Memorandum

DATE:	May 24, 2014
TO:	Michael Johnson, LSJRC Manager
COPY TO:	Lower San Joaquin River Committee (LSJRC) Larry Walker Associates (LWA) Team
SUBJECT:	**Development of a Basin Plan Amendment for Salt and Boron in LSJR: Task 1: Finalize Draft Agricultural Supply (AGR) EC Objectives**

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This memorandum is being submitted on behalf of the LWA Team[1] and fulfills the requirements of Task 1 of the Development of a Basin Plan Amendment (BPA) for Salt and Boron in the Lower San Joaquin River (LSJR) Workplan (Workplan).

The primary purpose of Task 1 is to review the comments received regarding the *Salt Tolerance of Crops in the Lower San Joaquin River Basin Report* (prepared by the Central Valley Regional Water Quality Control Board, 2010) [Crop Tolerance Report] and to provide recommendations to the LSJR (LSJR) Committee (LSJRC). The specific sub-tasks for this work effort include the following:

- *Subtask 1.1. Develop responses to technical comments using work which has been conducted for CV-SALTS since the report was written.*

  This work was completed in December 2013 and submitted to the LSRJC in January 2014. The finalized responses to the technical comments are incorporated as a part of this technical memorandum (**Table 3**). Those responses were originally submitted along with extensive technical references in an Excel workbook (Crop Tolerance Report Response to Technical Comments_Nov13, Apr 14 Update.xlsx) that is being provided again with this memo.

[1] The LWA Team consists of the following firms: Larry Walker Associates, Luhdorff and Scalmanini Consulting Engineers, Kennedy/Jenks Consultants, PlanTierra, Systech Water Resources, Carollo Engineers, Ascent Environmental, and Dr. Richard Howitt.

- *Subtask 1.2. Qualitatively evaluate the results of the staff report using the policy recommendations generated by the CV-SALTS Executive Committee and make recommendations as to any future work that should be completed.*

  This technical memorandum summarizes the results of the qualitative evaluation of the Crop Tolerance Report and provides recommendations on whether re-running the model with revised inputs is appropriate, with options for how any needed work might be accomplished.

The term "common crop" is employed in this work. As part of CV-SALTS' policy discussion, it was determined that sensitive crops that are relatively rare should not drive analyses that will inform AGR thresholds. Protection of 95% of crops was cited, without elaboration of exactly what the basis of the 95% calculation would be. In this memo, crops that are sufficiently widespread to merit protection are termed "common crops."

This memorandum is organized as follows:

- Section I Responses to Technical Comments (Subtask 1.1) – This section summarizes the work that was completed pursuant to Subtask 1.1 and includes the original responses and ancillary information provided to the LSJRC in December 2013.
- Section II Qualitative Evaluation and Recommendations for Future Work (Subtask 1.2) – This section summarizes the work that was completed pursuant to Subtask 1.2.
- A technical appendix describes methodology for determining common crops, and applies it to the study area. The analysis is provisional, and will need to be updated to reflect a) the whole acreage irrigated with diversions from the LSJR, and b) common crops irrigated from sub-reaches of the LSJR.
- References

I. RESPONSES TO TECHNICAL COMMENTS ON THE CROP TOLERANCE REPORT (SUBTASK 1.1)

The LWA Team developed additional responses to comments that had been provided on the Crop Tolerance Report (Montgomery et al., (2010). In developing these responses and later recommendations (see Subtask 1.2), policy discussions and decisions that had taken place within CV-SALTS since the first set of responses were developed were considered. In brief, these policy topics and decisions include the following:

- Use current cropping data as an indicator of future cropping patterns, with updated analyses occurring periodically to reflect future changes.
- Protected (common) crops: protect 95% of crops (by acreage). See **Appendix A** for a thorough discussion of how this can be implemented.
- Acceptable yield limitation due to applied water salinity: 95% of maximum relative yield.
- Protection furnished during dry years: 95^{th} percentile (1-in-20) dry (low precipitation) year.
- Leaching fraction - 15% (or higher, particularly in dry years) for surface and sprinkler irrigated fields.

Responses to comments are contained in the column labeled "Additional Comment Responses from LWA Team (November 2013)", in **Tables 1** and **3**. Since the authors had already responded to comments, the Team distinguished their comments from the original comments with the term "Additional…" in the column header.

In addition to the responses required by the scope, the LWA Team provided, in the workbook, an extensive set of tables and references related to a range of issues that are important when developing AGR objectives (whether narrative or numeric). This provides interested readers additional discussion and reference material to help improve understanding of the questions related to these types of analyses, but is not presented as a comprehensive discussion.

Technical comments received on Subtask 1.1 work are shown in **Table 2** along with responses. These comments were taken into account while performing work under Subtask 1.2 (i.e., when developing recommendations for updating the Crop Tolerance Report).

II. QUALITATIVE EVALUATION OF THE CROP TOLERANCE REPORT AND RECOMMENDATIONS FOR FUTURE WORK (SUBTASK 1.2)

The LWA Team performed a qualitative evaluation of the Crop Tolerance Report, and developed recommendations for updating that work. These recommendations were based on updated policy guidelines (see previous section), and on general information obtained from the LSJRC. For ease of reference, a number of these recommendations are shown in the right-hand column of the table of responses provided for Subtask 1.1 (**Table 3**). This allows them to be evaluated in the context of previous discussion. However, they are also shown free of antecedent discussion in **Table 1**. Additional recommendations based on the qualitative review are provided in the narrative following **Table 1**. These recommendations do not necessarily arise directly from comments made previously, but rather are based on the scoped review of the Crop Tolerance Report (Montgomery et al., (2010). In some cases, recommendations cite the need for field studies and consultations with experts. In general, consultations with experts are assumed to be feasible within the period allotted to perform and interpret revised model runs and develop the associated report. However, field work may not be feasible in this timeframe, so that refinements requiring fieldwork may not be feasible before completion of the proposed revisions. A field study might take 2 to 5 years. It would thus be prudent to identify items requiring such study, so that in the future, the needed information might be available. In the meantime, models can only be run with assumptions and inputs based on the best available, not perfect information. If indicated studies are initiated based on this and other reviews, then it may yet be possible to improve upon information currently available to modelers.

Methods for employing crop acreage data to determine common crops are described in **Appendix A**. In that Appendix, the methodology is also applied to available crop data for several districts in the LSJR Service/ Study Area to demonstrate the approach and to contribute to the larger LSJRC effort. Note that this effort was not scoped under **Task 1**, but was developed at the request of the LSJRC, and is included to reflect discussions on this topic with the LSJRC.

Discussions and recommendations for updating the Crop Tolerance Report[2] resulting from the qualitative evaluation (with the comment and response elements shown in **Table 3**) were added into the more concise **Table 1**.

[2] Documented in "Crop Tolerance Report_Response to Technical Comments_Nov13, Apr 14 Update.xlsx"

Table 1. Qualitative Analysis and Recommendations for Future Modeling Work

Category	Comment # (from comments and responses shown in Table 3)	Qualitative Analysis and Recommendation (April 2014)
Models	18	Modelers should review the literature provided as part of Subtask 1.1, and included in the comments workbook. CV-SALTS has the opportunity to present and discuss technical questions with experts attending the Salinity Forum 2014 (June 16-18, 2014 in Riverside, CA, http://salinityforum2014.ucr.edu/). This would require some pre-conference coordination. The technical questions discussed in these recommendations should be reviewed there.
Models	20	Modelers should avoid compounding of conservative assumptions in developing the model, and instead use recent literature and available expertise to guide assumptions, with the goal of providing the most accurate estimate of thresholds. To do otherwise would lead to thresholds that are overly conservative and which do not serve as a proper indicator of unacceptable impact. See also the response to Comment 18.
Models	21	Provide a concise summary of assumptions employed in any update of Hoffman modeling.
Leaching Fractions	9	A range of leaching fractions was previously analyzed, and this should again be the case in new analyses. The reason for the range is to capture uncertainty about this important parameter, to demonstrate the level of sensitivity of results to LF, and to provide a set of results that inform policy more fully. It may be that the LF selected in setting water quality thresholds will be determined by processes such as CV-SALTS, and may yet change after modeling is completed. To the extent practicable, leaching fractions should be informed by field observations of actual practices. The model should assume fractions that are representative of the most conservative (i.e. lowest LF) condition that is widely represented (on >5% of the total irrigable land, or that is the predominant method for a common, sensitive crop). Modelers should avoid overestimates of irrigation efficiencies or potential infiltration of water. The best means of determining representative leaching fractions, and of determining how to best to represent drip and microspray irrigation, may be to consult with irrigation specialists, such as those with UCCE.
Leaching Fractions	59	Realistic LF should be investigated with irrigators and/or irrigation specialists (see 9), and used in the modeling effort. Any LF assumption should be bracketed, meaning the analysis should be re-run with slightly higher and lower values to illustrate sensitivity. Emphasize that LF varies year to year, field-to-field, and within fields, further emphasizing the utility of the bracketed analyses. Unrealistically low or high LF may provide quantitative results that misinform policy. See also related LF comments in this set, and comments 28 and 30 by John Herrick.
Leaching Fractions	66	The 20-25% leaching fraction described for Beans should be investigated (as it was in the previous report. The same process can be followed for other crops, such as Almonds, which now look as if they may be the most sensitive crop in the LSJR study area, instead of Beans. See comments 9 and 59.
Planting and Harvesting Dates	57	The bracketing approach previously employed for uncertain or variable parameters such as planting date and leaching fraction is sound, and should again be employed to determine sensitivity to uncertain parameters.
Planting and Harvesting	89	At present, it is unclear to all exactly how to represent drought in a Hoffman analysis and in interpretations of analysis used to inform water quality objectives. This needs to be discussed with resource persons within CV-

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Category	Comment # (from comments and responses shown in Table 3)	Qualitative Analysis and Recommendation (April 2014)
Dates		SALTS and the technical community. UC Cooperative Extension representatives familiar with the sensitive crop(s) being modeled are excellent resources and should be consulted to the fullest extent necessary and needed. A workshop or set of focused interviews to vet parameters for analysis should be considered.
Soil Water Uptake Patterns	25	Unless good reasons to do otherwise are documented, the exponential root uptake model should be primarily used in the interpretation. There is no harm in analyzing alternative uptake patterns, however, inputs and results should be documented in a thorough and reviewable manner, so that others can reproduce the work if necessary. Please see other comments relative to addition of an uptake pattern that accurately reflects drip and microspray. These results should be used in interpretations for crops predominantly irrigated in this manner.
Temporal Scale	74	Run the analysis for a 95th percentile dry year, calculated from the longest available precipitation record that is representative of the locale. Threshold crop yield protection should be provided during that year. Such protection will then be achieved during wetter years as well.
Temporal Scale	76	Narrative should discuss the basis of the cropping pattern used in the analysis, and the extent to which sensitive crops driving the analysis would or would not be likely to differ in a dry year. If it is concluded that a more sensitive crop would drive the analysis during a wetter year, then a supplemental analysis of this year type, with the more sensitive crop, should be developed. See also comment 32 by John Herrick.
Spatial Scale	78	Please reference the "Cropping Patterns" memo contained in appendix. It provides guidance from the LSJR Committee on determination of representative, common, sensitive crop/irrigation system combinations.
Cropping Patterns	79	It may be possible to select a single, most sensitive, common crop-irrigation system combination. However, if other sensitive crops are also analyzed, then these results could be employed in the event that there is growth or resurgence in acreage of those crops. Policy recommendation: There should be a provision to periodically review crop acreage tables to ensure that thresholds remain protective of common crop/irrigation combinations.
Effective Rainfall	61	The methodology description in the response from the authors suggests that if irrigation, effective precipitation, ET, and bare-soil evaporation inputs to the model represent reality, the modeled soil salinity should also be reasonable. Thus, these inputs should be checked.
Factors Influencing Effective Rainfall	55	Effective precipitation estimates are uncertain, and should thus be part of the bracketed analysis.
	60	Review and refine soil evaporation estimates with expert assistance.
Pre-irrigation	58	To the extent practicable, incorporate transient effects of practices such as pre-irrigation into steady-state models (for example by reflecting sensitive growth stages in thresholds).
Groundwater	51	Where saline shallow groundwater or drainage condition can be shown to influence exposure of plants to salinity in the predominant condition in which a sensitive crop is irrigated, this should be reflected in modeling.

Table 1. Qualitative Analysis and Recommendations for Future Modeling Work

Category	Comment # (from comments and responses shown in Table 3)	Qualitative Analysis and Recommendation (April 2014)
Pre-irrigation	36	If there is uncertainty related to characterization of dynamic soil properties, such as salinity, begin with an assumption that systems reflect contemporary management. If there is doubt about this, then perform focused field studies to learn more about the parameter, and use those results to guide model assumptions. Address remaining uncertainty/variability by bracketing analyses.
Soils	45	Consult with resource persons (e.g., UC Cooperative Extension specialists) regarding the prevalence and nature of soil hydrologic processes associated with heavy textured soils. If necessary, alter Hoffman Model parameters to better reflect actual soil hydrology as it is affected by these processes.
Follow-up Studies	56	Consult with UC Cooperative Extension to discuss and plan focused field studies to verify important parameters and overall findings. Such studies are frequently performed to explore production or environmental questions. The importance of calculated salinity thresholds is such that studies of this nature are justified, and perhaps indispensible.
Follow-up Study - Crop Tolerance Curves	64	Where salinity functions are unknown (e.g., Walnuts), or out of date (e.g., Beans), the USDA Salinity Lab should be contracted to develop up-to-date salinity-yield functions. Where outdated functions are used, or where no functions are available in the near term, work performed should be re-done as soon as the new functions are available. As with field studies performed with UC Cooperative Extension, such studies are frequently performed to explore production questions. The importance of calculated salinity thresholds is such that studies of this nature are justified, and perhaps indispensible.

In addition to the above, the following comments and recommendations on the Crop Tolerance Report are offered. Unless otherwise specified, page and section references cited in these bullets refer to the most recent revision of the Crop Tolerance Report.

- The following pertains to the effort to establish the AGR criteria for the LSJR: Crop acreage for several districts/diverters irrigating with LSJR water (Patterson, West Stanislaus, and Twin Oaks Irrigation Districts, as well as Jim Coddington) were provided by the LSJR Committee. Data from El Solyo Irrigation District are being obtained. Acreage for other, mostly small diverters may be estimated from reports or from recent imagery. Based on this information, the methodology discussed in Appendix A should be used to define common crops. The analysis should be updated as soon as crop acreages for the remaining area are available. Modelers should be clear about the user area represented in the analysis when finalizing.
- Recommend removing the statement (p. 1 of the Crop Tolerance Report), "Staff feels that this coarse level of assessment is acceptable for the purposes of this Report, and caveats that it is not intended to confirm any party's existing or potential water rights."

- Incorporate the Policy recommendations provided by the CV SALTS Executive Committee in the interim since the report was previously revised, including the following:
    - Protect sensitive common crops from excessive salinity in their irrigation supply (see **Appendix A** for a review of methods for determining common crops).
    - Use current cropping data. While still an imperfect expression of future cropping patterns, recent data are superior to older data in this regard. To handle known or suspected fluctuations, averages of recent years may be used for those crops. To address future changes in cropping patterns, provisions to periodically re-assess cropping patterns should be developed. However, the recent expansion of permanent crops [e.g. Almonds and Walnuts] is a major feature, unlikely to be rolled back soon due to the lack of rotation in permanently cropped fields, and the high level of investment associated with their establishment. However, it should be noted that "permanent" crop locations also shift in response to market conditions and the availability of water to irrigate them.
    - Adequate protection constitutes a threshold allowing for 95% maximum relative yield.
    - Protection must also be provided in a 95th percentile dry year. This suggests that thresholds need to be developed for such dry years, but it does not state that these same thresholds need to be maintained in wetter years. Therefore, the work should analyze a range of water year types, possibly resulting in a range of protective thresholds.
- For the LSJR, it should be assumed that the LSJR is the sole source of irrigation in the user area.
- Working in units of dS/m for salinity is acceptable, but in a single summary table of potential thresholds should be generated which translates EC results into mg/L TDS with an explicit, approximate conversion factor.
- Provide timescales such as that on the x axis of Figure 2.1 so that seasons are apparent.
- Acreage accounting methods described in Section 2.3.2 under-represent double cropped acreage by assigning half the area actually planted. It is recommended that the methods as described in **Appendix A,** which avoid this problem by handling double cropping in a different way, be utilized.
- Correct all depths of precipitation and evaporation/ET to dimensions of depth/time. If depth alone is furnished, a time interval must be assumed by the reader to interpret the work.
- Clarify how the deep percolation term shown in Table 3.6 is calculated. In the current formulation, it is not intuitive that with a Png = 10.4 in/season and Es = 0.7 in/mo, that zero deep percolation would result. One might assume that modelers assume a dry, 5-foot profile at the end of the growing season, so that the Png surplus results in a change in storage. If so, this would make sense, but would need to be stated clearly.

- In section 3.12.2, it is possible that data referenced in the graphic and discussion do not represent the same type of groundwater. Shallow groundwater represented in Figure 3.16 certainly includes perched groundwater. Water table depths determined from well logs may not account for perching that can occur in agricultural fields, especially during precipitation and irrigation events. For example, for agricultural drains to flow (as has been observed periodically), water must rise above the reported depths. . Therefore, the depths to groundwater reported in the narrative should be confirmed for these circumstances, along with the conclusion that little groundwater is taken up by plants in the study area.
- The last paragraph of Section 3 should be re-written to provide greater clarity. The final two sentences are fine as they are.
- In Figure 4.2, the Y axis should probably indicate "Steady-state Soil Salinity (ECe), dS/m."
- The data and findings in Table 4.1 are important. Fits of the resulting predictions are plotted in the referenced paper (see Figure 1, below), and are helpful in visualizing the summary from Dr. Hoffman that is quoted in Section 4.3. In **Figure 2**, we have plotted predictions by the five methods against measured Lr. This provides a better idea of how the scatter of points relate to each method, and how variable the predictions by each method actually are. Part of this variation is due to the diversity of crops and conditions that are represented, but the magnitudes of error are always relative to a measured Lr. If some of the error is due to approximations inherent in steady-state modeling, then transient modeling results might produce errors of lower magnitude. This is another reason for a provision to entertain and, unless the work is flawed, accept alternative analyses performed with transient models.

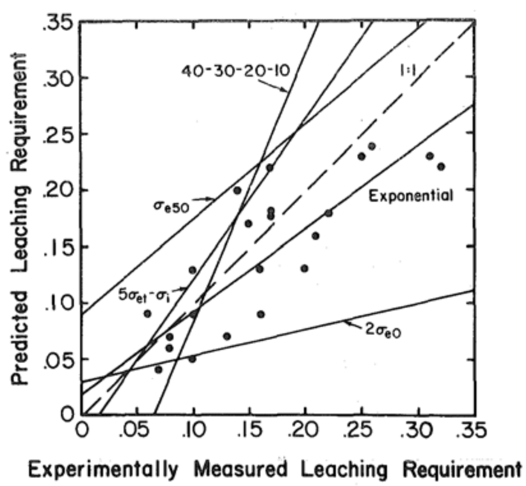

Figure 1. Linear correlations between experimental and predicted leaching requirements for several models. Data points are for the exponential model only. From Hoffman (1985).

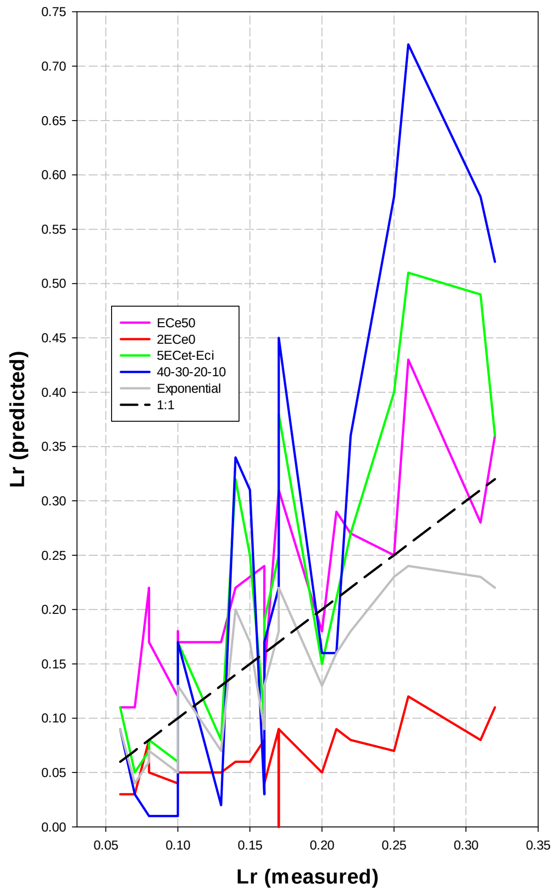

Figure 2. Plot of raw data from which correlations in Figure 1 were calculated. Note that part of the reason for the fluctuations is that a variety of crops and applied water salinity levels are being modeled, and models respond to these parameters (sometimes disproportionately) when estimating leaching fraction.

- In calculating ET for almonds, the predominance of cover crops should be assessed (as mentioned in Section 5.1.3), and the most sensitive, common approach should be modeled.
- In addition to confirming the leaching fraction for beans, the leaching fractions in almond fields should also be confirmed, so that they can be correctly used in modeling.
- If drip and microspray systems are modeled, the applicability of the model platform to these systems should be evaluated. This is because the relationships between applied water, leaching, and the salinity of water taken up by the crop can differ significantly from surface irrigated systems. Hanson and May (2011) discuss this, primarily in reference to row crops, but the same principles should apply to permanent crops. If the evaluation indicates that model modifications, or a different model, would be more appropriate to this situation, then these methodological adaptations should be implemented before modeling these systems to establish sensitivity thresholds In the Hoffman model, this might require a third approach to estimating concentration of water taken up by roots. The 40-30-20-10 and exponential models may not apply to drip and

microspray systems. However, other simplifications, such as assuming that water taken up has the same salinity concentration as the applied water, may be justifiable.

REFERENCES

Hanson, B. and D. May. 2011. Drip Irrigation Management for Row Crops. University of California Agriculture and Natural Resources Publication 8447.

Hoffman, G. J. 1985. Drainage required to manage salinity. Jour. Irrigation and Drainage Div., ASCE 111: 199-206.

Montgomery, A., F. Kixito, J. Simi, and C. Cheng. March 2010. Salt Tolerance of Crops in the Lower San Joaquin River (Merced Stanislaus to Stanislaus Merced River Reaches) – Draft Report. Central Valley Regional Water Quality Control Board

Table 2. LSJRC Comment Response Summary

Task	Task	Comment No.	Date Received	Comment Source	Deliverable	Comment	LWA Team Response
1	1	28	11/26/13	John Herrick SDWA	Complete technical comments on Draft Staff Report "Salt Tolerance of Crops in the Lower San Joaquin River Basin"	Comment 59 by SJRGA notes that leaching fractions of 0.10 id impossible. However the Hoffman Report for the SWRCB calculates local South Delta at and even below the 0.10 rate.	Agree that with surface and even sprinkler systems, this LF is not practicable. This is consistent with other comments and the most recent technical response to those comments.
1	1	29	11/26/13	John Herrick SDWA	Complete technical comments on Draft Staff Report "Salt Tolerance of Crops in the Lower San Joaquin River Basin"	Comment 63 by SJRGA. The Hoffman Report calculates leaching fractions using assumed applied water quality. If any of the data suggested here also uses an assumed water quality it should not be used.	The main point of a Hoffman (or analogous) analysis should be to estimate threshold applied water quality. Thus, applied water quality should not be an assumption. Where applied water quality is an input (such as in salt balance calculations), calculations depend heavily on this input. However, documentation of applied water quality is often lacking, compromising reliability of salt balance results. This, however, is outside the scope of this report.
1	1	30	11/26/13	John Herrick SDWA	Complete technical comments on Draft Staff Report "Salt Tolerance of Crops in the Lower San Joaquin River Basin"	Comment 92 by SJRGA. The Authority and Hoffman previously comments in the SWRCB process of the similarity of Imperial Valley to the Southern Delta. We should make sure that such comparison for this process (and different area) are not merely assertions.	A study by Corwin et al. (in press) of the influence of preferential flow (bypassing the soil matrix in cracking clay soils) on leaching efficiency and crop yield was referenced in the report. The main point was that some bypass flow can occur without depressing yields, so long as it is not more than 40% of the leaching volume. The study was conducted in the Imperial Valley, as the authors could not locate a comparable study performed in the South Delta. While the principal related to bypass flow should hold in the South Delta, the exact threshold may differ, due to differences in ET component of water balance, subsurface hydrology, etc.
1	1	31	11/26/13	John Herrick SDWA	Complete technical comments on Draft Staff Report "Salt Tolerance of Crops in the Lower San Joaquin River Basin"	Comments re models. It may be too late for general comments, but the idea of which model to use is a distraction. Each model has benefits and shortcomings. It is not a question of which model is best, it is a question of what actually is happening. The SWRCB process is very instructive. The models are based on laboratory conditions with the model being adjusted to make outputs which coincide with the lab results. However, varying conditions, including soil types, weather, ground water levels and quality result in laboratory results being only a shadow of reality. Standards should be based on test which have determined the ability of any area to actual achieve certain leaching fractions with specific crops. Everything else is speculation and results in regulatory beliefs in something that may not exist.	These are fair points to bear in mind when setting and enforcing salinity thresholds. Some ways to do this would include a) where models are to be used, select the most appropriate models and assumptions to represent field conditions, b) check model results, or better yet calibrate them, with field tests where necessary, c) if field conditions appear to differ from what was modeled and anticipated, include a checking and appeal process to ensure that thresholds are appropriate, d) check thresholds from time to time, especially where they are constraining dischargers' operations, to ensure that they are not more stringent than necessary to achieve needed crop yield protection, and e) avoid making conservative assumptions in calculating thresholds, particularly where multiple conservative assumptions may have the effect of compounding bias in calculations, driving excessively low and constraining thresholds. Of course the same is true of non-conservative assumptions, but this this problem seems to arise less frequently in a regulatory setting.
1	1	32	11/26/13	John Herrick SDWA	Complete technical comments on Draft Staff Report "Salt Tolerance of Crops in the Lower San Joaquin River Basin"	Comments 74 and 76 by SJRGA. Before altering the analysis one must consider other factors. A water year type may not be related to cropping; it depends on when during the year the criteria for the water year type is determined.	A good point that is not always considered when analyzing year-type scenarios. Cropping decisions that are particularly significant would be cases when, in response to a predicted dry year, planting of annual sensitive crops is avoided by many farmers in an area where these crops are usually planted. Another example is the effect on stand establishment of a more saline root zone after a dry winter, when little leaching has occurred.
1	1	33	11/26/2013	John Herrick SDWA	Complete technical comments on Draft Staff Report "Salt Tolerance of Crops in the Lower San Joaquin River Basin"	Comment 61 by SJRGA. Effective rainfall is difficult to use. A substantial amount of rainfall could actually achieve little if any leaching depending on the duration of the rainfall events. The use of effective rainfall takes an average impact and applies it to all circumstances which may yield some sort of useable data, but likely results in something that is only periodically correct.	Effective rainfall calculations are subject to substantial uncertainty, and depend on balancing storm, soil permeability, and antecedent moisture characteristics. This uncertainty should be borne in mind, and where assumptions can be affordably refined to reflect actual field conditions, this should be pursued.

Table 3. Technically-related Response to Comments: *Salt Tolerance of Crops in the Lower San Joaquin River* (Draft Report March 2010)						
Comments received from United States Bureau of Reclamation, City of Tracy, Central Valley Clean Water Association, Ecologic Engineering, San Joaquin River Group Authority						
Comment Category	**Comment #**	**Author**	**Comment**	**Comment Responses From Report Authors**	**Additional Comments Responses from LWA Team (November 2013)**	**Qualitative Analysis and Recommendation (April 2014)**
Models	18	Central Valley Clean Water Association	"Therefore, the final report should clearly separate the two major recommendations: the first being the recommended model for use in the State Water Board's current revaluation of salinity objectives, and the second being the additional study and investigation required to address uncertainty of model inputs and the validity of alternate models to determine the most appropriate models for evaluating salinity objectives."	Refer to CV-SALTS	Separate references regarding models, inputs, and assumptions are provided to outline these sorts of questions. Where possible, relevant literature has been quoted and cited. Technical performance is the focus of this summary, and should help CV-SALTS to decide among technical options in these regards. It should be recognized that technical information cannot finally resolve policy-based questions and choices. For example, after the levels of conservatism and risk related to alternative technical approaches has been clearly defined, the question of which level of conservatism and certainty is needed or desirable must be answered before a preferred approach can be selected.	Modelers should review the literature provided as part of Subtask 1.1, and included in the comments workbook. CV-SALTS has the opportunity to present and discuss technical questions with experts attending the Salinity Forum 2014 (June 16-18, 2014 in Riverside, CA, http://salinityforum2014.ucr.edu/). This would require some pre-conference coordination. The technical questions discussed in these recommendations should be reviewed there.
	20	Central Valley Clean Water Association	"CVCWA is concerned with the levels of conservatism that may be embodied in the final model. It is entirely appropriate to review the available information to develop the model inputs and select appropriately conservative values."	Refer to CV-SALTS	See response to comment 18.	Modelers should avoid compounding of conservative assumptions in developing the model, and instead use recent literature and available expertise to guide assumptions, with the goal of providing the most accurate estimate of thresholds. To do otherwise would lead to thresholds that are overly conservative and which do not serve as a proper indicator of unacceptable impact. See also the response to Comment 18.
	21	Central Valley Clean Water Association	"Finally, the use of a steady state model over a transient model will result in a conservative salinity objective for equivalent inputs. CVCWA recommends adding a list of the conservative assumptions made in selecting model parameters, so there will be confidence that the modeled result will be protective of the irrigation use with out being needlessly stringent."	Ultimate model selection to develop a new WQO is outside the scope of this Report but it's an issue that the CV-SALTS committee can evaluate further	See response to comment 18. It is recognized that transient and steady state model platforms are, and will likely remain, in a state of flux. It is also recognized that, even with sound transient models, input data to run them are more costly to develop and may not be readily available. Nevertheless, if alternate analyses with transient models are presented, their results should be carefully considered, because many of the processes mediating the impact of salinity on plants are transient, so that properly applied transient models better predict actual conditions. Steady-state analyses by definition ignore or greatly simplify the soil-water environment experienced by actual plants. Unless they can be shown to be invalid for sound technical reasons, the results of a properly conducted transient analysis should take precedence over those of a steady-state model.	Provide a concise summary of assumptions employed in any update of Hoffman modeling.
	24	Central Valley Clean Water Association	"The transient modeling approach should be utilized in the evaluation of the salinity objective. Information listed in the Hoffman Report and presented at the August 13, 2009 workshop point toward the ability of transient models to accurately replicate irrigation practices and crop responses to more robustly calculate the proper salinity objective. The steady state models calculate more conservative salinity requirements due to the fact that they cannot account for the natural variations that occur in the growing cycle. In the event the State Water Board determines the use of a steady state model is appropriate for the current salinity objective evaluation, the specific model should be carefully selected."	The Draft Report was only intended to present modeling results from a steady-state model. This is an issue that CV-SALTS may pursue further.	See response to comment 18.	See recommendations 18 and 21.
	26	Central Valley Clean Water Association	"...it seems appropriate to clearly define why the recommended model is selected and why other models were not selected."	This report was only intended to present results from a steady state model, not to make a final decision about what model should be used to develop a new WQO	See response to comment 18.	

Table 3. Technically-related Response to Comments: *Salt Tolerance of Crops in the Lower San Joaquin River* (Draft Report March 2010)

Comments received from United States Bureau of Reclamation, City of Tracy, Central Valley Clean Water Association, Ecologic Engineering, San Joaquin River Group Authority

Comment Category	Comment #	Author	Comment	Comment Responses From Report Authors	Additional Comments Responses from LWA Team (November 2013)	Qualitative Analysis and Recommendation (April 2014)
Leaching Fractions	9	United States Bureau of Reclamation	"Using [the data in Section 3.13.2] to calculate leaching fraction and to draw conclusions about irrigation management is a premature. Given the uncertainty in the leaching factor assumption, and the significance of this assumption in determining water quality objectives, CVSC should consider funding studies to reduce this uncertainty."	The additional studies suggested here would have to approved/coordinated with CV-SALTS	See response to comment 18. Leaching fractions are an important factor in determining actual sensitivity since it mediates the relationship between applied water and soil salinities. Several of the issues around this parameter include: 1) whether or not leaching by precipitation is considered; 2) how to handle the consideration that leaching can be modified by irrigation management to avoid or reduce yield impacts of salinity on sensitive crops; 3) salinity of water taken up by the crop at a given leaching fraction can be calculated, but the results depend heavily on the assumed distribution of water uptake; the 40-30-20-10 distribution that is often employed is now thought to significantly exaggerate the level of salinity to which the crop is actually exposed; 4) irrigation systems influence leaching relationships; for example, drip irrigated soils contain zones where roots can tap water whose salinity is often approximately that of the applied water.	A range of leaching fractions was previously analyzed, and this should again be the case in new analyses. The reason for the range is to capture uncertainty about this important parameter, to demonstrate the level of sensitivity of results to LF, and to provide a set of results that inform policy more fully. It may be that the LF selected in setting water quality standards will be determined by processes such as CV-SALTS, and may yet change after modeling is completed. To the extent practicable, leaching fractions should be informed by field observations of actual practices. The model should assume fractions that are representative of the most conservative (i.e. lowest LF) condition that is widely represented (on >5% of the total irrigable land, or that is the predominant method for a common, sensitive crop). Modelers should avoid overestimates of irrigation efficiencies or potential infiltration of water. The best means of determining representative leaching fractions, and of determining how best to represent drip and microspray, may be to consult with irrigation specialists, such as those with UCCE.
	59	San Joaquin River Group Authority	A portion of the modeling is done with unrealistic assumptions regarding leaching. The study uses leaching fractions of 0.10 or less for modeling production of almonds and alfalfa. A leaching fraction of 0.10 or less is impossible to achieve without very sophisticated irrigation technology that is presently not available in the study area.	Comment Noted. A given party could use leaching fractions that are applicable for their site specific conditions using the current model framework. However, choice of leaching fractions is a policy call that needs to be decided within the CV-SALTS initiative for further Regional Board consideration (See Section 6.2.1).	Comment and response are sound. We would add that when it comes to practices, it would be helpful to know what irrigators do, and what they could/would do, since irrigation practices are not static. See response to comments 9 and 18.	Realistic LF should be investigated with irrigators and/or irrigation specialists (see 9), and used in the modeling effort. Any LF assumption should be bracketed, meaning the analysis should be re-run with slightly higher and lower values to illustrate sensitivity. Emphasize that LF varies year to year, field-to-field, and within fields, further emphasizing the utility of the bracketed analyses. Unrealistically low or high LF may provide quantitative results that misinform policy. See also related LF comments in this set, and comments 28 and 30 by John Herrick.
Leaching Fractions	63	San Joaquin River Group Authority	**Actual leaching fractions may be higher than assumed:** The Study Report needs to take a closer look at actual leaching fractions (LF) in Western Stanislaus County. The tile drainage data presented in the Study Report shows that it may be 25% or higher and this is consistent with findings in the South Delta. Unfortunately the data upon which this conclusion is based is not a valid data set and the SJRGA is recommending the use of additional data that is in the Regional Board files. This new data will likely show that these high leaching fractions do exist as a result of present irrigation practices.	Comment noted. Staff appreciates efforts taken by SJRGA to share additional data sources for the tile drainage analysis. Additional data provided by the SJRGA was analyzed independently and compared to data from the Chilcott et al 1988 study. It should also be noted that not all data provided by the SJRGA was used, only drains within the LSJR Use Area were considered. Considering irrigation water salinity of 0.59 ds/m, average leaching fractions from the SJRGA data set was 0.22, the Chilcott study was 0.29 and when both data sets were pooled together the leaching fraction was 0.24. This additional analysis is attached as Attachment 1 to the Draft Report.(Could be pursued further by CV-SALTS)	Comment sound. No comment on response, as the underlying data are currently not available to our project team.	See recommendation 59.

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	66	San Joaquin River Group Authority	Water management practices for dry bean production will not change as water conservation measures are introduced: One of the factors of that will need to consider in reviewing the water quality objectives for Lower San Joaquin River is the State mandate for increased water conservation by both urban and agricultural users. Mandated water conservation needs will not likely change the water management practices for dry bean production. The present production returns on dry beans will not allow the level of investment needed for improved irrigation practices. As dry beans are planted for various reasons, including soil fertility improvement, it is unlikely that farmers will switch to a higher income cropping pattern. It is unlikely that water conservation will significantly change the leaching fraction. The primary reason is the continued need to pre-irrigate and the continued use of furrow irrigation. In water conservation efforts, the first and easiest water losses to control are those of surface water runoff. As these are a big component of the irrigation practices in Western Stanislaus County, they are likely to be the first to be controlled. This will leave deep percolation in the same range as it is now, in the range of 20-25%. This is the leaching fraction that should be assumed in future modeling when water conservation is assumed to occur.	Refer to CV-SALTS	The best manner in which to represent actual irrigation practices will be to review specific questions such as these with specialists, as suggested under 9. A minor point that could be added is that, in certain circumstances (such as when beans are rotated with crops providing higher returns), it is possible that the higher efficiency irrigation system installed for the higher-return crop would also be used to irrigate the beans. In this instance, the leaching fraction might be reduced from that observed under furrow irrigation. However, it has been shown that the quantity of leaching should be interpreted differently when (for example) drip irrigation is employed. The wetted zone in which crops take up water can sometimes be maintained at about the same pore water salinity as that if the applied water. As a result, an equivalent level of salinity is less likely to reduce the yield of a sensitive crop. Thus, even where conversions in irrigation method are implemented, it would be incorrect to assume that this would render the cropping system more sensitive to salinity in applied water.	The 20-25% leaching fraction described for Beans should be investigated (as it was in the previous report). The same process can be followed for other crops, such as Almonds, which now look as if they may be the most sensitive crop in the LSJR study area, instead of Beans. See comments 9 and 59.
Leaching Fractions	92	San Joaquin River Group Authority	Page 96, Alfalfa Write-up. The analysis shows that at no time would a yield loss occur at .15 LF even under the most extreme conditions and EC levels near 2.0 dS/m. This is consistent with the production practices in the Imperial Valley of California where similar conditions exist and no yield losses occur. There is extensive discussion however about high evaporative demand and not being able to get enough water into the soil to meet both ET and LF. This does occur during short periods in the hottest summer periods but stored soil water normally meets all crop demands during this period. The impact of salinity is not short-term; it is a buildup of salts over a season or several seasons. This does not occur in the San Joaquin Valley due to soil conditions and irrigation practices. The alternative LFs of .07 and .10 are unreasonable and unachievable with present technology and irrigation practices in the San Joaquin Valley. LF is likely to be closer to 0.20 and should have been included in the modeling effort results presented in Table 6.1.	The current model framework allows for choice of different leaching fractions based on site specific conditions.	Commenter observations are consistent with our own. Agree with response that the current model framework accommodates alternative inputs. However, previous comments and responses regarding conservatism inherent in assumptions and models should also be taken into account before additional resources are invested in model runs.	See recommendation 59.
	92b	San Joaquin River Group Authority	We recommend that the .20 LF model results be presented in Chapter 6 as a large portion of the alfalfa is grown on or near the high water table lands in the LSJR area. Table 3.10 shows that these lands are well drained and likely to have LF closer to .20 than to .07.	The current model framework allows for choice of different leaching fractions based on site-specific conditions	See response to comment 92.	See recommendation 59.
Planting and Harvesting Dates	57	San Joaquin River Group Authority	Dry beans are not planted before the first weeks of May yet they are assumed to be planted as early as April 1st.	Page 86, Table 5.3: The Report acknowledges that there are three possible planting dates with corresponding crop coefficients for the San Joaquin Valley. One of the example planting dates is May 1st as shown in Table 5.2. In addition, model output scenarios (exponential distribution) associated with each of the three planting dates at three varying leaching fractions are given in Table 5.3. Moving forward, CV-SALTS could choose any of the suggested dates as they see fit.	See response to comment 92.	The bracketing approach previously employed for uncertain or variable parameters such as planting date and leaching fraction is sound, and should again be employed to determine sensitivity to uncertain parameters.

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	89	San Joaquin River Group Authority	Page 74, Third Paragraph. This assumes that the first cutting of alfalfa occurs by March 13th. This needs to be confirmed with the growers in the area as this seems very early for this growing area. An early date like this may be applicable to the Southern San Joaquin Valley, but not here. It is unlikely also that any irrigations would take place prior to the middle of March as the ground is still wet from the winter and putting on additional irrigation water at this time would delay the soil warming up from the winter period and this is most important to an alfalfa grower.	Comment Noted. Staff endeavored to follow a similar approach to Dr. Hoffman based on dates given by Goldhammer and Snyder, 1989. As noted by the commenter, additional information from alfalfa growers could be helpful and can be pursued should CV-SALTS consider it necessary.	See response to comment 92. CV-SALTS current policy is to provide target crop protection in 95% of all years. This implies that climatic regimes analyzed would include statistical droughts, during which the influence of salinity might be more severe. One of the ways that this would play out would be the potential for earlier planting, and earlier irrigation during drought years. Another vehicle for informing model assumptions may be scheduling of water deliveries to fields growing sensitive crops. In this manner, data for numerous fields in a given district could be collected pretty efficiently. UC Cooperative Extension personnel (in addition to Goldhammer and Snyder) might also provide useful input to ensure that the timing of events is properly represented.	At present, it is unclear to all exactly how to represent drought in a Hoffman analysis and in interpretations of analysis used to set standards. This needs to be discussed with resource persons within CV-SALTS and the technical community. UC Cooperative Extension representatives familiar with the sensitive crop(s) being modeled are excellent resources and should be consulted to the fullest extent necessary and needed. A workshop or set of focused interviews to vet parameters for analysis should be considered.
Planting and Harvesting Dates	90	San Joaquin River Group Authority	Page 74, Fourth Paragraph. The dates for almond production need to be confirmed with growers on the Westside of the San Joaquin River. An almond tree begins to shut down with the onset of short days and colder night time temperatures. The largest change in night time lows occurs in October and it could be assumed that little crop growth or water use would occur after October 15th. It is also unlikely that an almond grower would irrigate his trees prior to the first two weeks of April. Because of winter rains and cold soil temperatures, irrigating prior to this time may cause root oxygen stress that could cause fruit drop or fruit delay due to the cold soil temperatures. It takes a wet soil much longer to warm up than one that is dryer. While you can define the growing season (and it does vary from year-to-year), you need to focus the steady-state modeling on the irrigation season which will normally not start until April 1st and will likely end by October 15th even though growth will be occurring outside that period. The irrigation period is when San Joaquin River water may be used.	Comment Noted. Staff endeavored to follow a similar approach to Dr. Hoffman based on dates given by Goldhammer and Snyder, 1989. As noted by the commenter, additional information from almond growers could be helpful and can be pursued should CV-SALTS consider it necessary. Staff notes that modeling of alfalfa presents a bigger challenge than bean or almond due to the numerous harvest cycles. Consultant with Dr. Hoffman may be necessary should CV-SALTS want to pursue this further.	See response to comment 89.	See recommendation 89.
Soil Water Uptake Patterns	25	Central Valley Clean Water Association	"Because of the demonstrated large variability in ability to replicate validation tests (depending on conditions, either greatly overestimating or greatly underestimating salinity requirements), the 40-30-20-10 model used in the Ayres and Westcott United Nations work does not appear as well suited to determine the salinity objectives in the southern Delta as the exponential model developed by Hoffman and van Genuchten, which replicated the validation data reasonably well. All parameters for the recommended model should be tabularized in the report, including the recommended values for the parameters specific for the critical crops in the southern Delta."	In Section 5.2, the results from both uptake models are presented in the Report. An additional tabular presentation of results from the exponential model is presented in Table 6.1 (Pg. 122)	The comment appears to align well with literature on the topic. See response to comment 9. The full display of work and results in the report is helpful to reviewers. For a good combination of concision and thorough documentation, it is sometimes helpful to write the body of the report as clearly and visually as practicable, and to reference appendices in which data are presented more comprehensively.	Unless good reasons to do otherwise are documented, the exponential root uptake model should be primarily used in the interpretation. There is no harm in analyzing alternative uptake patterns; however inputs and results should be documented in a thorough and reviewable manner, so that others can reproduce the work if necessary. Please see other comments relative to addition of an uptake pattern that accurately reflects drip and microspray. These results should be used in interpretations for crops predominantly irrigated in this manner.
	65	San Joaquin River Group Authority	The SJRGA supports the development of a transient model for evaluating the crop tolerance of crops in Western Stanislaus County but in the absence of a valid transient model, the Study Report should recommend the use of the exponential steady state model over the 40-30-20-10 steady-state model. The 40-30-20-10 model does not represent the present state of knowledge regarding crop water uptake and would only compound the Study Report shortcomings since present crop tolerance data used in the model is over 50 years old.	The study Report recommends use of the exponential model (See Section 6.2.1)	Comment and response are sound. See response to comment 9. Transient models exist and have been reviewed in the literature (see Letey et al., 2011). These would appear to be options to be explored.	See recommendation 25.
Temporal Scale	74	San Joaquin River Group Authority	Page 5, Final Paragraph describes a figure on water quality for a series of years. It would be more helpful if this analysis was conducted by water year types to see whether the water quality differences shown are related to the water year type. This would require a larger data set than used here.	Page 5, Final Paragraph: Comment Noted. Staff endeavored to follow a similar approach to Dr. Hoffman which was by calendar year. As noted by the commenter, consideration of water year could be helpful and can be pursued should CV-SALTS consider it necessary.	Current CV-SALTS policy post-dates comments and responses, and suggests that, in the same way that the most sensitive crop in a locale might drive thresholds, so might dry years. See response to comment 89.	Run the analysis for a 95th percentile dry year, calculated from the longest available precipitation record that is representative of the locale. Threshold crop yield protection should be provided during that year. Such protection will then be achieved during wetter years as well.

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	76	San Joaquin River Group Authority (cont.)	Page 8. It would be helpful if a similar presentation could be done based on water year types as the cropping pattern likely also varies by water year type.	Comment Noted. Staff endeavored to follow a similar approach to Dr. Hoffman which was by calendar year. As noted by the commenter, consideration of water year could be helpful and can be pursued should CV-SALTS consider it necessary.	See response to comment 74.	Narrative should discuss the basis of the cropping pattern used in the analysis, and the extent to which sensitive crops driving the analysis would or would not be likely to differ in a dry year. If it is concluded that a more sensitive crop would drive the analysis during a wetter year, then a supplemental analysis of this year type, with the more sensitive crop, should be developed. See also comment 32 by John Herrick.
Spatial Scale	78	San Joaquin River Group Authority	Page 17, Third Paragraph. There is no reason to spend additional time on developing the information for San Joaquin County as it makes up less than 2% of the total area.	Page 17, Third Paragraph: This Report addresses only the protection of one beneficial use agriculture (irrigation) of the many listed in the Basin Plan for the LSJR. Protection of each of the beneficial uses must be evaluated as part of the development of site specific water quality objectives. Thus irrespective of it's small size, adequate information needs to be developed for San Joaquin County not to inadvertently overlook any vital issue.	DWR crop cover data has now been joined into a Central-Valley-wide spatial layer, at least for the most contemporary surveys. Thus, county lines are immaterial when employing these data. On the narrower point of representativity, note that CV-SALTS' policy now holds that crops must occupy >5% of a crop sensitivity zone to be considered "major" and therefore to warrant automatic consideration in such an analysis. This policy post-dates the study in question. The 2% of the area represented by a minority county could conceptually tip the balance for a key crop. The GIS 5.2 report suggests that the location of sensitive major crops is important, since it is discharges flowing into irrigation supply recharge areas that are of interest. Thus, even if the 2% tips no acreage balance, the location of sensitive crops within this small area could be significant. This report and its findings are still not final.	Please reference the "Cropping Patterns" memo contained in appendix. It provides guidance from the LSJR Committee on determination of representative, common, sensitive crop/irrigation system combinations.
Cropping Patterns	79	San Joaquin River Group Authority	Page 18, Final Paragraph. The discussion shows an 8% decline in moderately sensitive crops and an 8% increase in moderately tolerant crops in 2000. In looking at the data in the table, you need to be careful in making too many interpretations from only two surveys. In 2000, the tomato processing plants were shifting to overseas and there was a serious reduction in tomato production. This may account for the changes in cropping patterns when only looking at two distinct years. The tomato production has since recovered in California. It may have been more helpful to look at the crop production figures compiled by the individual water districts as these are done annually. To keep the amount of effort in perspective, the SJRGA recommends this be done for the three crops analyzed in this report.	Page 18, Final Paragraph: Comment Noted. Staff endeavored to follow a similar approach to Dr. Hoffman. However, as noted by the commenter, should CV-SALTS consider it necessary, further data could be solicited from individual water districts.	Crop data are published by water districts on an annual basis. They are helpful for examining inter-annual trends. DWR data are valuable because they show the location of crops, which these reports do not. However, DWR crop mapping is completed on a rotational basis, approximately each 7 years in each county. There is a discussion of the use of crop data for these analyses in the CV-SALTS GIS Task 5.2 report. One of the points made, after some discussion with producers, is that contemporary (the most recent) crop mapping is the most indicative of probable future land cover. This is because farmers integrate more variables than we can model in planting decisions, and are very up-to-date. Also, changes in cropping patterns at a macro (not field) level are more directional than cyclic, because this is the manner in which market, infrastructure, and environmental changes occur. Nevertheless, future changes need to be monitored and accommodated. It is just that they cannot be reliably predicted by looking at past fluctuations. This discussion too postdates the report and comments. It is also possible to map more current crop distributions by employing publicly available data, and an effort like this is being considered for inclusion in the CV-SALTS ICM Phase 2 work plan.	It may be possible to select a single, most sensitive, common crop-irrigation system combination. However, if other sensitive crops are also analyzed, then these results could be employed in the event that there is growth or resurgence in acreage of those crops. Policy recommendation: There should be a provision to periodically review crop acreage tables to ensure that thresholds remain protective of common crop/irrigation combinations.
	80	San Joaquin River Group Authority	Page 26, First Full Paragraph. This same comment applies here. This decision may be based on economics, water supply availability and a variety of other factors none of which may be related to water quality. This is the short comings of using a survey that was only conducted once every ten years.	Comment Noted. Staff endeavored to follow a similar approach to Dr. Hoffman. However, as noted by the commenter, should CV-SALTS consider it necessary, further data could be solicited from individual water districts.	See response to comment 79.	
	81	San Joaquin River Group Authority	Page 28, First Full Paragraph and Figure 3.5b on page 31. The reduction in dry beans could be related to tomato prices, water availability or a number of factors. It is doubtful that it was related to water quality as bean production like many field crops in the Westside is cyclic and primarily based on economics, not water quality. Again this is the difficulty of using two surveys which were often conducted ten years	Refer to CV-SALTS	See response to comment 79. Cyclic changes such as those mentioned may best be captured by examining Ag Commissioner or water district crop reports. They are not spatially presented, but do show acreage trends for a region.	

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			apart.			
Effective Rainfall	61	San Joaquin River Group Authority	Winter Rainfall assumptions used in crop models are extremely conservative: Effective rainfall is assumed to be part of crop ET while in reality it also plays a major role in salinity control in any Mediterranean climate. This role of effective rainfall during the winter irrigation season has been left out of the report. This analysis needs to be conducted and the impact of winter rains on leaching and salt control needs to be fully evaluated. The lack of this analysis further validates the need for development of a transient model	In the model, effective rainfall is not assumed to be part of crop ET. Effective rainfall is a function of growing season precipitation, non-growing season precipitation less the bare soil evaporation. Crop ET is a product of the crop coefficient and reference evaporation. As illustrated in Table 5.1, the model computes (for both exponential and 40-30-20-10) "I2" which is the amount of irrigation required to maintain a given leaching fraction, considered in this computation is the crop ET and effective precipitation. Hence, the role of effective rainfall during the winter irrigation season was not left out of this Report. (can be pursued further by CV-SALTS)	It may be useful to clarify parameters that influence the amount of leaching accomplished by winter rainfall. Among these parameters are percentage of precipitation that infiltrates, and a clear statement about the fate of infiltrating water NOT partitioned to satisfy ET, and how this is presumed to alter soil salinity.	The methodology description in the response from the authors suggests that if irrigation, effective precipitation, ET, and bare-soil evaporation inputs to the model represent reality, the modeled soil salinity should also be reasonable. Thus, these inputs should be checked.
Factors Influencing Effective Rainfall	55	Ecologic Engineering	"Page 79 Section 5.1.4 -- Surface evaporation would be reduced when soil surface is dry and there is no precipitation (i.e. August, September, and potentially October), which would increase Peff and decrease the resultant soil salinity. Bypass flow and surface (or sub surface) run off would reduce Peff and increase soil salinity."	Comment Noted. The scenarios mentioned by the commenter are feasible but may require doing some modifications to the steady state model to investigate their occurrence. Should CV-SALTS want to investigate this further, it's advisable to contact Dr. Glenn Hoffman before any Steady State Model modifications are performed.	Although adjustments could be made to a steady-state model to reflect these exceptional conditions, transient conditions such as those cited are probably best captured in a transient model.	Effective precipitation estimates are uncertain, and should thus be part of the bracketed analysis.
	60	San Joaquin River Group Authority	Estimate of effective rainfall using soil evaporation rates that do not reflect reality during the winter period.	Page 48, Figure 3.11: Comment Noted: Soil evaporation is function of the crop coefficient and estimated bare soil evaporation and is a component of effective precipitation. CV-SALTS may modify soil evaporation rates to reflect reality during the winter period. However this would need modifications to the current model settings. Staff advises to contact Dr. Hoffman.	Methods for estimating effective rainfall probably warrant review relative to literature, given their importance to these types of calculations. Dr. Hoffman and other experts like him are good resources.	Review and refine soil evaporation estimates with expert assistance.
Pre-irrigation	58	San Joaquin River Group Authority	Need to verify and consider that present-day cultural practices include pre-irrigations, which minimize or eliminate any potential salinity impacts during germination and seedling emergence as well as greatly reduce salinity control throughout the growing season.	Comment Noted: This would need potential adjustments to current model settings. E.g. for the "I2" term: amount of irrigation required to maintain the leaching fraction (also accounts for precipitation: See Table 5.2), consideration has to be made to existing soil moisture conditions resulting from pre-irrigation. Staff advises further discussion with Dr. Hoffman before making model modifications.	Timed flushing of the upper root zone before establishment may not be fully captured in steady-state models. Thus, transient approaches could be considered among the options to resolve this issue, where it is considered critical, and where adjustments to steady state models do not adequately reflect conditions.	To the extent practicable, incorporate transient effects of practices such as pre-irrigation into steady-state models (for example by reflecting sensitive growth stages in thresholds).
Groundwater	50	Ecologic Engineering	"Page 59 Section 3.12.2 -- Well level data from the DWR is collected from wells with several purposes, and generally the wells are used for production. A production well will likely be screened at deeper interval than that associated with shallow groundwater. Therefore, data from these wells may not reflect the depth to shallow groundwater."	Page 59 Section 3.12.2: Groundwater basins throughout Northern California are monitored to determine water quality and related factors affecting beneficial uses. The DWR wells referenced in this study are not production wells. The DWR data source clearly states that the wells are for monitoring shallow groundwater. DWR conducts comprehensive assessments on a 3 to 4 year rotation to determine general chemical characteristics, including mineral, nutrient, heavy metal concentrations, organic and bacterial concentrations. Most of the sampled wells are either irrigation, stock, or domestic wells.	In work that post-dates this report and previous comments, CV-SALTS have compiled a relatively thorough database of groundwater data, and some water quality coalitions have done the same for their locales. These data can be screened to focus on wells that best represent shallow groundwater, but details regarding screened intervals may yet be lacking.	
	51	Ecologic Engineering (cont.)	"Page 64 Section 3.13.2 -- There is no discussion with respect to depth of groundwater (Figure 3-17) nor the design or depth of the drains."	Page 64 Section 3.13.2: There is no discussion with respect to depth of groundwater because the study that this Report relied upon (Chilcott et al, 1988) specifically noted that data on shallow groundwater was not reported since the focus of the study was to monitor only actively discharging subsurface tile drainage systems. The Chilcott study further notes that previous studies (Deverel et al., 1984) have shown that shallow groundwater quality is closely associated with the differing soils and topographic position in the basin, however, the data collected in their study was not analyzed for this association. Staff's review of the Chilcott study did not reveal details on drain designs or depth.	Tile and open drain systems and operation, and resulting soil drainage conditions, influence water flow to layers below the root zone, and therefore the ability to effectively remove salts. Further, if saline shallow groundwater exists at shallow depth, then it can contribute salt.	Where saline shallow groundwater or drainage condition can be shown to influence exposure of plants to salinity in the predominant condition in which a sensitive crop is irrigated, this should be reflected in modeling.

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Comment Category	**Comment #**	**Author**	**Comment**	**Comment Responses From Report Authors**	**Additional Comments Responses from LWA Team (November 2013)**	**Qualitative Analysis and Recommendation (April 2014)**
Soils	34	Ecologic Engineering	"Pages 13 - 16 Table 2.1. -- Moreover, for purposes relevant to soil salinity, limiting layer (slowest) saturated hydraulic conductivity should be reported."	Pages 13 - 16 Table 2.1: Comment Noted. However due to limited data range, SSURGO data base dos not provide data on limiting layer. There may be additional sources of data, but they may be difficult to integrate with the SSURGO data unless they are geo-referenced.	The following soil surveys cover most of the area and appear to be available as downloads from SSURGO: Madera Area, Fresno County, Merced County, Merced Area, Stanislaus County, Western and Eastern parts. Minor areas are in San Joaquin and Stanislaus Northern Part. Normally profile features such as limiting layers, although not called out explicitly, can be extracted with Soil Data Viewer, but the queries may be more complex. Once extracted, they can be mapped and used in analyses.	
	36	Ecologic Engineering	"Page 34 Section 3.3.2 -- The depiction of saline and/or sodic soils appears to be a relic of the Soil Survey's used. Saline and sodic soils all occur in the Eastern Stanislaus Area Soil Survey, which was mapped prior to being published in 1964, and incorporated salinity classes into map units. The 1992 San Joaquin Soil Survey and 2002 Stanislaus County, Western Part Soil Survey did not incorporate salinity classes into the map units. The lack of salinity classes in the later survey's is largely attributable to high variability in the salinity of a soil series associated with irrigation water source and management (e.g. Fresno slightly saline vs. Fresno strongly saline, same soil different salinity) and to advances in surface water supply and engineered drainage in the area since the 1960's. Soil chemical data collected and provided with the later soil surveys should be reviewed to determine if there are potentially saline and/or sodic soils in this greater portion of the irrigation use area."	Page 34 Section 3.3.2: Soil chemical data collected and provided with the later soil surveys was reviewed to determine if there are potentially saline and/or sodic soils in the greater portion of the irrigation use area as suggested by the commenter. However, since the information provided by NRCS is not geo-referenced, it's challenging to translate any specific information to the LSJR Irrigation Use Area.	Soil survey data is tied to mapping units, which are normally in shapefiles. Therefore, it is possible to associate soil properties with locations, and in this sense (and others) soil survey data is georeferenced. However, these associations are determined on typical mapping units at particular locations, and then extrapolated to all areas that fall within that mapping unit, whether actual measurements were made there or not. Salinity is indeed strongly influenced by water management, and thus can go different directions in the same mapping unit, depending on whether and how it is irrigated and drained. Rather than using soil salinity data as a single parameter taken at face value, it may be more helpful to look at it in conjunction with other indicators of how salinity might have changed. Some of these are crops grown, salinity of water supply, presence or absence of subsurface drainage facilities, and type of irrigation system. Factors like limiting layers and drainage class can also be helpful. There is a more basic question of how saline soils affect interpretation of AGR narrative standards. If a soil is already saline, is it determined that fresh water is needed to reclaim it, or is it assumed that since soil reclamation has not been maintained, the land is going to be saline no matter the irrigation water quality? Both cases probably exist, and might be distinguished by examining the factors just listed. More broadly, saline soils were mapped along a sliver of the eastern margin of the study area, and therefore do not seem to play much into the analysis. Due to their small acreage, trends associated with their use might not provide much insight.	If there is uncertainty related to characterization of dynamic soil properties, such as salinity, begin with an assumption that systems reflect contemporary management. If there is doubt about this, then perform focused field studies to learn more about the parameter, and use those results to guide model assumptions. Address remaining uncertainty/variability by bracketing analyses.
	41	Ecologic Engineering	"Page 40 Section 3.4.2 -- Review of the coefficient of linear extensibility (COLE) for soils mapped in 1964 would allow for evaluation of shrink-swell potential."	Page 40 Section 3.4.2: Staff's initial assessment found that it was more appropriate to use the shrink-swell rationale provided by NRCS for Merced (1990), San Joaquin (1992) and Stanislaus (1992 and 2002). Staff found the Eastern Stanislaus Soil Survey for 1964 and review of this survey did not yield any information related to the COLE index. In addition, Staff's ability to relate any information to the LSJR Irrigation Use Area would be limited since this data is not geo-referenced. However, this is an issue that CV-SALTS can take for further investigation to verify shrink-swell soils in the Irrigation Use Area.	Normally there are data in a soil survey such as those cited regarding clays of this type.	
Soils	43	Ecologic Engineering (cont.)	"Page 40 Section 3.4.2 -- Shrink-swell and bypass flow are a major process affecting water movement in the use area and needs to be addressed with respect to irrigation and soil salinity management. There is potential that high shrink-swell potential soils may require increased leaching fractions when compared to low shrink-swell soils to allow for leaching salts from the entire root zone. However, bypass flow in soil cracks may actually be beneficial to controlling soil salinity (see Crescimanno and Garofalo, 2006. Soil Science Society of America Journal 70: 1774-1787)."	Page 40 Section 3.4.2: Comment Noted. Addressing high shrink-swell soils through increasing leaching fractions for the LSJR Irrigation Use Area when compared to low shrink-swell soils to allow for leaching of salts from the entire root zone is a major decision that CV-SALTS could address as is necessary.	Where it can be demonstrated that higher leaching fractions are in fact required to maintain a given level of root zone soil salinity, this should be taken into account.	

Table 3. Technically-related Response to Comments: *Salt Tolerance of Crops in the Lower San Joaquin River* (Draft Report March 2010)						
Comments received from United States Bureau of Reclamation, City of Tracy, Central Valley Clean Water Association, Ecologic Engineering, San Joaquin River Group Authority						
Comment Category	**Comment #**	**Author**	**Comment**	**Comment Responses From Report Authors**	**Additional Comments Responses from LWA Team (November 2013)**	**Qualitative Analysis and Recommendation (April 2014)**
	45		"Page 46 Section 3.5.2 -- Based on widespread shrink swell potential in the use area, there is great potential that initial rainy season storms will be largely ineffective in providing moisture to the root zone. Additionally, high clay content and low hydraulic conductivities of the soils may increase surface runoff and reduce effective precipitation. Further, subsurface drains may remove precipitation that would otherwise be stored in the root zone. Figure 3.11 shows at least five years where Png is below the Es, and several years have Png below 10 inches, the level necessary to reduce irrigation requirement by 4 inches."	Page 46 Section 3.5.2: We don't have actual field soil moisture data available. Such data would be helpful in confirming the scenarios noted by the commenter. The scenarios given by the commenter are potentially feasible but site specific data would have to be collected to confirm them. CV-SALTS could follow up on these issues in case field studies are conducted in the LSJR Irrigation Use Area.	The importance of specific soil hydrologic scenarios can also be assessed by consulting with knowledgeable resource persons who are familiar with irrigation of heavy textured soils in this area. The types of processes discussed may be better handled in a transient model; however they could also be addressed in the steady state platform through adjustments to affected parameters.	Consult with resource persons (e.g., UC Cooperative Extension specialists) regarding the prevalence and nature of soil hydrologic processes associated with heavy textured soils. If necessary, alter Hoffman Model parameters to better reflect actual soil hydrology as it is affected by these processes.
Follow-up Studies	18	Central Valley Clean Water Association	"Therefore, the final report should clearly separate the two major recommendations: the first being the recommended model for use in the State Water Board's current revaluation of salinity objectives, and the second being the additional study and investigation required to address uncertainty of model inputs and the validity of alternate models to determine the most appropriate models for evaluating salinity objectives."	Refer to CV-SALTS	See response to comment 18.	
	27	Central Valley Clean Water Association	"Additionally, the recommendation should clearly include: (1) additional studies necessary to provide confidence in other models or approaches, and (2) provisions for the objectives to be reconsidered when new information becomes available from the recommended studies and transient models or CV-SALTS, possibly through the triennial review process."	Refer to CV-SALTS	Comment appears reasonable.	
Follow-up Studies	56	Ecologic Engineering	"Page 123 Section 7 -- Additional future evaluations should include the following: 1. Field studies of bean should be accompanied by comparison of uptake models to determine if one more closely predicts bean water uptake. 2. Potential leaching fractions should be evaluated as well as actual leaching fractions in the LSJR area to determine possible potential salinity control measures. 3. The extent of subsurface drains in the LSJR area should be evaluated, since several soils could not be properly managed for salinity if artificial drainage was not provided. 4. Further, the effects of soil salinity management on LSJR salinity should be evaluated."	Page 123 Section 7: Section 6.2.1 of the Report notes that actual selection of a salinity threshold(s) protective of the agriculture (irrigation) beneficial use will involve a number of policy considerations some of which are mentioned by the commenter such as leaching fractions. In addition, to the degree that the requested studies go beyond date what is stated in the draft report, CV-SALTS and Regional Board staff may evaluate appropriateness of inclusion	Special studies can be useful but also relatively costly and time consuming. It is therefore best to exhaust existing literature and knowledge (for example, of similar studies), and then to focus on the remaining, unresolved, yet important questions.	Consult with UC Cooperative Extension to discuss and plan focused field studies to verify important parameters and overall findings. Such studies are frequently performed to explore production or environmental questions. The importance of calculated salinity thresholds is such that studies of this nature are justified, and perhaps indispensible.
Follow-up Study - Crop Tolerance Curves	64	San Joaquin River Group Authority	The study report is based on the 100%-yield potential defined by the 1977 Mass and Hoffman analysis that established crop tolerance curves for major crops. Unfortunately, the dry bean data used for this analysis is now over 50 years old and does not represent more salt tolerant varieties used today and is likely over conservative. It is recommended that the Study Report strongly advise against the continued use of these data and it recommend that a new curve be established for dry beans.	Comment Noted. In Section 7. "Next Steps", the Study Report recommends updated field studies for relevant cultivars of dry beans that span the entire bean growth cycle. The study Report cannot recommend against the continued use of the 1977 Mass and Hoffman analysis with no current peer reviewed study in place (with updated curves) that suggests otherwise.	USDA Salinity Lab should have apparatus and ability to perform yield reduction/salt tolerance studies with modern cultivars, if needed. Other field studies could be planned carefully with investigators to meet CV-SALTS needs as efficiently as possible.	Where salinity functions are unknown (e.g., Walnuts), or out of date (e.g., Beans), the USDA Salinity Lab should be contracted to develop up-to-date salinity-yield functions. Where outdated functions are used, or where no functions are available in the near term, work performed should be re-done as soon as the new functions are available. As with field studies performed with UC Cooperative Extension, such studies are frequently performed to explore production questions. The importance of calculated salinity thresholds is such that studies of this nature are justified, and perhaps indispensible.

Appendix A. Tabulation of Crop Acreage in the Lower San Joaquin Service Area: Analysis of Common Crops

MEMO

From: *John Dickey/PlanTierra*

To: *Michael Johnson*

Date: May 24, 2014

Subject: ***Tabulation of Crop Acreage in the Lower San Joaquin Service Area: Analysis of Common Crops***

Background and Purpose

The Lower San Joaquin River (LSJR) Committee is developing an approach to protection of AGR (irrigated agriculture) beneficial use. One of the important factors in establishing this approach is the selection of an appropriate cropping system to represent crop sensitivity to a constituent (usually salinity, as in this analysis) in the area. The purpose of this memo is to summarize alternative methods for performing this work, and to describe methods and results for the LSJR Service/Study area.

The outer boundaries of the irrigable acres considered are intended to correspond as closely as possible to lands irrigated with water diverted from the LSJR. The crop inventory is intended to feed into a Hoffman analysis to determine a threshold salinity tolerance that is protective of 95% of maximum relative yield, in a 95th percentile drought year. Many other factors must also be considered in such an analysis, a number of which are not discussed in this memo. The resulting threshold will inform a numeric salinity objective for the LSJR itself.

The status of this work is as follows:

- The methodology discussion reflects the current state of knowledge and policy development in CV-SALTS, as they author is aware of it.
- The crop data employed in the analysis is as yet incomplete. Portions of the study area are not represented. Also, there is a desire to subdivide the analysis among three sub-reaches, but the information needed to do this are not yet available. Therefore, the results of the common crop analysis will need to be updated by incorporating new information before it is employed to determine common crops in the study area.

General Considerations

Several aspects of analyses to define common crops merit discussion of how they affect thresholds that inform AGR objectives.

- **Numeric vs. narrative objectives.** The LSJR work is aimed at developing a numeric objective. AGR objectives for many areas in the Central Valley are anticipated to be principally narrative (i.e., narrative objectives). However, many of the principles associated with analysis to determine common crops and cropping systems based on basic land cover data hold true in both situations.
- **Protection of waters that recharge applied water sources.** In the CV Salts GIS Project, it was determined that when informing narrative AGR objectives, there should be a focus on waters that constitute the irrigation water supply flowing to the fields whose crop yields are sensitive and to be protected. Where sensitive crops are grown in clusters within an area, surface waters and groundwaters supplying irrigation to these clustered fields can be a focus. To protect crop yield in the cluster, this irrigation water supply must not become too saline for the sensitive crop(s) grown there. To avoid this degree of salinization, these supplies need to be protected upstream of the sensitive crops. In waters that are not applied to sensitive crops, thresholds based on the needs of these crops are not relevant to determination of a suitable AGR threshold.

- **Blending of irrigation waters.** Where irrigation water sources (e.g., surface water, groundwater, recycled drainage) are blended (e.g., in an irrigation supply canal), the effect of the blending on applied water quality should be included in modeling and when interpreting results to inform water quality objectives. If a concentrated supply is diluted with a supply with a different concentration before application, or if supplies with differing levels of salinity are commonly used on the same fields, the effect of these practices should be considered included in modeling and when interpreting results to inform water quality objectives.
- **GIS layers versus tabular land cover data**. Crop data can be obtained in the form of annual crop reports, normally from County Agricultural Commissioners (normally posted on county websites) or from Irrigation Districts (normally from their offices), or as geographic information shape files (maps, from [for example] the California Department of Water Resources land use website, http://www.water.ca.gov/landwateruse/lusrvymain.cfm). The latter are developed with less frequency, but are geographically malleable to virtually any area of interest that one might choose. Crop reports pertain to specific geographic areas, which works well when they coincide with the edge of one's area of interest. Crop reports also capture double cropping. Crop map shape files may contain double cropping in their legend, but often do not. It should be noted that many irrigation district acreage reports tabulate crop acres each time a crop is grown in a year. Irrigable acres are the physical acres irrigated. Thus, where double cropping occurs, crop acres may exceed the physical area that is irrigated (the irrigable acres). This comes into play later in this methodology, where acreage reports from irrigation districts are employed.
- **Land cover (or crop) classes.** Regardless of the form of crop acreage data, each data set will contain or imply a crop class legend. When more than one data set is employed, two or more legends may need to be reconciled. This is best done by someone familiar with farming, and with the intended end use in mind. For example, when data will be used to determine salinity thresholds for irrigation supply water (as in the current application), it will be useful to avoid combining crops with differing levels of salt tolerance into a single class, particularly if the class comprises a significant proportion (>4%) of the total acreage.
- **Methods A and B**. Two guidelines for determining common crops from crop acreage data have been discussed by CV-SALTS. In Method A, common crops represent at least 5% of the basis acreage. In Method B, common crop classes cumulatively represent at least 95% of basis area. After considerable discussion, the LSJR Committee determined the following:

  - Such determinations should not be purely quantitative (see "Qualitative factors" discussion, below).
  - Start with Method A and then tabulate crops that are protected, unprotected, and whose protection status is unknown. If <5% of the irrigable acres are unprotected (i.e., if Method B criteria are not met), then the common crops have been identified. If not, consider adding additional, smaller crop classes to meet this goal (i.e., consider adding additional crops indicated by Method B).

- **GIS vs. tabular cropping data.** At present, GIS crop pattern layers (such as those developed by the California Department of Water Resources) are not developed with the same frequency as tabular data (from irrigation districts and county agricultural commissioners), and therefore may be less timely (older) for a given analysis. For example, DWR land cover data are developed for counties on an approximately 7-year rotation. Also, GIS data may express a "snapshot" of cropping patterns, and thus miss such important features as multiple crops grown during the same year.
- **Timely land cover data.** It is advantageous to work with recent land cover data. For example, in the SJ Valley, plantings of Almonds have been widespread during recent years, so that their acreage is under-represented in older data.
- **Double cropping.** If crop acreages are to be transformed into percentages to illustrate their ratios to a total area, some thought will need to be given to how that total (the denominator) is defined. Reported crop acres from irrigation districts may contain double crop acres. That is, if wheat and beans are grown in the reporting year on an 80-acre field, 80 acres of each are entered into the data, so that the 80 irrigable acres in that field contribute 160 crop acres. Employing crop acres in the denominator results in percentages that sum to 100% and that numerically express a ratio of the class to the total for all crop classes. Employing irrigable acres results in percentages that sum to 100% plus the proportion of irrigable acres that are double cropped (e.g., 120% where 20% of the irrigable land is double cropped). These percentages numerically express a ratio of each class to the total irrigable acres considered. The LSJR Committee determined to use irrigable acres as the

denominator to identify common crops. The resulting extent of protection can then be expressed as percentages of crop acres, irrigable land acres, or both.

- **Consideration of irrigation method**. While crop classifications segregate plant species with various levels of salt sensitivity, they can ignore other important factors. Notably, irrigation method (type of system and operation) can affect salt sensitivity of a cropping system. For example, when the same crop is shifted from surface to drip irrigation with the same water supply, the crop may experience lower levels of salt stress (Hanson and May, 2011). In general, the most sensitive, common crop-irrigation combination should be considered. Crop-irrigation combinations that are rare (<5% of irrigable acres) need not be evaluated, unless it is determined that their exclusion results in inadequate overall protection.
- **Qualitative factors**. Based on discussions with the Lower San Joaquin River Committee, it is important in such an analysis to recognize crops as economic, rather than purely mathematical entities in acreage tables. That is, the context in which the crop is typically cultivated by growers, and the economic benefit to farming operations relative to other crops in a rotation, should be considered. This approach helps to avoid unintended economic damage to irrigators.
- To facilitate analysis, **levels of protection can be estimated** by calculating a critical value of salinity in applied water (ECw) for each crop, assuming a 15% leaching fraction and 95% maximum relative yield (see Table 1). This calculation can only be made for crops for which salinity yield reduction functions have been developed. The conversion of soil salinity to irrigation water salinity contains other implicit assumptions that can be found in Ayers and Westcot (1985). These figures can be used to inform a relative ranking of crop sensitivity. They should not be used for regulatory purposes such as determination of regulatory threshold salinities to protect crops. To develop such thresholds, more detailed, site-specific calculations need to be made for the specific, most sensitive crop to which one is required to furnish protective levels of salinity in the water supply in question.

Summary of Methods and Results for the LSJR Service/Study Area

Acreages and related calculations are summarized in Table 1. Raw data from each irrigation district are in Appendix A.

In an area such as the LSJR Service/Study area, the water body in question (the LSJR) forms the predominant water supply for several irrigation districts. Thus, its quality must be protected so that yields of sensitive crops within the Service/Study area are not excessively diminished by salinity.

Crop data can be obtained in the form of annual crop reports, normally from County Agricultural Commissioners or from Irrigation Districts, or as geographic information shape files (maps). For the LSJR service area, crop reports worked well, since the area of interest is defined by crops irrigated with water diverted locally from the San Joaquin River, and this area coincides with a combination of irrigation districts/water users. This group includes:

- Twin Oaks ID
- West Stanislaus ID (WSID)
- Patterson ID (PID)
- Jim Coddington
- El Solyo ID

Other areas using primarily this water supply, primarily individual diverters, have not been included. Although available, it still needs to be reviewed with the resource persons providing the data to ensure that it is properly used. The tabulated acreage is currently about 84% of the total in the LSJR Service/Study area. Where the service area is discussed here, conclusions are drawn from the acreage for which data have thus far been catalogued.

In the LSJR service area, Almonds have become a common crop, and are among the most sensitive species. Almonds (particularly new plantings) are frequently irrigated by microspray or drip, and these fields may be less sensitive to salt than surface irrigated Almonds. It will be worth evaluating Almonds in such a way that the most sensitive, common irrigation system is represented. Based on Montgomery et al. (2010), surface irrigated Almonds may be too rare to warrant evaluation.

Of the four areas reporting crop class acreages, double cropping was explicitly reported in PID and WSID, which together account for 89% of the acreage and seem to contain most of the potential double crop acreage. Thus, double cropping appears to be reasonably well reflected in the available data. Fallow land was excluded from irrigable acres used in calculations for WSID and PID. This is consistent with employing irrigable land acreage to reflect the area on the landscape that received irrigation during the year in question. Data from 2013 were obtained and used for all areas.

In the current work, it was decided to work with ratios of crop class acres to total irrigable acres during the analysis.

Methods A and B (see General Considerations section) for determining common crops yielded a similar resulting list of common crops for the LSJR Service/Study area when irrigable acres are used as the basis (see Table 1). Wheat is the least widespread, common crop by Method A (with a 5% minimum class acreage threshold), and Walnuts are the least widespread, common crop by Method B (with a 95% cumulative class acreage threshold).

The most sensitive, common crops are Almonds and Walnuts. Beans, which are significantly more sensitive than Almonds and Walnuts, are not included among the common crops. The reasons for this change from previous analyses could include the following:

1. Recent expansion of Almond and Walnut acreage relative to most other crops.
2. Previous accounting may have used crop acreage as a denominator, which would have led to the inclusion of more very-low-acreage crops by Method B.

An important qualitative consideration is that Beans are grown in this area largely in rotation with Tomatoes, with Tomatoes generating most of the revenue in the rotation. Were salinity discharge requirements driven by highly sensitive Beans, profitability of the rotation as a whole might decline (perhaps due to more stringent discharge requirements). Such a decline would cause economic harm to the very growers the threshold is intended to protect from such harm. Where possible, this type of unintended economic harm should be understood and given due consideration.

After selection of a threshold crop (in this case Almonds [probably under microspray irrigation], but this could change), crops are classed according to whether or not the threshold would be protective. Crop class protection statuses, as a percentage of crop acres, are shown in Figure 1. About 89% of crop acres are protected, 3% not protected, and 8% unknown. As percentages of irrigable acres, these groups come to 104, 9, and 3%.

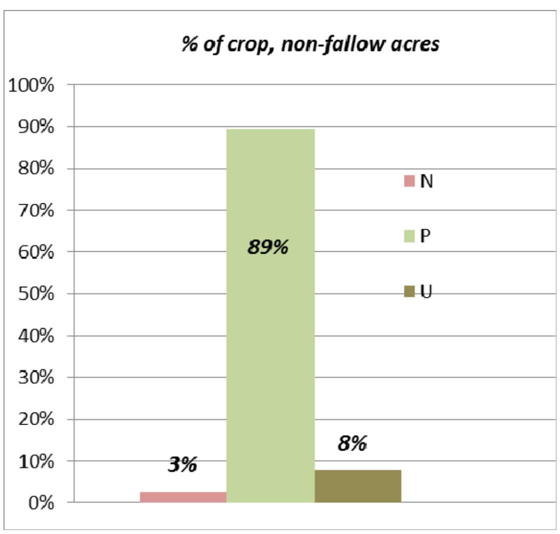

Figure 1. Approximate extent of crop protection when Almonds drive the irrigation water salinity analysis. The three classes are P=protected (the threshold is below the level for this crop, or the protected crop is in a more sensitive class), N= not protected (the threshold is above the level for this crop, and/or the protected crop is in a less sensitive class), or U=unknown (the yield reduction function is unknown, and the sensitivity class is either similar to that of Almonds, or is also unknown).

There may be some advantage to subdividing the common crop analysis among reaches of the Lower San Joaquin. This can be done when data tying diversion points to irrigated acres become available.

References

Ayers, R.S., D.W Westcot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29. Food and Agriculture Organization of the United Nations, Rome.

Hanson, B. and D. May. 2011. Drip Irrigation Management for Row Crops. University of California Agriculture and Natural Resources Publication 8447.

Montgomery, A., F. Kixito, J. Simi, and C. Cheng. March 2010. Salt Tolerance of Crops in the Lower San Joaquin River (Merced Stanislaus to Stanislaus Merced River Reaches) – Draft Report. Central Valley Regional Water Quality Control Board

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Table 1. Common Crop Identification for Lower San Joaquin River Service Area[1]

Crop Class Name, LSJR	PID	Twin Oaks	WSID	Jim Coddington	El Solyo	Total		Cumulative (%)	Salinity Tolerance	Approx. AW TDS for 95% MRY, 15% LF	Protected?[2]
	(acres)						(% of area)		(class)	(mg/L)	
Almonds	2,018	-	9,575	14	1,891	13,497	35%	35%	S	752	P
Alfalfa	3,837	1,454	1,999	800	378	8,468	22%	58%	MS	1,146	P
Tomatoes	1,062	62	5,592	-	378	7,094	19%	76%	MS	1,282	P
Corn, Silage	2,574	360	1,482	-	-	4,416	12%	88%	MS	1,056	P
Walnuts	1,096	-	1,349	-	945	3,390	9%	97%	unknown	unknown	U
Wheat	1,277	671	824	-	-	2,772	7%	104%	MT	2,860	P
Oats	1,286	40	419	-	-	1,745	4.6%	109%	T	unknown	P
Beans	222	-	989	-	189	1,400	4%	112%	S	772	P
Apricots	534	-	708	-	-	1,242	3%	116%	S	539	N
Corn, field	-	-		800	-	800	2%	118%	MS	903	P
Melons	172	121	431	-	-	724	2%	120%	MS	681	P
Grapes	21	-	695	-	-	716	2%	122%	MS	862	P
Pasture	494	-	20	-	-	514	1%	123%	MT	2,067	P
Other, Seed	20	-	436	-	-	456	1%	124%	unknown	unknown	U
Parsley	95	-	164	-	-	259	1%	125%	unknown	unknown	U
Cherries	147	-	89	-	-	236	1%	125%	S	unknown	U
Peaches	37	-	176	-	-	213	1%	126%	S	827	P
Sudan, Other Hay	127	-	-	-	-	127	0%	126%	MT	1,691	P
Apples	20	-	61	-	-	81	0%	127%	S	unknown	U
Turf	22	-	-	-	-	22	0%	127%	MS	unknown	P
Peppers	20	-	-	-	-	20	0%	127%	MS	792	P
Nursery	17	-	-	-	-	17	0%	127%	S	unknown	U
Pecans	13	-	-	-	-	13	0%	127%	unknown	unknown	U
Basil	11	-	-	-	-	11	0%	127%	unknown	unknown	U
Cactus	10	-	-	-	-	10	0%	127%	unknown	unknown	U
Pomegranate	10	-	-	-	-	10	0%	127%	MT	unknown	P
Pistachio	5	-	-	-	-	5	0%	127%	unknown	unknown	U
Total	11,708	2,708	22,029	1,614	3,781	48,259	127%				

[1] Total for 2013 in Twin Oaks, WSID, PID, and Jim Coddington. Total acreage used as a denominator for percentages is irrigable crop areas. Due to double cropping, crop acres sum to >100% of this amount. Crop classes were selected to accommodate reporting from all areas, and to correspond to classes with distinct salt sensitivity levels, as defined in the scientific literature. The three classes are P=protected (the threshold is below the level for this crop, or the protected crop is in a more sensitive class), N= not protected (the threshold is above the level for this crop, and/or the protected crop is in a less sensitive class), or U=unknown (the yield reduction function is unknown, and the sensitivity class is either similar to that of Almonds, or is also unknown).

[2] P = Protected, N = Not protected, U = Protection status unknown due to lack of crop class sensitivity data

Appendix A. Raw Data from Irrigation Districts

	Twin Oaks Irrigation District							
	Yearly Irrigated Crops							
	Year		2011	2012	2013		3 year percentage	
Corrsponding PID Crop Class	Crop		Acres	Acres	Acres	Average	Total Acres	%
Alfalfa	Alfalfa		1,360	1,184	1,454		3,998	47.09
Corn, Silage	Corn		650	663	360		1,673	19.71
Wheat	Wheat		483	531	671		1,685	19.85
Oats	Oats		271	403	40		714	8.41
Tomatoes, Cannery	Tomatoes		62	132	62		256	3.02
Cantaloupe	Melons			43	121		164	1.93
	Total Acres Harvested		2,826	2,956	2,708		8,490	100.00

West Stanislaus Irrigation District								
Corrsponding PID Crop Class	Crop	Stanislaus County	S Joaquin County	Sub Total	Whitelake	Total	Acre Feet Used	Acre Feet Per Acre
ALMONDS	ALMONDS	7401	1204	8605	970	9575	26171	2.7
Tomatoes, Cannery	CTOMATO	3312	80	3392	616	4008	15462.6	3.9
ALFALFA	ALFALFA	1806	193	1999	0	1999	7472.7	3.7
GTOMATO	GTOMATO	1289	7	1296	288	1584	9116.2	5.8
Corn, Silage	CORN	1290	192	1482	0	1482	1982.8	1.3
WALNUTS	WALNUTS	1238	71	1309	40	1349	3145.7	2.3
Beans	DRYBEANS	989	0	989	0	989	2185.6	2.2
WHEAT	WHEAT	824	0	824	0	824	981	1.2
APRICOTS	APRICOTS	646	62	708	0	708	1226.7	1.7
GRAPES	GRAPES	695	0	695	0	695	1271.9	1.8
Cantaloupe	MELONS	0	260	260	171	431	1318.8	3.1
OATS	OATS	216	93	309	110	419	2040	4.9
FALLOW	FALLOW	239	82	321	0	321	0	0
PEACHES	PEACHES	176	0	176	0	176	47	0.3
PARSLEY	PARSLEY	164	0	164	0	164	123.9	0.8
Other, Seed	SPINACH	163	0	163	0	163	71.7	0.4
Other, Seed	ANUNKNO	139	0	139	0	139	0	0
Other, Seed	OLIVES	131	0	131	0	131	391.3	3
CHERRIES	CHERRIES	0	89	89	0	89	202.4	2.3
APPLES	APPLES	61	0	61	0	61	143.5	2.4
PASTURE	PASTURE	20	0	20	0	20	21.1	1.1
Other, Seed		3	0	3	0	3	0	0
Other, Seed	BARLEY	0	0	0	0	0	0	0
Other, Seed	Other						0	
	Irrigated Ac	20802.00	2333.00	23135.00	2195.00	25330	73375.90	2.90
	Dbl Crop Ac	2527	453	2980	0	2980		
	Irrigable Ac	18275	1880	20155	2195	22350		
	Non-Irrigated	Acreage		0.00				
	Total District	Acreage		20155				

Patterson Irrigation District
2013 Crop Report

PID Crop Class	Crop Class Name, LSJR	Acres	
Almonds	Almonds	2,017.53	
Alfalfa	Alfalfa	3,837.03	
Tomatoes, Cannery	Tomatoes	1,062.39	
Corn, Silage	Corn, Silage	2,573.55	
Wheat	Wheat	1,277.15	
Walnuts	Walnuts	1,095.90	
Oats	Oats	1,286.37	
Apricots	Apricots	534.06	
Beans	Beans	221.67	
Corn, field	Corn, field		
Cantaloupe	Melons	171.58	
Grapes	Grapes	21.08	
Pasture	Pasture	493.68	
Other, Seed	Other, Seed	19.76	
Parsley	Parsley	94.89	
Cherries	Cherries	147.04	
Peaches	Peaches	37.08	
Sudan, Other Hay	Sudan, Other Hay	127.16	
Apples	Apples	19.62	
Turf	Turf	22.04	
Peppers	Peppers	20.00	
Nursery	Nursery	17.04	
Pecans	Pecans	13.26	
Basil	Basil	11.25	
Cactus	Cactus	10.00	
Pomegranate	Pomegranate	10.00	
Pistachio	Pistachio	5.43	
TOTAL FARMED		15,146.56	Acres
OPEN/FALLOW GROUND		952.08	Acres
TOTAL ACRES		12,660.05	Acres
DOUBLE CROP		3,438.59	Acres
		16,098.64	

Jim Coddington	
Acerage	**Crop**
800	Alfalfa
800	Rotation between oats and field corn
14	Almonds

El Solyo Crops	
Crop	**Acres**
Almond	1,891
Walnuts	945
Tomatoes	378
Alfalfa	378
Beans	189
Total	3,781