Attachment

Seepage Management Plan

Draft
Physical Monitoring and Management Plan Appendix

SAN JOAQUIN RIVER
RESTORATION PROGRAM

Draft
April 2011

DRAFT

Seepage Management Plan

SAN JOAQUIN RIVER
RESTORATION PROGRAM

March 28, 2011

1. Introduction

This Seepage Management Plan (Plan) for the San Joaquin River Restoration Program (SJRRP) describes the monitoring and operating guidelines for reducing Interim or Restoration Flows to the extent necessary to address any material adverse impacts caused by Interim and Restoration Flows in the San Joaquin River identified by the SJRRP groundwater monitoring program. The geographic scope of this Plan, referred to as the Restoration Area, is the area within five miles of the San Joaquin River and associated bypass system along the 150-mile reach from Friant Dam to the confluence with the Merced River. This 150-mile reach and associated defined sub-reaches are shown in Figure 1.

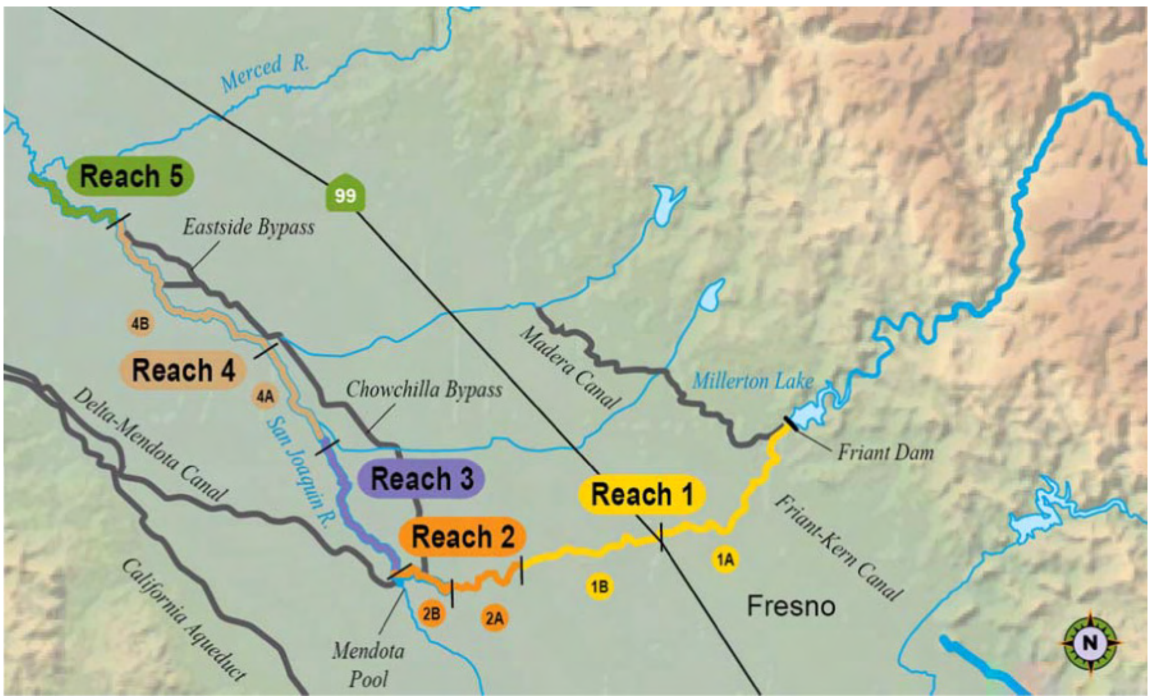

Figure 1. Restoration Area

This Plan is meant to be a dynamic, adaptive plan. Implementation of SJRRP activities over time will result in new information and subsequent revisions of the Plan. The Plan provides the framework to facilitate this adaptive process. Stakeholder input and feedback has helped to shape this plan and will continue to improve the process.

The seepage-related effects considered in this Plan are related to lateral flow through levees and associated seeps, and rising of the water table in areas where it is shallow. The former is straightforward in concept, but the latter requires some explanation. Two mechanisms may cause the water table to rise in association with Restoration Flows. Along losing reaches, where river water surface elevation is above groundwater level, increased seepage from the river/bypass system may result in increased groundwater recharge. Along gaining reaches, where river water surface elevation is below groundwater level, groundwater discharge to surface water may be impeded by an increase in surface-water stage. In response, the water table will rise until equilibrium with surface water, or the discharge to surface water is established, or evapotranspiration and/or other forms of discharge increase to regain the previous rate of discharge. In this document, all impacts caused by groundwater rise associated with changes in river/bypass stage, regardless of mechanism, are referred to as *seepage impacts*.

The Plan provides a means to reduce or avoid risk of seepage impacts through a combination of monitoring and analyses to better understand and predict system response to Restoration activities, and development of thresholds and response actions designed to reduce or avoid undesirable outcomes. Components of the Plan include:

- Purpose and Objectives: the purpose and intended outcomes of the Plan;
- Seepage Effects: description of undesirable outcomes and the processes that contribute to seepage.
- Locations of Known Risks: areas identified as at risk for seepage effects through landowner identified parcels, historical groundwater levels, the Central Valley Hydrologic Model (CVHM), and the current monitoring program.
- Operations Plan: procedures for assessing flow rates and responding to real-time concerns identified by monitoring and landowner feedback through making changes in flow releases.
- Monitoring Program: the data collection program including a series of telemetry, logged, and manually measured monitoring well transects and staff gages spaced roughly 8-10 miles apart with additional wells at locations identified by the SJRRP and landowners to document the hydrologic response to Interim and Restoration Flows, inform analyses, constrain modeling, and identify potential or actual seepage impacts.
- Thresholds, Triggers, and Operational Criteria: groundwater levels that identify the potential for seepage effects, and events that result in increased scrutiny and provide operational criteria to restrict the magnitude, timing, or duration of flows.
- Site Visits and Response Actions: specific actions or alternative actions that will be implemented as necessary to meet operational criteria and avoid or reduce seepage impacts;
- Projects: potential modifications to reduce seepage effects and allow for higher flows that require independent, supplemental environmental documentation and regulatory review; and
- Revision Process: process for modifying and/or updating the Plan on the basis of information obtained during implementation of the Plan.

Data and tools to support the Plan include historical measurements, anecdotal evidence, hydrologic models, and analytical computations. The release of Interim Flows allows the SJRRP to study groundwater and seepage effects and remove conveyance constraints prior to the release of full Restoration Flows. Implementation requires a number of site-specific tasks to determine monitoring locations, install monitoring systems, establish thresholds, and prescribe response actions for various levels of SJRRP-induced changes. Local landowners can provide information to improve the effectiveness of the program including continued input through the Seepage and Conveyance Technical Feedback Group meetings. The main body of the Plan describes the components and interactions of operations to reduce or avoid seepage impacts. The following appendixes contain supporting technical information:

A. Seepage Effects
B. Areas Potentially Vulnerable to Seepage Effects
C. Historic Groundwater Levels and Surface-Water Flow
D. Sediment Texture and Other Data
E. Operations
F. Monitoring Well Network Plan and Other Seepage-Related Monitoring
G. Development of Soil Salinity Thresholds
H. Development of Groundwater-Level Thresholds
I. Landowner Claims Process
J. Modeling
K. References Cited

This Plan is part of the project description for the SJRRP and the expected environmental impacts of implementing the Plan must comply with NEPA and CEQA criteria.

2. Purpose and Objectives

The Plan will convey Interim and Restoration Flows while reducing or avoiding SJRRP-induced seepage impacts along the San Joaquin River and the Eastside and Mariposa Bypasses from Friant Dam to the Merced Confluence. This Plan addresses several components of the San Joaquin River Restoration Settlement Act, H.R. 146, which requires the Secretary of the Interior to:

(1) prepare an analysis that includes channel conveyance capacities and the potential for levee or groundwater seepage;

(2) describe a seepage monitoring program; and

(3) evaluate possible impacts associated with the release of Interim Flows.

3. Seepage Effects

This plan identifies and evaluates a physical impact by describing the measurable impact mechanisms, processes, and thresholds where actual or pending seepage could cause damage. Impact mechanisms under the Plan include:

1. **Waterlogging of crops –** inundation of the root zone resulting in mortality or reduced crop yields.
2. **Root-zone salinization –** salinity increases resulting in mortality or reduced crop yields.
3. **Levee instability –** boils or piping (seeps) that may compromise the short- or long-term integrity of the levee.

4. Locations of Known Risks

This plan represents potential risks by sites and areas of likely or known vulnerability to seepage effects on the basis of (1) mapped depth to the water table using measured water levels; (2) problematic areas identified by landowners; (3) analysis of flow, precipitation, and water-level data; and (4) simulation results using a regional hydrologic model, particularly in areas where water-level data are sparse. Appendix B: Areas Potentially Vulnerable to Seepage Effects includes documentation of these data and analyses.

The analysis of potential risks documents local knowledge, assists in siting monitoring stations, and scopes additional studies. Data and analyses that support baseline seepage conditions are included in Appendixes B: Areas Potentially Vulnerable to Seepage Effects and Appendix C: Historic Groundwater Levels and Surface-Water Flow.

5. Monitoring Program

Reclamation monitors the effects of SJRRP activities which informs identification of when, where, what, and how potential response actions may be implemented. Thresholds, discussed in Section 6, indicate potential for seepage effects and inform response actions and/or additional data collection needs. The monitoring program informs modeling and analysis to evaluate strategies for implementing response actions. See Appendix F: Monitoring Well Network Plan and Other Seepage-Related Monitoring for details on the existing Monitoring Plan and future directions.

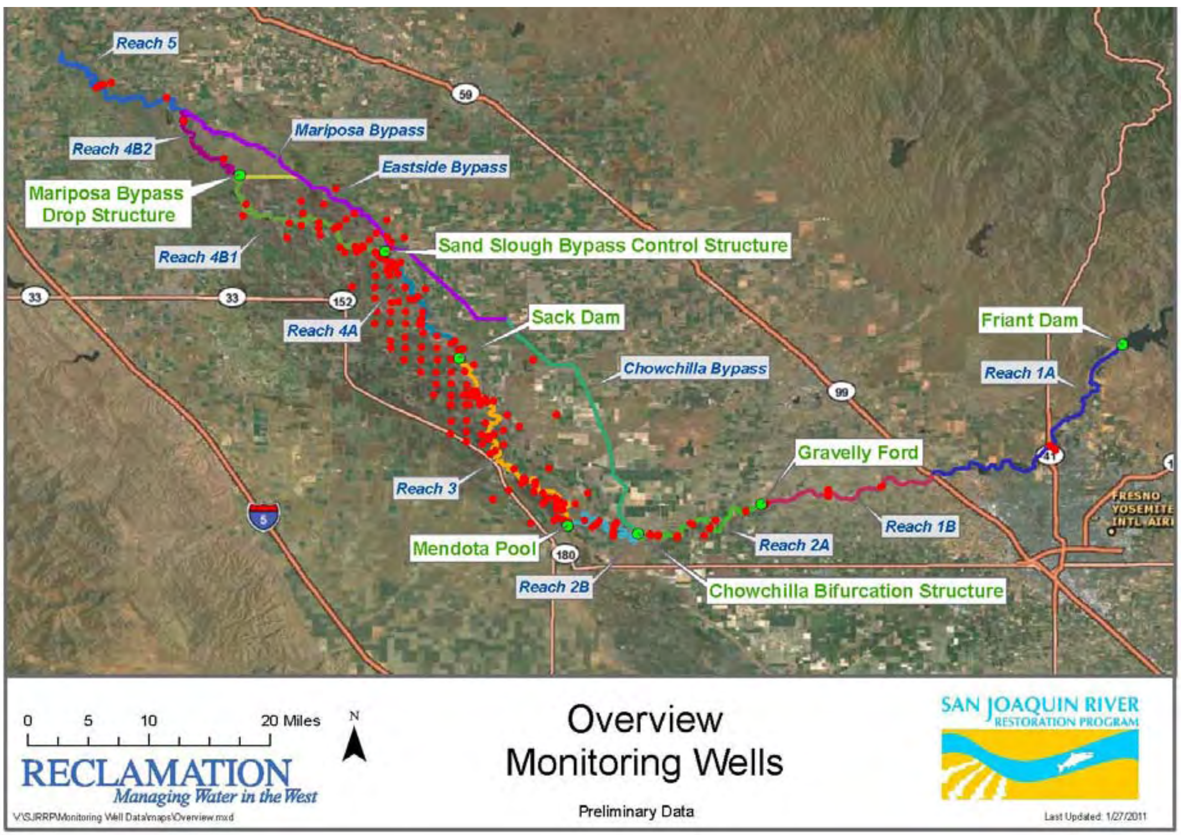

Figure 2. Cover of SJRRP Monitoring Well Atlas showing SJRRP monitoring well network including stakeholder wells

Areas underlain by a shallow water table, herein referred to as shallow groundwater areas, are of particular interest in the monitoring program. The SJRRP currently takes measurements in 111 monitoring wells as of February 21, 2011. The monitoring program includes:

1. Well transects spaced at roughly every 8–10 miles with 4–6 shallow monitoring wells (indicative of the water table aquifer), a staff gage measuring river stage, and 1–2 deeper monitoring wells (potentially indicative of the underlying semiconfined or confined aquifer) at each transect;
2. Additional shallow wells located in known shallow groundwater areas that may be affected by seepage, in collaboration with local landowners and the Central California Irrigation District (CCID);
3. Soil sampling and soil salinity surveys using electromagnetic (EM) methodology, in collaboration with local landowners;
4. Reporting from local landowners on visual crop health, levee seeps, and other observations through phone and email with established SJRRP-designated points of contact.

Information from monitoring, analysis, and local landowners will be used to determine well locations, subject to potential access limitations. New information may indicate that wells should be added, decommissioned, excluded from particular cross-sections or otherwise modified in the future. The Monitoring Well Atlas, available on the SJRRP website, contains details of the monitoring well network and will be updated periodically as additional information is gained and wells are installed or modified.

6. Thresholds

Thresholds identify transition points where seepage effects cross into a range that may cause damages. Thresholds also collect information before an impact occurs and provide time to initiate a response. Thresholds may take the following forms:

1. **Water surface elevation –** measured elevation of the water surface in a well relative to a vertical datum.
2. **Depth to water –** measured vertical distance to the water surface in a well relative to the land surface.
3. **Root-zone salinity –** measured (using direct or indirect methods) salinity in the plow or root zone and/or distribution of salinity in soil profiles.

A groundwater levels shallower than a threshold indicates the potential for impacts in the absence of actions to avoid, minimize, rectify, reduce, or compensate for seepage impacts. Site-specific customization of specific thresholds will continue to be enhanced by coordination with local landowners and may depend upon characteristics such as:

1. Local geology;
2. Presence, design considerations, and state/condition of the levee system;
3. Historical experience and areas of known historical seepage problems;
4. Structures and operations;
5. Soil salinity profile;
6. Crop type; or
7. Intent of threshold.

Draft thresholds associated with the water table and monitoring thresholds for soil salinity in farmed shallow groundwater areas are shown in Table 1. The salinity thresholds apply only where current conditions are more favorable than the threshold values. If current conditions exceed threshold values, thresholds will be a specified change from current conditions.

Table 1. Draft thresholds for groundwater and soil salinity underlying agricultural lands

Impact indicator	Threshold	Basis
Plow layer soil salinity (0-12 inches below land surface)	ECe[1] = 2.0 deciSiemens/m (ds/m) (See Appendix G)	Salinity affects germination or emergence of vegetable and other crops
Active root zone soil salinity (0-30 inches below land surface)	River-reach-specific; e.g., ECe[1] = 1.5 ds/m for reach 2B (See Appendix G)	Known salt tolerance for crops
Minimum depth to water table	Variable, depending on crop type, historical water levels, and local conditions (see Appendix H)	Waterlogging affects crop yields and increases soil salinity

[1] ECe is electrical conductivity of soil-water extract (saturation extract)

The SJRRP has identified specific groundwater thresholds for each well and priority wells for measuring groundwater thresholds in areas of known risk. There are three methods for determining the groundwater threshold. These include:

- Agricultural Practices
- Historical Groundwater
- Drainage

The thresholds are generalized, and adjustments may be required to account for on-site and/or seasonal conditions. Crop health can be affected by conditions unrelated to SJRRP activities, including various climatic conditions and other factors such as plant diseases. The procedures used for establishing thresholds are described in Appendix G: Development of Soil-Salinity Thresholds and Appendix H: Development of Groundwater-Level Thresholds.

7. Operations Plan

The approach to operations is a conservative, iterative one. The SJRRP will estimate a release from Friant Dam and Mendota Dam that avoids seepage impacts. The release will estimate non-damaging flows by establishing groundwater thresholds, as described in Section 6 and Appendix H, and linking thresholds to river stage through a conceptual model. The conceptual model initially assumes one foot of increase in river stage causes one foot of increase in groundwater. If the monitoring program identifies areas where the conceptual model predicts overly conservative flow limits, the SJRRP may update flow releases based on site specific information. When the SJRRP cannot estimate a higher release that will not exceed a threshold, the stage or flow rate in the river becomes an operational criterion. An operational criterion is a specific measurable or observable criterion (such as a river stage) that indicates impending impacts, is established based on site-specific analysis, and will limit flow releases.

Prior to an increase in the targeted Friant Dam release, the SJRRP conducts a Flow Bench Evaluation. The purpose of the Flow Bench Evaluation is to avoid seepage impacts through checking factors and reducing or eliminating the proposed increase accordingly. Flow Bench Evaluations verify:

1) Conveyance Capacity:

   Avoid levee instability by limiting flows to the rated conveyance capacity of the channel.

2) Flow Stability:

   Account for travel time and potential changes that may not have materialized since the prior change in releases by allowing flows to stabilize before the next change in releases.

3) Groundwater Projections:

   Avoid seepage impacts by predicting groundwater level rise from the proposed increase assuming a one foot increase in river stage equates to a one foot increase in groundwater level. If groundwater levels are predicted to rise above thresholds, this triggers a site visit as described in Section 8, prior to the change in flow.

4) Groundwater Telemetry:

   Avoid seepage impacts by monitoring real-time groundwater wells and conducting a site visit if levels are near thresholds.

5) Groundwater Manual Measurements:

   Avoid seepage impacts by measuring groundwater wells weekly and conducting a site visit if levels are near thresholds.

6) Mendota Pool Operations:

   Avoid infeasible operations through the Mendota Pool operations calls including exchangeable demand, water quality, and Central Valley Project South of the Delta operations.

7) Landowner Feedback (Seepage Hotline):

   Avoid potential seepage impacts by gathering data from Seepage Hotline calls and subsequent site visits.

8) Operations Feedback:

   Avoid infeasible operations and levee instability through coordination with the Central California Irrigation District, San Luis Canal Company, and Lower San Joaquin Levee District on potential concerns with the proposed flow increase.

In addition to Flow Bench Evaluations, the SJRRP conducts Daily Flow Evaluations when flows are above 475 cfs. Daily Flow Evaluations include documentation of the checks on conveyance capacity, Mendota Pool operations, and landowner feedback as described above. Daily Flow Evaluations also trigger site visits if real-time or measured groundwater levels are near thresholds.

Flow Bench Evaluations and Daily Flow Evaluations help the SJRRP avoid seepage impacts and document decisions to increase flows. These evaluations also trigger site visits and response actions based on SJRRP's monitoring network.

See Appendix E: Operations for example forms.

8. Triggers

Triggers describe when the SJRRP will take action through site visits and flow management. There are three different types of triggers. Two of these are SJRRP actions, and the last one allows landowners observations to trigger SJRRP action. These triggers include:

1. Flow Bench Evaluations: A site visit and response action is triggered when groundwater levels are predicted to rise above thresholds
2. Daily Flow Evaluations: A site visit and response action is triggered when measured groundwater levels are near thresholds
3. Seepage Hotline Call: A site visit and response action is triggered when landowners observe seepage-related issues

Following a trigger, the SJRRP will initiate a site visit. The SJRRP may re-evaluate the estimated flow rate and/or the threshold as a result of information collected at a site visit.

9. Site Visits and Response Actions

Site visits, triggered by flow bench evaluations, daily flow evaluations, or seepage hotline calls, collect a variety of information to inform management response decisions. Site visits provide an initial assessment to determine the type of impact, description of the seepage, the relationship to interim flows, the immediacy of the response, a recommended real-time response action, and any needed follow-up regarding projects. Site visits may include monitoring and conversation with the landowner to gather the following types of data:

1. Landowner Input on Seepage Effects
2. River Stage
3. Soil Texture
4. Hand Auger Groundwater Levels (allows rapid response rather than waiting for backhoe or well installation)
5. Drive Point Installation
6. Soil Salinity
7. Infrastructure

8. Crop Health
9. Photos

The operations for releasing Interim and Restoration Flows are designed to safely convey flows without triggering the need for response actions. If site visits are triggered, response actions will be evaluated and implemented as soon as practicable to avoid or reduce seepage impacts. Flood operations supersede SJRRP releases and may occur irrespective of groundwater monitoring. Potential response actions include:

1. **Planned releases can occur** – no seepage impacts are anticipated at the site based on the planned release schedule. Anticipated releases can occur.
2. **Increased monitoring** – no seepage impacts are anticipated at the site for the near-term anticipated releases, however, an increased monitoring frequency will gather additional information to assist in evaluating the potential seepage impacts of future releases.
3. **Adjustment to local flow rate** – the conceptual model linking thresholds to river stage may be adjusted at this site based on information gathered at the site visit. This may or may not create a new restriction on maximum release.
4. **Adjustment to threshold** – information gathered at the site visits regarding crops, historical groundwater, or drainage will adjust the threshold at the site. This adjustment will be done in collaboration with the landowner.
5. **Flow Response Actions** – an immediate or future change in flows is needed to prevent material adverse seepage impacts. Potential flow response actions include:
    a. **Restrictions on maximum release** – flow rates in each reach will be established below documented historical rates known to cause seepage impacts, to be accomplished through a combination of releases from Friant Dam, infiltration, and agreements with diverters.
    b. **Restrictions on ramping rates and duration** – limits on the incremental increases in flow rates provide the ability to evaluate the system response through the monitoring program while limiting the volume of upstream water if an impending impact is observed, measured, or predicted through simulation.
    c. **Reduction of Restoration Flow releases at Friant Dam** – reductions in Restoration Flows released from Friant Dam will limit the amount of water available to cause seepage impacts. Reductions at Friant Dam will need to consider travel time and the associated delay in response.
    d. **Redirection of flows at Chowchilla Bifurcation Structure** – directing flow into the bypass system at the Chowchilla Bifurcation Structure will provide a faster response for downstream reaches compared to Friant Dam operational changes. This response requires coordination with the Lower San Joaquin River Levee District for such operations.
    e. **Delivery of flows to Exchange Contractors and Refuges at Mendota Pool** – delivery of water to Mendota Pool will reduce flows in Reach 3 and downstream. Use of diversion into Mendota Pool to reduce downstream flows will require

coordination with the Central California Irrigation District and the San Luis Delta-Mendota Water Authority.

f. **Delivery of flows to Exchange Contractors and refuges at Sack Dam –** at times when the San Luis Canal Company has canal conveyance capacity, additional water diversions at Sack Dam can assist with reducing potential seepage impacts in Reach 4A and downstream. Use of the Sack Dam response will require coordination with the San Luis Canal Company.

g. **Redirection of flows at Sand Slough Control Structure –** during Interim Flows water will not be directed into Reach 4B. In subsequent years, water causing concerns in Reach 4B may be diverted into the Eastside Bypass. Use of the Eastside Bypass will require coordination with the Lower San Joaquin River Levee District.

10. Projects

Potential future actions may be needed if meeting Settlement goals through specified Restoration Flows is sufficiently compromised by seepage-related constraints. Such actions may include real estate actions or structural additions. These actions likely would require landowner agreements and initiation of project-specific environmental documentation to comply with NEPA, CEQA, and other regulatory requirements. Potential future actions may include:

1. Easements and/or compensation for seepage effects;
2. Acquisition of lands;
3. Slurry walls between the river/bypass and seepage-impacted lands to reduce water-table response to increased surface-water stage;
4. Seepage berms to protect against levee failure;
5. Drainage interceptor ditches to lower the water table;
6. Tile drains to lower the water table;
7. Operate new drainage and/or existing irrigation wells to lower the water table; and/or
8. Conveyance improvements such as sand removal.

The Plan will not result in planning, design, environmental compliance or construction of potential projects, but will assist in identifying such actions.

11. Revisions

Updates to the Plan may include changes derived from data obtained through the monitoring program, results from improved modeling and analysis tools, modified objectives or thresholds, and/or identification of additional concerns that arise through Plan implementation. The policy for revising the Plan includes:

1. Stakeholders may submit recommendations to the Program Manager at any time;
2. The Program Manager will acknowledge and respond to recommendations; and

3. A periodic review of the Plan through the Seepage and Conveyance Technical Feedback Group meetings may incorporate changes, including any new information such as the findings of a peer review panel.

The revision process sets the expectations for stakeholder and management participation. The SJRRP may not be able to commit to specific recommended actions, but all comments and recommendations will be considered.

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Appendix A. Seepage Effects of Concern

This appendix describes the undesired outcomes of higher groundwater levels and other seepage effects. The three main seepage effects are listed, and then additional information regarding the mechanisms that these seepage effects impact crop production is provided. Stakeholders gathered much of this and provided it to Reclamation as comments.

1 Seepage Effects

There are three main effects of seepage of concern. These are:

Waterlogging of crops - inundation of the root zone resulting in mortality or reduced crop yields.

Root-Zone Salinization - salinity increases resulting in mortality or reduced crop yields.

Levee Instability - boils or piping (seeps) that may compromise the short- or long-term integrity of the levee.

2 Mechanisms of Crop Impact

Crop growth and production depends on many variables. Crops are generally the most sensitive during early growth periods. This period is generally during the month of May.

Table A- 1. Critical growth stages for major crops[1]

Crop	Critical period	Symptoms of water stress	Other considerations
Alfalfa	Early spring and immediately after cuttings	Darkening color, then wilting	Normally 3-4" of water is needed between cuttings
Corn	Tasseling, silk stage until grain is fully formed	Curling of leaves by mid-morning	Needs adequate water from germination to dent stage for maximum production
Sorghum	Boot, bloom and dough stages	Curling of leaves by mid-morning	Yields are reduced if water is short at bloom during seed development
Sugar beets	Post-thinning	Leaves wilting during heat of the day	Excessive full irrigation lowers sugar content
Beans	Bloom and fruit set	Wilting	Yields are reduced if water short at bloom or fruit set stages
Small grain	Boot and bloom stages	Dull green color, then firing of lower leaves	Last irrigation is at milk stage

Potatoes	Tuber formation to harvest	Wilting during heat of the day	Water stress during critical period may cause deformation of tubers
Onions	Bulb formation	Wilting	Keep soil moist during bulb formation, let soil dry near harvest
Tomatoes	After fruit set	Wilting	Wilt and leaf rolling can be caused by disease
Cool season grass	Early spring, early fall	Dull green color, then wilting	Critical period for seed production is boot to head formation
Fruit trees	Any point during growing season	Dulling of leaf color and drooping	Stone fruits are sensitive to water stress during last irrigation
[1]Taken from *National Engineering Handbook, Section 15: Irrigation*, Natural Resources Conservation Service.			

2.1 Soil Moisture

Mechanism: Roots cannot grow without soil moisture. Seepage increases soil moisture allowing plants to uptake water and nutrients. A fluctuating water table allows deep root growth and then saturates the root zone, causing anoxia.

2.2 Anoxia

Critical Time Period: Early spring (RMC comments)

Mechanism: Anoxia may kill the ends of new roots in 1 to 4 days of saturated soil conditions. Longer term saturation can lead to chlorosis (lack of photosynthesis), or wilting of leaves (Micke, 1996).

Considerations: Higher soil temperatures for almonds increase the risk of root damage from saturated soil conditions (Micke, 1996). Fine grained soils drain slowly and are higher risk for anoxia (Micke, 1996).

2.3 Soil Temperature

Critical Time Period: Early to Mid spring (RMC comments)

Mechanism: Inhibits root hair growth In later greenhouse experiments, it was reported that a drop in root temperatures from 77o to 59o F for a period of only five days had a depressing effect on yield of Caloro rice, particularly when the low temperature occurred during tillering and flowering. Studies of Red Kidney beans show reduced yield of root, shoot, and beans after soil temperatures were reduced to 50o F for 3 days. Multiple cold soil treatments reduced yields by 30%. Experiments in-field did not show reduced yields (Wierenga, 1966). Potatoes, lettuce, and strawberries may benefit from lower soil temperatures (Wierenga, 1966). Cotton seedlings exposed to soil temperatures below 50o F within 2 days of planting will fail to form roots or expire. The UC Cotton Production Manual recommends planting cotton between March 20 and April 15 (Hake, 1996). Cotton growth ceases when the average daily temperature falls below 60o

F (Hake, 1996). During the first 3 or 4 days of growth the developing cotton taproot is especially vulnerable to injury caused by cold soil or excess moisture (Rude, 1996).

Considerations: Soil temperature causes greater crop impacts in finer textured soils (RMC comments).

2.4 Nutrients

Mechanism: De-nitrifying conditions can cause loss of applied Nitrogen (RMC comments).

2.5 Fungi and Bacteria

Mechanism: Wet conditions foster fungi and bacterial growth, such as root rot (Phytophthora for cotton, Armillaria for almonds). Cotton seedling diseases are generally more severe under damp conditions. Also cool weather bringing damp conditions may delay cotton seedling growth, leaving seedlings in their most vulnerable state (Rude, 1996). Wet soil conditions exacerbate root rot and reduce the effectiveness of fungicide treatments (Flint, 2002).

2.6 Salinity

Critical Time Period: Early growth stages (RMC comments)

Mechanism: Both specific ion toxicity and osmotic effects are mechanisms for saline conditions to impact crop production, with specific ion toxicity a greater concern for tree crops. Specific ion toxicity is the mechanism by which excess sodium ions from the salts collect at the root surfaces and prevent or reduce potassium uptake. A sign of specific ion toxicity is necrosis (death, brown color) or chlorosis (lack of photosynthesis, white color) of the leaves. Saline conditions also reduce the osmotic pressure of the surrounding soil, making it more difficult for crops to uptake water and leading to water stress. (Micke, 1996; SCS NEH 15-1, 1991)

Considerations: Young plants are especially susceptible at the upper boundary of the capillary fringe. Almond rootstocks accumulate high levels of chloride and sodium (Micke, 1996). Leaching can remove salinity concerns.

Appendix B. Areas Potentially Vulnerable to Seepage Effects

This appendix describes the information and analyses used to develop an initial estimate of areas vulnerable to seepage effects associated with implementation of Interim and Restoration Flows. Data used in these analyses are documented in Appendix C. This document focuses on the 150-mile reach between Friant Dam and the confluence with the Merced River.

1. Historical depth to the water table

The history of hydrologic and associated water-table changes in and around the Restoration Area helps define areas potentially vulnerable to seepage effects. Agricultural development began in the late 1800s, but accelerated rapidly post-World War II (Bertoldi and others, 1991). Through the 1960s, most of the water used for irrigation in areas surrounding the exchange contractors was groundwater, and this was reflected in a long-term decline of water levels throughout most of the San Joaquin Valley (Belitz and Heimes, 1987).

Although water levels declined over much of the valley, some areas near the San Joaquin River, particularly on the west side, continued to be shallow groundwater areas (U.S. Bureau of Reclamation, 1962). Causes of this may include fine-grained soils in the shallow subsurface and the primary use of surface water for irrigation in these areas. Landowners in this area used riparian water from the San Joaquin River before Friant Dam was constructed. In exchange for the loss of this source of irrigation water, Reclamation delivered surface water from the Delta via the Delta-Mendota Canal to the San Joaquin River Water Authority Exchange Contractors, including CCID, SLCC and CCC starting in 1951. Agricultural tile drains were installed in the 1950s and 1960s to help manage many of these areas (Joseph McGahan, Summers Engineering, written commun., 2002; Stuart Styles, Irrigation Training and Research Center, written commun., 2002)).

Figure B- 1 is a preliminary map of depth to the water table below land surface in 1965, a normal precipitation year preceded by several normal years, showing large areas with depth to water within 10 feet of land surface despite overall declining water levels. Note that this map and similar subsequent maps indicate the locations of wells used to interpolate the contours of depth to water (shown as depth-to-water intervals); those areas without wells are poorly understood, and interpolated values in these areas should not be used to draw conclusions without additional information. Methods used to develop these maps are described in Appendix C.

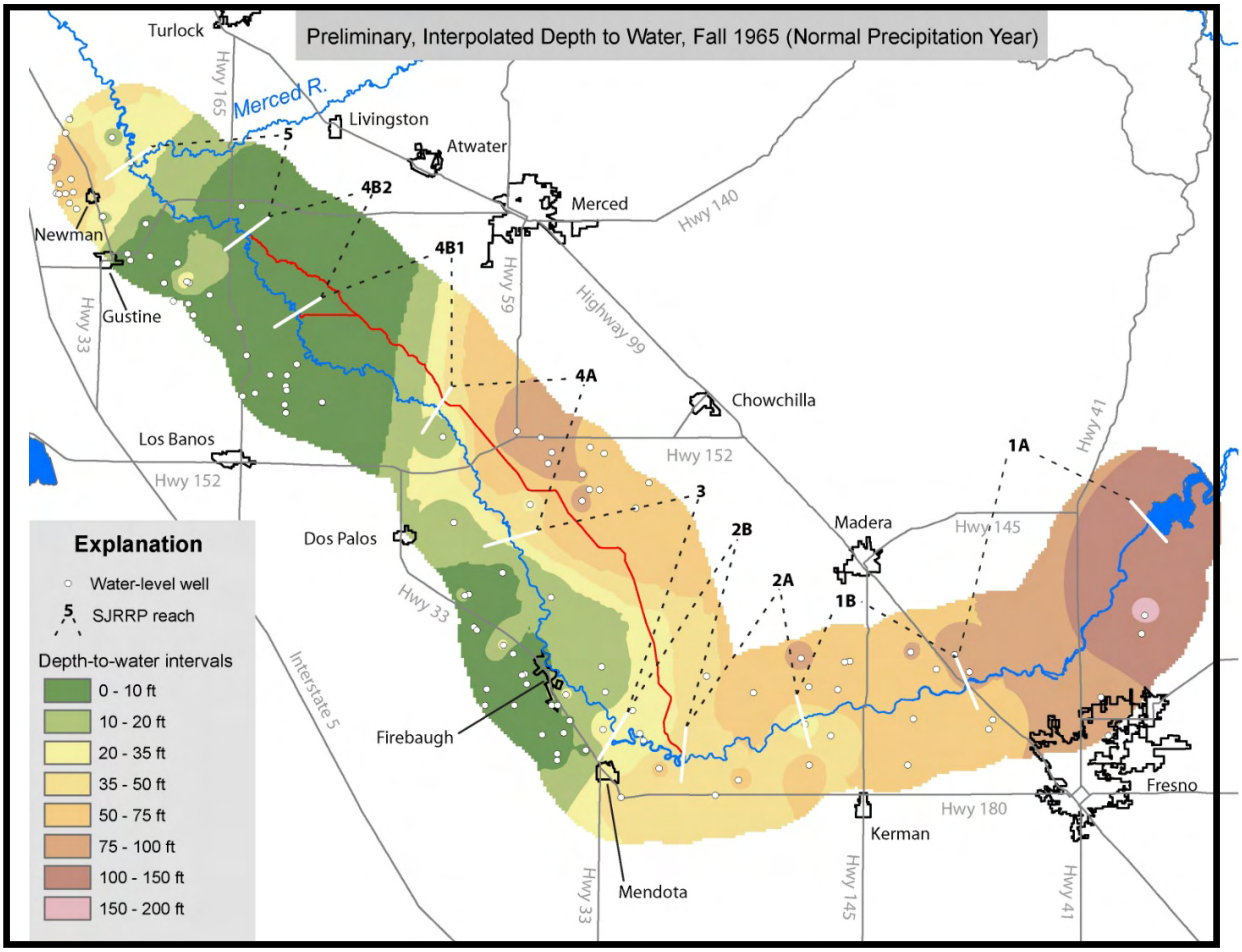


Figure B- 1. Fall 1965 Depth to Water

Substantial deliveries of surface water to the west side of the San Joaquin Valley began during the early 1970s with the completion of the California Aqueduct. Accompanied by a large decrease in groundwater pumping, this caused a dramatic recovery of water levels over much of the west side of the valley (Belitz and Heimes, 1991). Water levels on the east side, however, continued to decline, and by 1981 were much lower than in 1965 (Figure B- 2). 1981 was a normal precipitation year preceded by two normal years. Notably, the shallow groundwater areas in 1965 generally remain in 1981, but it appears that the eastern margin of these areas has moved westward in response to continued groundwater pumping and associated declining water levels in the eastern part of the study area towards Chowchilla and Madera.

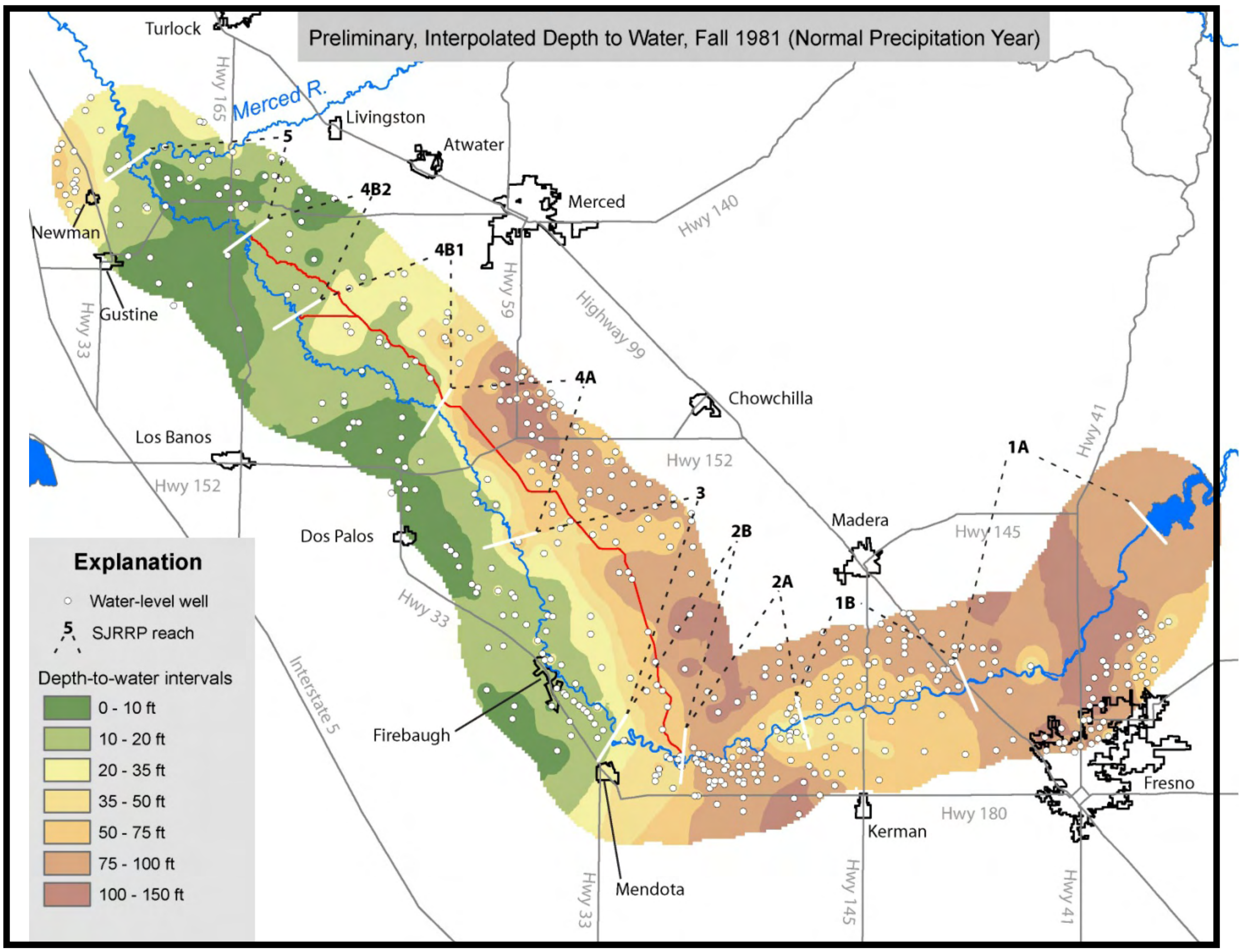


Figure B- 2. Fall 1981 Depth to Water

Following 1981, two years of above-normal precipitation caused substantial increases in the water table over most of the study area. Figure B- 3 shows depth to water in 1983, which indicates recovery of water levels along the eastern margin of the study area towards Chowchilla and Madera, and considerable growth in the shallow groundwater areas along the west side. Insufficient data prohibit a comprehensive mapping of these areas near the river on the east side, but there are indications that this growth did occur.

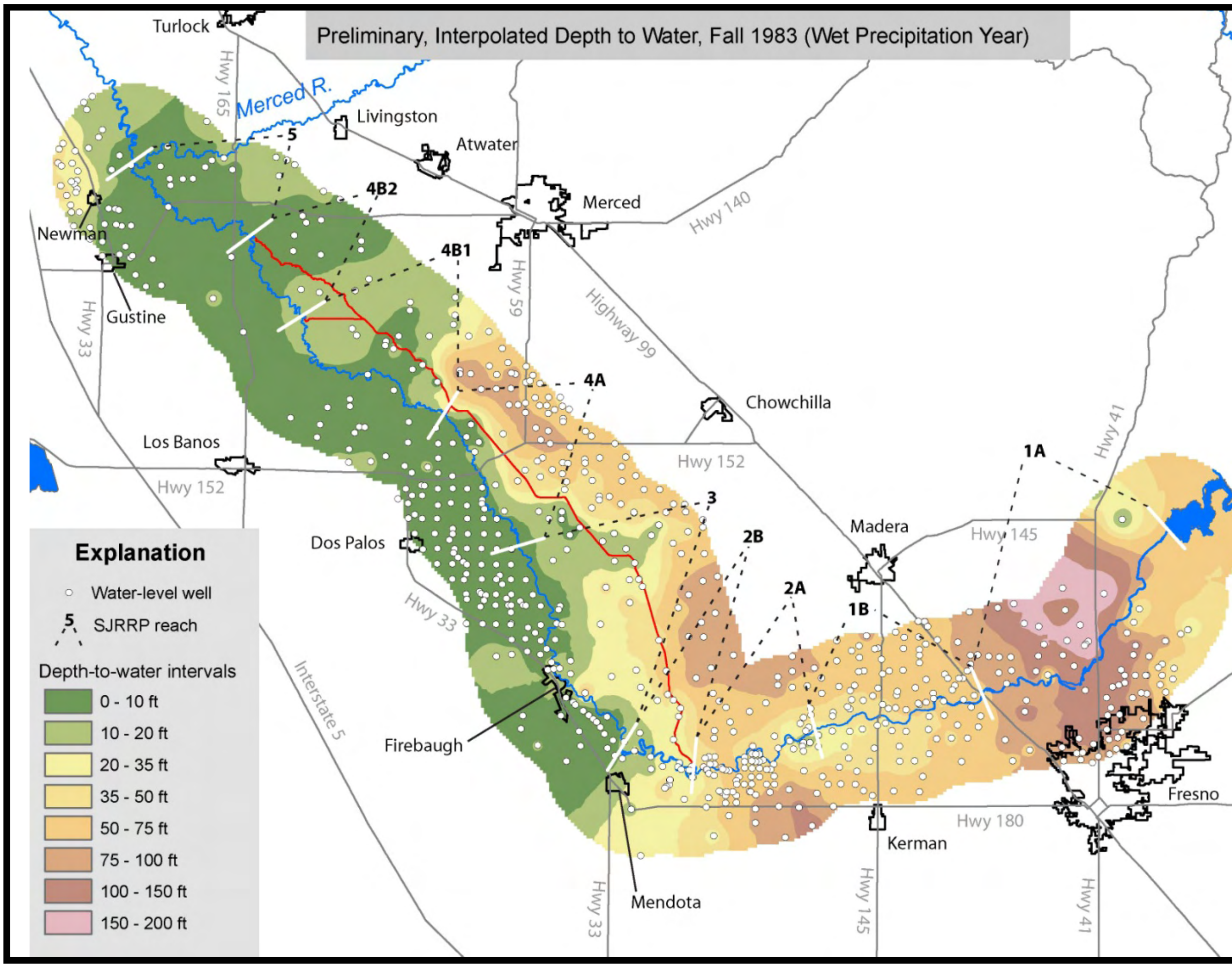


Figure B- 3. Fall 1983 Depth to Water

Several years of normal to dry-normal precipitation followed 1983. By 1988 (dry-normal), water levels along the eastern margin of the study area had declined, and the area of shallow groundwater had retreated westward somewhat; however, the shallow groundwater area was widespread on the west side (Figure B- 4).

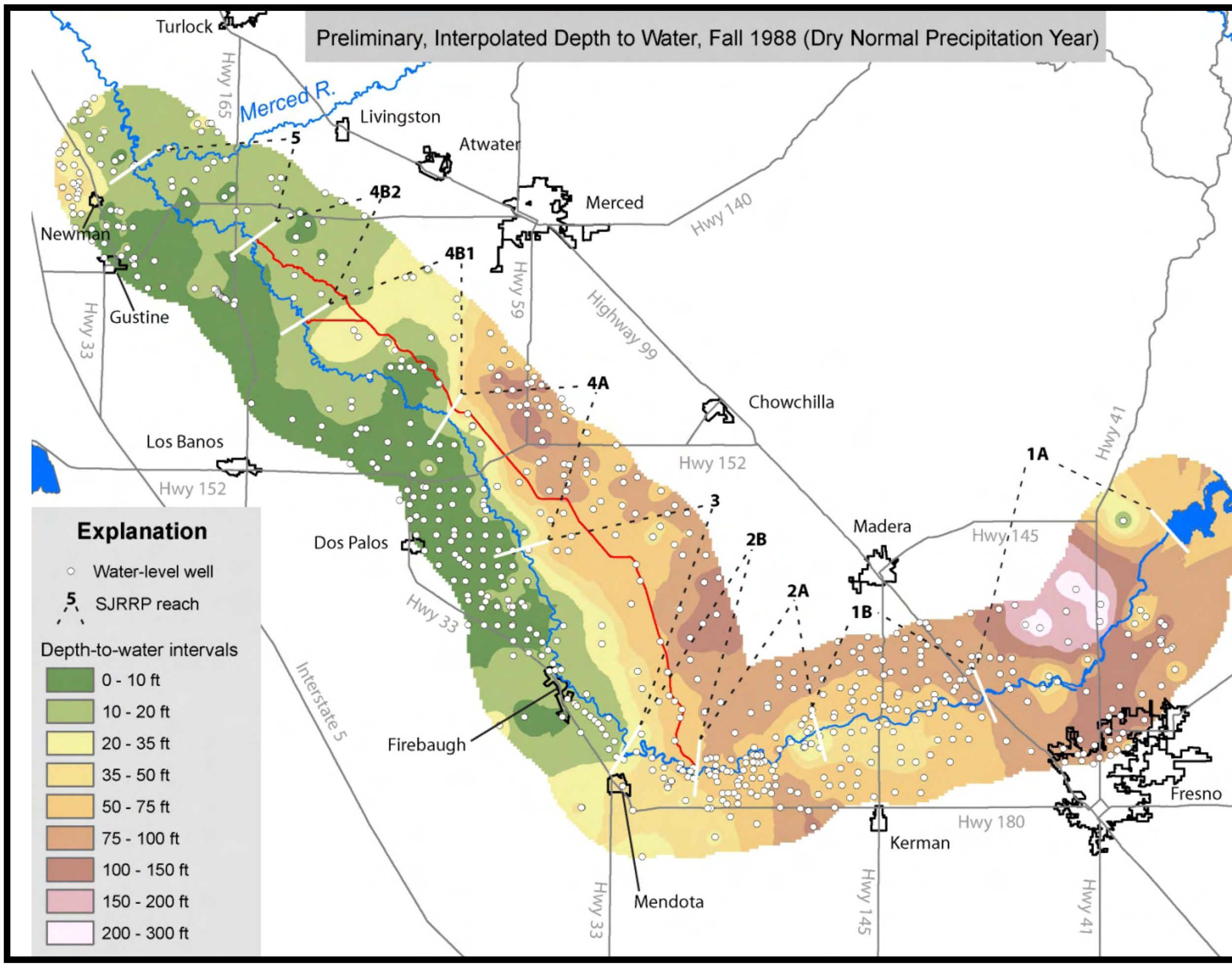


Figure B- 4. Fall 1988 Depth to Water

Data from 1991, the fifth year of a six-year drought, show a marked change in water levels in response to the combination of greatly reduced availability of surface water, greatly increased groundwater pumping, and reduced recharge from precipitation. Figure B- 5 shows that by 1991, water levels had declined greatly along the eastern margin of the study area, and the areas of shallow groundwater had retreated considerably. Although data are sparse in 1991, it is clear that some areas where water levels were persistently shallow during the 1960s were not a drainage concern during the latter part of the 1987–92 drought.

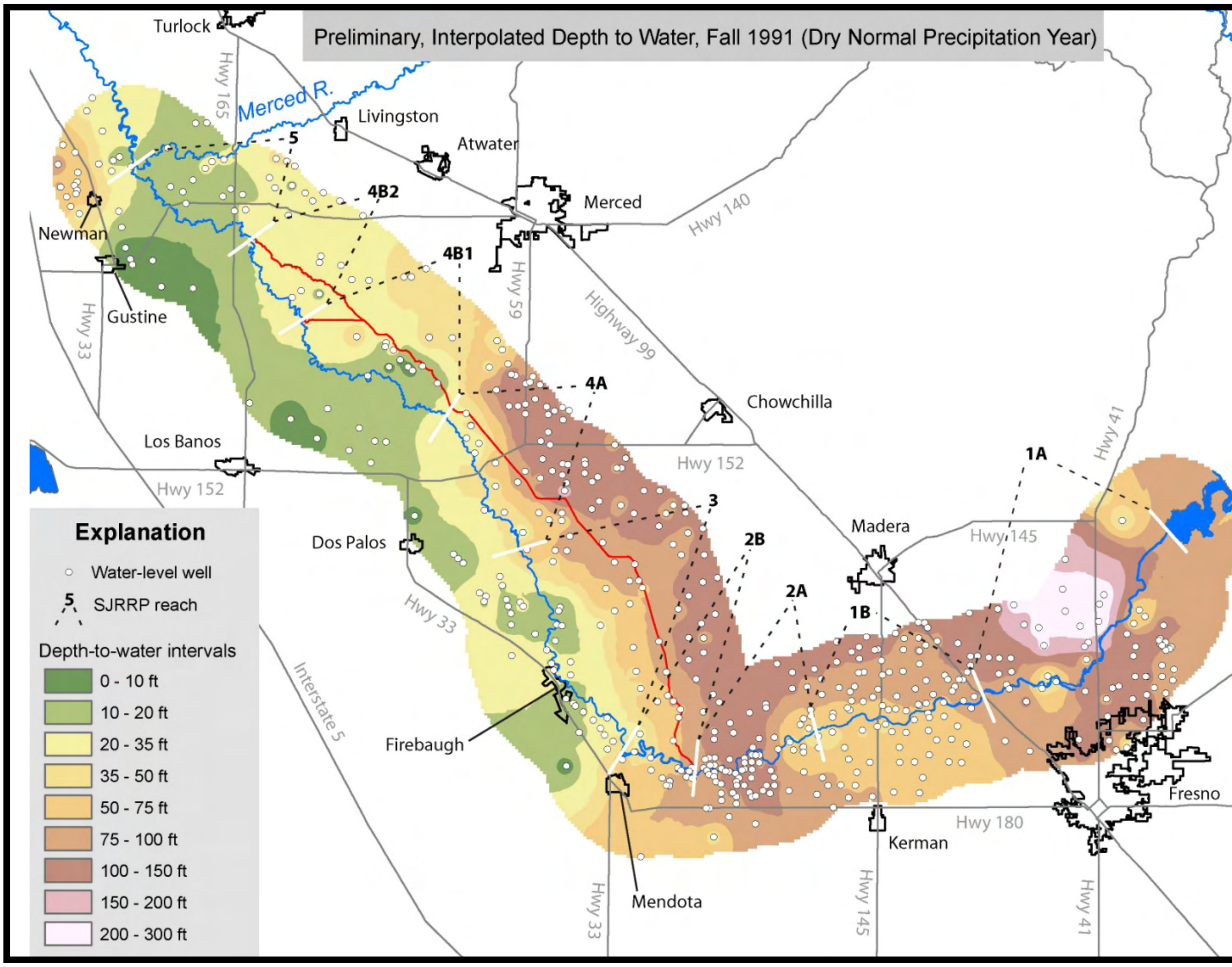


Figure B- 5. Fall 1991 Depth to Water

By 1999, a year of dry-normal precipitation preceded by several years of variable precipitation, the aquifer system had largely recovered from the earlier drought as evidenced by the return of substantial shallow groundwater areas on the west side despite persistently low water levels along the eastern margin (Figure B- 6).

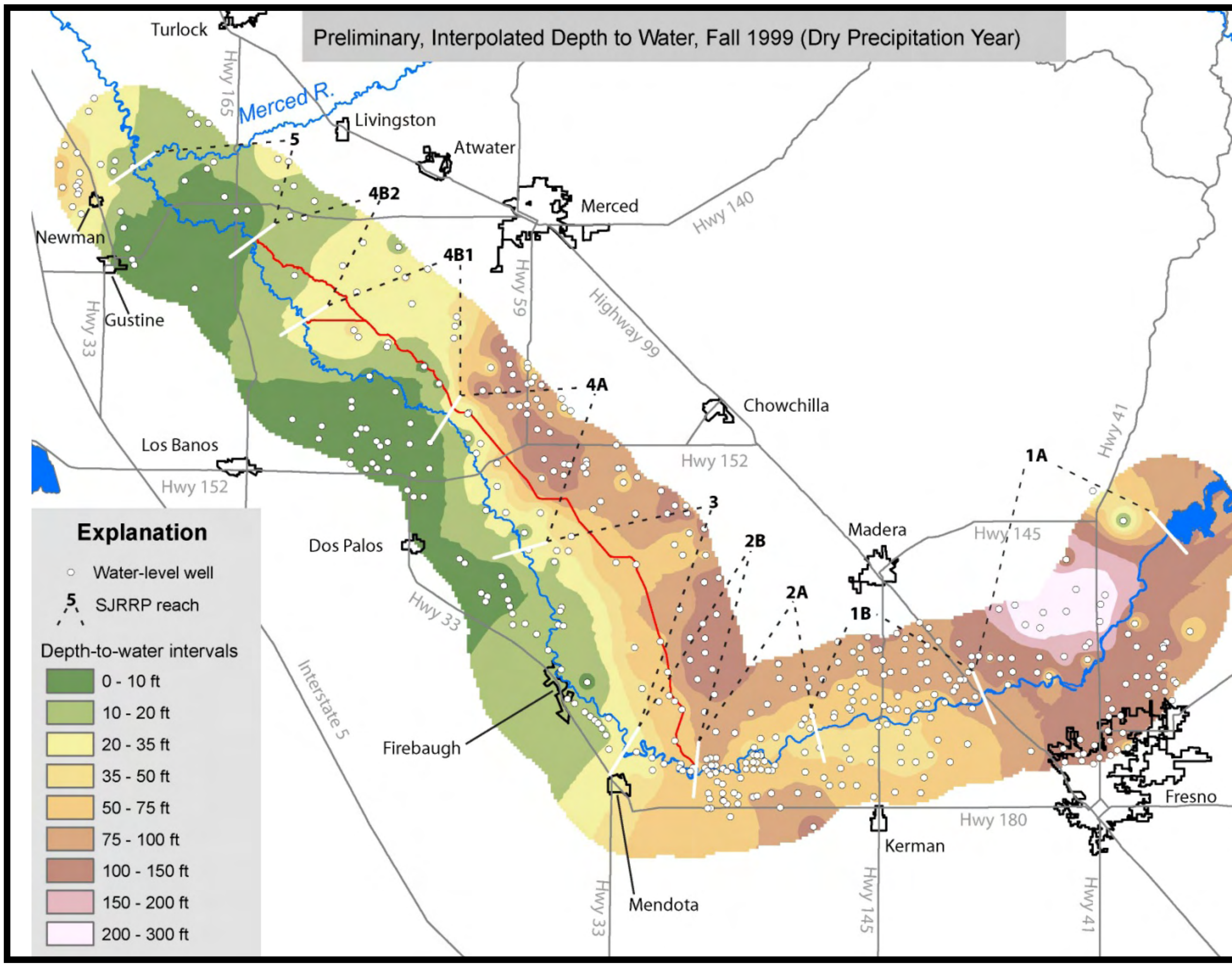


Figure B- 6. Fall 1999 Depth to Water

Figure B- 7 shows depth to the water table in 2006, a normal precipitation year preceded by several normal years. Although water levels along the eastern margin had remained low, the shallow groundwater areas west of the river were fully re-established.

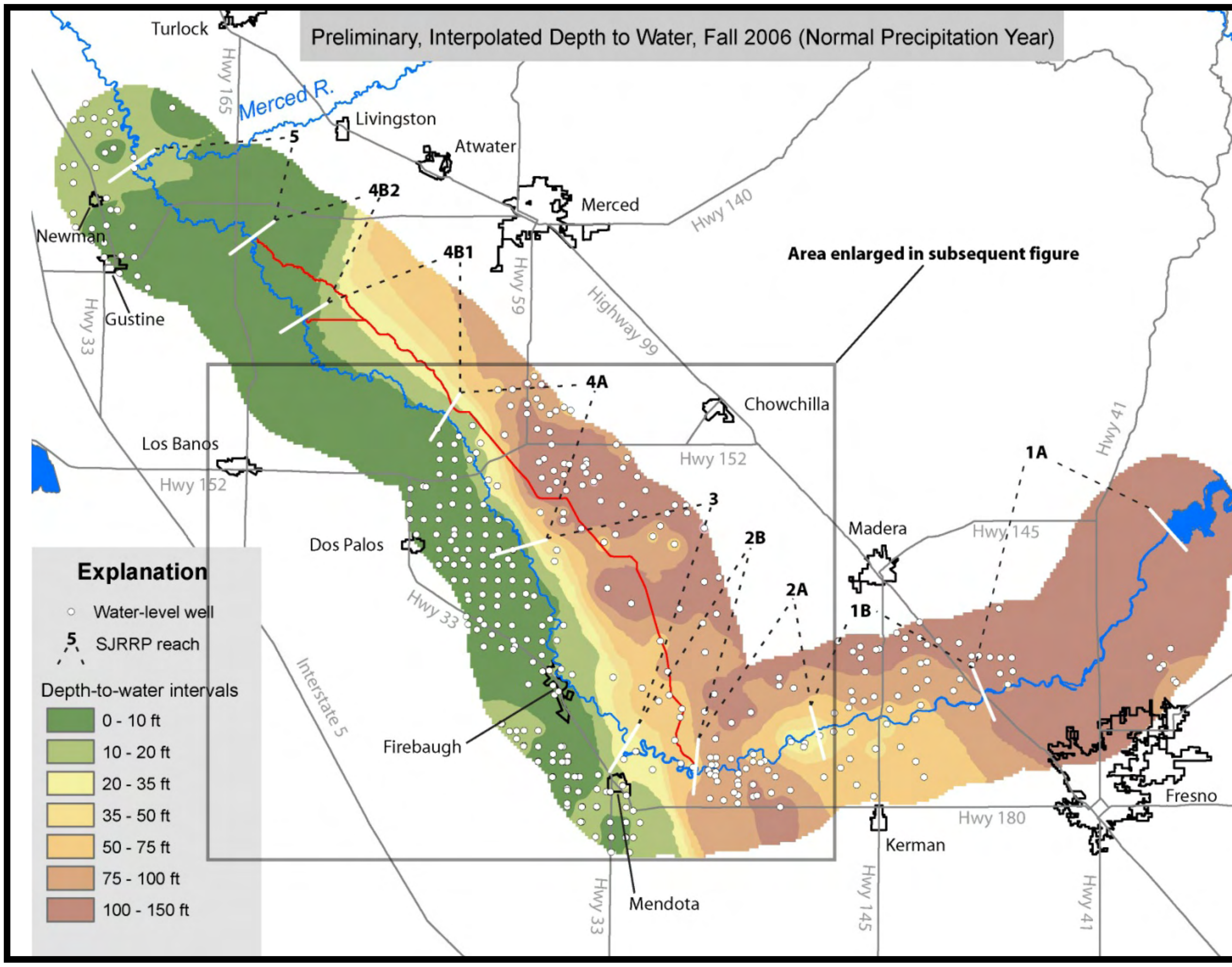


Figure B- 7. Fall 2006 Depth to Water

This brief historical review shows that there are shallow groundwater areas, particularly west of the San Joaquin River, that have persisted through time with the sole exception of during the latter part of the 1987–92 drought. It is possible that extensive shallow groundwater areas exist east of the river as well, but more data are needed to comprehensively map depth to the water table on the east side. Persistent shallow groundwater areas that are shown to be within the hydraulic influence of the San Joaquin River potentially are vulnerable to seepage effects from Interim and Restoration Flows.

The historic response of shallow groundwater areas to drought and other dry climatic conditions indicates that the shallow water table is sensitive to groundwater pumping on both sides of the river, which is consistent with previous findings (Phillips and others, 1991; Belitz and others, 1993; Belitz and Phillips, 1994; K.D. Schmidt & Associates, reported in the McBain and Trush, Inc. Background Report, 2002, p. 4–26). This has implications for year-to-year operations of the SJRRP, and for enhanced groundwater pumping as a potential future response action.

2. Anecdotal information from landowners and other stakeholders

Stakeholders have identified some of the farmland that is currently vulnerable to seepage effects. These effects range from water-table rise that is currently manageable through the use of drainage wells, tile drains or other means, to seepage-related inundation causing crop damage or loss. Identification of these areas is important for the monitoring program because they are known to be highly sensitive to river stage and associated seepage effects, and therefore may be good locations for monitoring wells and associated monitoring thresholds used to avoid or minimize seepage impacts.

Meetings with landowners resulted in identification of areas vulnerable to seepage. The vast majority of the landowner-identified farmlands currently vulnerable to seepage effects are in two physical settings expected to be sensitive to high-stage events. The first setting is the interior of a river meander, or bend, where the land is surrounded on three sides by the river. The second is lands situated between two waterways, including the river, bypasses, and unlined canals.

In addition to vulnerable locations identified by landowners, the San Joaquin River Resources Management Coalition (RMC) mailed surveys to their members and provided the SJRRP with parcels that could be of concern regarding seepage impacts. The parcels identified by the RMC are generally large areas of land, some of them a mile or more from the San Joaquin River or bypass system.

Finally, at Seepage and Conveyance Technical Feedback Group meetings in December 2010 and February 2011, irrigation district and canal companies identified some areas potentially vulnerable to seepage impacts as well as datagaps of concern in the existing monitoring well network. Some of these areas overlap with previously identified vulnerabilities, and some are broad areas identified as datagaps in the monitoring well network (for example, the large area in Reach 4B1).

Figure B- 8 through Figure B- 13 show stakeholder-identified locations of concern.

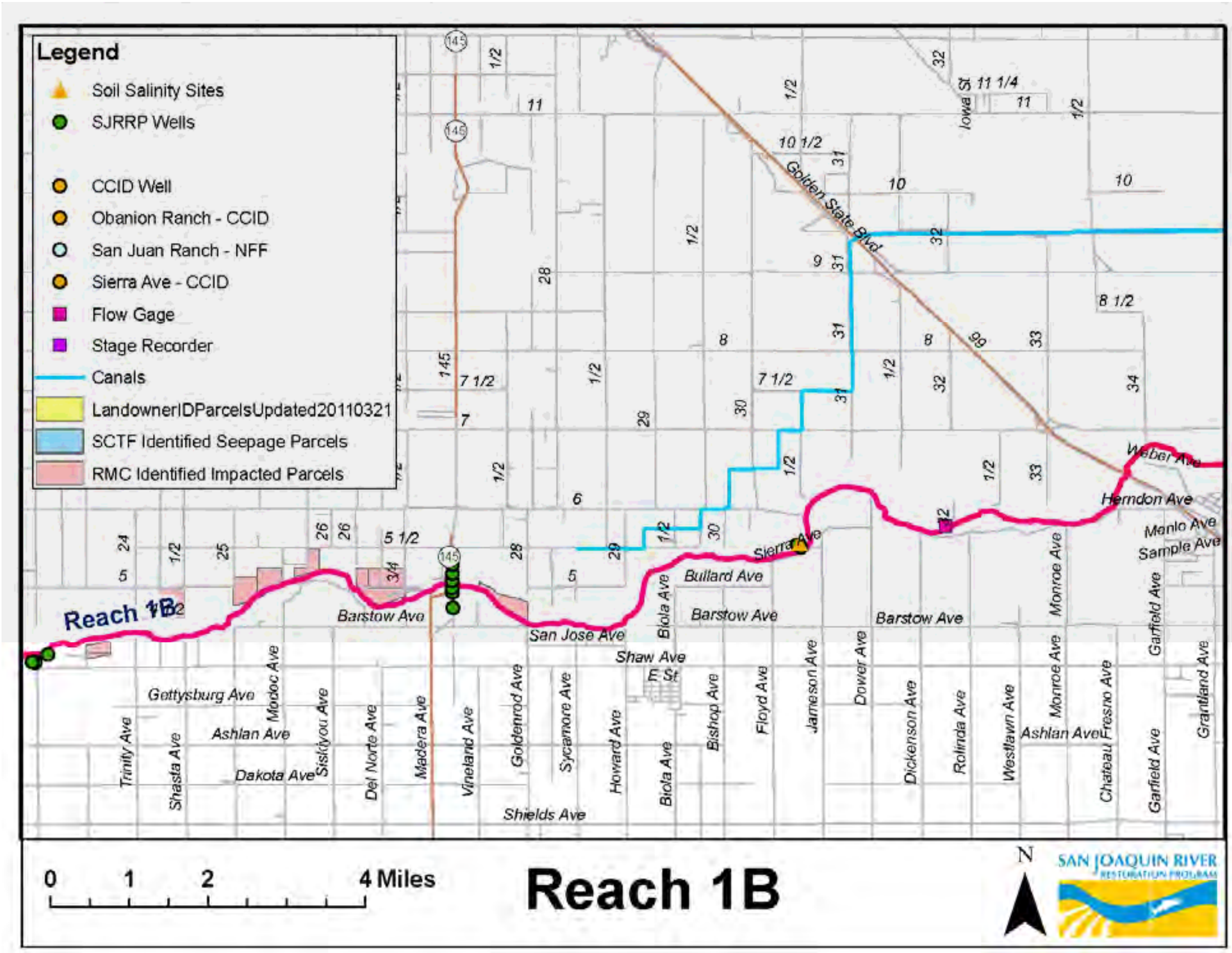


Figure B- 8. Reach 1B Locations of Identified Risk

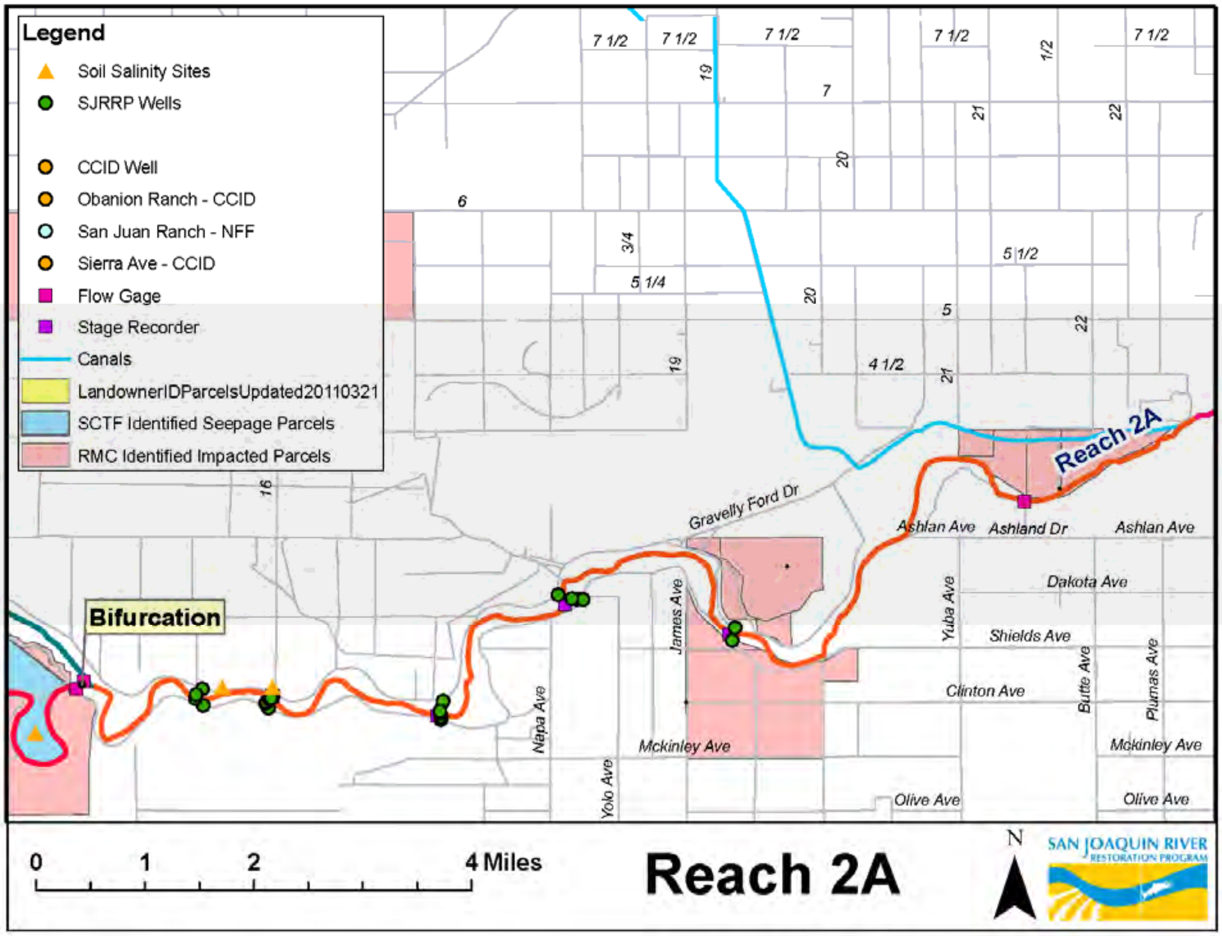


Figure B- 9. Reach 2A Locations of Identified Risk

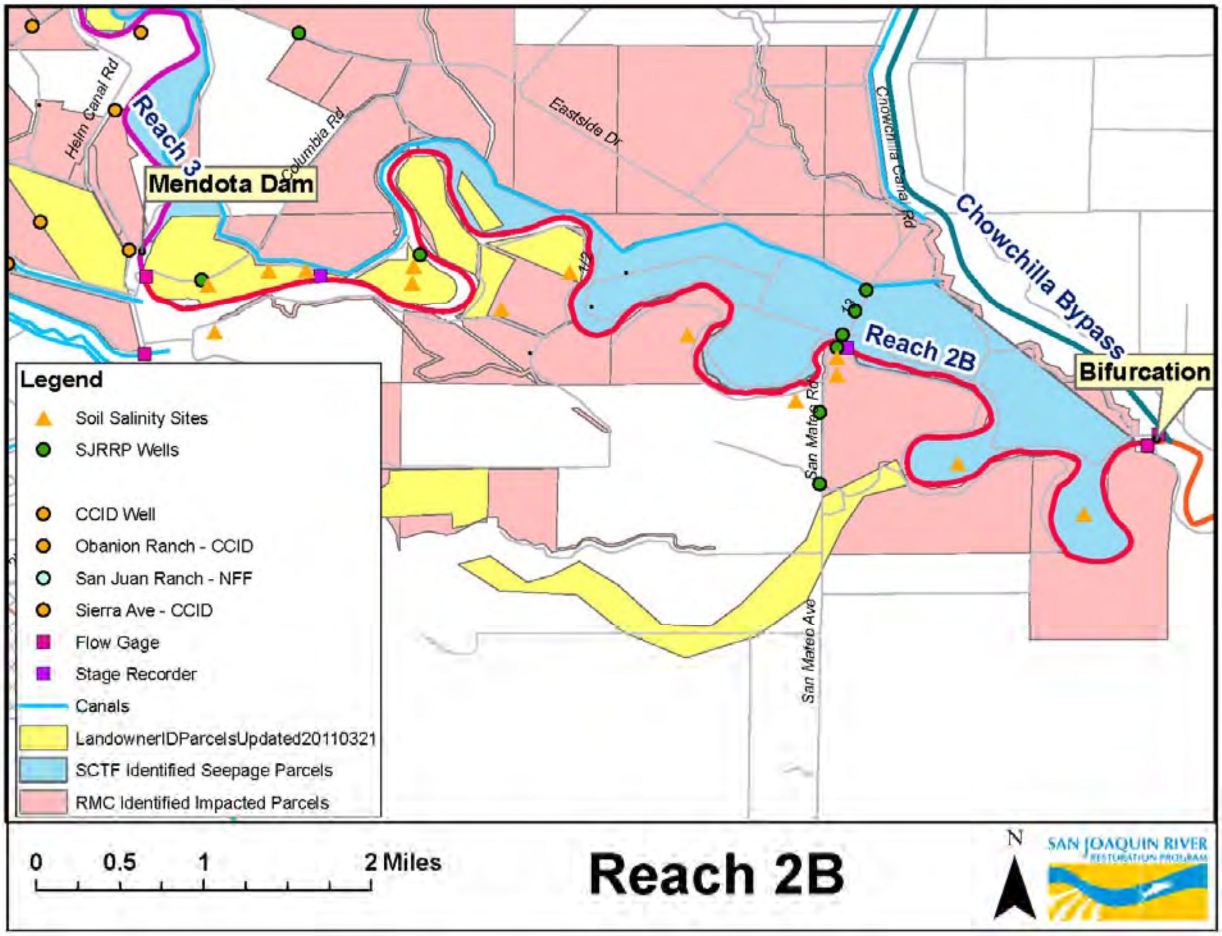


Figure B- 10. Reach 2B Locations of Identified Risk

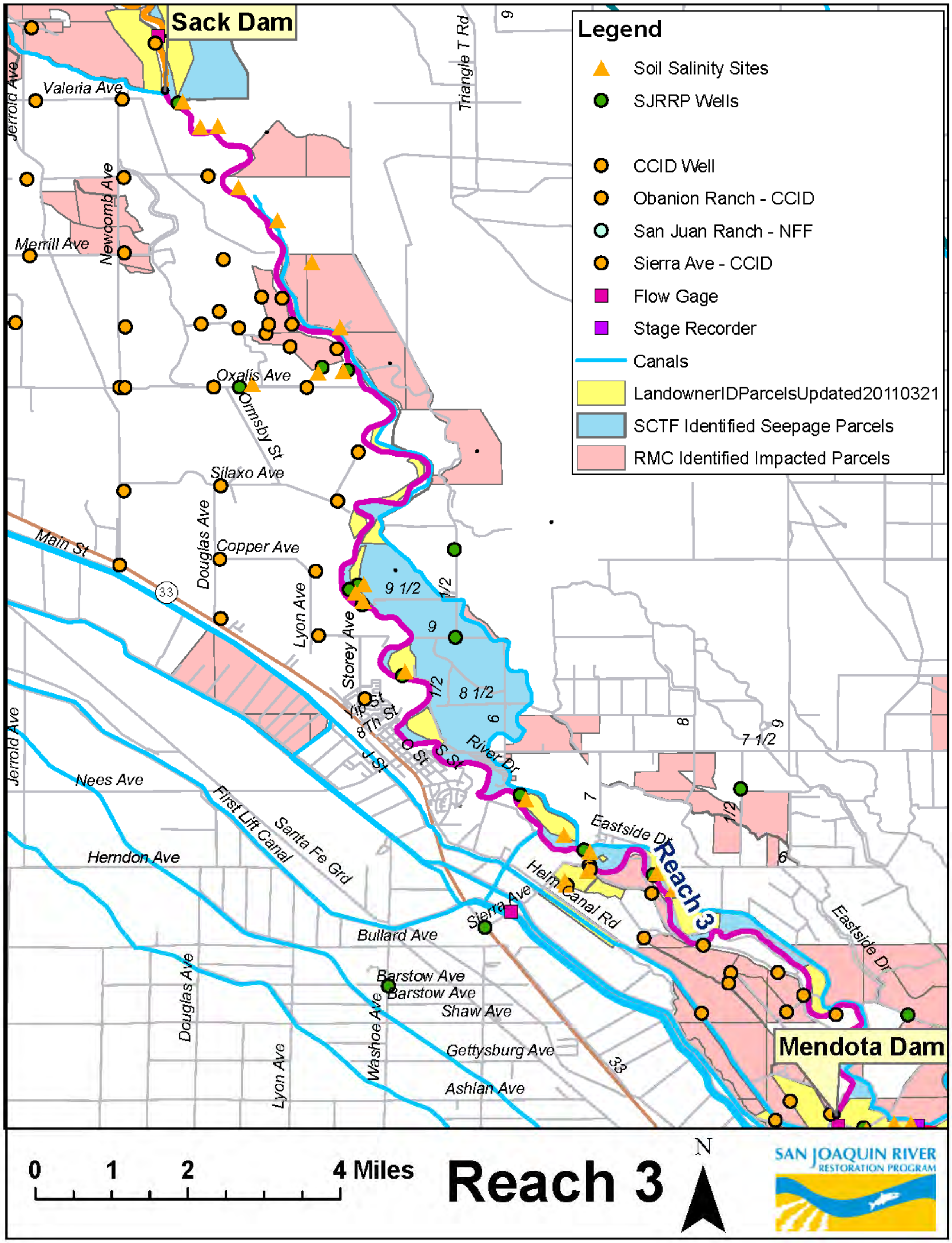


Figure B- 11. Reach 3 Locations of Identified Risk

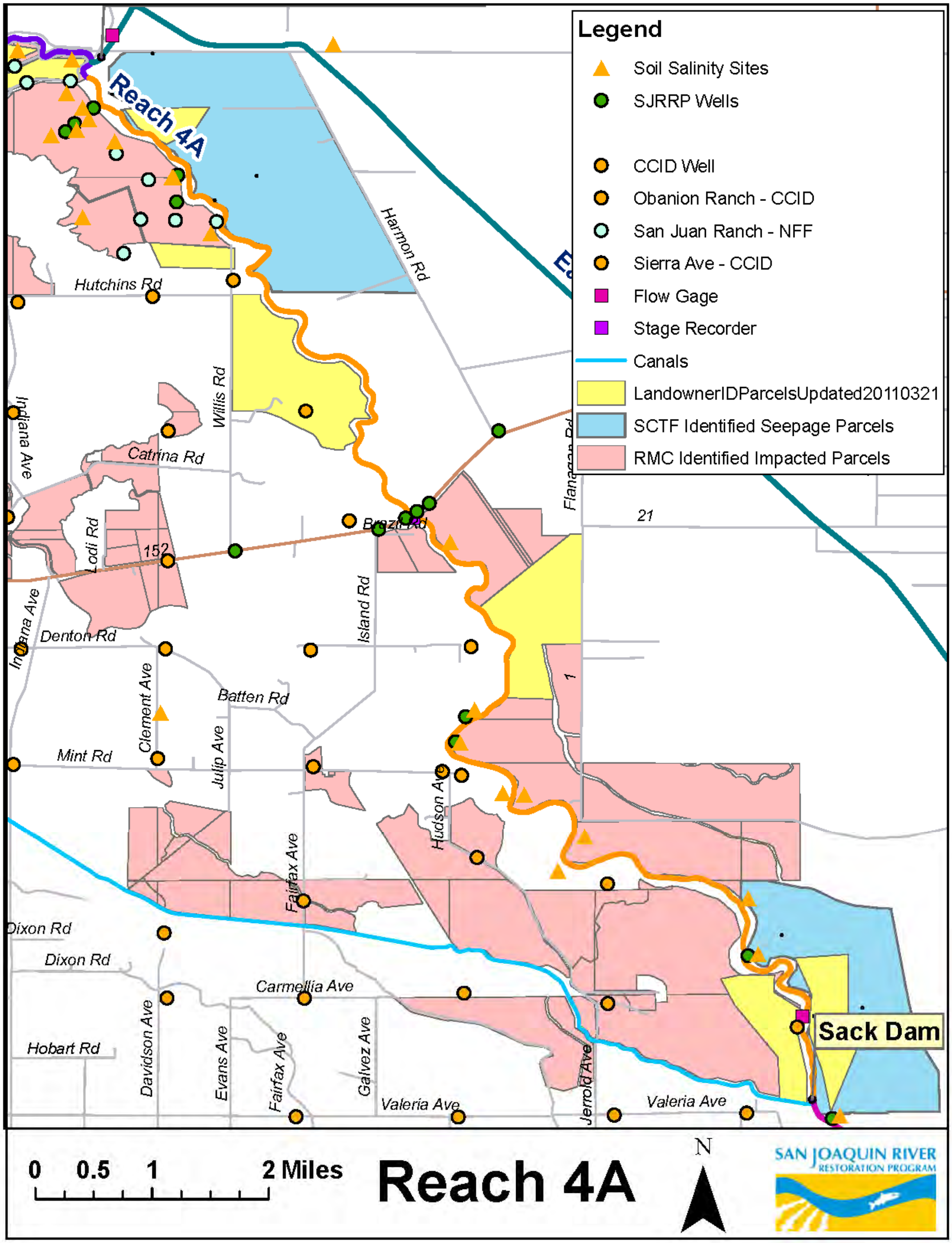


Figure B- 12. Reach 4A Locations of Identified Risk

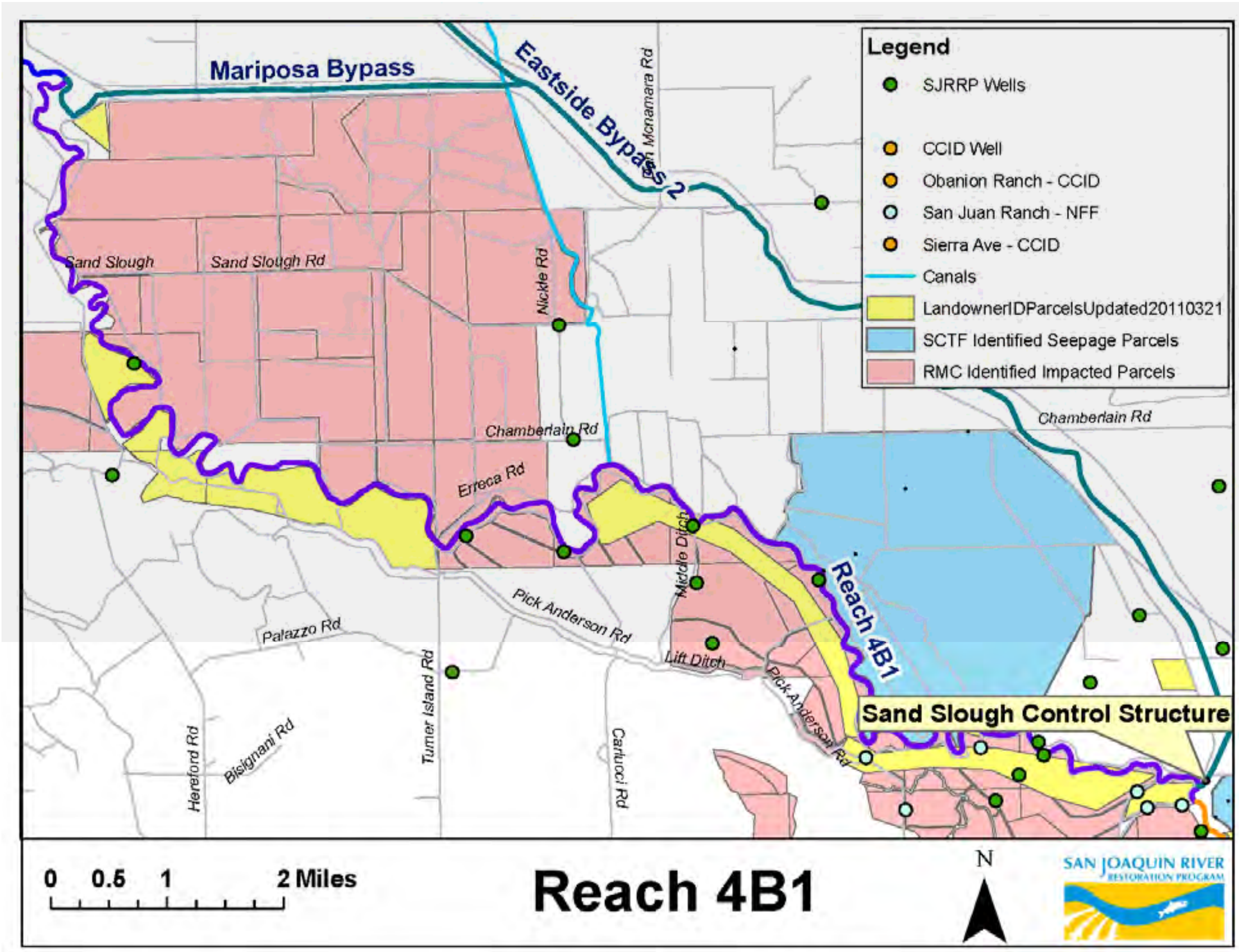


Figure B- 13. Reach 4B1 Locations of Identified Risk

3. Elevation

This section includes analysis to screen for potential locations of seepage risk based on land elevation and predicted water surface up to 4500 cubic feet per second (cfs), to allow full Restoration Flows. Seepage management includes real-time management of flows to reduce or avoid material adverse seepage impacts, as well as implementation of projects to increase capacity outside of site-specific projects, as part of Paragraph 12 in the Stipulation of Settlement (Settlement) in *NRDC et al., v. Rodgers, et al.* Locations will require a more detailed analysis to determine if seepage concerns exist and an evaluation to identify the type, advantages, and limitations of a potential project. This section screens out locations that do not require more detailed site evaluations for installation of seepage projects.

San Joaquin River water surface elevations taken from the HEC-RAS hydraulic model as well as surveys were compared with terrain. The analysis extended water surface elevations beneath the adjacent fields to obtain predicted depths below ground surface, as shown in Figure B- 14.

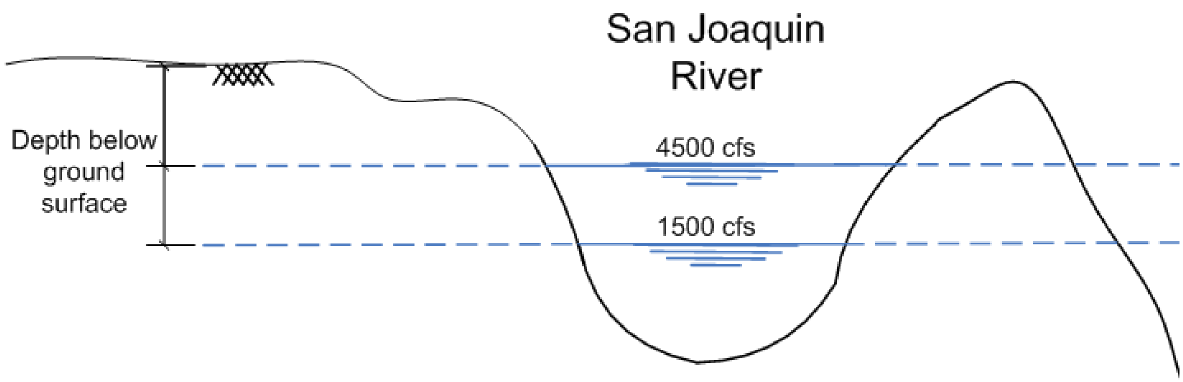


Figure B- 14. Seepage Project Elevation Analysis Conceptual Model

The one-dimensional hydraulic model predicts water surface elevations at cross-sections. Analysis included local flows of 1500 and 4500 cfs. Reclamation subtracted the water surface elevations from the 2008 LiDAR. Subtracted values give the shallowest depth below ground surface, and do not consider groundwater gradient.

A second analysis used surveyed water surface elevations from surveys. See Table B- 1 below for a description of the surveys and hydraulic modeling runs used to conduct this elevation analysis.

Table B- 1. Results by Reach

Reach	Type	Date	Local Flow (cfs)
1B	HEC-RAS Results		1500
1B	HEC-RAS Results		4500
2A	HEC-RAS Results		1500
2A	HEC-RAS Results		4500
3	HEC-RAS Results		1500
3	DWR Survey	January 5 – 11, 2011	1880
3	HEC-RAS Results		4500
4A	HEC-RAS Results		1500
4A	HEC-RAS Results		4500

Maps shown below in Figure B- 15 through Figure B- 25 include colored areas based on the groundwater depth below ground surface assuming no gradient to the groundwater table. The results assume the water surface elevation in the river matches the groundwater elevation. Areas colored blue indicate that the water surface elevation in the river is above the ground surface. If there was a flat groundwater gradient, there would be surface ponding at that flow. Areas in red indicate that the water surface elevation in the river and assumed groundwater level is between 0 and 3 feet below the ground surface. Both blue and red areas indicate a high potential for seepage risks.

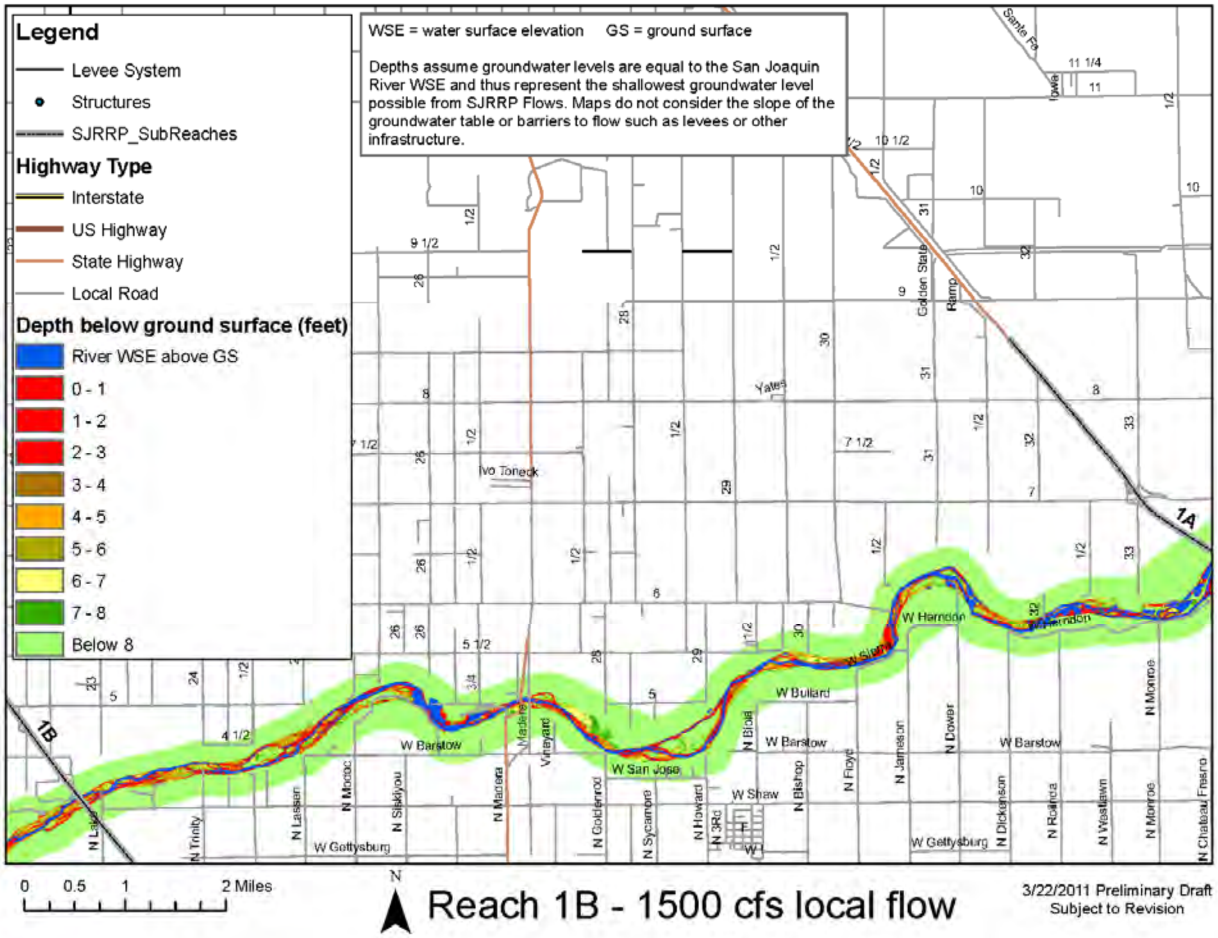


Figure B- 15. Reach 1B 1500 cfs

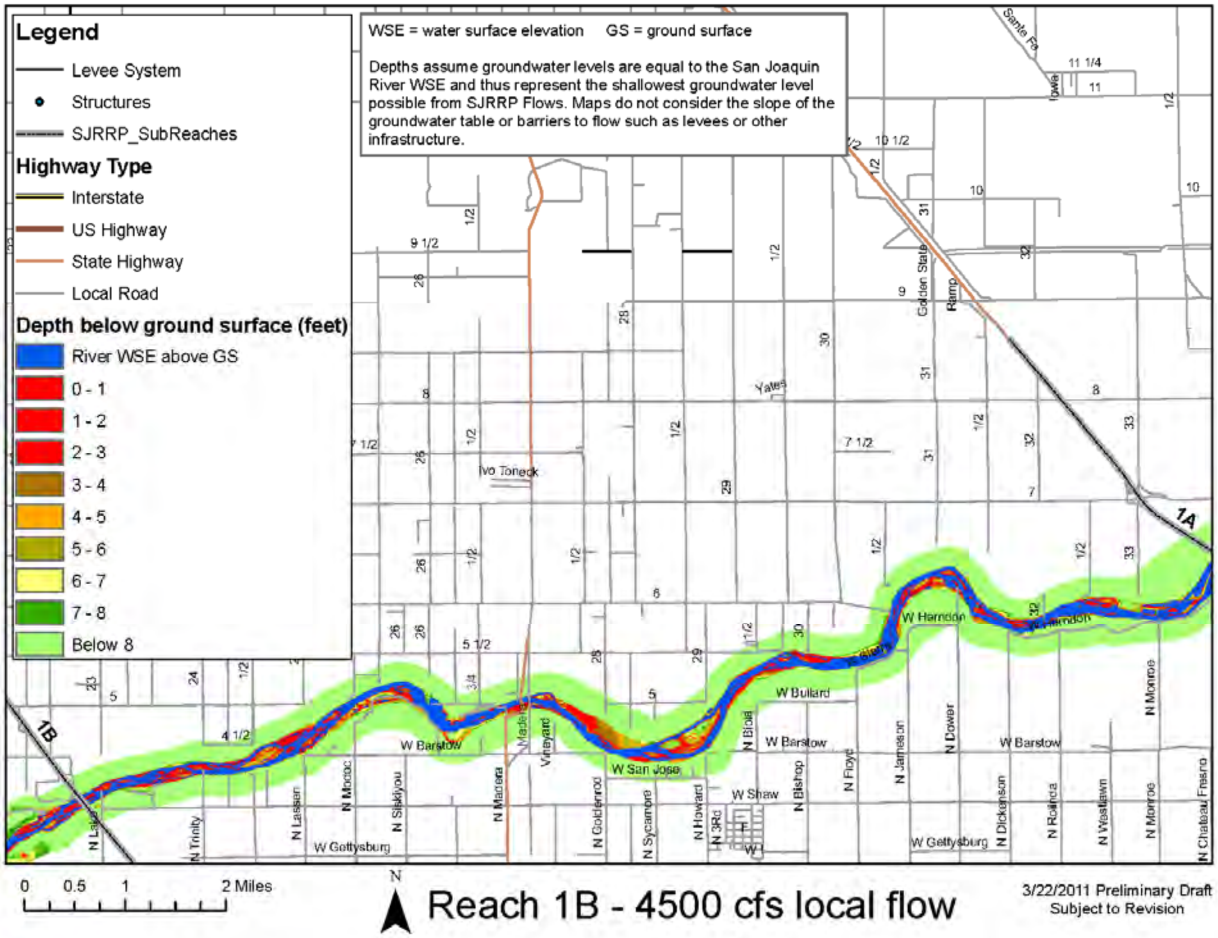


Figure B- 16. Reach 1B 4500 cfs

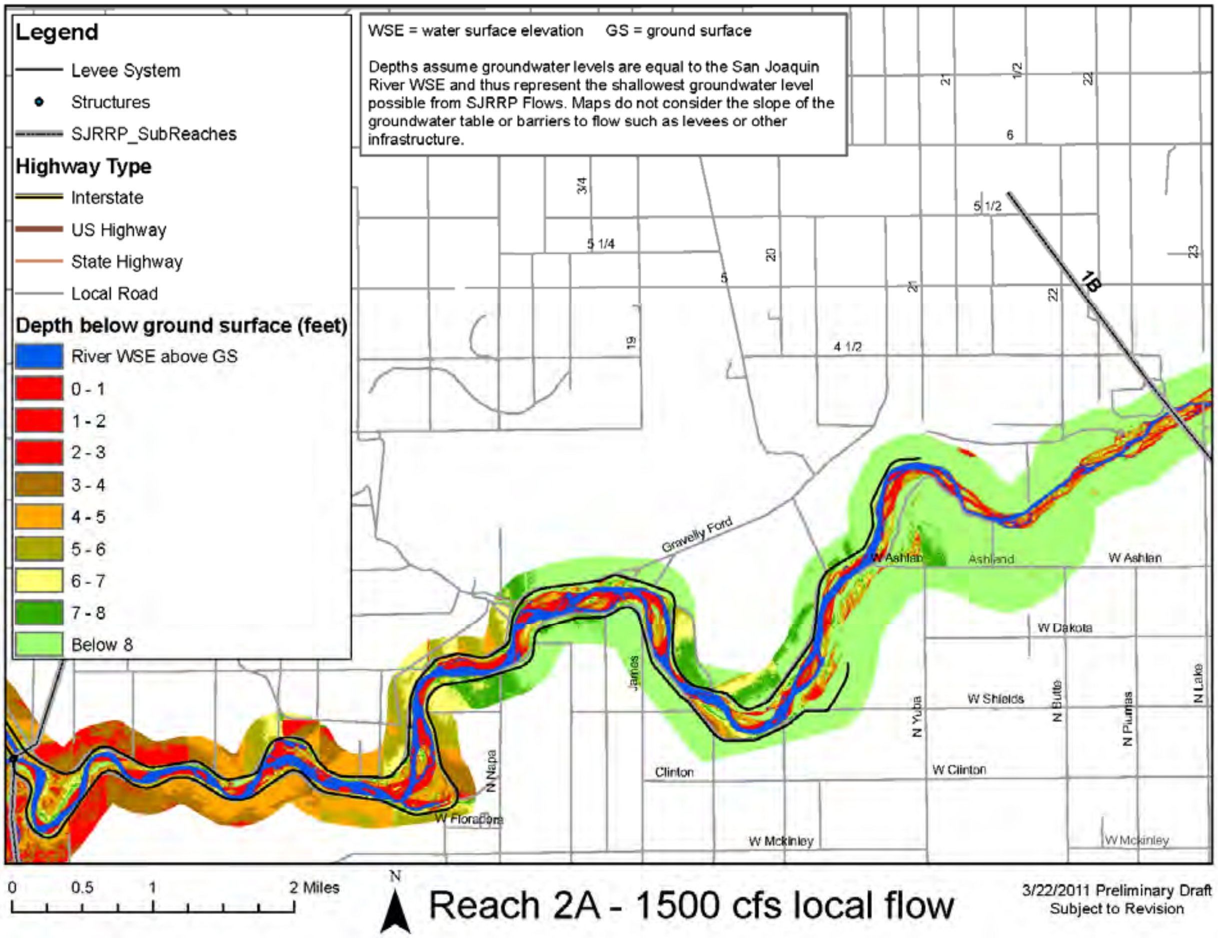


Figure B- 17. Reach 2A 1500 cfs

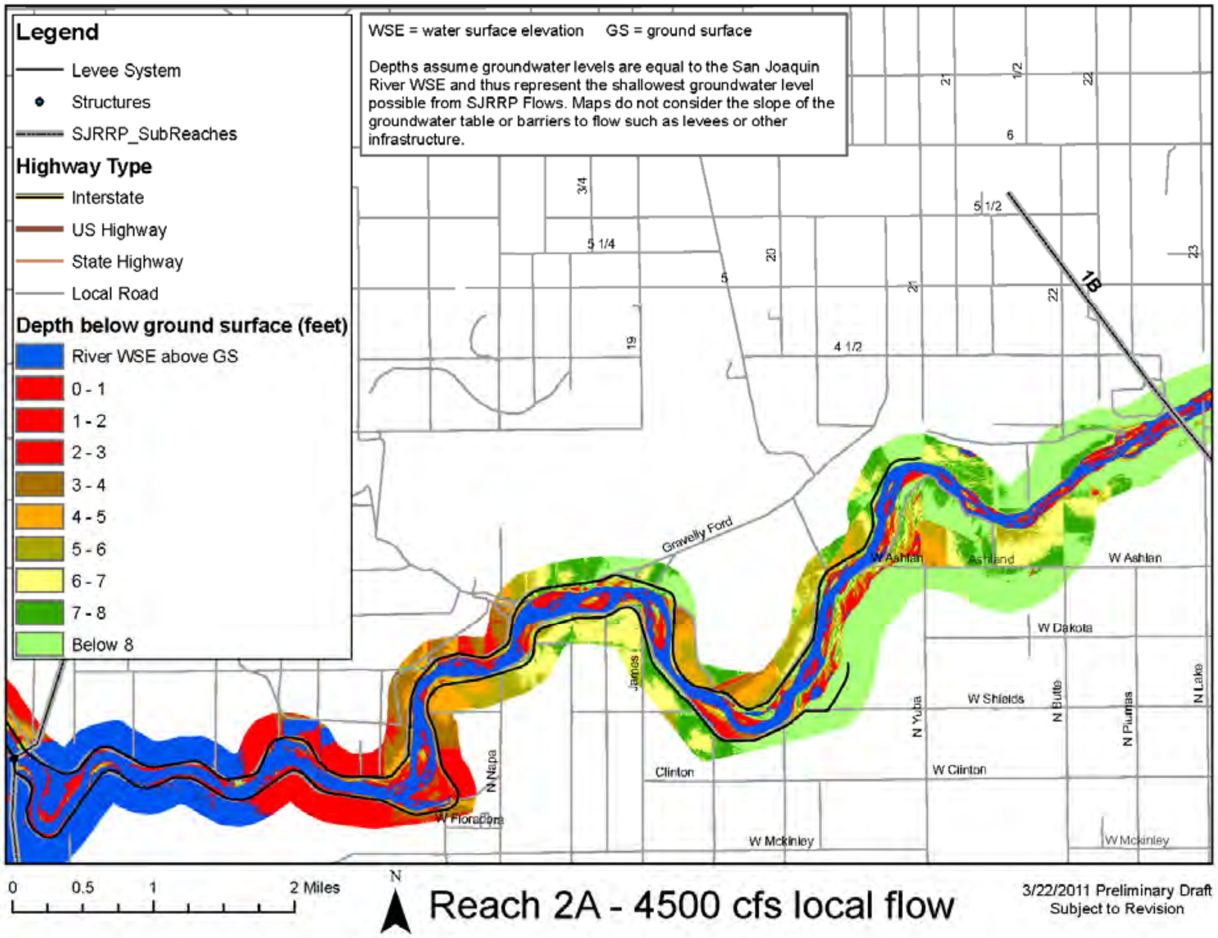


Figure B- 18. Reach 2A 4500 cfs

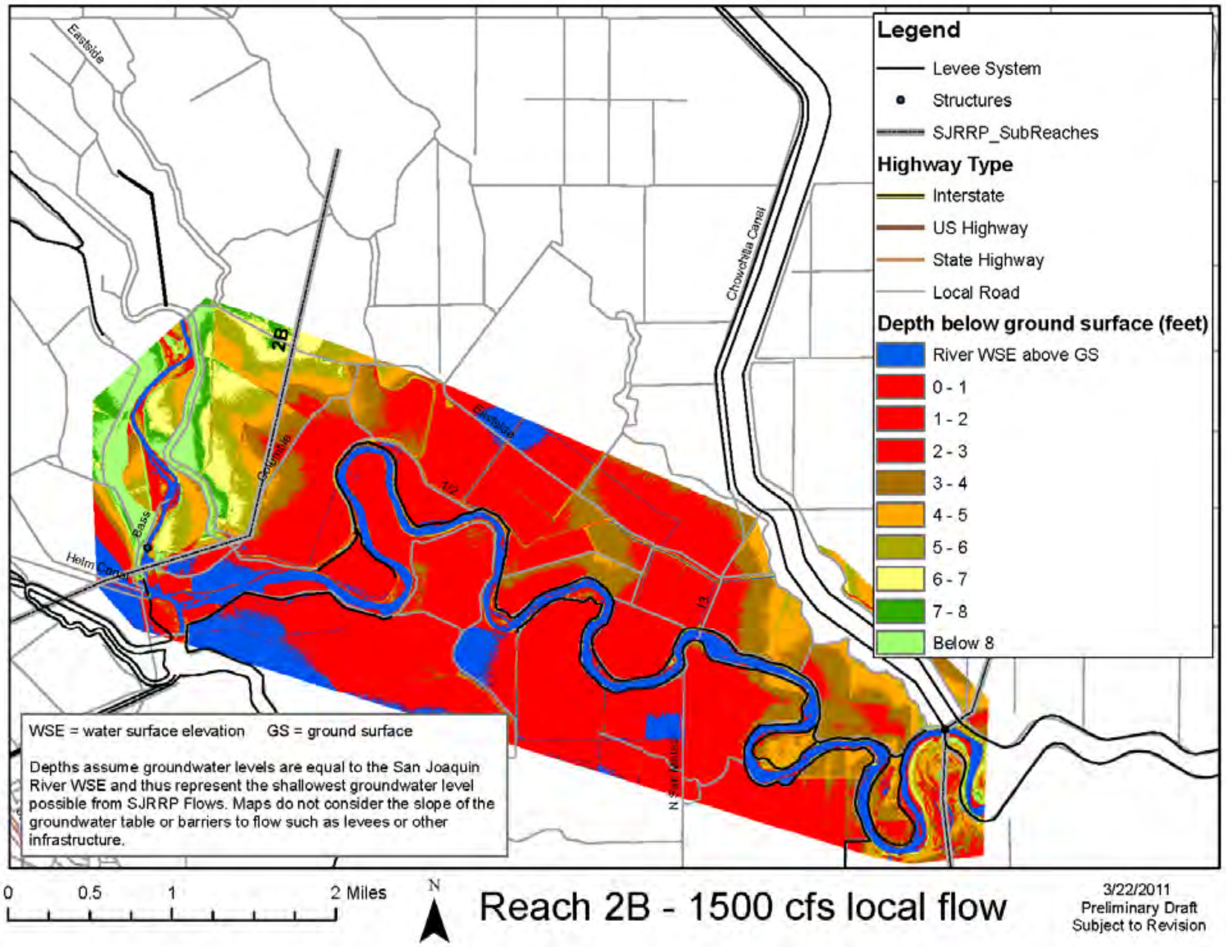


Figure B- 19. Reach 2B 1500 cfs

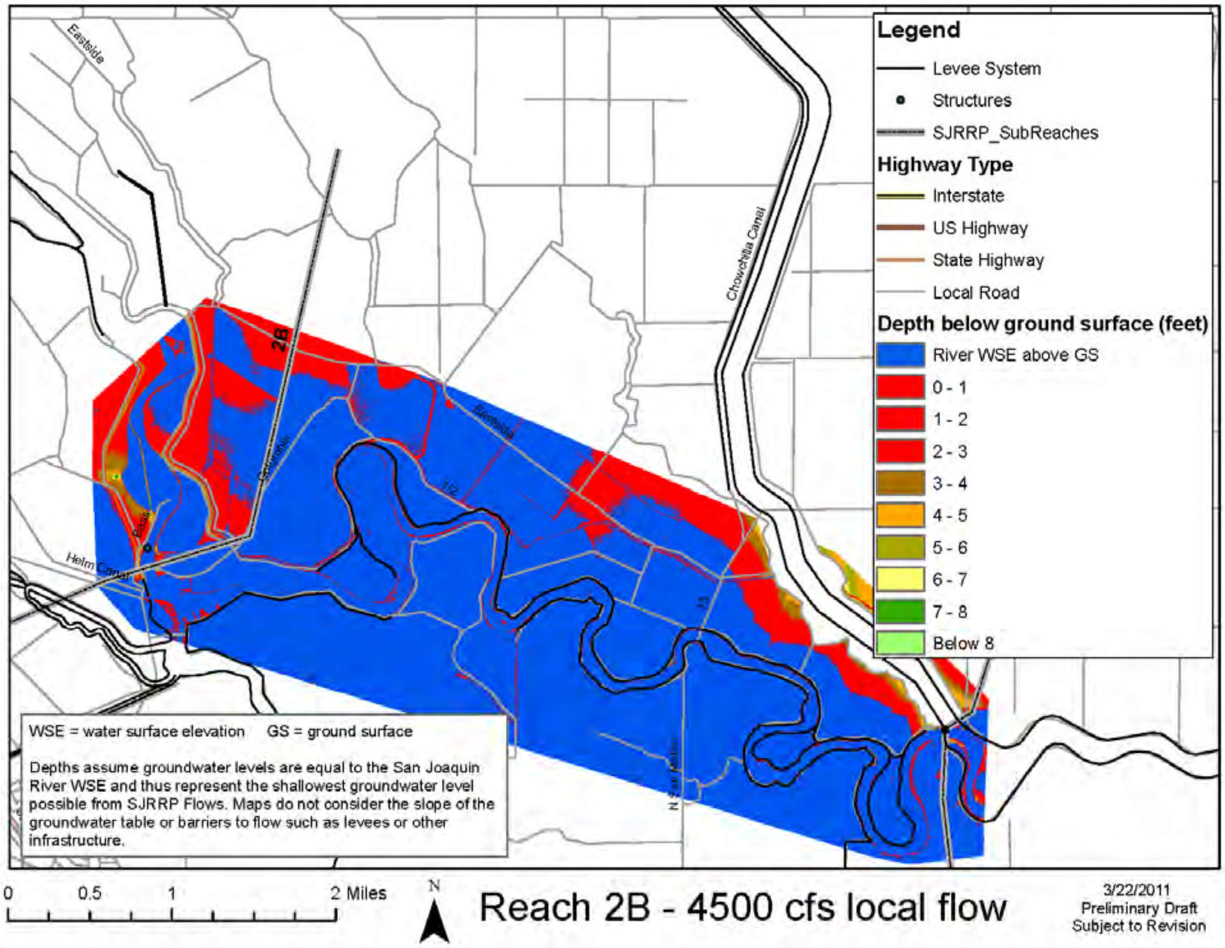


Figure B- 20. Reach 2B 4500 cfs

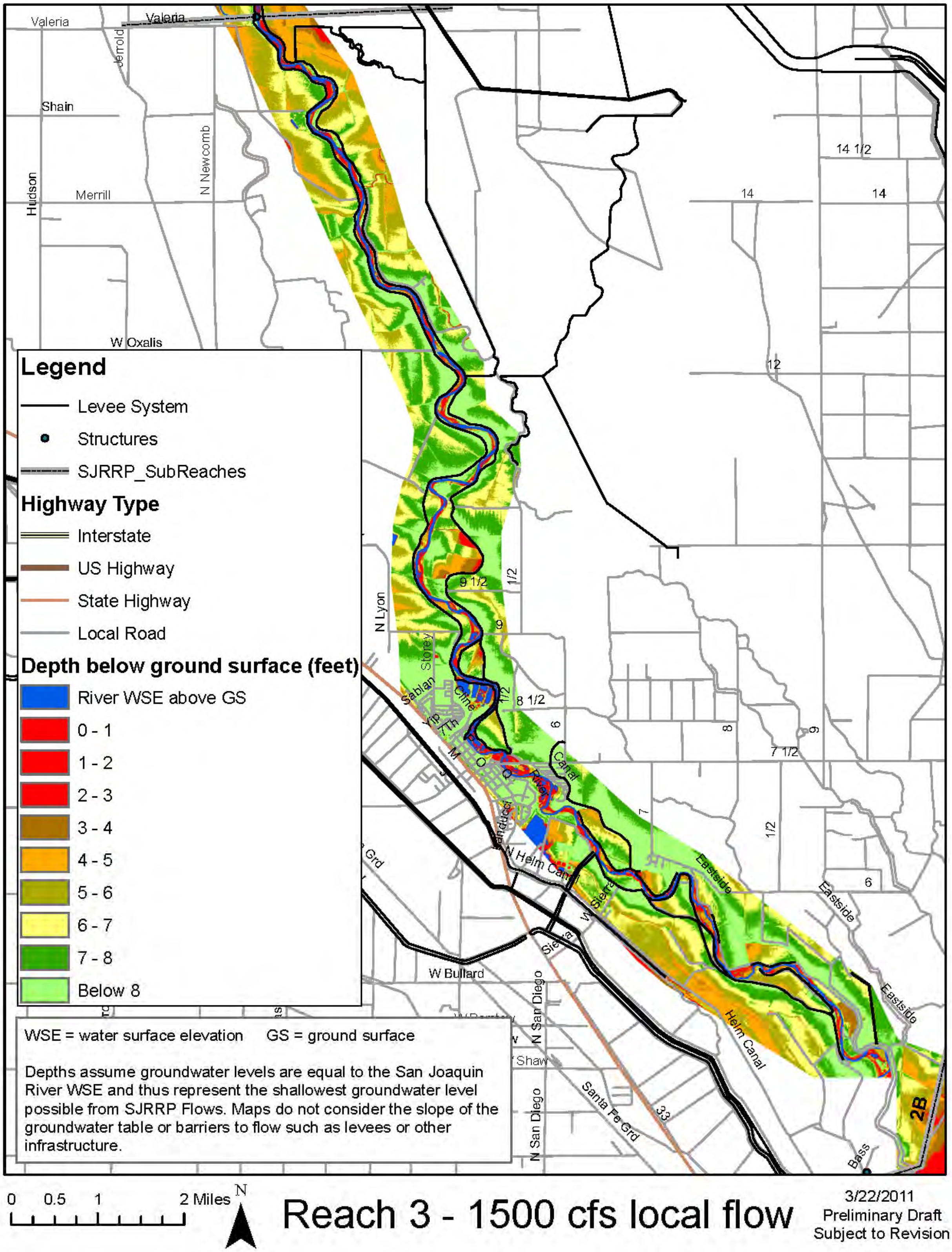


Figure B- 21. Reach 3 1500 cfs

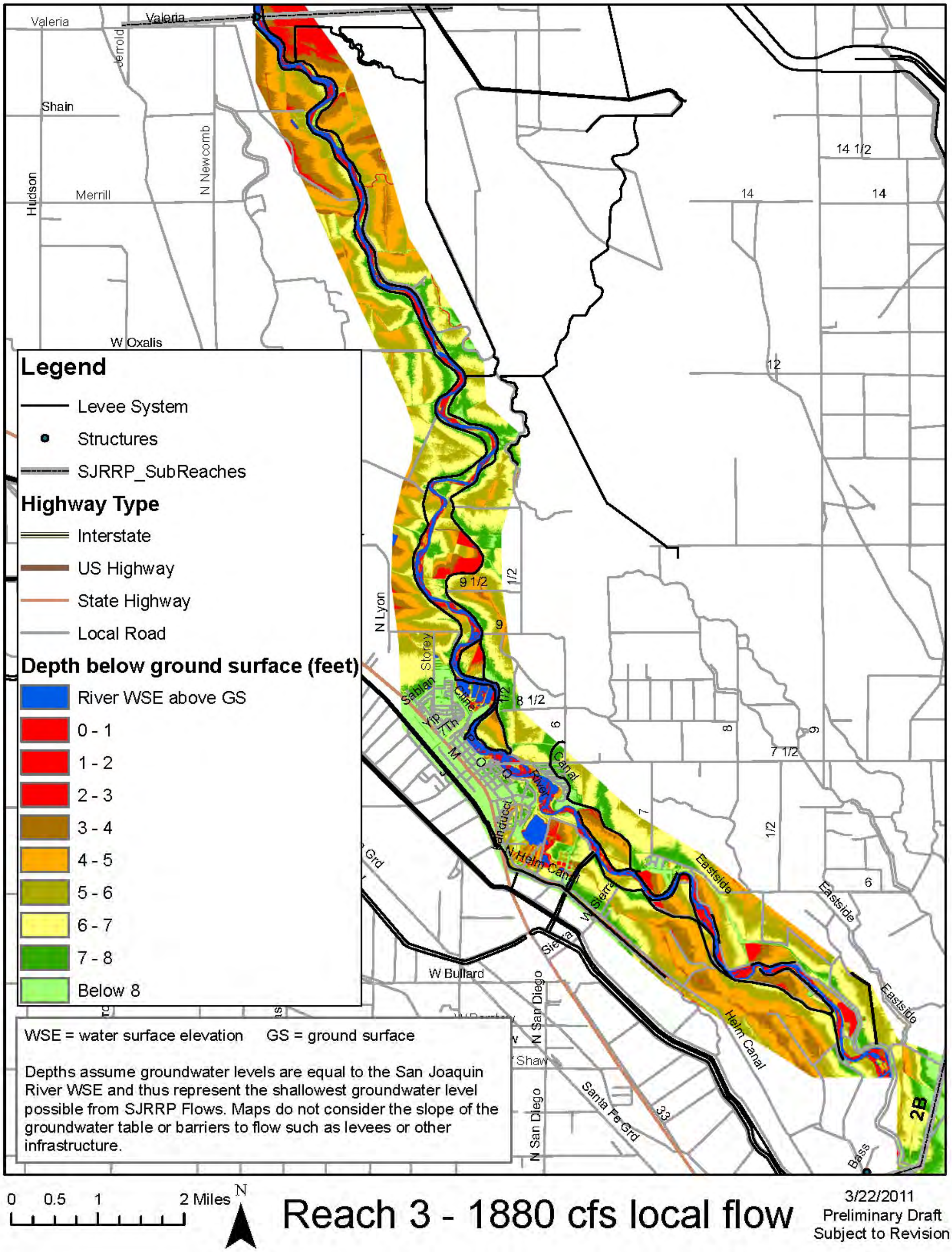


Figure B- 22. Reach 3 1880 cfs

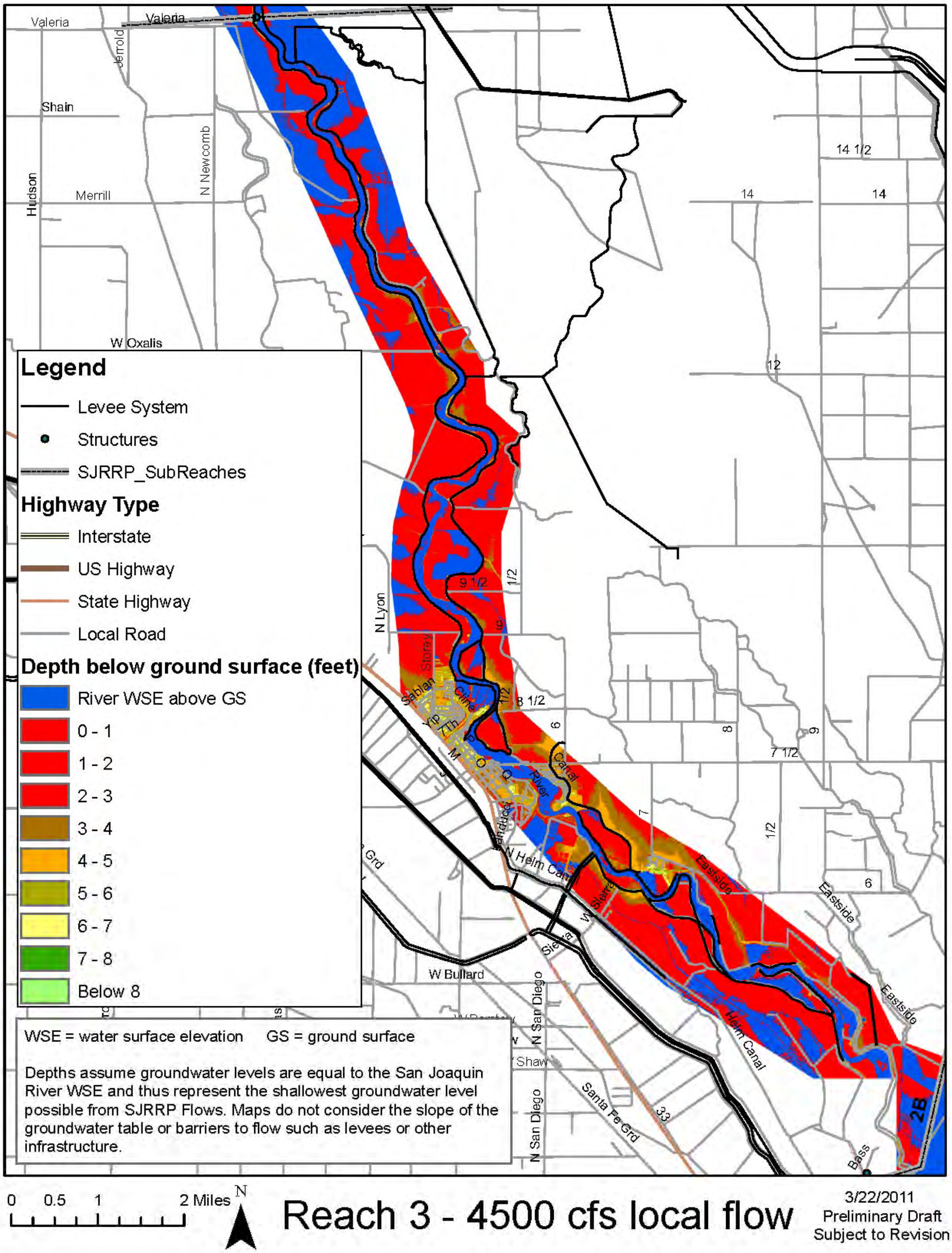


Figure B- 23. Reach 3 4500 cfs

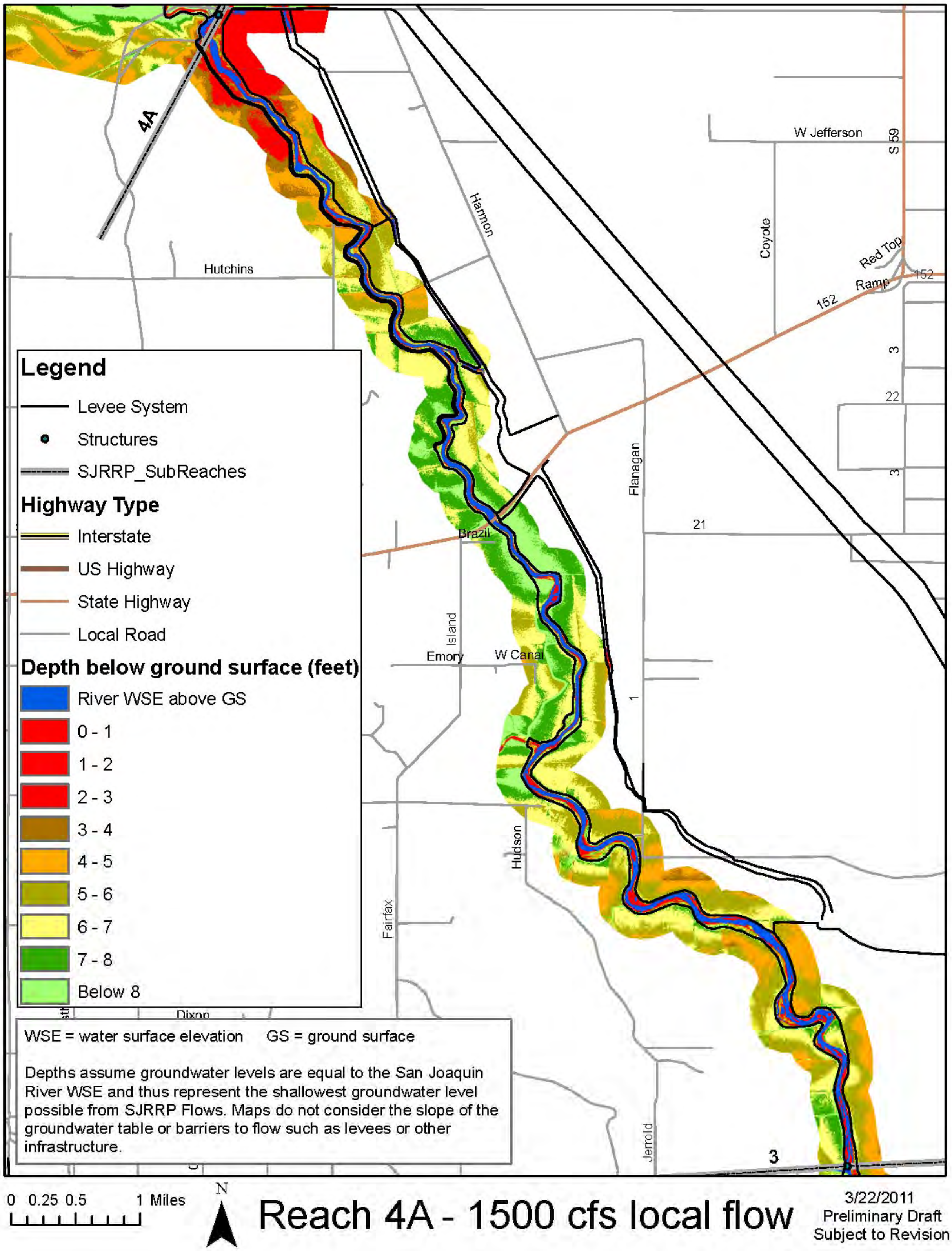


Figure B- 24. Reach 4A 1500 cfs

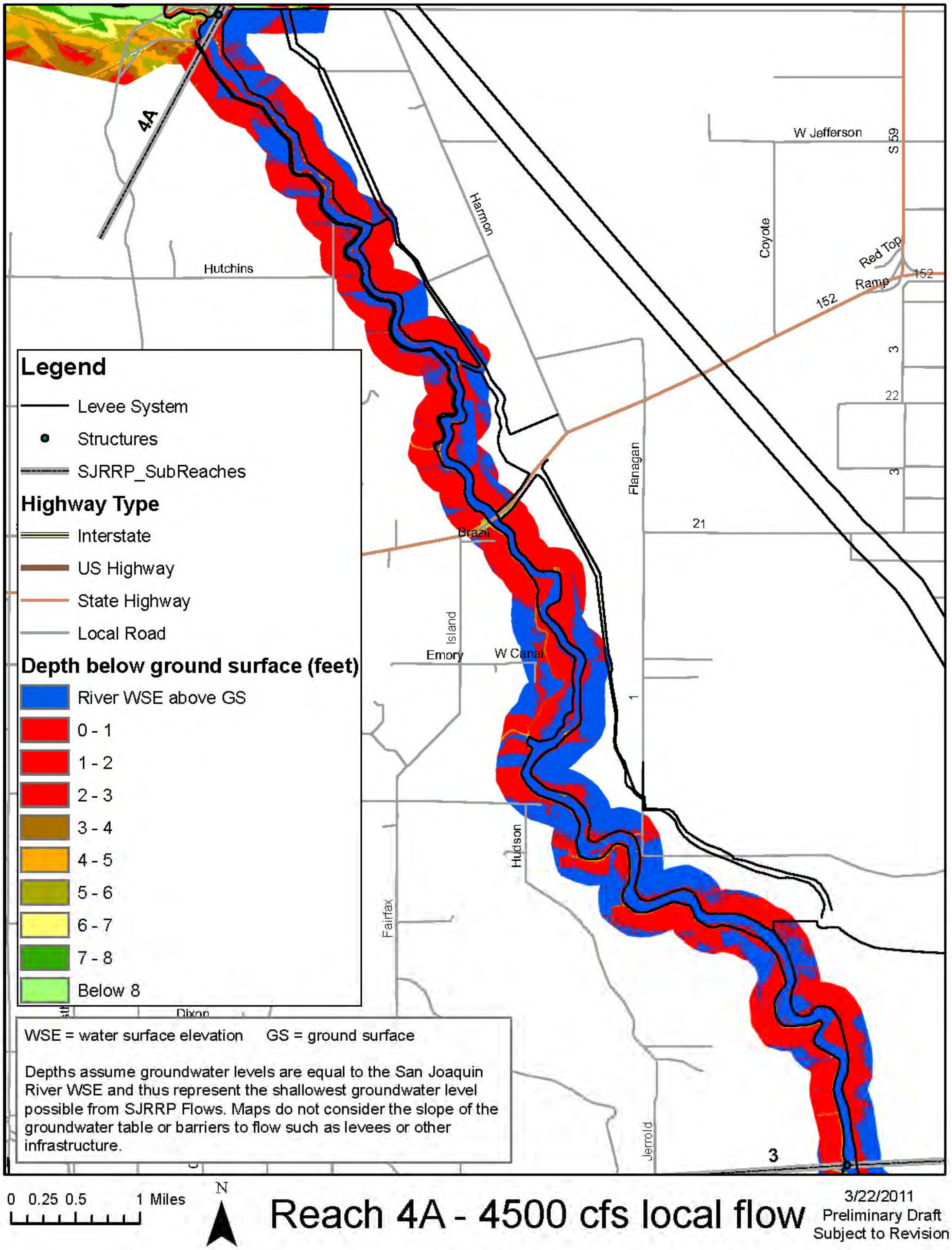


Figure B- 25. Reach 4A 4500 cfs

This analysis assumes a flat groundwater table with no gradient. Monitoring data collected by the SJRRP during the last 2 years indicates gradients exist in most locations. The lack of gradient analysis thus overestimates the effects of river stage on seepage. This approach results in more locations and larger areas identified. The approach taken overestimates potential seepage risks, making it conservative with respect to protection of agricultural lands. The key areas of concern for seepage projects include the downstream end of Reach 2A, portions of Reach 3, and the downstream end of Reach 4A.

4. Map of areas potentially vulnerable to seepage impact

All of the information discussed above will be combined into a map of areas potentially susceptible to SJRRP-related seepage impacts. A conceptual version of this map is shown in Figure B- 26. Such a map, in combination with model simulations, will inform monitoring efforts, threshold development, and locations for seepage projects.

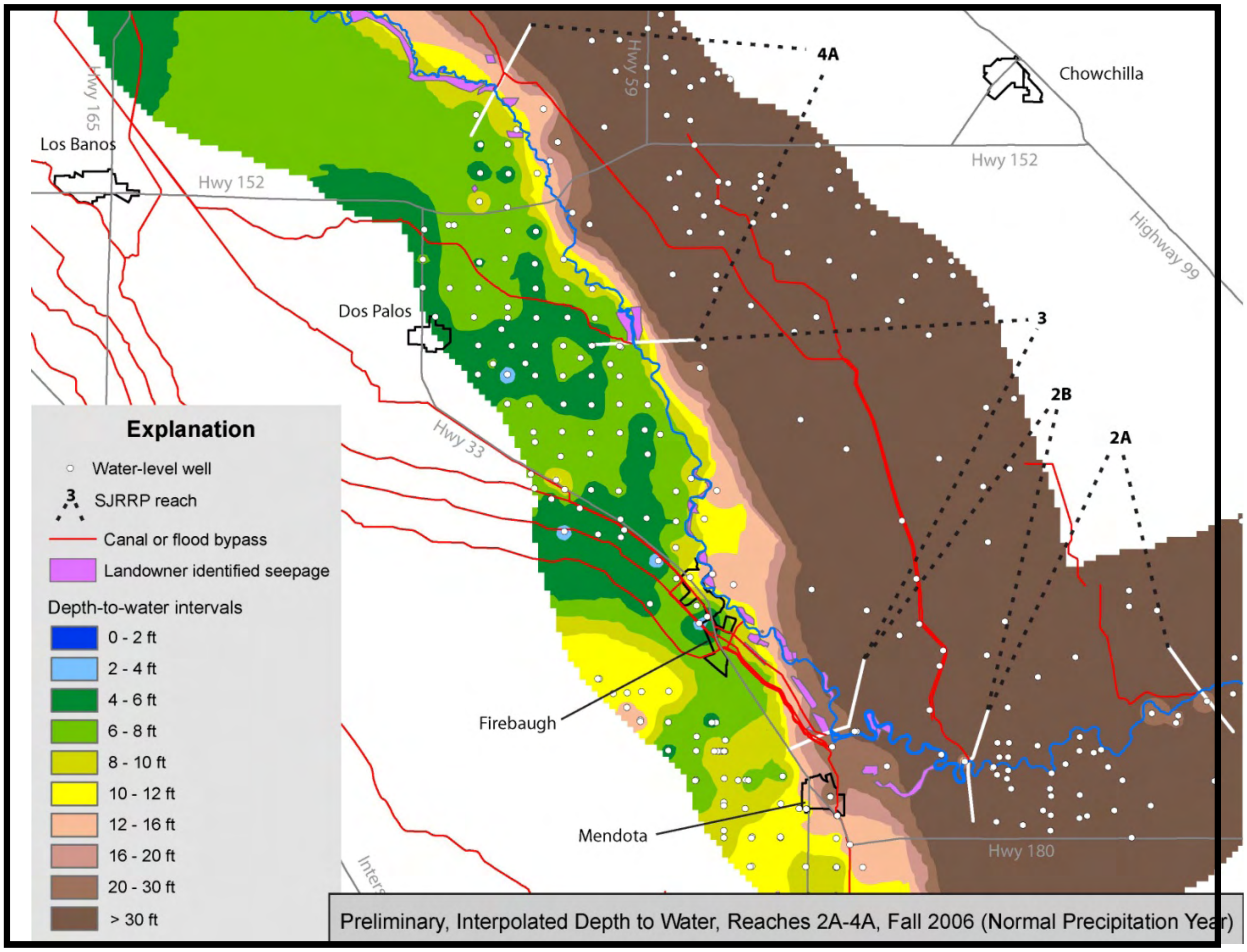


Figure B- 26. Preliminary seepage vulnerability map.

Appendix C. Historic Groundwater Levels and Surface-Water Flow

This appendix describes the groundwater-level (water-level) and surface-water flow data used to develop maps of depth to the water table presented in Appendix B, and for various analyses and model calibration. Also described are the methods used to develop water-table maps. Groundwater hydrographs are presented in section 4, and surface-water data are presented in section 5.

1. Water-Level Database

The water-level database for the SJRRP consists of approximately 75,000 water-level records for nearly 2,800 wells located within 5 miles of the SJJRP study area. The period of record extends back to the early 1900's, but almost 90-percent of the available records represent the period from 1960 to present. The frequency of water-level measurements for any particular well is generally limited to biannual spring and fall measurements, although monthly, weekly, and even daily records are available for a few wells for short time periods.

Water-level records were obtained from the California Department of Water Resources (DWR) Water Data Library (WDL) online database, the U.S. Geological Survey, and from the Central California Irrigation District (CCID). Additional data will be added as it becomes available, including measurements from U.S. Bureau of Reclamation cross-section monitoring wells in reaches 1 and 2, data from the Mendota Pool Group, and recent measurements compiled by the DWR, but not yet available in the WDL database.

2. Methodology for Developing Water-Table Maps

Maps of depth to the water table were developed using GIS and the inverse distance weighting (IDW) method of interpolation. The IDW method weights the *z* (depth-to-water) value of each point by its distance to the cell being analyzed and averages the values. Less weight is given to values farther away from the cell being analyzed. The smaller the distance between points or the greater the concentration of points within a particular cell the better the resulting interpolation. Interpolated values in areas having few or no wells can at best be considered only approximations of actual conditions.

Using the IDW approach, the depth to water table maps were created for the fall measurement period (September 15–November 15) for years having the greatest number of measurements and (or) the greatest interest with respect to particular climatic conditions (dry, dry normal, normal, or wet). Dry or wet year designations were based on rainfall deficiency or excess greater than one standard deviation from the long-term mean. For years designated as normal dry, rainfall was deficient by more than 10 percent, but less than one standard deviation (about 40 percent) from the long term average. Fall maps were developed for the following years (values in parentheses represent the number of measurements and the climatic designation, respectively):

- 1965 (136, normal)

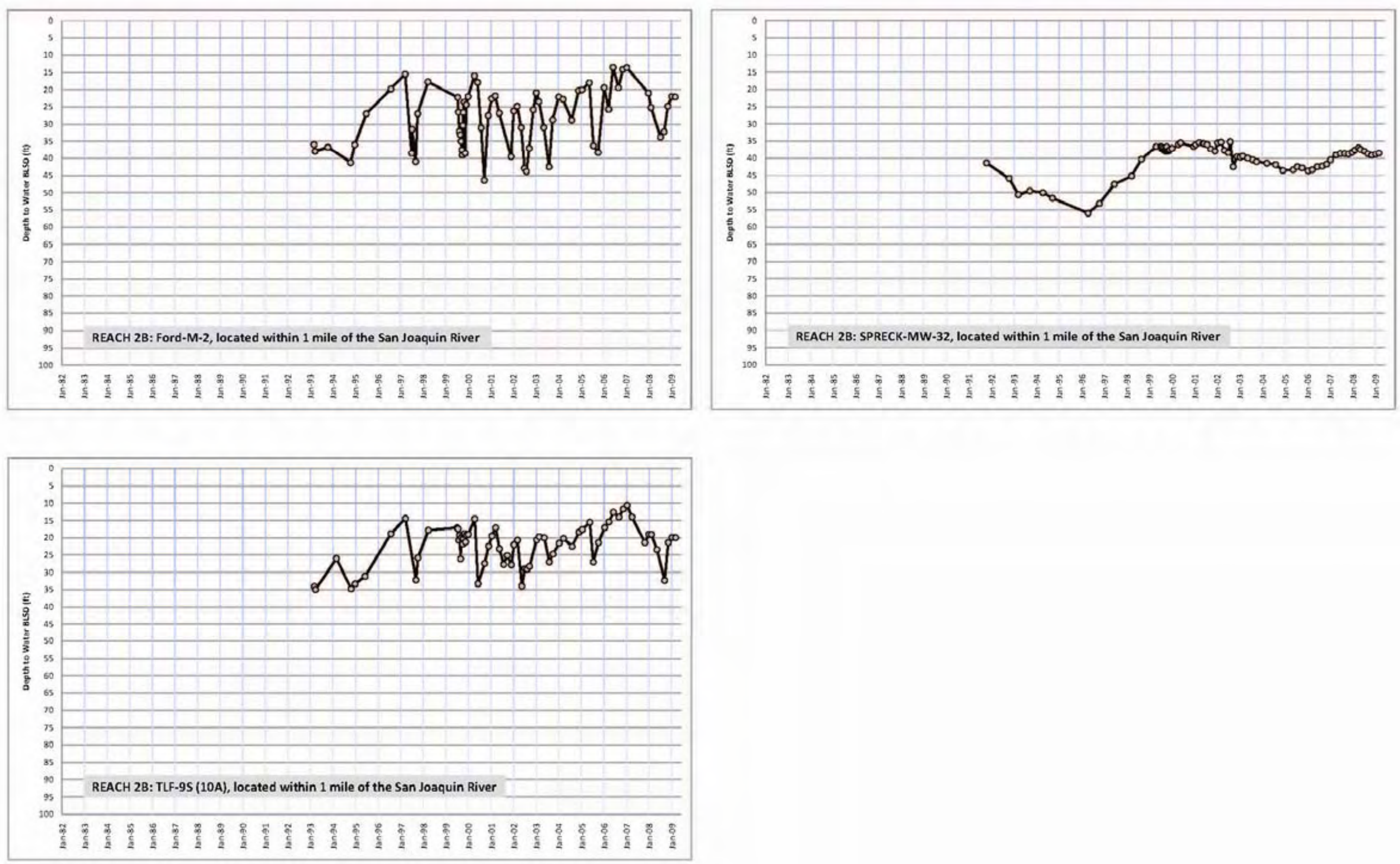
- 1981 (524, normal)
- 1983 (705, wet)
- 1988 (657, dry normal)
- 1991 (518, dry normal)
- 1994 (632, normal)
- 1999 (449, dry)
- 2006 (417, normal)

3. Maps of Historical Water-Table Elevation

Maps of historical water-table elevation are being developed using the same database used to create the maps of depth to the water table. Greater error will be associated with these maps because elevations associated with the monitoring wells (measuring points and land surface) are subject to a combination of errors associated with methods used to derive these elevations, and land subsidence, which exceeds 8 feet in some places in the Restoration Area.

4. Representative hydrographs

Hydrographs will be generated for a variety of well types along the San Joaquin River with long-term measurements available. Representative hydrographs for shallow wells with relatively long term records along reach 2B are shown in Figure C- 1.



Note: BLSD = Below land surface datum

Figure C- 1. Hydrographs for shallow wells along reach 2B

5. Surface-Water Flow

Presented in this section of the Plan are historical records of end-of-month storage from Millerton Lake (Figure C- 3), average annual flow and selected hydrographs from various streamflow gaging stations along the San Joaquin River (Figure C- 4–Figure C- 8), and gaging station information by reach of the San Joaquin River (Table C- 1–Table C- 7). Locations of all gaging stations for which data are available are shown in Figure C- 2. Data for all of these gaging stations are compiled in a database for use in various SJRRP analyses.

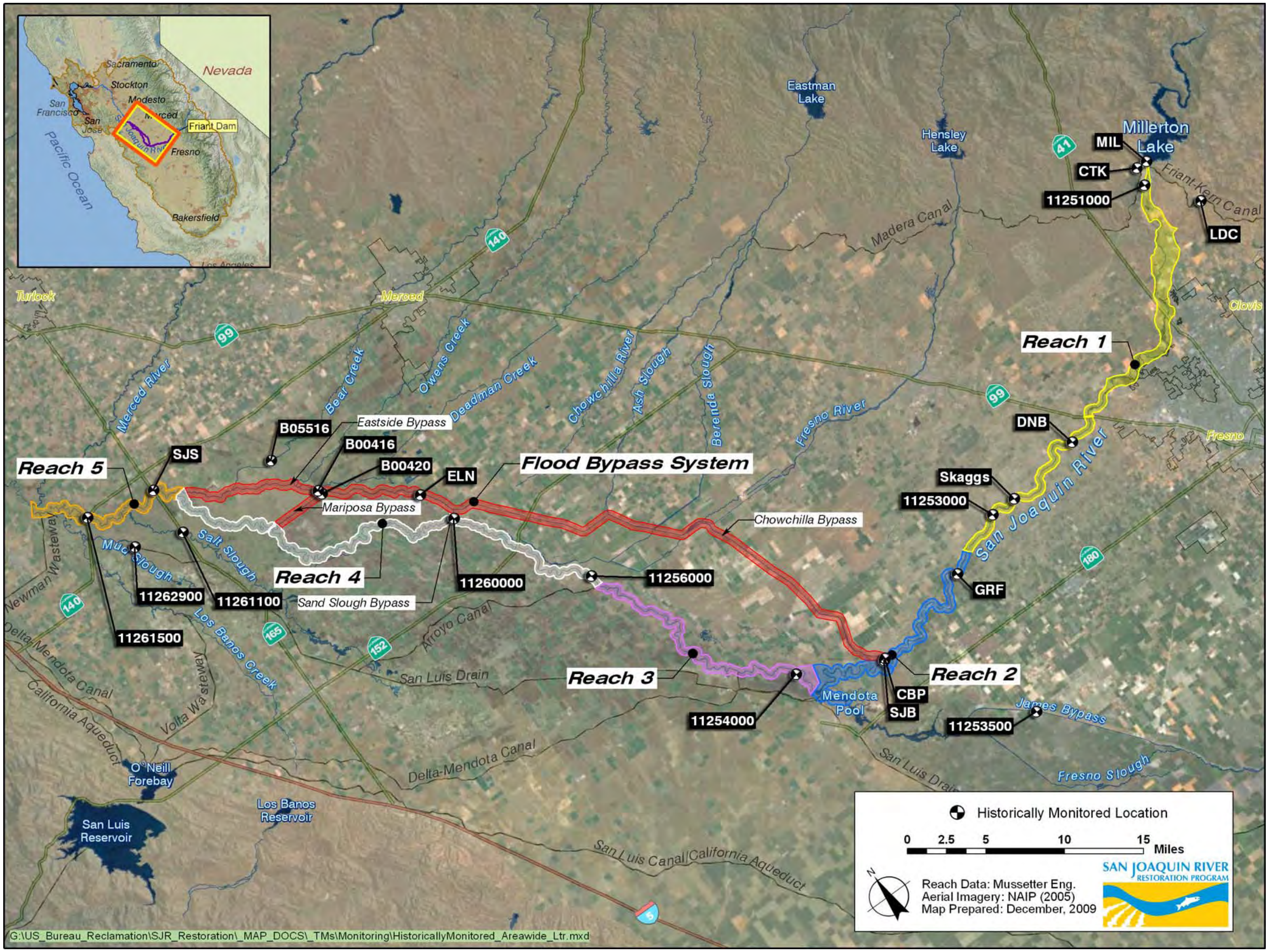


Figure C- 2. Locations of historically monitored streamflow gages with available data

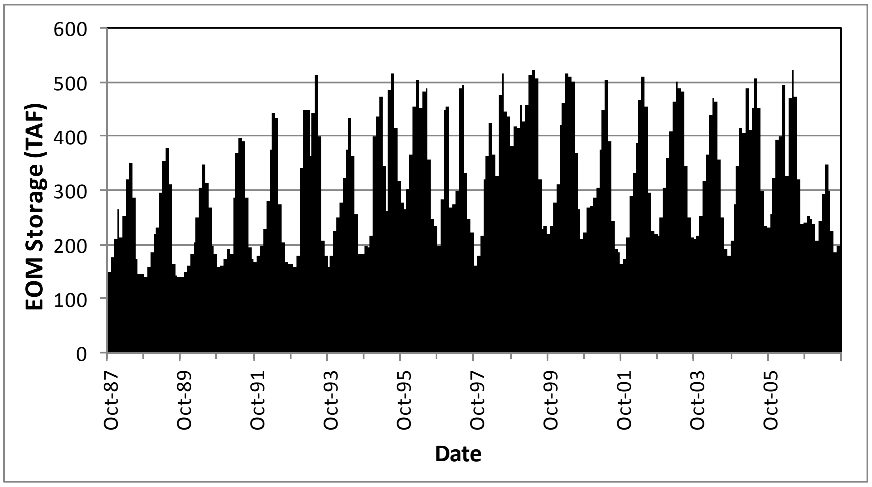


Figure C- 3. Historical Millerton Lake End-of-Month Storage, Water Years 1988–2007

Table C- 1. Streamflow Gages in Reach 1A

Station Name	USGS Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record[1]	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River release from Friant Dam	MIL	267.6	1,675	1974 – 2007	707	25,556 (January 4, 1997)
San Joaquin River below Friant Dam	11251000	266.0	1,676	1950 – 2007[2]	703	36,800 (January 3, 1997)
Cottonwood Creek near Friant Dam	CTK	NA	35.6	1974 – 2007	7	783 (January 27, 1983)
Little Dry Creek near Friant Dam	LDC	NA	57.9	1974 – 2007	22	2,457 (March 11, 1995)

Source: CDEC 2008; USGS 2008
Notes:
[1] Calendar years.
[2] Period of record coincides with start of diversions from Friant Dam (1950).

Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

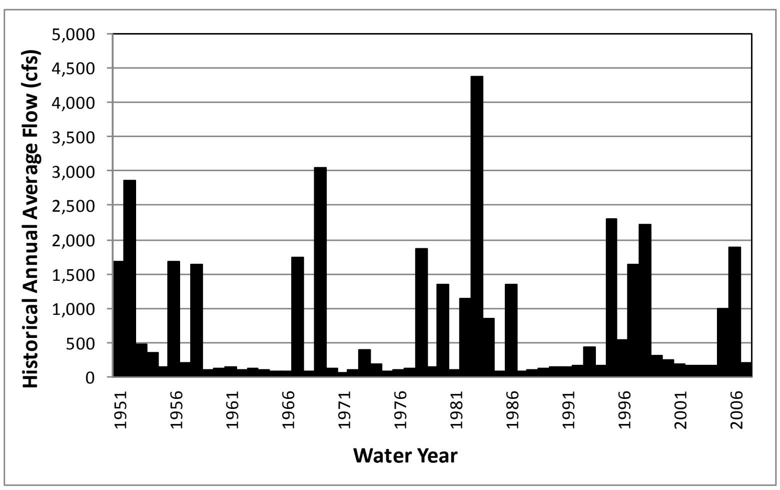


Figure C- 4. Historical Annual Average Flow for below Friant Dam

Table C- 2. Streamflow Gages in Reach 1B

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record[1]	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River at Donny Bridge	DNB	240.7	NA	1988 – 2007	122	7,900 (December 30, 1996) [2]
San Joaquin River at Skaggs Bridge	NA[3]	232.1	NA	1974 – 2007	215	7,900 (December 30, 1996)[2]
San Joaquin River near Biola	11253000	NA	1,811	1952 – 1961	514	7,860 (April 7, 1958)

Source: CDEC 2008, USGS 2008, Reclamation 2007

Notes:

[1] Calendar year.

[2] This maximum daily average streamflow was exceeded in the January 1997 flooding event.

[3] Data obtained from U.S. Department of the Interior, Bureau of Reclamation (2007)

Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

Table C- 3. Streamflow Gage in Reach 2A

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River at Gravelly Ford	GRF	236.9	NA	1974 – 2007	652	37,843 (January 4, 1997)

Source: CDEC 2008
Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

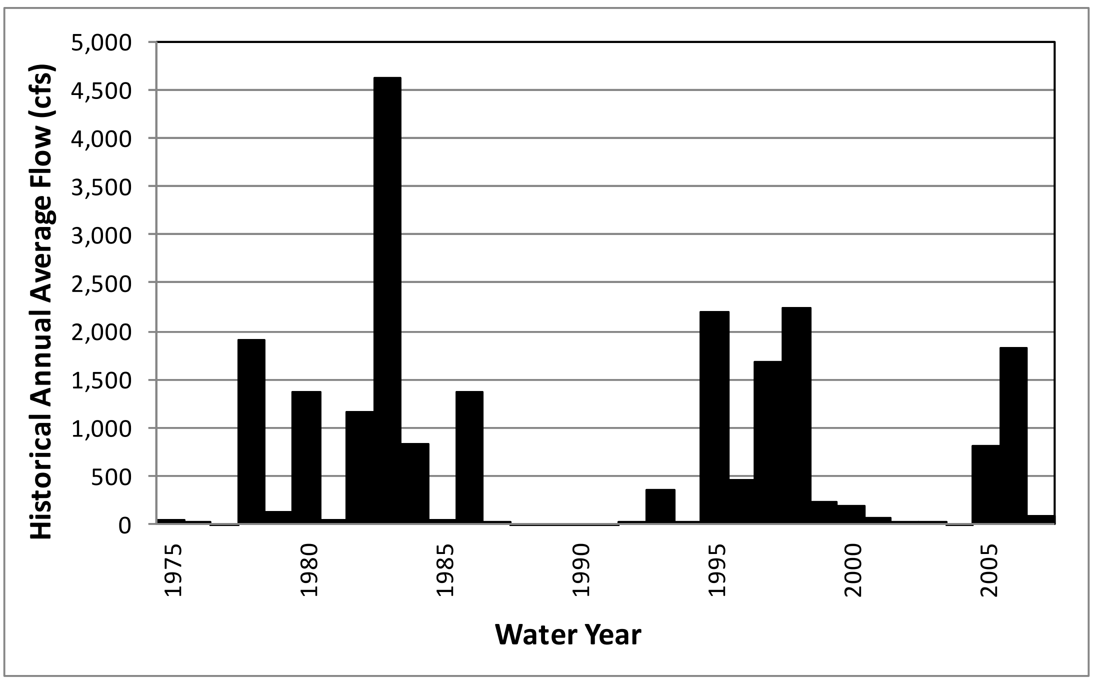


Figure C- 5. Historical Annual Average Flow for San Joaquin River at Gravelly Ford

Table C- 4. Streamflow Gage in Reach 2B

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River below Chowchilla Bypass Bifurcation Structure	SJB	217.8	NA	1974 – 1986, 1988 – 1997, 2005 – 2007	159	2,660 (May 23, 1978)

Source: CDEC 2008
Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

Table C- 5. Streamflow Gage in Reach 3

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River near Mendota	11254000	217.8	3,940	1950 – 1954, 1974 – 2007[1]	545	8,770 (May 29, 1952)

Source: USGS 2008

Note:

[1] Period of record coincides with start of diversions from Friant Dam (1950).

Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

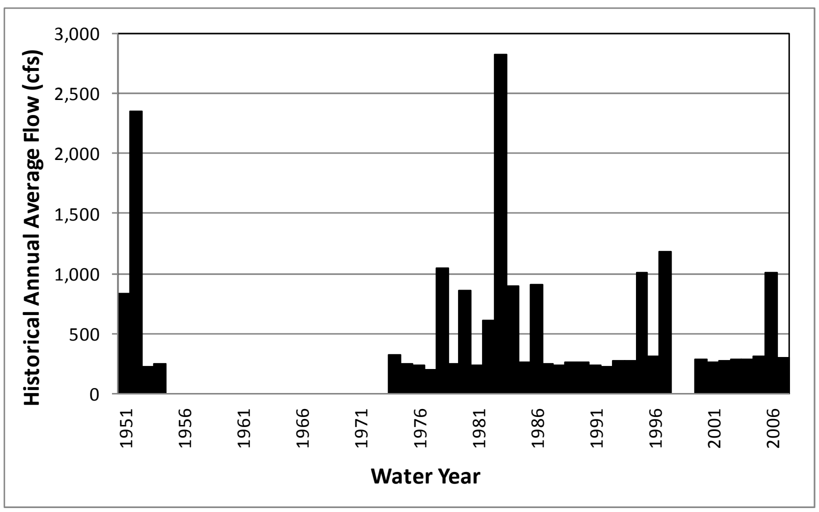


Figure C- 6. Historical Annual Average Flow for San Joaquin River near Mendota

Table C- 6. Streamflow Gages in Reach 4A

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River near Dos Palos	11256000	NA	4,669	1950 – 1954, 1974 – 1987, 1995[1]	478	8,170 (June 5, 1952)
San Joaquin River near El Nido	11260000	NA	6,443	1939 – 1949[2]	705	3,700 (June 22, 1942)

Source: USGS 2008

Notes:

[1] Period of record coincides with start of diversions from Friant Dam (1950).

[2] Period of record is during Friant Dam construction and filling.

Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

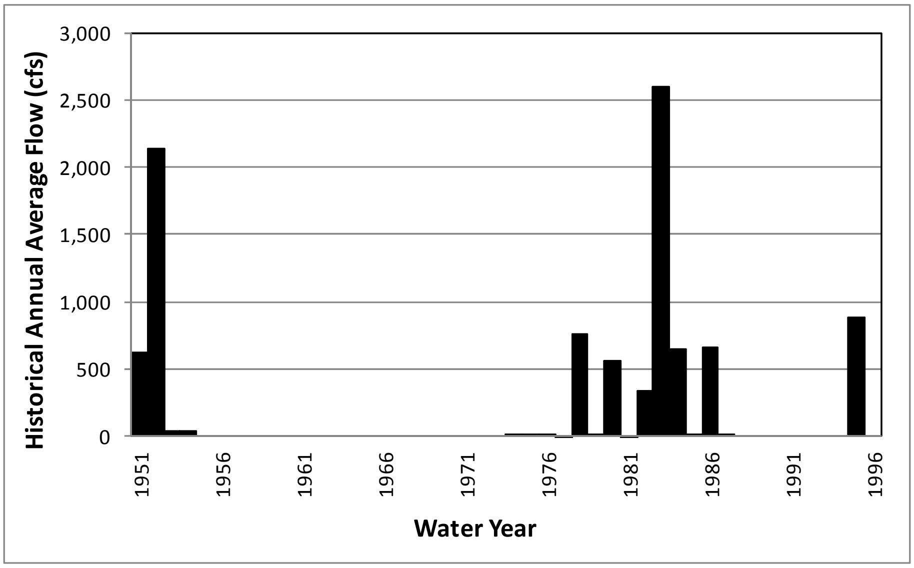


Figure C- 7. Historical Annual Average Flow for San Joaquin River near Dos Palos

Table C- 7. Streamflow Gages in Reach 5

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River near Stevinson	SJS	118.2	NA	1981 – 2007	1,042	23,900 (January 28, 1997)
Salt Slough at HW 165 near Stevinson	11261100	NA	NA	1985 – 2007	206	810 (February 20, 1986)
San Joaquin River at Fremont Ford Bridge	11261500	118.2	7,615	1950 – 1971, 1985 – 1989, 2001 – 2007[1]	640	22,500 (April 8, 2006)
Mud Slough near Gustine	11262900	NA	NA	1985 – 2007	101	1,060 (February 9, 1998)

Source: CDEC 2008; USGS 2008

Note:

[1] Period of record coincides with start of diversions from Friant Dam (1950).

Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
HW = highway
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

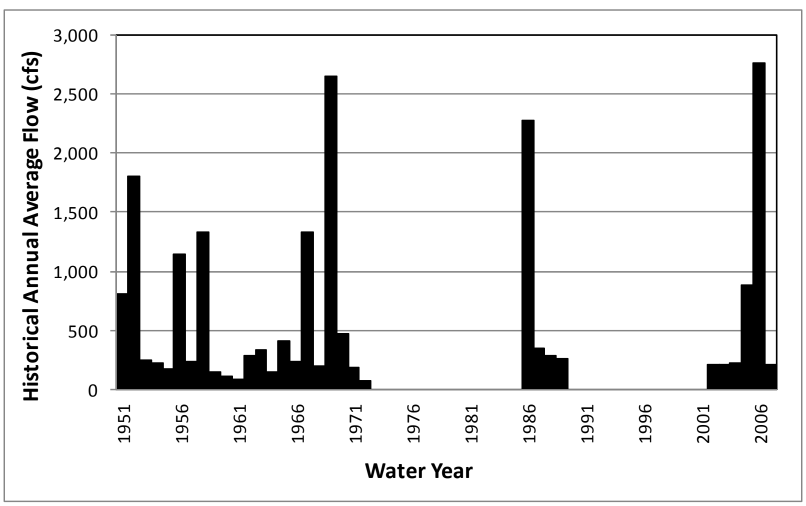


Figure C- 8. Historical Annual Average Flow at Fremont Ford Bridge

Appendix D. Sediment Texture and Other Data

This appendix describes data associated with sediment texture in the aquifer system, and locations of artificially drained farmlands.

1. Sediment texture

The texture of sediments making up the aquifer system, and the distribution of these textures, can have a strong influence on the hydrology. For example, an unpublished study of the central part of the west side of San Joaquin Valley, which is close to the Restoration Area, showed a very high correlation between shallow sediment texture and the tile drainage network (Figure D-1), and presumably an equally high correlation to the need for drainage. This shows the correlation between soil type and drainage which may be further explored in the Restoration Area. Figure D- 1 shows the sediment texture of the upper 15 feet of the Grasslands Drainage Area and vicinity, overlain by the tile drain network in blue (unpublished data, Phillips).

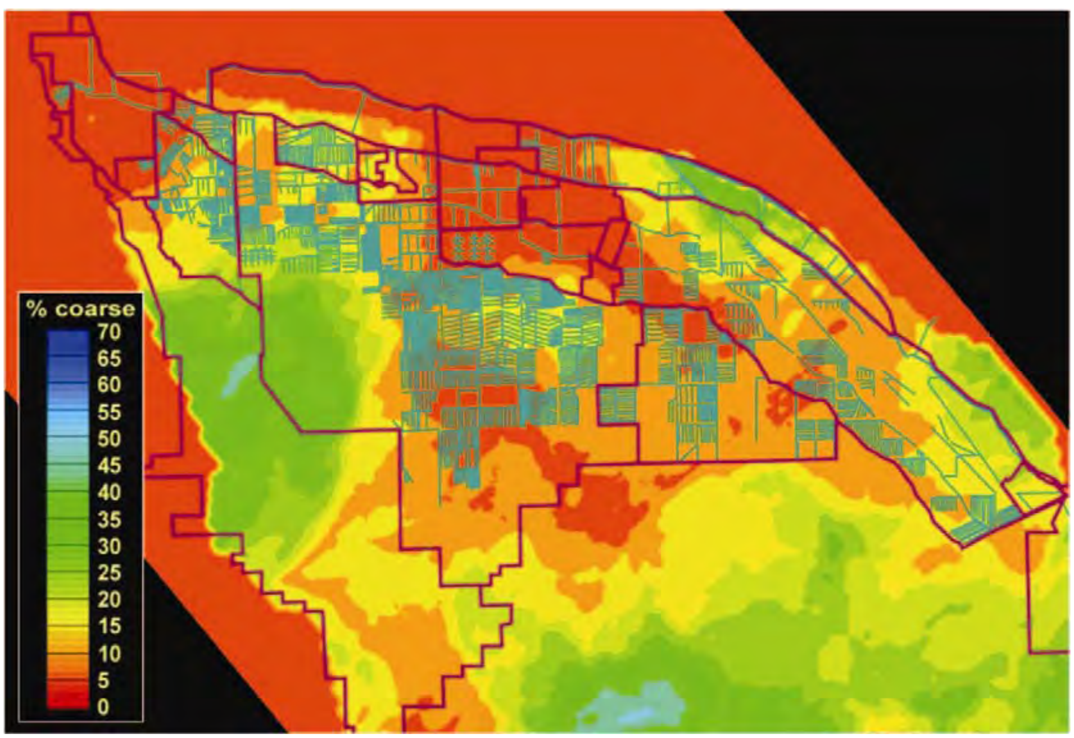


Figure D- 1. Sediment texture and tile drains

Also, as discussed in Appendix B section 1, the shallow water table is sensitive to groundwater pumping — but it is not equally sensitive in all areas. This variability is likely controlled primarily by sediment texture and its distribution.

Thus, it is important to quantify sediment texture in the Restoration Area. This has been done on a regional (square mile) scale for the upper 50 feet in support of the USGS Central Valley Hydrologic Model (Faunt, 2009); the Restoration Area is shown in Figure D- 2. This level of detail certainly is useful for developing a better understanding of the hydrology, but the method used by Faunt (2009) may be inadequate for evaluating local vulnerability to seepage effects. For example, a profile with 15 feet of clay overlying 35 feet of sand would, when averaged over the upper 50 feet, appear to be a course-grained unit; in reality, it would present a drainage problem.

The data presented in Figure D- 2 represent only a subset of the available lithologic logs in the study area. For example, the high density of data shown in the northern part of the study area represents the useful logs culled from the set of all available logs for that area, done as part of a subregional study to the north (Burow and others, 2004). Additional very high-quality lithologic data will be available from the analysis of continuous core samples and other lithologic data being collected during the installation of monitoring wells by the SJRRP.

Additional well logs and core data within the Restoration Area will be added to an existing texture database, and one of several methods will be used to generate a more refined texture model for use in modeling efforts and other analyses. One such method is TProGS (Carle and Fogg, 1996), a geostatistical method that uses transition probabilities (the probability of transitioning from one hydrofacies, or sediment type, to another) generated from borehole data to develop multiple equally probable distributions of hydrofacies throughout the model domain.

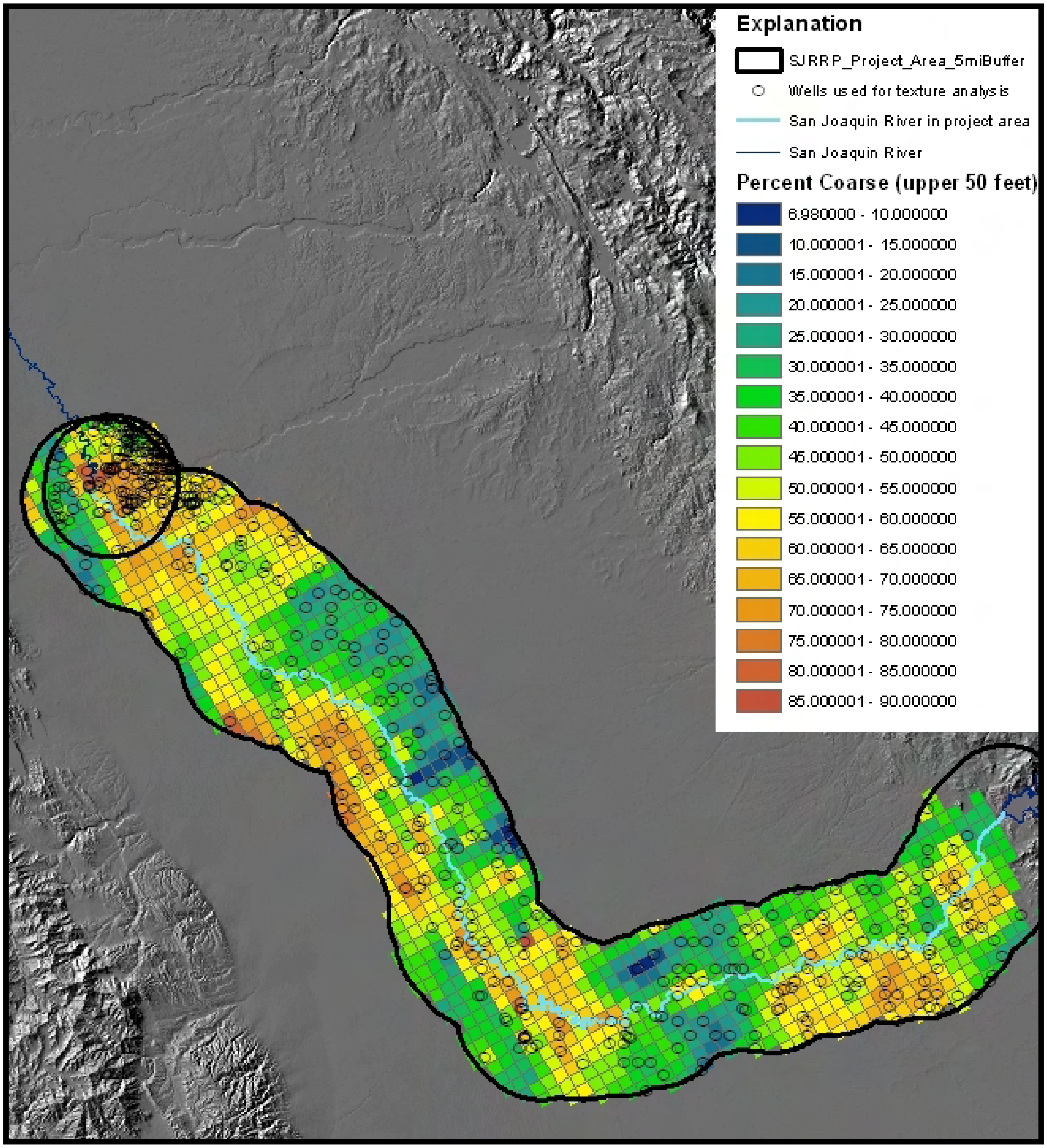
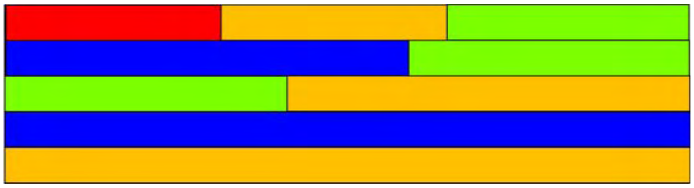


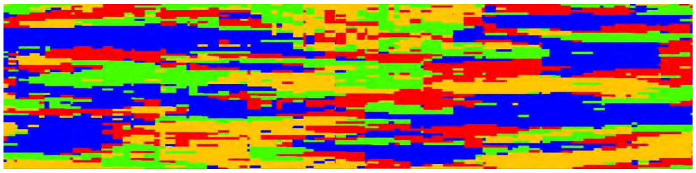
Figure D- 2. Percent of coarse-grained sediments in the Restoration Area

Each square is one square mile representing a cell in the USGS Central Valley Hydrologic Model (Faunt, 2009). Small circles represent locations associated with lithologic logs used to determine sediment texture; large areas with no wells are highly uncertain. The higher concentration of logs at the northern end is associated with the southern tip of a more detailed study of sediment texture (Burow and others, 2004).

For example, a standard model cross-section might be configured like this, where the colors represent sediment types or their associated hydraulic conductivities:



The same dataset might be used to generate a configuration like this using TProGS:



The second configuration, which is one realization from TProGS for an area along the Merced River (Phillips and others, 2007), allows for more 3-dimensional interconnections than a less heterogeneous, less realistic configuration. TProGS or another suitable method will be used to make best use of available sediment texture data.

2. Locations of artificially drained farmlands

The locations of artificially drained farmlands are important for understanding and simulating the response to water-table rise. Some of these locations are known outside of the Restoration Area, e.g. Figure D- 1, but many are not. Improved mapping of these areas will be accomplished by compiling existing anecdotal information from landowners, seeking additional information from landowners/stakeholders, and focusing on priority areas characterized by fine-grained textures near the land surface.

Appendix E. Operations

1 Triggers

Triggers determine when the SJRRP will take action through site visits and flow management. Two of these are triggered by SJRRP monitoring, and the third allows landowner observations to trigger SJRRP action.

1.1 Flow Bench Evaluations

Flow Bench Evaluations use model data to predict groundwater levels in priority wells prior to an increase in the target Friant Dam release flow. If the Flow Bench Evaluation predicts levels above identified thresholds, this triggers a site visit. See the example Flow Bench Evaluation attached to this Appendix.

Flow Bench Evaluations are posted on the SJRRP website on the Flow Scheduling page under the Monitoring section.

1.2 Daily Flow Evaluations

Daily Flow Evaluations check real-time and measured groundwater levels. If current groundwater levels in priority wells are above identified thresholds, this triggers a site visit. See the example Daily Flow Evaluation attached to this Appendix.

Daily Flow Evaluations are posted on the SJRRP website on the Flow Scheduling page under the Monitoring section.

1.3 Seepage Hotline

Landowners may report seepage concerns such as tile drains running, waterlogging, levee boils or piping to the Seepage Hotline. A Seepage Hotline call triggers a site visit. See the template Seepage Hotline Intake Form attached to this Appendix.

Seepage Hotline calls and forms are posted on the SJRRP website on the Groundwater page under the Monitoring section.

2 Site Visit and Response Actions

2.1 Site Visit

The SJRRP conducts site visits when triggered by the items above. Hand-auger holes to quickly measure groundwater levels and other types of monitoring done at a site visit determine the response action. See the template Site Visit Form attached to this Appendix.

Seepage Site Visit forms are posted on the SJRRP website on the Groundwater page under the Monitoring section.

2.2 Response Actions

Response actions may include releases as planned, increased monitoring, adjustment of the link between groundwater levels and river stage, adjustment of the threshold, or any of several flow response actions. See the template Response Action Form attached to this Appendix.

Seepage Response Action forms are posted on the SJRRP website on the Groundwater page under the Monitoring section.

SJRRP Flow Bench Evaluation

March 16, 2010

Flows below Friant Dam will increase to 800 cfs on March 16, 2010 based on the Restoration Administrator 2010 Interim Flow Recommendations for the San Joaquin River Restoration Program, February 1 through December 1, 2010. The evaluation of the increase is shown below.

As of March 15, 2010, Reclamation personnel have reported the following:

1. Flows are below known conveyance thresholds (8,000 cfs in Reach 2A, 1,300 cfs in Reach 2B, and 1,300 cfs in Reach 3) based on preliminary real-time data.
2. Mendota Pool operations calls did not identify groundwater seepage or flow problems.
3. The seepage hotline received two calls, on March 4th regarding R2B-1, and on March 11th regarding an airstrip near river mile 238.5. Both site evaluations determined the planned releases could proceed.
4. Real-time groundwater in Reach 2B and 3 has not risen above identified groundwater level thresholds based on preliminary data.
5. Manually monitored groundwater wells do not show groundwater levels above identified thresholds, with the exception of wells R2B-1 and MW-49B. R2B-1 shows a depth below ground surface of 5.58 ft, with groundwater levels stabilizing (buffer 4-6 feet). The groundwater in MW-49B was measured at 5.79 feet below ground surface (buffer 4-6 feet).
6. Measured losses in Reach 2A are around 160 cfs, but have not yet stabilized.
7. Projected groundwater levels from the upcoming increase in flow are below monitoring thresholds except for wells R2B-1, MW-49B, and MW-55B. R2B-1 shows a predicted depth below ground surface of 4.8 ft (buffer 4-6 feet). MW-49B shows a predicted depth of 4.7 feet (buffer 4-6 feet). MW-55B shows a predicted depth of 6.8 feet (buffer 6-8 feet).
8. No problems have been reported from the LSJLD and they were notified of potential increase or continuance in flows and identified no potential issues.
9. No problems have been reported from CCID or SLCC and they were notified of potential increase or continuance in flows and identified no potential issues.

A seepage hotline call was placed on March 4, 2010 regarding well R2B-1 and a site evaluation was conducted with Reclamation, Columbia Canal Company, and Paramount Farms representatives the same day. The evaluation determined that the planned releases could proceed with close monitoring.

Another seepage hotline call was placed on March 11, 2010 regarding an airstrip near river mile 238.5. A site evaluation was conducted on March 15, 2010. Reclamation will install and monitor two temporary piezometers on the site to verify water level observations and estimate the extent of seepage under the orchard. The evaluation determined that planned releases could proceed.

A third seepage hotline call was placed on March 15, 2010 regarding concerns for future seepage impacts at Fort Washington Beach campground. There are no immediate problems – the call identified issues at 1100 cfs and above. Planned 800 cfs release can occur.

Monitoring Well 49B is in Reach 2A, on the river side of the levee. It is currently within the buffer zone and is predicted to rise to 4.7 feet, which is still within its buffer zone of 4-6 feet. Due to the slope of the water table away from the river, and the short root depth of alfalfa, it is unlikely seepage impacts will occur in the adjacent alfalfa field. However, SJRRP will conduct a site investigation to confirm. The groundwater level is not predicted to exceed the top of the buffer zone. Planned releases can occur.

Monitoring Well 55B is at San Mateo Road. Although it is not currently in the buffer zone, a site investigation and evaluation is planned. The groundwater level is not predicted to exceed the top of the buffer zone. Planned releases can occur.

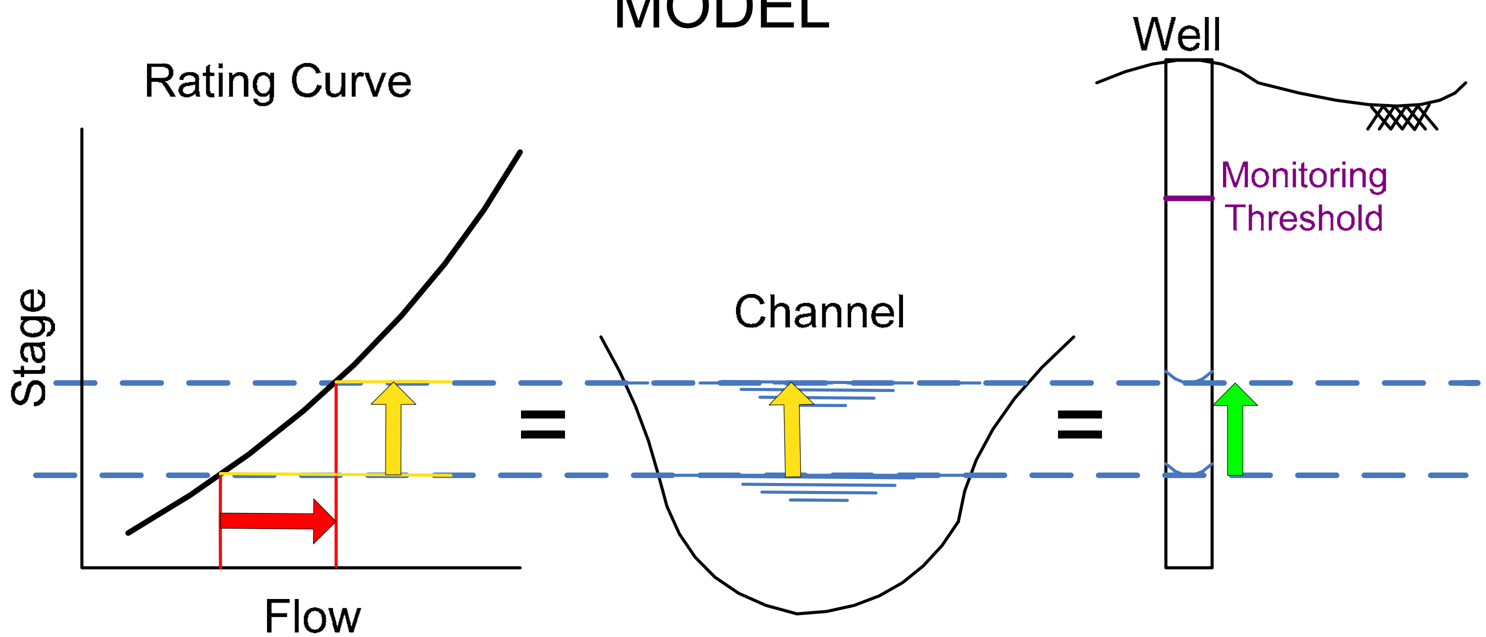
DATA:
Depth versus discharge rating curves along with Exhibit B assumptions and an estimated 300 cfs delivery to Arroyo Canal predicted new groundwater levels. Assumed changes in flows are:

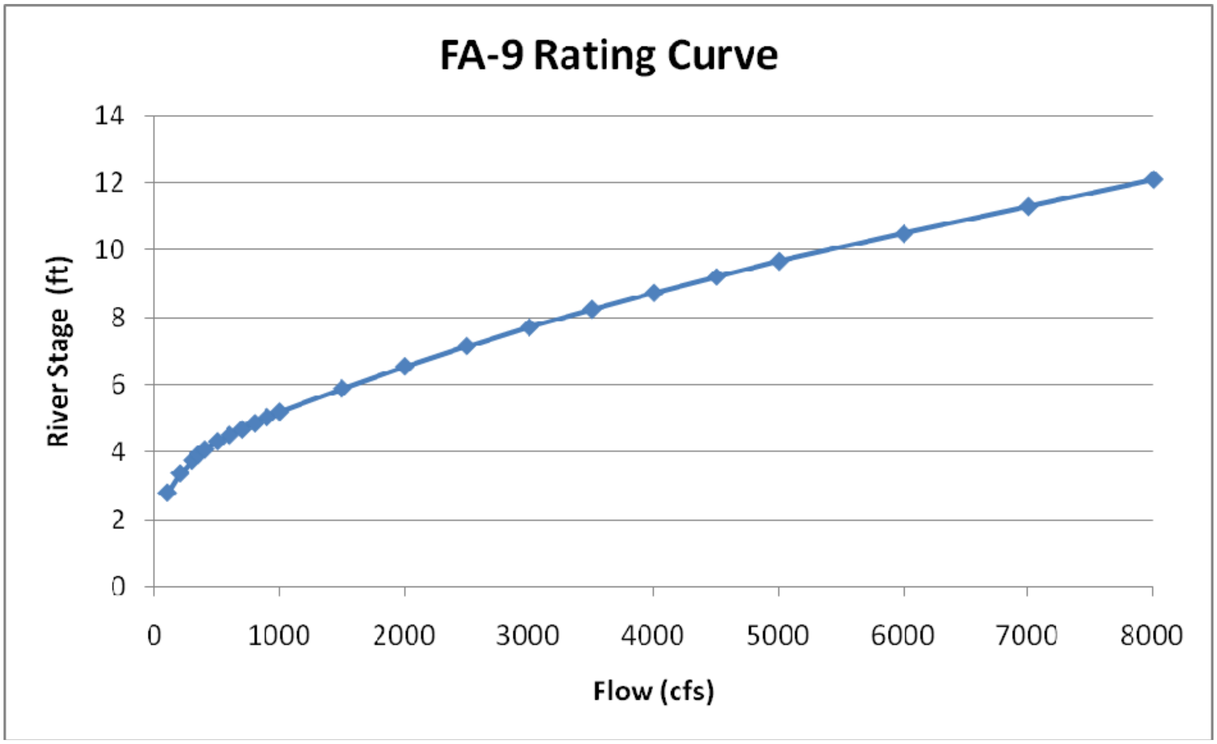
	Current Target (cfs)	Future Target (cfs)	Change (cfs)
Reach 2A	375	675	300
Reach 2B	255	555	300
Reach 3 and 4A	555	855	300

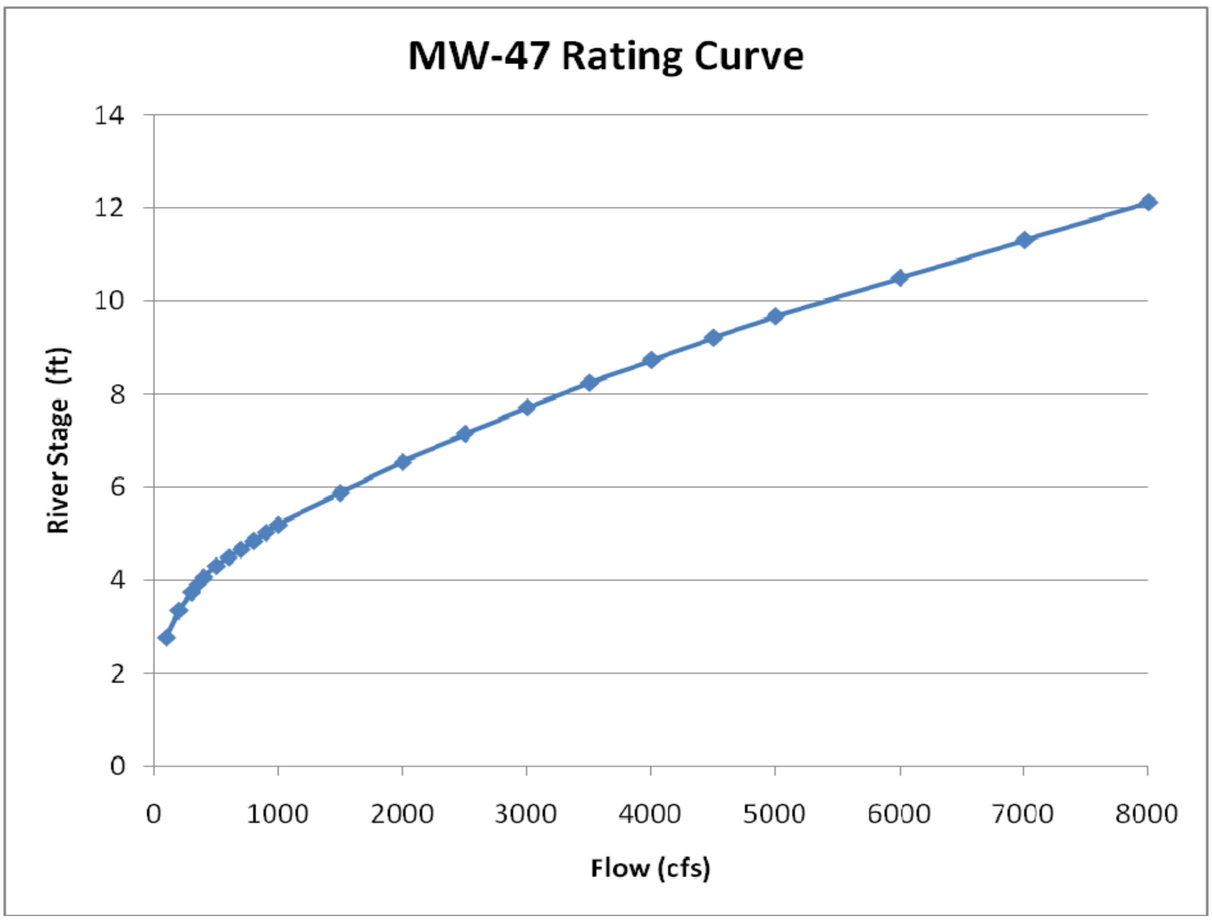
Manual measurements via electronic well sounder are taken weekly and provided along with recent flow data in the Weekly Groundwater Report, available at: http://restoresjr.net/activities/if/index.html. Table 1-1 shows the anticipated rise in groundwater. Subsequent pages contain the rating curves for each of these key wells from the TetraTech hydraulic model.

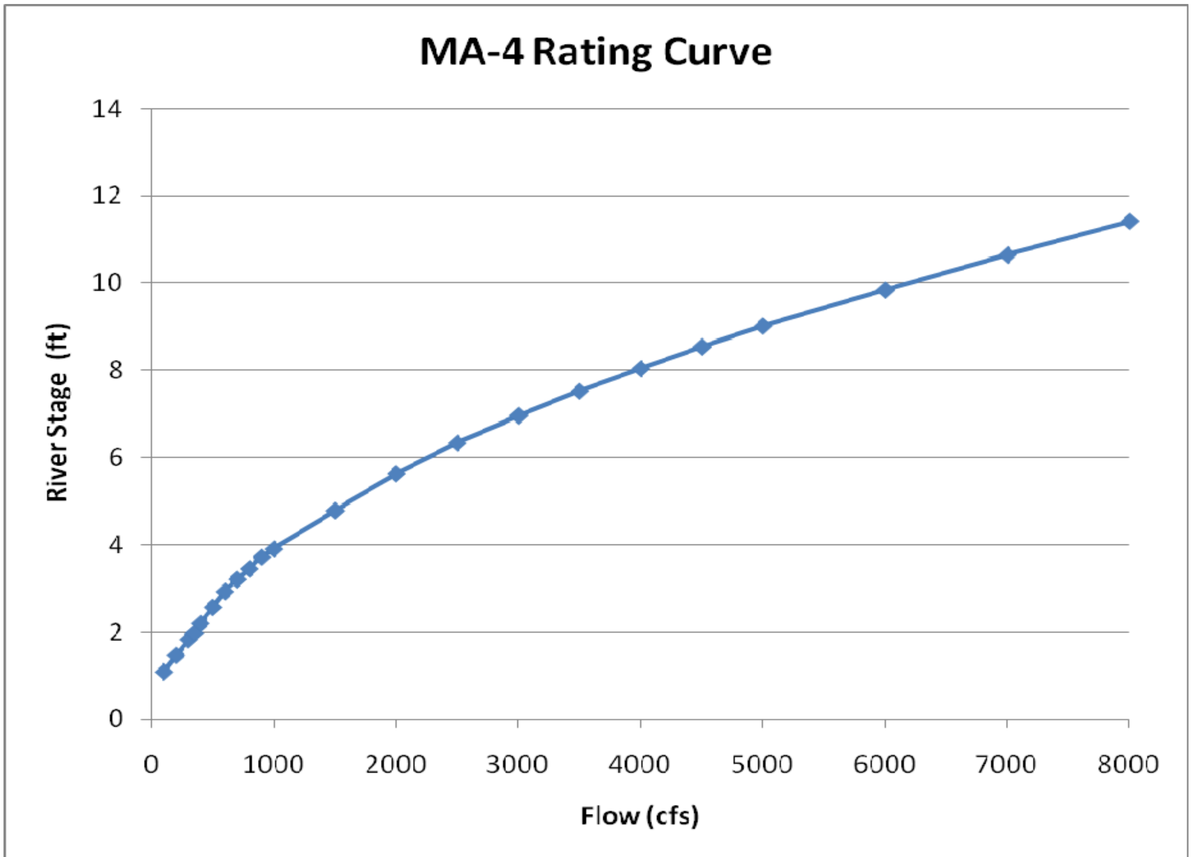
Table 1-1: Predicted Increases in Groundwater Level in Key Wells						
Well_ID	**Site**	**Buffer Zone (ft bgs)**	**Screen Depth (ft bgs)**	**Current GW Depth (ft bgs) as of week of 3/8/2010**	**Predicted Increase in Stage (ft)**	**Anticipated New GW Depth (ft)**
FA-9	Reach 2A – Transect 12 – Left	4-6	12-32	9.53	0.6325	8.9
MW-47	Reach 2A – Transect 12 – Right	6-8	20-40	8.94	0.6325	8.3
MA-4	Reach 2A – Transect 13 – Right	6-8	15-25	11.92	1.0475	10.9
MW-49B	Reach 2A – Transect 13 – Left	4-6	10-20	5.79	1.0475	4.7
MW-54B	Reach 2B – San Mateo Ave. – Right	TBD	TBD	17.2	1.51	15.7
MW-55B	Reach 2B – San Mateo Ave. – Left	6-8	10-15	8.26	1.51	6.8
R2B-1	Reach 2B – Right	4-6	8-11	5.58	0.814	4.8
R2B-2	Reach 2B – Right	4-6	17-20	12.72	0.814	11.9
R3-1	Reach 3 – Right	4-6	9-24	9.63	0.947	8.7
R3-6	Reach 3 – Right	4-6	17-20	9.12	1.068	8.1
R3-7	Reach 3 – Right	3-5	17-20	7.72	1.158	6.6
MW-84	Reach 4A – Highway 152 – Right	4-6	32-52	36.42	1.0715	35.3
MW-87B	Reach 4A – Highway 152 - Left	4-6	TBD	>14 (dry)	1.0715	12.9 to dry

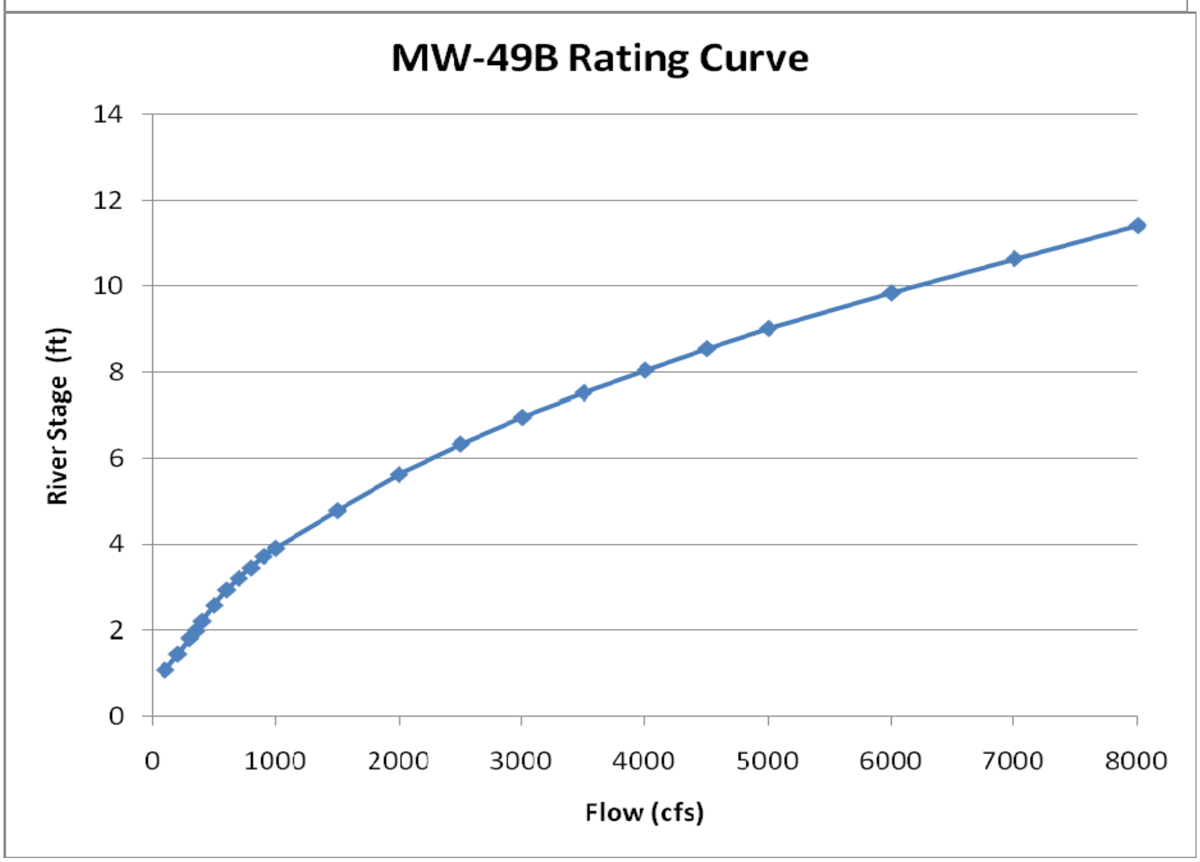
SEEPAGE EVALUATION CONCEPTUAL MODEL

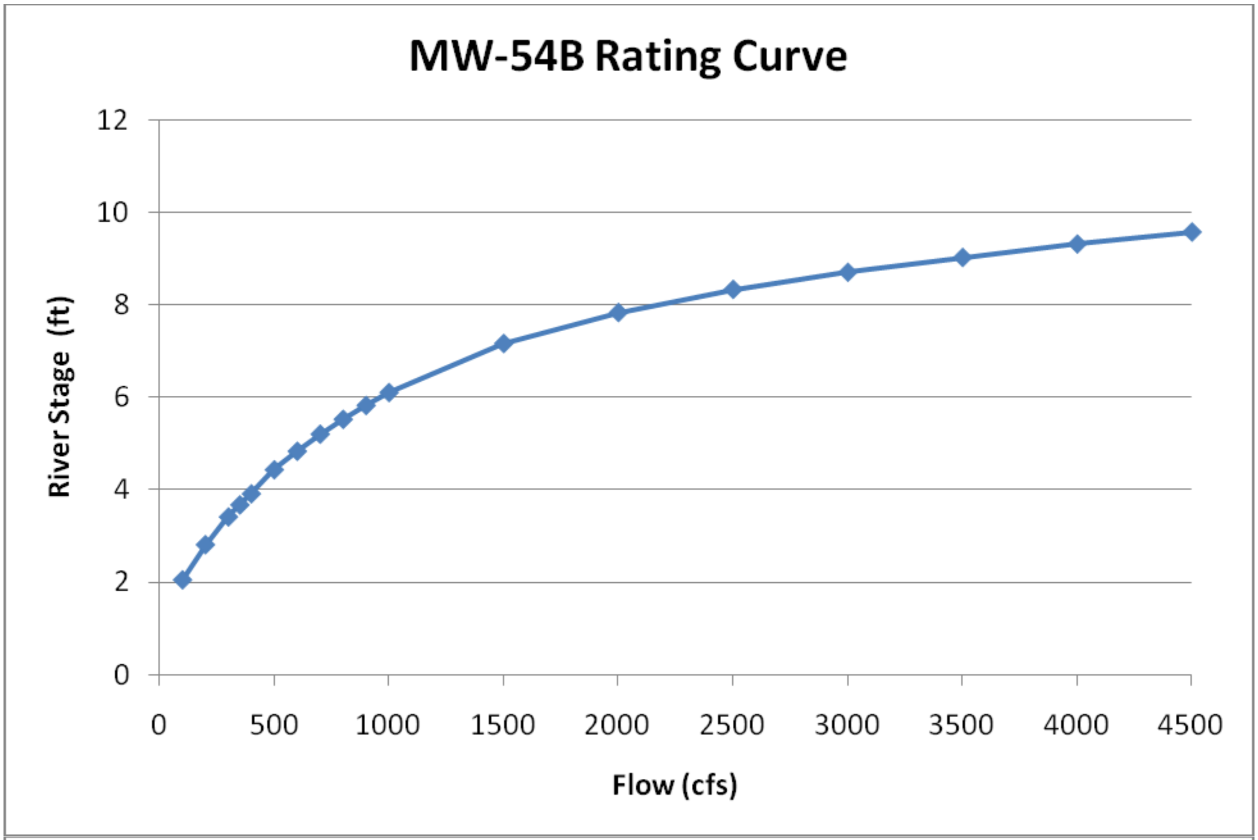


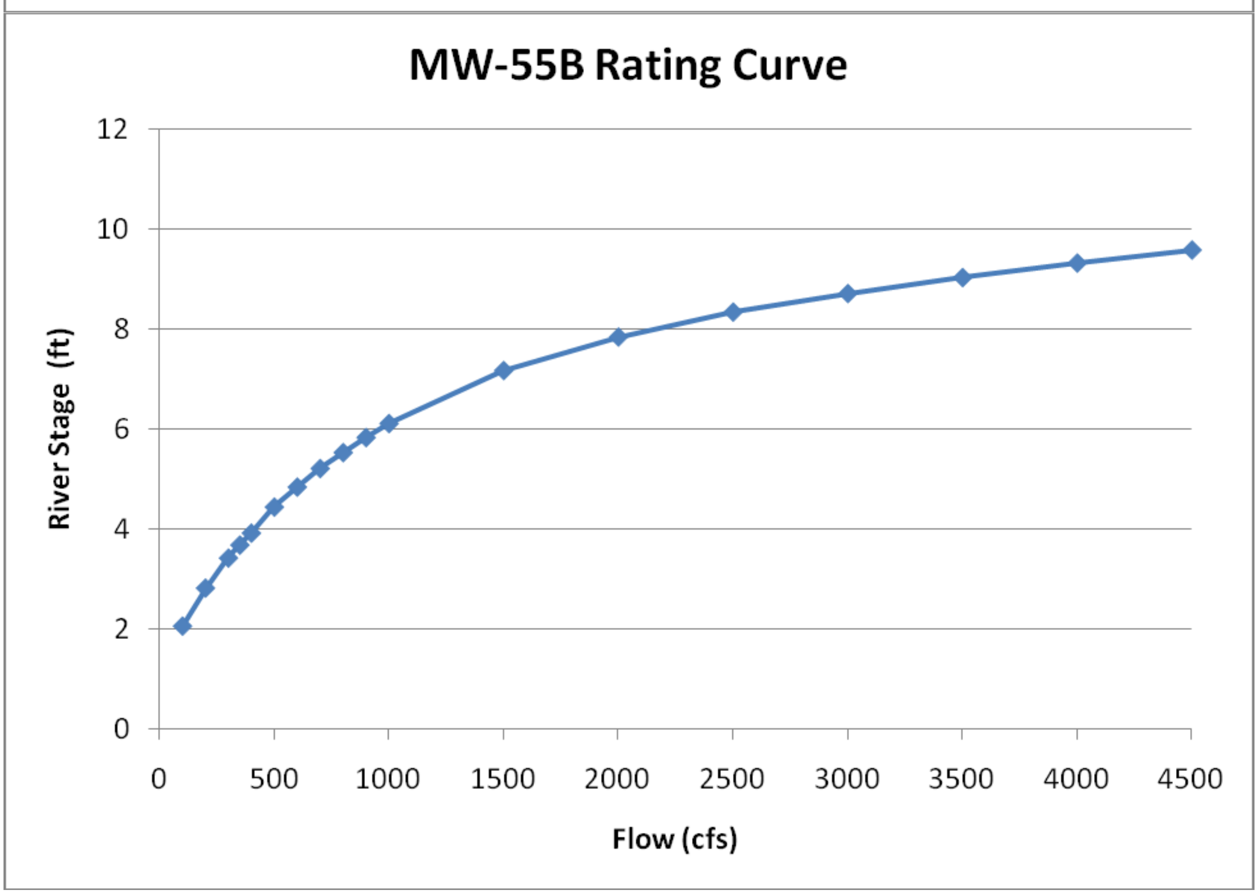

FA-9 Rating Curve
River Stage (ft)
Flow (cfs)
0
2
4
6
8
10
12
14
0
1000
2000
3000
4000
5000
6000
7000
8000

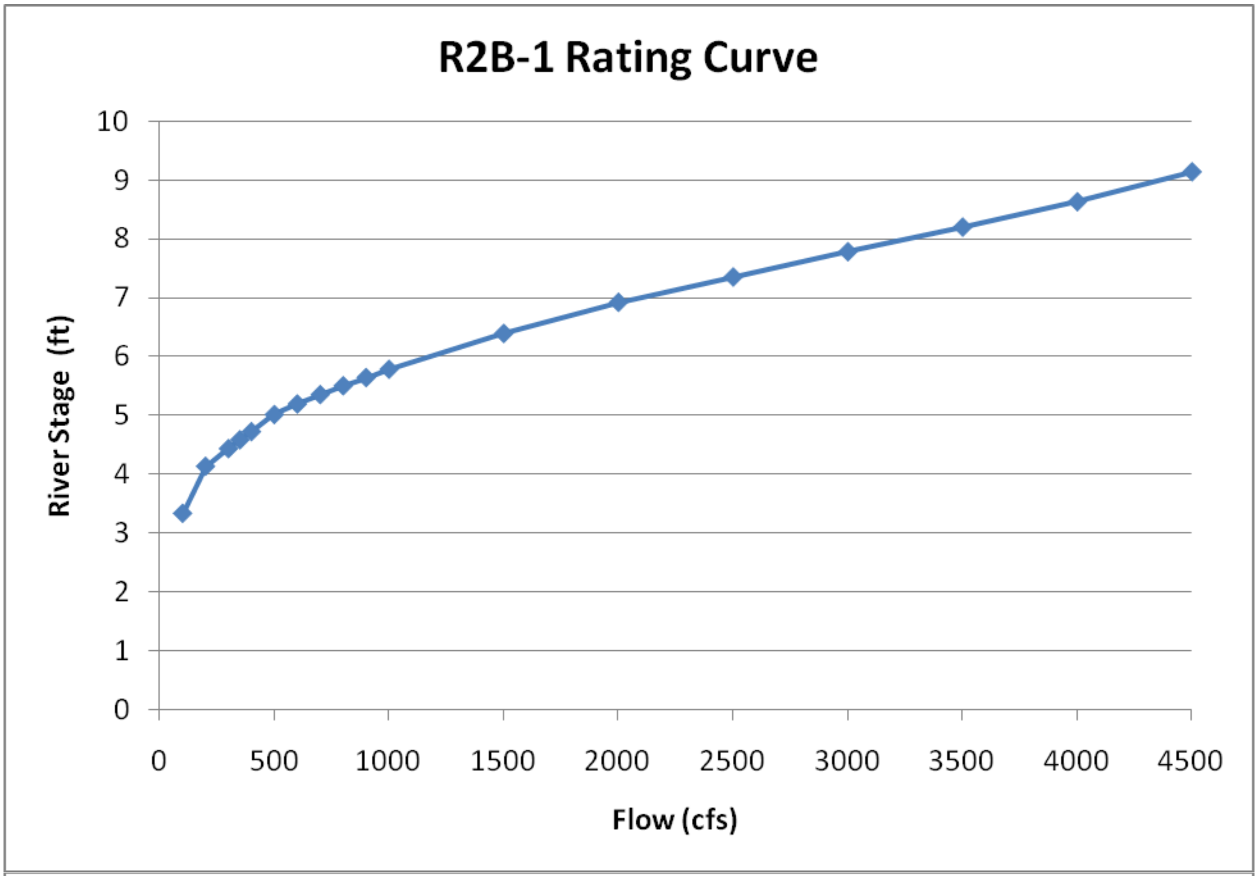

MW-47 Rating Curve
River Stage (ft)
Flow (cfs)
0
2
4
6
8
10
12
14
0
1000
2000
3000
4000
5000
6000
7000
8000

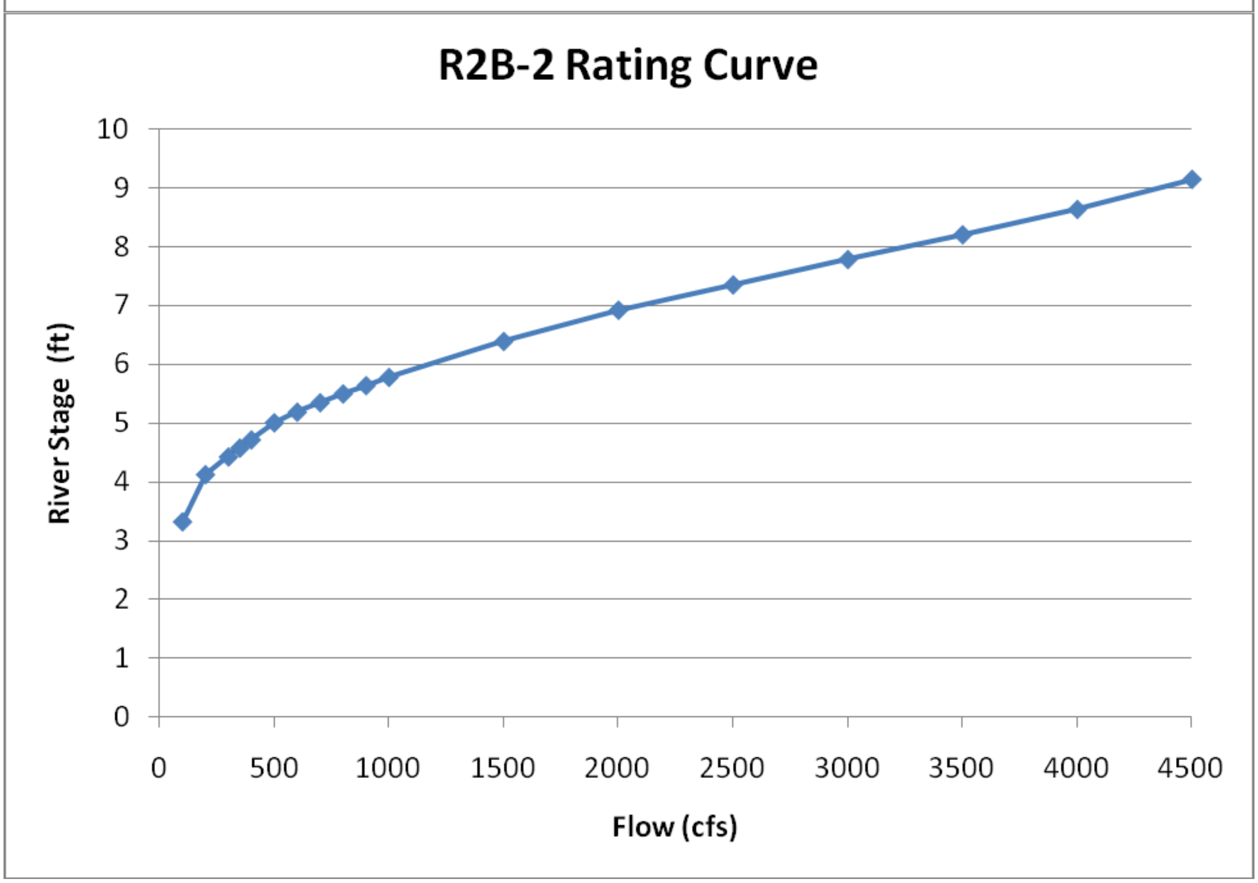

MA-4 Rating Curve
River Stage (ft)
Flow (cfs)
0
2
4
6
8
10
12
14
0
1000
2000
3000
4000
5000
6000
7000
8000

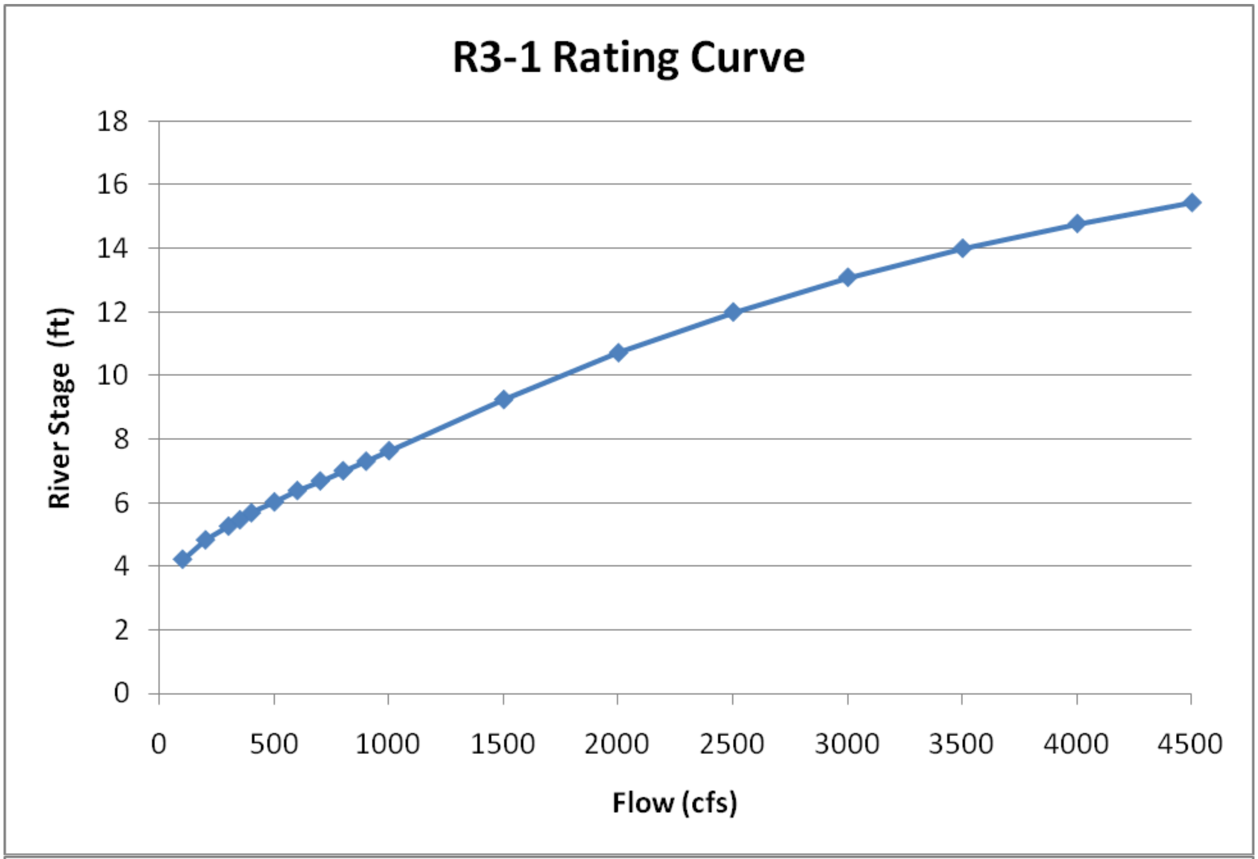

MW-49B Rating Curve
River Stage (ft)
Flow (cfs)
0
2
4
6
8
10
12
14
0
1000
2000
3000
4000
5000
6000
7000
8000

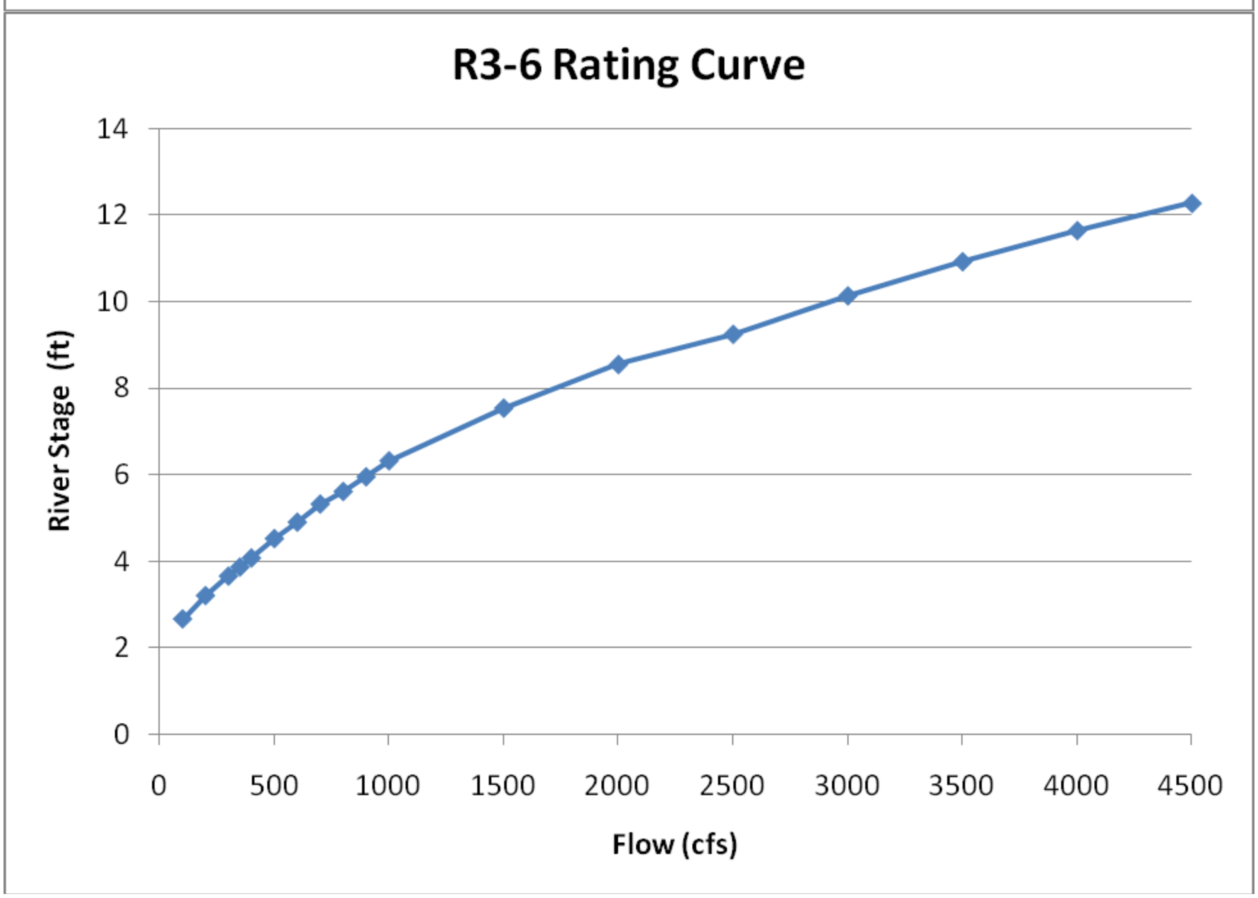

MW-54B Rating Curve
River Stage (ft)
0
2
4
6
8
10
12
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Flow (cfs)

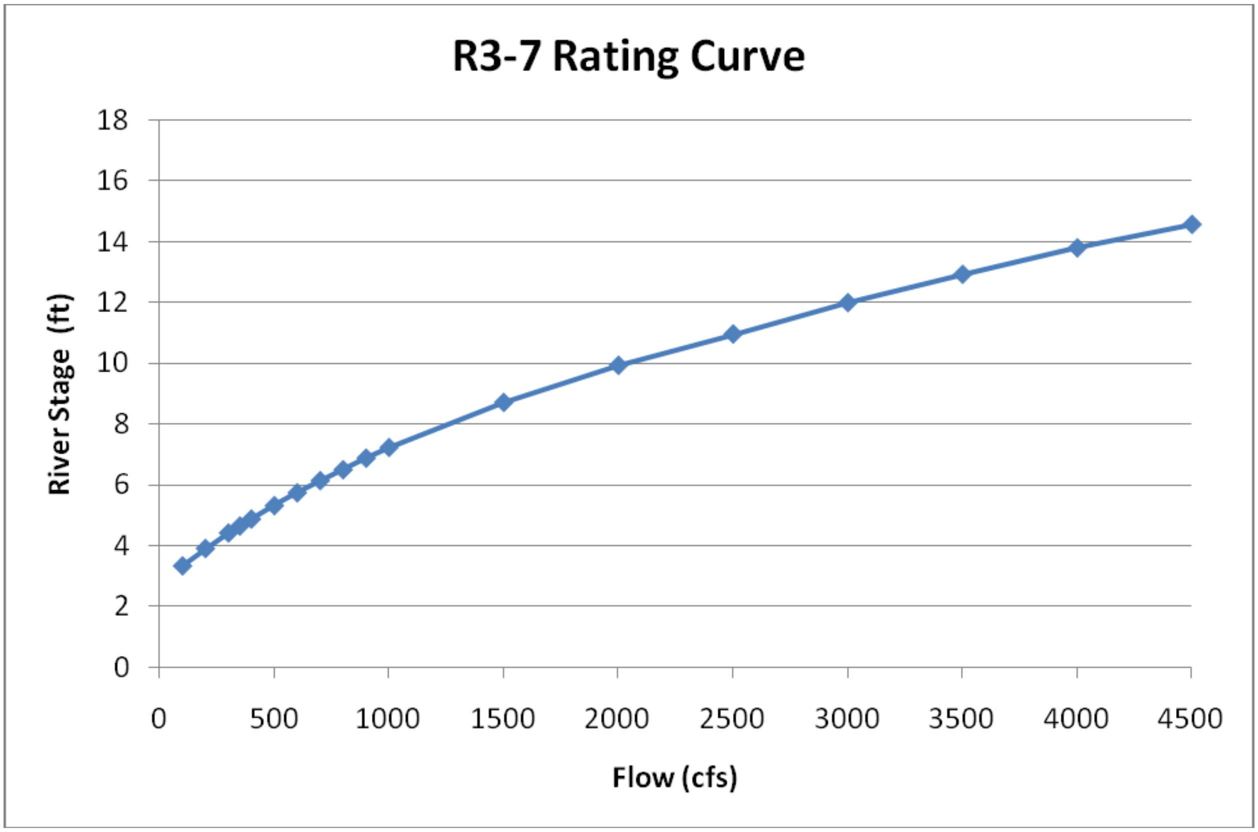

MW-55B Rating Curve
River Stage (ft)
0
2
4
6
8
10
12
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Flow (cfs)

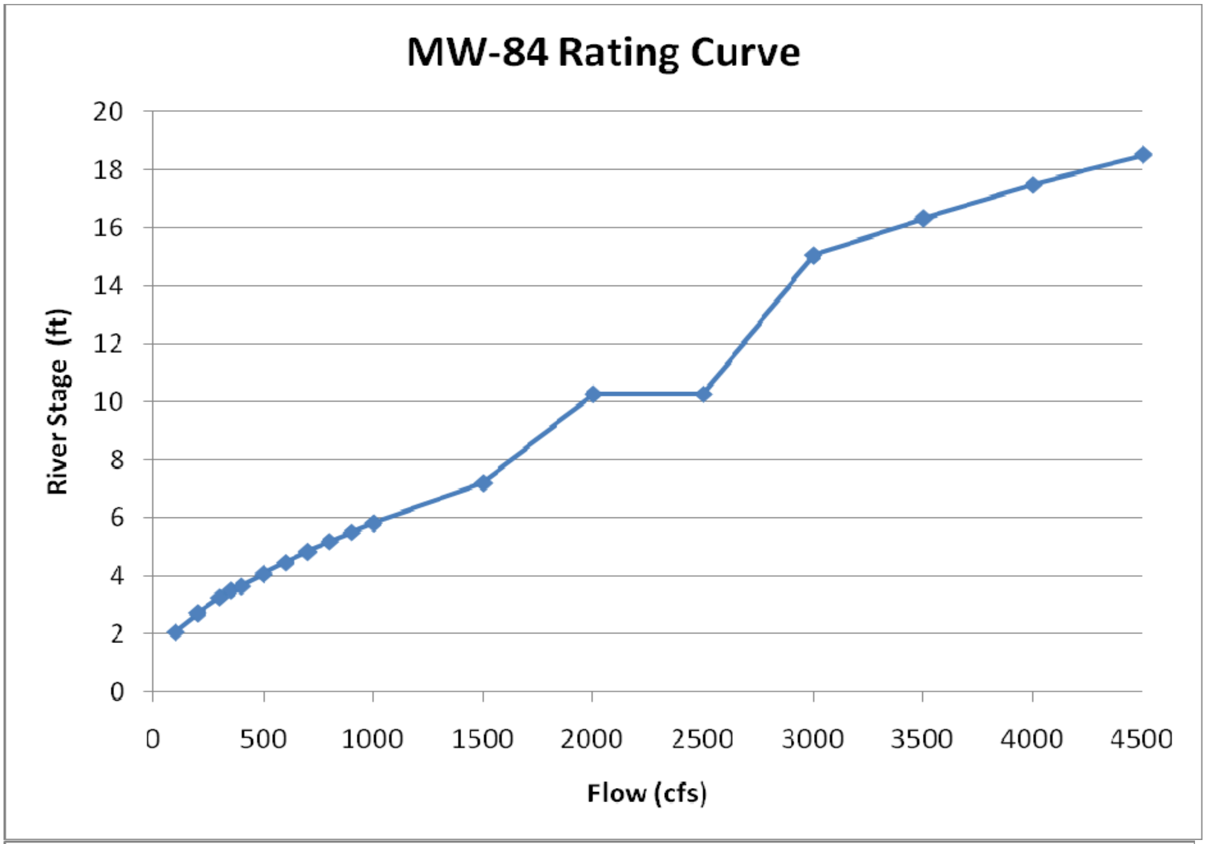

R2B-1 Rating Curve
River Stage (ft)
10
9
8
7
6
5
4
3
2
1
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Flow (cfs)

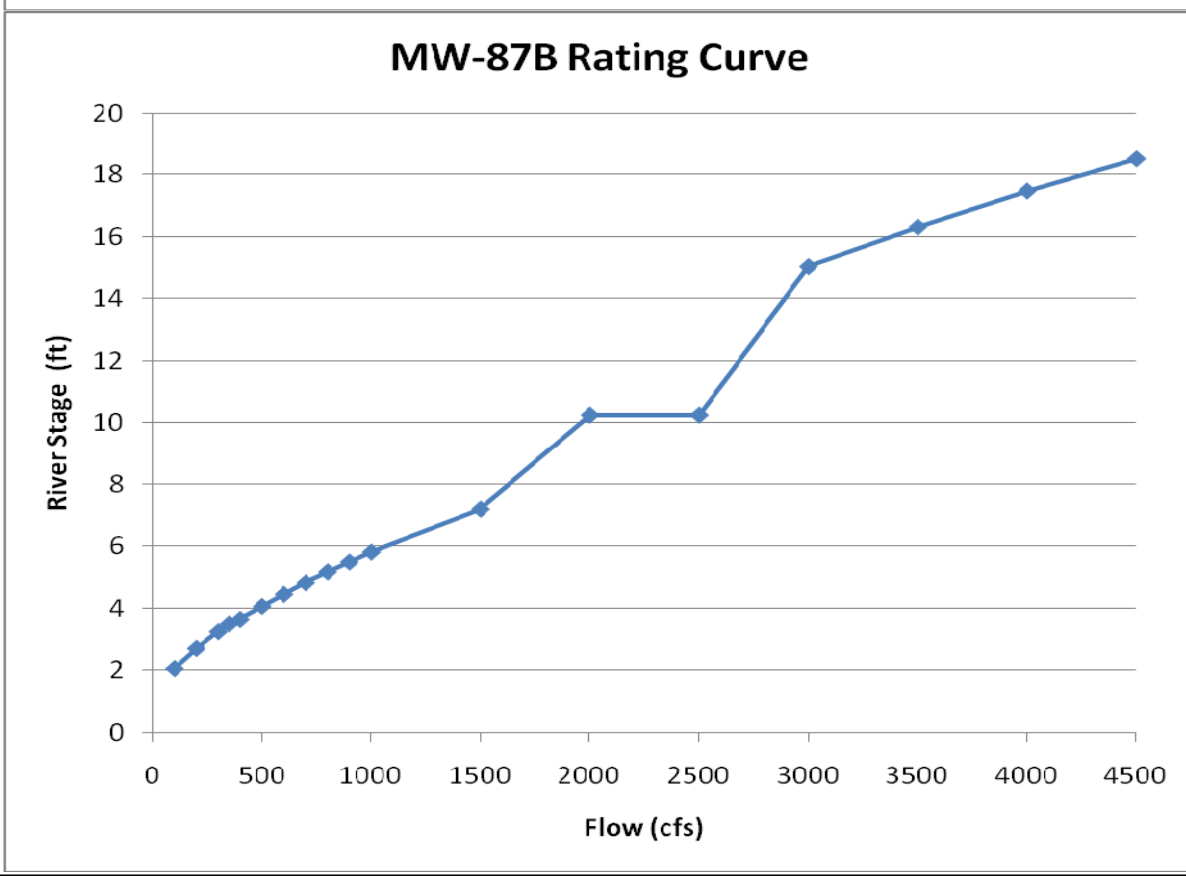

R2B-2 Rating Curve
River Stage (ft)
10
9
8
7
6
5
4
3
2
1
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Flow (cfs)


R3-1 Rating Curve
River Stage (ft)
Flow (cfs)
0
2
4
6
8
10
12
14
16
18
0
500
1000
1500
2000
2500
3000
3500
4000
4500


R3-6 Rating Curve
River Stage (ft)
Flow (cfs)
0
2
4
6
8
10
12
14
0
500
1000
1500
2000
2500
3000
3500
4000
4500


R3-7 Rating Curve
River Stage (ft)
18
16
14
12
10
8
6
4
2
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Flow (cfs)


MW-84 Rating Curve
River Stage (ft)
Flow (cfs)
0
2
4
6
8
10
12
14
16
18
20
0
500
1000
1500
2000
2500
3000
3500
4000
4500


MW-87B Rating Curve
River Stage (ft)
Flow (cfs)
0
2
4
6
8
10
12
14
16
18
20
0
500
1000
1500
2000
2500
3000
3500
4000
4500

SJRRP Seepage Daily Evaluation

March 15, 2010

Based on preliminary data, flow exceeded 475 cfs in Reach 2A as recorded at the Gravelly Ford gaging station on March 13, 2010. Flow exceeded 475 cfs in Reach 3 as recorded at the Mendota Pool gaging station on March 8, 2010. Based on the available information below, no seepage problems are anticipated and Reclamation will continue with the Interim Flow releases as scheduled. Daily evaluations will continue while flow remains above this evaluation threshold.

As of 8:00 AM, March 15, 2010, Reclamation personnel have reported the following:

1. Flows are below known conveyance thresholds (8,000 cfs in Reach 2A, 1,300 cfs in Reach 2B, and 1,300 cfs in Reach 3) based on preliminary real-time data.
2. Mendota Pool operations calls did not identify groundwater seepage or flow problems.
3. The seepage hotline received two calls, on March 4th regarding R2B-1, and on March 11th regarding an airstrip near river mile 238.5. The R2B-1 site evaluation determined flow releases could continue as planned. The river mile 238.5 site evaluation is currently underway.
4. Real-time groundwater in Reach 2B and 3 wells has not risen above identified groundwater level thresholds based on preliminary data.
5. Manually monitored groundwater wells do not show groundwater levels above identified thresholds, with the exception of wells R2B-1 and MW-49B. R2B-1 shows a depth below ground surface of 5.58 ft, with groundwater levels stabilizing (buffer 4-6 feet). The groundwater in MW-49B was measured at 5.79 feet below ground surface (buffer 4-6 feet).
6. Known upstream conditions do not indicate likely seepage impacts.

DATA:

- Most recent stage and flow data: http://restoresjr.net/maps/SJRRarea_Map.html
- Real-time Wells: Three wells in Reaches 2B and 3 are real-time and posted on CDEC. Links are available on restoresjr.net under "Interim Flows Information". http://restoresjr.net/activities/if/index.html
- Weekly Groundwater Report: Manual measurements taken weekly via electronic well sounder of groundwater monitoring wells in Reaches 2A, 2B, 3 and 4 are provided in the Weekly Groundwater Report. http://restoresjr.net/activities/if/index.html
- Well Atlas: Manual measurements for all wells are provided in the well atlas, available on the Interim Flows Information page under "Well Atlas". http://restoresjr.net/activities/if/index.html
- Bench Evaluation: The most recent evaluation for the decision to increase to the next flow bench is available at: http://restoresjr.net/activities/if/index.html under "Flow Bench Evaluation".

BACKGROUND:

Condition 9 of Order Water Right 2009-0058-DWR (Order) for the Water Year 2010 Interim Flows Project requires Reclamation to conduct a daily evaluation of groundwater levels and flow and stage levels when flows are greater than 475 cubic feet per second (cfs) in Reaches 2A and 3 and post the results of this evaluation to a publicly available website.

SJRRP Seepage Hotline Intake Form

Responder Name:

Date and Time Received:

Seepage Report ID Number:

Contact Information

Landowner Name:

Contact Email or Phone:

Date and Time Contacted:

Seepage Location

Address or Parcel:

How best to access site for conducting a site evaluation?

River Mile (if known):

Approximate Distance from SJR:

Proximity to levee toe of most seepage (feet) – or through levee:

Description of Seepage (describe what was observed):

☐ Boils or piping ☐ Erosion on levee ☐ Levee close to overtopping ☐ River stage

☐ Visible standing water ☐ Waterlogged field(s) ☐ Monitoring Well Elevations increase

Description:

[Enter what observations occured and any supporting data that is available.]

When was this seepage first noticed, and how long has it been going on?

SJRRP Seepage Hotline Intake Form

Type of Potential Impact (describe the potential impacts of concern):

☐ Crop impacts ☐ Land Access (roads) ☐ Levee or Structure Integrity

Description:

[Please enter information regarding the extent and magnitude of anticipated impacts including supporting data such as EM probes, hand augers, crop records, etc.]

Interim Flow Relationship (describe why the impact is a result of the SJRRP flows.)

☐ River Stage ☐ Drainage ☐ Canals ☐ Irrigation ☐ Flood Operations

Description:

[Please include recent land-use practices in the area as well as any efforts to reduce or avoid adverse impacts]

Has a SJRRP monitoring well been requested? ☐ Yes ☐ No

Has the parcel been identified as at risk? ☐ No ☐ At a Public Meeting
☐ In EIS/R Comments ☐ Personal Communication with SJRRP Staff

Description: *[Insert text here describing when and with what language the parcel was identified as at risk]*

Immediacy of Response Needed (identify the timeframe for decision making)

☐ Impacts Occurred ☐ Levees at risk ☐ Impacts are imminent ☐ Adjust Future Flows
☐ Potential Future Impacts

Description:

Please attach additional comments as necessary.

SJRRP Seepage Site Visit Form

Seepage Report ID Number:

Date and Time of Site Evaluation:

Names of personnel attending site evaluation, agencies belonging to and contact info (phone):

Landowner Name, phone, contact info:

Seepage Location

Address or Parcel:

How easy was access? How should it be accessed in the future?

River Mile (if known):

Approximate Distance from SJR:

Proximity to levee toe of most seepage (feet) – or through levee:

GPS Coordinates tracing Seepage Boundaries:

If possible, please attach an aerial map and mark seepage extent on it.

Immediacy of Response Needed (identify the timeframe for decision making)

☐ Levee Failure ☐ Imminent ☐ Adjust Future Flows ☐ Impacts Occurred

Description:

SJRRP Seepage Site Visit Form

Description of Seepage (describe what was observed):

☐ Boils or piping ☐ Erosion on levee ☐ Levee close to overtopping ☐ River stage

☐ Visible standing water ☐ Waterlogged field(s) ☐ Monitoring Well Elevations increase

Description (what observations occurred and what supporting data is available):

Type of Potential Impact (describe the potential impacts of concern):

☐ Crop impacts ☐ Land Access (roads) ☐ Levee or Structure Integrity

Description (extent and magnitude of anticipated impacts including supporting data such as EM probes, crop records, etc.):

Interim Flow Relationship (describe why the impact is a result of the SJRRP Flows. Include recent land-use practices in the area as well as any efforts to reduce or avoid adverse impacts)

☐ River Stage ☐ Drainage ☐ Canals ☐ Irrigation ☐ Flood Operations

Description:

Do you recommend a particular response action to reduce or avoid impacts? Explain.

Is follow-up needed to perform a site evaluation and develop a long-term project? Explain.

SJRRP Seepage Site Visit Form

Photo Log

Please include a Photo number or ID, the time (and date, if different from Site Evaluation date) the photo was taken, the location the photo was taken from and a description of the image subject and important points shown in it.

1)

2)

3)

4)

5)

6)

7)

8)

9)

10)

11)

12)

Please attach additional pages as needed to describe all photos taken, or to add additional information, comments, records or supporting data to the Site Evaluation.

SJRRP Seepage Response Action Form

Date and Time of Response:

Address or Parcel:

Seepage Report ID Number:

Relevant Data:

Groundwater Observations:

Site Evaluation:

Landowner Input:

Comments:

SJRRP Seepage Response Action Form

Action:

☐ Planned Releases can occur ☐ Increased Monitoring

☐ Adjust local flow/conceptual model ☐ Adjust threshold

Flow Response Actions - Adjust Future Flows

☐ Restrictions on Maximum Release ☐ Restrictions on ramping rates and duration

☐ Reduction of Restoration Flow releases at Friant Dam ☐ Set Operational Criteron

Flow Response Actions - Immediate Action

☐ Emergency Measures (sandbagging, riprap, etc)

☐ Reduction of Restoration Flow releases at Friant Dam

☐ Redirection of flows at Chowchilla Bifurcation Structure (reduces impacts in Reach 2B on)

☐ Delivery of flows to Exchange Contractors at Mendota Pool (reduces impacts in Reach 3 on)

☐ Delivery of flows to Exchange Contractors and Refuges at Sack Dam (reduces impacts in Reach 4A and downstream)

Comments:

Follow-Up:

☐ Restrictions on Releases ☐ Initiate Site Evaluation for Projects

Comments:

Appendix F. Monitoring Well Network Plan and other Seepage-Related Monitoring

This appendix describes a monitoring plan for measuring and/or observing seepage-related effects associated with implementation of Interim and Restoration Flows. High-quality data inform determining, understanding and documenting the effects of these Flows on groundwater levels, root-zone salinity, levees, and crop health conditions in the vicinity of the San Joaquin River/bypass system. This document focuses on the 150-mile reach of the San Joaquin River between Friant Dam and the confluence with the Merced River.

1 Groundwater Levels

A variety of existing and new monitoring wells will be used to collect data to document seepage-related effects from Interim and Restoration Flows, improve simulation models used to help anticipate and respond to these effects, and to establish and monitor thresholds for avoiding seepage-related impacts. Water levels in many of these wells will be measured electronically at a high frequency (e.g., hourly), and manual measurements will be made periodically to assure the quality of data recorded by the instruments. Generally monthly groundwater level measurements will be made, with more frequent weekly measurements made in priority wells. Several key wells will be telemetered, transmitted real-time to a central database and posted on CDEC, with links from the SJRRP groundwater monitoring page. Following is a description of the three types of monitoring wells that will be used and real-time wells established to date.

Please see the Monitoring Well Atlas available and updated monthly on the SJRRP groundwater monitoring page to view the complete monitoring well network and a description of each well, along with measurements made to date.

2 Cross-River Monitoring Well Transects

Multi-depth monitoring well transects that cross the San Joaquin River will be used to measure the near-river effects of Interim and Restoration Flows. Specifically, these wells will measure and/or allow calculation of the following:

- Depth to the water table and water-table elevation;
- The horizontal hydraulic gradient (slope) toward, or away from, the river; and
- The vertical hydraulic gradient (indicating upward or downward flow).

The design for the cross-river well transects includes transects spaced at about every 8–10 miles along the river from Friant Dam to the confluence with the Merced River. Figure F- 1 shows cross-river transect wells installed thus far by the SJRRP and stakeholders; the Monitoring Well Atlas includes additional information for these wells.

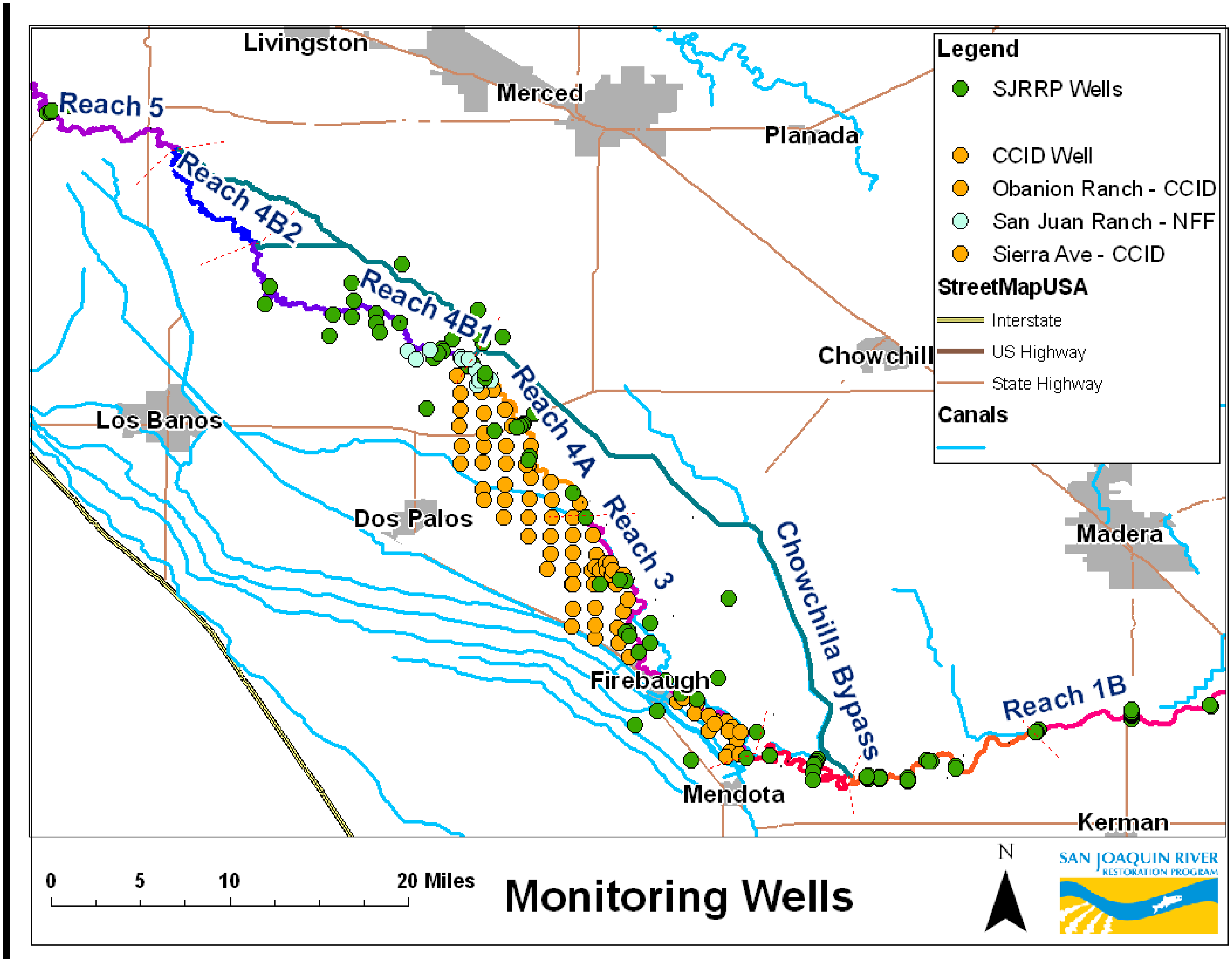


Figure F- 1: Groundwater Monitoring Well Network

Within each transect 4–6 shallow wells will be paired with 1–2 deeper wells (Figure F- 2). These wells will range in depth from about 15–80 ft. A staff gage will be co-located in the river at each transect; most or all staff gages will be instrumented to record river stage at the same time interval as groundwater levels.

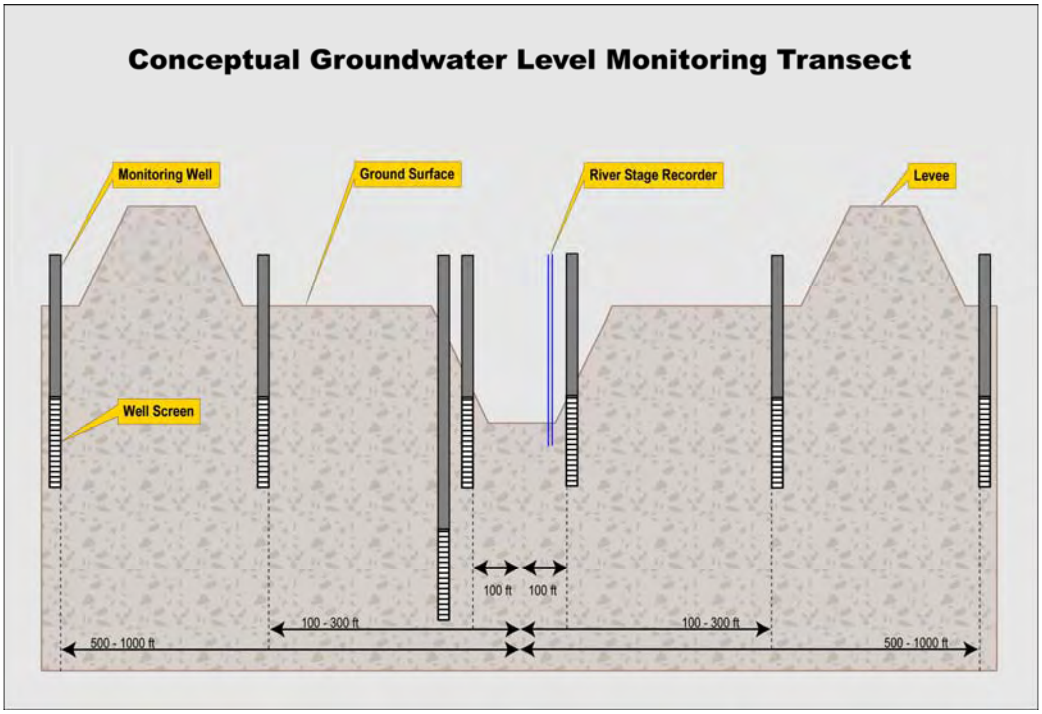


Figure F- 2: Conceptual design of cross-river monitoring well transect.

2.1 Stakeholder Monitoring Wells

A subset of existing, mostly shallow monitoring wells owned by Central California Irrigation District (CCID) are instrumented to record hourly water-level response to Interim and Restoration flows in off-river areas adjacent to the river. The SJRRP also makes manual measurements in a subset of CCID wells. The likely areal extent of seepage-related effects is currently unknown. Monitoring of off-river wells will improve this understanding and, in conjunction with regional simulation results, will indicate whether a narrowing or widening of the groundwater-level monitoring corridor will be necessary for the future.

2.2 Drive-Point Wells

Drive-point wells have been and will continue to be installed in areas adjacent to the river where the water table is within about 10 feet of the land surface, pending landowner/stakeholder agreements. Like the existing off-river monitoring wells, these drive-point wells would allow measurement of water-level response to Interim and Restoration flows in areas adjacent to the river to inform the likely areal extent of seepage-related effects. Drive-point wells also can be installed near the river in areas inaccessible to large drilling rigs. Water levels will be recorded manually on approximately a monthly or weekly schedule, and a subset of drive-point wells will be instrumented to record high-frequency (e.g., hourly) measurements. Figure F- 1 shows locations of all SJRRP and stakeholder monitoring wells, including drive-point wells installed thus far.

3 Priority Wells

A subset of SJRRP transect, drive-point and stakeholder wells track well with the groundwater response to San Joaquin River flows and are appropriate to use for operations. The SJRRP makes weekly measurements in these wells and posts their measurements at the end of each week to the SJRRP website. Figure F- 3 below shows the locations of priority wells. Figure F- 4 shows the weekly groundwater report available on the SJRRP website. The SJRRP evaluates the most recent measurement in priority wells when conducting a Flow Bench Evaluation or Daily Seepage Evaluation.

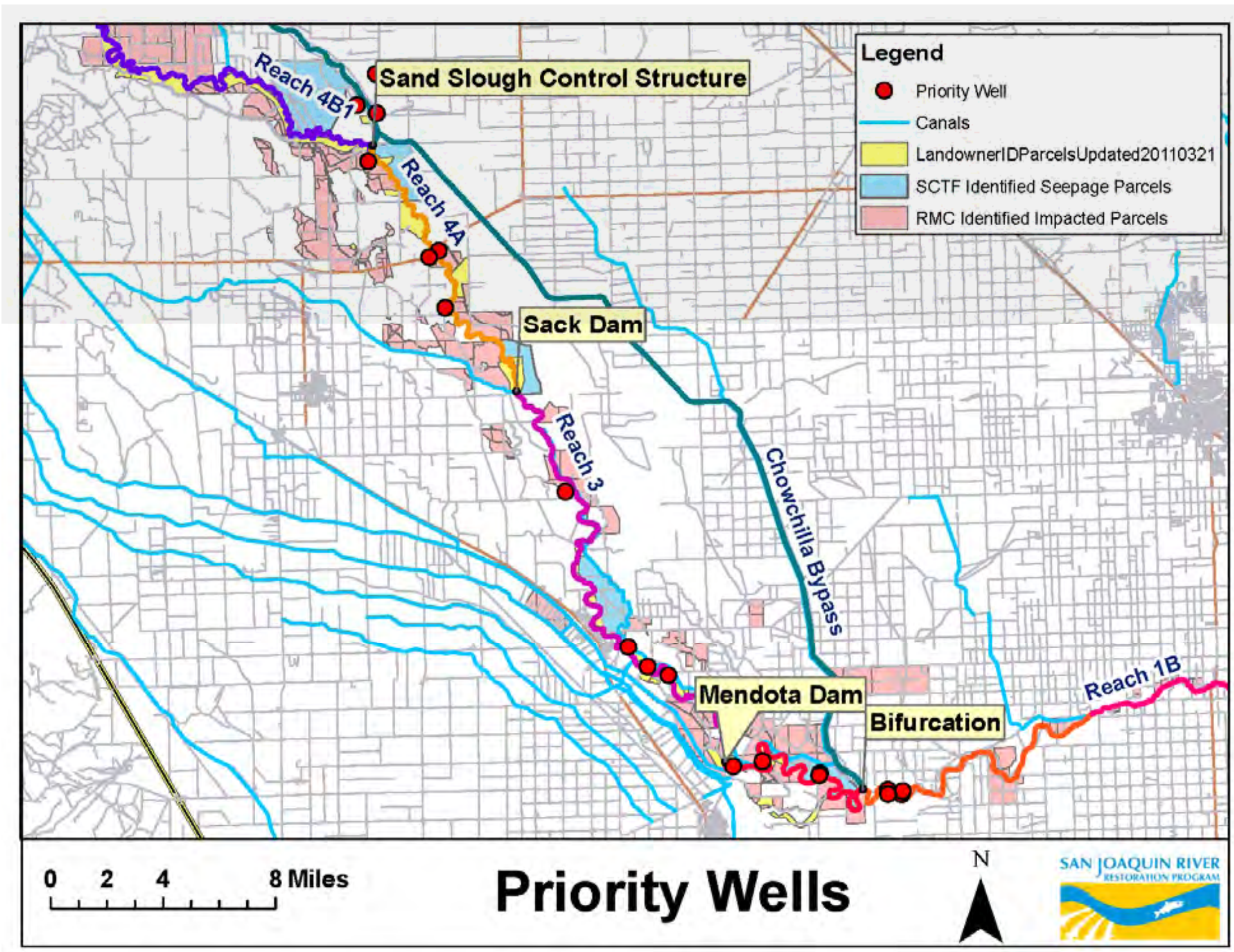


Figure F- 3: Priority Well Locations

SAN JOAQUIN RIVER RESTORATION PROGRAM
Weekly Groundwater Report - Week Ending March 26, 2011

Well ID	Date	DTW_GS (ft)	Buffer Zone (ft BGS)	River Mile	Bank
REACH 2A					
FA-9	3/21/2011	7.32	4-6	218.2	Left
MW-47	3/21/2011	7.24	6-8	218.2	Right
MA-4	3/21/2011	10.78	6-8	217.2	Right
MW-49B	3/21/2011	3.98	4-6	217.2	Left
REACH 2B					
MW-54B	3/21/2011	12.50	TBD	211.8	Right
MW-55B	3/21/2011	6.73	6-8	211.8	Left
R2B-1	3/23/2011	5.13	4-6	207.1	Right
R2B-2	3/23/2011	11.34	4-6	205.1	Right
REACH 3					
R3-5	3/23/2011	10.57	TBD	197.8	Right
R3-6	3/23/2011	9.62	4-6	196.6	Right
R3-7	3/23/2011	8.40	3-5	199.2	Right
MW-75	3/24/2011	5.97	6-8	187.0	Left
REACH 4A					
MW-84	3/23/2011	18.85	4-6	173.9	Right
MW-87B	3/23/2011	Dry	4-6	173.9	Left
MW-89	3/24/2011	10.12	6-8	175.4	Right
MW-92	3/24/2011	6.85	TBD	170.0	Left
REACH 4B					
MW-90	3/25/2011	NR	TBD	168.0	Right
MW-94	3/25/2011	NR	TBD	166.7	Right
MW-95	3/25/2011	NR	TBD	166.7	Right

PRELIMINARY SAN JOAQUIN RIVER FLOW DATA

Location	Station_ID	Reach	River Mile	Flow (cfs)	Date	Time
Friant Dam	MIL	1	267.6	4556	3/24/2011	24 hr Avg.
Gravelly Ford	GRF	2A	227.6	3110	3/24/2011	1200
SJR below BIF	SJB	2B	216	405	3/24/2011	1200
SJR near Mendota	MEN	3	202.1	980	3/24/2011	1200
SJR near Dos Palos	SDP	4	181.5	389	3/24/2011	1200
SJR at Fremont Ford	FFB	5	125.1	6440	3/24/2011	1200
SJR above Merced River	11273400	5	118.3	2990	3/24/2011	0

REAL TIME GROUNDWATER MONITOR WELL INFORMATION

Well ID	CDEC_ID	Weblink
MW-54B	W54	http://cdec.water.ca.gov/cgi-progs/queryF?s=w54
R3-7	R37	http://cdec.water.ca.gov/cgi-progs/queryF?s=r37
MW-75	W75	http://cdec.water.ca.gov/cgi-progs/queryF?s=w75
MW-89	W89	http://cdec.water.ca.gov/cgi-progs/queryF?s=w89
MW-92	W92	http://cdec.water.ca.gov/cgi-progs/queryF?s=w92

NOTE: All data are provisional and are subject to revision

TBD=To be determined NR=No Reading (Well Inaccessible)
Buffer Zone as defined in the Draft SJRRP Seepage Mgt Plan (ft BGS= feet below ground surface)
DTW_GS = Depth to Groundwater from Ground Surface
CDEC = California Data Exhange Center
BRT=Below Rating Table
ART=Above Rating Table

Figure F- 4: Weekly Groundwater Report

4 Real-Time Wells

Five wells in the Restoration area currently are equipped for real-time transmission of water-level data to a central database. Data from these wells are served to the CDEC website. These real-time data are available to the public on this site, and will be used by the SJRRP to help make water management decisions during Interim and Restoration Flows. As additional wells are installed and more is learned during these Flows, more real-time sites will be established.

Figure F- 5: Real-time monitoring well

Well and data logger are below-ground in a vault (foreground). Power is supplied by a solar panel on the pole, and data are transmitted via satellite using the antenna on top of the pole.

5 Shallow Groundwater and Soil Salinity

Potential seepage-related rising of the shallow water table may cause salinity to increase; therefore, it is an important component of the monitoring plan. Shallow groundwater conditions cause salinity to increase in the shallow subsurface by way of evapotranspiration. Plant transpiration, or water consumption, increases salinity by selectively filtering various salts from groundwater and irrigation water prior to consumption. Evaporation occurs not only from plant and land surfaces, but also from the subsurface, leaving behind most of the salts. This subsurface evaporation has been estimated to occur to a depth of 7 feet below land surface west of the San Joaquin River in the southern part of the Restoration Area (Belitz and others, 1993).

Shallow subsurface salinity likely will be monitored using the two methods described below, though other methods may be employed.

5.1 Soil-Water Extracts

Analyses of soil-water extracts will be used to define baseline conditions in shallow groundwater areas potentially susceptible to seepage effects and to check the calibration of meters to be used thereafter to detect changes in salinity (described below). A soil-water extract is defined herein as a *saturation extract*, or the solution extracted from a saturated soil paste prepared by adding water to the soil until it reaches a defined consistency.

Soil cores of the upper 30 inches, at a minimum, will be collected in shallow groundwater areas, and the extractions will be done in a laboratory. The electrical conductivity of the soil-water extracts (ECe), which is a standard measurement in salinity/crop response (ASCE Manuals and Reports on Engineering Practice No.71: Agricultural Salinity Assessment and Management, pg 271), will then be measured. Because this is a labor-intensive process, most of the salinity monitoring will thereafter be done using electromagnetic surveys, described below.

5.2 Electromagnetic Surveys

Electromagnetic (EM) surveys will be conducted using EM meters capable of measuring the bulk electrical conductivity (EC) of various depth intervals in the soil column. Initially, EM measurements will be taken simultaneously with soil cores used for ECe analyses. The EM-derived EC will be compared to the ECe from soil-water extracts, and the EM meters will be calibrated to match the ECe. Thereafter, the EM meters can be used to rapidly measure changes in root-zone salinity at greatly reduced cost. Occasional soil cores will be collected to obtain ECe values for re-evaluation of meter calibration.

The above application of EM surveys focuses on the upper 30 inches of the soil profile, an important part of the root zone. However, much can be learned by looking deeper. A normal salinity profile is characterized by increased salinity with depth. An inverted salinity profile, in which the soil surface layers are more saline than deeper in the root zone, is indicative of root-zone salinization likely caused by a shallow water table. Multiple depth intervals will therefore be measured using the EM meters to detect development or worsening of inverted salinity profiles.

6 Visual Observations

Visual observations associated with seepage effects from Interim or Restoration Flows may fall into many categories, but two primary categories of observations are anticipated: those having to do with seepage through levees, and those involving deterioration of crop health. Landowners may contact the SJRRP through the Seepage Hotline via phone or email to report observations.

Standing water, boils, and piping are all signs of seepage through levees, and may compromise the short- or long-term integrity of the levee.

Landowner reports of deteriorating crop health may indicate an excessive rise in the water table and/or increasing root-zone salinity. A Seepage Hotline call reporting this would trigger a site visit and a response action as described in Sections 8 and 9 of the main body.