse volume may be flexibly scheduled from October 1 to November 30. In wet year types, an additional volume is available for riparian recruitment that can extend 60 to 90 days past the end of the spring pulse flow.

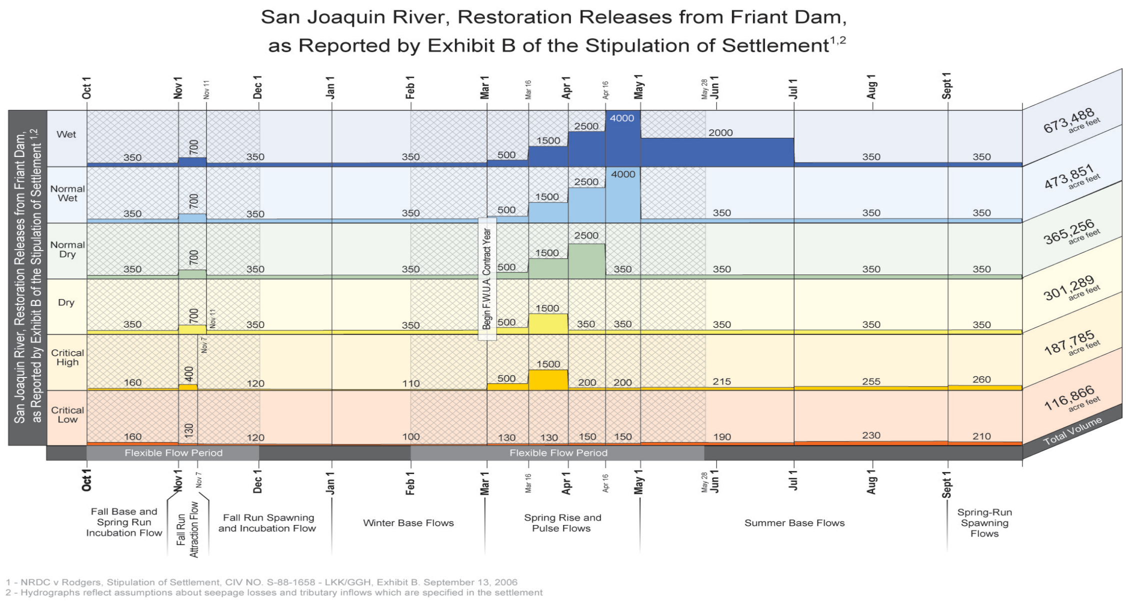


**Figure 5 - 1**

**Restoration Flow Hydrograph at Friant Dam**

In order to determine the Restoration Hydrograph, Reclamation will first use DWR forecasts to predict the unimpaired inflow to Millerton Lake. Then this volume is allocated to the Friant Division long-term contractors and water users in Reach 1 per Reclamation standard practice, and to the SJRRP using a methodology called Method 3.1 gamma. Reclamation then submits an allocation and a default flow schedule to the Restoration Administrator, with flow volumes by type (i.e., base flow, spring pulse, fall pulse, riparian recruitment). The Restoration Administrator responds with a flow recommendation using the flexibility as described above to change the flow schedule. Reclamation confirms that the Restoration Administrator recommendation is consistent with all applicable regulation (Settlement, Water Board Orders, channel capacity), accepts the recommendation, and then implements the schedule. For more information see the Restoration Flow Guidelines at the following website:

http://www.restoresjr.net/download/program-documents/program-docs-2013/SJRRP_RFG_December_2013.pdf.

Based on the schedule identified in the Settlement, Restoration Flows began on January 1, 2014. At present, because of seepage and possible levee stability issues, the river system is not capable of passing the full Restoration Flows, and so flows are released up to the then-existing channel capacity. This report provides Reclamation's analysis of then-existing channel capacities, and the CCAG was formed to provide a peer review of that analysis in helping Reclamation determine the recommended Restoration Flows that can be released without significantly increasing flood risk. Preparation of this report and review by the CCAG will continue until such time that then-existing channel capacities are determined to equal or exceed the maximum proposed Restoration Flows throughout the Restoration Area.

The studies described in Section 7 “Completed Channel Capacity Studies and Related Work” evaluate a maximum flow of 4,500 cfs in each of the study reaches. This maximum flow is based on the Settlement required capacity in Reach 2B and Reach 4B. Restoration Flows may be as high as 8,000 cfs in the upper reaches to perform functions such as flushing spawning gravels, but are expected to attenuate so not to exceed a maximum channel capacity of 4,500 cfs in Reach 2B.

## 5.2 Hydraulics

One-dimensional (1-D) steady-state Hydrologic Engineering Center’s River Analysis System (HEC-RAS) hydraulic models of the 150-mile reach of the San Joaquin River and Bypass System between Friant Dam (RM 267.6) and the mouth of the Merced River (RM 118.2) were developed and validated by Tetra Tech, Inc. (Tetra Tech) and DWR to support the SJRRP. Two-dimensional (2-D) hydrodynamic models of all of the reaches except for Reach 5 were developed by Reclamation. DWR also developed a site specific model of a 2.5-mile segment of the downstream portion of Reach 2A. The following describes how these models were used to evaluate channel capacity in this report.

### 5.2.1 One-dimensional (1-D) Modeling

The HEC-RAS hydraulic models provide a means of evaluating current 1-D hydraulic conditions along the river and flood bypass system over a range of flows, including those specified in the Settlement and flood events (Tetra Tech, 2014). The 1-D models have been used to perform a number of analyses related to channel capacity, including:

- Assess channel capacities, including an evaluation of the degree to which sedimentation would affect channel capacities in Reach 2A.
- Provide input to sediment-transport analyses, including an evaluation of the sediment-transport behavior in Reaches 2A, 2B and 3; and the Eastside Bypass.
- Assess potential effects of Restoration Flows on levee underseepage, levee erosion and stability, channel stability and flood carrying capacity.
- Assess the effects of subsidence in Reach 2B, Reach 3, Reach 4A and the Middle Eastside Bypass on channel capacity.

Most of the studies completed by the SJRRP, including estimating channel capacity, used DWR’s existing conditions HEC-RAS model of the river, which contains overbank topography based on 2008 LiDAR mapping. Surveys by Reclamation and DWR have demonstrated that considerable subsidence has occurred along Reach 3, Reach 4A, and the Eastside Bypass. Using survey data collected in 2013 and 2014, DWR has updated the models in those reaches to reflect subsidence. These models, until further updated, will continue to be used by the SJRRP in evaluating channel capacity.

### 5.2.2 Two-dimensional (2-D) Modeling

Reclamation has developed 2-D hydrodynamic models for reaches 1B, 2A, 2B, 3, 4A, 4B1, 4B2 of the San Joaquin River and the Eastside Bypass. The 2-D models use the depth-averaged St. Venant equations and an unstructured mesh to model water surface elevation, depth, and velocities and report the above plus bed shear stress, critical sediment diameter, and sediment transport capacity at each quadrilateral or triangular mesh cell. Applications of 2-D models for channel capacity studies could include modeling of side channels, bank erosion, local flow velocity and eddy patterns, as well as flow over in-channel bars and levees.

## 5.3 Sediment Transport

1-D and 2-D sediment transport models are also being employed by the SJRRP. These models were developed to evaluate the effects of SJRRP actions on sediment transport along the river and flood bypasses. The existing sediment transport models were developed using Reclamation's SRH modeling system and incorporate the same foundational input data used in the hydraulic models described above. In addition, DWR also developed an existing conditions sediment model for much of the bypass using HEC-6T. These models were or will also be employed to evaluate channel capacity as described below.

### 5.3.1 1-D Modeling

Reclamation developed SRH-1D sediment transport models to assess the reach-averaged erosion and deposition impacts of the SJRRP to Reaches 1 through 5 in the PEIS/R. These models would be useful for evaluating future channel capacity studies by simulating the future reach-averaged sediment transport, erosion and deposition in the SJR and flood bypass system under various flow routing scenarios. DWR also developed a mobile-boundary sediment-transport model using HEC-6T of the bypass from the San Joaquin River Control Structure to the Eastside Bypass Control Structure. Similar to the SRH-1D models, this model will be useful for evaluating the long-term trends of aggradation and degradation in the bypass under Restoration Flow and subsidence conditions. However, SRH-1D, HEC-6T, and other 1-D models are limited in their ability to simulate local sediment transport conditions resulting from topographic variability within a cross section, in river bends, around structures (such as bifurcations), and the differences between channel and floodplain deposition.

### 5.3.2 2-D Modeling

Tetra Tech developed and calibrated a 2-D sediment-transport model for the approximately 2.5-mile reach immediately upstream from the CBBS. The model was developed to provide a refined tool that can be used to predict the behavior of the downstream portion of Reach 2A and to provide a more accurate estimate of sediment movement from Reach 2A through the San Joaquin River Control Structure at the CBBS and into Reach 2B under various conditions (Tetra Tech, 2013a). This model was used to complete a Reach 2A Sediment Study, which is summarized in the 2014 Report. This model will likely continue to be used in future evaluations of the sediment conditions within the vicinity of the CBBS.

## 5.4 Geotechnical

The seepage and stability analyses to evaluate levee impacts were performed using the 2-D finite element software program SEEP/W, developed by GEO-SLOPE International, Ltd. The model uses topographic and geotechnical data to analyze underseepage and excess pore-water pressure. This is to determine exit gradients and the controlling water surface elevation that may result in failure due to underseepage. The levee slope stability analysis was performed using SLOPE/W, a 2-D limit equilibrium stability analysis software program developed by GEO-SLOPE International, Ltd. following the Spencer Method. The same topography used for the seepage analysis was also used for the slope stability analysis. Pore-water pressures calculated by the SEEP/W models are imported into SLOPE/W. The model uses effective shear strengths for the different soil layers to determine the minimum factor of safety for surfaces that affect the overall stability of the levee for different water surface elevations. The SEEP/W and SLOPE/W tools are used in the geotechnical evaluations of the SJLE Project described in Section 7.2 and Section 10.1.1.

## 5.5 Modeling Strategy

Numerical modeling has been a key tool used by the SJRRP to develop designs for the site-specific projects and perform quantitative evaluation of SJRRP actions. The SJRRP has developed a set of hydraulic and sediment transport modeling tools to evaluate then-existing channel capacity, as well as to complete other studies and actions implemented by the SJRRP. Having separate tools available for different modeling applications provides the flexibility to meet both efficiency and accuracy needs. No single model was deemed appropriate to effectively model all aspects that are necessary to understand the actions of the SJRRP. The additional complexity caused by employing different models that can generally meet similar objectives is necessary to ensure that the appropriate models are being utilized for the appropriate purpose. To allow for consistency in the application of the modeling tools, Reclamation and DWR have developed a strategy memorandum specifically for the hydraulic and sediment transport modeling. The strategy can be found in Appendix B of the 2015 Report at the following website:

> http://www.restoresjr.net/download/program-documents/program-docs-2015/CCAG_Report_Appendix_B_01132015_Accessible.pdf.

The strategy will be updated, as necessary to reflect changes and updates to the modeling tools. The strategy summarizes the models available, general differences, and preferred usage to develop and evaluate SJRRP actions. Selection of the appropriate tool for any specific study, including channel capacity, will depend on the purpose of the study, level of detail needed, and the preference of the agency performing the analysis.

# 6.0 Current Then-existing Channel Capacity

For the 2016 Restoration Year, the SJRRP limited Restoration Flow releases to then-existing channel capacities recommended in the 2016 Report. These capacities were based on the *San Joaquin River In-channel Capacity Study* (Tetra Tech, 2015b) and the Priority 1 Levee Geotechnical Assessment described in Section 7.0 of the 2016 Report. Limiting Restoration Flows to these capacities reduced the risk of levee failure due to underseepage, and through-seepage. The current then-existing channel capacities are shown in Table 6-1.

**Table 6-1**
**Current Then-existing Channel Capacity**

| Reach | Current Then-existing Channel Capacity (cfs) |
|---|---|
| Reach 2A | 6,000 |
| Reach 2B | 1,120 |
| Reach 3 | 2,860 |
| Reach 4A | 2,840 |
| Reach 4B1 | Not Analyzed |
| Reach 4B2 | 930 |
| Reach 5 | 2,350 |
| Middle Eastside Bypass | 580 |
| Lower Eastside Bypass | 2,890 |
| Mariposa Bypass | 350 |

These channel capacities will remain the same for this year's report and will continue to be based on the studies and related work described in the following section.

# 7.0 Completed Channel Capacity Studies and Related Work

The following section summarizes the technical studies and related work that has been completed at the time of publication of this report that relate to channel capacities. In the 2016 Report, two studies were directly used to recommend then-existing channel capacities: the *San Joaquin River In-channel Capacity Analysis* (Tetra Tech, 2015b), and the Priority 1 Levee Geotechnical Assessment of levees within Reach 2A, Reach 4A, and the Middle Eastside Bypass. These studies will continue to determine the recommended then-existing channel capacities in this report and are described below.

## 7.1 In-channel Capacity Study

The *San Joaquin River In-channel Capacity Analysis* (Tetra Tech, 2015b) was performed to determine in-channel capacity of the San Joaquin River and the Eastside and Mariposa bypasses between Friant Dam and the confluence with the Merced River. The study incorporates ground subsidence in significantly impacted areas of Reach 3, Reach 4A, and the Eastside Bypass and geotechnical conditions of the levees in Reach 2A, Reach 4A, and the Middle Eastside Bypass. Besides in-channel capacity for each reach the study also identified the approximate length of the left and right bank levee where the water surface elevation of 2,000 cfs and 4,500 cfs flows exceeded the outside ground elevation. This study provides the most recent in-channel capacity estimates within leveed reaches that can inform then-existing channel capacity and can be found in Appendix B.

### 7.1.1 Methodology and Assumptions

The in-channel capacity was evaluated for each subreach that is bounded by levees in Reaches 2A, 2B, 3, 4A, 4B2, 5, Middle Eastside Bypass, Lower Eastside Bypass, and the Mariposa Bypass. As part of the SJRRP, new setback levees are being evaluated for Reach 4B1 to safely convey Restoration Flows. Since the current capacity is assumed to be negligible, it is assumed that no Restoration Flows will be conveyed in this reach until channel capacity improvements are made. Therefore, Reach 4B1 was not included in this analysis. Setback levees are also anticipated in Reach 2B, but because Restoration Flow releases will be routed through this reach prior to their construction, channel capacity was evaluated along the levees upstream from the direct impacts of Mendota Pool.

The 1-D HEC-RAS hydraulic models discussed in Section 5.2 “Data and Analytical Tools” were used for the analysis. The models in Reach 3, Reach 4A and the Middle Eastside Bypass were adjusted to consider subsidence. The magnitude of the elevation adjustments made to the models to account for subsidence is indicated in Attachment B (Figure 2). Elevation adjustments in Reach 3 range from near zero at the upstream end to about 2.3 feet at the downstream end. The largest change in elevation (2.7 feet) occurs just below the upstream end of Reach 4A, which decreases in the downstream direction to about 1.3 feet at the boundary between Reach 4A and the Middle Eastside Bypass. Elevation changes in the Middle Eastside Bypass range from about 1.3 feet at the upstream end to near zero at the downstream end of the reach.

To determine the outside ground to which the models results would be compared to determine in-channel capacities, the landside levee toe elevations were identified for each reach. In this analysis, the outside ground elevation adjacent to the landside levee toe was selected to represent the elevation of the landside levee toe. The elevations were identified at each hydraulic model cross-section primarily through inspection of the cross-sectional topography and were verified through review of the aerial photography, contour mapping, and topographic surveys. The outside ground elevations were selected for both the left and right levees. In-channel capacities reported in this analysis are based on water-surface profiles developed by running the models over a series of local flows. Figure 7-1 is a conceptual figure of the outside ground elevation location and the in-channel flow capacity.

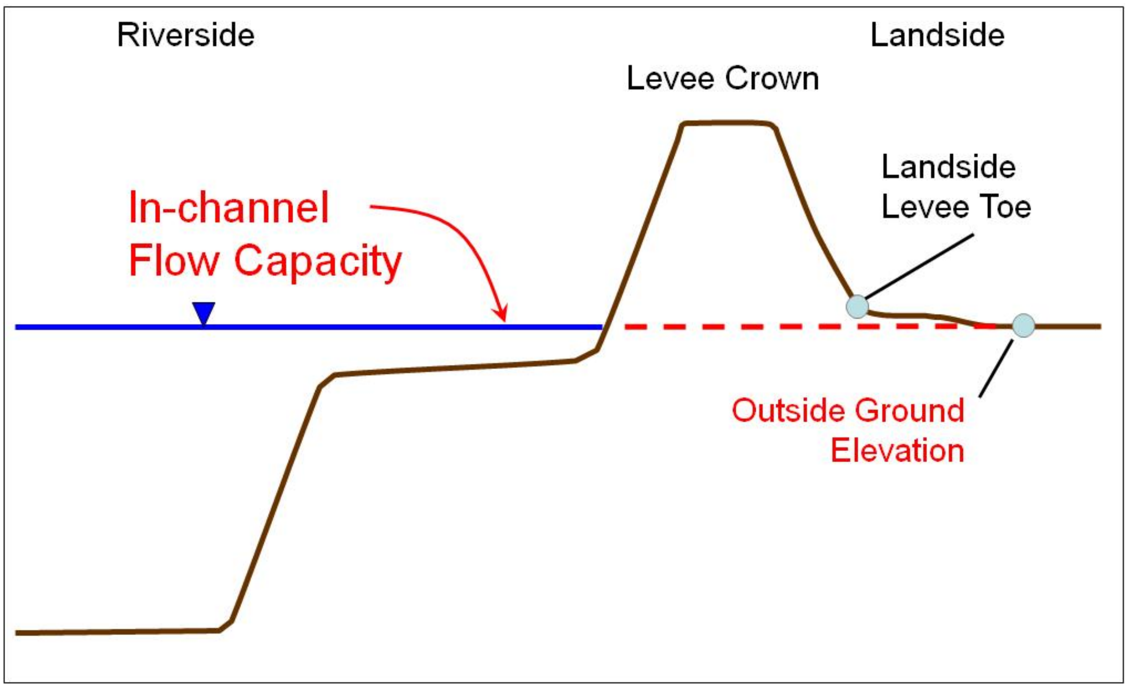


**Figure 7-1.**
**Levee Schematic Defining Levee Features and In-channel Capacity**

### 7.1.2 Analysis and Results

Computed water-surface profiles were compared to the outside ground elevations adjacent to both the left and right levees along the extent of each reach. The in-channel flow capacity of each reach was determined to be the highest flow rate through the reach where the water-surface elevation is at or below the outside ground elevation for any part of the reach. Results for each reach are described in the following sections and are summarized in Table 7-1.

**Table 7-1.**
**Summary of In-channel Capacity for Each Side of Levee by River Reach**

| Reach | Levee Side | In-channel Capacity[1] (cfs) |
|---|---|---|
| | | |
| Reach 2A | Left | 2,430 |
| Reach 2A | Right | 1,630 |
| | | |
| Reach 2B (Entire Reach) | Left | 0 |
| Reach 2B (Entire Reach) | Right | 0 |
| Reach 2B (Excluding Mendota Pool)[2] | Left | 1,120 |
| Reach 2B (Excluding Mendota Pool)[2] | Right | 1,550 |
| | | |
| Reach 3 | Left | 3,960 |
| Reach 3 | Right | 2,860 |
| | | |
| Reach 4A (Inside Geotechnical Study Area)[3] | Left | 980 |
| Reach 4A (Inside Geotechnical Study Area)[3] | Right | 1,340 |
| Reach 4A (Outside Geotechnical Study Area) | Left | 2,840 |
| Reach 4A (Outside Geotechnical Study Area) | Right | 2,840 |
| | | |
| Reach 4B2 | Left | 1,370 |
| Reach 4B2 | Right | 930[4] |
| | | |
| Reach 5 | Left | 2,350 |
| Reach 5 | Right | 2,500 |
| | | |
| Middle Eastside Bypass (Eastside Bypass Reach 2) (Boards Out)[5] | Left | 10[6] |
| Middle Eastside Bypass (Eastside Bypass Reach 2) (Boards Out)[5] | Right | 340[6] |
| | | |
| Lower Eastside Bypass (Eastside Bypass Reach 3) | Left | 2,970 |
| Lower Eastside Bypass (Eastside Bypass Reach 3) | Right | 2,890 |
| | | |
| Mariposa Bypass | Left | 650 |
| Mariposa Bypass | Right | 350 |

[1] Capacity based on outside ground elevations.
[2] Portion of reach above influence of Mendota Pool (about RM 209.5).
[3] Includes the length of levee that was analyzed under the SJLE Project and is included in the Geotechnical Conditions Report.
[4] Capacity excludes localized deep depressions, which would reduce capacity to 50 cfs.
[5] "Boards Out" condition assumes that the weirs used to divert flows into the MNWR are not operating.
[6] In-channel capacity is essentially 0 cfs when the refuge is diverting flow and the weirs are operating ("Typical Boards" and "Boards In").

In **Reach 2A**, along the right and left levees, the highest local flow for which the water-surface is at or below the outside ground elevation is 1,630 and 2,430 cfs, respectively (Figures 3 through 6 in Appendix B). For about 3.3 miles of levees in this reach, the water surface at Restoration Flows of 4,500 cfs would be at or above the outside toe of the levee. Generally, the impact of subsidence has been fairly minor in Reach 2A compared to other reaches. Because there is geotechnical data available that shows that the capacity is much greater than in-channel capacity, subsidence was not considered at this time and no updates were made to in-channel capacity. However, additional studies, as described in Section 10.1.3 will also be completed once the 2015 LiDAR is finalized to determine if significant changes in capacity has occurred in this reach as a result of subsidence.

In **Reach 2B**, outside ground elevations along the lower portion of this reach are generally lower than the normal pool elevation at Mendota Dam (Figures 7 through 10 in Appendix B). When considering the entire reach, including Mendota Pool, the capacity along both sides of the channel is 0 cfs. As a result, the existing flow capacity was evaluated for the entire reach as well as only for the portion of the reach upstream from the influence of the pool. When only the portion of the reach upstream from the influence of the pool is considered, the highest local flow in which the water surface is at or below the outside ground elevation is about 1,120 cfs along the left levee and 1,550 cfs along the right levee. For about 17.7 miles of levees in this reach, the water surface at Restoration Flows of 4,500 cfs would be at or above the outside toe of the levee (includes the levees influenced by Mendota Pool). However, it should be noted that model results show that at 4,500 cfs, portions of the levees are overtopped under existing conditions and therefore would not convey 4,500 cfs.

Subsequent to the information in the in-channel analysis, a preliminary analysis was completed to evaluate the impact of subsidence on channel capacity in the reach. Preliminary 2015 LiDAR data was evaluated to determine the potential for subsidence to change the channel slope in all or a portion of the reach, which would change channel capacities. Currently, the amount of subsidence along the reach was about 0.4 feet over an approximately seven year period and does not show any trends that indicated channel capacity has changed since the 2008 LiDAR. A preliminary hydraulic evaluation showed the limiting channel capacity is the same as is published in the 2016 Report. Therefore, an update to the Reach 2B channel capacity was not performed for this report and will be included in the next report once the 2015 LiDAR is finalized. Section 10.1.3 includes more details regarding the preliminary analysis, as well as what future analysis will be completed to determine if significant changes in capacity has occurred in this reach considering the LiDAR data and subsidence.

In **Reach 3**, outside ground elevations are reasonably high along much of the reach except for an area immediately upstream of Sack Dam (Figures 11 through 13 in Appendix B). The hydraulic model and outside ground elevations have been updated to consider subsidence and the in-channel capacity results in this reach are based on those updates. Flow capacity in this area is limited by a depression on the right side that has a capacity of 2,860 cfs. On the left side of the channel, the capacity of the outside ground elevation is 3,960 cfs. For about 4.3 miles of levees in this reach, the water surface at Restoration Flows of 4,500 cfs would be at or above the outside toe of the levee. In general, subsidence has caused the overall slope in this reach to steepen, which has increased capacity and reduced the length of levee that is at or below the outside toe by 2.8 miles if subsidence since 2008 is not considered.

In **Reach 4A**, the maximum local flow for which the water-surface is at or below the outside ground elevation for the levees is characterized both within and outside of where geotechnical data has been collected. In addition, the hydraulic model and outside ground elevations have been updated to consider subsidence and the in-channel capacity results in this reach are based on those updates (Tetra Tech, 2015c). For the levees within the geotechnical study area, the maximum local flow is 1,340 cfs for the right levee and 980 cfs for the left levee (Figures 14 through 17 in Appendix B). For levees outside of the geotechnical study area, the maximum local flow is 2,840 cfs for both the left and right levees. In general, subsidence is causing the reach to steepen and flatten out. At the downstream end of the reach, there is an area of subsidence that is significantly greater than Reach 3, and the downstream portion of Reach 4A, creating a "bowl" effect that has reduced capacity in the upstream portion of the reach. However, changes in in-channel capacity as a result of subsidence are fairly minor. The overall length of levee where the water surface elevation would be at or above the outside toe of the levee for 4,500 cfs is 19.7 miles, compared to 17.8 miles if subsidence since 2008 is not considered.

In **Reach 4B2**, the ground adjacent to the right levee in Reach 4B2 has many depressions, but due to one localized and deep depression along the right levee, the in-channel capacity is limited to about 50 cfs (Figures 18 through 21 in Appendix B). Aerial photographs and contour mapping indicate that these depressions are relatively small, and can contain water even at low flows, which would not make them a levee stability issue. If these local, right-side depressions are excluded from the analysis, the capacity along the right levee increases to 930 cfs. The outside ground along the left levee is not as low, which results in an in-channel capacity of approximately 1,370 cfs. For about 14.0 miles of levees in this reach, the water surface at Restoration Flows of 4,500 cfs would be at or above the outside toe of the levee. Subsidence is not significant in this reach, so in-channel capacities were not updated to consider subsidence.

In **Reach 5**, most of the areas with limited capacities occur along the mid- to upper- portion of this reach, but one exception is a levee feature that exists along the left side of the channel near the downstream end of the reach (Figures 22 through 24 in Appendix B). This segment of levee does not have a hydraulic connection to the main channel for flows up to 4,500 cfs. Therefore, this levee segment was removed from the analysis. The highest local flow for which the water-surface is at or below the outside ground elevation is 2,350 cfs and 2,500 cfs along the left and right levees, respectively. For about 3.5 miles of levees in this reach, the water surface at Restoration Flows of 4,500 cfs would be at or above the outside toe of the levee. Subsidence is not significant in this reach, so in-channel capacities were not updated to consider subsidence.

In the **Middle Eastside Bypass**, at the upstream end of this reach, the channel bed is near the elevation of the ground outside of the levees on both the right and left sides. The hydraulic model and outside ground elevations have been updated to consider subsidence and the in-channel capacity results in this reach are based on those updates (Tetra Tech, 2015a). There are two weirs with boards located in the Middle Eastside Bypass that are used to divert water into the MNWR. To provide information regarding the sensitivity of the weir settings on the in-channel capacities, three weir configurations were evaluated. One configuration assumes that the upstream and downstream weirs remain fully open. This condition represents the conditions of the boards when the refuge is not diverting flows and is referred to as “Boards Out”. The second weir configuration is representative of the most typical setting of the boards that is required by the refuge to divert flows during most years, and is referred to as "Typical Boards." The elevation of the boards in this configuration is based on surveys that were conducted in 2015, and represents a partial closure of the downstream weir, and the upstream weir remaining completely open. The third weir configuration assumes that both the up- and downstream weirs are completely closed. According to refuge staff, if water is available, the refuge will occasional place all of the boards into the weirs so that they can fill the upstream ponds within the bypass. This condition is referred to as “Boards In”.

Under the Boards Out condition, the computed water-surface profiles indicate that the highest local flow for which the water-surface is at or below the outside ground elevation along the left levee is about 10 cfs, and along the right levee is 340 cfs (Figures 25 through 28 in Appendix B). When there are "Typical Boards" or "Boards In" conditions, the in-channel capacity is essentially 0 cfs. These low in-channel capacities are the result of the low outside ground elevations compared to the channel bed.  Subsidence has caused the reach to steepen for most of the reach, but there has also been a "bowl" of greater subsidence at the upstream end, which is where capacity is already an issue. Therefore, the overall capacity and the length of levee impacted have not significantly changed. For about 18.5 miles of levees in this reach, the water surface at Restoration Flows of 4,500 cfs would be at or above the outside toe of the levee.

In the **Lower Eastside Bypass** (Eastside Bypass Reach 3), the computed water-surface profiles indicate that the highest local flow for which the water-surface is at or below the outside ground elevation along the left levee is 2,970 cfs and along the right levee is 2,890 cfs (Figures 29 through 31 in Appendix B). For about 3.6 miles of levees in this reach, the water surface at Restoration Flows of 4,500 cfs would be at or above the outside toe of the levee. Subsidence is not significant in this reach, so in-channel capacities were not updated to consider subsidence.

In the **Mariposa Bypass** along the left and right levees, the highest local flow for which the water-surface is at or below the outside ground elevation is 650 cfs and 350 cfs, respectively (Figures 32 through 35 in Appendix B). As evident from the low in-channel capacity, the outside ground elevations in this reach are relatively low when compared to the main flow channel, but they are also relatively uniform throughout the entire reach. For about 6.6 miles of levees in this reach, the water surface at Restoration Flows of 4,500 cfs would be at or above the outside toe of the levee. Subsidence is not significant in this reach, so in-channel capacities were not updated to consider subsidence.

## 7.2 Priority 1 Levee Geotechnical Assessment

Levee evaluations along the San Joaquin River and flood bypasses are being conducted by DWR to assist the SJRRP assess flood risks due to levee seepage and stability associated with the release of Restoration Flows for the SJRRP. The evaluations were performed under DWR’s SJLE Project (Section 10.1.1) and included the exploration and evaluation of existing levees within the Restoration Area that will be used to convey future Restoration Flows. The evaluation will allow the SJRRP to identify the maximum flow that can be conveyed on the levees without exceeding USACE criteria for levee underseepage and slope stability.

In identifying the priorities of the SJLE Project, DWR classified levee segments in the Restoration Area in one of three categories representing an increasing priority for the need to complete the geotechnical evaluation and analyses. Details of the specific tasks, including the methodology for prioritization of the levees are summarized in Section 10.1.2 of the 2014 Report. Priority 1 levees are located in Reach 2A (14.9 miles), the Middle Eastside Bypass (from Sand Slough to the Eastside Bypass Control Structure) (20.6 miles), and the lowest portion of Reach 4A (4.1 miles). The following section summarizes the geotechnical investigations for the Priority 1 levees, and the subsequent flow analysis to identify the maximum allowable flow that can be conveyed on the levees in each reach.

### 7.2.1 Geotechnical Investigations

The initial phase of the SJLE Project included levee evaluations within two Priority 1 study areas: 15 miles of levees in Reach 2A (Gravelly Ford Study Area) and 25 miles of levees along the lower portion of Reach 4A and the Middle Eastside Bypass (Middle Eastside Bypass Study Area). Figures 7-2 and 7-3 show the Gravelly Ford and Eastside Bypass Study Areas, respectively.

The evaluations included reconnaissance-level geotechnical explorations, soils testing, and seepage and stability analyses at multiple water surface elevations along multiple levee segments. Geotechnical Conditions Reports (GCR) that includes the evaluations for both study areas can be downloaded from DWR at the following link:

http://www.dwr-lep.com/.

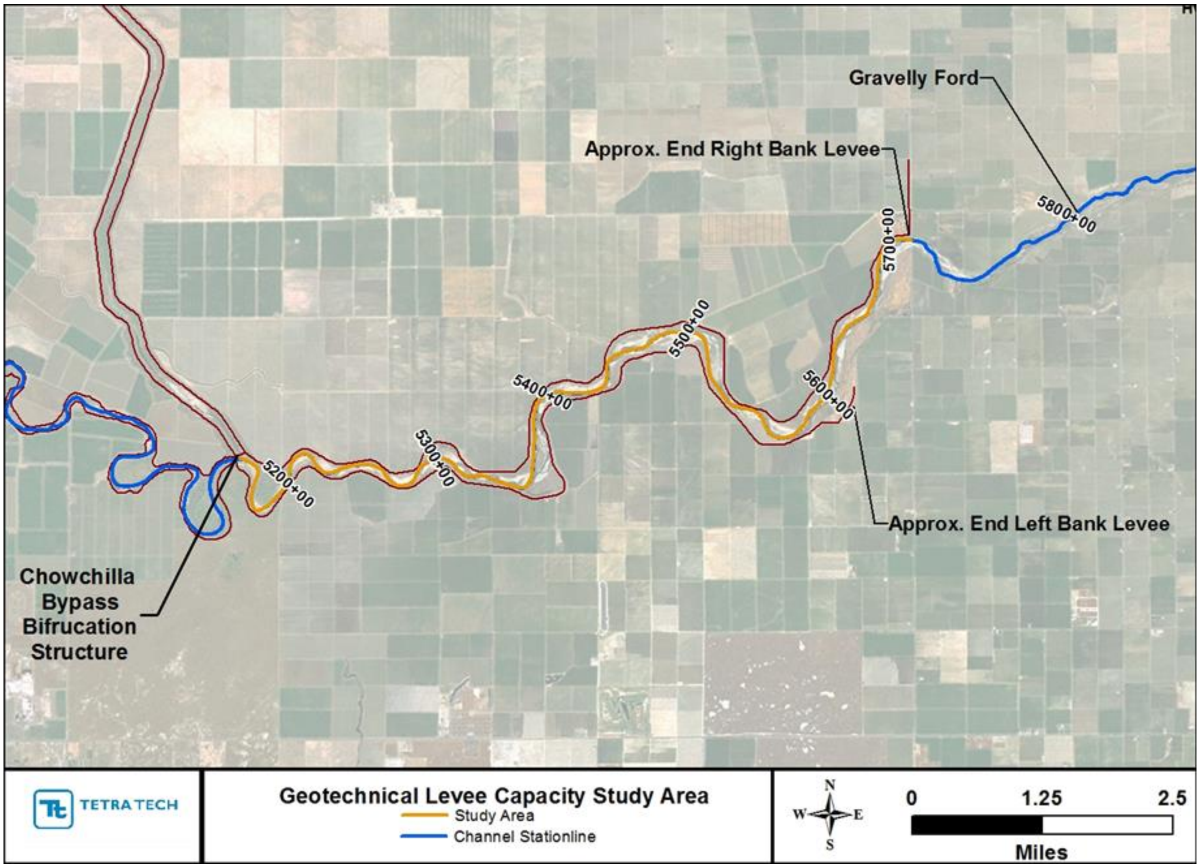


**Figure 7-2.**

**Gravelly Ford Study Area**

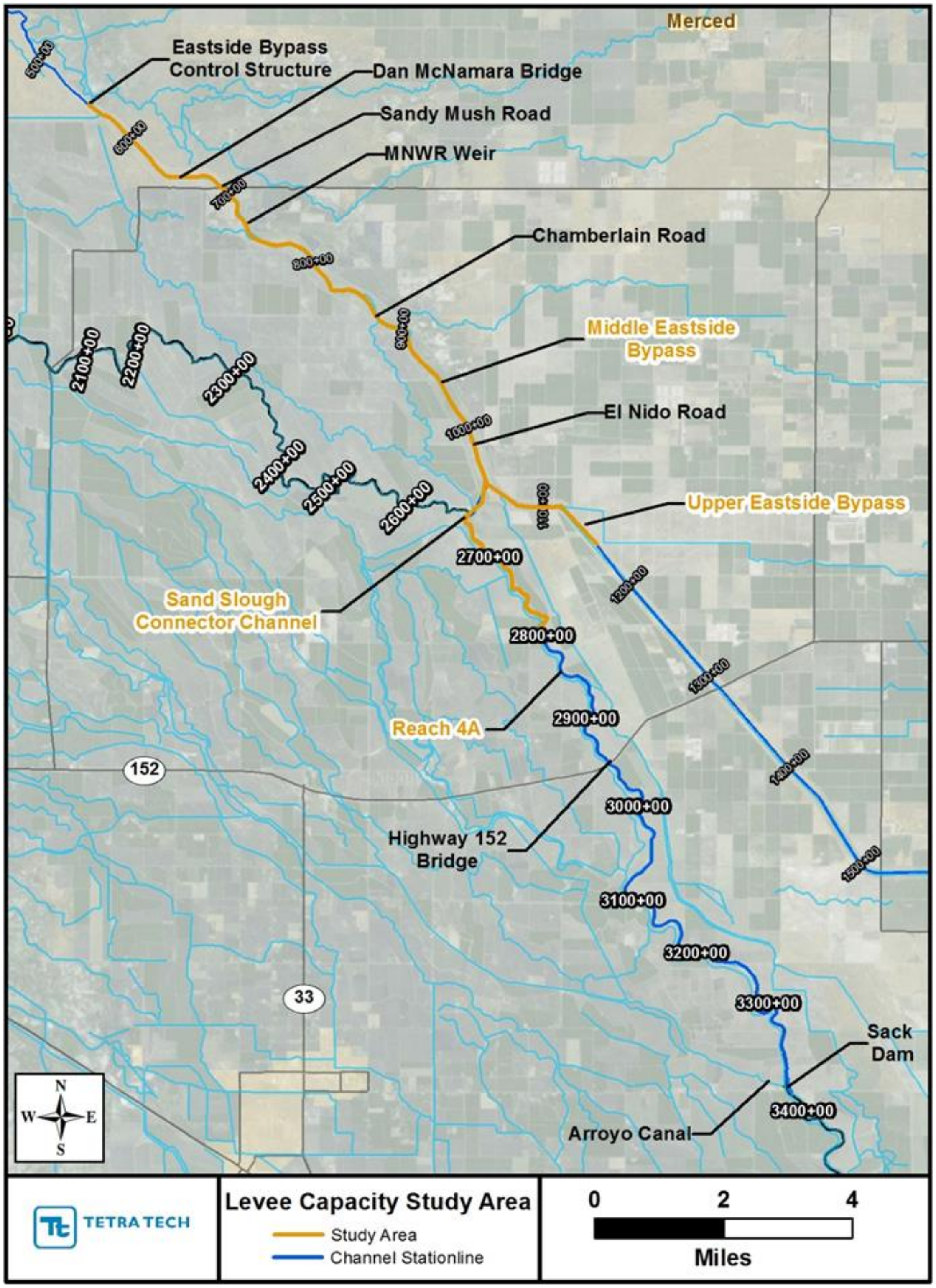


**Figure 7-3.**

**Middle Eastside Bypass Study Area**

Investigations were initially performed in these study areas to develop subsurface stratigraphy, establish soil parameters for analyses, and characterize levee performance. These investigations were comprised of historical data review and geomorphic studies, which included reviewing aerial photography, topographic base maps, surficial geologic maps, and maps and documents that describe historic levee performance. The geomorphic study was used to generate maps to develop a preliminary characterization of levee foundation conditions. The maps were also used to plan subsurface explorations and to assess potentially problematic conditions and areas where potentially adverse geologic conditions were identified.

Initial field investigations were then conducted including geophysical surveys, soil borings and cone penetrometer tests (CPTs). The drilling program included soil borings approximately every 1 mile of levee and cone penetrometer tests approximately every 1,000 feet along the levee crowns. Explorations completed for this investigation include 44 hollow-stem auger and/or mud-rotary borings and 138 CPTs. Generally, explorations advanced along the levee crown were completed to a depth of four times the height of the levee, or to a minimum depth of 40 feet and explorations performed along the levee toe were completed to a depth of three times the levee height, or to a minimum depth of 30 feet. CPTs were also performed next to existing mud-rotary borings to ascertain reliability of CPT correlation between drilling methods, and to assess stratigraphy between borings and other CPT locations.

Geophysical surveys were then conducted to help investigate and characterize subsurface materials along specific areas selected based on the geomorphology map and initial field investigation results. Electrical resistivity imaging was selected as the method of geophysical investigation. Electrical resistivity survey results identified variations in electrical resistivity that correlate to different material types. Higher electrical resistance indicates coarser-grained, more permeable materials, and lower electrical resistance indicates fine-grained and less-permeable blanket materials. Review of the geophysical and drilling data informed a second phase of drilling that included hand auger borings along the levee toe hand augers. A total of 46 hand auger borings were performed on the landside and waterside levee toes. Hand auger borings performed along the landside and waterside toes of the levee were completed generally to a depth of about 10 feet.

A total of 176 explorations were completed along the levee crown and 56 explorations were completed along the landside levee toe. Geotechnical laboratory tests were performed on selected soil samples obtained from borings to learn about the geotechnical characteristics and engineering properties of subsurface materials including grain-sizes, permeabilities, shear strengths, and hydraulic conductivities. This information was then input into the levee seepage and stability models to identify the maximum allowable water surface elevations that can occur on the levees without exceeding USACE criteria for seepage and stability.

The results of the seepage and stability modeling were used to identify the controlling failure mechanism in the Priority 1 levee reaches and to estimate the highest elevation that water could be placed on the waterside levee slopes and still meet seepage and stability criteria. In this analysis, Priority 1 levees were divided into individual levee reaches, based on similarities in subsurface conditions, levee geometry and the presence of canals and ditches alongside the levees. A total of 8 levee reaches were assessed for the Gravelly Ford Study Area and 18 levee reaches were assessed for the Middle Eastside Bypass Study Area. An analysis cross section was selected for each reach as being representative of the location where seepage or stability issues are most likely to occur (i.e., the most critical point on the levee for potential failure). The maximum water surface elevation at each levee cross section that would not exceed geotechnical criteria for seepage and slope stability was then identified for each levee reach.

The extent of analyses performed for the SJLE Project was limited to seepage and stability analyses and does not include assessment of other levee failure mechanisms that may affect levee performance such as erosion, penetrations, and discontinuities in levee protection. The seepage and stability modeling evaluated through-levee seepage, underseepage, and landside stability. Assessment results indicate that underseepage controls the maximum allowable water surface elevation for about 80 percent of the levees in the study area.

### 7.2.2 Maximum Allowable Flow Analysis and Results

The result of the SJLE Project evaluations was a maximum water surface elevation in 26 levee reaches within the Gravelly Ford and Middle Eastside Bypass Study Areas that can be safely conveyed by the existing levees without exceeding USACE criteria. Hydraulic analyses to establish a maximum flow capacity in these levee reaches were then performed on results of the SJLE Project analysis.

In performing the analyses, 1-D hydraulic models (described in Section 5.2.1) developed for the SJRRP were employed. The geometry in the existing-conditions hydraulic models are based on 2008 LiDAR overbank elevations and 2011/2012 in-channel bathymetry. To address recent subsidence, the model geometry, and maximum water surface elevations from the GCR were adjusted in Reach 4A and the Middle Eastside Bypass. The models and maximum water surface elevations were not adjusted for subsidence in Reach 2A since subsidence was assumed to have minimal impact on the results.

A range of flows up to the full Restoration flow of 4,500 cfs were modeled in the Eastside Bypass Study Area and up to 6,000 cfs maximum flows for the Gravelly Ford Study Area (Restoration Flow magnitudes above 4,500 cfs are possible to account for attenuation and flow losses upstream of Reach 2B which will have a capacity of 4,500 cfs). All flows used in the model were assumed to be local flows.  The maximum water surface elevations at the assigned model cross section were then used to interpolate a discharge based on flow profiles for the range of flows. If the associated discharge was greater than 4,500 cfs in the Eastside Bypass Study Area and 6,000 cfs in the Gravelly Ford Study Area, then a capacity of “>4,500 cfs” or “>6,000 cfs” was reported and no further analyses was made. Similar to the In-channel Capacity Analysis described in Section 7.1, the MNWR three weir conditions were considered.

The result of the Priority 1 levee evaluations of maximum flows showed that allowable flows in Reach 2A are over 6,000 cfs throughout the entire reach when considering levee seepage and stability; in Reach 4A, the capacity of the evaluated portion of the reach was over 4,500 cfs. However, a few portions of the Middle Eastside Bypass cannot convey 4,500 cfs without exceeding USACE criteria for levee seepage and slope stability. In this reach, four levee reaches could not convey a 4,500 cfs without exceeding USACE criteria, including one 3-mile reach of the right bank downstream of Sand Slough that can only convey flows up to 1,070 cfs without exceeding USACE criteria. This reach is shown as Reach O on Figure 7-4. This reach, when the MNWR weirs are operating with "Boards In", cannot convey any flow without exceeding USACE criteria. When the weirs are operating in the "Typical Board" configuration, flows up to 580 cfs can be conveyed without exceeding USACE criteria. Figure 7-4 identifies all of the levee reaches that do not convey at least 4,500 cfs and Tables 7-2 and 7-3 summarize the maximum water surface elevation, and the respective allowable flows that can be put into each reach of the Priority 1 levees. These analyses are fully described in *Levee Capacity Evaluation of Geotechnical Gravelly Ford (Reach 2A) Study Area*, dated May 22, 2015 and *Levee Capacity Evaluation of Geotechnical Middle Eastside Bypass (Reach 4A, Sand Slough Connector Channel, Upper and Middle Eastside Bypass) Study Area*, dated May 26, 2015, included in Appendices C and D, respectively.

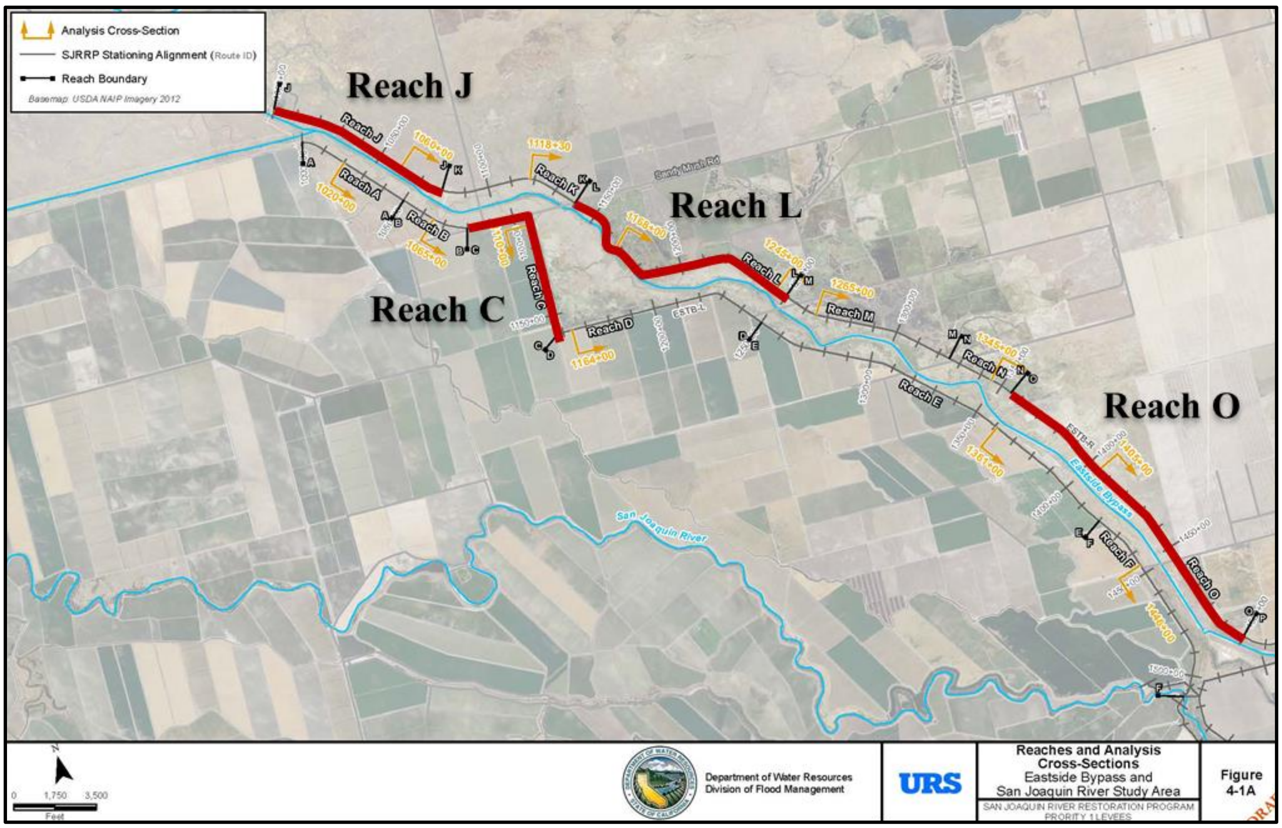


**Figure 7-4.**

**Reaches with Maximum Allowable Flows of less than 4,500 cfs**

**Table 7-2.**

**Priority 1 Maximum Allowable Flows on Levees for the Gravelly Ford Study Area**

| GCR Reach | GCR Station (ft) | Representative Model Cross Section | GCR Reference Elevation (ft) | Capacity (cfs) |
|---|---|---|---|---|
| **Gravelly Ford Study Area (Reach 2A)** | | | | |
| A | 11418+00 | 526981 | 176.0 | >6,000 |
| B | 11560+00 | 541706 | 182.5 | >6,000 |
| C | 11644+00 | 549708 | 185.3 | >6,000 |
| D | 11708+00 | 555801 | 189.7 | >6,000 |
| E[1] | | | | |
| F | 11647+00 | 521166 | 173.3 | >6,000 |
| G | 11742+00 | 532395 | 178.7 | >6,000 |
| H | 11830+00 | 538908 | 182.6 | >6,000 |

[1] Reach E was not evaluated due to the low height of the levee.

**Table 7-3.**
**Priority 1 Maximum Allowable Flows on Levees for the Eastside Bypass Study Area**

| GCR Reach | GCR Station (ft) | Representative Model Cross Section | Post-Subsidence | | |
|---|---|---|---|---|---|
| | | | GCR Reference Elevation (ft) [post-subsidence] | Capacity (cfs) | |
| | | | | Typical Boards | Boards Out |
| **Eastside Bypass Study Area (Reach 4A and Middle Eastside Bypass)** | | | | | |
| A | 102000 | 60106 | 99.4 | >4,500 | >4,500 |
| B | 106500 | 64035 | 105.5 | >4,500 | >4,500 |
| C | 111000 | 69622 | 98.2 | 3,290 | 3,290 |
| D | 116400 | 73247 | 100.9 | >4,500 | >4,500 |
| E | 136100 | 93015 | 103.2 | >4,500 | >4,500 |
| F | 144600 | 101445 | 102.6 | >4,500 | >4,500 |
| G | 152300 | 107371 | 111.4 | >4,500 | >4,500 |
| H | 155500 | 108228 | 109.2 | >4,500 | >4,500 |
| I | 157000 | 109849 | 108.6 | >4,500 | >4,500 |
| J | 106000 | 61699 | 96.3 | 4,150 | 4,150 |
| K | 111830 | 67946 | 100.2 | >4,500 | >4,500 |
| L | 116800 | 72501 | 99.6 | 2,600 | 2,600 |
| M | 126500 | 82690 | 105.6 | >4,500 | >4,500 |
| N | 134500 | 90952 | 102.3 | >4,500 | >4,500 |
| O | 140500 | 96995 | 99.2 | 580[1] | 1,070 |
| P | 152500 | 109849 | 104.3 | >4,500 | >4,500 |
| Q | 937400 | 269381 | 109.7 | >4,500 | >4,500 |
| R | 926300 | 270685 | 107.3 | >4,500 | >4,500 |

[1] If all of boards are placed in the weirs at the refuge, the capacity of this reach is essentially 0 cfs.

# 8.0 Recommended Then-existing Channel Capacities

The purpose of this section is to present the recommended then-existing channel capacities based on results from the current channel capacity studies summarized in the previous sections of this report. Then-existing channel capacities are defined as flows that would not significantly increase flood risk from Restoration Flows in the Restoration Area. To reduce this risk, the PEIS/R included levee design criteria for levee slope stability and underseepage Factors of Safety based on USACE criteria for levees. The application of the criteria requires the collection and evaluation of data at locations throughout the Restoration Area. Until adequate data are available to apply the USACE criteria, the release of Restoration Flows would be limited to those that would remain in-channel (the water surface elevation in the river remains below the levees).

Two studies were completed for the 2016 Report and will continue to provide the best information to better inform channel capacities for the 2017 Report: the *San Joaquin River In-channel Capacity Analysis* (Tetra Tech, 2015b) summarized in Section 7.1 and the Priority 1 Levee Assessment summarized in Section 7.2. The results in these two studies were used to inform recommended then-existing channel capacities. This information uses in-channel capacity as the best estimate of then-existing channel capacities for Reach 2B, Reach 3, portions of Reach 4A, Reach 4B2, Reach 5, Lower Eastside Bypass and Mariposa Bypass. For Reach 2A, the lower 2.5 miles of Reach 4A and the Middle Eastside Bypass, adequate data was available to perform a geotechnical analysis and these results were used to determine then-existing channel capacity.

Based on the results summarized in Sections 7.1 and 7.2 and detailed in Appendices B, C, and D, the recommended then-existing channel capacities for the San Joaquin River and flood bypasses within the Study Area are described below.

- The recommended then-existing channel capacity for Reach 2A is at least 6,000 cfs based on the geotechnical data and a maximum water surface elevation on the left levee less than 1 mile upstream from the CBBS. There is no change from the then-existing channel capacity recommended in the 2016 Report.

- The recommended then-existing channel capacity for Reach 2B considering in-channel capacity is 1,120 cfs based on a low point along the left levee approximately 4.6 miles upstream of the Mendota Dam. The influence of the Mendota Pool was not considered because normal pool water surface elevations in the pool are already higher than some outside ground elevations adjacent to levees. Restoration Flows would not significantly change this water surface due to the requirements to operate Mendota Dam to maintain a relatively constant pool elevation. There is no change from the then-existing channel capacity that was recommended in the 2016 Report, even when subsidence is considered.

- The recommended then-existing channel capacity for Reach 3 considering subsidence and in-channel capacity is 2,860 cfs based on a low depression along the right levee about 11.4 miles upstream of Sack Dam. There is no change from the then-existing channel capacity recommended in the 2016 Report.

- The recommended then-existing channel capacity for Reach 4A considering subsidence, in-channel capacity, and geotechnical assessment is 2,840 cfs, which is the in-channel capacity of the reach outside of the geotechnical study area. The critical area is on the left and right levees approximately 2 miles upstream of Sand Slough. There is no change from the then-existing channel capacity recommended in the 2016 Report.

- The recommended then-existing channel capacity for Reach 4B2 considering in-channel capacity is 930 cfs based on the low ground elevation along the right levee approximately one mile downstream of the confluence of the Mariposa Bypass. The three major depressions were not considered in this or the previous analysis, which would limit the flow to 50 cfs, since these depressions would likely fill with water and reduce levee stability concerns. There is no change in then-existing channel capacity that was recommended in the 2016 Report.

- The recommended then-existing channel capacity for Reach 5 considering in-channel capacity is 2,350 cfs, based on a low point along the right levee near the downstream end of the reach. There is no change in the then-existing channel capacity recommended in the 2016 Report.

- The recommended then-existing channel capacity for the Middle Eastside Bypass considering subsidence and geotechnical assessment is 580 cfs. This is based on a 3-mile portion of the right bank downstream of Sand Slough. This flow assumes that the weirs are configured and operated at their typical board setting ("Typical Boards") that is required by the refuge to divert flows during most years. If the refuge is not diverting flows, the capacity would increase to 1,070 cfs. On the rare occasion that all of the boards are in the weirs, no Restoration flow can be put in the bypass without exceeding USACE criteria. The then-existing channel capacity recommended is based on the "Typical Boards" condition, geotechnical data and subsidence. There is no change in then-existing channel capacity recommended in the 2016 Report.

- The recommended then-existing channel capacity for the Lower Eastside Bypass considering in-channel capacity is 2,890 cfs based on the low point along the right levee just downstream of the Eastside Bypass Control Structure. There is no change in then-existing channel capacity that was recommended in the 2016 Report.

- The recommended then-existing channel capacity for the Mariposa Bypass considering in-channel capacity is 350 cfs based on a low point along the right levee about 1.3 miles upstream of the drop structure. There is no change in then-existing channel capacity that was recommended in the 2016 Report.

Table 8-1 summarizes the current and recommended then-existing channel capacities for each reach of the San Joaquin River and the flood bypasses, as well as what study was used to determine then-existing channel capacity. Then-existing channel capacities recommended above do not consider limitations to Restoration Flows as it relates to agricultural seepage. For the 2017 Restoration Year, releases of Restoration Flows in Reach 2A, Reach 3, and Reach 4A are limited by agricultural seepage, and not levee stability. Table 8-1 also notes current limitations of

Restoration Flows based on agricultural seepage. Details of how these seepage limits are determined and limit Restoration Flows are in the *Seepage Management Plan* described in Section 9.2.4.

**Table 8-1.**
**Current and Recommended Then-existing Channel Capacity**

| Reach | Current Then-existing Channel Capacity (cfs) | Recommended Then-existing Channel Capacity (cfs)[1] | Study that determines Then-existing capacity |
|---|---|---|---|
| Reach 2A | 6,000 | 6,000[2] | Geotechnical Assessment (Table 7.2) |
| Reach 2B | 1,120 | 1,120[3] | In-channel (Table 7.1) |
| Reach 3 | 2,860 | 2,860[4] | In-channel (Table 7.1) |
| Reach 4A | 2,840 | 2,840[5] | Geotechnical Assessment (Table 7.3) and In-channel (Tables 7.1) |
| Reach 4B1 | Not Analyzed | Not Analyzed | -- |
| Reach 4B2 | 930 | 930 | In-channel (Table 7.1) |
| Reach 5 | 2,350 | 2,350 | In-channel (Table 7.1) |
| Middle Eastside Bypass | 580 | 580[6] | Geotechnical Assessment (Table 7.3) |
| Lower Eastside Bypass | 2,890 | 2,890 | In-channel (Table 7.1) |
| Mariposa Bypass | 350 | 350 | In-channel (Table 7.1) |

[1] Then-existing channel capacity shown in this table is based on levee stability only and does not consider limitations to Restoration Flows related to agricultural seepage.
[2] Capacity not assessed for flows greater than 6,000 cfs. Restoration Flows are limited to approximately 2,140 cfs due to agricultural seepage.
[3] Restoration Flows are limited to approximately 1,300 cfs due to agricultural seepage.
[4] Restoration Flows are limited to approximately 900 cfs due to agricultural seepage.
[5] Restoration Flows are anticipated to be limited to approximately 300 cfs due to agricultural seepage.
[6] The recommended then-existing channel capacity reflects the typical board setting at the weirs that allows for flow diversions within the Merced National Wildlife Refuge. If all of the boards are removed from the weirs, the capacity could increase to 1,070 cfs. If all of the boards are placed in the weirs, Restoration Flows could not be put into the bypass without exceeding USACE criteria. Restoration Flows are anticipated to not be limited due to agricultural seepage.

# 9.0 Future Program Actions with the Potential to Improve Then-existing Channel Capacity

Throughout Settlement implementation, the maximum downstream extent and rate of Restoration Flows to be released would be limited to then-existing channel capacities. As channel or structure modifications are completed with additional environmental compliance, corresponding maximum Restoration Flow releases would be increased in accordance with then-existing channel capacities and the release schedule. Consistent with the commitments made in the PEIS/R ROD, Restoration Flows would be reduced, as needed, to address material seepage and levee stability impacts, as identified in the *Physical Monitoring and Management Plan* in Appendix D of the PEIS/R. If releases of water from Friant Dam are required for flood control purposes, concurrent Restoration Flows would be reduced by an amount equivalent to the required flood control release. If flood control releases from Friant exceed the concurrent scheduled Restoration Flows, no additional releases above those required for flood control would be made for SJRRP purposes.

Until sufficient data are available to determine the levee seepage and stability Factors of Safety, Reclamation would limit Restoration Flow releases to those flows which would remain in-channel. When sufficient data are available to determine the Factors of Safety, Reclamation would limit the release of Restoration Flows to those flows which would maintain standard USACE levee performance criteria at all times.

The following sections identify potential immediate, near-term and long-term actions by the SJRRP that could affect then-existing channel capacity due to changes in the physical conditions within the Restoration Area. The listed potential actions and projects is not a comprehensive list, but a list of actions that may be implemented. Future actions listed in future annual channel capacity reports may change as monitoring is conducted and physical changes within the Restoration Area occur and are identified. If any actions increase then-existing channel capacities, a new Channel Capacity Report will be prepared prior to Reclamation increasing Restoration Flows.

## 9.1 Immediate Actions

Immediate actions are described at a project-level in the PEIS/R including specific details in the *Physical Monitoring and Management Plan* in Appendix D. Potential immediate actions to a reduction in channel capacity continue to include removal of vegetation and debris and/or restrictions on Restoration Flows that would exceed channel capacity.

Since the start of Restoration Flows, the SJRRP has implemented flow limitations and immediate flow reductions to address issues related to then-existing channel capacity, mainly for groundwater seepage and will continue to do so on an as-needed basis during the release of Restoration Flows.

Vegetation removal would be conducted by mechanical or chemical means. Nonnative plant removal would receive priority over removal of native species. These responses could include unplanned emergency actions or actions taken within the water year.

## 9.2 Near-Term Actions

In addition to immediate actions, the SJRRP is evaluating sediment, vegetation and operational and maintenance projects that are being considered for implementation in the next couple of years (near-term) to address the potential to maintain or increase then-existing channel capacities. The following sections update the anticipated implementation schedules of the near-term actions described in the previous year's 2016 Report, as well as provide updates and future activities related to levee stability and channel capacity summarized in the *Physical Monitoring and Management Plan*.

### 9.2.1 Sediment Removal Projects

Sediment deposition in the Eastside Bypass contributes to reduced channel capacities. The Sand Slough Conveyance Project at El Nido Road was planned to remove sediment from the Middle Eastside Bypass. In 2016, a contract was awarded to remove 30,000 cubic yards of sediment from the Middle Eastside Bypass downstream of El Nido Road. This project had the potential to increase the low-flow channel capacity in the Middle Eastside Bypass, which parallels Reach 4B1. Sand removal was completed in August 2016 and included excavation of a 360 foot wide by 2,500 feet long by 2-5 feet deep area along the low flow channel of the Eastside Bypass on the Merced National Wildlife Refuge. In addition, four 36 inch culverts that were buried within the bypass at El Nido Road were also removed. This work did not result in a change in the overall then-existing channel capacity for this reach.

### 9.2.2 Vegetation Removal Projects

Vegetation within the channel can reduce channel capacity by increasing channel roughness. Vegetation management may be necessary to maintain then-existing channel capacities. Reclamation is continuing to work with a local non-profit, the San Joaquin River Parkway and Conservation Trust, to identify, manage, and monitor invasive aquatic and riparian species. The existing program is anticipated to continue into the future.

### 9.2.3 Operations and Maintenance Improvements

Overall operation and maintenance including vegetation and sediment management, structure and gate operations, levee stability and integrity of the San Joaquin River and flood bypasses can impact then-existing channel capacity. Reclamation remains open to providing funding to help the LSJLD adapt to changes in maintenance type and frequency as a result of Restoration Flows. However, these funds have to be provided consistent with Federal Law.

### 9.2.4 Seepage Management Plan

Reclamation has developed a *Seepage Management Plan* and *Seepage Project Handbook* to guide efforts related to groundwater seepage. It should be noted that the actions and findings of the *Seepage Management Plan*, although related to channel capacity, is being reported as it relates to agricultural seepage only. However, data collection and seepage projects will be closely coordinated to determine effect on channel capacities. Reclamation releases Restoration Flows in a manner that groundwater levels do not exceed thresholds that could cause seepage issues.

There are 93 groups of assessor parcels that may need seepage projects and will be evaluated for impacts. Reclamation will be gradually implementing seepage projects by parcel group based on flow restriction. Reclamation has implemented three projects to allow approximately 300 cfs to pass through Reach 4A (subject to real time groundwater monitoring). Anticipated Restoration Flow limitations for each reach due to agricultural seepage for the 2017 Restoration Year is shown in Table 9-1.

**Table 9-1**
**Restoration Flow Limitations at it Relates to Agricultural Seepage**

| Reach | Seepage Management Plan Approximate Restoration Flow Limitations[1] (cfs) |
|---|---|
| Reach 2A | 2,140 |
| Reach 2B | 1,300 |
| Reach 3 | 900 |
| Reach 4A | 300 |
| Reach 4B1 | Not Analyzed |
| Reach 4B2 | -- |
| Reach 5 | -- |
| Middle Eastside Bypass | -- |
| Lower Eastside Bypass | -- |
| Mariposa Bypass | -- |

[1] Subject to real time groundwater monitoring.

The *Seepage Management Plan* and *Seepage Project Handbook* can be found at the SJRRP website under the following link:

http://www.restoresjr.net/download/program-documents/program-docs-2014/SMP_Draft_September_2014.pdf.

## 9.3 Long-Term Actions

Long-term actions by the SJRRP will be needed to achieve then-existing channel capacities in the San Joaquin River and flood bypasses that can convey maximum Restoration Flow releases. Potential long-term actions could include, but would not be limited to, the following: providing a larger floodplain between levees through the acquisition of land and construction of setback levees; re-grading of land between levees; construction of sediment traps; sediment removal; levee improvements; construction of grade control structures; and channel grading.

Long-term actions would require a determination of need, identification for funding, and site-specific environmental compliance documentation. These actions would be considered by the SJRRP to allow the continued increase of then-existing channel capacity to meet full Restoration Flows.

The SJRRP is continuing to work on several long-term projects related to increasing site-specific channel capacity as provided for in the Settlement paragraphs 11(a) and 11(b). These projects include the following activities to be completed in future years:

- Construct Mendota Pool Bypass. Build a bypass around the Mendota Pool to convey at least 4,500 cfs from Reach 2B to Reach 3. This could also include a fish screen to avoid fish straying into Mendota Pool. Construction of this project is planned to begin in 2017.
- Modify Reach 2B to convey at least 4,500 cfs. The channel would be modified to expand its capacity to at least 4,500 cfs with integrated floodplain habitat. New levees would be constructed to accommodate Restoration Flows, increasing the flood capacity of the reach.
- Modify Reach 4B to allow for fish and flows. The Reach 4B Project consists of channel and structural improvements in Reach 4B (the Reach 4B area is described as the San Joaquin River and flood bypass channels between the Sand Slough Control Structure and the confluence of the Eastside Bypass and Reach 5 of the San Joaquin River) to provide fish passage and increased floodplain habitat to support the Restoration Goal of the Settlement. The project is currently going through a consensus-based process and the SJRRP is meeting with all of the stakeholder groups and agencies with the goal of developing consensus on a preferred alternative.
- Construct several early implementation elements of the Reach 4B Project. These early implementation projects include the improvement of two structures and the Reach O levees of the Middle Eastside Bypass to allow sufficient flow conveyance and fish passage through the reach by 2019.

## 9.4 Framework for Implementation

The long-term actions identified above are included in the SJRRP's draft *2015 Revised Framework for Implementation* (Revised Framework). The Revised Framework is an update and revision to the *Third Party Working Draft Framework for Implementation*, dated June 19, 2012 (2012 Framework), and establishes a realistic schedule for the Framework's "core" actions based upon the best available technical, biological, schedule and funding information. Specifically, the Revised Framework establishes the following:

- Five year visions to provide clear, realistic, and accomplishable steps towards meeting the Restoration Goal and Water Management Goal;

- Achievable schedules based upon realistic Federal and State of California appropriation levels, improving our ability to plan and be transparent on actions; and
- More clearly defined roles and responsibilities for each Implementing Agency, increasing each agency's ability to budget, plan, and approve construction actions.

This Revised Framework provides a more realistic schedule and associated future funding needs for the SJRRP Implementing Agencies to focus on "core" actions identified in the 2012 Framework and implementation of the Settlement and the Settlement Act. The Revised Framework includes objectives to have 1,300 cubic feet per second of channel capacity throughout the San Joaquin River to Reach 4A, the Eastside Bypass and Reach 5 by the end of 2019, 2,500 cfs of capacity by the end of 2024, and 4,500 cfs capacity by the end of 2029. Channel capacity improvements include levee improvements identified by the remaining reaches constrained by then-existing channel capacity, and groundwater seepage projects needed to release flows without causing crop yield impacts. Approximately $300 million of levee improvement projects and $189 million of seepage projects are included in the Revised Framework, which combined total about a third of the total SJRRP cost.

The Revised Framework can be found at the SJRRP website under the following link:

http://www.restoresjr.net/wp-content/uploads/Revised-Framework_Final_20150729.pdf.

# 10.0 Future Program Studies and Monitoring with the Potential to Inform Then-existing Channel Capacity

There are several factors that can impact and limit channel capacity. Potential factors could include overall levee construction or integrity (e.g., insufficient slope stability factor of safety or underseepage factor of safety); flow duration and timing that could saturate the levee and cause instability; erosion of the stream banks that could cause potential levee failure; sedimentation or scouring; ground subsidence; and increased roughness from vegetation. Other future conditions, such as climate change and operation and maintenance while not directly impacting channel capacity, could have long-term impacts on overall performance of the conveyance system. These factors, as well as others were considered in developing future SJRRP studies and monitoring to determine then-existing channel capacity. The following section summarizes the specific studies and data collection activities planned by the SJRRP to provide a better understanding of then-existing channel capacity or changes in in-channel capacity.

## 10.1 Technical Studies

The 2016 Report described several future technical studies that build on the studies described in Section 7.0 “Current Channel Capacity Studies and Related Work Completed” and will provide additional information necessary to identify future then-existing channel capacities. The following describes the activities that may be conducted during the following Restoration Year.

### 10.1.1 San Joaquin Levee Evaluation Project

The SJLE Project assists the SJRRP in assessing flood risks associated with the SJRRP with respect to levee seepage and stability. As part of the work, DWR identified three priorities for levee evaluations representing an increasing priority for the need to complete geotechnical evaluations and analyses. Currently, DWR is performing the next steps on the SJLE Project by providing guidance on flood risk due to the release of Restoration Flows on the levees along the San Joaquin River and flood bypasses.

One of the steps is to initiate a feasibility-level study on a critical levee reach that initial levee evaluations have shown will exceed USACE criteria for underseepage at a target Restoration Flow release of 1,300 cfs. The evaluation of the Priority 1 levees resulted in a single 3-mile levee reach (Reach O) in the Middle Eastside Bypass that will need feasibility-level study to identify if the levee will need to be improved to allow Restoration Flow releases of 1,300 cfs from Friant Dam. DWR performed additional data collection on Reach O to refine the analysis and start evaluating remediation measures for improving the levee segment that considers subsidence and design flood flows. DWR will also coordinate any levee remediation projects with Reclamation to ensure that levee improvements are consistent with improvements to address agricultural seepage issues and the preferred alternative for the Reach 4B site-specific project. The goal of the work is to implement a solution by 2019 to correspond with the Revised Framework schedule of releasing 1,300 cfs Restoration Flows in 2019.

DWR is also continuing the exploration of Priority 2 levees to inform the SJRRP of future remediation needs and costs. Priority 2 evaluations are currently being performed on about 30 miles of levees in Reach 4B2 and the Mariposa Bypass. The explorations, including 152 bore holes, CPTs, and geophysical surveys, and testing of the soils data has been completed. The evaluations and determination of capacities for these reaches will continue in 2017.

Since the evaluations of the SJLE Project are limited to seepage and stability analyses, and do not include assessment of other levee failure mechanisms, a field monitoring program will also be implemented to document levee performance under Restoration Flow conditions. Because it is not anticipated that Restoration Flows will be placed on the levees until spring 2017, the monitoring plan will be developed and incorporated into the 2018 Channel Capacity Report. Additional details of the specific tasks that are included in the SJLE Project are summarized in Section 10.1.2 of the 2014 Report.

### 10.1.2 Reach 2A Morphology Study

The Reach 2A Sediment Study was carried out in the lower portion of Reach 2A to investigate sediment deposition upstream from the CBBS, which may have been a result of the 2009 through 2011 Restoration and 2011 flood flow releases. The study showed that in the short-term, and Restoration Flows did not have a significant impact on channel capacity in the lower portion of Reach 2A. Continued monitoring may be conducted to improve understanding of longer term impacts and to test the hypothesis that Restoration Flows will continue the pattern of general degradation throughout Reach 2A, but that deposition will continue to occur immediately upstream of the CBBS. This study would help the SJRRP determine the short-term and long-term channel response in Reach 2A and its potential impact on then-existing channel capacity, as well as on operation of the CBBS. This information can also be used to assess the potential need to change then-existing channel capacity in Reach 2A or to take immediate or long term-actions. The initial study was described in Section 7.3 of the 2014 Report; a summary of the potential work that could be completed is in Section 10.1.3 of the 2014 Report.

### 10.1.3 Subsidence Monitoring and Studies

The 2015 and 2016 Reports include a description of the methods and results of the subsidence monitoring and levee surveys completed from 2011 to 2013 by Reclamation, Mid–Pacific Region, Division of Design and Construction, Surveys and Mapping Branch (MP-220) and the California Department of Water Resources, South Central Region Office (DWR-SCRO) for the San Joaquin River Restoration Program (SJRRP). Additional details are also provided in *Technical Memorandum, Subsidence Monitoring,* dated September 2014 and prepared by DWR and Reclamation that are included in the 2015 Report (Attachment E). The results of the monitoring are being used to study subsidence within the Restoration Area and to support the various studies that will help the SJRRP determine changes in then-existing channel capacities as a result of subsidence. The following sections provide an update to the monitoring and study efforts.

### *Reclamation Geodetic Control Network*

In 2011, Reclamation established the SJRRP Geodetic Control Network, using static GPS methods, to investigate subsidence within the Restoration and surrounding study areas. To monitor the rate of subsidence over time, Reclamation conducts bi-annual surveys, in July and December, of the established network made up of 85 control points. The control point elevations are updated after each survey and are used by the SJRRP to study subsidence, as well as to provide more accurate horizontal and vertical control for other studies.

After each survey, Reclamation prepares exhibit maps that compare the most recent data with the data from the previous survey, as well as from previous years. The exhibit maps give a good overall picture of the subsidence trends within the Restoration Area. Figure 10-1 shows the calculated annual subsidence rates continue to range from about 0.15 ft/year to 0.90 ft/year based on survey data collected in December 2011 and December 2015, and averaged over a four year period.

Beginning in May 2012 Reclamation began monitoring the Arroyo and Temple-Santa Rita (TSR) Canals to understand the localized subsidence near Sack Dam. This data is being collected to support the design efforts for the Arroyo Canal Fish Screen and Sack Dam Fish Passage Project. The project is currently on hold until the SJRRP can better understand the magnitude of future subsidence and the effect of subsidence on the final design and operations.

The SJRRP is using the semiannual monitoring data and the Arroyo and TSR survey, in part to support and update a design criteria technical memorandum which will document subsidence within the SJRRP Restoration Area. The technical memorandum will establish the recommended subsidence criteria that will be applied to the designs for future site-specific projects in Reach 2B, Reach 4B, and at the Arroyo Canal diversion in Reach 3, as well as for the levee, seepage projects and other site-specific project designs in Reaches 2A through 4B.

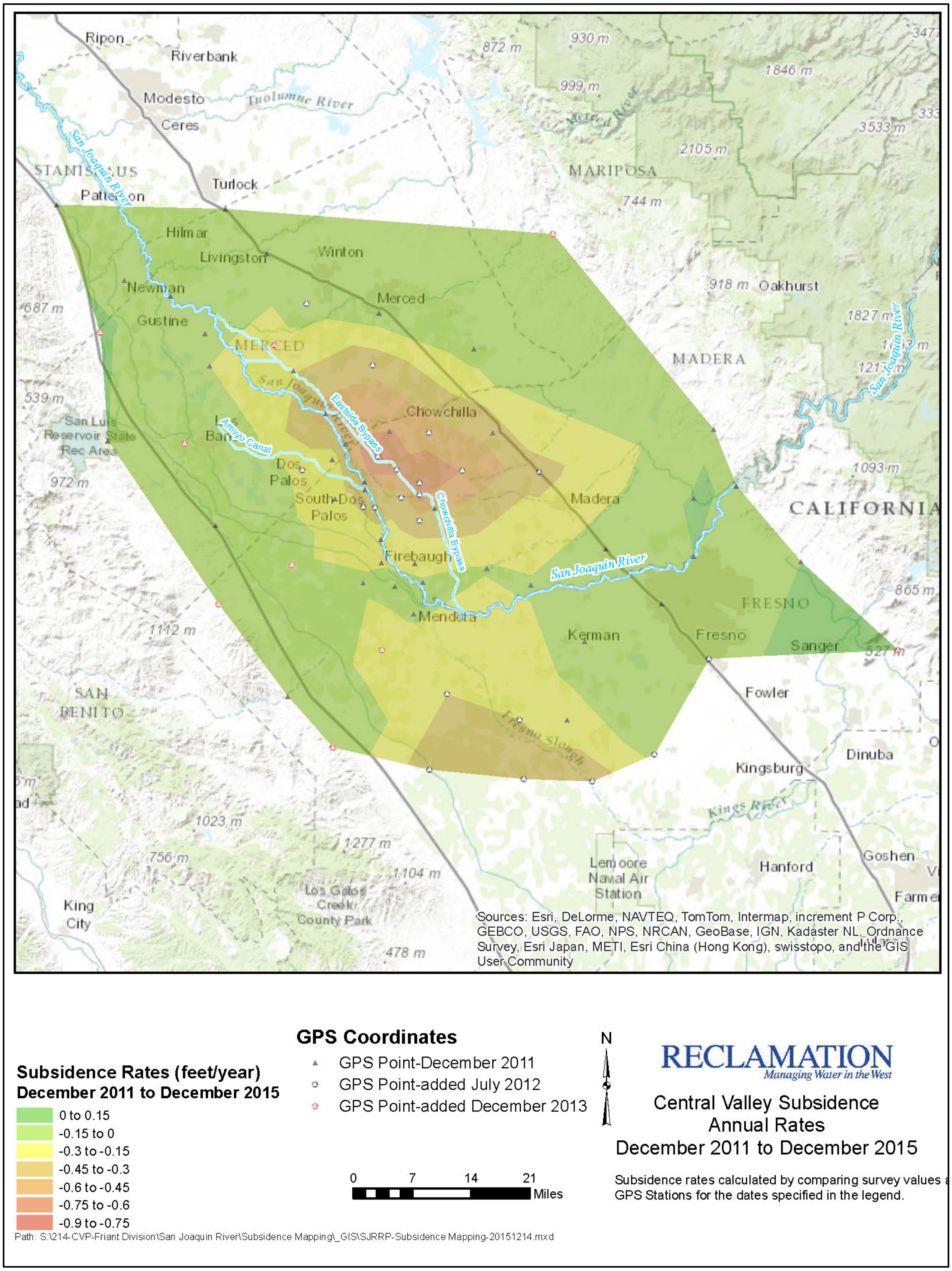


**Figure 10-1.**

**Regional Subsidence Map**

***DWR Capacity Studies and Analysis***

DWR, in coordination with Reclamation, will conduct a study to better understand the effects of long-term subsidence on channel capacity, and the designs of the levee, seepage, and site-specific projects. In performing this study, the 1-D hydraulic models will be developed using the latest LiDAR data collected in early 2015 and additional levee survey data in 2016, and employed for existing and future design conditions considering subsidence for the entire Restoration Area. The study will also include an assessment of the subsidence in Reach 2A and Reach 2B and its impact on channel capacity. The future subsidence rates will be based on the average rate of subsidence currently being measured by Reclamation since 2011. Because of delays in the processing of the new LiDAR data, this study is expected to be completed in 2017.

In addition to updating the models, and assessing the channel capacity to consider future subsidence, DWR is performing a study within the flood bypasses to understand how subsidence is changing the sediment transport. The study is designed to better understand and quantify how subsidence-induced sedimentation will affect channel capacity over the next 13-years before the larger Reach 4B project is implemented and to provide information on the amount of sediment removal that may be required to maintain necessary design flow capacities. Results from the sediment transport study could provide information to further evaluate bypass flow capacities, as well as refine certain aspects of the design for the Reach 4B, Eastside Bypass and Mariposa Bypass Channel and Structural Improvements Project. The study was completed in November 2016 and the results will be summarized in the 2018 Report.

### 10.1.4 Vegetation Modeling

Reclamation will use existing SRH-2D hydraulic models to quantify potential increases in river stage given increases in riparian growth in reaches that convey the SJRRP Restoration Flows. This study will help the SJRRP determine if action needs to be taken to maintain or reduce then-existing channel capacities. It is expected that the analysis may be performed in Reaches 2A and 4A as they have the highest potential for vegetation recruitment as a result of rewetting. The existing conditions Reclamation-built 2-D models, described briefly in Section 5.0 “Data and Analytical Tools,” will be used as a starting condition. The potential increase in vegetation will be estimated using analogs to surrounding reaches. Various methods will be used to predict the increase in river stage due to increasing vegetation density. A technical report documenting the effect of vegetation roughness in Reaches 2A and 4A may be completed in 2017.

## 10.2 Monitoring Activities

The SJRRP is continuing various monitoring activities for different studies and purposes. The monitoring described below will guide implementation of the Settlement for observing and adjusting to changes in physical conditions within the Restoration Area including those changes that may impact channel capacity. These monitoring activities are described in the *Physical Monitoring and Management Plan*, which is in Appendix D of the PEIS/R, the *Restoration Flow*

*Guidelines,* or the *Seepage Management Plan.* The following sections describe the monitoring that may be undertaken on an as-needed basis.

### 10.2.1 Flow Monitoring

The objective of continuing to monitor flow is to ensure compliance with the hydrograph releases in Exhibit B of the Settlement and any other applicable flow releases without exceeding then-existing channel capacity. Reclamation, DWR and the USGS currently maintain 23 flow and staff gages along the San Joaquin River and tributaries between Friant Dam and the Merced confluence. These gages are used to determine the flow in each reach of the river. All of the gages shown in Figure 10-2 below are telemetered and available online at the California Data Exchange Center (CDEC). Each of the operating agencies also conducts periodic flow measurements in order to develop and adjust rating curves as necessary. Final daily average data is determined monthly by Reclamation, as requested by DWR, and annually by the USGS. Flow monitoring stations provide calibration data for hydraulic models and a key dataset for comparison and evaluation. Monitoring of these stations would continue as needed to help ensure Restoration Flows do not exceed then-existing channel capacities.

In addition to the flow monitoring already being completed, DWR will also develop a flow and channel capacity water surface elevation monitoring plan to evaluate future changes in channel capacity at critical sites due to vegetation, sedimentation, or other channel changes. The objective is to develop a monitoring plan for the critical locations identified in each reach that limit the flow capacity of the reach. The plan will include a review of the existing monitoring stations to determine if they are close enough and adequate for monitoring the critical sites. If the existing monitoring sites are not adequate, new sites will be identified in consultation with other on-going programs so that new stage and flow measuring devices can be installed. The plan will allow the SJRRP to identify when channel capacities are changing to inform when or if actions discussed in Section 9.0 need to be implemented. This plan is expected to be completed in 2017.

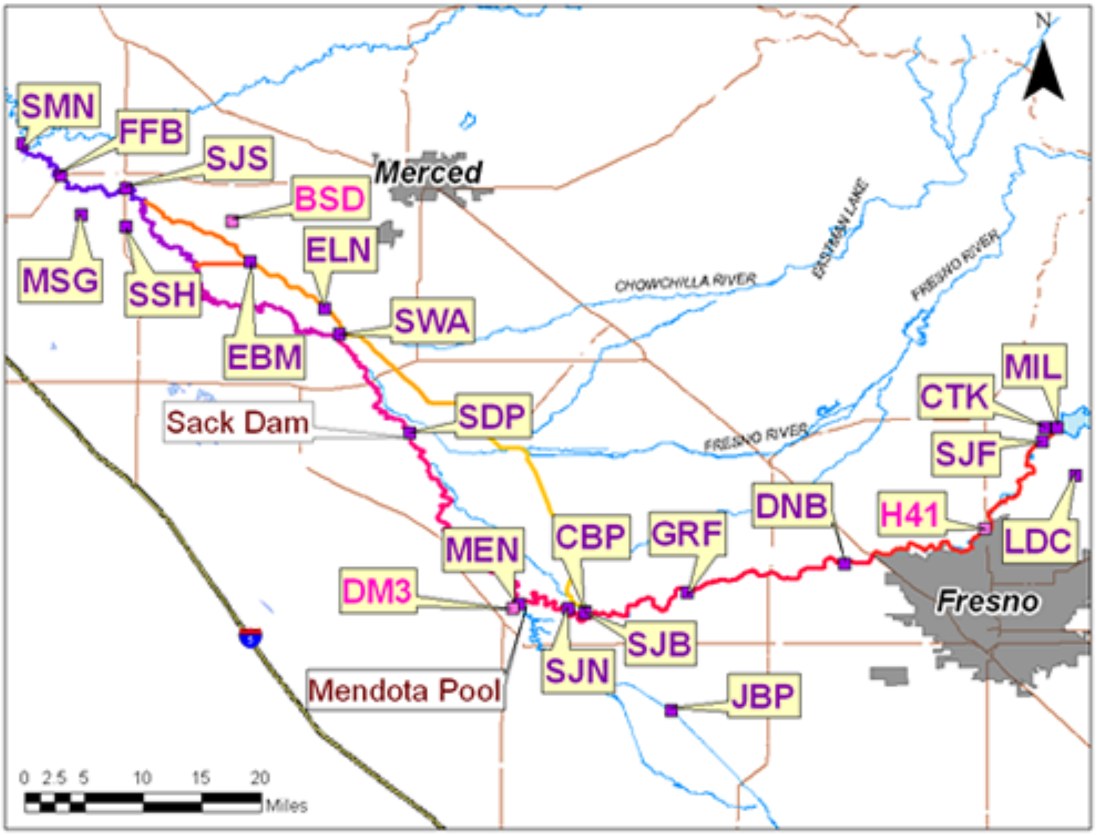


**Figure 10-2.**
**Current flow gages (purple) and staff gages (pink) available on CDEC**

### 10.2.2 Water Surface Profile Surveys

Along with flow monitoring, water surface profile (WSP) surveys help inform the SJRRP of the potential changes in stage and channel capacity as a result of a change in specific or reach-wide conditions due to subsidence, vegetation, channel work and sediment transport. In 2016 and 2017, additional WSP surveys may be completed in some reaches, depending on flow releases from Friant and model calibration needs.

### 10.2.3 Aerial Photography and Topographic Surveys

The purpose of the aerial photography and topographic surveys is to obtain information about the river stage, hydraulic roughness, river width, and bed elevation to assist with scientific studies that would inform the SJRRP about how physical changes in the system are impacting then-existing channel capacities. A number of survey data sets have been collected in this region before and after the Settlement to support the SJRRP. The current topography is based on 2008 LiDAR and 2010/2011 bathymetry. Due to continued subsidence, a new flight of aerial photography and LiDAR was flown in 2015 within 1 mile of all reaches of the San Joaquin River from Friant Dam to the Merced River confluence as well as the Chowchilla, Eastside, and

Mariposa Bypasses. Bathymetric surveys were also completed in 2015 and 2016. The data is currently being reviewed and new terrain surfaces will be created with this updated topographic data and will be used for site-specific designs and to update hydraulic models and studies which could be used to inform then-existing channel capacity. In addition to the LiDAR surveys, additional surveys may be completed to support other ongoing and future studies related to subsidence, channel capacity, erosion monitoring, and sediment transport.

### 10.2.5 Vegetation Surveys

The purpose of the previous and future vegetation surveys is to obtain information on the establishment and recruitment of vegetation. This information can be used by the SJRRP to determine if actions need to be taken to address capacity issues as a result of increased channel roughness from vegetation. Annual surveys have occurred since 2011 and future surveys will be conducted annually after flood events as part of baseline SJRRP monitoring. The extent and scope of the monitoring is discussed in Section 10.2.5 of the 2014 Report.

### 10.2.6 Sediment Mobilization Monitoring

The purpose of sedimentation mobilization monitoring is to obtain information on sediment mobilization, bar formation, and bank erosion. This information will be useful for implementing sediment removal strategies to help maintain channel capacity, developing studies to determine the impacts of sedimentation on channel capacity, as well as identifying and mitigating areas that could compromise levee integrity. Future sedimentation monitoring includes suspended sediment and erosion monitoring.

#### *Erosion Monitoring*

Erosion monitoring of the channel and channel banks is conducted by DWR to identify areas that may potentially compromise levee integrity for consideration of future management actions (e.g., flow reduction, revetment, armoring, etc.). The objective of the work performed thus far is to test methods and develop a final plan to detect, monitor, document, and report erosion and deposition within the Restoration Area. The plan will be designed to provide proactive detection of hazards prior to incurring damage to infrastructure, property, and communities.

DWR is monitoring channel changes by comparing sequential aerial photographs and LiDAR survey datasets to identify eroded channel margins. From those results, DWR will field-verify the detections, as well as areas where these remote detection methods provide less certainty (e.g., due to vegetative cover, shadows, image quality, etc.). For each aerial photograph set, DWR will use a Geographic Information System (GIS) to record delineations of the channel margins and other relevant features for comparison with past and future delineations. Differences in delineations will be used to detect erosion and then examined more closely. Detected erosion sites will be identified and each assessed to determine the lateral distance and eroded volume, and then catalogued in a table that will record its characteristics and location.

The pilot study is currently underway, which includes DWR reviewing aerial photographs collected in 2015 and comparing them with archived photographs. DWR has initially focused on a 5-mile reach through the community of Firebaugh (Reach 3). The pilot study has allowed evaluation of the effectiveness of proposed monitoring methods. For example, at each site, the bank lines and other informative features were delineated with GIS (Figure 10-3). Delineations are able to be saved as shape files for later comparisons with subsequent photographs and delineations. In addition, DWR used LiDAR data from 2015 and compared it with LiDAR data collected in 2008. The data were converted to digital elevation maps (DEM). Then the 2015 DEM was subtracted from the 2008 DEM thereby generating a DEM surface that spatially illustrates the difference in elevations between the surveys (Figure 10-3). The subtraction surface could also be used to calculate a volume of sediment eroded from the bank, thereby providing an additional metric that can be used for making estimates of bank retreat rates at locations with different bank heights. This technique was applied to a site in Firebaugh, which identified several bank erosion sites that were later confirmed by site visits. The results demonstrate that the techniques are capable of detecting erosion at the scale necessary for alerting the SJRRP of problematic locations. These results can be used for monitoring, documenting, and reporting sites where erosion is occurring and its extent.

In future years, DWR will continue to collect and review aerial photography periodically, as needed, based on the magnitude of flows experienced in each reach. This will also help determine the differences in erosion as a result of Restoration or flood flows. In addition, part of the monitoring plan in future years could include analysis and review of reach-wide mapping by SJRRP LiDAR or other means as it becomes available. More frequent supplemental surveys could be performed in areas identified as sensitive erosion locations and established as needing closer monitoring. Reports will be prepared annually for review to determine the flow effects on channel capacity and potential hazards to infrastructure and communities.

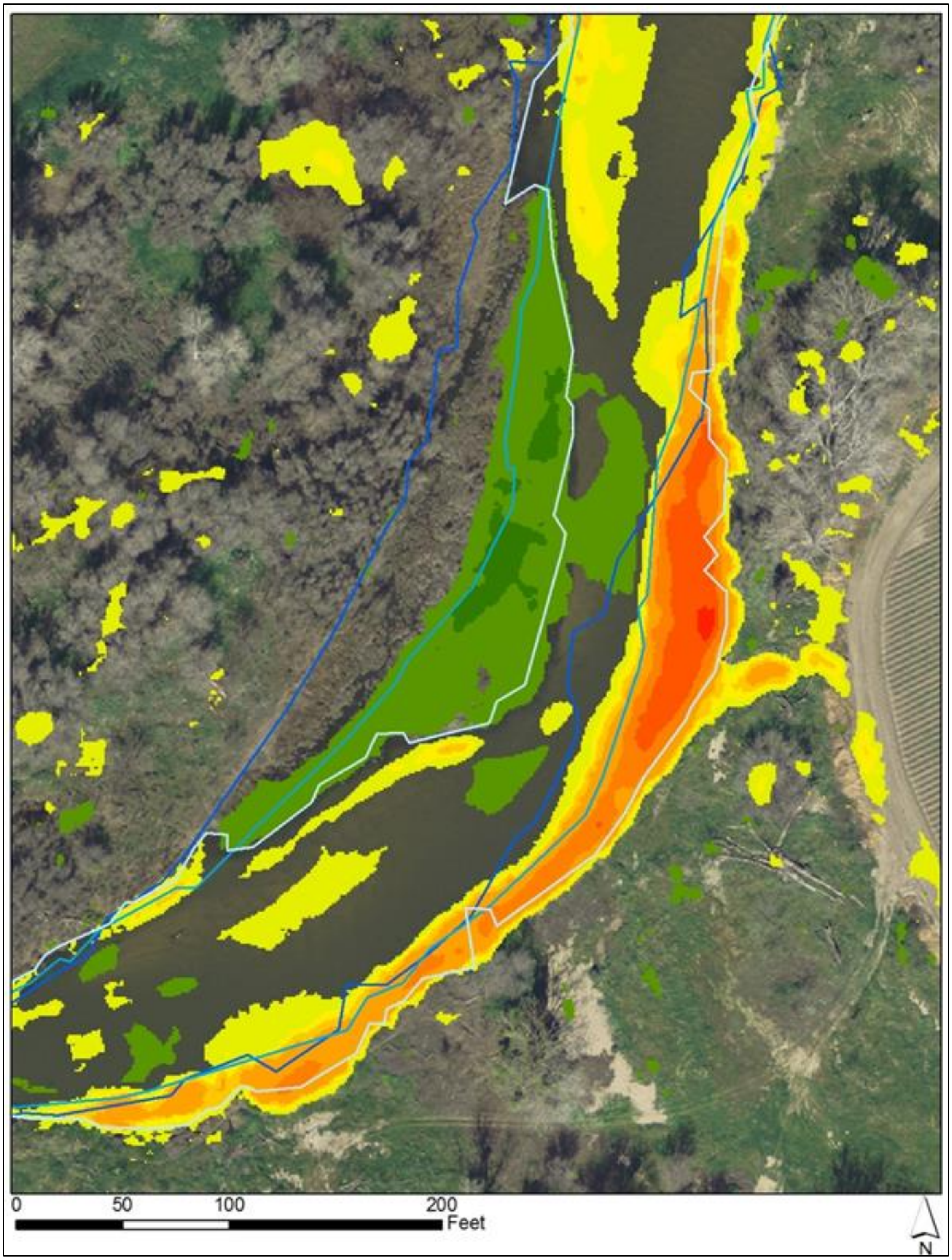


**Figure 10-3.**

**Firebaugh Surface Differences 2015-2008**

# 11.0 Non-Program Actions and Studies that May Influence Future Channel Capacity

There are several entities that are active in the Restoration Area and whose programs may help inform or impact then-existing channel capacity. The SJRRP will need to closely coordinate and collaborate with these entities by sharing information and data, as well as coordinate specific actions along the river that can inform or impact channel capacity. This section provides recent updates of the programs, actions, and studies of other agencies that could impact or allow a better understanding of future channel capacity within the SJRRP Restoration Area.

## 11.1 Lower San Joaquin Levee District

The LSJLD is a local agency responsible for operation, maintenance, and emergency management of the LSJRFC Project, which is part of the State Plan of Flood Control (SPFC) facilities within the SJRRP Restoration Area. The LSJLD operates and maintains levees, bypasses and other facilities built in connection with the SPFC and these actions directly impact the capacities of the reaches in the study area. The LSJLD identified six erosion sites along Reach 2A of the San Joaquin River experiencing increased levels of bank erosion that threaten the flood control levee system. To reduce this potential and maintain channel capacity, bank stabilization efforts currently underway consist of lining the banks with erosion-resistant materials such as rock, concrete rubble and local hard-pan. Five of the six sites have been completed. The LSJLD will evaluate whether the last site warrants a repair, as this area appears to be more stable than originally thought.

## 11.2 Merced National Wildlife Refuge

The U.S. Fish & Wildlife Service (USFWS) currently operates a pair of weirs within the boundaries of the MNWR along the Middle Eastside Bypass that could have an impact on channel capacity. These weirs are referred to as the upper and lower wildlife refuge weirs, since they are located at the upstream and downstream intersections of the MNWR and the bypass. These structures have the ability to check water both upstream of the MNWR and within its boundaries for diversion to the various wetlands operated by USFWS. When the boards are placed into the weirs, they have significant impact on water surface elevation and capacity of the bypass, as described in Section 7.0 “Completed Channel Capacity Studies.” Coordination of the release of Restoration Flows and the operation of the weirs will be critical to ensure that USACE criteria are being met.

## 11.3 DWR

DWR is leading three specific efforts within the SJRRP Restoration Area in support of the Central Valley Flood Protection Plan (CVFPP) that may affect or inform channel capacity.

### 11.3.1 Non-Urban Levee Evaluations

As a component of the CVFPP, DWR has been performing geotechnical evaluations of over 1,800 miles of levees throughout the Central Valley. The evaluations are divided into the Urban Levee Evaluations Project for levees protecting populations greater than 10,000 and the Non-Urban Levee Evaluation (NULE) Project for the remaining levees including a portion of the levee features within the Restoration Area. The evaluations are limited to Project levees and appurtenant Non-Project levees, which protect part of a basin partially protected by Project levees or may impact the performance of Project levees.

The subsurface exploration portion of the program was completed in 2012 and consisted of exploration along levees in Reaches 2A, 3, 4A, Eastside Bypass, and Chowchilla Bypass Canal. The Geotechnical Data Report (GDR) for this effort was completed in February 2014. Seepage and stability evaluations were also perform on these levees and the results of these analyses in Reach 3 and 4A are presented in a Geotechnical Overview Report (GOR). The analyses for Reach 2A were combined with the SJLE Project analysis and presented in the Gravelly Ford Study Area GCR as described in Section 7.2 "Priority 1 Levee Geotechnical Assessment." The reports also include proposed alternatives and preliminary costs for remediating the existing levees. The NULE assessments will continue to be used by the SJLE Project in areas where priority levees were identified. The levee evaluation reports are located at the website under the following link:

http://www.dwr-lep.com/.

### 11.3.2 Regional Flood Management Planning

DWR launched the Regional Flood Management Planning effort in 2012. The regional planning effort supports locally-developed Regional Flood Management Plans (RFMP) and is an important step in updating and implementing the CVFPP. The Central Valley was divided into six RFMP regions with the goal of identifying high priority regional flood risk reduction solutions that are both economically viable and implementable. The RFMP region that encompasses a significant portion of the Restoration Area is the Upper San Joaquin River (USJR) Region.

The USJR Region prepared a RFMP that describes the region's flood hazards, flood control systems, and ultimately their vision for a "floodsafe" region. There are 88 management actions that were proposed in the USJR RFMP and it is expected that several of the proposed projects will reduce flood risk in the Restoration Area. Ten SJRRP projects are included on the USJR Region's project list and the USJR Region has been coordinating with the SJRRP on potential projects that could increase then-existing channel capacities in the Restoration Area.

With the completion of the regional flood plan, the USJR Region has now moved to the second phase of the planning effort, which is intended to continue the meaningful engagement by the Regional Partners to further develop strategies for addressing governance and institutional issues in improving flood management and implementing projects. DWR has reviewed each RFMP, and management actions proposed in the RFMPs that are consistent with CVFPP goals will be used to develop a portfolio of management actions. These portfolios will be included in the 2017 CVFPP to help identify the investment needed over the next 30 years to achieve the CVFPP goals and intended outcomes.

The USJR Region will also continue its collaboration with DWR's San Joaquin Basin-wide Feasibility Study (BWFS), another critical effort supporting the 2017 CVFPP update. The BWFS is looking at major system elements potentially led by the State or possible State interest in region-wide management actions that achieve the goals of the CVFPP. The BWFS has incorporated several USJR RFMP management actions in its planning including groundwater recharge, subsidence improvements, and flood infrastructure rehabilitation. One project, Firebaugh Multi-benefit Flood Project, looks to provide the city with 100-year flood protection while incorporating ecosystem and recreational elements. The project incorporates existing levee improvements, levee setback and land acquisition elements that could change then-existing channel capacities and benefit the SJRRP. Reclamation recently received a Proposition 1 grant to implement a portion of the land acquisition element of the project.

### 11.3.3 Flood System Repair Project

As part of implementing actions in the CVFPP, DWR is also implementing near-term priority actions, the Flood System Repair Project (FSRP) to help Local Maintaining Agencies (LMAs) reduce flood risks in non-urban areas. Through FSRP, DWR is assisting LMAs by providing them with technical and financial support to repair documented critical problems with flood control facilities of the State Plan of Flood Control (SPFC) in non-urban areas.

The objectives of the FSRP are to repair documented critical problems like erosion sites (50-feet in length or less), hydraulic control structures, and deteriorated levee patrol roads. Under the FSRP, DWR worked with the LSJLD to complete the re-rock 25.5 miles of levee roadways to provide all-weather access to the levees. This project was completed in October of 2015 and is helping to reduce flood risks by improving the reliability of the levees for levee monitoring during flood events.

# 12.0 References

Bureau of Reclamation, 2010. SRH-2D version 2: Theory and User's Manual: Sedimentation and River Hydraulics—Two-Dimensional River Flow Modeling. Technical Service Center, Denver, CO, 2010.

______,2012). San Joaquin River Restoration Daily Flow Model (SJRRP) Documentation for the Reach 4B Study, Technical Report No. 86-68210-2012-04, Prepared for the San Joaquin River Restoration Program, Technical Service Center, Denver, CO, 2012.

CA Department of Water Resources, 1985. Flood Channel Design Flows (Modified) May 1985.

______, Division of Flood Management, 2012. Identification and Prioritization of Levee Segments for Geotechnical Exploration and Analyses, August 30.

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

McBain & Trush 2002. San Joaquin River Restoration Study Background Report. Prepared by Friant Water Users Authority, Lindsay, California, and Natural Resources Defense Council, San Francisco, California. December.

Reclamation Board, 1967; amended 1978, revised 1985. Lower San Joaquin River Flood Control Project: Operation and Maintenance Manual for Levees, Irrigation and Drainage Structures, Channels, and Miscellaneous Facilities.

Tetra Tech, Inc. 2013a. San Joaquin River, Reach 2B, Two-dimensional Sediment-transport Modeling to Evaluate Sediment Budget through the San Joaquin River Bypass Structure, Prepared for California Department of Water Resources, April 2013.

______, 2014. Draft San Joaquin River and Bypass System 1-D Steady State HEC-RAS Model Documentation, Prepared for California Department of Water Resources, April 2014.

______, 2015a. Reaches 3, 4A and Middle Eastside Bypass (MESB) Subsidence and Capacity Study, Draft technical memorandum prepared for the California Dept. of Water Resources, Fresno, California, February.

______. 2015b. Draft San Joaquin River In-channel Capacity Analysis, Draft technical memorandum prepared for the California Dept. of Water Resources, Fresno, California, June.

San Joaquin River Restoration Program. 2011. Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project, Initial Alternatives Technical Memorandum, October 2011.

Towill, Inc., 2009. Topographic and Bathymetric Mapping of the San Joaquin River from Friant Dam to Highway 99 (Reach 1A). Letter of Transmittal submitted with mapping to Tetra Tech-MEI for California Department of Water Resources, Fresno, California, April 24.

URS, 2013. Channel Capacity Assessment Based on Geotechnical Considerations. Prepared for the California Department of Water Resources, August 30.

U.S. Army Corps of Engineers. 2000. Design and Construction of Levees Engineering and Design Manual. Manual No. 1110-2-1913. April 2000. Table 6-1b, page 6-5.

______. 2003. Engineering and Design – Slope Stability. Manual No. 1110-2-1902. October 2003.

______. 2005. Design Guidance for Levee Underseepage Engineering Technical Letter. ETL 1110-2-569. May 2005.