Appendix E. Monitoring Network

This appendix describes a monitoring plan for measuring and/or observing seepage-related effects associated with implementation of 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 appendix focuses on the 150-mile portion of the San Joaquin River between Friant Dam and the confluence with the Merced River.

E.1 Groundwater Levels

A variety of monitoring wells have been, and will continue to be, used to collect data to document seepage-related effects from 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. Additional monitoring wells will also be installed as needed to supplement existing datasets. Groundwater levels in many of these wells will be measured electronically at a high frequency (hourly) and manual measurements will be made periodically to assure the quality of data recorded by the instruments. Generally weekly/monthly manual 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 website (restoresjr.net). A description of the three types of monitoring wells that will be used and real-time wells established to date is provided below.

The *Monitoring Well Atlas* available and updated periodically on the SJRRP website (restoresjr.net) describes the locations of the wells in the SJRRP monitoring well network. Attachment 1 to Appendix E provides the SJRRP's groundwater level monitoring and QA/QC procedures.

E.1.1 SJRRP-Installed Wells

The typical construction of SJRRP-installed monitoring wells is shown in Figure E-1. The construction of specific wells may vary depending on site-specific needs. For example, flush-mounted, traffic-rated vaults may be required for wells located within a roadway.

Figure E-1.
Typical Construction for SJRRP-Installed Monitoring Wells

Drive-point wells have been and will continue to be installed in areas adjacent to the river where the water table is typically within about 10 feet of the land surface, pending landowner/stakeholder agreements. Similar to the existing off-river monitoring wells; these drive-point wells would allow measurement of water-level response to 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 (hourly) measurements. Figure E-2 shows locations of the existing SJRRP and stakeholder monitoring wells, including drive-point wells installed thus far.

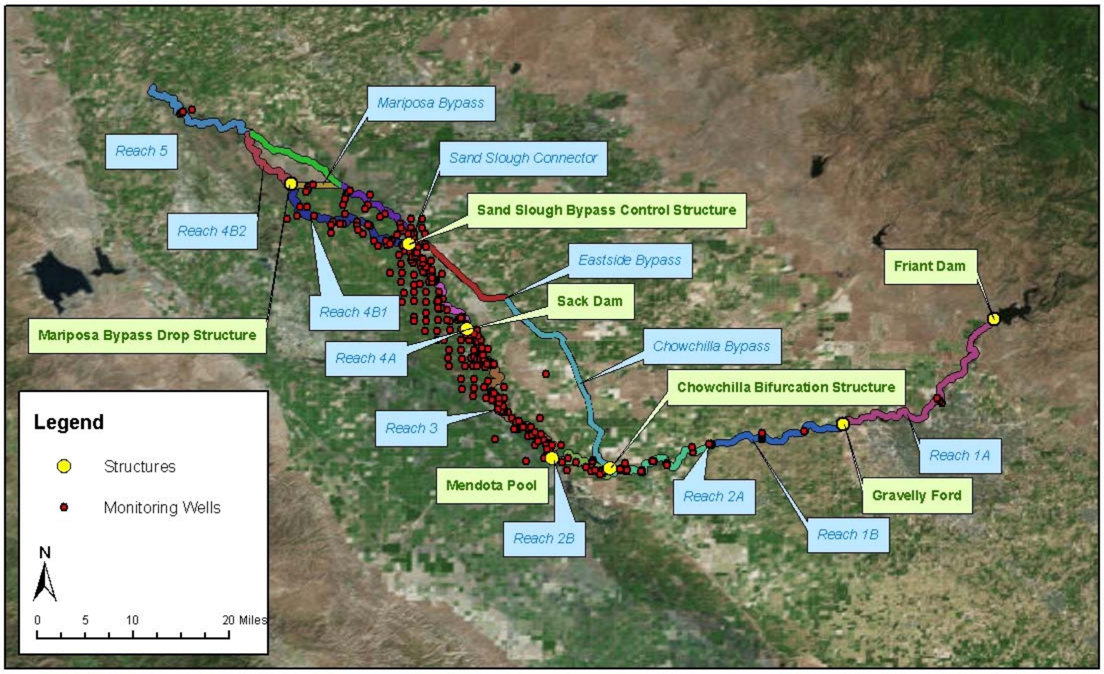

Figure E-2.
Locations of Existing Groundwater Monitoring Wells

E.1.2 Stakeholder Monitoring Wells

A subset of existing, mostly shallow monitoring wells owned by CCID are instrumented to record hourly groundwater level response to Restoration flows in off-river areas adjacent to the river. The SJRRP also makes manual groundwater level measurements in a subset of CCID wells. Monitoring of off-river wells will improve the understanding of the lateral extent of seepage-related effects 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.

E.1.3 Priority Wells

Groundwater levels in a subset of the available groundwater level monitoring network wells appear to correlate well with the groundwater response to San Joaquin River flows. These "priority" wells are used by Reclamation to guide operational decisions. The SJRRP makes weekly measurements in these wells and posts a "Weekly Groundwater Report" with the measurements from these wells at the end of each week. This report is posted to the SJRRP website (restoresjr.net). A sample report is shown in Figure E-3. Figure E-4 shows the locations of wells and flow gages listed in the weekly report. The SJRRP evaluates the most recent measurement in priority wells when conducting a Flow Bench Evaluation or Daily Seepage Evaluation.

When a groundwater seepage project is completed, whether it is a realty action or physical seepage project, Reclamation will no longer reduce Restoration Flows based on groundwater levels in those wells. The seepage project has protected the property. Any priority wells that may have existed on that property will be replaced by the next most priority well, regardless of where it is located.

SAN JOAQUIN RIVER RESTORATION PROGRAM
Weekly Groundwater Report - Week Ending January 14, 2016

REACH 2A						
Well ID	Date	DTW_GS (ft)	Well Threshold (ft BGS)	Field Threshold (ft BGS)	River Mile	Bank
FA-9*	1/10/2017	4.05	7.2	7.0	218.2	Left
MW-09-47*	1/10/2017	2.59	7.2	7.0	218.2	Right
MA-4*	1/10/2017	4.48	8.5	7.0	217.2	Right
MW-09-49B*	1/10/2017	NR	4.8	6.5	217.2	Left

REACH 2B						
Well ID	Date	DTW_GS (ft)	Well Threshold (ft BGS)	Field Threshold (ft BGS)	River Mile	Bank
MW-09-54B	1/10/2017	24.30	12.4	10.0	211.8	Right
MW-09-55B	1/10/2017	DRY	6.7	6.0	211.8	Left

REACH 3						
Well ID	Date	DTW_GS (ft)	Well Threshold (ft BGS)	Field Threshold (ft BGS)	River Mile	Bank
PZ-09-R3-5	1/12/2017	NR	7.2	6.0	197.8	Right
MW-12-191	1/12/2017	NR	11.7	9.0	196.6	Right
PZ-09-R3-7	1/11/2017	10.79	6.2	5.5	199.2	Right
MW-10-75	1/12/2017	19.77	6.6	6.3	187.0	Left

REACH 4A						
Well ID	Date	DTW_GS (ft)	Well Threshold (ft BGS)	Field Threshold (ft BGS)	River Mile	Bank
MW-14-208	1/12/2017	NR	7.1	5.0	169.7	Right
MW-10-89	1/12/2017	17.87	7.4	4.0	175.4	Right
MW-10-92*	1/12/2017	9.29	8.2	5.6	170.0	Left

PRELIMINARY SAN JOAQUIN RIVER FLOW DATA						
Location	Station_ID	Reach	River Mile	Flow (cfs)	Date	Time
Friant Dam	MIL	1	267.6	6115	1/11/2017	24hr avg
Gravelly Ford	GRF	2A	227.6	5741	1/12/2017	1200
SJR below BIF	SJB	2B	216.0	514	1/12/2017	1200
SJR near Mendota	11254000	3	202.1	20	1/11/2017	1200
SJR near Dos Palos	SDP	4	181.5	0	1/11/2017	24hr avg
SJR at Fremont Ford	11261500	5	125.1	7710	1/12/2017	1200
SJR above Merced River	11273400	5	118.3	1360	1/9/2017	1200

REAL TIME GROUNDWATER MONITOR WELL INFORMATION		
Well ID	CDEC_ID	Weblink
MW-09-49B	49B	http://cdec4gov.water.ca.gov/cgi-progs/queryF?s=49b
PZ-09-R3-7	R37	http://cdec.water.ca.gov/cgi-progs/queryF?s=r37
MW-10-75	W75	http://cdec.water.ca.gov/cgi-progs/queryF?s=w75
MW-10-89	W89	http://cdec.water.ca.gov/cgi-progs/queryF?s=w89
MW-10-92	W92	http://cdec.water.ca.gov/cgi-progs/queryF?s=w92
MW-11-130	130	http://cdec4gov.water.ca.gov/cgi-progs/queryF?130

NOTES

All data are provisional and are subject to revision
Thresholds are defined in the Draft SJRRP Seepage Mgt Plan

KEY

TBD: To be determined
* Protected by existing interceptor drain
NR: No Reading (Well Inaccessible)
NA: Not Applicable
DTW_GS: Depth to Groundwater from Ground Surface
CDEC: California Data Exchange Center
ft BGS: feet below ground surface
BRT: Below Rating Table

Figure E-3.
Sample Weekly Groundwater Report

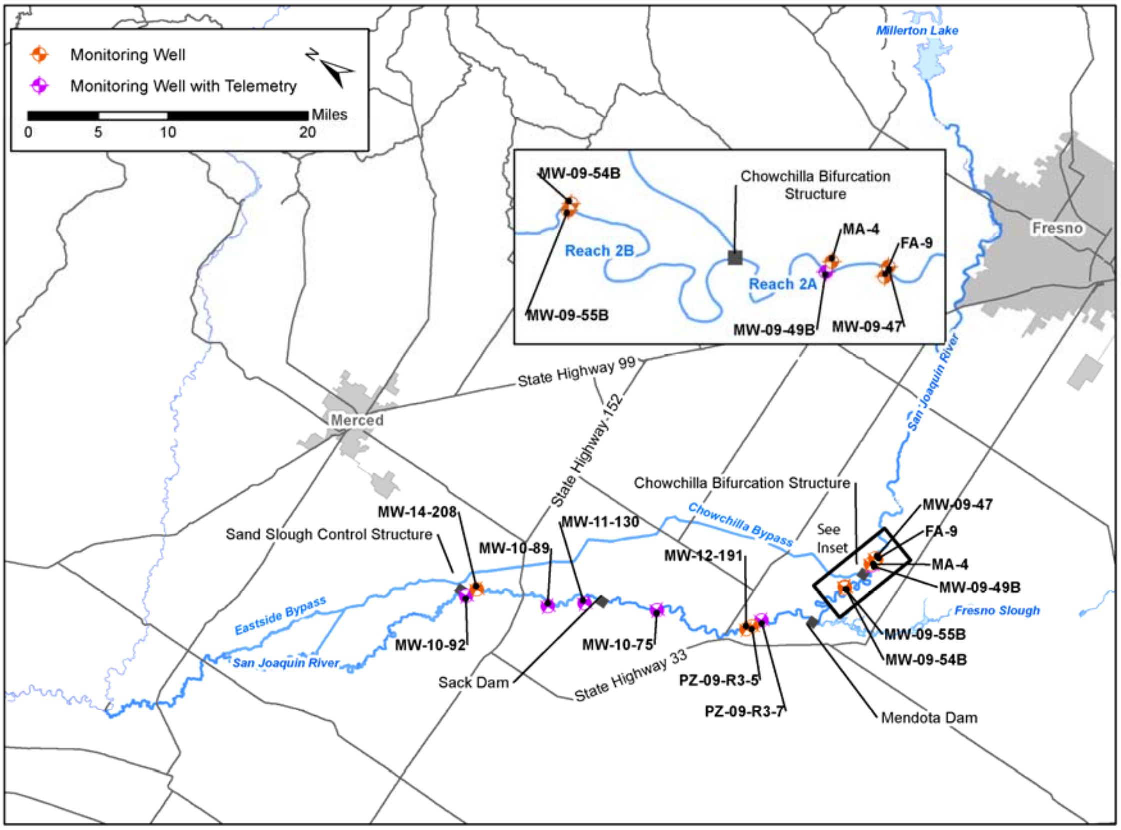

Figure E-4.
Priority Monitoring Locations

E.1.4 Cross-River Transects

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

- Depth to the groundwater table and water-table elevation;
- The horizontal hydraulic gradient (slope) of the groundwater table toward or away from the river/bypass; 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 to 10 miles along the river from Friant Dam to the confluence with the Merced River. Figure E-5 shows cross-river transect wells installed thus far by the SJRRP and stakeholders; the *Monitoring Well Atlas* includes additional information for the wells in these transects.

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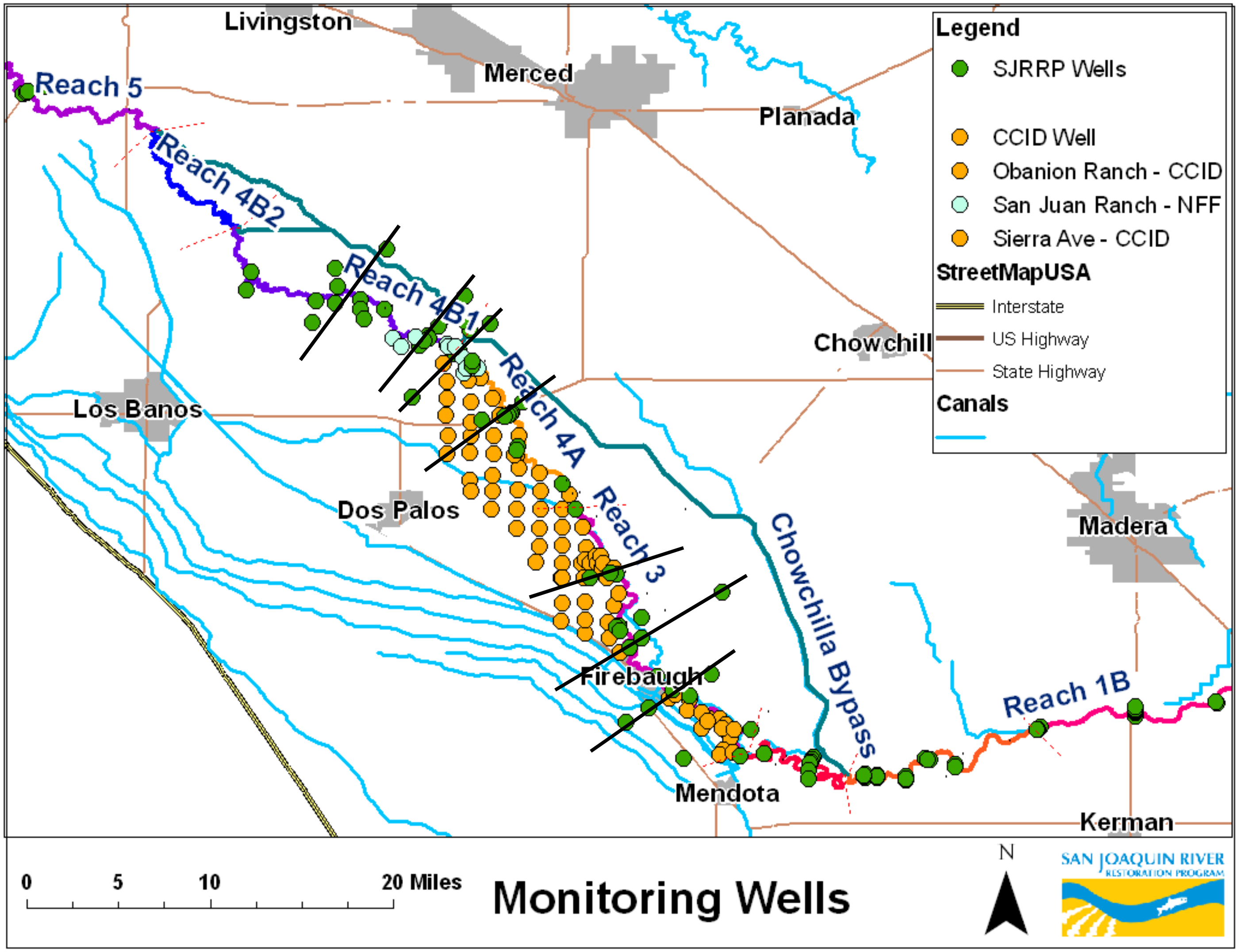

Figure E-5.
Groundwater Monitoring Well Network

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Typically, within each transect, four to six shallow wells will be paired with one to two deeper wells (Figure E-6). These wells will range in depth from about 15 to 80 feet. 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.

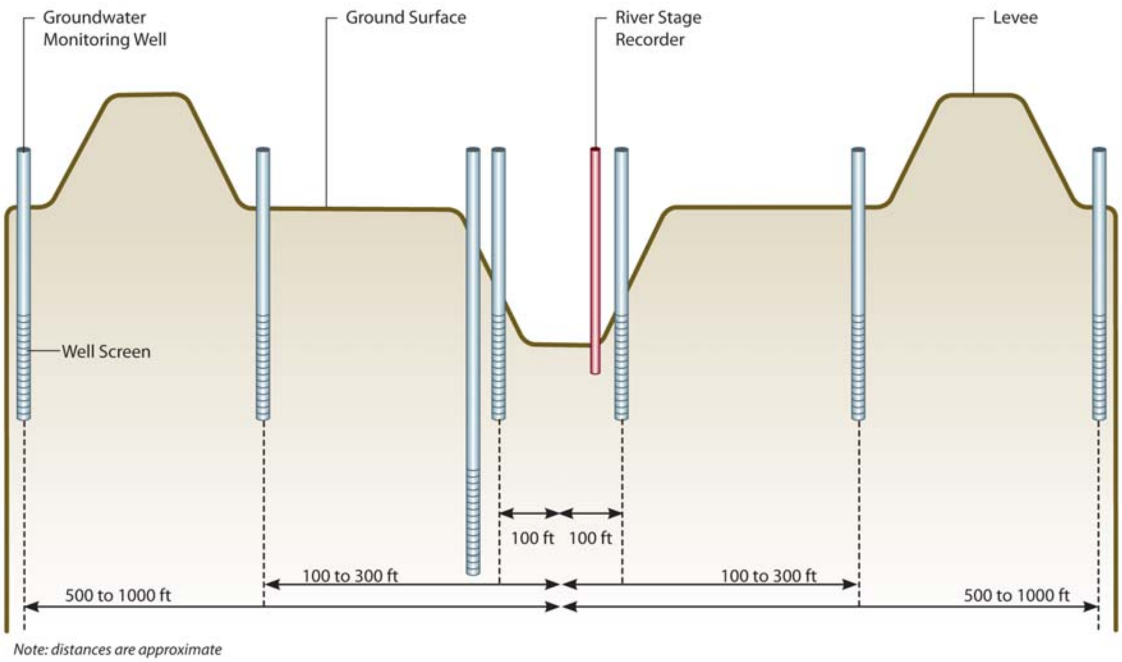

Figure E-6.
Conceptual Design of Cross-River Monitoring Well Transect

E.2 Real-Time Wells

Eight wells in the Restoration area currently are equipped for real-time transmission of groundwater level data to a central database. Data from these wells are automatically transmitted and uploaded 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 Restoration Flows. As additional wells are installed and more is learned during these Flows, more real-time sites will be established.

In a real-time well (Figure E-7), the well and data logger are located in a vault (foreground of Figure E-7). Power is supplied by a solar panel on a pole and data is transmitted via satellite using the antenna on top of a pole.

Figure E-7.
Typical Real-Time Monitoring Wells

E.3 Shallow Groundwater and Soil Salinity

An increase in shallow groundwater levels due to seepage-related conditions may cause soil salinity to increase; therefore, it is an important component of the monitoring plan. Shallow groundwater conditions cause soil 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 previously dissolved salts. Subsurface evaporation occurs where the water table is sufficiently close to the ground surface and has been estimated to occur to a depth of seven 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.

E.3.1 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.

E.3.2 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 estimate 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. Twenty baseline soil salinity sites were established in the spring of 2013. These sites complement the existing 117 sites established in the spring of 2010, 2011, and 2012. 2013 was the last scheduled year of the baseline soil salinity sampling program. In 2014, only a few selected sites and sites requested by landowners will be sampled and/or EM surveyed. Details of the sampling sites are included in Appendix E, Attachment 2.

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 soil salinity profile is characterized by increased salinity with depth. An inverted soil salinity profile, in which the soil surface layers are more saline than layers 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.

E.4 Visual Observations

Visual observations associated with seepage effects from 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 Plan.