Appendix G. Development of Soil Salinity Thresholds

1 General Salinity Considerations

Implementation of the SJRRP has the potential to change soil salinity levels in surrounding lands. The depth and duration that shallow groundwater saturates the soil can influence soil salinity. In the presence of shallow groundwater, an inverted soil salinity profile, whereby the salinity of the surface soil is higher than that of the underlying strata, can develop by way of evapotranspiration (plant transpiration and evaporation). This condition can complicate germination and emergence of crops and reduce crop yield. Drainage engineers typically design artificial drainage systems to maintain the water table at depths below 4 feet from the land surface, providing for an aerated root zone suitable for a wide range of crops and leaching of salts for a favorable salt balance and profile. Other factors that could influence soil salinity include:

- Increased pumping and use of groundwater for irrigation in some areas to help control the water table could increase soil salinity because groundwater typically is more saline than surface water, and
- Water released from Friant Dam contains less salt than water pumped from the Delta; all other factors being equal, the use of Friant Dam releases would tend to lower soil salinity.

2 Common Crop Salt Tolerance Data

Table G- 1 lists salt tolerance data for crops commonly grown in the area. These data generally apply to soil salinity in the active root zone (0–30 inches). Salt tolerance is expressed as the electrical conductivity of the saturation extract (ECe) value in decisiemens per meter (dS/m) at 25 degrees Celsius. Data shown in Table G- 1 are from Allen and others (1998) and are based on data developed by Maas and Grattan (1999) for soils that do not contain residual gypsum.

Table G- 1: Crop Salt Tolerance Data (Allen and others, 1998)

Crop	Salt tolerance threshold ECe dS/m	% yield decline per 1dS/m increase	Yield potential at 2 dS/m (percent)	Yield potential at 3 dS/m (percent)	Yield potential at 5 dS/m (percent)	Yield potential at 10 dS/m (percent)
Alfalfa hay	2.0	7.3	100	93	79	44
Almonds	1.5	19	90.5	71.5	43.5	Zero
Barley	8.0	5.0	100	100	100	90
Muskmelon	1.0	8.4	92.6	83.2	66.4	24.4
Cotton	7.7	5.2	100	100	100	88
Grape	1.5	9.6	95.2	85.6	66.4	18.4
Maize	1.7	12.0	96.4	84.4	60.4	Zero
Pistachio*	2.5	10.5	100	94.8	73.8	21.3
Pomegranate**	5.0	6.7	100	100	100	66.5
Safflower**	5.0	6.7	100	100	100	66.5
Sorghum	6.8	16.0	100	100	100	48.8
Sugar beet	7.0	5.9	100	100	100	82.3
Tomato	2.5	9.9	100	95	75.3	25.8
Wheat	6.0	7.1	100	100	100	71.6
Onions	1.2	16	87.2	71.2	39.2	Zero
Garlic	3.9	14.3	100	100	84.3	12.8

****** Qualitative assessment based on midpoint of moderately tolerant range.

***** Qualitative assessment based on midpoint of moderately sensitive range.

3 Preliminary Salinity Thresholds

Soil salinization is a slow process in comparison to water-table response to changes in river flow, and additional monitoring will inform the current magnitude and distribution of soil salinity in the Restoration Area. Preliminary thresholds will be in place to ensure that sufficient monitoring is done to measure increases in soil salinity that may be attributable to SJRRP activities. Exceedances of a preliminary salinity threshold will trigger increased monitoring intensity to better characterize the process(es) causing the salinity increase. In time, this information can be used to develop improved thresholds.

The salinity thresholds presented below are preliminary values, and may change on the basis of results from future field measurements and other advancements in the understanding of local soil salinity conditions.

Thresholds for salinity are expressed as crop salt tolerance levels of concern (LOC) for the active root zone (0–30 inches below ground surface) and LOC for the plow layer (0–12 inches) associated with early-season establishment of crops.

3.1 Levels of Concern for the Active Root Zone by River Reach

Different reaches have different crop types, drainage, and soil types, affecting the levels of concern.

- **Reach 2B –** This reach has many orchards and vineyards, including almonds, grapes, and pomegranates, which tend to be sensitive to salts. The crop salt tolerance for almonds is the proposed LOC for this reach.
- **Reach 3 –** The most common crops found in reach 3 are alfalfa and field corn; field corn (maize) is a common crop near the river. The crop salt tolerance for maize is the proposed LOC for reach 3.
- **Reach 4A and 4B –** Alfalfa is the most common crop observed in reaches 4A and 4B. Processing tomatoes are also an important and valuable crop. The crop salt tolerance for tomatoes is the proposed LOC for reaches 4A and 4B.

3.2 Levels of Concern for the Plow Layer

Salinity is critical during the late spring to permit germination, emergence, and good stand establishment of field crops. The preliminary threshold (LOC) for the plow layer will be 2 dS/m to accommodate this. If March/April soil salinity levels exceed an ECe of 2 dS/m in the plow layer, monitoring intensity will increase. This salinity level corresponds with an alfalfa yield potential of about 100 percent. Alfalfa the most common crop in the area and is an important rotation crop.

4 Other Indicators of Increasing Soil Salinity

In addition to the active root zone and plow layer thresholds discussed above, the following indicators also may be used to indicate a need for increased soil salinity monitoring:

- Significant (95% confidence level) increases in measured soil salinity at monitoring sites,
- Increase in the occurrence of inverted soil salinity profiles at monitoring sites,
- Landowners and grower observations of reduced crop vigor,
- The appearance of poor or weak spots in fields,
- Decrease in crop yields compared to prior years,
- Increasing electricity use at drainage sump pumps, and
- Indications from observation wells that the water table is approaching the LOC

5 General Description of Soil Monitoring Methods

Much of the salinity monitoring will be done using EM38 meters. These portable electro-magnetic meters permit real-time measurement of large volumes of soil. EM38 surveys will be conducted when soils are moist, ideally 2–4 days following an irrigation event. These data will be supplemented with laboratory analyses of multi-increment spatial composite soil samples from the plow layer. Soil sampling also will be used to determine the relationship between EM38 readings and ECe. Soils in deeper layers will be sampled to determine the salinity distribution in soils.

Reclamation sampled 78 baseline soil salinity sites during March and April of 2010 and conducted electromagnetic soil electrical conductivity surveys at nearly all sites. Some of these sites are offset from nearby observation wells while some additional sites were selected based on field observations, access considerations, and crop type. These sites will be resampled periodically to determine soil salinity trends over time. The primary purpose of the soil sampling was to determine baseline soil salinity levels prior to the increase San Joaquin river flows. Since the soil sampling in Reaches 2, 3 and 4A was done after the initial rise in river flows these samples may not be a true baseline of pre-Interim Flow conditions. The assessment of baseline conditions is also complicated by the shift from gravity to drip irrigation in some fields. Reach 4B sites were sampled prior to water releases into the old channel of the San Joaquin River.

Additional surveying may be done using the following types of surveys:

- Transects along furrows,
- Entire field salinity mapping, and/or
- One-acre representative site evaluations.

Appendix H. Development of Groundwater-Level Thresholds

This appendix documents the ongoing development of thresholds associated with water levels measured in wells. This process has included input from stakeholders, and will continue to do so as part of the update and revision process.

1 Conceptual Development of Thresholds

Thresholds indicate surface or groundwater elevations that may risk adverse impacts due to groundwater seepage. The SJRRP will operate to maintain groundwater levels below thresholds. Estimates of flow increases that would exceed a threshold will trigger a site visit and a response action. Crop type and associated rooting depths, soil type, and other factors vary spatially; therefore, the thresholds are customized to represent site conditions at each monitoring well location.

Events unrelated to river flows may cause groundwater levels to exceed thresholds. For example, an irrigation event or local precipitation may cause a rapid rise in the water table. Such events would likely cause short-term saturation of the root zone resulting in no effect on crop health. Field notes during groundwater measurements and site visits address this complication. Temporal aspects to thresholds, for example during the dormant season or fallow periods, may allow increased flows, in coordination with landowners, above threshold levels.

1.1 Purpose

- To describe the development of thresholds for SJRRP wells.

1.2 Objectives

The objectives of monitoring well thresholds development include:

- Determine the components to include in threshold development.
- Determine the values to use for each of the components.
- Solicit stakeholder input and comments on each threshold component.

1.3 Approach

Reclamation has developed three different methods to determine monitoring well thresholds. These include approaches based on idealized agricultural practices, historical groundwater levels, and drainage.

1.3.1 Agricultural Practices Method

A conceptual model has been developed for determining thresholds based on idealized agricultural practices. This model is based on input from landowners and water district managers. The model considers several different components including site characteristics, farming practices, and physical processes.

The components of the threshold model, as illustrated in Figure H- 1, include:

- a root zone, to provide an unsaturated zone to avoid waterlogging;
- an irrigation buffer, to allow space for furrow irrigation or leaching treatments to drain;
- a capillary fringe component, to allow for the saturated portion of the capillary rise and maintain an aerated root zone;
- a ground surface adjustment, to adjust for differences in elevation between the ground surface of the field and the ground surface at the monitoring well. Wells located in locations most convenient for landowners may not be in the most critical seepage location.

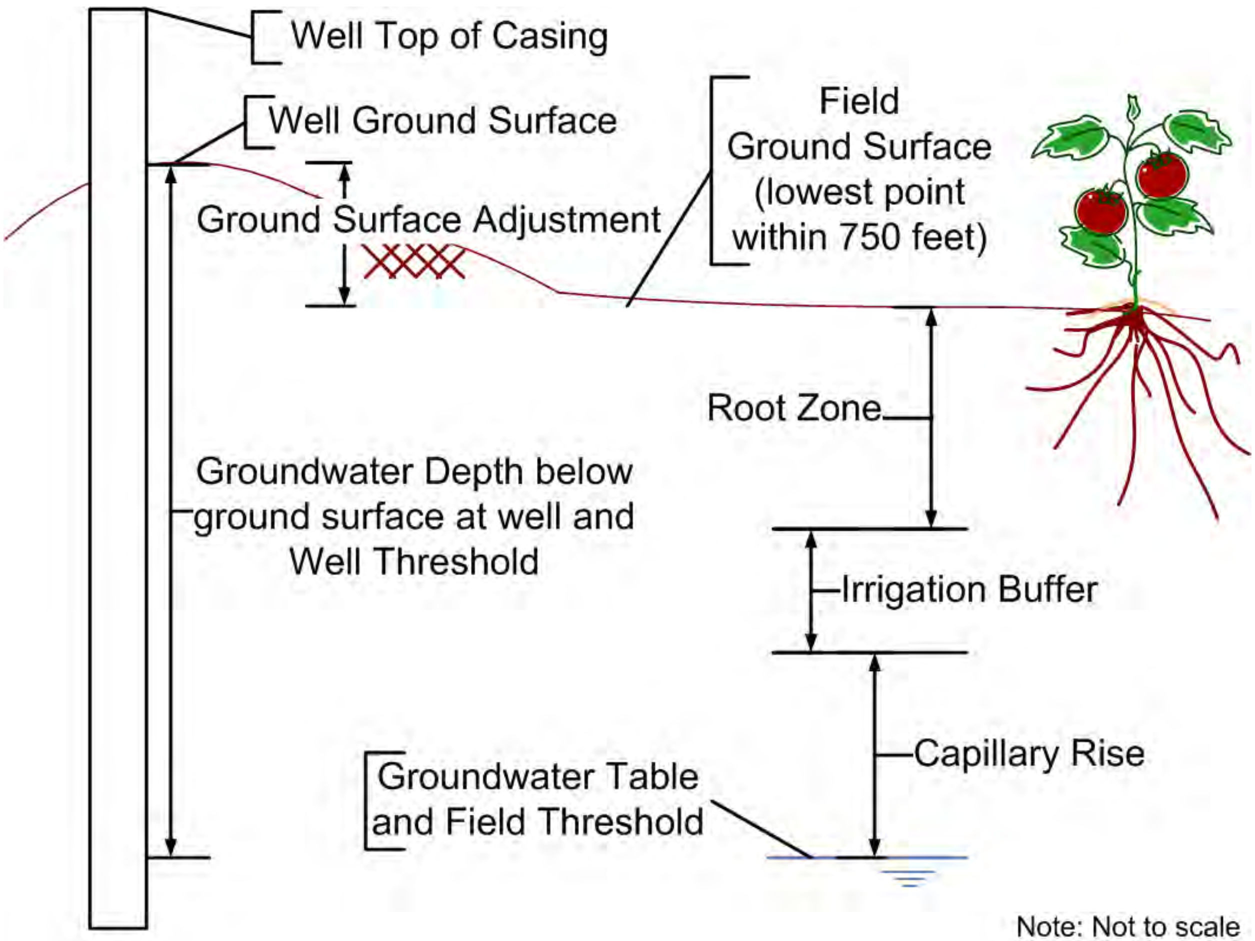


Figure H- 1
Schematic Diagram of Idealized Agricultural Practices Threshold Model

The following sections detail the approaches for each of these components. The Field Threshold is defined according to the following:

$$Threshold_{field} = h_{Root\text{-}Zone} + h_{Capillary\ Fringe} + h_{IrrigationBuffer}$$

Where, $h_{Root\text{-}Zone}$ = depth of the root zone;

$h_{Capillary\ Fringe}$ = height of capillary fringe; and

$h_{IrrigationBuffer}$ = height of the buffer for leaching irrigation.

To monitor for groundwater levels at the field threshold in a monitoring well, which may not be located at the same elevation as the most critical location, a ground surface adjustment is made. The Well Threshold is defined as:

$$Threshold_{well} = h_{Root\text{-}Zone} + h_{Capillary\ Fringe} + h_{IrrigationBuffer} + (Elevation_{WellGS} - Elevation_{FieldGS}),$$

Where, $Elevation_{WellGS}$ = elevation of the ground surface at a monitoring well; and

$Elevation_{FieldGS}$ = elevation of the ground surface with 750 feet of the well in the adjacent field.

Thresholds also include a time component, resulting in different thresholds in spring than during other times throughout the year.

1.3.2 Historical Groundwater Method

In some locations along the San Joaquin River, historical groundwater measurements show elevations above the computed threshold. In locations where thresholds estimated using the outlined approach above are deeper than historical groundwater levels, historical groundwater level will be used. This second method results in more localized thresholds rather than generalizations.

Thresholds based on historical groundwater levels were developed using three methods:

- For wells with long-term groundwater level records, thresholds were calculated on the basis of spring measurements of groundwater levels in those wells.
- For wells without long-term records, nearby wells with long-term records were used to calculate the threshold.
- For wells without long-term records and with no nearby wells, depth to water (DTW) maps were created; groundwater levels were interpolated between wells for a number of years and seasons. This analysis allows for using available groundwater level data in the region to inform the choice at each threshold location.

1.3.3 Drainage Method

In some locations along the San Joaquin River, the river channel gains water from the surrounding groundwater. For these gaining reaches, the river stage may be increased to near the level of the surrounding water table without influencing groundwater levels in adjacent fields.

The drainage method uses cross-sections at monitoring well transects to plot the river stage and groundwater table at a variety of dates.

1.4 Next Steps

Thresholds, as a component of the Seepage Monitoring and Management Plan, may undergo revisions as additional information and historical groundwater analysis becomes available. The continued development of thresholds would benefit from landowner input and knowledge.

2 Method #1: Agricultural Practices

The following section describes the components of threshold development including the crop root zone, ground surface buffer, irrigation buffer, and capillary rise.

2.1 Crop Root Zone Objectives

The objectives for crop root zones include the following:

- Identify different root zones based on crop type to expand upon the existing crop root zones in the 2009 Seepage Monitoring and Management Plan.
- Include multiple root zones for each crop based on young and mature plants if information is available.

2.1.1 Approach

The type of crop, soil texture, irrigation practices, and depth to the groundwater table affect crop rooting depth. Poorly drained soils restrict crop root growth (Sands, 2001). Fine-grained soils can restrict crop root growth, as shown in Table H- 1 (Westlands, 2009). Irrigation practices can result in more roots near the top of the soil column and fewer roots at depth (Speigel-Roy, 1996).

A literature review was conducted to identify sources of crop root depths. References found include:

- University of California Division of Agriculture and Natural Resources Almond Production Manual Publication 3364
- University of California Division of Agriculture and Natural Resources Cotton Production Manual Publication 3352
- University of California Division of Agriculture and Natural Resources Small Grains Production Manual Publication 8167
- Westlands Irrigation District
- Allen et al., Crop Evapotranspiration, Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage Paper No. 56.
- Food and Agriculture Organization of the United Nations, 2009 Crop Water Information.
- U.S. Department of the Interior, Bureau of Reclamation (Reclamation) Drainage Manual

The Reclamation Drainage Manual (page 48) does not make recommendations by crop type but generalizes 2 feet for the shallow-rooted crops such as potatoes and vegetables and 6 feet for peach, walnut, and avocado trees. For most irrigated crops, a 3 to 4 foot root zone can be used. The Reclamation Drainage Manual assumes adequate drainage and leaching for salinity control are provided. Crop roots may adapt to historical groundwater levels, but the current methods do not address long-term fluctuations in water tables.

Local information is available on tomato root zones from the Irrigation Training and Research Center (ITRC) report (Burt, 2010). This local information was used over other sources. Other crops were split into two groups, permanent and annual. Thresholds used root depths on the higher end of typical values for permanent crops as their roots are deep early in the season. Annual crops generally have shallower root zones.

2.1.2 Results

Table H- 1 below shows crop root depths by crop type, soil type, and time in the season.

Table H- 1
Crop Root Depths

Crop	Crop Root Depth, Early Season (feet)	Crop Root Depth, Late Season (feet)	Crop Root Depth, Late (feet) – Coarse Textured Soil	Crop Root Depth, Late (feet) – Fine Textured Soil
Alfalfa (Hay)		3-6 [3], 6 [1, 2]	4-6 [1, 2], 6-12 [7]	
Almonds		3-6 [3]	2-12 [8], 9 [9]	
Barley		3-5 [3], 4 [1]	4 [1]	
Lima Beans		2-4 [3]		
Cotton	1 [4], 4/5 [10]	3-5 [3], 5 [1], 6 [10]	5-6 [1]	4-5 [1]
Grape	5 [4]	3-6 [3]		
Corn	1 [4]	3 [4]		
Melon		2-5 [3], 6 [1]	5-6 [1]	
Pistachio		3-5 [3]		
Safflower		3-6 [3],15 [1]	15 [1]	10 [1]
Spring Wheat Winter	1 [4]	4 [4]		
Sugar Beet	1 [4]	6 [4]	6 [1]	
Sugarcane		5 [4]		
Tomato	1 [4]	3 [6], 2-5 [3] , 6 [1]	5-6 [1]	
Wheat	1 [4]	3-5 [5, 3] , 5 [4]	4-5 [1]	4 [1]

Notes:
[1] Westlands Water District 2009
[2] Crop root depth could exceed 6 feet if unrestricted
[3] Allen et al. 1998, larger values are for soils having no significant layering or other characteristics that can restrict rooting depth
[4] Food and Agriculture Organization of the United Nations, www.fao.org
[5] University of California Division of Agriculture and Natural Resources Small Grains Production Manual
[6] Irrigation and Research Training Center, November 2010
[7] University of California Division of Agriculture and Natural Resources Irrigated Alfalfa Management. Under the best conditions roots will grow to 6-12 feet. A minimum of 3 feet of unrestricted rooting depth should be provided.
[8] University of California Division of Agriculture and Natural Resources Almond Production Manual. Roots of almond trees may extend to depths of 4 meters in coarse-textured, well-drained soil, but they are frequently much shallower. Often 75 percent or more of the roots are in the upper 0.7 to 1.0 meter of soil.
[9] University of California Division of Agriculture and Natural Resources Integrated Pest Management for Almonds.
[10] University of California Division of Agriculture and Natural Resources Integrated Pest Management for Cotton

For the purposes of the current Seepage Monitoring and Management Plan buffer zones and action level thresholds, the root zone values that were used include:

- Cotton, alfalfa, other annual crops and unknown – 4 feet
- Grapes, Pistachio, and Pomegranates – 6 feet
- Almonds – 9 feet
- Tomatoes, beans, melons and corn – 3 feet

2.1.3 Limitations

Limitations of this analysis include:

- This approach does not address soil type or irrigation methods which could affect root zones and may restrict root growth to shallower depths.
- These values do not take into consideration the effects of a historically shallow water table on crop root depths or seasonal or long term trends in the water table. Comparison to historical groundwater levels in a later section accounts for this in a broad sense.
- The root zone buffer does not include changes in the root zone based on age of crops and uses mature plants to choose deeper root depths.
- Field crops are generally rotated each year, which may require changing thresholds on an annual basis as crop types change. Landowners should review the SMMP and notify the SJRRP when crop changes require adjustments to the root zone assumptions.

2.2 Ground Surface Objectives

Adjustments due to changes in ground surface elevation intend to:

- Thresholds should represent groundwater levels below agricultural fields near to the well.
- To set the well threshold, adjust based on the difference between the elevation of the ground surface in the adjacent field and the ground surface elevation at the monitoring well.

2.2.1 Approach

The difference between ground surface elevation at the well and in the adjacent field was determined by the minimum field elevations within 750 feet for the field adjacent to each well. Field elevations were chosen from the 2008 LiDAR survey.

All wells drilled in Fall 2009 and Spring 2010 by Reclamation have ground surface elevations surveyed in North America Vertical Datum (NAVD) 88. In addition, Reclamation monitors several hand-augered piezometers, private wells, and Central California Irrigation District (CCID) wells that have not been surveyed. For wells that are not surveyed, a ground surface elevation was interpolated from a 2008 Light Detection And Ranging [1](LiDAR) survey.

The LiDAR survey was flown within approximately ¼ to 1 mile on either side of the San Joaquin River and flood control bypasses. Figure H- 1 provides an example of one monitoring well that uses a 750 ft buffer zone that is partially missing due to the lack of available LIDAR data. Wells located outside the LiDAR data area have no ground surface buffer. Some wells used data from fields further away if there was no available LiDAR data in an adjacent field.

[1] An optical remote sensing technology that measures properties of scattered light to find topographic information.

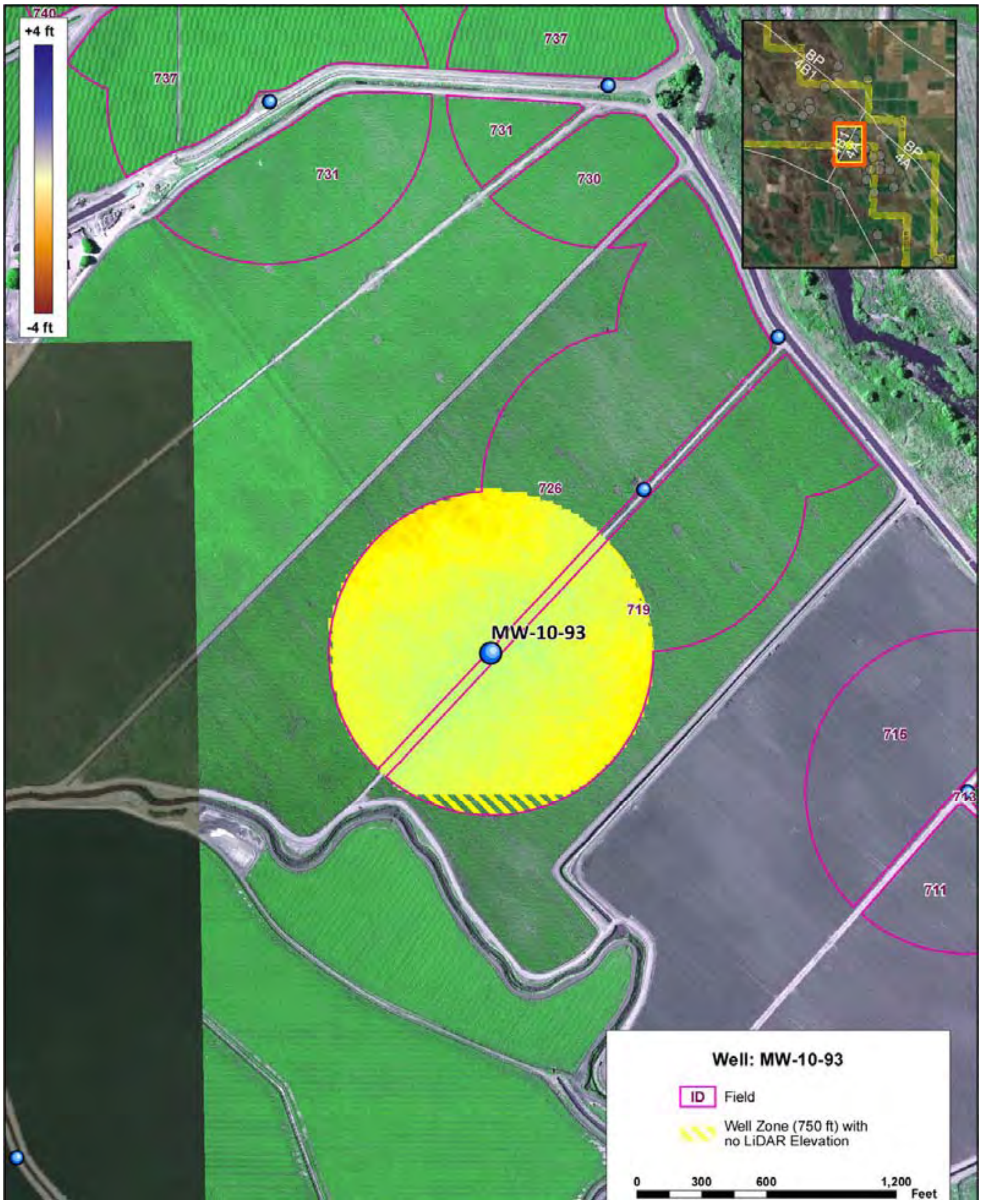


Figure H- 2
Monitoring Well MW-10-93

Thresholds assume a flat groundwater surface in the area they represent. Groundwater level measurements taken in a well only accurately represent nearby groundwater conditions. Further away fields may have canals, sloughs, ditches, changes in soil type, or other factors influencing groundwater levels that are not represented in the well or threshold.

The difference between the ground surface elevation at the well and the minimum field elevation within 750 feet of the well was used as the ground surface buffer. A negative ground surface buffer indicates that the well is located lower than the adjacent field, such as in the river channel. An example of this is shown in Figure H- 3.

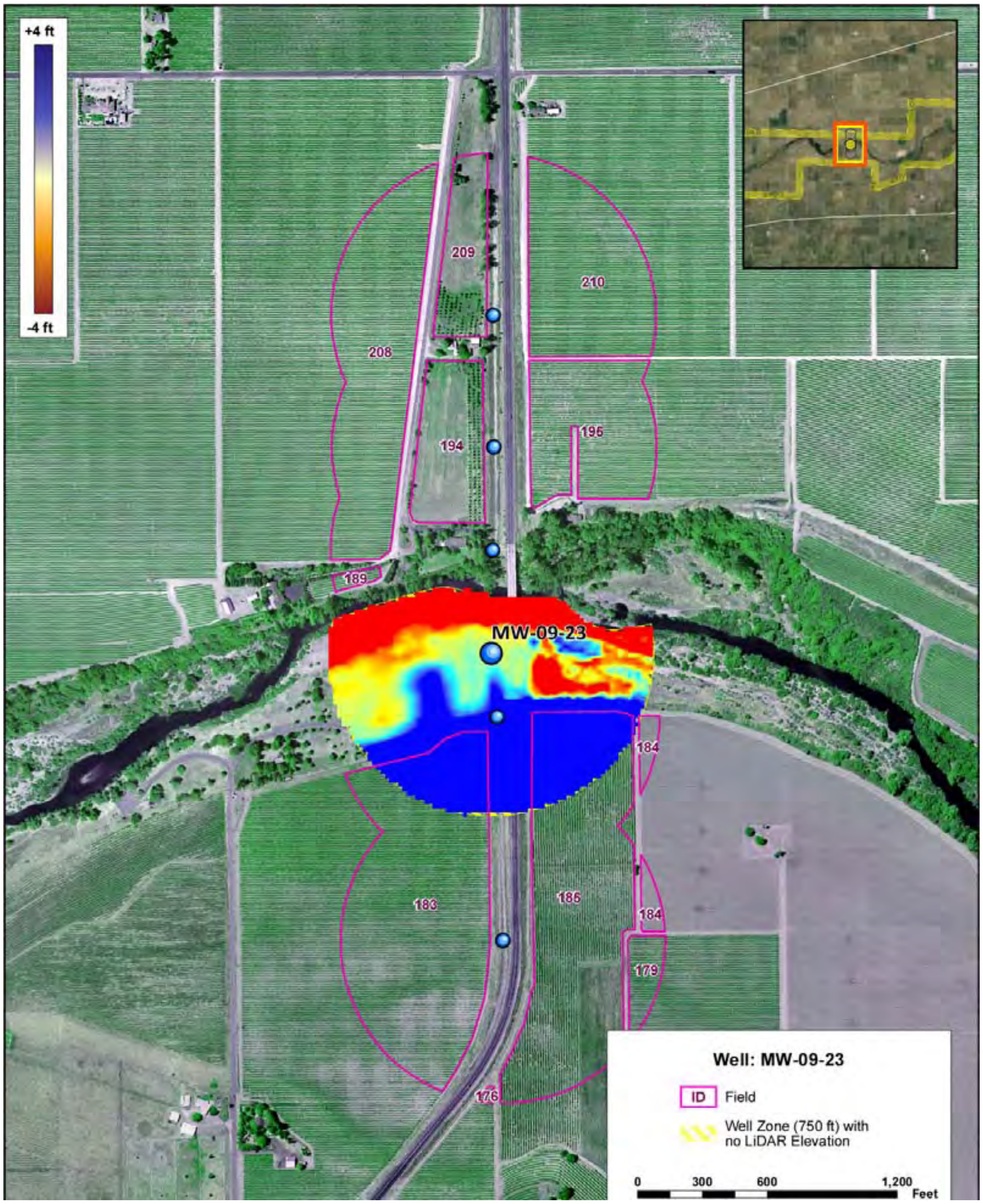


Figure H- 3
Monitoring Well MW-09-23

2.2.2 Results

Corrections made for changes in elevation range from 8 to -9.5 feet. Results are shown per well in Table H- 2 below.

Table H- 2. Ground Surface Adjustment ($Threshold_{field}$ to $Threshold_{well}$)

Well	Ground Surface Elevation at Well (feet NAVD '88)	Minimum Adjacent Field Elevation (feet NAVD '88)	Ground Surface Adjustment (feet)
191	110.9	108.0	2.8
186A	108.1	106.1	2.0
FA-1	206.87	205.1	1.8
FA-2	207.17	204.9	2.2
FA-3	206.43	204.9	1.5
FA-4	179.84	184.4	-4.6
FA-5	179.45	184.2	-4.7
FA-6	180.86	176.1	4.8
FA-7	181.57	175.9	5.6
FA-8	172.7	170.9	1.7
FA-9	174.48	170.8	3.7
MA-1	206.65	204.9	1.7
MA-2	182.69	179.8	2.9
MA-3	179	178.1	0.9
MA-4	174.45	168.4	6.1
MW-09-23	210.6	219.4	-8.8
MW-09-23B	210.6	219.4	-8.8
MW-09-36	191	186.5	4.5
MW-09-37	191.8	189.1	2.7
MW-09-37B	192.1	189.1	3.15
MW-09-39	184.9	184.4	0.5
MW-09-39B	184.9	184.4	0.5
MW-09-41	180.7	184.2	-3.5
MW-09-44	179.2	176.1	3.1
MW-09-46	173.5	170.9	2.5
MW-09-47	174.7	171.2	3.5
MW-09-49	171	169.2	1.8
MW-09-49B	170.9	169.2	1.7
MW-09-52	162.1	161.2	0.9
MW-09-54	168	160.3	7.7
MW-09-54B	168.2	160.3	7.9
MW-09-55	166.1	162.0	4.1
MW-09-55B	165.7	162.0	3.7
MW-09-56	161.2	159.5	1.7
MW-09-57	163.1	161.5	1.6
MW-09-85B	120.6	113.7	6.9
MW-09-86B	120.9	113.0	7.9
MW-09-87B	115	113.1	1.9
MW-10-100	102.7	98.2	4.5
MW-10-102	95.7	93.3	2.4
MW-10-103	99.1	94.5	4.6
MW-10-105	96.7	95.3	1.4
MW-10-106	95.08	93.1	1.9

Table H- 2. Ground Surface Adjustment ($Threshold_{field}$ to $Threshold_{well}$)

Well	Ground Surface Elevation at Well (feet NAVD '88)	Minimum Adjacent Field Elevation (feet NAVD '88)	Ground Surface Adjustment (feet)
MW-10-107	96	93.3	2.7
MW-10-108	96.5	94.7	1.7
MW-10-109	98.09	96.5	1.5
MW-10-110	88.84	87.0	1.8
MW-10-111	90.64	88.9	1.8
MW-10-113	99.53	95.1	4.4
MW-10-114	98.9	97.0	1.9
MW-10-118	138	135.6	2.4
MW-10-119	139.31	136.9	2.4
MW-10-124	154.07	153.4	0.6
MW-10-188	116.9	114.8	2.0
MW-10-74	136	131.8	4.2
MW-10-78	125.3	122.3	3.0
MW-10-80	124.9	119.8	5.1
MW-10-89	118.8	115.4	3.4
MW-10-91	107.2	103.5	3.7
MW-10-92	106	103.4	2.6
MW-10-93	105.4	103.2	2.2
MW-10-96	100.4	98.4	2.0
MW-10-97	101.2	97.8	3.4
MW-10-98	102.2	98.2	4.0
MW-10-99	104.3	99.6	4.7
PZ-09-R2B-1	155.16	153.9	1.2
PZ-09-R2B-2	153.17	149.3	3.9
PZ-09-R3-1	137.12	133.1	4.1
PZ-09-R3-2	138.39	136.8	1.5
PZ-09-R3-3	141.06	136.7	4.3
PZ-09-R3-4	140.24	136.7	3.5
PZ-09-R3-5	140.33	139.2	1.2
PZ-09-R3-6	141.56	140.1	1.5
PZ-09-R3-7	144.08	143.3	0.7
R1-1	216.85	215.3	1.5
R1-2	218.38	215.3	3.1
SJR W-1	100.17	98.4	1.8
SJR W-10	106.74	104.9	1.8
SJR W-11	108.23	106.4	1.8
SJR W-12	106.19	104.1	2.1
SJR W-2	103.19	98.9	4.2
SJR W-3	102.54	98.8	3.8
SJR W-4	106.35	105.2	1.1
SJR W-5	103.42	101.5	1.9
SJR W-6	105.65	101.3	4.4
SJR W-7	106.99	102.9	4.0
SJR W-8	108.88	105.5	3.3
SJR W-9	105.07	104.0	1.1

Key: NAVD = North America Vertical Datum

2.2.3 Limitations

Limitations of this analysis include:

- This approach assumes the groundwater level measured at a monitoring well represents the groundwater level under the lowest point within 750 feet of the well in the adjacent field. It does not address ground slope away from the river and assumes there is no groundwater table gradient within 750 feet of each well.
- The lowest adjacent field elevation within 750 feet may not represent a large acreage of the actively growing adjacent crop. The adjacent field could have a small depression that would result in a large ground surface adjustment and a conservative threshold in the well.

2.3 Irrigation Buffer Objectives

Objectives of the irrigation buffer include:

- Address salinity buildup in the soil column
- Allow space for furrow irrigation
- Allow space for leaching irrigation

2.3.1 Approach

Irrigation depends on crop type, evapotranspiration, and a variety of other factors. For the purposes of this study irrigation is generally either by drip lines or furrow.

In crops irrigated by furrow, a portion of irrigation in excess of evapotranspiration (ET), a combination of evaporation and plant transpiration of water from the soil to the atmosphere , passes through and beyond the crop root zone. The lower portion of the root zone may have higher salinity than the upper portion due to the smaller volume of water that passes through it (Ayers, 1985). Buildup of salts from irrigation or poor drainage may require periodic leaching applications. The purpose of this excess irrigation is to remove some of the applied salts from the lower portion of the root zone. This leaching fraction, with salts in a reduced volume and proportionately increased concentration, could dissolve additional salts from the underlying soil. If this situation occurs and there is inadequate drainage, a perched water table could occur, bringing water and concentrated salts back into the root zone (Rhoades, 1999).

Drip irrigation is generally matched to evapotranspiration rates, and thus has no deep percolation (Burt, 2010). These draft thresholds assume that there is no excess irrigation that could raise the water table, and thus, there is no buffer needed for drip irrigation.

The efficiency of drip lines results in a buildup of salts. These salts may require leaching. Deep percolation from drip irrigation in orchards in California leaves substantial amounts of salt in the soil (Burt, 2003). A buffer is assumed during the month prior to planting to ensure the lowering of the groundwater level prior to leaching and space for the leachate.

The irrigation buffer allows extra space for drainage following leaching of both furrow and drip irrigation to prevent a stagnant water table. This may be done pre-planting to address salt buildup in the root zone from salts that rose after the previous harvest. The lower water table avoids the waterlogging of roots and potential ‘subbing up’ of salts back into the root zone (Rhoades, 1999).

Reclamation gathered data and information from various sources for use in establishing a more locally based understanding of the irrigated agricultural practices. Table H- 3 presents information on irrigation practices per crop type.

Table H- 3
Irrigation By Crop Type

Crop Type	Pre-Irrigation Time	Pre-Irrigation Amount	Planting Time	Irrigation Timing	Irrigation Applied at surface (total)
Cotton and Corn (furrow)[1]	February / March	6” to 1’ of water applied at surface	By May 1	June on, every 10 days	6” more than total ET, generally 3 to 3.5’
Tomatoes (drip)	Generally None[1]	Generally None[1]		Mid-May to September, every few days[3]	2.2’[2]
Wheat and small grains (furrow)				Every 7-18 days	4-8” each time[4]

Notes:
[1] C. White personal communication, 12/23/2010
[2] ITRC Report, November 2010
[3] San Juan Ranch irrigation records
[4] University of California Division of Agriculture and Natural Resources Publication 8168

Immediately following 6-inch furrow irrigation, the water can rise up to a couple of feet, however it should recede fairly rapidly with natural drainage or functioning artificial drains. On properties that do not have good natural drainage or artificial drains, extra space is allowed for excess furrow irrigation water to percolate. Reclamation has assumed an initial draft buffer during typical months of furrow irrigation, to allow groundwater levels to lower and excess irrigation to drain. This buffer may be applied as more information is obtained on properties with poor natural and no artificial drainage.

2.3.2 Results

The leaching buffer, presented in Table H- 4 represents a buffer added only in certain times of the year to thresholds in areas with poor natural and no artificial drainage. Identification of additional areas with poor drainage may be aided by observation of inverted soil salinity profiles (Rhoades, 1999).The purpose of the leaching buffer is to allow for leaching irrigation, if needed, to remove accumulated salts in the soil from irrigation or groundwater. The irrigation buffer is not intended to prevent the temporary rise of the water table several feet, but rather to allow the water table to recede by allowing for drainage. A leaching application of 1 foot of water may cause a 3 foot or more rise in the water table temporarily, but would not be expected to move salts and the water table would recede.

Table H- 4
Irrigation Buffer

Type	Time of Year	Leaching Buffer
Poorly drained areas	Feb & March – planting	1’

2.3.3 Limitations

SJRRP groundwater thresholds would benefit from landowner input to determine timing and amounts of leaching. Limitations of the analysis include:

- For annual crops the timing of the water table fluctuations will be different than for semi-permanent crops such as orchards and vineyards. This approach does not take a crop-specific planting time into account.
- Crop rotations may influence the irrigation buffer zones each year. Planting of winter rotation crops may result in more irrigation in the spring. This approach uses values based on general irrigation per crop as recorded in Table H- 3.
- Existing management of salinity by leaching will likely continue.
- Monitoring wells located underneath irrigation header lines will show increases in groundwater levels above the adjacent field. This approach does not take this into account.

2.4 Capillary Fringe Objectives

Inclusion of a capillary fringe buffer intends to:

- Account for the anoxic portion of the capillary fringe

2.4.1 Approach

The height of the capillary fringe depends on soil texture, depth to the water table, evaporative demand of the atmosphere, and land use (Belitz, 1993). Fine-grained soil texture with broad distribution of grain sizes contains small pores, which increases the capillary rise (Hackett, 1927; Carman, 1941). A deeper water table will often have a larger capillary fringe. In addition, crop roots transpire water, affecting capillary rise and concentrating salts.

Two related items that are a part of the monitoring of a shallow water table are the potential saturation of the crop root zone and the movement of dissolved salts and potential to increase the salinity of the soil root zone. Saturation of the crop root zone is addressed in this section by including a capillary fringe buffer for the anaerobic portion of the capillary fringe. Salt movement through the entire capillary fringe is addressed by the irrigation buffer, to allow drainage for leaching.

A water table and associated capillary rise under actively growing crops can increase soil moisture and supply some of the crop water demand, reducing irrigation (Ramirez, 1996). If the water table is too deep, then groundwater is not able to move up far enough, or at a rate fast enough, to supply much of the crop demand. If the water table is too shallow and encroaches on the root zone then crop production will suffer due to lack of air in the root zone. Also, if the water table is too saline, the crop cannot use much of the ground water.

The following illustrations presented in Figure H- 4 and Figure H- 5 (Sands, 2001) show the relationship of soil capillary rise potential vs. the amount of saturation and air in the soil pore space. Capillary forces can conduct water several feet above a water table in medium and fine textured soils. A large portion of the capillary fringe above the water table contains air and water and is not detrimental to plant root growth from the water logging standpoint. The capillary fringe is a zone above a water table that is nearly saturated near the base and just above field capacity at the top. Field capacity is representative of the condition when a fully saturated soil profile is allowed to drain for 12-24 hours, water held under slight tension often defined as 1/3 bar or 1/3 atmospheric pressure (Brady, 1974). Only the part of the capillary rise that is immediately above the water table is the area of concern for water-logging and could be included in the monitoring threshold. For the purposes of this Plan, only this anoxic portion will be included in the capillary fringe buffer.

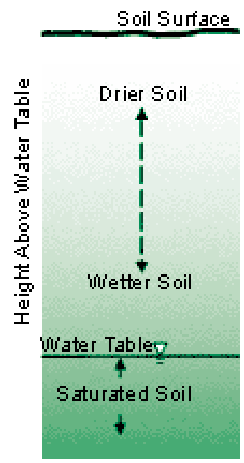


Figure H- 4
Soil Moisture Variation Between the Water Table

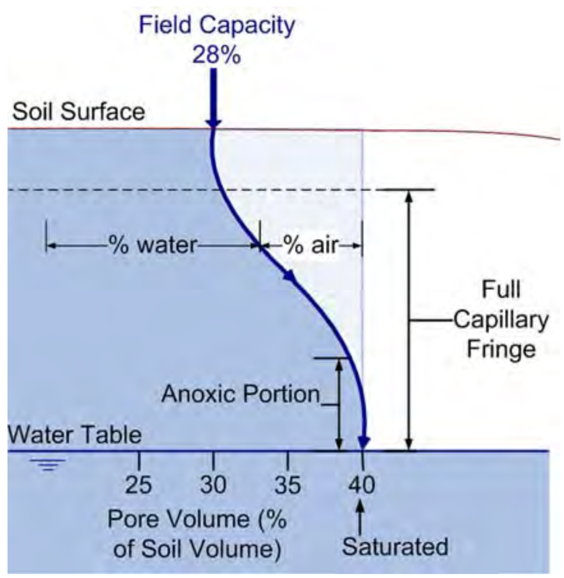


Figure H- 5
Proportion of Air- and Water-Filled Pores Between the Water Table and the Soil Surface After the Downward Flow of Water Ceases

The lower portion of the capillary fringe is considered too wet for crop health and few roots penetrate this zone. Crops do however use water from the top portion of this capillary fringe zone where there is more entrapped air. Capillary fringes may be thicker in the non crop season, under roads and other barren areas, and when water tables are deeper in the substrata.

Usually entrapped air, soil stratification and the discontinuity of soil pores and structural channels limit the thickness of a capillary fringe. The field setting can present a different capillary fringe than a theoretical or laboratory experiment under uniform controlled conditions. Thus, measurements made in the field are the basis for this analysis.

The capillary fringe is dependent on matric suction (or negative pressure head) to rise. During the furrow irrigation season, when infiltration from the ground surface adds a zone of near saturation at the top of the soil column, matric suction is reduced. If the matric suction within the pore spaces between the bottom of the irrigation zone and the capillary fringe is not great enough, capillary rise will be limited. In addition to the reduced capillary rise under irrigation, the capillary fringe and associated salinity may be pushed down depending on the leaching fraction of the applied irrigation (Rhoades, 1999). Between furrow irrigations, plants could pull up salts by transpiring water and capillary forces would then cause water and salt to rise above the water table and potentially into the root zone. These same crops could also limit the capillary rise however, by transpiring water before it can rise further into the root zone.

Soil boring logs from 85 soil sampling sites collected in March and April of 2010 were reviewed to determine the potential thickness of capillary fringe zones in soils of various textures on lands near the San Joaquin River. These are presented in Table H- 5 below.

Drill logs or, when available, the logs from soil borings offset from the wells were examined to determine soil textures in the monitoring wells from 4-6 feet deep. Many soil sampling sites were offset from stakes that were planned for future monitoring well sites when wells had not yet been drilled. In some cases the drill logs had fill. Under these circumstances the texture evaluation was 4-6 feet below the fill / native soil boundary as noted on the logs for the subsurface profile. Each well was assigned a capillary fringe thickness based on this analysis. Capillary fringe thicknesses for each well are presented in Table H- 6.

2.4.2 Results

A summary of the findings from the review of soil logs is presented below in Table H- 5.

Table H- 5
Capillary Fringe Thickness (inches)

Category	Soil Texture	Number of Observations	Average Rise, Inches	95% Confidence Range, inches
1	Sand, loamy sand	15	6.9	4.1 – 9.1
2	Sandy loam, loamy fine sand	4	13.75	9.5 – 18.1
3	Fine sandy loam, loam, silt loam, very fine sandy loam	21	18.3	14.3 – 22.3
4	Clay loam, silty clay loam, clay	6	10.3	5.1 – 15.5
2 and 3	Loamy fine sand, silt loam	25	17.6	14.1 – 20.9

Based on the data presented above from soil sampling sites (mostly in Reaches 4a and 4b) a capillary fringe (CF) thickness of 1 foot for all soils except the loamy sand and sand soils was incorporated. A 0.5 foot CF thickness would be used for these soils. The reasons for this decision are listed below.

- The upper portion of CF contains enough air to permit root establishment. The CF chosen here only includes the saturated anaerobic portion.
- The sites were evaluated based on spring conditions before the crop season. When an actively growing crop is present and is consuming water from the upper portion of the capillary fringe the thickness of the capillary fringe should be less.
- Categories 2-4 were combined since the 95 percent confidence intervals overlapped. The clay loam and clay soils were added to the 1 foot CF category since the low macro pore space present in these soils makes field observations of capillary fringe difficult.
- Only hand augured holes were evaluated. Large drill rigs tend to advance flight augurs too rapidly to evaluate and estimate capillary fringe conditions.
- The thick capillary fringe observed in October by ITRC researchers (Burt, 2010) was partially due to the lack of crop in the field and the depth to the water table. No crop roots were using water from the capillary fringe at the time, resulting in large observed capillary moisture content at some distance above the actual water table. The water table was about 7 to 8 feet deep rather than in the 4-5 foot threshold range. Capillary fringe thickness should increase with a deeper water table that is farther away from the influences of evaporative and crop consumptive use forces near the soil surface.

2.4.3 Limitations

- Timing of the capillary fringe vs. growing season or root development is not addressed in this approach.
- Water quality of the groundwater is not included as part of this evaluation. The irrigation buffer discussed below allows for leaching of potentially saline groundwater from the root zone.
- This approach does not address the degree of soil salinity existing at each site, or the potential for salts to rise through the entire capillary fringe rather than just the anaerobic portion addressed here. Soil salinity is addressed through the irrigation buffer.

2.5 Agricultural Practices Threshold Results

Table H- 6 below shows the results of the agricultural practices method.

Table H- 6. Agricultural Practices Method Thresholds

Well ID	Reach	Bank	Crop Type	Root Zone (feet)	Capillary Rise (feet)	Threshold in field (feet bgs)	Ground Surface Adjustment	Threshold in well (feet bgs)
JR-1	1A	Left	Public Land	4	1	5.0	0	5.0
JR-2	1A	Left	Public Land	4	1	5.0	0	5.0
MW-09-1	1A	Right	Public Land	4	.5	4.5	0	4.5
MW-09-2	1A	Right	Public Land	4	.5	4.5	0	4.5
FA-1	1B	Left	Vineyard	6	1	7.0	1.8	8.8
FA-2	1B	Left	Vineyard	6	1	7.0	2.2	9.2
FA-3	1B	Left	Vineyard	6	1	7.0	1.5	8.5
MA-1	1B	Left	Fallow	4	1	5.0	1.7	6.7
MW-09-23	1B	Left	Public Land	4	.5	4.5	-8.8	-4.3
MW-09-23B	1B	Left	Public Land	4	.5	4.5	-8.8	-4.3
MW-09-25	1B	Right	Public Land	4	1	5.0	-9.6	-4.6
R1-1	1B	Right	Pomegranate	6	.5	6.5	1.5	8.0
R1-2	1B	Right	Pomegranate	6	.5	6.5	3.1	9.6
FA-4	2A	Left	River Channel	4	1	5.0	-4.6	0.4
FA-5	2A	Left	River Channel	4	1	5.0	-4.7	0.3
FA-6	2A	Left	River Channel	4	1	5.0	4.8	9.8
FA-7	2A	Left	Almonds	9	1	10.0	5.6	15.6
FA-8	2A	Left	River Channel	4	1	5.0	1.7	6.7
FA-9	2A	Left	Alfalfa	4	1	5.0	3.7	8.7
MA-2	2A	Right	Annual Crops	4	1	5.0	2.9	7.9
MA-3	2A	Right	Annual Crops	4	1	5.0	0.9	5.9
MA-4	2A	Right	Vineyard w Drains	6	1	7.0	6.1	13.1
MW-09-36	2A	Right	Annual Crops	4	1	5.0	4.5	9.5
MW-09-37B	2A	Left	Vineyard	6	1	7.0	3.0	10.1
MW-09-39B	2A	Left	Almonds	9	.5	9.5	0.5	10.0
MW-09-47	2A	Right	Vineyard w Drains	6	1	7.0	3.5	10.5
MW-09-49B	2A	Left	Annual Crops w Drains	4	.5	4.5	1.7	6.2
MW-09-52	2B	Right	Almonds	9	1	10.0	0.9	10.9
MW-09-54B	2B	Right	Almonds	9	1	10.0	7.9	17.9

Table H- 6. Agricultural Practices Method Thresholds

Well ID	Reach	Bank	Crop Type	Root Zone (feet)	Capillary Rise (feet)	Threshold in field (feet bgs)	Ground Surface Adjustment	Threshold in well (feet bgs)
MW-09-55B	2B	Left	Palms	6	1	7.0	3.7	10.7
MW-09-56	2B	Left	Pistachios	6	1	7.0	1.7	8.7
PZ-09-R2B-1	2B	Right	Annual Crops	4	1	5.0	1.3	6.3
PZ-09-R2B-2	2B	Right	Annual Crops	4	.5	4.5	3.9	8.4
155	3	Left	Almonds	9	1	10.0	3.3	13.3
MW-10-117	3	Right		4	1	5.0	0	5.0
MW-10-118	3	Right		4	1	5.0	2.4	7.4
MW-10-119	3	Right		4	1	5.0	2.4	7.4
MW-10-120	3	Left		4	1	5.0	0	5.0
MW-10-121	3	Left		4	1	5.0	0	5.0
MW-10-122	3	Right		4	1	5.0	0	5.0
MW-10-123	3	Left		4	1	5.0	0	5.0
MW-10-124	3	Right		4	1	5.0	0.6	5.6
MW-10-74	3	Left	Almonds	9	.5	9.5	4.2	13.7
MW-10-75	3	Left	Almonds	9	1	10.0	0.5	10.5
MW-10-76	3	Left	Annual Crops	4	1	5.0	2.7	7.7
MW-10-78	3	Right	Annual Crops	4	1	5.0	3.0	8.0
PZ-09-R3-1	3	Right		4	.5	4.5	4.1	8.6
PZ-09-R3-2	3	Right	Annual Crops	4	1	5.0	1.5	6.5
PZ-09-R3-3	3	Right	Annual Crops	4	1	5.0	4.3	9.3
PZ-09-R3-4	3	Right	Annual Crops	4	1	5.0	3.5	8.5
PZ-09-R3-5	3	Right	Annual Crops	4	1	5.0	1.2	6.2
PZ-09-R3-6	3	Right	Annual Crops	4	1	5.0	1.5	6.5
PZ-09-R3-7	3	Right	Annual Crops	4	.5	4.5	0.7	5.2
191	4A	Left		4	1	5.0	2.9	7.9
186A	4A	Left		4	1	5.0	2.0	7.0
MW-09-83B	4A	Right	Public Land	4	1	5.0	0	5.0
MW-09-85B	4A	Right	Public Land	4	1	5.0	6.9	11.9
MW-09-86B	4A	Left	Public Land	4	1	5.0	7.9	12.9
MW-09-87B	4A	Left	Public Land	4	.5	4.5	1.9	6.4

Table H- 6. Agricultural Practices Method Thresholds

Well ID	Reach	Bank	Crop Type	Root Zone (feet)	Capillary Rise (feet)	Threshold in field (feet bgs)	Ground Surface Adjustment	Threshold in well (feet bgs)
MW-09-88	4A	Left	Public Land	4	1	5.0	2.2	7.2
MW-10-115	4A	Left		4	1	5.0	0	5.0
MW-10-116	4A	Right		4	1	5.0	0	5.0
MW-10-188	4A	Left	Annual Crops	4	1	5.0	2.1	7.1
MW-10-80	4A	Right	Annual Crops	4	1	5.0	5.1	10.1
MW-10-89	4A	Right	Almonds	9	.5	9.5	3.4	12.9
MW-10-91	4A	Left	Tomatoes	3	1	4.0	3.7	7.7
MW-10-92	4A	Left	Tomatoes	3	1	4.0	2.6	6.6
MW-10-93	4A	Left	Tomatoes	3	1	4.0	2.2	6.2
SJR W-10	4A	Left	Tomatoes	3	1	4.0	1.8	5.8
SJR W-11	4A	Left	Tomatoes	3	1	4.0	1.8	5.8
SJR W-12	4A	Left	Tomatoes	3	1	4.0	2.1	6.1
SJR W-4	4A	Left	Corn	3	1	4.0	1.1	5.1
SJR W-5	4A	Left	Tomatoes	3	1	4.0	1.9	5.9
SJR W-6	4A	Left	Tomatoes	3	1	4.0	4.4	8.4
SJR W-7	4A	Left	Tomatoes	3	1	4.0	4.0	8.0
SJR W-8	4A	Left	Alfalfa	4	1	5.0	3.3	8.3
SJR W-9	4A	Left	Tomatoes	3	1	4.0	1.1	5.1
MW-10-100	4B1	Left	Annual Crops	4	1	5.0	4.5	9.5
MW-10-102	4B1	Right	Annual Crops	4	1	5.0	2.4	7.4
MW-10-103	4B1	Right	Annual Crops	4	1	5.0	4.6	9.6
MW-10-105	4B1	Left		4	1	5.0	1.4	6.4
MW-10-106	4B1	Left		4	1	5.0	2.0	7.0
MW-10-107	4B1	Left		4	1	5.0	2.7	7.7
MW-10-108	4B1	Left		4	1	5.0	1.7	6.7
MW-10-109	4B1	Left		4	1	5.0	1.5	6.5
MW-10-110	4B1	Left		4	1	5.0	1.8	6.8
MW-10-111	4B1	Left		4	1	5.0	1.8	6.8
MW-10-112	4B1	Right		4	1	5.0	0	5.0
MW-10-113	4B1	Left		4	1	5.0	4.4	9.4
MW-10-114	4B1	Left		4	1	5.0	1.9	6.9
MW-10-90	4B1	Right	Pistachios	6	1	7.0	4.7	11.7

Table H- 6. Agricultural Practices Method Thresholds

Well ID	Reach	Bank	Crop Type	Root Zone (feet)	Capillary Rise (feet)	Threshold in field (feet bgs)	Ground Surface Adjustment	Threshold in well (feet bgs)
MW-10-94	4B1	Right	Pistachios	6	1	7.0	0	7.0
MW-10-95	4B1	Right	Alfalfa	4	1	5.0	2.2	7.2
MW-10-96	4B1	Right	Alfalfa	4	1	5.0	2.0	7.0
MW-10-97	4B1	Right	Annual Crops	4	.5	4.5	3.4	7.9
MW-10-98	4B1	Left	Annual Crops	4	1	5.0	4.0	9.0
MW-10-99	4B1	Left	Annual Crops	4	1	5.0	4.7	9.7
SJR W-1	4B1	Left		4	1	5.0	1.8	6.8
SJR W-2	4B1	Left		4	1	5.0	4.2	9.2
SJR W-3	4B1	Left		4	1	5.0	3.8	8.8
MW-09-125	5	Right	Alfalfa	4	1	5.0	0	5.0

3 Historical Groundwater Levels

The second method of analysis, historical groundwater levels, makes use of long-term groundwater-level measurements to derive thresholds in the context of historical field conditions and agricultural practices. Groundwater level data along the San Joaquin River does not exist in all areas and times of interest. Sources of historical groundwater data include CCID, which maintains a network of shallow monitoring wells; the United States Geological Survey (USGS); and the California Department of Water Resources (DWR). Ninety percent of the available records represent the period from 1960 to the present, with some wells covering a longer time period. Although some wells have monthly or weekly measurements for short periods of time, the majority of wells have biannual spring and fall measurements.

3.1 Objectives

The objective of the historical groundwater level method is to use long-term groundwater-level data to indicate hydrologic conditions under which agriculture has historically operated, and to derive thresholds on the basis of this information.

3.2 Approach

Threshold development using historical groundwater levels is approached in three ways, depending on availability of long-term data:

1. If the threshold well has been monitored long term, the groundwater levels are used directly to derive a threshold;
2. If the threshold well has not been monitored long term, but a nearby well has, the groundwater levels from the nearby well are used indirectly to derive a threshold; or
3. If the threshold well has not been monitored long term, and no nearby wells have been monitored long term, mapped estimates of the depth to water at the well location are used to derive a threshold.

3.2.1 Method A: Thresholds for long-term wells

Long-term groundwater level data for a shallow well provide a good indication of historical variability and position of the water table. These data reflect a combination of climatic influences and agricultural practices. Climatic influences include local precipitation and flows in canals and the river. Agricultural practices include irrigation, groundwater pumping, and various forms of drainage. Groundwater levels represent the combined effect of these processes, making these data very useful for developing monitoring thresholds.

Hydrographs were made for threshold wells having available data during the period from 1983 through September 2009, just prior to the first Interim Restoration flows in October 2009. This time period is relatively data rich, and represents the post-recovery period following importation of surface water to various areas surrounding the exchange contractors and the associated decline in groundwater pumping (Belitz and others, 1993).

From these hydrographs, spring (March through May) measurements were identified and grouped. For each group of spring measurements for a threshold well, the greatest 31 percent of the groundwater-level elevations were assumed to be representative of relatively wet climatic conditions, and therefore not representative of typical agricultural conditions. The 31 percent cutoff was based on the number of wet years (9) that occurred during the period of record for groundwater level measurements in CCID monitoring wells (29 years). The threshold was then defined as the greatest remaining groundwater-level elevation after removal of the top 31 percent of values.

Figure H- 6 shows the location of threshold well CCID-191, and Figure H- 7 shows the historical groundwater threshold developed for CCID-191 using this method. Groundwater levels (points) shown in blue were measured during the spring; those in grey were measured during other times of the year, or were among the greatest 31 percent of spring measurements. The green dashed line is the threshold; note that the high groundwater levels associated with 1983 and other relatively wet years are above the threshold, as designed.

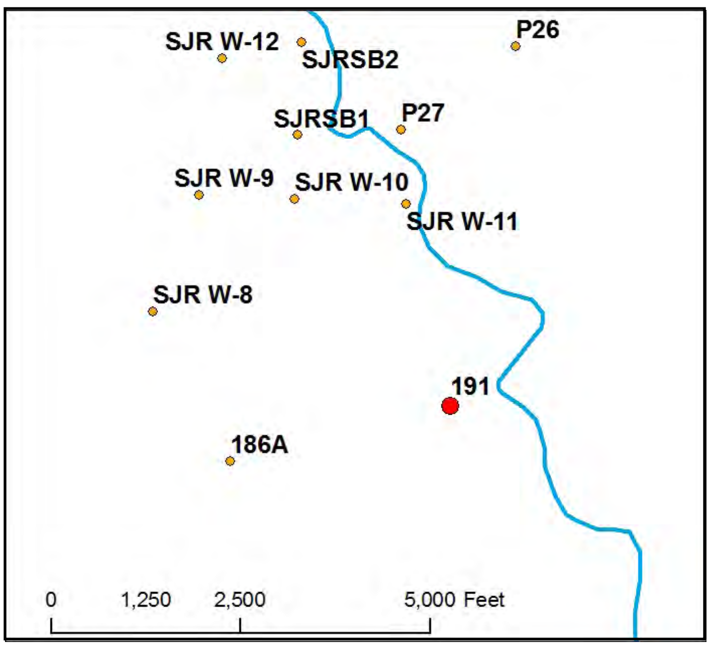


Figure H- 6
General location of CCID shallow monitoring well 191

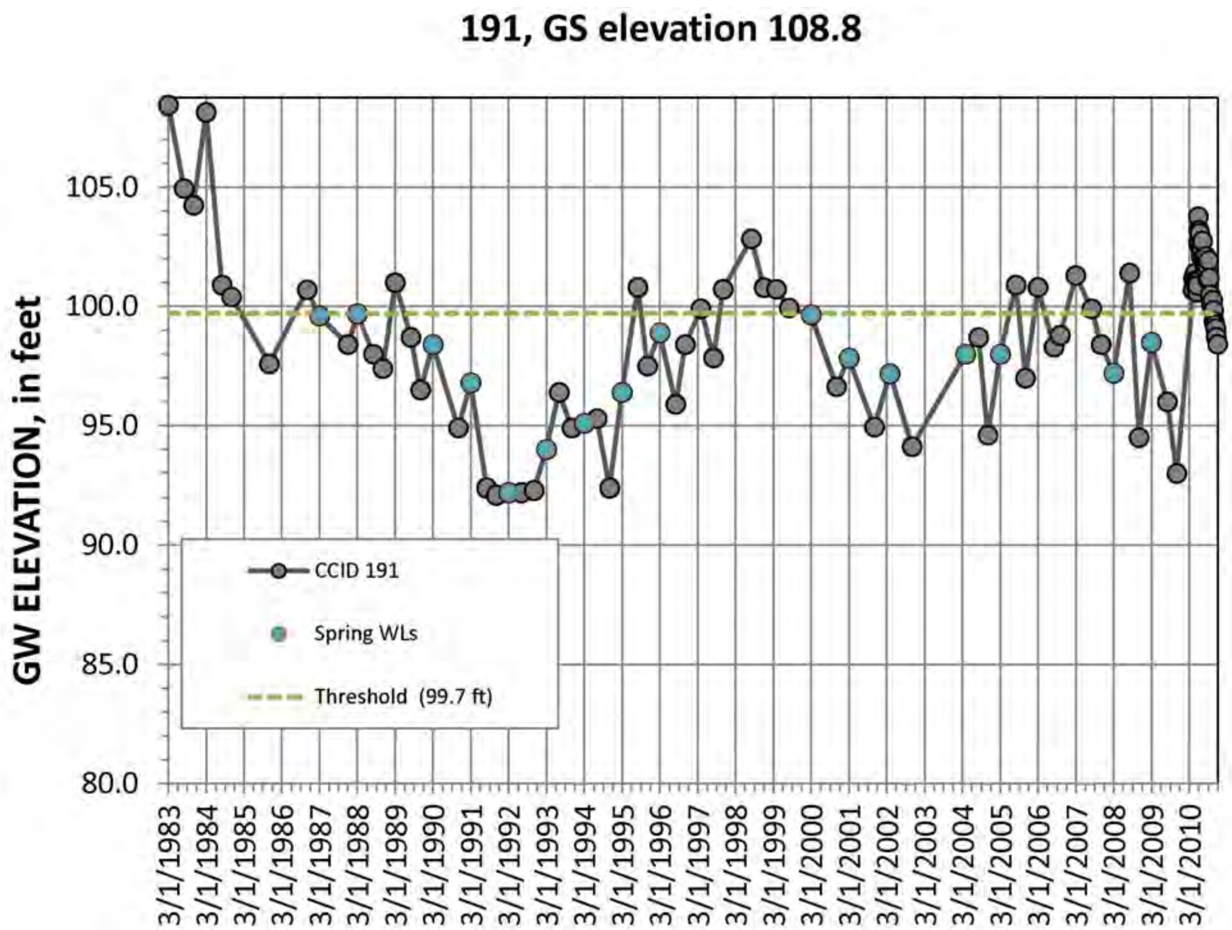


Figure H- 7
Thresholds developed using historical groundwater-level measurements in CCID Well 191

3.2.2 Method B: Thresholds for wells near long-term wells

To assign thresholds for wells having only short-term groundwater level date (i.e., beginning in 2009 or later), use was made of long-term groundwater level data associated with a nearby well (within one mile). Thresholds were calculated as described above using long-term groundwater levels from the nearby well, with one exception: groundwater-level elevations for the nearby well were adjusted by the difference in ground-surface elevation between the nearby and threshold wells.

A key assumption in this approach is that hydrologic conditions local to the well having long-term data, such as depth to water, are similar to those at the threshold well. This assumption was tested graphically by comparing historical data from the nearby well to short-term data from the threshold well. This is not a precise comparison, but it is a reasonable first-cut test of the assumption.

Figure H- 8 shows the location of threshold well MW-09-88 and nearby well CCID-188a, which has long-term groundwater level data that was used to develop the threshold. The ground surface at the CCID well happens to be the same as that at the threshold well; therefore, no adjustment for the difference in elevation was necessary in this case. Groundwater levels (points) shown as blue circles in Figure H- 9 were measured in CCID-188a during the spring, and those in grey were measured during other times of the year, or were among the greatest 31 percent of spring measurements; dark blue diamonds represent measurements in MW-09-88. The green dashed line is the threshold; note that the high groundwater levels associated with 1983 and other relatively wet years are above the threshold, as designed. Also note that the cluster of measurements in MW-09-88 during 2010 reasonably match measurements made in CCID-188a; thus, the assumption of similar hydrologic conditions at the two wells appears reasonable.

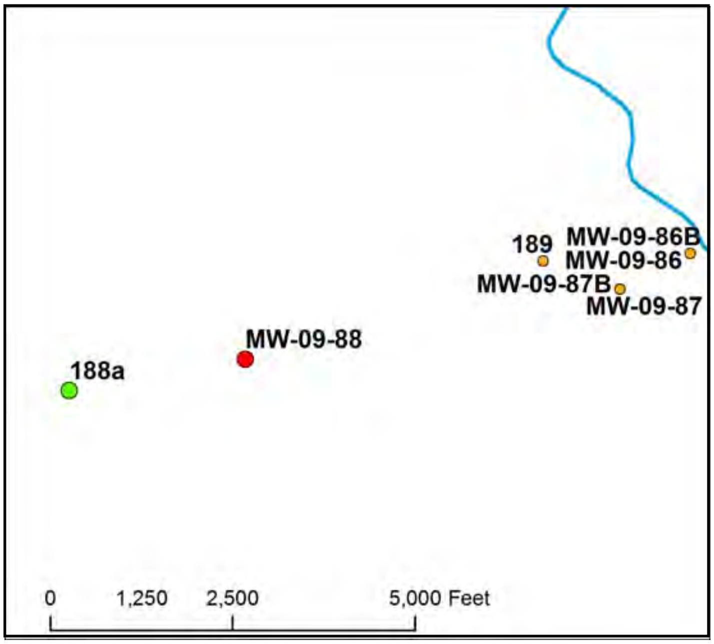


Figure H- 8
General location of well MW-09-88 and nearby CCID shallow monitoring well 188a

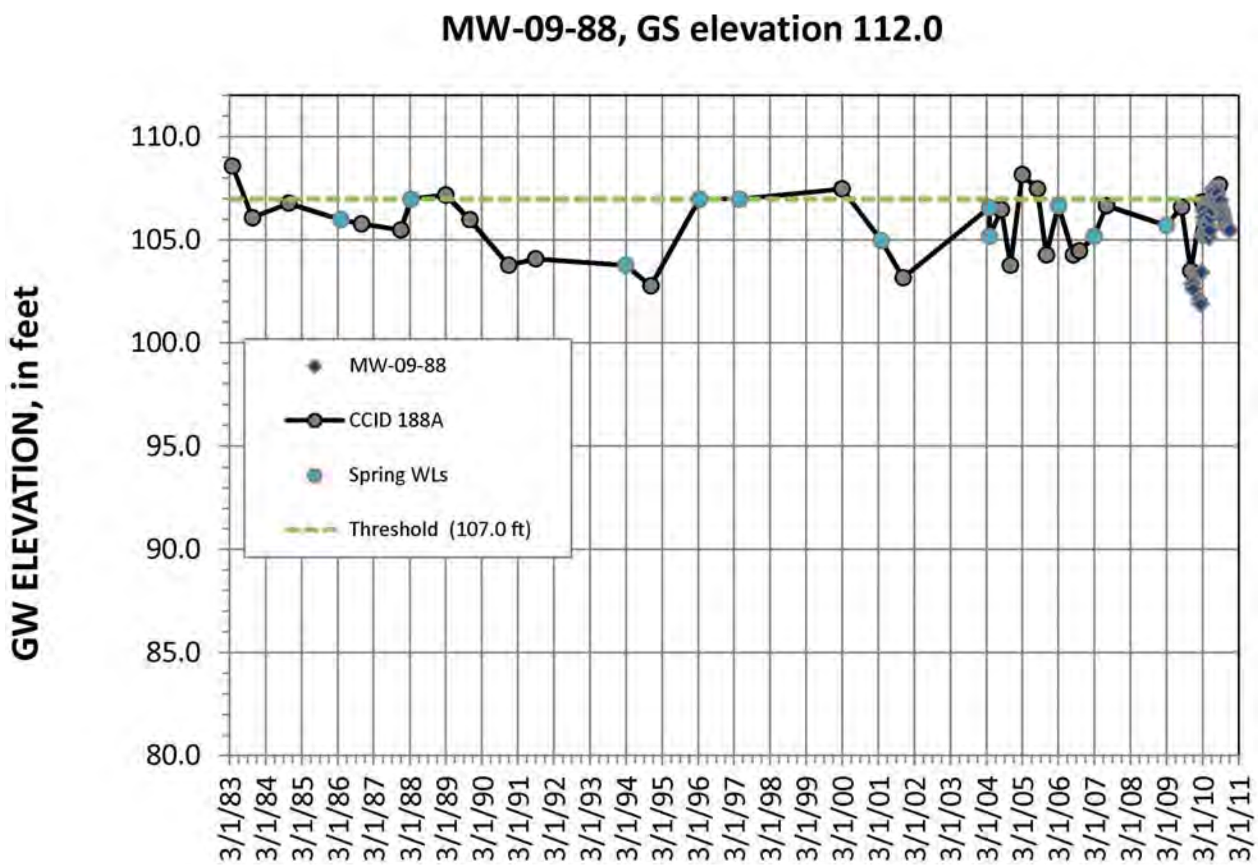


Figure H- 9
Threshold developed for MW-09-88 using historical groundwater-level measurements from nearby CCID well 188a

3.2.3 Method C: Thresholds for wells with no long-term data

There is a third set of threshold wells for which little or no short-term groundwater level data are available, and no nearby wells provide long-term data. Thresholds for these wells based on historic groundwater levels, regardless of methodology, will have a relatively high degree of uncertainty. A means was developed, however, for providing ballpark threshold estimates using existing maps of depth to water, and a new map based on average long-term data from CCID.

3.2.3.1 Thresholds Based on Maps of Depth to Water

The USGS developed maps of depth to water (DTW) for various years from the 1960s to present having the greatest number of measurements. These maps were developed before some of the well construction information was available, and therefore include both shallow and deep wells in some areas. There are few shallow wells available outside of Reaches 3 and 4A. The DTW maps cover a variety of year types; the three maps chosen for use in this analysis represent average, or normal, conditions. Spring 2008 represents springtime conditions in normal-dry year, fall 2008 represents fall conditions in a normal-dry year, and fall 1999 represents fall conditions in a normal-wet year. The water-level database contains relatively few spring groundwater level measurements, thus few spring DTW maps were made, and no map is available to represent normal-wet springtime conditions. This, and the inclusion of deep wells, may result in lower groundwater levels than a truly representative sample.

The DTW maps presented in Figure H- 10 through Figure H- 15 were developed by the USGS using data from CCID, DWR, and USGS; these data were interpolated using the inverse distance weighting (IDW) method. The IDW method averages the depth to water in adjacent wells while weighting measurements from closer wells more heavily than those from more distant wells. A greater concentration of points results in a better interpolation. Interpolations in areas having few or no wells can only be considered an approximation of actual conditions. Interpolated depths to water at SJRRP monitoring well locations were assigned as threshold values. In areas completely without data (for example, in Fall 2008 Reaches 1A through 2A - Figure H- 10 below), no thresholds were assigned.

The SJRRP converted depths to water from the maps below, which represent depth to water below the field, to depth to water in the well assuming the same ground surface adjustment used in the Agricultural Practices Method.

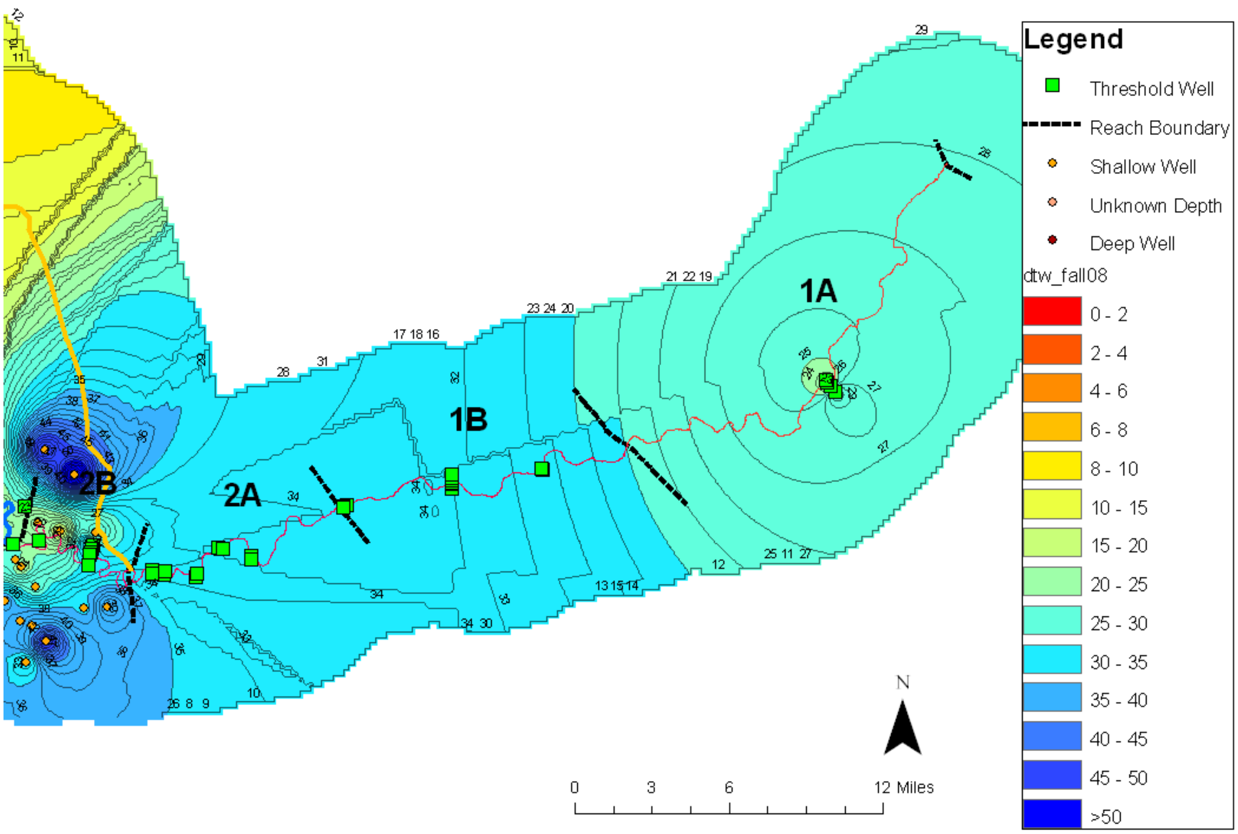


Figure H- 10
Fall 2008 Depth to Water in Reaches 1A through 2B

The DTW maps contain deep wells, which likely represent hydraulic conditions within the confined aquifer, where the majority of groundwater pumping occurs, rather than the unconfined surficial aquifer that contains the water table. These wells include Mendota Pool Group production wells and other groundwater extraction wells. Because of this, low spots can be seen on the maps surrounding production wells; this is particularly noticeable in Figure H- 13. When interpolated on DTW maps with sparse data, these pumping centers affect groundwater levels far away from the pumps. This limitation, combined with the fact that they may represent the production zone of the confined aquifer, calls into question their appropriateness for representing water-table conditions. However, some deep wells may have water levels representative of the water table, especially those northeast of the San Joaquin River. To reduce the influence of deep pumping wells on results, the minimum value from the three DTW maps was assigned as the DTW-based threshold.

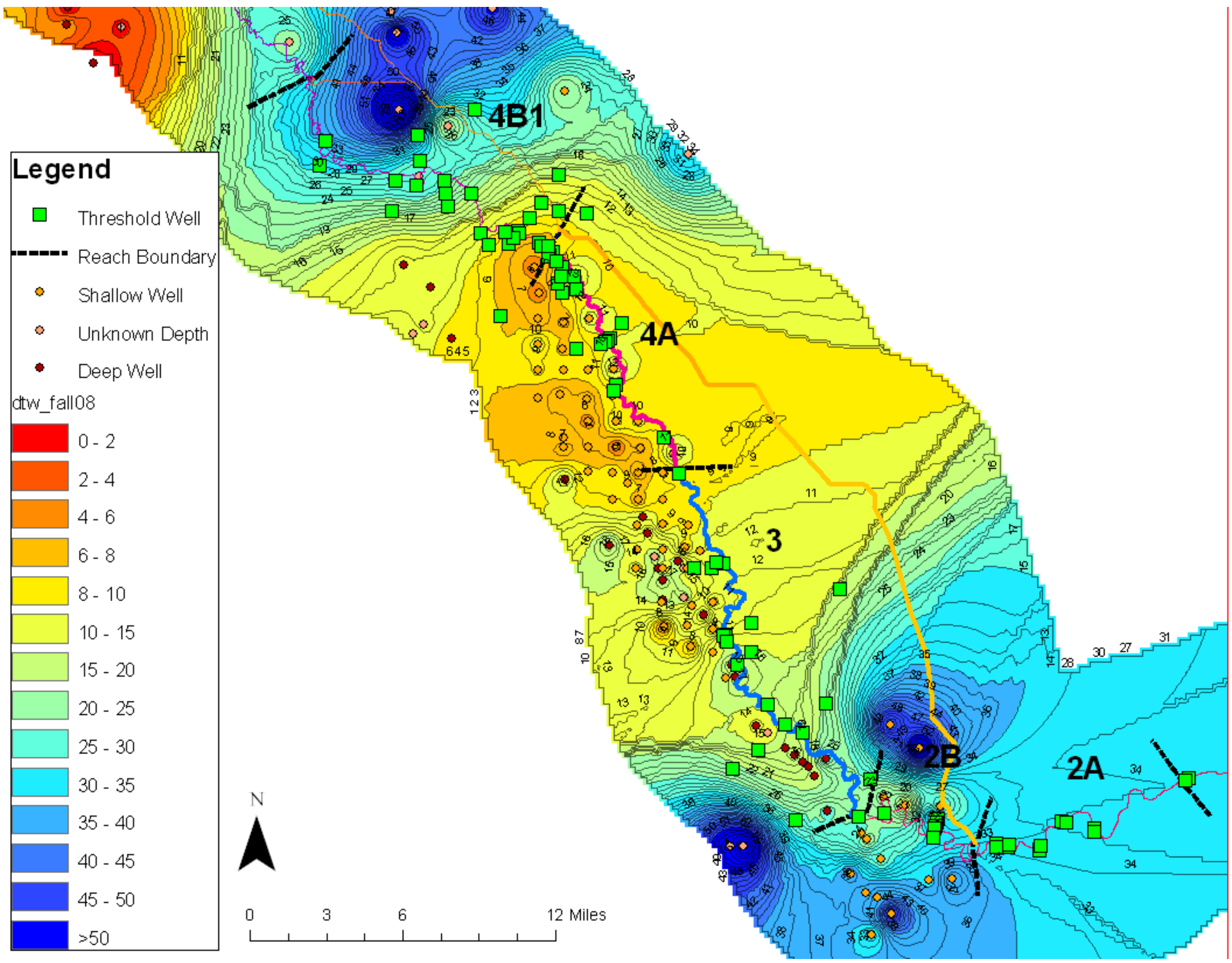


Figure H- 11
Fall 2008 Depth to Water in Reaches 2B through 4B1

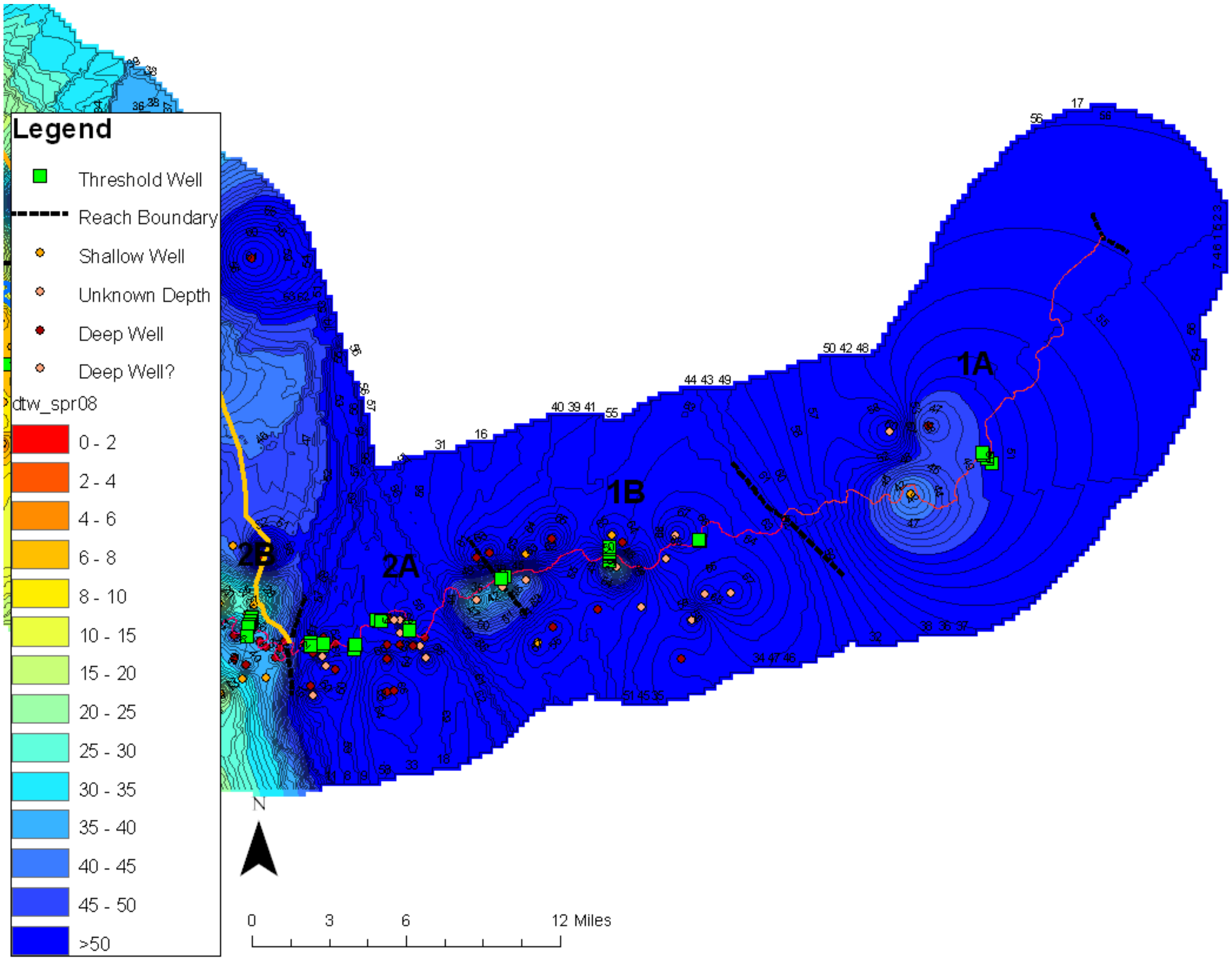


Figure H- 12
Spring 2008 Depth to Water in Reaches 1A through 2B

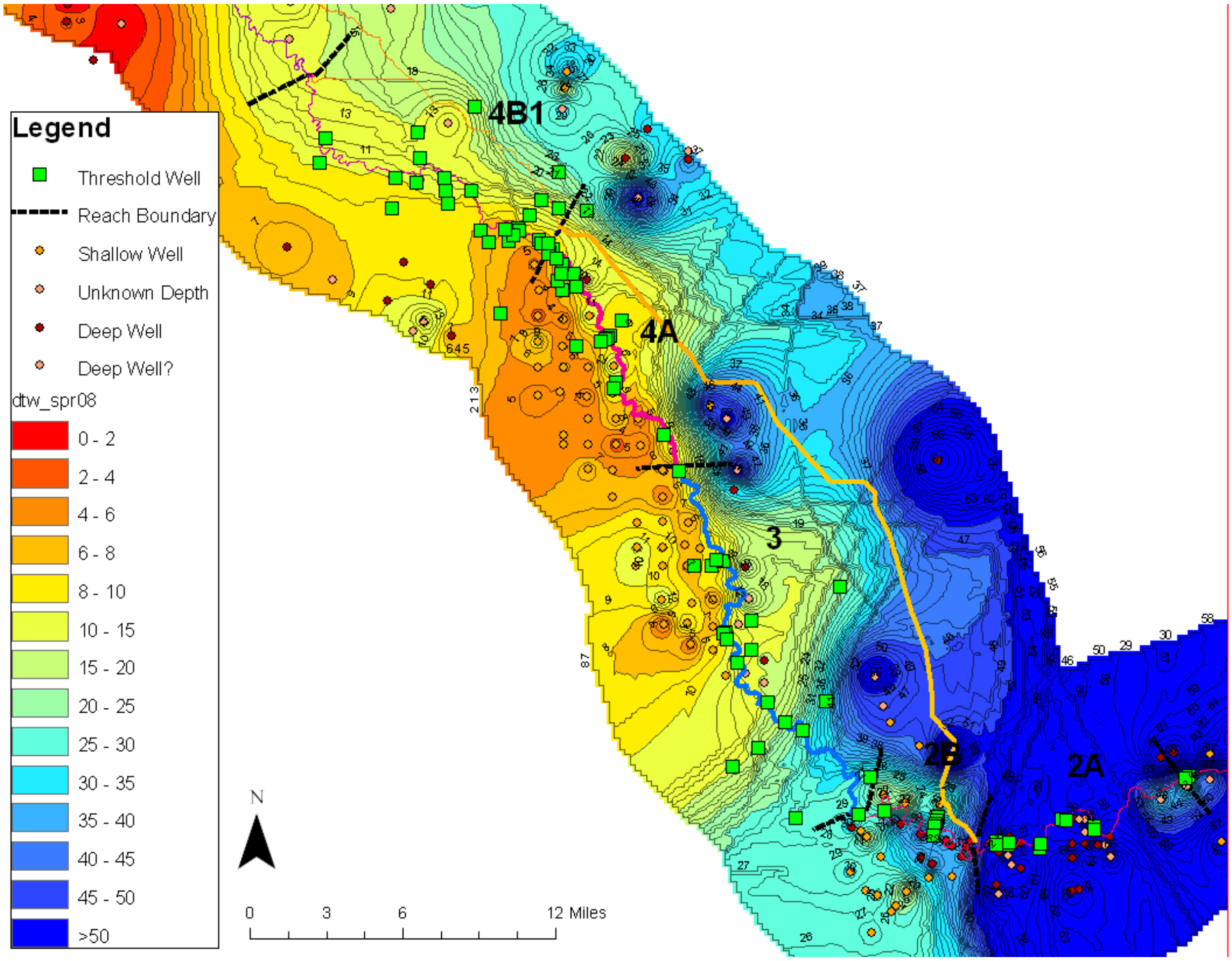


Figure H- 13
Spring 2008 Depth to Water in Reaches 2B through 4B1

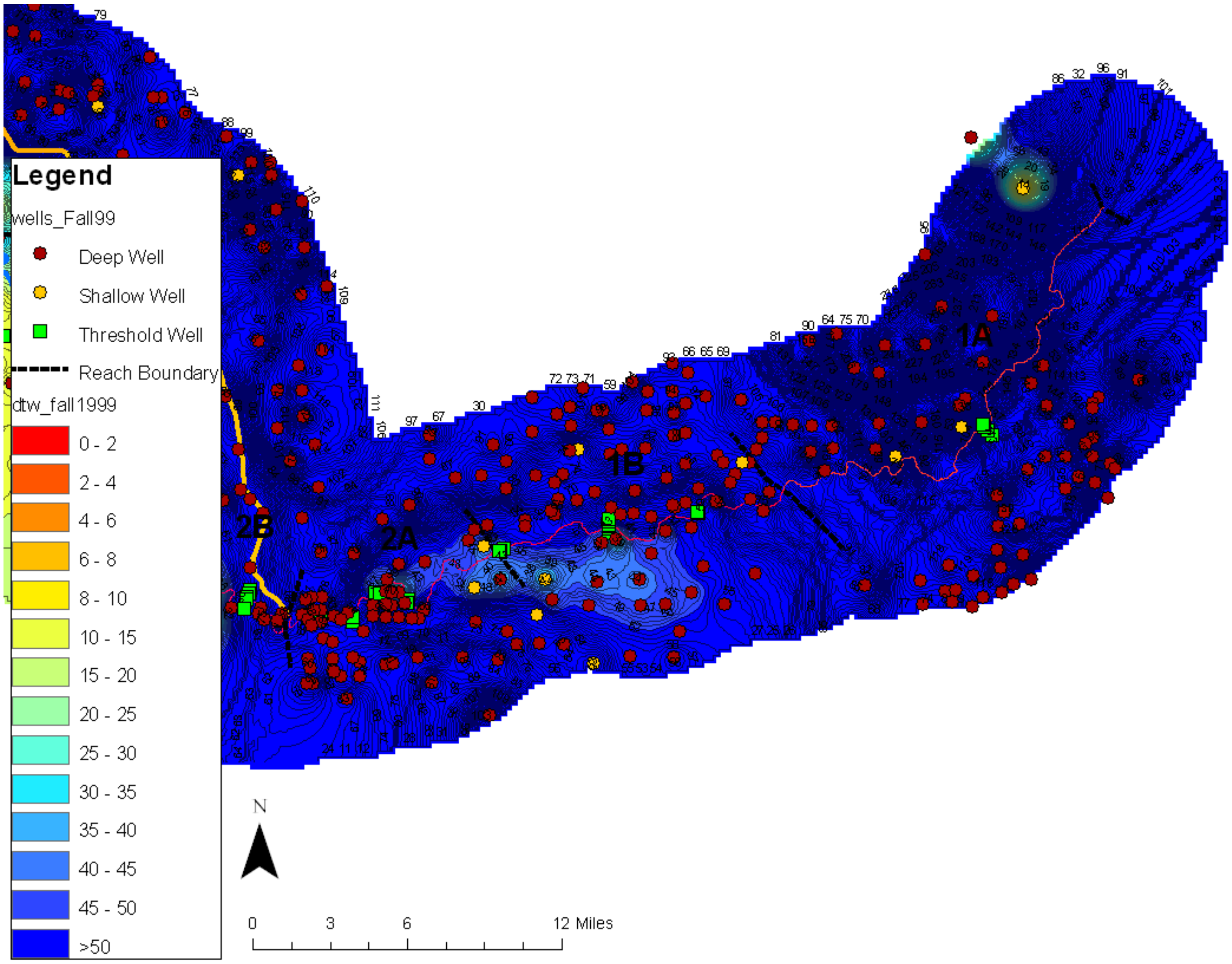


Figure H- 14
Fall 1999 Depth to Water in Reaches 1A through 2B

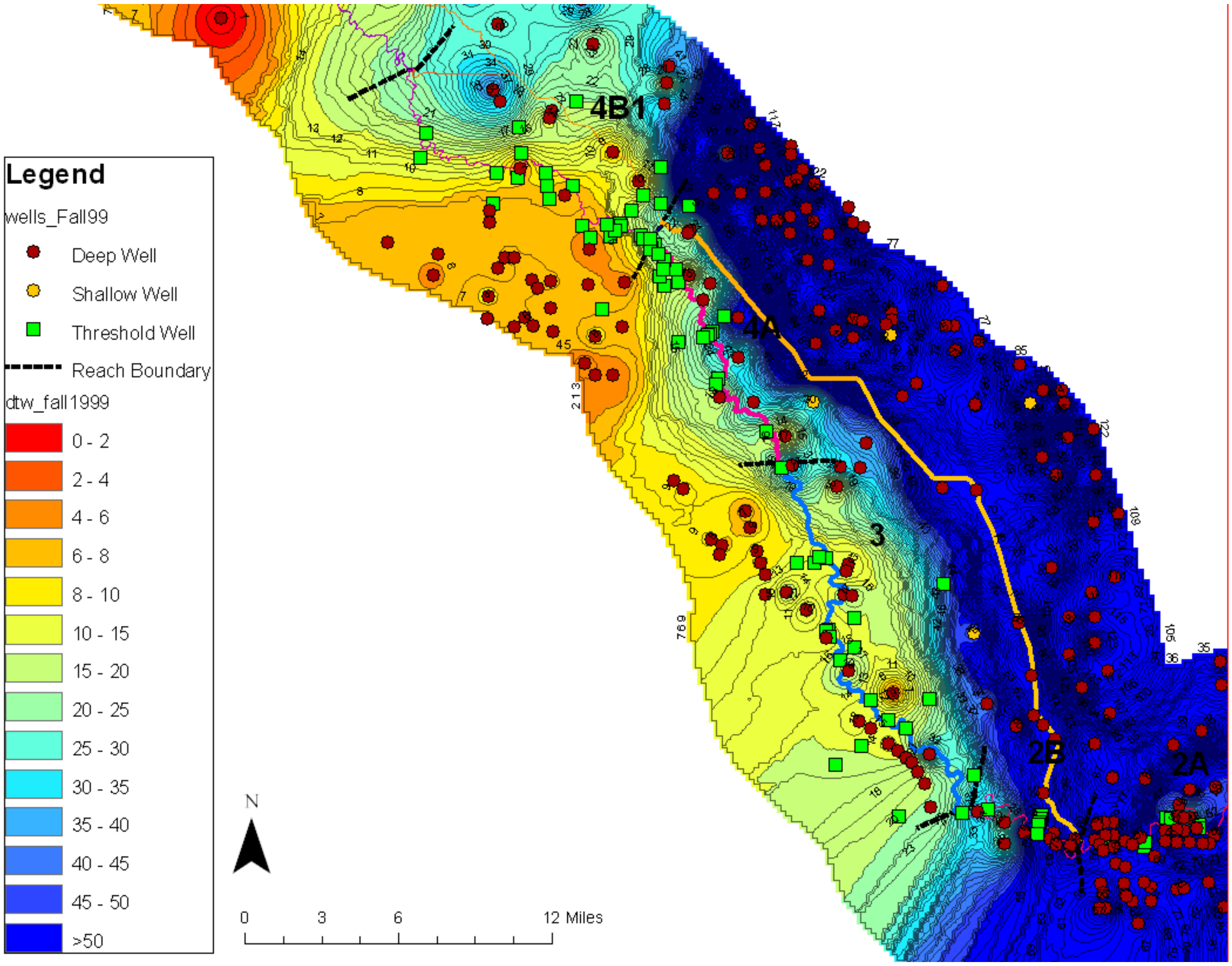


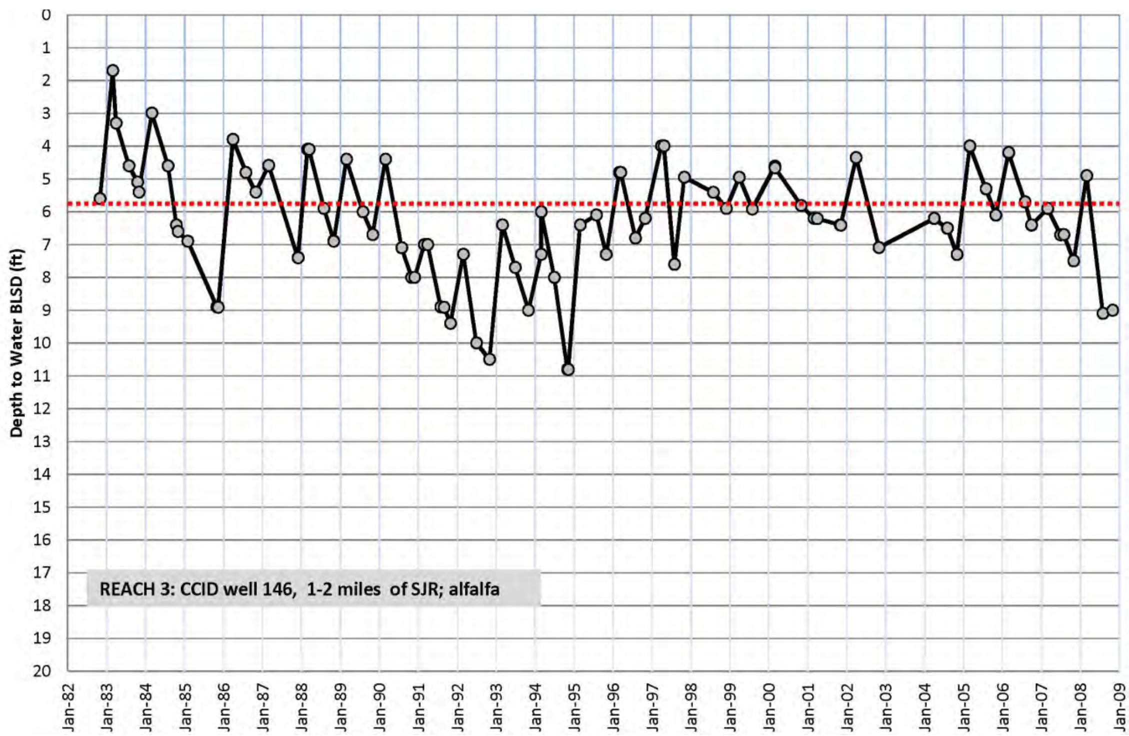
Figure H- 15
Fall 1999 Depth to Water in Reaches 2B through 4B1

3.2.4 CCID Threshold Wells

3.2.4.1 Thresholds Based on Map of Long-Term Average CCID Data

The above approach uses a database of mainly bi-annual measurements. However, CCID maintains an extensive monitoring well network along the west side of Reaches 3 and 4A of the San Joaquin River, representing a long historical record. Ground surface elevation is available for all CCID wells, thus ensuring vertical control and a large set of groundwater levels that represent the water table. Groundwater levels were averaged for each well; these measurements were made over an extensive period of time and at a set interval, which raises confidence that an average of these measurements best represents average groundwater conditions in this area.

Figure H- 16 shows a typical hydrograph for wells in CCID. The dotted line represents the average groundwater level during the period shown. Average groundwater levels for wells similar to this were used in the analysis; wells indicating strong influence from groundwater pumping were not used.



Note: BLSD = below land surface datum (equivalent to below ground surface)

Figure H- 16
Hydrograph of CCID Well 146 showing long-term average

As a first step, average DTW below ground surface was converted to water-table elevation using the known ground surface elevation near to CCID wells (CCID corrects their depth to water measurements to be below field ground surface) and interpolated using IDW across Reaches 3 and 4A.

Figure H- 17 below shows the resultant water table elevation map. Green stars represent the subset of CCID wells with consistent data that the USGS created hydrographs for. These represent data points used for interpolation. Thresholds at this point were assigned for wells marked with a black square on the basis of the colored interpolation surface in Figure H- 17. This water-table elevation was converted back to DTW for each well. Converting to elevation and then back to DTW below ground surface corrects for wells located on levee banks or otherwise at a different elevation.

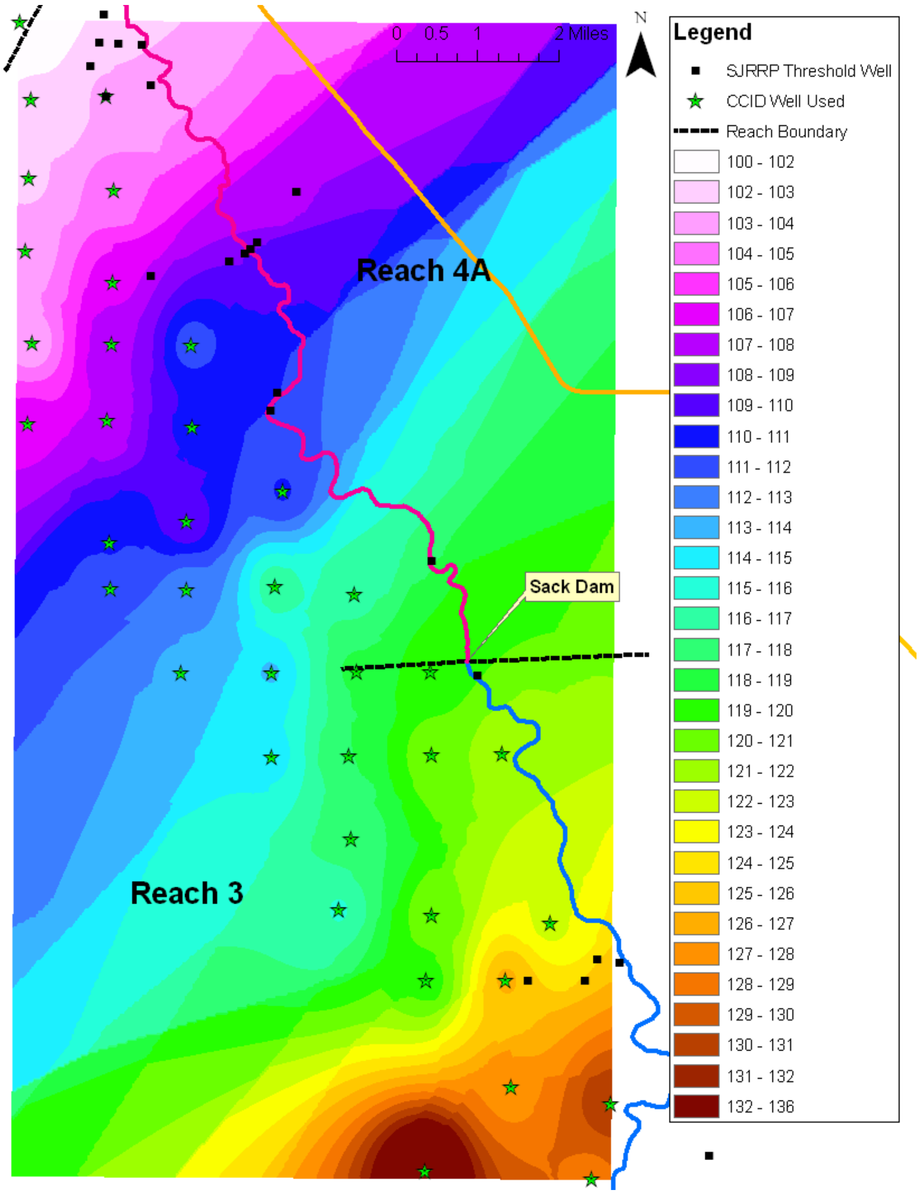


Figure H- 17
Map of Average Historical Water-Table Elevation in CCID wells

3.3 Results

Table H- 7 below shows thresholds derived from historical groundwater levels, based on these analyses.

1

Table H- 7. Historical Groundwater Method Thresholds

Well ID	Method A - Based on water levels in well (feet bgs in field)	Method B - Based on water levels in nearby well (feet bgs in field)	Method C - CCID Well Average Groundwater Elevation (feet)	Method C - CCID Well Average Groundwater Depth (feet bgs in field)	Method C - Groundwater Depth Fall 1999 (feet bgs in field)	Method C - Groundwater Depth Spring 2008 (feet bgs in field)	Method C - Groundwater Depth Fall 2008 (feet bgs in field)	Historical Groundwater Method Used	Historical Groundwater (feet bgs in field)
JR-1						50		C	50
JR-2						50		C	50
MW-09-1					112	51		C	51
MW-09-2					101	51		C	51
FA-1					48	44		C	44
FA-2					46	36		C	36
FA-3					46	36		C	36
MA-1					46	36		C	36
MW-09-23					50	54		C	50
MW-09-23B					50	54		C	50
MW-09-25					50	54		C	50
R1-1					58	65		C	58
R1-2					61	66		C	61
FA-4					42	59		C	42
FA-5					42	59		C	42
FA-6					63	60		C	60
FA-7					63	60		C	60
FA-8					73	58		C	58
FA-9					72	60		C	60
MA-2					40	59		C	40
MA-3					60	60		C	60
MA-4					72	54		C	54
MW-09-36					49	56		C	49
MW-09-37B					49	56		C	49
MW-09-39B					34	59		C	34
MW-09-47					72	60		C	60
MW-09-49B					68	56		C	56
MW-09-52					58	31	31	C	31

Table H- 7. Historical Groundwater Method Thresholds

Well ID	Method A - Based on water levels in well (feet bgs in field)	Method B - Based on water levels in nearby well (feet bgs in field)	Method C - CCID Well Average Groundwater Elevation (feet)	Method C - CCID Well Average Groundwater Depth (feet bgs in field)	Method C - Groundwater Depth Fall 1999 (feet bgs in field)	Method C - Groundwater Depth Spring 2008 (feet bgs in field)	Method C - Groundwater Depth Fall 2008 (feet bgs in field)	Historical Groundwater Method Used	Historical Groundwater (feet bgs in field)
MW-09-54B					59	33	33	C	33
MW-09-55B					60	33	32	C	32
MW-09-56					57	38	31	C	31
PZ-09-R2B-1					34	27	24	C	24
PZ-09-R2B-2					30	27	24	C	24
155	6.7		125.3	6.0		8	12	A	6.7
MW-10-117						24	16	C	16
MW-10-118					15	14	13	C	13
MW-10-119					15	13	15	C	13
MW-10-120						14	21	C	14
MW-10-121					15	16	16	C	15
MW-10-122						33	21	C	21
MW-10-123						29	27	C	27
MW-10-124						28	25	C	25
MW-10-74		9.6	125.6	6.2	13	11	12	B	9.6
MW-10-75			125.0	6.3		9	12	C	6.3
MW-10-76			125.3	2.7		7	13	C	2.7
MW-10-78			119.9	2.4	29	8	9	C	2.4
PZ-09-R3-1					12	9.7	14	C	9.7
PZ-09-R3-2					12	9.7	14	C	9.7
PZ-09-R3-3					12	9.9	16	C	9.9
PZ-09-R3-4					17	12	17	C	12
PZ-09-R3-5					14	19	16	C	14
PZ-09-R3-6					13	15	15	C	13
PZ-09-R3-7					16	28	18	C	16
191	9.1		103.1	5	16	10	10	A	9.1
186A	3.5		103.1	3		6	8	A	3.5
MW-09-83B			107.6	7.4		9	10	C	7.4
MW-09-85B			108.4	5.3		9	10	C	5.3
MW-09-86B			108.4	5.0		9	10	C	5.0

Table H- 7. Historical Groundwater Method Thresholds

Well ID	Method A - Based on water levels in well (feet bgs in field)	Method B - Based on water levels in nearby well (feet bgs in field)	Method C - CCID Well Average Groundwater Elevation (feet)	Method C - CCID Well Average Groundwater Depth (feet bgs in field)	Method C - Groundwater Depth Fall 1999 (feet bgs in field)	Method C - Groundwater Depth Spring 2008 (feet bgs in field)	Method C - Groundwater Depth Fall 2008 (feet bgs in field)	Historical Groundwater Method Used	Historical Groundwater (feet bgs in field)
MW-09-87B			108.9	4.2		9	10	C	4.2
MW-09-88		5.0	107.6	2		6	8	B	5.0
MW-10-115						5.6	8	C	5.6
MW-10-116					55	22	11	C	11
MW-10-188		9.5	111.0	4	23	9	9	B	9.5
MW-10-80			117.6	2	18	9	9	C	9
MW-10-89			111.2	4	21	9	9	C	9
MW-10-91						8	8	C	8
MW-10-92						8	7	C	7
MW-10-93						7	7	C	7
SJR W-10			102.8	2	18	11	13	C	11
SJR W-11		11.2	102.9	4	17	11	14	B	11.2
SJR W-12						9	10	C	9
SJR W-4						8	9	C	8
SJR W-5						8	7.0	C	7.0
SJR W-6						7	6.8	C	6.8
SJR W-7						9	7.2	C	7.2
SJR W-8			102.8	3		7	8	C	7
SJR W-9			102.5	1		9	9	C	9
MW-10-100					7	6.5	8	C	6.5
MW-10-102						14	36	C	14
MW-10-103					11	13	28	C	11
MW-10-105					7.4	10	28	C	7.4
MW-10-106					9.6	10	27	C	9.6
MW-10-107					6.9	9	21	C	6.9
MW-10-108					9.1	12	25	C	9.1
MW-10-109					7.8	11	22	C	7.8
MW-10-110						12	34	C	12
MW-10-111						10	30	C	10
MW-10-112					20	17	30	C	17

Table H- 7. Historical Groundwater Method Thresholds

Well ID	Method A - Based on water levels in well (feet bgs in field)	Method B - Based on water levels in nearby well (feet bgs in field)	Method C - CCID Well Average Groundwater Elevation (feet)	Method C - CCID Well Average Groundwater Depth (feet bgs in field)	Method C - Groundwater Depth Fall 1999 (feet bgs in field)	Method C - Groundwater Depth Spring 2008 (feet bgs in field)	Method C - Groundwater Depth Fall 2008 (feet bgs in field)	Historical Groundwater Method Used	Historical Groundwater (feet bgs in field)
MW-10-113					7.7	11	20	C	7.7
MW-10-114					7.3	9	20	C	7.3
MW-10-90						15	11	C	11
MW-10-94					36	23	14	C	14
MW-10-95					13	15	11	C	11
MW-10-96						11	9.0	C	9.0
MW-10-97						8.2	9	C	8.2
MW-10-98						8.2	8.0	C	8.0
MW-10-99						6.6	8	C	6.6
SJR W-1						6.8	10	C	6.8
SJR W-2					6.2	8	11	C	6.2
SJR W-3					5.5	7	9	C	5.5
MW-09-125						9.3	10	C	9.3

Key: bgs = below ground surface; CCID = Central California Irrigation District

3.4 Limitations

All thresholds based on measured groundwater levels are subject to inaccuracies associated with the DTW measurements themselves, and with the local datum used to calculate groundwater level elevations. Given the low-precision nature of threshold estimation and good measurement protocols in place, the potential error in measurement of DTW can be neglected. However, some measurements may have been taken during, or soon after, irrigation and would not represent static conditions. If field notes are obtained, these measurements will be filtered from the data set.

Thresholds calculated on the basis of long-term spring water levels measured in the threshold well are strongly tied to known field conditions, and therefore are relatively well posed. The elimination of the greatest 31 percent of groundwater level elevations, based on the percentage of wet years during the CCID well network period of record, is subject to change as analysis continues.

Thresholds calculated using long-term data from a nearby well are subject to error from the assumption that hydrologic conditions at the two wells are similar. This error is minimized by graphically comparing groundwater level elevations for each well (having offset values for the nearby well by the difference in ground surface elevations); however, historic conditions differ from those that include Interim Restoration flows, so a graphical comparison is an imprecise indication of error.

Those thresholds estimated using interpolated values from various maps, because the threshold well and nearby wells had no long-term measurements, have the greatest potential for error. The DTW maps used to estimate thresholds have several limitations, including:

- Only three seasonal maps were available that represent average (normal) conditions; only one of these represents spring conditions, and that was for a normal-dry year. Threshold elevations based on these maps are therefore biased low.
- DTW maps do not take into account elevation differences between wells and fields.
- The available DTW maps include deep production wells; this also leads to lower estimates of threshold elevations.

The map generated using only CCID well data has clear advantages, including a data set of only shallow wells relatively unaffected by groundwater pumping and compensation for varying ground surface elevations, but also has disadvantages, including:

- The average of all measured groundwater elevations was used for each CCID well. With regard to a threshold, this translates to having historically been at or above the threshold about 50 percent of the time. Consideration will be given to using an alternative to the average, e.g., the 69th percentile.
- There are no CCID wells east of the San Joaquin River, and most of the SJRRP threshold wells are east of the CCID wells; therefore, extrapolated, not interpolated values are assigned as thresholds.

4 Method #3: Drainage

The third method of calculating thresholds considers drainage and the slope of the groundwater table.

4.1 Objectives

The drainage method considers data from groundwater transects to determine the slope of the groundwater table, and to derive thresholds on the basis of this information. For river stages that allow water to drain from fields into the channel, restrictions on the release of Interim Flows below groundwater will not reduce or avoid seepage into adjacent fields.

4.2 Approach

The SJRRP plotted cross-sections of the water table and terrain at groundwater transects. The slope of the water table gives an indication of the elevation of the threshold by tracking baseline groundwater levels and the rise in groundwater as river stage increases.

Cross-sections showing a gaining reach will set thresholds at baseline groundwater levels in the fields as Method #3.

For losing reaches, the groundwater gradient provides a check on the historical groundwater analysis. A threshold below baseline groundwater levels would indicate conservatism.

4.3 Results

Monitoring data at groundwater transects during the 2010 Interim Flows shows the horizontal groundwater gradient away from the river. As shown by this data, the groundwater surface is not flat. Influences include irrigation and groundwater pumping as well as river stage. Generally the cross-sections show increasing groundwater levels near to the river as river stage increases, and the influence of the river decreases as distance from it increases.

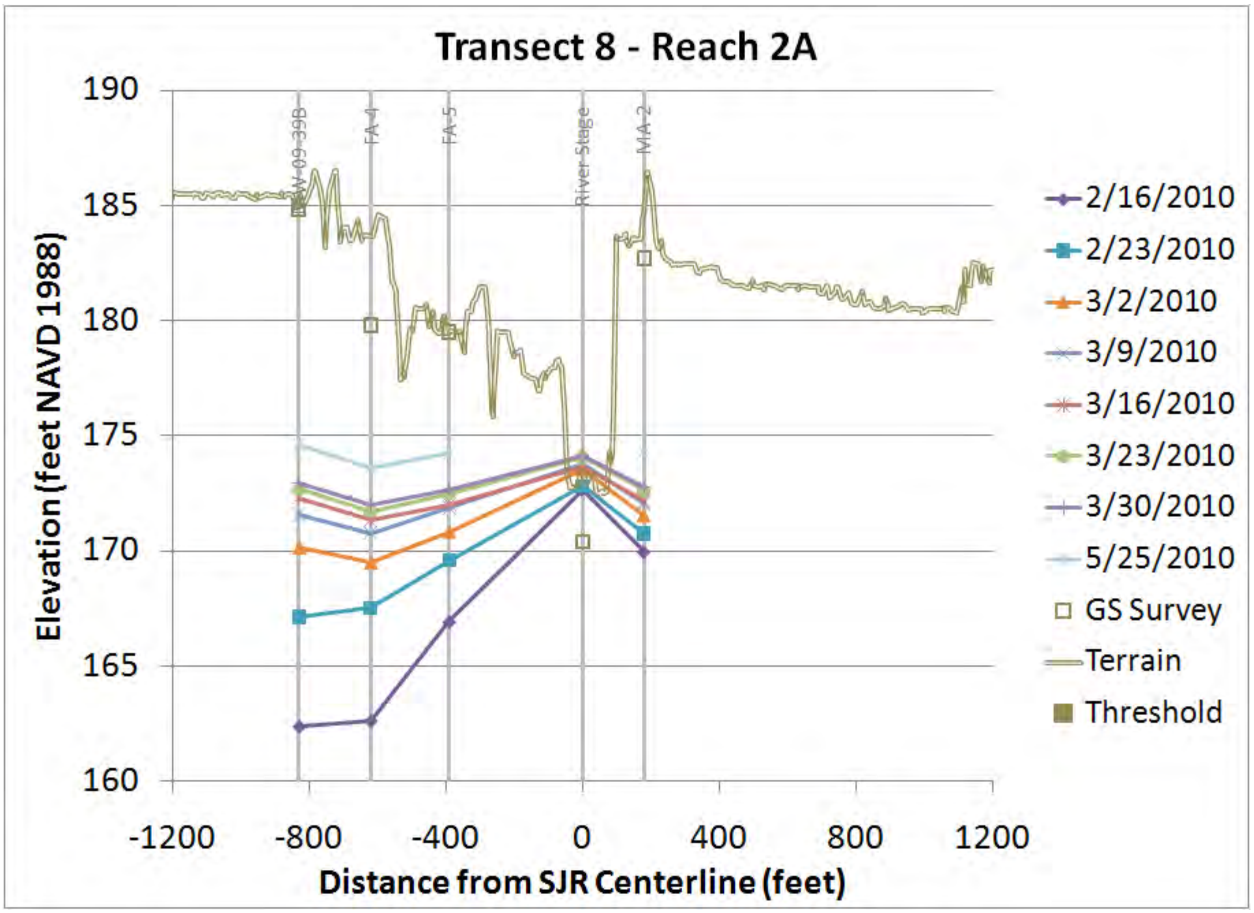


Figure H- 18
Cross-section plot at Transect 8 in Reach 2A.

This transect includes wells from the Pilot Project drilled to measure groundwater for riparian vegetation. It does not have wells located in agricultural fields. This indicates an increase in near-river groundwater levels as river stage increases. It also shows a slope to the groundwater table away from the river, and the influence of additional factors – perhaps irrigation. The lack of groundwater level data in fields makes interpretation of groundwater gradients difficult at this transect.

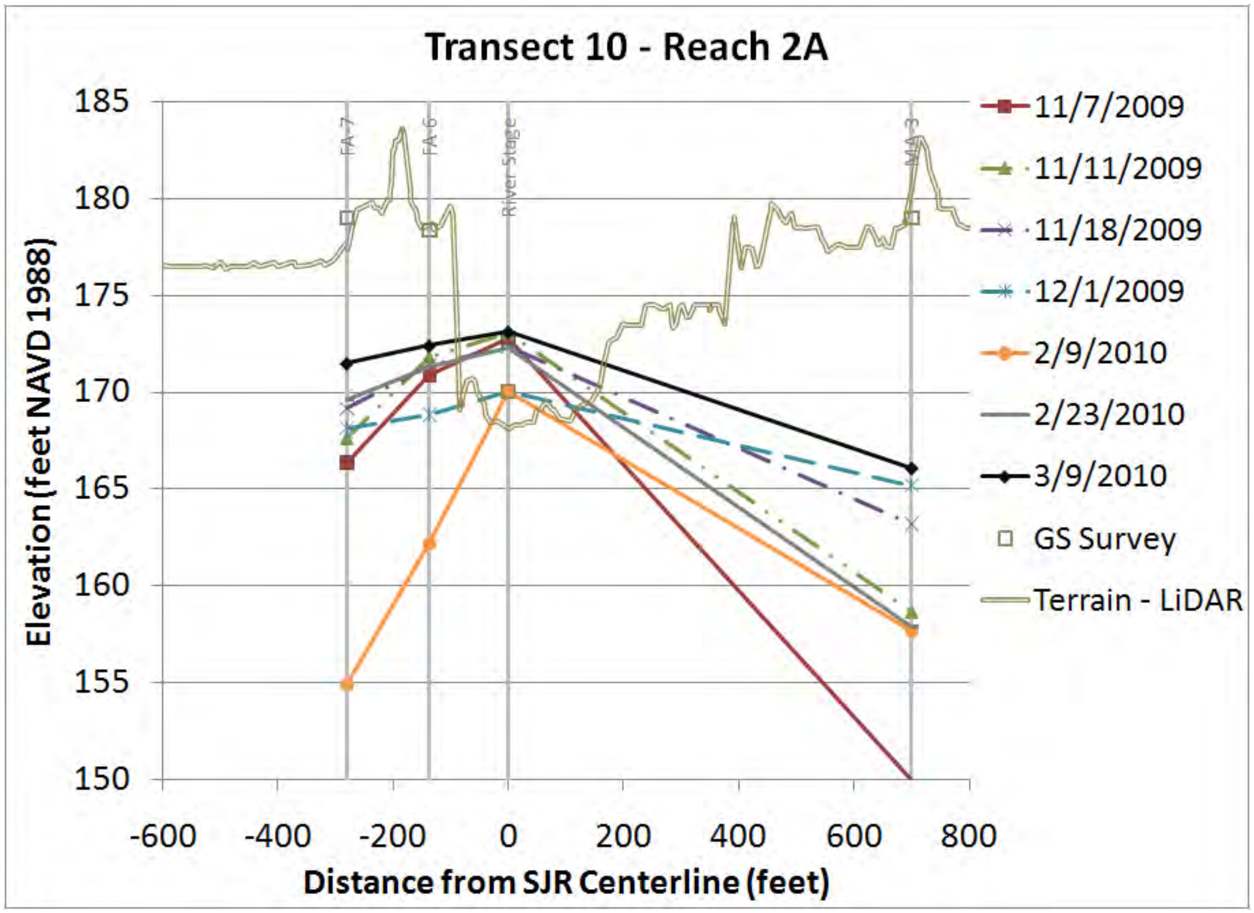


Figure H- 19
Cross-section plot at Transect 10 in Reach 2A.

This transect also includes wells from the Pilot Project drilled to measure groundwater for riparian vegetation. It does not have wells located in agricultural fields. This indicates an increase in near-river groundwater levels as river stage increases. It also shows a slope to the groundwater table away from the river, which decreases with increasing river stage as the influence of the river increases in lateral extent.

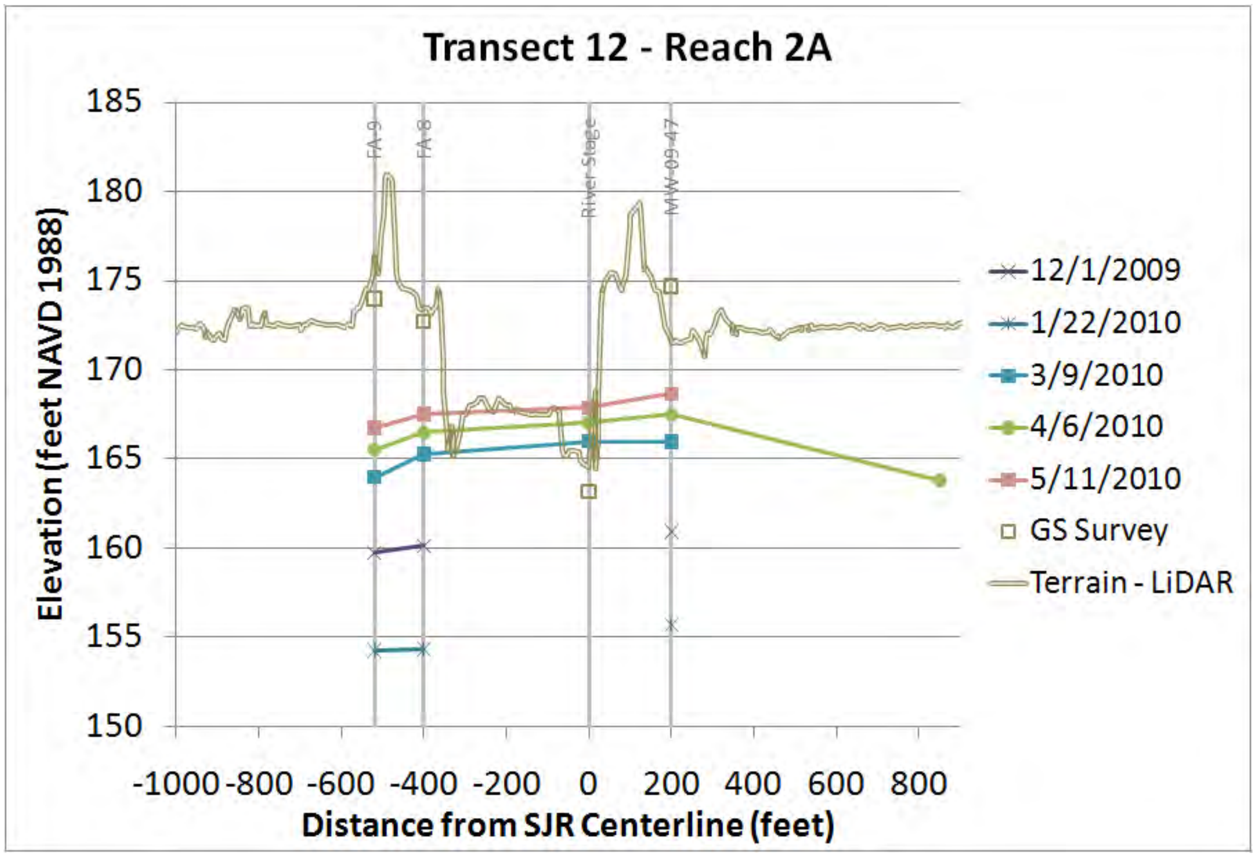


Figure H- 20
Cross-section plot at Transect 12 in Reach 2A.

This transect also includes wells from the Pilot Project drilled to monitor water levels for riparian vegetation. It does not have wells located in agricultural fields, with the exception of hand-auger hole drilled and groundwater level measured on April 6, 2010. This indicates an increase in near-river groundwater levels as river stage increases. The monitoring wells would indicate a nearly flat groundwater table, but the addition of the hand-auger data indicates there is a slope to the groundwater table away from the river channel.

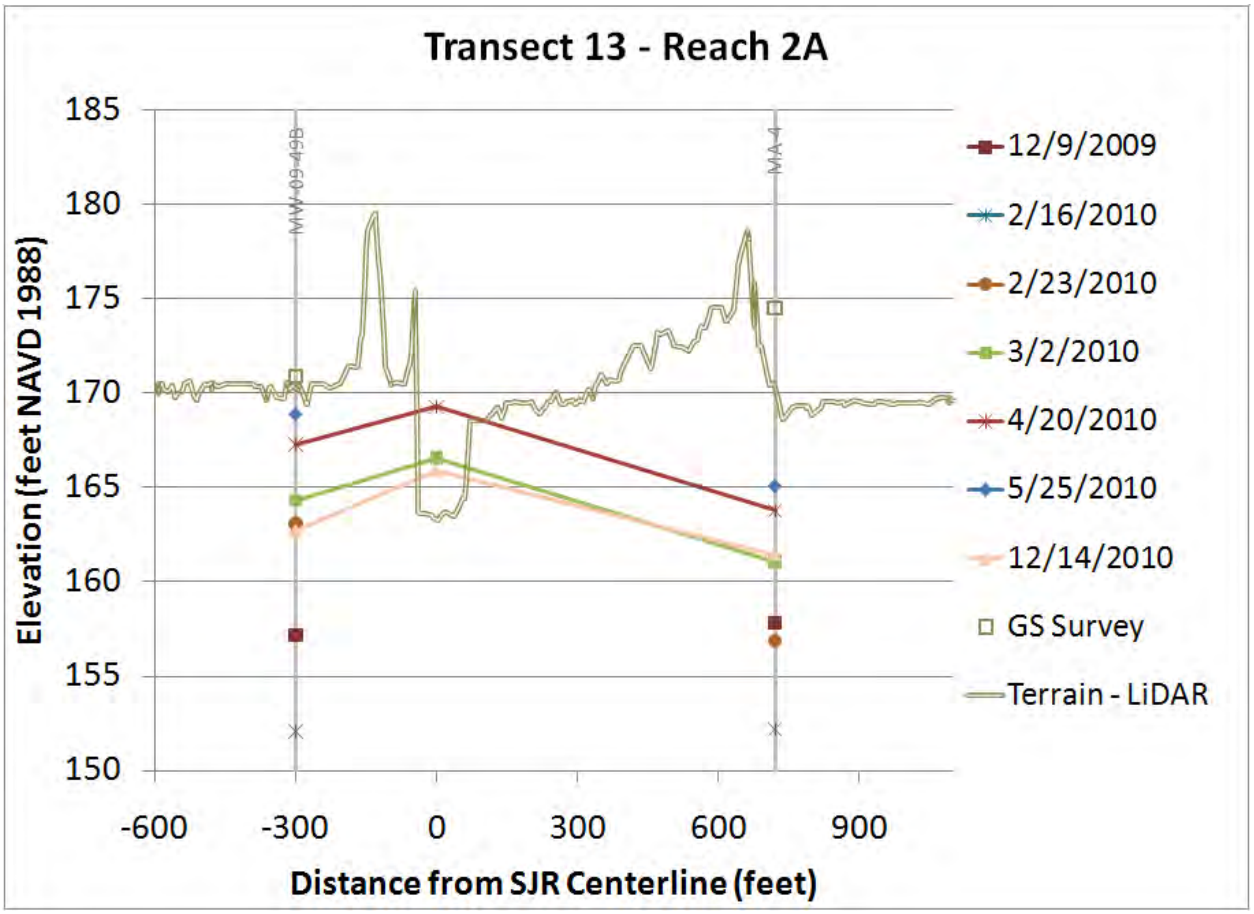


Figure H- 21

Cross-section plot at Transect 13 in Reach 2A.

This transect also includes wells from the Pilot Project drilled to monitor water levels for riparian vegetation. It does not have wells located in agricultural fields. This indicates an increase in near-river groundwater levels as river stage increases.

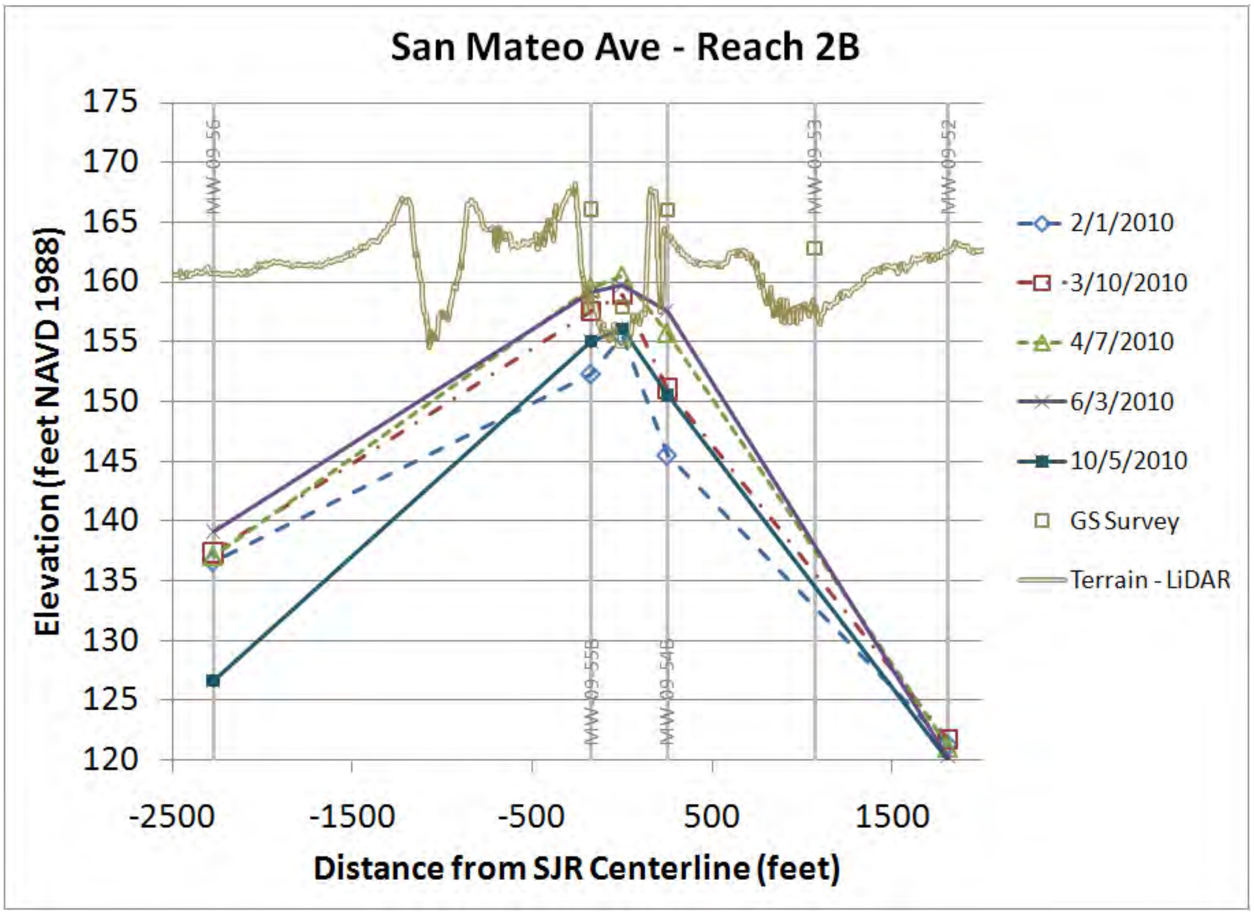


Figure H- 22
Cross-section plot at San Mateo Avenue in Reach 2B.

This cross-section, at San Mateo Avenue, has groundwater wells located further away from the river channel. It appears that groundwater levels 2000 feet away from the river on the North-East side of the river channel (positive values on this plot) are not influenced by river stage. This may be due to the influence of groundwater pumping. Baseline groundwater levels in Reach 2B appear to be around an elevation of 125 feet (approximately 40 feet below ground surface). A threshold below this would be too conservative. The chosen threshold is above these levels.

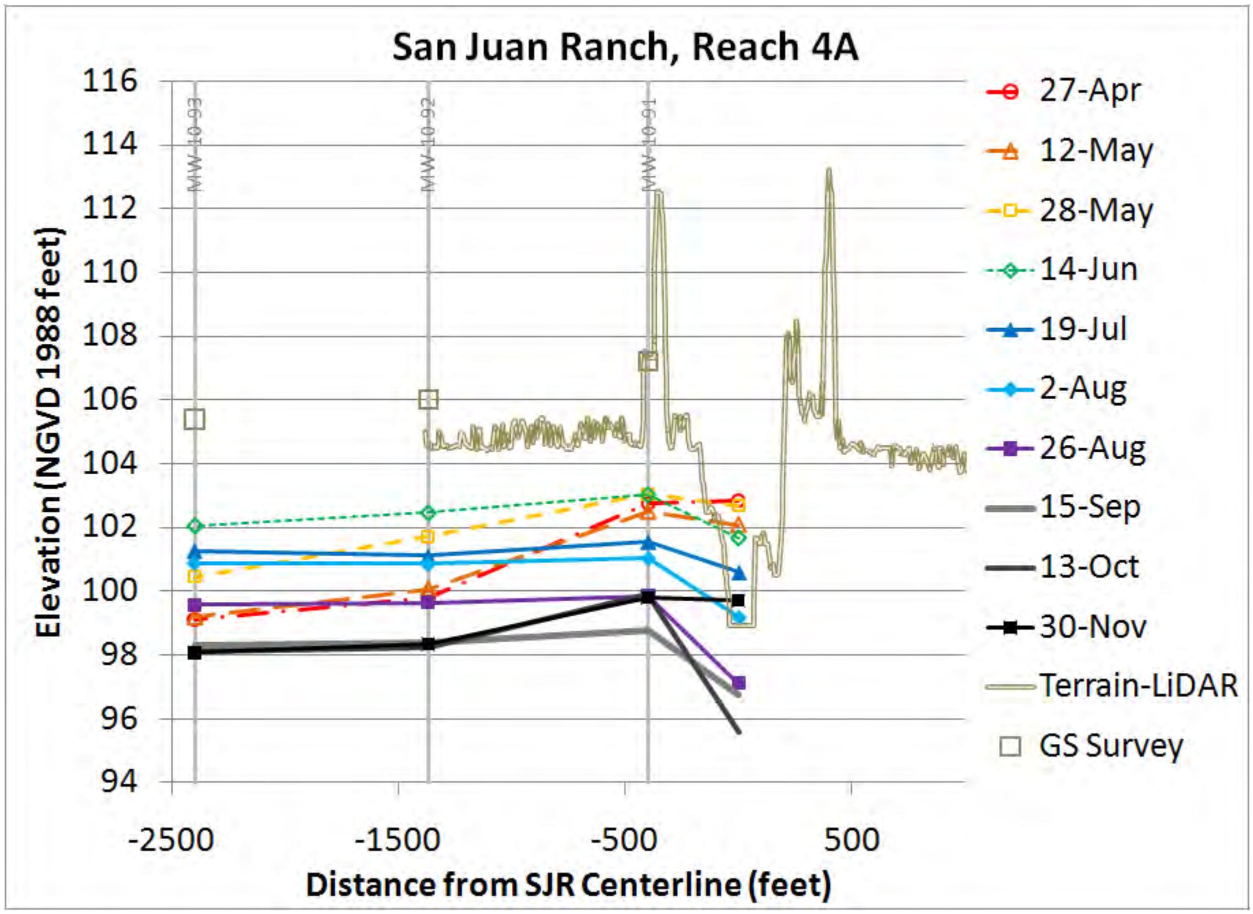


Figure H- 23

Cross-section plot at San Juan Ranch in Reach 4A.

Baseline groundwater levels at the end of Reach 4A appear to be around an elevation of 98 feet (approximately 7 to 9 feet below ground surface). A threshold below this would be too conservative.

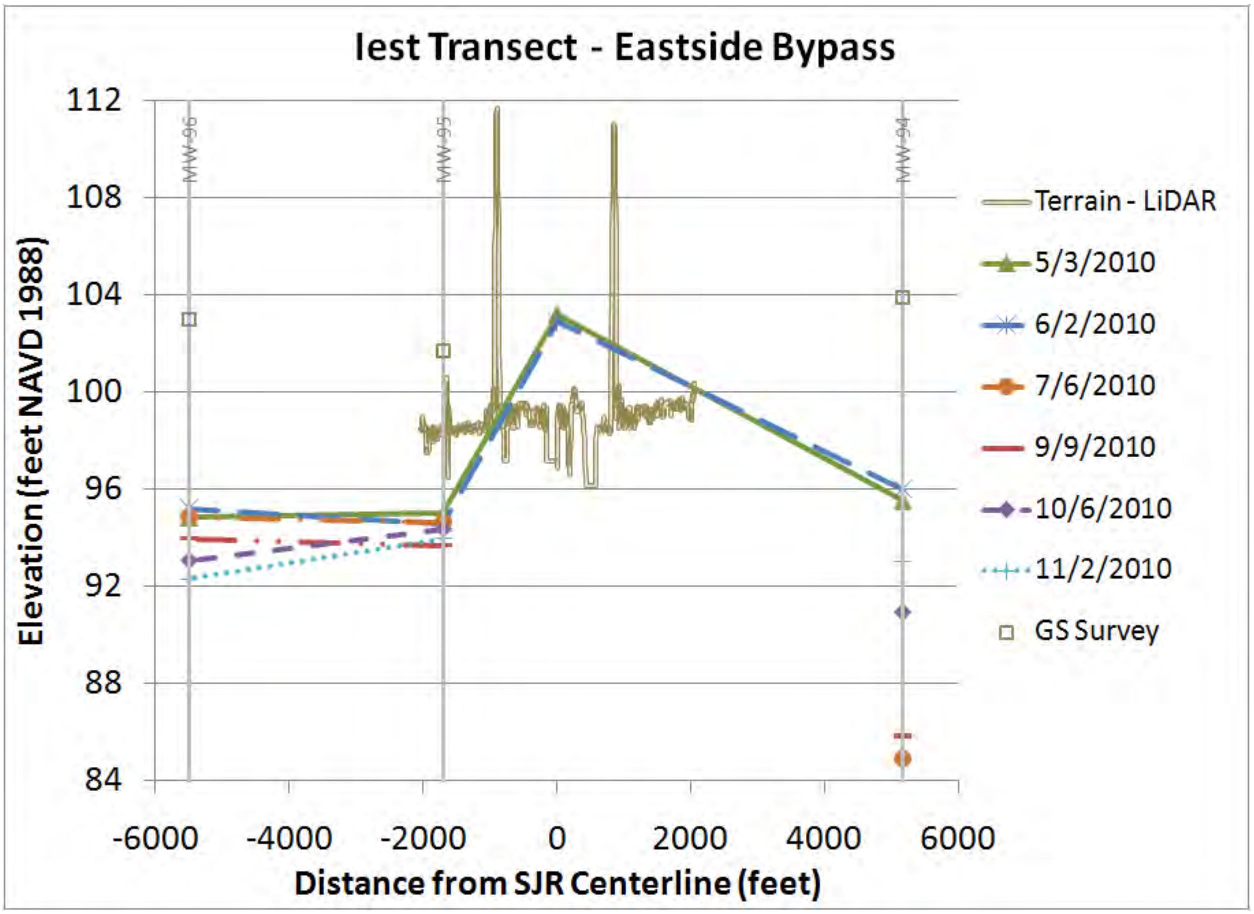


Figure H- 24

Cross-section plot at the Eastside Bypass near El Nido Road.

This transect includes monitoring wells distant from the Eastside Bypass. Groundwater levels do not appear to have much of a gradient during the irrigation season. Groundwater levels on the South-West side of the bypass (negative values on this plot) are flat and constant from May to July. This may indicate irrigation is a controlling factor. Groundwater levels begin to recede as Interim Flows and then irrigation begin to slow in the fall. Baseline groundwater levels on the South-West side of the river appear to be around an elevation of 93 feet. A threshold below this would be too conservative.

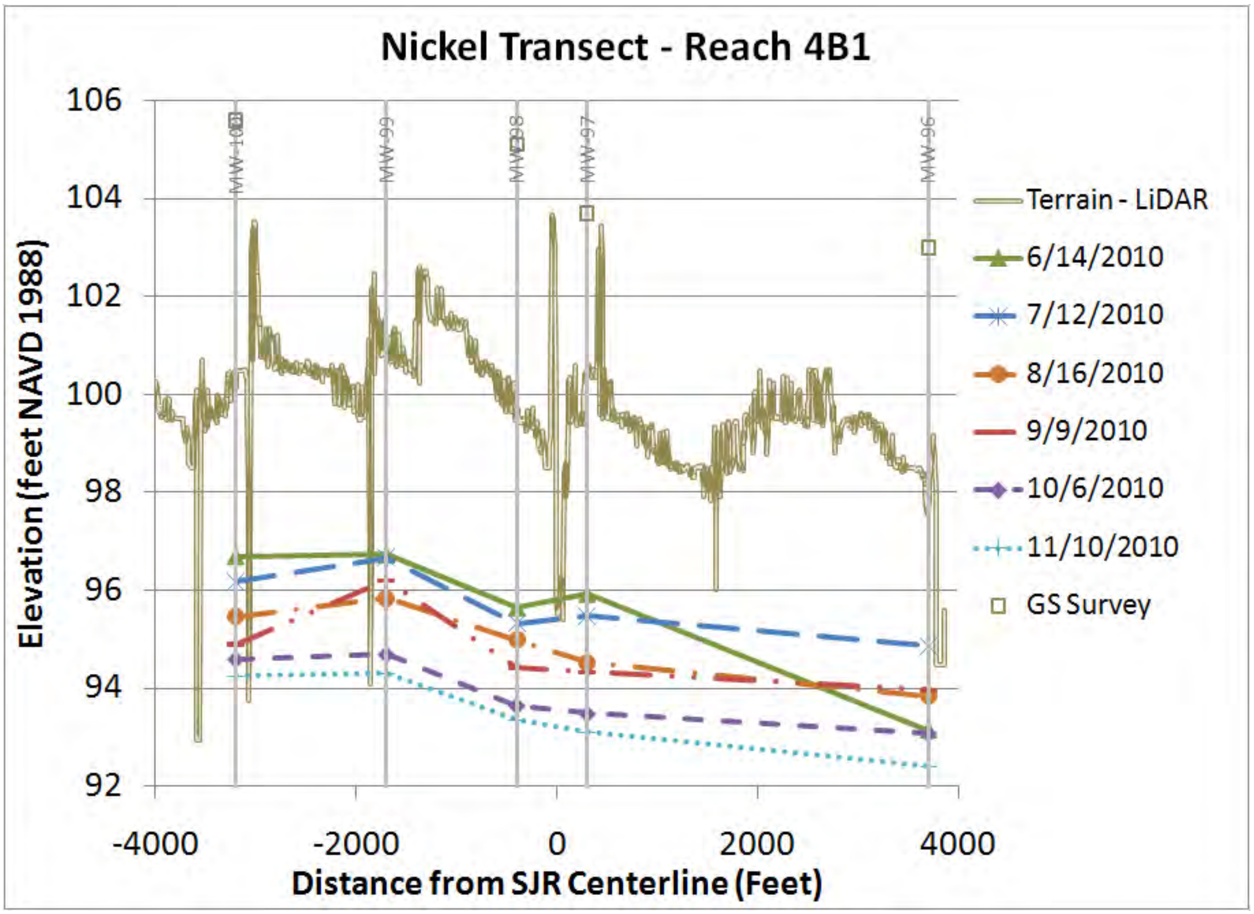


Figure H- 25
Cross-section plot at Reach 4B1.

This transect includes monitoring wells near the Reach 4B1 channel, which does not convey Interim Flows. Groundwater levels appear to decrease on the left (South-West) side of the river after June and on the right (North-East) side of the river decrease after July. Additional monitoring data may allow a better determination of baseline groundwater levels, but an elevation of 94 feet seems likely based on this data.

None of the cross-sections show a gaining reach at all river stage levels, so Method #3 will not be used to set thresholds based on data available to date.

4.4 Validation of thresholds

The Reclamation Drainage Manual was first printed in 1978 and revised in 1993. The drainage manual states: “All the methods and techniques covered in the manual have proven to be very satisfactory through observed field conditions on irrigated lands throughout the world. Some methods have a more elegant development and basis in science than others, but all have been designed to solve practical problems in the field. The manual contains techniques developed over the last 50 years by personnel in the Bureau of Reclamation.”

According to the Drainage manual, a depth-to-water table of 3 to 5 feet is generally satisfactory, depending on local conditions including type of crops grown (Reclamation, 1993;

pg 132). Many thresholds established above are deeper than 3 to 5 feet, indicating that those thresholds may be conservative, depending on crop type and other factors.

5 Threshold Results

The results of the threshold analyses are presented in Table H- 8; some considerations follow:

- Three CCID wells are measured frequently by Reclamation; thresholds were developed for these wells. No other CCID wells are measured by Reclamation; thus, no thresholds have been developed for the rest of the CCID wells.
- Several SJRRP monitoring wells are deeper wells, intended to monitor groundwater flow across a transect rather than water-table effects. Thresholds were developed for these wells, but will not be used for operations as they do not monitor the shallow groundwater table.
- A negative threshold indicates the well is in the river channel, and screened at an interval deeper below ground surface than the threshold in the adjacent field. These wells cannot be used to monitor groundwater levels in the adjacent field and will not be used for operations.
- Wells without a threshold elevation have not yet been surveyed and were outside of the LiDAR survey range. Thus, the ground surface elevation for these wells is unknown.
- Thresholds will continue to be revised as additional monitoring and data collection results in modification to assumptions. The results of surveying for CCID wells will result in adjusted thresholds.

Table H- 8. Threshold Summary Table

Well ID	Reach	Bank	Crop Type	Method 1 - Agricultural Practices (feet bgs) in field	Method 2 - Historical Groundwater (feet bgs) in field	Method Used	Threshold in field (feet bgs)	Threshold Elevation (feet)
JR-1	1A	Left	Public Land	5.0	50	1	5.0	
JR-2	1A	Left	Public Land	5.0	50	1	5.0	
MW-09-1	1A	Right	Public Land	4.5	51	1	4.5	266.2
MW-09-2	1A	Right	Public Land	4.5	51	1	4.5	265.7
FA-1	1B	Left	Vineyard	7.0	44	1	7.0	193.7
FA-2	1B	Left	Vineyard	7.0	36	1	7.0	196.1
FA-3	1B	Left	Vineyard	7.0	36	1	7.0	196.0
MA-1	1B	Left	Fallow	5.0	36	1	5.0	199.9
MW-09-23	1B	Left	Public Land	4.5	50	1	4.5	214.9
MW-09-23B	1B	Left	Public Land	4.5	50	1	4.5	214.9
MW-09-25	1B	Right	Public Land	5.0	50	1	5.0	229.5
R1-1	1B	Right	Pomegranate	6.5	58	1	6.5	208.8
R1-2	1B	Right	Pomegranate	6.5	61	1	6.5	208.8
FA-4	2A	Left	River Channel	5.0	42	1	5.0	179.4
FA-5	2A	Left	River Channel	5.0	42	1	5.0	179.2
FA-6	2A	Left	River Channel	5.0	60	1	5.0	168.6
FA-7	2A	Left	Almonds	10.0	60	1	10.0	163.4
FA-8	2A	Left	River Channel	5.0	58	1	5.0	166.0
FA-9	2A	Left	Alfalfa	5.0	60	1	5.0	165.3
MA-2	2A	Right	Annual Crops	5.0	40	1	5.0	174.8
MA-3	2A	Right	Annual Crops	5.0	60	1	5.0	173.1
MA-4	2A	Right	Vineyard w Drains	7.0	54	1	7.0	161.4
MW-09-36	2A	Right	Annual Crops	5.0	49	1	5.0	181.5
MW-09-37B	2A	Left	Vineyard	7.0	49	1	7.0	182.1
MW-09-39B	2A	Left	Almonds	9.5	34	1	9.5	174.9
MW-09-47	2A	Right	Vineyard w Drains	7.0	60	1	7.0	164.2
MW-09-49B	2A	Left	Annual Crops w Drains	4.5	56	1	4.5	164.7
MW-09-52	2B	Right	Almonds	10.0	31	1	10.0	151.2

Table H- 8. Threshold Summary Table

Well ID	Reach	Bank	Crop Type	Method 1 - Agricultural Practices (feet bgs) in field	Method 2 - Historical Groundwater (feet bgs) in field	Method Used	Threshold in field (feet bgs)	Threshold Elevation (feet)
MW-09-54B	2B	Right	Almonds	10.0	33	1	10.0	150.3
MW-09-55B	2B	Left	Palms	7.0	32	1	7.0	155.0
MW-09-56	2B	Left	Pistachios	7.0	31	1	7.0	152.5
PZ-09-R2B-1	2B	Right	Annual Crops	5.0	24	1	5.0	148.9
PZ-09-R2B-2	2B	Right	Annual Crops	4.5	24	1	4.5	144.8
155	3	Left	Almonds	10.0	6.7	2	6.7	125.3
MW-10-117	3	Right		5.0	16	1	5.0	
MW-10-118	3	Right		5.0	13	1	5.0	130.6
MW-10-119	3	Right		5.0	13	1	5.0	131.9
MW-10-120	3	Left		5.0	14	1	5.0	
MW-10-121	3	Left		5.0	15	1	5.0	
MW-10-122	3	Right		5.0	21	1	5.0	
MW-10-123	3	Left		5.0	27	1	5.0	
MW-10-124	3	Right		5.0	25	1	5.0	148.4
MW-10-74	3	Left	Almonds	9.5	9.6	1	9.5	125.6
MW-10-75	3	Left	Almonds	10.0	6.3	2	6.3	125.0
MW-10-76	3	Left	Annual Crops	5.0	2.7	2	2.7	125.3
MW-10-78	3	Right	Annual Crops	5.0	2.4	2	2.4	119.9
PZ-09-R3-1	3	Right		4.5	9.7	1	4.5	128.6
PZ-09-R3-2	3	Right	Annual Crops	5.0	9.7	1	5.0	131.8
PZ-09-R3-3	3	Right	Annual Crops	5.0	9.9	1	5.0	131.7
PZ-09-R3-4	3	Right	Annual Crops	5.0	12	1	5.0	131.7
PZ-09-R3-5	3	Right	Annual Crops	5.0	14	1	5.0	134.2
PZ-09-R3-6	3	Right	Annual Crops	5.0	13	1	5.0	135.1
PZ-09-R3-7	3	Right	Annual Crops	4.5	16	1	4.5	138.8
191	4A	Left		5.0	9.1	1	5.0	103.0
186A	4A	Left		5.0	3.5	2	3.5	102.6
MW-09-83B	4A	Right	Public Land	5.0	7.4	1	5.0	110.0
MW-09-85B	4A	Right	Public Land	5.0	5.3	1	5.0	108.7
MW-09-86B	4A	Left	Public Land	5.0		1	5.0	109.1
MW-09-87B	4A	Left	Public Land	4.5	4.2	2	4.2	108.9
MW-09-88	4A	Left	Public Land	5.0	5.0	2	5.0	105.7

Table H- 8. Threshold Summary Table

Well ID	Reach	Bank	Crop Type	Method 1 - Agricultural Practices (feet bgs) in field	Method 2 - Historical Groundwater (feet bgs) in field	Method Used	Threshold in field (feet bgs)	Threshold Elevation (feet)
MW-10-115	4A	Left		5.0	5.6	1	5.0	
MW-10-116	4A	Right		5.0	11	1	5.0	
MW-10-188	4A	Left	Annual Crops	5.0	9.5	1	5.0	109.8
MW-10-80	4A	Right	Annual Crops	5.0		1	5.0	116.5
MW-10-89	4A	Right	Almonds	9.5		1	9.5	111.6
MW-10-91	4A	Left	Tomatoes	4.0		1	4.0	99.5
MW-10-92	4A	Left	Tomatoes	4.0		1	4.0	99.4
MW-10-93	4A	Left	Tomatoes	4.0		1	4.0	99.2
SJR W-10	4A	Left	Tomatoes	4.0		1	4.0	101.7
SJR W-11	4A	Left	Tomatoes	4.0	11.2	1	4.0	103.1
SJR W-12	4A	Left	Tomatoes	4.0		1	4.0	100.8
SJR W-4	4A	Left	Corn	4.0		1	4.0	101.7
SJR W-5	4A	Left	Tomatoes	4.0	7.0	1	4.0	97.5
SJR W-6	4A	Left	Tomatoes	4.0	6.8	1	4.0	97.3
SJR W-7	4A	Left	Tomatoes	4.0	7.2	1	4.0	99.0
SJR W-8	4A	Left	Alfalfa	5.0		1	5.0	102.1
SJR W-9	4A	Left	Tomatoes	4.0		1	4.0	100.8
MW-10-100	4B1	Left	Annual Crops	5.0	6.5	1	5.0	93.2
MW-10-102	4B1	Right	Annual Crops	5.0	14	1	5.0	88.3
MW-10-103	4B1	Right	Annual Crops	5.0	11	1	5.0	89.5
MW-10-105	4B1	Left		5.0	7.4	1	5.0	90.3
MW-10-106	4B1	Left		5.0	9.6	1	5.0	88.1
MW-10-107	4B1	Left		5.0	6.9	1	5.0	88.3
MW-10-108	4B1	Left		5.0	9.1	1	5.0	89.8
MW-10-109	4B1	Left		5.0	7.8	1	5.0	91.5
MW-10-110	4B1	Left		5.0	12	1	5.0	82.0
MW-10-111	4B1	Left		5.0	10	1	5.0	83.9
MW-10-112	4B1	Right		5.0	17	1	5.0	
MW-10-113	4B1	Left		5.0	7.7	1	5.0	90.1
MW-10-114	4B1	Left		5.0	7.3	1	5.0	92.0
MW-10-90	4B1	Right	Pistachios	7.0	11	1	7.0	89.6
MW-10-94	4B1	Right	Pistachios	7.0	14	1	7.0	94.6

Table H- 8. Threshold Summary Table

Well ID	Reach	Bank	Crop Type	Method 1 - Agricultural Practices (feet bgs) in field	Method 2 - Historical Groundwater (feet bgs) in field	Method Used	Threshold in field (feet bgs)	Threshold Elevation (feet)
MW-10-95	4B1	Right	Alfalfa	5.0	11	1	5.0	91.8
MW-10-96	4B1	Right	Alfalfa	5.0	9.0	1	5.0	93.4
MW-10-97	4B1	Right	Annual Crops	4.5	8.2	1	4.5	93.3
MW-10-98	4B1	Left	Annual Crops	5.0	8.0	1	5.0	93.2
MW-10-99	4B1	Left	Annual Crops	5.0	6.6	1	5.0	94.6
SJR W-1	4B1	Left		5.0	6.8	1	5.0	93.4
SJR W-2	4B1	Left		5.0	6.2	1	5.0	94.0
SJR W-3	4B1	Left		5.0	5.5	1	5.0	93.8
MW-09-125	5	Right	Alfalfa	5.0	9.3	1	5.0	69.4

Key: Bgs – below ground surface
Note: Thresholds have been rounded to the nearest ½ foot.

Appendix H Attachment 1 – Responses to Threshold Comments

Condition 7 of the State Water Resources Control Board Order WR 2010-0029-DWR states:

> *Release of transfer water is conditioned upon implementation of the Seepage Monitoring and Management Plan in Appendix D of the Final WY 2010 EA/IS.*
>
> *The groundwater monitoring network shall account for subsidence in the area when determining differences in groundwater elevations. Groundwater elevation thresholds shall be established to determine when impacts to agricultural lands or levee stability are imminent. Interim flows shall only be released in a manner consistent with the Plan.*
>
> *As part of implementing the Seepage Monitoring Plan, Reclamation shall publish the then-current well locations, monitoring / buffer groundwater thresholds, and proposed process for development of and updates to action thresholds on the SJRRP website by January 10, 2011 for public review and comment and shall also provide this information to the Division. In the event that written comments are submitted within 20 calendar days, Reclamation shall consider these comments and provide written responses, which may include revisions to the thresholds, by March 1, 2011. Comments, responses, and then-current thresholds shall be published on the SJRRP website by March 1, 2011, and also provided to the Deputy Director for Water Rights for review, modification and approval.*

1 Comments Received

The comments received on the Monitoring Well Thresholds Technical Memorandum (Thresholds TM), which was posted on the San Joaquin River Restoration Program's (SJRRP) website on January 10, 2011 for public review and comment, and the responses to these comments received are provided below.

1

Harrison, Katrina E

From: Larry R. Harris [mailto:LHarris@murdoc.com]
Sent: Monday, January 31, 2011 8:17 AM
To: Craig Moyle
Cc: 'Gidding, Margaret A'; cwhite@ccidwater.org
Subject: RE: SJRRP Seepage and Conveyance TFG Meeting No. 1

Craig,

1 - Wolfsen

I had an opportunity to review Dan Royer's notes from the Jan 14th seepage technical feedback group meeting. I noticed that there was discussion about setting the seepage threshold at 7 to 7.5 feet in reach 4A. Setting the threshold at that level is unacceptable. This threshold does not protect the land owner who currently has a base water level of 12 to 15 feet. At this 7 foot level the landowner will suffer the consequences of losing their ability to grow permanent crops. For example a landowner may currently be growing tomatoes on his property that has a 12 to 15 foot water level pre restoration flows. If, restoration flows take the water level to 7 feet, as discussed in your meeting, it might be fine for tomatoes, but it takes from the land owner the opportunity to grow permanent crops such as almonds and pistachios in the future. As I am sure you are aware there is a substantial difference between the value of row crop ground and tree ground.

I think this same scenario is true in certain portions of reach 4B as well.

I would appreciated it if you pass my comments on to the appropriate person at USBR drafting the seepage technical memorandum.

Thanks,
Larry Harris
Wolfsen

1

2

RMC

San Joaquin River
Resource Management Coalition

P.O. Box 2115
Los Banos, CA 93635
Phone: (209) 827-8616
Fax: (209) 827-9703
Email: contactus@sjrecwa.net
Website: http://www.sjrmc.info

January 31, 2011

Via Email: interimflows@restoresjr.net
San Joaquin River Restoration Program
MP170
2800 Cottage Way
Sacramento, CA 95825

RE: ***Comments on "Draft Technical Memorandum," "Monitoring Well Thresholds"***

Ladies and Gentlemen:

The RMC represents the landowners along the San Joaquin River potentially impacted by the activities associated with the restoration activities of the agencies implementing the River settlement and the law. We continue to seek reasonable and practical solutions to the challenges of implementation of the restoration program and offer the following in the spirit of that commitment.

The RMC is submitting comments on the subject draft technical memorandum. The comments are included in the cover letter and a supplementary report included as an attachment. The letter outlines our general concerns regarding the effort and the technical memorandum provides an analysis of the additional considerations needed to make the well thresholds more reflective of the actual field conditions that give our landowners the protections required by law and improve the seepage impacts protection process.

At the January 14, 2011 Seepage Management meeting, the United States Bureau of Reclamation indicated that requests and corrections were forthcoming to the proposal. For instance, the background data and process behind the development of Table 2 – 5, "capillary fringe thickness" is needed before we can finalize comments on this section. We anticipate having the opportunity to do so even though the overall comments are being submitted as of the date requested. **2 - RMC**

With regard to the comment made in the report about the thickness of the capillary fringe in the Cal Poly Nickel study, your record needs to be corrected.

San Joaquin River Restoration Program
RE: ***Comments on "Draft Technical Memorandum," "Monitoring Well Thresholds"***
January 31, 2011
Page 2

There may be a compaction element under a farm field road but the depth of that compaction would be at most 18 inches. **3 - RMC** However, we confirmed with the property owner that the investigation was truly in a farm field, in fact, the owner authorized cutting through field drip irrigation tape to optimize the understanding of the irrigation water and seepage relationship. Therefore, the capillary fringe discovered there is more related to the naturally compacted layers at depth (see attached technical memorandum on soil layers). **4 - RMC**

We have repeatedly stated that many of the monitoring wells in the well atlas are perforated well below the surface of the water table and therefore are too deep for use as seepage threshold sites. The wells need to be more carefully sorted and the resulting Table shortened to reflect the sites that truly qualify. **5 - RMC**

The following additional comments are specific to sections of the report.

6 - RMC In section 1.0 Introduction, line 24 the sentence should read; "zones necessary to protect"…. In section 1.1 Background, line 31 and 32 should read; "Confluence of the San Joaquin River while avoiding material adverse impacts such as groundwater seepage impacts to crops in adjacent fields". **7 - RMC** In line 37 we agree with the need for "operational criteria and response actions" and wonder when they will be ready for inclusion in the program documents. **8 - RMC**

On page 1-2, we offer further suggestions for clarity and continuity.

In line one, while 100 wells have been constructed to assess hydrologic conditions near the River, we have pointed out above that many of these wells are not qualified to serve as seepage threshold stations. The report should reflect which are qualified. **9 - RMC**

Starting with line 7, we believe the report would be better served if it reflected the following three points:

10 - RMC
1. Reclamation will endeavor to limit interim flows so as to not exceed seepage thresholds.

11 - RMC
2. If groundwater levels exceed or are approaching a threshold, Reclamation will conduct a site visit to determine if the water levels are correct at the site.

12 - RMC
3. Based on the site visit, Reclamation shall reduce interim flows in the Reach to last known safe flow and re-evaluate field control seepage thresholds.

San Joaquin River Restoration Program
RE: ***Comments on "Draft Technical Memorandum," "Monitoring Well Thresholds"***
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With regard to the paragraph beginning with line 17, we mentioned previously the need for operational criteria and response actions. We also believe that the criteria and responses should be by River Reach and that notion reflected in this paragraph. **13 - RMC**

Regarding the Table on page 2-15 we understand there is a problem with the contractor who developed the information and request additional effort be made to resolve the contract issue so as to allow us the opportunity to review the field information this chart is based on. **14 - RMC**

Our summary request is that the current process be finished as soon as possible so as to completely link together the flows, the monitoring wells, the adjacent field seepage thresholds process and the response and remediation activities into one complete program element. Until that is done, the RMC will devote all its energy to make sure any interim flows are held to the absolute minimum necessary to prevent any injury at all to potentially impacted landowners. **15 - RMC**

Thank you for the opportunity to provide these comments. We look forward to your response.

Sincerely,

Mari Martin,
RMC President

Enclosure: RMC Technical Memorandum on Soil and Groundwater Relationships

RMC Technical Comments

On

The "Monitoring Well Thresholds"

Draft Technical Manual

Introduction:

The following comments include discussion on three of the major issues the draft "technical manual" is proposing to address. The issues are hydrology, soil hydraulic conductivity and agronomic impacts of River Restoration flow seepage management and the attendant monitoring wells. The comments include general comments and then additional analysis of three core issues. The concluding remarks propose to offer a field confirmation strategy to properly link the seepage monitoring wells to field conditions.

General Comments

A significant premise of the "Monitoring Well Thresholds" draft technical manual (SJRRP January 10, 2011) proposed as a core strategy to protect the nearby lands from adverse impacts to crop production is that the monitoring well condition, an elevation of depth to a saturated water table or zone, will be sufficiently conservative to protect all of the neighboring lands and soils from any adverse impacts of a shallow water table that can impact crop growth. The premise is based primarily on a preliminary understanding of local hydrology (vertical and horizontal movement of the zone of saturation). Unfortunately, there has not been enough time and effort to verify the correlations to the variable conditions one finds in certain stretches of the River and that is a fatal flaw. The chief disconnect is the lack of information on the differences between the hydrology and the hydraulic conductivity (both saturated and unsaturated flow, horizontally and vertically) of the varying soil types within the spheres of the proposed monitoring wells. The current assumption is the "factors" used for the crop protection thresholds are sufficiently conservative to protect the crops even without knowing the properties of the various soil types and the resulting agronomic conditions. The representatives of the RMC are not in agreement with that notion and propose that additional field work be conducted to confirm the viability of the strategy. Of particular concern is the implementation of the thresholds during the spring pulse flows in years when the flows may extend through the month of May (March, April and May). Many of the crops in place and contemplated in the vicinity of the project are in critical growth stages during the early to late spring and those growth stages are susceptible to various water-related impacts including, but not limited to; anoxia, fungi and bacteria associated with wet conditions, temperature, salinity and nutrient availability. These items will be explained further in a technical discussion below with associated reference materials.

16 - RMC

17 - RMC

1

Technical Issues Review

The three core technical issues that need to be integrated more carefully are hydrology, conductivity and agronomy.

Hydrology

18 - RMC

The current proposal uses "key" monitoring wells to determine a depth to saturation that will ostensibly protect the crops nearby. The discussion above provides the "general" case that there may be a disconnection between the wells proposed and the real-time condition of the immediate and contiguous soils in the vicinity of the monitoring well. Additional analysis is warranted about the need to correlate the monitoring wells with field investigations to assure the wells provide the intended protection. The technical issue has two primary facets. The first is the well construction of each of the wells has to be carefully analyzed to make sure the information is about the true "first" water (zone of saturation) in the soil profile and can be correlated to seepage from the flow in the San Joaquin River. In the primary threshold table (Table 4-1) each monitoring well is currently correlated to the threshold under the assumption that the first water zone is the source of the seepage. If the wells are perforated in deeper zones and the hydrostatic head is insufficient to cause a rise in the water column, the well may not be representative of the true water surface elevation, especially down gradient. Coincidentally, if the perforated zone is under hydrostatic pressure and the zone is a semi-confined zone of say a sand lens that travels for some distance away from the origin, that hydrostatic pressure may not reveal itself in a meaningful, visible way but be in contact with a finer textured material above which has a propensity to have larger capillary fringe. The result of these instances is an erroneous threshold depth may occur. 19 - RMC Each existing monitoring well needs to be carefully re-evaluated to make sure it is constructed in a manner that allows the free water surface to be accurately measured. Future monitoring wells need to be designed with the same goal. 20 - RMC The second hydrologic discontinuity is the variability of the soils with respect to their complex horizons, especially in the west of river stretches 3W, and all of 4. The variability is spatially complex with both vertical and horizontal components. What happens at a monitoring well near the source of the seepage may not adequately reflect the conditions in an adjacent area within a short distance of the well. Further discussion of the localized impacts of this likely phenomena will be presented in the hydraulic conductivity section of this report, but suffice it to say that additional investigation and monitoring techniques will be needed to make the necessary correlations and corrections to the thresholds in order to compensate for the dynamic variability in or near several stretches of the River.

Conductivity

The category of conductivity, or "flux", includes all phases: liquids, gases, heat and ion exchange. The conductivities in the soil matrix are a key element missing in the consideration of the thresholds established in the document. The proposed process in the technical memorandum uses primarily a hydrologic process in what is offered as a "conservative" approach to protect crops and crop root zones from the seepage anticipated with a fully operational River. The following is a discussion of the

2

additional elements of conductivity that need to be considered and integrated into the hydrologic approach.

1. Hydraulic conductivity – hydraulic conductivity covers all of the movement of fluids in soil, primarily water; saturated and unsaturated movement, vadose zone and capillary fringe. **21 - RMC**
2. Gas flux; anoxia, oxygen, CO_2, de-nitrification. **22 - RMC**
3. Heat and temperature. **23 - RMC**
4. Ion exchange (including salts and specific ions).

24 - RMC

The core issue of water movement substantially influences the other above issues with the notable exception of ion exchange. Ion exchange is a soil- texture dominated phenomena. Sandy soils have low ion exchange. However, a number of the soils in the vicinity of the San Joaquin River have a fine texture (clay content). Therefore the exchange activity can be affected by the hydraulic conditions. Exchange materials such as nutrients (NH_4) and major elements such as calcium and magnesium are affected by the salt and physical conditions induced by irrigation or flux of the groundwater table.

25 - RMC

The hydraulic conductivity issue is also texture-related and the main concern about using a key well to predict the water table conditions in the adjacent soil areas is the issue of concern. The differences can be demonstrated in the soil map extract from the California soil survey in the vicinity of River stretch 4a. A soil nearer the River is the Palazzo sandy loam and the adjacent down gradient soil is Escano clay loam. The soils vary horizontally and vertically with the sandier materials (Palazzo) nearer the river channel and finer textured materials further away (Escano). That changeover is one of the more important conditions that need to be considered when establishing the threshold because when the water table runs into the finer textured Escano, the impact will be different in terms of the impacts to the capillary fringe, temperature and gas flux than the coarser Palazzo. A suggested mitigation method is to instrument the Escano with tensiometers at numerous depths so as to develop a correlation database that reflects the difference in impact from where a well is located and the different soil types.

More information on the relationship of the other soil differences related to the hydraulic conductivity; gas flux, temperature and de-nitrification are as follows and their impacts discussed further in the agronomy section.

22 cont. - RMC **23 cont. - RMC**

Saturated soil conditions have an impact on gas transfer and a significant issue for some crops is the lack of oxygen, therefore, any differences in soil types that are not accounted for or if the threshold is not conservative enough could cause oxygen deprivation. Saturated conditions and the associated capillary fringe and vadose zone also demand more heat calories for altering (increasing, an important plant growth need) the soil temperature. Therefore, if the well thresholds are not reflective of the soil conditions, excess moisture will cause the temperature of soil to decrease with wetter conditions. The soil physics of the impact are included in the attachments.

Agronomy

Agronomy issues are the result of all the above discussion but they are somewhat crop specific. The literature in the attachments offers information on these differences. The following general case is presented to inform the existing discussion of rooting depths and crop needs to establish the thresholds needed for optimum production of the principal cultivars used in the area.

1. Temperature – the agronomic impact of temperature is primarily the need for soil warming in the critical root hair growth stage in early to middle spring. Whether the crops are annual or permanent, the same processes are occurring and the physiological impact of cool soil is that the stage is set for ultimate production by the plant in the critical spring stage; cooler soil inhibits the proper root growth that then decreases the ultimate production of the desired plant materials. Cool soil from the endothermic impact of high moisture content is more of an issue in finer textured soils. While such soils have a more rapid heat transfer capability, the soil moisture content and hence evaporation is the foremost caloric demand before the soil temperature actually rises to meet the more favorable crop root growth conditions. **26 - RMC**
2. **27 - RMC** Anoxia – lack of oxygen is also a critical issue in the early spring growth stage of plants. Many crops can withstand low oxygen in the soil during the dormant stage but as soon as the air and soil temperature is adequate for the root development or upper growth stages, the oxygen content becomes critical, especially for certain root-types. Plant respiration also includes the release of CO_2 into the soil matrix; high water content impedes that flux. The soil water oxygen and carbon dioxide balance are all impacted by wet conditions. Further discussion of these requirements is in the reference material.
3. Nutrients, fungi and bacteria – soil water content and temperature also impact the biosphere of the soil, and the biosphere impacts the plants in numerous ways. Soils that are too wet can foster fungi and bacterial conditions that are detrimental to the crops. Wet conditions also can induce de-nitrifying conditions that cause loss of critical nitrogen that has been applied for optimum crop production. Soil temperature that fosters the right mix of fungi and bacteria that induce nutrient and minor element flux in symbiotic relationships with plant root structure are can also be impeded by adverse wet conditions. These issues are also presented in the attachments. **28 - RMC**
4. **29 - RMC** Salinity – while many of the soils under investigation in the 3W and 4 River Reaches have a propensity to harbor significant salts and some crops generally grown in the area (cotton, small grains) have salt tolerance, none have a tolerance for salt in the early growth stages. The plants build their capacity to tolerate salt over time with a more diverse root system. Young plants are susceptible to salt accumulation at the upper boundary of the capillary fringe. The soil thresholds need to consider that salt accumulation near the fringe.
5. Crop rooting depth protection proposals - specific crop rooting depths for protection from water tables have been proposed for the area under investigation and the literature generally supports most of the depths proposed with the exception of almonds. Since almond varieties, rooting stock and the likelihood of the introduction of more permanent crops is likely in the area; additional review of the proposal is needed. To make sure the almond trees do not have production reduction or fatalities, the sensible approach is to use the most conservative threshold to protect the investment. The thresholds can be adjusted somewhat to the age of the planting but any mature orchard will need a twelve foot root- **30 - RMC**

4

protective zone in the sensitive portion of the year. The references include information on almond root physiology.

Summary and Recommendations

The current proposed method of using key wells for establishing thresholds for certain crops has depended on the understanding of the hydrologic conditions determined by a network of monitoring wells. That information has to be augmented with the understanding of the soil physics to make the necessary correlations to the actual field conditions of the complex soil and crop areas adjacent to the San Joaquin River. Before the network is used for the flow releases in the River the RMC recommends the correlation work be done among the different soil and crop types to make sure the wells and soil characteristics are sufficiently normalized such that the well information provides the crop protection anticipated. Additional tools are available to evaluate and provide data to develop such correlations. One tool that perhaps could determine differing soil and field conditions is tensiometers. In order to be truly complete, the total process needs full incorporation of: flow, river stage elevation, monitoring wells constructed to intercept the first zone of saturation, monitoring of the different soil types with correlation to the well information so the best crop protection thresholds can be ascertained and a response and remediation process if the River flow results in potential crop impacts.

Attachments:

1. Alfalfa reference document
2. Almond reference document
3. Root system physiology pgs. 107 -113 – two pdfs.
4. Baldocchi's "Why Ecologists need Soil Physics"
5. Jury, W.A. and R. Horton, 2004, "Soil Physics", 6th Edition
6. Effects of Irrigation on Soil Temperature
7. Soil Science 107, UC Davis, soil temperature, heat and water flux
8. Cotton Production Reference
9. Cotton Seedling Diseases
10. IPM for Cotton
11. Crop Water Use and Growth Stages – Colorado State Extension
12. FAO Irrigation and Drainage Paper 56
13. Soil Aeration and Temperature – Morton Arboretum
14. Plant Growth and Yield as Affected by Wet Soil – University of Nebraska, Lincoln
15. UC Cotton Planting Forecasting
16. Baker et. al. "Tutorials on Soil Physics"
17. Soil Physics with Hydrus
18. Palazzo-Escano soils map and descriptions

NICKEL FAMILY LLC

Memo

To:	Seepage Technical Feedback Group interimflows@restoreSJR.net	File:	1.35
From:	James L. Nickel	**Date:**	February 3, 2011
Re:	COMMENTS ON THRESHOLDS		

My comments on the 1/10/11 Draft are as follows:

31 - Nickel

1.1 Background

It states that "if groundwater levels increase above a threshold, Reclamation will conduct a site visit to evaluate the potential seepage conditions at the site". We need to clarify/expand upon what a site visit consists of. Just driving by and looking doesn't accomplish much. I would hope that there would be some extensive investigation and testing, such as digging a pit and calculating the capillary rise of the salts.

2.3.1 Approach

32 - Nickel

A buffer for drip irrigation crops is needed for more than a month prior to planting to allow for leaching. First off, planting times are never when we plan them due to numerous factors. Secondly, leaching can occur in the Fall or Winter. It depends upon many factors, such as availability of water, timing of ground preparation, weather, availability of equipment and sprinklers, etc.

I don't think you can vary the depth of the thresholds based upon the season.

2.3.3 Limitations

33 - Nickel

I don't agree with the statement that monitoring wells located underneath irrigation header lines will show increases in groundwater levels. This

1

statement assumes huge leaks in the header (main) lines which is not always the case.

An additional limitation would be if the drainage lines are installed and the disposal of the tile drain water.

34 - Nickel

2.4.1 Approach

Rather than utilizing data from old text books, I suggest that actual in-field studies on different soil types be conducted to determine capillary rise.

2.4.2 Results

35 - Nickel

It is an incorrect statement that the analysis conducted by ITRC was sited on a compacted road. It was in the field, not under a road.

36 - Nickel

3.2 Approach

It states the values were averaged. It is dangerous to use averages when setting standards.

JLN/rjr

• Page 2

2 Responses to Comments

Reclamation provided an initial draft of thresholds in the Thresholds TM posted on the SJRRP website on January 10, 2011. This section includes Reclamation's responses to comments received on Thresholds TM. Comments received on the Thresholds TM were also incorporated these into this Seepage Management Plan. Landowners may continue to submit comments during the continuing development of the Seepage Management Plan.

2.1 Comment 1 – Wolfsen

Comment: I had an opportunity to review Dan Royer's notes from the Jan 14th seepage technical feedback group meeting. I noticed that there was discussion about setting the seepage threshold at 7 to 7.5 feet in reach 4A. Setting the threshold at that level is unacceptable. This threshold does not protect the land owner who currently has a base water level of 12 to 15 feet. At this 7 foot level the landowner will suffer the consequences of losing their ability to grow permanent crops. For example a landowner may currently be growing tomatoes on his property that has a 12 to 15 foot water level pre restoration flows. If, restoration flows take the water level to 7 feet, as discussed in your meeting, it might be fine for tomatoes, but it takes from the land owner the opportunity to grow permanent crops such as almonds and pistachios in the future. As I am sure you are aware there is a substantial difference between the value of row crop ground and tree ground. I think this same scenario is true in certain portions of reach 4B as well.

Response: Reclamation's understanding of historical practices is that landowners may leach salts after flood events. Reclamation will adjust thresholds when notified about conversion to permanent crops. Landowners should call the Seepage Hotline at 916-978-4398 to notify about conversion to permanent crops or submit comments to interimflows@restoresjr.net.

2.2 Comment 2 – RMC

Comment: The background data and process behind the development of Table 2-5, "capillary fringe thickness" is needed before we can finalize comments on this section. We anticipate having the opportunity to do so even though the overall comments are being submitted as of the date requested.

Response: See response to Comment 14.

2.3 Comment 3 – RMC

Comment: Compaction element under a farm field road would be at most 18 inches

Response: This comment has been incorporated into the Seepage Management Plan.

2.4 Comment 4 – RMC

Comment: ITRC report pits were dug in a farm field, in fact, the owner authorized cutting through field drip irrigation tape to optimize the understanding of the irrigation water and seepage relationship. Therefore, the capillary fringe discovered there is more related to the naturally compacted layers at depth (see attached TM on soil layers).

Response: This comment has been incorporated into the Seepage Management Plan.

2.5 Comment 5 – RMC

Comment: Only use shallow monitoring wells for setting thresholds. Update table to only use these.

Response: Reclamation developed a groundwater monitoring network to collect data on surface and subsurface physical processes. The network includes both shallow wells suitable for thresholds during Interim Flows and deeper wells for a long term understanding of deep percolation. Wells are installed to understand relevant physical processes as well as detect seepage. Some wells will help understand hydrologic conditions, but may not provide operational information. Thresholds as described in Appendix H of this Seepage Management Plan include only wells perforated in shallow zones. Perforation intervals for all monitoring wells are included in the Monitoring Well Atlas, available on the SJRRP website at: http://www.restoresjr.net/flows/Groundwater/Groundwater.html.

2.6 Comment 6 – RMC

Comment: In Section 1.0 Introduction, line 24 the sentence should read; "zones necessary to protect"

Response: This language has been modified.

2.7 Comment 7 – RMC

Comment: In section 1.1 Background, line 31 and 32 should read; "Confluence of the San Joaquin River while avoiding material adverse impacts such as groundwater seepage impacts to crops in adjacent fields."

Response: This language has been modified.

2.8 Comment 8 – RMC

Comment: Request operational criteria and response actions included in program documents.

Response: See response to Comment 15.

2.9 Comment 9 – RMC

Comment: In line one on page 1-2, while 100 wells have been constructed to assess hydrologic conditions near the River, we have pointed out above that many of these wells are not qualified to serve as seepage threshold stations. The report should reflect which are qualified.

Response: See response to Comment 5.

2.10 Comment 10 – RMC

Comment: Suggested adding at line 7 page 1-2 "Reclamation will endeavor to limit interim flows so as to not exceed seepage thresholds."

Response: This has been clarified in the Operations section of the Seepage Management Plan main body.

2.11 Comment 11 – RMC

Comment: Suggested adding at line 7 page 1-2 "If groundwater levels exceed or are approaching a threshold, Reclamation will conduct a site visit to determine if the water levels are correct at the site."

Response: This has been addressed in the main body of the Seepage Management Plan, through the Triggers section.

2.12 Comment 12 – RMC

Comment: Suggested adding at line 7 page 1-2 "Based on the site visit, Reclamation shall reduce interim flows in the Reach to last known safe flow and re-evaluate field control seepage thresholds."

Response: This has been addressed in Operations section of the main body of the Seepage Management Plan.

2.13 Comment 13 - RMC

Comment: With regard to the paragraph beginning with line 17 (page 1-2), we mentioned previously the need for operational criteria and response actions. We also believe that the criteria and responses should be by River Reach and that notion reflected in this paragraph.

Response: See response to Comment 15.

2.14 Comment 14 – RMC

Comment: Regarding the Table on page 2-15 we understand there is a problem with the contractor who developed the information and request additional effort be made to resolve the contract issue so as to allow us the opportunity to review the field information this chart is based on.

Response: A full write-up of soil salinity data including the measurements of the capillary fringe is expected by the end of March. Reports must be given to individual landowners 10 days prior to public release. This information will be made available to the public as soon as possible.

2.15 Comment 15 – RMC

Comment: Our summary request is that the current process be finished as soon as possible so as to completely link together the flows, the monitoring wells, the adjacent field seepage thresholds process and the response and remediation activities into one complete program element.

Response: Operational criteria will be continually updated and so will not be part of the updated Seepage Management Plan. The updated Seepage Management Plan will identify monitoring wells, thresholds, potential remediation activities, potential projects. A process to select and implement potential seepage projects will be developed in more detail in the upcoming Seepage Project Handbook. Operational criteria will be updated during the Interim Flows program and can be found in the flow bench evaluations posted on the SJRRP website at: http://www.restoresjr.net/flows/FlowScheduling/flow_scheduling.html#Evals.

2.16 Comment 16 – RMC

Comment: Lack of information on the differences between the hydrology and the hydraulic conductivity (both saturated and unsaturated flow, horizontally and vertically) of the varying soil types within the spheres of the proposed monitoring wells.

Response: Reclamation's thresholds do not depend upon hydraulic conductivity. The significance of this variability under the proposed approach is unclear. Reclamation will discuss additional information needed from landowners or stakeholders regarding this topic at a future Seepage and Conveyance Technical Feedback Group meeting. This information can be incorporated on a site-specific basis.

2.17 Comment 17 – RMC

Comment: May is the critical month for thresholds, crops are the most sensitive during this time to “various water-related impacts including… anoxia, fungi and bacteria associated with wet conditions, temperature, salinity, and nutrient availability.”

Response: Comment noted. Thresholds will be consistent for large portions of the year for ease of operations and to avoid the potential need for frequent leaching.

2.18 Comment 18 – RMC

Comment: Only use monitoring wells with shallow perforations to set thresholds.

Response: See response to Comment 5.

2.19 Comment 19 – RMC

Comment: Design new wells to be perforated in the first zone of saturation correlated with shallow seepage.

Response: Perforation intervals for shallow monitoring wells are generally 10-25 feet, with the exact perforation determined by the geologist in the field based on site conditions. Reclamation will continue to use deep wells where warranted to understand hydrology, and use shallow wells to manage for seepage. Also see response to Comment 5.

2.20 Comment 20 – RMC

Comment: Account for variability in soil types in thresholds due to vertical and horizontal changes in soil types.

Response: See response to Comment 16.

2.21 Comment 21 – RMC

Comment: Hydraulic conductivity including saturated and unsaturated movement, vadose zone and capillary fringe “need to be considered and integrated into the hydrologic approach”.

Response: The flow stability section of the Flow Bench Evaluations addresses hydraulic conductivity and the vadose zone. Capillary fringe is included in the agricultural practices threshold.

2.22 Comment 22 – RMC

Comment: Gas flux; anoxia, oxygen, CO2, de-nitrification should be considered and integrated into the hydrologic approach.

Response: Appendix A was modified to add the effects of high water on these concerns. The agricultural practices threshold - root zone addresses this concern.

2.23 Comment 23 – RMC

Comment: Heat and temperature should be considered and integrated into the hydrologic approach.

Response: Appendix A was modified to add the ability of groundwater to influence these concerns. The agricultural practices threshold addresses this concern.

2.24 Comment 24 – RMC

Comment: Ion exchange (including salts and specific ions) should be considered and integrated into the hydrologic approach.

Response: Appendix A was modified to add the ability of groundwater to influence these concerns. The agricultural practices threshold addresses this concern.

2.25 Comment 25 – RMC

Comment: Change capillary fringe buffer based on soil types in broader area around well. Well may be in coarse material close to clays.

Response: Changes in thresholds based on soil types may be incorporated as an approach for future analysis is determined.

2.26 Comment 26 – RMC

Comment: Soil warming is critical during the root hair growth stage in early to middle spring. Cool soil from the endothermic impact of high moisture content is more of an issue in finer textured soils. While such soils have a more rapid heat transfer capability, the soil moisture content and hence evaporation is the foremost caloric demand before the soil temperature actually rises to meet the more favorable crop root growth conditions.

Response: Appendix A was modified to add the ability of groundwater to influence these concerns. The agricultural practices threshold addresses this concern.

2.27 Comment 27 – RMC

Comment: Anoxia is critical in the early spring growth stage of plants.

Response: Appendix A was modified to add the ability of groundwater to influence these concerns. The agricultural practices threshold addresses this concern.

2.28 Comment 28 – RMC

Comment: Soils that are too wet can foster fungi and bacterial conditions that are detrimental to the crops. Wet conditions also can induce de-nitrifying conditions that cause loss of critical nitrogen that has been applied for optimum crop production.

Response: Appendix A was modified to add the ability of groundwater to influence these concerns. The agricultural practices threshold addresses this concern.

2.29 Comment 29 – RMC

Comment: While many of the soils under investigation in the 3W and 4 Reaches have a propensity to harbor significant salts and some crops generally grown in the area (cotton, small grains) have salt tolerance, none have a tolerance for salt in the early growth stages. The plants build their capacity to tolerate salt over time with a more diverse root system. Young plants are susceptible to salt accumulation at the upper boundary of the capillary fringe. The soil thresholds need to consider that salt accumulation near the fringe.

Response: Thresholds will use the root zone depths of mature plants and include a capillary fringe.

2.30 Comment 30 – RMC

Comment: The literature generally supports most of the depths proposed with the exception of almonds. Since almond varieties, rooting stock and the likelihood of the introduction of more permanent crops is likely in the area; additional review of the proposal is needed. To make sure the almond trees do not have production reduction or fatalities, the sensible approach is to use the most conservative threshold to protect the investment. The thresholds can be adjusted somewhat to the age of the planting but any mature orchard will need a twelve foot root-protective zone in the sensitive portion of the year.

Response: The references provided show a 9 foot root zone for almonds. Thresholds have been adjusted accordingly. These thresholds will be implemented year-round.

2.31 Comment 31 – Nickel Family LLC

Comment: Section 1.1 "It states that 'if groundwater levels increase above a threshold, Reclamation will conduct a site visit to evaluate the potential seepage conditions at the site'. We need to clarify/expand upon what a site visit consists of. Just driving by and looking doesn't accomplish much. I would hope there would be some extensive investigation and testing, such as digging a pit and calculating the capillary rise of the salts."

Response: Site visits often include stage measurements, hand auger holes, and collection of soil texture information, soil moisture content, and water levels. This is clarified in the Operations Appendix to the Seepage Management Plan.

2.32 Comment 32 – Nickel Family LLC

Comment: Section 2.3.1 "A buffer for drip irrigation crops is needed for more than a month prior to planting to allow for leaching. First off, planting times are never when we plan them due to numerous factors. Secondly, leaching can occur in the Fall or Winter. It depends upon many factors, such as availability of water, timing of ground preparation, weather, availability of equipment and sprinklers, etc. I don't think you can vary the depth of the thresholds based upon the season."

Response: When a landowner notifies the SJRRP of poor drainage, the irrigation buffer will be added year-round.

2.33 Comment 33 – Nickel Family LLC

Comment: Section 2.3.3 "I don't agree with the statement that monitoring wells located underneath irrigation header lines will show increases in groundwater levels. This statement assumes huge leaks in the header (main) lines which is not always the case. An additional limitation would be if the drainage lines are installed and the disposal of the tile drain water."

Response: Reclamation does not assume huge leaks in the header lines at all times. Monitoring wells located underneath irrigation header lines may show increases in groundwater levels during flushing of lines, testing, or if there are large leaks. Knowing the timing of these events helps understand and analyze groundwater levels in a well. The future Seepage Project Handbook will discuss advantages and disadvantages of different potential projects, including tile drain water disposal.

2.34 Comment 34 – Nickel Family LLC

Comment: Section 2.4.1 "Rather than utilizing data from old text books, I suggest that actual in-field studies on different soil types be conducted to determine capillary rise."

Response: Over 80 soil borings were augered throughout the SJRRP area. These actual in-field studies collected samples for soil salinity testing, and noted soil moisture content and the capillary rise in each boring. These borings were then used to determine capillary rise by soil type. Soil types in locations without a soil sampling location were taken from Reclamation drill logs. Based on the capillary rise classifications by soil type identified from the 80 hand auger soil borings, capillary rise was extrapolated to areas where soil borings were not conducted. This information is used to set the capillary rise buffer as described in Appendix H. This information will be publicly available soon, see the response to Comment 14.

2.35 Comment 35 – Nickel Family LLC

Comment: Section 2.4.2 "It is an incorrect statement that the analysis conducted by ITRC was sited on a compacted road. It was in the field, not under a road."

Response: This text has been corrected.

2.36 Comment 36 – Nickel Family LLC

Comment: Section 3.2 "It states the values were averaged. It is dangerous to use averages when setting standards."

Response: Historical groundwater levels are not available in every location and require some method of averaging or statistical analysis. The historical groundwater section has been revised to use a statistical analysis.

3 Reach 4A Thresholds

The following section addresses Condition 28 of the Order Granting in Part and Denying in Part the Petition for Reconsideration of WR 2010-0029-DWR.

This condition states:

> *By March 1, 2011, Reclamation shall submit to the Deputy Director for Water Rights, to the extent this information is not already provided to the Division under Condition 7, a report describing: (a) current and proposed groundwater elevation thresholds (acceptable, potential buffer, and threat) in Reach 4A; (b) a summary of its evaluation of seepage monitoring data from the WY 2010 Interim Flows Project regarding Reach 4A; (c) any changes to its assessment of channel capacities in Reach 4A; and (d) any measures taken to ensure that flows under the SJRRP do not cause exceedance of a groundwater elevation action threshold in Reach 4A.*

3.1 Current Thresholds in Reach 4A

Thresholds in Reach 4A are provided in Appendix H of the revised Seepage Management Plan.

3.2 Monitoring Data

A summary of seepage monitoring data from the WY 2010 Interim Flows Project related to Reach 4A is provided in the Monitoring Well Atlas, which is available and updated approximately monthly on the SJRRP website at: http://www.restoresjr.net/flows/Groundwater/Groundwater.html#Atlas. This information is also included in the Annual Technical Report, available on the SJRRP website at: http://www.restoresjr.net/flows/atr.html.

3.3 Channel Capacities

Reclamation has not formally changed its assessment of channel capacity in Reach 4A.

3.4 Measures Taken

As of March 4, 2011, Reclamation is currently holding Interim Flows to no more than 50 cfs in Reach 4A and downstream due to thresholds on properties adjacent to the Eastside Bypass. This operational criteria (formerly known as action threshold) will remain until a site evaluation determines another flow is more acceptable or a project is implemented.

Appendix I. Landowner Claims Process

Seepage concerns and impacts anticipated or observed by landowners should be reported to the San Joaquin River Restoration Program (SJRRP). The SJRRP has a Seepage Hotline to address real-time immediate concerns, as well as additional landowner processes to address future or anticipated concerns. The SJRRP will add to this appendix as more information becomes available regarding reimbursement for past impacts.

1 Seepage Hotline for Real-Time Concerns

Landowners with an immediate concern regarding upcoming or current releases of Interim Flows should follow the process below:

1.1 Step 1 – Contact

- Call the Seepage Hotline: 916-978-4398

or

- Send an email to InterimFlows@restoresjr.net
- Provide the following information:
  - Your name, landowner name, phone number, and the best time to contact
  - Description of the potential seepage location(s)

Program staff will follow up to discuss further and arrange a site visit, if needed.

1.2 Step 2 – Seepage Hotline Intake

Based on the follow-up discussion, SJRRP staff will fill out a Seepage Hotline Intake Form that gathers information including:

- Landowner contact info
- Address and directions to the location of the concern
- Type of concern – location, severity, how long it has been happening
- Immediacy of the concern
- Relationship to Interim Flows (timing of concern in relation to Interim Flows)

A Seepage Hotline call may trigger a site visit depending on the nature of the concern. See the template Seepage Hotline Intake Form in Appendix E.

1.3 Step 3 – Site Visit

After the Seepage Hotline Intake Form is complete, SJRRP staff may contact the landowner to schedule a site visit to better understand the concern. Any data the landowner may have gathered on the situation will be useful. During the site visit, SJRRP staff may be especially interested in:

- Type of concern (ponding water, crop germination challenges, and similar issues)
- GPS coordinates of the specific area of concern
- Photos of the area of the concern
- Groundwater levels nearby – SJRRP staff may ask to take hand auger measurements for a rapid check of groundwater levels

- River characteristics adjacent to the area of concern
- Soil salinities in the area of concern

The SJRRP will gather any relevant information and compile it into a Seepage Site Visit Form. See the template Seepage Site Visit Form in Appendix E.

1.4 Step 4 – Resolution

Following a site visit, SJRRP staff will determine if changes to flows are needed as well as if this is a concern that might be resolved with a future project. These decisions and the key pieces of information gathered to make them are documented in the Seepage Response Decision Form (see Appendix E). SJRRP staff will follow up with the landowner on the results of the site visit and the anticipated response decision.

Seepage Intake Forms and Response Decision Forms are available in the Draft and Final Annual Technical reports available on the SJRRP website. Current seepage hotline calls and progress made on them are posted on the groundwater monitoring page on the SJRRP website.

2 Potential Project Process

Any real-time Seepage Hotline concerns that require a site visit and some type of follow-up actions will initiate this process. In addition, landowners that do not have a real-time concern but have concerns about future higher flows may initiate this process as described in Step 1 below.

2.1 Step 1 – Contact

If a landowner has a seepage concern that could be resolved with a project, the landowner may call the Seepage Hotline at 916-978-4398 or email at InterimFlows@restoresjr.net to identify a concern. Following is a list of the types of projects that could be pursued:

- Easements
- Acquisitions
- Agreements
- Tile drains
- Drainage interceptor ditches
- Slurry walls
- Seepage berms
- Operating new drainage or existing irrigation wells to lower the water table
- Conveyance improvements

2.2 Step 2 – Site Evaluation Methods

The SJRRP staff will consult with landowners to conduct an evaluation of their property. This evaluation will consist of:

- *Existing Data Review* - The SJRRP will ask the landowner for any information the landowner may have on historic or current conditions, such as:
    - Groundwater levels
    - Soil salinity
    - Hydraulic conductivity

- Water quality information in the river, irrigation canals, and groundwater
    - Drill logs or other soil information
    - Tile lines and infrastructure
    - Crop data including type and typical yields

- *Additional Monitoring* - The SJRRP will identify any additional monitoring that needs to take place on the property to better identify the appropriate project. This may consist of:
    - Groundwater well installation
    - Soil salinity measurements
    - Hydraulic conductivity tests
    - Water quality testing

This will be documented in a Site Evaluation Methods Technical Memorandum (TM) within a few weeks of the initial site visit. SJRRP staff will work with the landowner to identify additional monitoring needed and obtain landowner approval for additional studies.

2.3 Step 3 – Site Evaluation Technical Memorandum

Following a period of additional monitoring as identified in the Site Evaluations Methods TM, SJRRP staff will issue a Site Evaluation TM consolidating previously existing and newly gathered data sources and identifying a range of potential remediation projects to address landowner concerns in locations restricting flow releases. This process could take several months depending on what additional monitoring is needed.

2.4 Step 4 – Project Report

The SJRRP will then build upon the Site Evaluation TM and develop a Project Report, including additional data collection, analysis and design. Appraisal level designs will be developed for the range of options identified in the Site Evaluation TM and final designs will be developed for the preferred alternative. Considerations for choice of the preferred alternative include:

- Design/Feasibility
- Suitability to Site Conditions
- Landowner Acceptability
- Cost
- Environmental Compliance
- Agreement with the Landowner

The Project Report will include designs, quantities and costs, as well as environmental compliance.

2.5 Step 5 – Compliance, Contracting, and Agreements

Once final designs are known, SJRRP staff will begin the environmental compliance activities necessary to construct the preferred alternative. Reclamation is required to comply with Federal environmental laws, including the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and the National Historic Preservation Act (NHPA). Other Federal and some State and local laws may also be applicable, depending on the project. These activities will require access to the property to conduct various studies. During this time, SJRRP staff will also being the process to get a contract or financial assistance agreement in place to construct the project. Implementation of a seepage project on a landowner's property will require mutual agreement between Reclamation and the landowner on such things as site access, ownership of the project facilities, and operations and maintenance responsibilities. All of these actions could take anywhere from 3 to 6 months or more.

2.6 Step 6 – Implementation

Following Reclamation completing the necessary environmental compliance actions, executing a contract or financial assistance agreement for the project, and entering into an agreement with the landowner, construction of the project can proceed. SJRRP staff will coordinate with the landowner regarding construction timeframes, taking into consideration landowner schedules and activities on the property.

Appendix J. Modeling

This appendix describes current plans for future modeling efforts associated with the Seepage Management Plan.

1. Current Objectives of Planned Modeling Efforts

The objectives of planned future modeling efforts include:

- Evaluation and support of water-level and soil salinity monitoring plans,
- Evaluation of the relative effects of precipitation on the valley floor and high river flows on the water table,
- Identification of potential seepage impact areas where data are sparse,
- Estimation of long-term changes in seepage rates and associated potential impacts,
- Evaluation of effects of likely changes in regional hydrologic conditions,
- Evaluation of the effectiveness of potential response actions, and
- Detailed evaluation of groundwater/surface-water interactions.

Implicit in each objective are specifications for the type and scale of model needed to meet the objective. Following is a discussion of each objective and the related model requirements.

1.1. Evaluation and Support of Monitoring Plans

The geographic extent of water-table response to Restoration Flows is currently unknown. The current monitoring plan focuses on a zone within one mile of the river, but there are anecdotal accounts of water levels in wells as far as three miles from the river responding to high flows. A regional-scale model of surface-water and groundwater flow could be used to help define this geographic extent and design an appropriate monitoring corridor surrounding the river.

1.2. Evaluation of Effects of Precipitation on Water Levels

The relative effects on the water table of precipitation on the valley floor and high river flows are unknown, and water-level data of adequate frequency for separating these effects may not be available, or may only exist for a small number of locations. A temporally refined regional-scale model of surface-water and groundwater flow could adequately address this question.

1.3. Identification of Potential Seepage Impact Areas

There currently are large geographic areas within the Restoration Area with sparse water-level data available, making it difficult to evaluate the potential for seepage impacts in these areas. A regional-scale model of surface-water and groundwater flow could be used to simulate water-table changes in these areas associated with Restoration Flows to help evaluate relative vulnerability to seepage impacts.

1.4. Estimation of Future Changes in Potential Seepage Impacts

Estimation of long-term changes in seepage rates and associated potential impacts could be done using a regional-scale model of surface-water and groundwater flow.

1.5. Evaluation of Effects of Changes in Regional Hydrology

Future changes in regional hydrologic conditions likely include increased groundwater pumping in areas with decreased deliveries from Friant Dam, development of groundwater banking projects to take advantage of surface-water availability during wet years, and continued expansion of urban areas and associated groundwater use. Evaluation of effects of these changes in and around the Restoration Area on seepage and related impacts could be accomplished using a regional-scale model of surface-water and groundwater flow that accommodates major changes in the water budget and associated processes.

1.6. Evaluation of Potential Response Actions

Evaluation of the effectiveness of potential response actions requires a range of spatial and temporal resolution. It may not be practical to simulate all potential responses, but most can be reasonably simulated at the local to regional scale and daily to monthly time scale. Regardless of the scales, the model(s) would need to simulate both surface-water and groundwater flow.

1.7. Detailed Evaluation of Groundwater/Surface-Water Interactions

Detailed evaluation of groundwater/surface-water interactions would require local-scale grid resolution to adequately represent the river and associated variability in streambed and near-subsurface hydraulic properties.

2. Model Selection

On the basis of model requirements noted above for meeting the modeling objectives of the Seepage Management Plan, the USGS Central Valley Hydrologic Model (CVHM) has been selected for future work. The CVHM (Faunt, 2009) is in the public domain, freely available to all. It uses MODFLOW-2005 (Harbaugh, 2005), the most recent version of the widely-used USGS hydrologic modeling software.

Simulation features of CVHM include:

- Monthly hydrology from 1961–2003 (currently being extended);
- Square-mile resolution with 10 vertical model layers;
- Surface-water and groundwater flow;
- Irrigated agriculture using the Farm Process, a sophisticated new tool that incorporates data on crop characteristics, soils, climate, and other factors affecting landscape processes;
- Land subsidence; and
- Intra-borehole flow through well bores.

Many of the objectives could apply to the entire Restoration Area and beyond, but also to smaller areas. At least two of the objectives require local-scale resolution. Current plans involve grid refinement to a ¼ mile resolution within 5 miles of the San Joaquin River, with further refinement to a few hundred feet resolution within about 1 mile of the San Joaquin River. The USGS expects completion of the initial refinement to a quarter mile grid by June 2011.

MODFLOW-2005 supports grid refinement through the Local Grid Refinement (LGR) package (Mehl and Hill, 2005). The LGR capability will be used to spatially refine CVHM as needed to address problems at multiple scales. A key feature of LGR is that it not only allows refinement of a local area of interest within a regional model, but also maintains a dynamic linkage between the refined local model and the regional model, thus providing reasonable hydrologic boundary conditions for the local area.

Appendix K. References Cited

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