Appendix G. Soil Salinity Thresholds

This appendix discusses the development of the soil salinity thresholds used by the SJRRP for analysis of potential seepage-related effects.

G.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 slow the germination and emergence of crops and reduce crop yield. Drainage engineers typically design artificial drainage systems to maintain the water table at depths below four 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 could increase soil salinity because groundwater typically is more saline than surface water, and
- Surface water released from Friant Dam contains less salt than surface water pumped from the Delta; all other factors being equal, the use of Friant Dam releases, instead of Delta water, would tend to lower soil salinity.

G.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 to 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

Crop	Salt Tolerance Threshold ECe (dS/m)	Yield Decline per 1dS/m Increase (%)	Yield Potential at 2 dS/m (%)	Yield Potential at 3 dS/m (%)	Yield Potential at 5 dS/m (%)	Yield Potential at 10 dS/m (%)
Alfalfa hay	2.0	7.3	100	93	79	44
Almonds	1.5	19	90.5	71.5	43.5	0
Barley	8.0	5.0	100	100	100	90
Cotton	7.7	5.2	100	100	100	88
Garlic	3.9	14.3	100	100	84.3	12.8
Grape	1.5	9.6	95.2	85.6	66.4	18.4
Maize	1.7	12.0	96.4	84.4	60.4	0
Muskmelon	1.0	8.4	92.6	83.2	66.4	24.4
Onions	1.2	16	87.2	71.2	39.2	0
Pistachio	4.2	7.4	100	100	94.1	57.1
Pomegranate[1]	2.5	10.5	100	94.6	73.6	21.8
Safflower[2]	6.5	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

Notes:
1: California Pistachio Orchards,' Early Rootstock Trials L. Ferguson and others
2: Qualitative assessment based on midpoint of moderately tolerant range
Source: Allen and others, 1998
dS/m: decisiemens per meter

Soil salinity levels used for crop yield reduction estimates are an average of the ECe levels for the zero to 12 inch, 12 to 30 inch, and 30 to 60 inch sampling zones (described in Section G.5). This procedure weights the shallowest soil depths more than the deeper depths. This weighting is considered appropriate since most crop roots are shallow and most water uptake is from shallower soil depths. On inverted soil salinity profiles, the top 12 inch zone is double weighted relative to the 12 to 30 inch zone and the 30 to 60 inch zone is not used to calculate the ECe value for yield potential estimation.

G.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 (zero to 30 inches below ground surface) and LOC for the plow layer (zero to 12 inches) associated with early-season establishment of crops.

G.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 LOC.

- Reach 2B: This reach has many orchards and vineyards, including almonds and grapes, which tend to be sensitive to salts. The crop salt tolerance for almonds (1.5 dS/m) is the proposed LOC for this Reach 2B.

- Reach 3: The most common crops found in Reach 3 are almonds, corn, and alfalfa Large acreages of young almonds have recently been established near the river. The crop salt tolerance threshold for almonds (1.5 dS/m) is the proposed LOC for Reach 3.

- Reaches 4A and 4B: Alfalfa is the most common crop observed in Reaches 4A and 4B. Processing tomatoes and cotton are also common crops. The crop salt tolerance threshold for alfalfa (2 dS/m) is proposed as the LOC for Reaches 4A and 4B.

G.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 valuable vegetable crops such as tomatoes. 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 1.5 dS/m in the plow layer, monitoring intensity will increase. This salinity level corresponds with an alfalfa yield potential of about 100 percent.

G.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 percent 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 or increased flow at drainage sump pumps, and
- Indications from observation wells that the water table is approaching the LOC.

G.5 General Description of Soil Monitoring Methods

Soil sampling was typically done by a two or three man crew under the direction of a soil scientist.

G.5.1 EM38 Survey

An EM38 survey was conducted within a 100-foot radius of the initial selected site. The EM38 provides multiple real time soil salinity measurements. The instrument measures bulk soil electrical conductivity of an area about six feet long, five feet deep and about 2.5 feet wide. The EM38 instrument allows for:

- Collection of multiple real-time soil salinity measurements in a short period of time;
- Measurement of bulk soil electrical conductivity for a large volume of soil as compared to soil samples; and
- Collection of real-time information on soil salinity levels, salt distribution in the profile, and spatial variation of soil salinity within an area surrounding a boring site.

The EM38 survey can be conducted in the horizontal (EMh) or vertical (EMv) position. The EMh signal measures the top meter of soil. The EMv signal measures from the top two meters of soil. (Geonics 1998) For this project it is assumed the EMh generally measures the bulk soil electrical conductivity to a depth of about 30 inches, while the EMv generally reflects the bulk electrical conductivity of the 0 to 60-inch soil depth. Both readings can be used to estimate the soil salinity of the 0 to 36-inch soil zone (Rhoades, et al. 1999). The number of measurements can be increased if the survey area has variable readings. Following the measurements, the EM readings were averaged and adjusted for soil temperature (i.e., corrected to 25ºC). The survey included least 12 paired EM measurements.

G.5.2 Central Boring

Following the EM38 survey, a final central boring soil sampling site was placed directly under a pair of EM measurements. The site selected for the central boring included EM measurements that were generally well within the range of readings measured surrounding the site. Sites with unusually high or low EM readings were typically not chosen as central boring sites because these sites did not appear to represent the average condition for the site.

The central boring was hand augured and soil samples were collected at depths of 0 to 12, 12 to 30, and 30 to 60 inches. In a few cases (see Appendix A for sampling intervals), the soils could not be sampled to the full 60 inches due to hardpan layers or the presence of unstable saturated soils. The soil was examined and a soil profile log (Appendix B) was prepared using the U.S. Department of Agriculture (USDA) soil textural system and nomenclature. Special attention was given to the depth of mottling and/or gleying, capillary fringe thickness, and the depth to shallow groundwater.

G.5.3 Composite Sample

A separate multi-increment spatial composite soil sample of surface soil (0 to 12 inches) was collected from an area within a 100-foot radius of the central boring. These samples typically contained between 15 and 30 increments. These samples were collected with either a one-inch diameter Dakota or Oakfield probe. Baseline soil samples in field crops and row crops were collected in a stratified random manner to ensure that the top, sides, bed shoulders, and furrows were represented in the composite surface soil samples. Orchard and vineyard areas were carefully sampled to avoid underground plastic pipe manifolds and trench backfill; and to make sure that the spatial composite soil samples included increments collected from near the emitter, near the center of the tree rows, and areas near the edge of the tree canopy. In some cases soil sampling procedures were customized for each orchard or vineyard, depending on the type of irrigation system used. Replicate soil salinity samples were also collected from the area within a 100-foot radius around some of the boring sites. The multi-increment surface soil composite samples were used for most evaluations, including establishing baseline soil salinity values and estimating crop yield potential. A soil sample from a depth of 0 to 12 inches was also collected from the central site. This sample was mainly used for EM meter calibration and soil salinity profile characterization.

Soil samples were sent to the Fruitgrower's Laboratory in Santa Paula, California for analysis. A screenable testing procedure was used. If the electrical conductivity of the soil saturation extract (ECe) exceeded 3 deciSeimens per meter (dS/m) or the pH paste (pHp) was 8.5 or higher, a Sodium Adsorption Ratio (SAR) analysis was requested. The SAR is a ratio for soil extracts and irrigation water used to express the relative activity (i.e., excess) of sodium ions in exchange reactions with soil, specifically calcium and magnesium. The SAR is the result of the calculation, Na+/[(Ca2+ + Mg2+)/2]1/2, where ionic concentrations are expressed in milliequivelents per liter (meq/L) (Ayers and Westcot, 1994). If the SAR testing found saturation extract calcium concentrations over 15 meq/L then calcium was determined on a 1:5 soil:water extract. This data was used to estimate soil gypsum content in milliequivlevents per 100 grams (meq/100g).

G.5.4 Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) of laboratory salinity data was provided by the Environmental Monitoring Branch of Reclamation's Sacramento Regional office. All laboratory data presented in this report met or exceeded SJRRP acceptance criteria.

G.5.5 Estimation of ECe from EM38 readings

The EM38 meter reads bulk soil conductivity. The readings are in mS/m. These readings are sometimes called signals in the remainder of this document. The EMh signal represents bulk soil electrical conductivity to a depth of about 0 to 30-inches while the EMv signal represents bulk soil conductivity to a depth of about 0 to 60-inches. Bulk conductivity values are not ECe values. ECe is a laboratory determined electrical conductivity value determined under controlled moisture, temperature, and volume conditions. Conversion of raw EM signal data to an estimate of ECe requires measurements of soil temperature, moisture, and soil texture information. These factors can be used to adjust the EM measurements and ECe estimations from EM data. The ECe is normally determined on a 200 to 400 gram disturbed soil sample while the EM38 meter is reading from an undisturbed area 2.5 feet wide, six feet long, and five feet deep.

The EM38 signal is affected by soil moisture levels, soil texture, and soil temperature. All these parameters can be estimated or measured in the field. For the SJRRP, soil temperature is measured at two inches and 16 inches. It is impractical to continuously measure soil temperature from zero to 60-inches so temperature is measured at two depths for calibration purposes.

These depths correspond to depths with the maximum EMh and EMv signal returns. Soil texture is estimated by the hand texturing method although a small soil sample is occasionally checked for particle size using the hydrometer method. Saturation percentage is also determined on the soil sample which is input into the EM/ECe estimation spreadsheet program. Percent soil moisture by weight is also determined on the soil sample. It is estimated that the saturation percentage is about twice the water content as the soil when it is at field capacity.

G.6 Soil Salinity Samples in 2013

Twenty baseline soil salinity sites were established in the spring of 2013. These sites complement the existing 117 sites established in the spring of 2010, 2011, and 2012. Most of the previously investigated sites were reevaluated for soil salinity in 2013 to determine if soil salinity had changed. Eight additional sites that were specifically located by a landowner were also sampled. Six sites were not reevaluated in 2013. The most common reason for not resampling a site is because access permission could not be obtained. The 2013 salinity results are presented in the SJRRP's "Soil Salinity Monitoring Report: 2013", dated February 2014.

In the future, additional salinity appraisals may be done using the following types of surveys:

- EM38 transects along furrows,
- EM38 entire field salinity mapping,
- One-acre representative site evaluations, and/or
- Soil sample analyses provided by landowners and/or growers.