Appendix X Response to CV-SALTS TAC Comments

RE: CENTRAL VALLEY SALINITY ALTERNATIVES FOR LONG-TERM SUSTAINABILITY (CV-SALTS) TECHNICAL ADVISORY COMMITTEE RECOMMENDATIONS REGARDING THE CITY OF DIXON'S SITE SPECIFIC BORON STUDY AND ADDENDUM (ORDER NO. R5-2008-0136)

CV-SALTS submitted a letter, dated April 11, 2014, to the Regional Board regarding their review of the City of Dixon's Site Specific Boron Objective Study and Addendum (Reports). The letter listed several comments related to various portions of these reports and whether the study fulfilled the August 2013, City of Dixon: Site Specific Boron Objective Work Plan (Work Plan).

This appendix has been prepared to address each comment from the letter individually. The original comment (as presented in DRAFT form in the TAC agenda package) is presented in blue font, and the DRAFT Preliminary) response in black font.

[It is understood both the DRAFT CV_SALTS letter and this response may be substantially revised prior to submittal to the Regional Board]

General Comments

Site Specific Boron Objective Study

1. The site-specific objective studies generally attempt to determine the threshold concentrations in soil solution below which the crops would be protected at a 95 percent of yield basis for those crops that comprised more than 5 percent of the land use in the study area. A steady-state salinity model (Rhoades and Merrill, 1976) based on plant uptake was used to determine boron concentrations in soil solution as a function of boron concentrations in irrigation water for various crops under one or more leaching fraction/irrigation scenarios[1]. *The salinity model and the results shown in Figure 2 should be explained with greater clarity to improve understanding. Dixon should consider adding a table that illustrates the steps used in the analyses in a sequential manner. Working through a specific example would be helpful. If possible, the model should be included as an electronic addendum to facilitate the review process.*

The study used a widely used model for soil salinity based on the linear average of root zone salinity, proposed initially by Rhoades and Merrill, 1976 and subsequently used by Ayers and Westcott, 1976 in developing criteria for irrigation water quality. The criteria developed by Ayers and Westcott, 1976 (using this same model) have largely been the adopted and used as the basis for agricultural water quality objectives. Others have provided more detailed analysis on the theory, science, and application of the model, including the aforementioned as well as Hoffman, 2010 in his report regarding salinity objectives for the South Delta and prepared for the State Water Resources Control Board. Below is an abbreviated description of the basis for and context of the model.

[1] Figure 2, page 2.6, Stantec 2014a

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The model is a simple steady state salt build up calculation based on conservation of mass, where the salt concentration (C) at a depth of soil (s) can be calculated from

$$Cs = \frac{Cw \times Vw}{Vs} \qquad \text{eq 1}$$

where Vw is the volume of water applied including effective precipitation (Pe) and irrigation water (Iw) to meet crop demand (ETc) and leaching fraction (Lf); Cw is the concentration in all water applied, i.e. $(C_{Iw}+C_{Pe})/(V_{Iw}+V_{Pe})$; and Vs is the leached volume (Vs=ETc x Lf). Since the concentration of salt in precipitation is negligible, equation 1 can transformed to

$$Cs = \frac{CIw \times (VIw+VPe)}{ETc \times Lf} \qquad \text{eq 2}$$

For each quarter fraction of the root zone the Lf_i can be determined by the volume of plant uptake (fVu) in the above quarter fraction by the following:

$$Lfi = 1 - \frac{fVu}{VIw} \qquad \text{eq 3}$$

Using the 40-30-20-10 uptake model (i.e. crop gets 40 percent of its ETc in the top quarter fraction of the soil, 30 percent in the second quarter fraction, etc) the linear average salt concentration of the root zone (Crz) becomes,

$$Crz = \left(Cw + \frac{Cw \times Vw}{Vw-(0.4 \times ETc)} + \frac{Cw \times Vw}{Vw-(0.7 \times ETc)} + \frac{Cw \times Vw}{Vw-(0.9 \times ETc)} + \frac{Cw \times Vw}{Vw-ETc}\right) \div 5 \qquad \text{eq 4}$$

The model requires site specific and crop specific inputs, including plant/harvest dates; growing season precipitation; growing season ETo; crop ET coefficients (kc) for growth stages; non-growing season precipitation and evaporation; and leaching requirements. These factors are derived from different sources and need to be compiled for each crop and location, so there is no electronic database available for these steps. (A spreadsheet was used for the calculations and resultant graphs presented in the studies)

Growing seasons and Kc values were acquired from raw data compiled for the University of California Basic Irrigation Scheduling (BIS) Program revised 2007 and available online at
http://biomet.ucdavis.edu/irrigation_scheduling/bis/bise.xls

The crop (or multicrop) information was used to determine the growing season irrigation demand and effective precipitation by applying a monthly bare soil evaporation of 0.7 inches to the nongrowing season precipitation (DWR, MacGillivray and Jones, 1989; Hoffman, 2010). These values were input directly into equation 4 to determine irrigation water quality objectives based on published boron tolerance threshold data. A summary of inputs and model results is presented in Table 4 of the report. Irrigation water quality was used as a variable to obtain curves presented in Figure 2. The 95 percent yield ranges are based on available yield response data and/or tolerance thresholds, most thoroughly compiled in E.V. Maas, 1990 and Maas and Grattan, 1999. See below for additional discussion regarding the basis of 95 % yield levels. The published ranges in tolerance threshold result in ranges in water quality objectives.

2. There are a number of assumptions and statements throughout the study that are not supported with sufficient citations from literature or with actual data to allow the reviewer to easily come to the conclusions reached in the report. As an example, the following statement[2] is made: “Assuming that sunflower yield responds similar to other seed and grain crops, adding 1 mg/L boron to the threshold would reduce yield by less than 5 percent; therefore, a soil solution boron concentration of 1.75 mg/L is anticipated to be protective of the 95 percent yield for sunflowers.” There are two potential issues with this statement: (i) the assumption that the yield of sunflower response to boron concentration in soil

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solution is similar to other seed and grain crops is not supported herein by literature, and (ii) the data showing the yield r1esponse curve for other seed and grain crops is not presented. Dixon should support *all statements and assumptions in the studies with literature or with data.*

The need for, and basis of, arbitrary 95 percent yield response concentrations was presented in the work plan.

Specifically, the results of previously conducted yield response to boron experiments by many researchers was compiled in Maas and Grattan, 1999. Of this data only cowpea, snap beans, and scallop squash had yield response slopes substantially greater than 5 percent decline for each 1 mg B/L increase over the tolerance threshold. Other squashes were near the 5 percent (5.2 % for winter) and 4.8 % for zucchini) per mg/L level, and all other crops had yield declines of less than 5 percent per 1 mg B/L increase over the tolerance threshold. The two legumes had 12 percent declines per 1 mg B/L increase over the tolerance threshold, and legumes were considered to be more sensitive than other crops. Since all other yield response data showed a slope decline of less than 5 percent, this value was selected to arbitrarily set the 95 percent yield response for crops that have not had a yield response established.

Sunflowers do not have a fully defined yield response established empirically. Pathak et al. 1975 conducted a study relating sunflower yield (grown in pots) to irrigation boron quality, where the optimum level was determined to be "less than 1 ppm" and a critical level was determined to be "greater than 2 ppm;" However, no yield response curve was developed from the limited data set of 0, 1, and 2 ppm B irrigation water treatments. The 1.8 mg/L objective is below their critical value.

3. In Section 2.3.4, the following two statements[3] are made: "This 95 percent threshold for a wheat bean rotation can be achieved using an irrigation water supply with a boron concentration [of] 1.5 mg/L at both 15 and 25 percent LR. Increasing the irrigation water supply boron concentration to 1.8 mg/L is protective of 95 percent yield of snap beans and wheat rotation at both LR, and weighing all factors this value is proposed as an appropriate site specific objective (SSO) for boron." Snap beans are not shown to be a crop that comprises more than 5 percent of the land use in the study area. *It appears that the study supports – if additional information is provided – a site-specific boron objective of 1.5 mg/L and not the value of 1.8 mg/L based on snap beans.*

Of the crops with established yield response only there are only two legumes, which have 12 percent declines per 1 mg B/L increase over the tolerance threshold, so legumes were considered to be more sensitive than other crops. "Beans" is a general term largely comprised of the *Phaseolus* and *Vigna* genera. Eaton, 1944 conducted sand column studies on many plants to determine boron tolerance based on visual symptoms, this included kidney beans and lima beans (*Phaseolus vulgaris* and *lunatus*) which were ranked as sensitive which corresponds to a threshold range of 0.75 to 1 mg/L. Mung beans (*Vigna radiata*) were ranked by Khudairi, 1961 in this same class based on shoot length. Yield responses have only been developed for snap bean (*Phaseolus vulgaris*) and cowpea (*Vigna unguiculata*) and their yield based tolerance thresholds are 1 mg/L and 2.5 mg/L (Francois, 1988).

Therefore, the most conservative yield based relationship established for "beans" is that of snap beans, which is equivalent to the upper limit of the sensitive range. The lower limit of this range is also presented, but not substantiated by yield based research, to present an alternative more conservative condition.

4. Table 1[4] has column headings for the constituents of concern that include "Potable Water," "Raw Wastewater," and "Proposed Discharge to Groundwater (annual average)." Please add footnotes to the table to clarify the meaning of the column headings. Consider renaming the last column to "Estimated

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[4] Page 1.2 of Stantec 2014a

Concentrations in WWTF Discharge to Groundwater." Also consider renaming the table from "Agricultural Use Protection – Constituents of Concern (mg/L)" to "Summary of Average Concentrations of Constituents of Concern inform 20XX to 20YY."

Noted and will be revised.

5. In the first paragraph of Section 2.3[5], the following statement is made: "This model calculates the salt concentration in quarter fractions of the root zone, and the linear average of these concentrations is recommended to represent soil salinity under infrequent irrigations." Please provide some supporting information that this model is applicable to cropping conditions in the Dixon area. Also include an example regarding "infrequent irrigation" (e.g., weekly).

See response to comment 1. This model is widely used to assess irrigation water quality globally (Ayers Westcott, 1976) and locally (Hoffman, 2010). The use of the linear average was initially recommended for conventional irrigation practices (infrequent irrigations: i.e. the soil is allowed to dry between irrigations), while the crop uptake weighted average was recommended for frequent irrigations where soil moisture is maintained near an optimum level in the root zone, such as micro irrigation practices.

6. In the second paragraph of Section 2.4[6], the following statement is made: "If the maximum rate of irrigation (12.3 inches) and maximum irrigation water boron concentration (1.8 mg/L) from the boron buildup modeling were applied to an acre of this soil, and all boron remained in the surface foot of soil, it would take over 11 years to apply 4 lbs of boron and achieve the equilibrium 0.7 mg/L soil solution boron concentration." *It is not clear what is meant by the "equilibrium 0.7 mg/L soil solution boron concentration" – please clarify. Filling sorption sites with boron within 11 years makes this irrigation scenario appear to be less than sustainable. Perhaps the underlying assumptions should be re-visited or more clearly explained.*

It would take 11 years of irrigation at the objective to obtain an equilibrium soil solution boron concentration of 0.7 mg/L (the current default objective). This would result in 4 percent of the soils boron adsorption capacity being filled, and does not account for leaching of boron out of the soil. Boron in soil is largely adsorbed and unavailable, the size of this pool is controlled by long term boron additions and it, the unavailable pool, controls the soil solution concentration through chemical equilibrium. It would take 22 years of this closed system application to obtain 1.4 mg B/L in the soil solution (e.g. the 95 percent yield reduction objective level). The soil build up modelling does not account for soil adsorption and suggests this level would be obtained in the first year. Since it will actually take 20 plus years to obtain the condition presented in the soil buildup modeling, objectives developed from the soil buildup modeling are sufficiently conservative that fluctuations in applied water quality will be effectively buffered by the soils in its effect on crops over a period of many years. Therefore an annual average criteria is proposed as sufficiently conservative to ensure the agricultural use is protected.

7. In the second paragraph of Section 3.2[7], the following statement is made: "The Yolo County Flood Control and Water Conservation District (YCFCWD) reported the long term average boron concentration for its irrigation supply (Cache Creek at the Capay Dam) was 1.7 mg/L and average boron concentrations of groundwater in Yolo County range from 0.6 to 6.6 mg/L (YCFCWD, 2007)." *While the boron concentrations in the irrigation supply and groundwater are similar to concentrations in the study area, no data are presented that would support the argument that there was not significant yield (greater than 5 percent) reductions due to the presence of boron in irrigation supply at those concentrations.*

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[7] Page 3.2 of Stantec 2014a

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The need to compare the study area to current production in areas with elevated boron in the water supply was presented in the work plan, largely due to the lack of significant yield response data for many crops.

It was the intent to show that economically viable agriculture similar to practices in the study area could successfully be conducted with boron in the irrigation water supply at a concentration similar to or greater than the proposed site specific objective. The only systematic comparison of yield generally available would be based on statistics from the Annual Crop Reports for the two counties. Such a comparison would have many uncontrolled variables, such as regional climate, past land use, fertilizer inputs, irrigation amount and quality, crop timing, pest damage, etc. In establishing a salinity threshold (or objective) all of these parameters must be equal and optimum; therefore, the utility of such a comparison is of limited value beyond confirming yield is sufficient to support commercial farming of sunflowers in both Counties with irrigation water boron levels encompassing a wide range, including above the proposed site-specific objective. Nevertheless, a comparison was made based on County data, and from 2003 through 2012 average value per acre of sunflowers in Yolo County was 80 percent of the value per acre in Solano County.

Site Specific Salinity Objective Study as an Addendum to the Boron Study

8. In Section 1.1[8], the following statements are made: “The major findings of the salinity research were that osmotic stress was the primary cause of crop decline…” and “Generally, annual crops are not susceptible to sodium and chloride toxicity.” However, it is recognized that leaf burn and foliar stress can result from overhead sprinkler irrigation if it is not timed properly. *Please provide background or rationale for developing site-specific objectives for sodium and chloride, because the crops comprising more than 5 percent of the study area – while affected by osmotic stress (electrical conductivity [EC]) – are not susceptible to sodium or chloride toxicity. The sodium adsorption ratio (SAR) and the EC are the critical parameters for protecting AGR beneficial uses in this study area.*

The Regional Board requested further information including sodium and chloride site specific objectives for AGR in order to better evaluate discharge limits values, and if they are necessary.

9. In Section 2.1[9], Table 1 provides salinity threshold and the EC value where there is less than a 95 percent yield reduction. *Please cite the reference(s) for these values. Pursuant to Comment 2, please provide references or supporting data for all assumptions and statements.* Table 1 also lists sodium and chloride concentrations supposedly associated with a less than 95 percent yield reduction for the study area crops. *However, these concentrations may not be directly related to yield reduction, because they were estimated based on ratios of these ions to EC. Also please consider reducing the number of significant figures to two and adding “Estimated” to the table title.*

Various researchers for individual crops, compilations of salinity yield response data are included in Maas & Grattan, 1999; Ayers and Westcott, 1976; and “Western Fertilizer Handbook” (CFA) for reference. Since these levels were based on molar relationships and empirical percent yield decline, the whole number values were used to preserve conservatism in determining the objectives.

Rounding to two significant figures is appropriate if the table is to be used as a stand-alone reference for salinity tolerance. The ECe values are not estimated; the chloride levels are approximate but reflect chloride concentrations of the salinity yield response experiments, due to the use of chloride salts to achieve various salinities (US Salinity Lab, 1954); the sodium levels are estimated based on the ability of calcium to regulate sodium related effects on crops. Regardless of the sodium and chloride objectives, neither should be allowed to cause an exceedance of the ECe objective; therefore,

[8] Page 1.1 of Stantec 2014b
[9] Page 2.1 of Stantec 2014b

any sodium or chloride limits derived directly from the calculated values presented should be constrained to a corresponding maximum ECe limit.

Averaging Period

10. The October 17, 2013 CV-SALTS letter states that the "TAC recommended that the project proponent provide the technical justification for the proposed annual average in the Study Report. In addition, the TAC recommends that the project proponent participate in future TAC discussions regarding the averaging periods." The Site-Specific Boron Objective study states that "there is limited knowledge on boron's role in plant nutrition as well as on the mechanisms responsible for boron toxicity.[10]" *This should be documented with literature citations*. This study also discusses the buffering or signal-dampening response to fluctuations in boron concentration in the soil system, which is likely to occur. The salinity addendum also cites best management practices (BMPs) that can ameliorate higher salinity during stages of plant growth where there is higher sensitivity to salinity: "1) salt sensitive crops are generally planted in the spring after seasonal precipitation has leached soluble salts from the soil; 2) Pre-plant irrigations can be applied to minimize soil salinity encountered during the early growth stages.[11]" *These BMPs should be documented. The TAC continues to recommend that Dixon stay involved and continue to participate in the on-going discussions concerning the averaging periods.*

General statement based on Gupta et. al, 1985. For a discussion on the current state of knowledge regarding boron toxicity see: Reid, R. 2010. *Can we really increase yields by making crop plants tolerant to boron toxicity?* Plant Science. 178:9-11

The "BMPs" are common site specific practices and only two of many factors in determining the frequency, efficiency, and total seasonal amount of irrigation water a particular farmer must utilize to economically raise a particular crop, in a particular location, and particular time.

Work Plan Consistency Review

In reviewing these two studies, the TAC performed a consistency review between the work plan and the study – in other words, did the study achieve the work plan objectives. The work plan objectives and findings are summarized below.

1. "Additional crop types of regional significance have been compiled by the Dixon RCD and Solano County. The California Department of Water Resources (DWR) conducted land use surveys of Solano County in 1994 and 2003, which identified crops grown and irrigation methods in individual fields during those years. **These sources of information will be used to document agricultural practices in the area."[12]** *This work plan requirement/proposed task is substantively accomplished in the study.*

2. "Other pertinent agriculture practices which help reduce impacts from salt, and therefore boron, include artificial drainage, adjustments to leaching fraction, soil amendments, and supplemental (i.e. higher quality) irrigation water, if available. These practices are more difficult to characterize and quantify, primarily due to individual farmers experience with, and application of, these practices. Generally, the best source of this information is from discussions with local Cooperative Extension agents, resource conservation districts, and/or irrigation districts. **Therefore, the study will solicit such input from the Dixon RCD.[13]"** *Difficult to tell if RCD or the cooperative extension staff was contacted for information, but agricultural practices are discussed in Section 2.3. The TAC recommends clarification regarding degree to which input was provided by Dixon RCD.*

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[11] Page 3.1 of Stantec 2014b
[12] Page 4 of Stantec 2013
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The Dixon RCD provided email responses to questions and was provided a copy of the report, but has declined to provide any comments. Their responses regarding practices were used in the report, where appropriate. UC Cooperative extension and UC DANR information was reviewed, but no additional input was solicited. The City has advised the Dixon RCD of the Dixon WWTF RWD process and has offered to support alternative values for the objectives if the Dixon RCD or the larger agricultural use community so proposes as they weigh other factors beyond the scope of the Studies.

3. **"Available SID reports and the available groundwater reports will be reviewed to identify irrigation water quality in the area. We will also obtain water quality information that may be provided by the local farmers.[14]"** *A summary of irrigation and groundwater quality data are not presented. The TAC recommends that these data be presented to the extent that they were acquired.*

No significant data was acquired.

4. The Soil Survey of Solano County prepared by the Soil Conservation Service (NRCS) in 1977 provides the most comprehensive assessment of soils in the area and **will be used to identify soil types and salinity management related aspects of those soils**.[15]" *This work plan requirement/proposed task is substantively accomplished in the study.*

5. "Additionally, the presence of calcium, nitrogen, and potassium can affect plant uptake as well as expression of boron deficiency and toxicity symptoms. **Available literature will be reviewed to assess, at least qualitatively, the ability of area soils to buffer the concentration of boron in the soil solution and ameliorate detrimental effects on crops.[16]"** *This work plan requirement/proposed task appears to have been substantively accomplished in the study. However, as noted in General Comment 2, the literature needs to be sufficiently cited in the studies to demonstrate adherence to this element.*

Soil adsorption calculations were conducted and presented based on data presented in Gupta et. al, 1985, as cited in section 2.4 of the boron report.

6. "Local climatic data will be reviewed and used to assess boron loading and where applicable any discrepancies with reported tolerance studies. **Average year rainfall amounts will be used to calculate loading and/or leaching of boron.[17]"** *This work plan requirement/proposed task is substantively accomplished in the study. Climatic data should be provided as an attachment.*

7. **"The potential for flooding in the area will be reviewed to determine if substantial volumes of stormwater are contributing to irrigation demand and/or flushing the soils.[18]"** *This work plan requirement/proposed task is not discussed in the study. This task should be re-visited or an explanation of why it is no longer required should be included in the study.*

The study area is essentially an open gradually sloping landscape and has an engineered drainage system to prevent flooding, and is not largely susceptible to flooding beyond that associated with irrigation practices. The most easterly parcels in the Dixon RCD are in the Yolo Bypass and therefore do flood with some regularity. The presence of flooding generally reduces soil salinity and irrigation application volumes.

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