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Bogle Vineyards / Delta Watershed Landowner Coalition
Diablo Vineyards and Brad Lange / Delta Watershed Landowner Coalition
Stillwater Orchards / Delta Watershed Landowner Coalition

BEFORE THE

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

HEARING IN THE MATTER OF CALIFORNIA DEPARTMENT OF WATER RESOURCES AND UNITED STATES BUREAU OF RECLAMATION REQUEST FOR A CHANGE IN POINT OF DIVERSION FOR CALIFORNIA WATER FIX	**TESTIMONY OF MICHELLE LEINFELDER-MILES** **Joint Case in Chief of: Islands, Inc., Delta Watershed Landowner Coalition, Bogle Vineyards, Diablo Vineyards, Stillwater Orchards and Local Agencies of the North Delta**

I, Michelle Leinfelder-Miles, do hereby declare:

I. INTRODUCTION

I am the Delta Crops Resource Management Advisor with the University of California Cooperative Extension, based in San Joaquin County. I have 4.5 years of experience working in this capacity and fourteen years of research experience in agricultural cropping systems, which includes work in grains and forages, vegetable crops, and tree and vine fruit crops. I received my B.S. in Crop Science and Management from UC Davis (2001), my M.S. in Horticulture from Cornell University (2005), and my Ph.D. in Horticulture from Cornell University (2010). As the Delta Crops Resource Management Advisor, I conduct a multidisciplinary research and outreach program on agricultural production and resource stewardship. My research projects center on row crops and the management of water and soil resources in those agricultural systems. My outreach program is directed toward agricultural producers, allied industry representatives, and natural resource managers. I conduct instructional meetings and demonstration field meetings where I communicate research results from my own program and those of my UC colleagues to the agricultural community. A description of my research projects is included in my statement of qualifications. I have dedicated considerable time to assessing soil salinity conditions in the Delta because salinity has the potential to impact crop productivity and soil resource management.

II. INTRODUCTION TO SALINITY

Salt problems occur on approximately one-third of all irrigated land in the world. In the United States, salt problems occur near the coasts and in soils of the arid west. Some soils are salty because parent materials weather to form salts; while on croplands, salts may be carried in irrigation water, added as fertilizers or other soil amendments, or be present due to a shallow saline groundwater.

Measuring the salt load, or Total Dissolved Solids (TDS), in soil or water is not a practical way of deriving a salinity condition (II-16, Hanson et al., 2006). Rather, the salt load is typically estimated by measuring electrical conductivity (EC). Positively-charged cations (Ca^{2+},

Mg^{2+}, K^+, and Na^+) join with negatively-charged anions (Cl^-, SO_4^-, HCO_3^-) to form soluble salts ($NaCl$, $CaCl_2$, $MgCl_2$, $CaSO_4$, $CaCO_3$, and KCl). In a solution, the ions disassociate and will move toward an electrode of the opposite charge, creating a current that can be measured with an EC meter. When the solution comes from a soil saturated paste (methods described in Section IV), the abbreviation used is ECe, and when the solution is water, the abbreviation is ECw. A unit of measure for EC is decisiemens per meter (dS/m) or millimhos per centimeter (mmhos/cm), which are equivalent. Decisiemens per meter can be converted to microsiemens per centimeter (µS/cm) by multiplying by 1,000 (i.e. 1 dS/m equals 1,000 µS/cm).

III. EFFECTS OF SALINITY ON PLANT GROWTH

Salt impairs plant growth by exerting osmotic stress that results in decreased turgor pressure in plant cells, by causing specific ion toxicities that vary by plant species, or by degrading soil conditions that limit plant water availability. Osmotic stress is the most common means by which salt impairs plant growth (II-16, Hanson et al., 2006). Under a non/low-saline condition, the concentration of solutes (i.e. sugars and organic acids transported in the plant vascular system) is higher in plant roots than in the soil-water solution. This means that water moves freely into the plant roots because there is more force, called osmotic potential, pulling the water into the plant roots than there is force holding the water to the soil particles. Under conditions of higher soil salinity, plants must transport solutes within the plant to the roots in order to keep root solutes higher than soil-water solution solutes to avoid water stress. Remobilizing solutes requires energy, and that energy, then, is not used for plant growth. Thus, some plants will not show specific salt-induced symptoms as a result of saline soil conditions; rather, they may just exhibit lower growth or generic stunting which may or may not be realized by the farmer as being salt-induced (II-16, Hanson et al., 2006). Tables 2 through 5 in Hanson et al. (2006) present salt tolerance ratings (i.e. sensitive, moderately sensitive, moderately tolerant, tolerant) of various crops grown in California and in the Delta.

Plant growth may also be impaired by specific ions, like sodium (Na^+), chloride (Cl^-), or boron (B), which can accumulate in plant stems and leaves. This results in burning on the leaf tips or around the margins. Sodium is not an essential nutrient for plants, and in addition to specific toxicity, the presence of Na^+ in the soil may limit plant calcium, magnesium, or potassium uptake, and therefore, result in plant nutrient deficiencies. Chloride and B are essential plant nutrients, but they are micronutrients and are only needed in small amounts. When toxic concentrations of Cl^- or B occur in plant leaves, it appears as yellowing and progresses to burning along the leaf edges. When leaves yellow or burn, it reduces their photosynthetic capacity, thus reducing plant growth.

Plants may also be affected by salinity if soil conditions are degraded and water infiltration and drainage are impaired. Degraded soil conditions may exhibit white or black crusts on the soil surface or wet spots on the soil surface. The white crusting is the result of evapoconcentration of salts on the surface of the soil, and the black crusts form because humus is carried upward with water as water evaporates. Slick spots form because the soil particles are completely dispersed and soil structure is lost. To understand at the soil particle scale, consider that soil clay particles have a negative charge and cations like sodium, calcium, and magnesium are attracted to the clay particles. Sodium cations are not held closely to the clay particles, so if sodium dominates the other two cations in the soil, the clay particles will be more disperse. The soil swells, and water infiltration into the soil will decrease. Poor infiltration can result in standing water on the soil surface or poor aeration in the soil pores, neither of which promotes plant health and growth.

Since osmotic stress is the most common means by which salt impairs plant growth, it is important to address the relationship between applied water salinity and soil salinity. Irrigation water carries salts, and when irrigation water is applied to fields, salts are added to the soil. Thus, the applied water salinity influences the soil salinity. Salts accumulate in the soil at higher concentrations than they existed in the applied water because evaporation and plant uptake extract water from the soil leaving the salts behind. While salts may accumulate disproportionately in the soil profile depending on soil properties, leaching, irrigation systems, or other reasons, crops respond to the average soil salinity in the root zone (II-15, Ayers and Westcot, 1985). For these reasons, crop salinity tolerances are expressed as both seasonal average applied water salinity and average root zone soil salinity.

IV. DELTA RESEARCH PROJECT FINDINGS

I have led several field projects over the last few years where we have investigated soil salinity conditions in the south Delta under various cropping and irrigation regimes. In multi-year studies of a drip-irrigated processing tomato field (i.e. tomatoes made into paste or other products) and flood irrigated alfalfa fields, we found that salts were accumulating in the soil. In the tomato study, leaching occurred laterally away from the buried drip emitters. Salts concentrated in the top 10 cm (4 in) of soil and at about 90 cm (3 ft) below the surface, where fine-textured organic matter likely impeded downward water movement. Using surface irrigation water that ranged from 400-750 µS/cm (0.4-0.75 dS/m) across the three-year study, average root zone salinity increased over that time, from 0.79 dS/m at the start of the project to 1.31 dS/m at the end. In the alfalfa project, where seven fields were evaluated over three years, four out of seven sites had an ECe that met or exceeded 10 dS/m at 90 cm (3 ft) below the surface. This illustrates that salinity may build up in soil layers just below the depth which is typically sampled for soil nutrient and salinity status, approximately the top 60 cm (2 ft) for orchards (II-22, Brown and Niederholzer, 2007) and possibly shallower in annual crop systems. Thus over time, growers may not be aware of the degree to which soil salinity has increased in their fields.

In the aforementioned alfalfa study, average root zone salinity ranged from 0.71 dS/m to 7.18 dS/m across the seven south Delta sites and three years. At only two sites was an average root zone salinity below 2.0 dS/m maintained across the study period, the level at which 100 percent yield potential is expected for alfalfa. Some of the study sites likely accumulated salts because shallow groundwater impeded salts from leaching out of the root zone or low permeability soil impaired leaching. Seasonal average salinity of the irrigation water at these sites ranged from 360-1,930 µS/cm (0.36-1.93 dS/m) across the study period.

V. SOIL SAMPLES AT RYER ISLAND

In August 2016, I surveyed soil salinity conditions of two permanent crops, grapes and pears, on Ryer Island in the North Delta. Soil series information for these sites is available from the United States Department of Agriculture Natural Resources Conservation Service (NRCS, 2017). The soil series of the pear orchard is Valdez silt loam, which characterizes approximately 23,088 acres in California, most of which are in the Delta. This soil has low permeability. Soil maps provide the saturated hydraulic conductivity, or Ksat, of this soil as being approximately 32 mm/hr down to about 38 cm and 10 mm/hr from about 38-152cm. The Ksat of a soil is the ease with which water passes through a soil. The soil series of the vineyard is Egbert silty clay loam, which characterizes approximately 45,284 acres in California, most of which are located in the Delta. (The soil of the aforementioned processing tomato study was also an Egbert silty clay loam.) Soil maps of this soil provide a low Ksat of approximately 10 mm/hr in the top 15 cm, and a very low Ksat of approximately 5 mm/hr from 15-152 cm.

In the pear orchard, sampling procedures were as follows. Eight holes were augered (4.5-cm diameter) in-line with the tree row from random locations across a span of 20 rows. The orchard is sprinkler-irrigated with nozzle risers in the tree row. Four of the holes were sampled from between a nozzle and tree, and four were taken opposite the tree from the nozzle in a "shadow" of direct irrigation. The holes were augured in 30-cm increments to a depth of 150-cm. Samples from the same depth were composited into bulk samples, for a total of five representative samples from the orchard.

At the same time that bulk soil samples were taken, a soil moisture sample was also collected using a volumetric sampler (60-cm^3). The sample was collected from the center 7 cm of each 30-cm depth increment. After extracting the soil, it was sealed in a metal can to prevent moisture loss. The soil was weighed before and after oven-drying at 105 degrees C for 24 hours, and the soil moisture content (as a percent of the soil volume) was calculated.

A groundwater sample was collected by auguring until water was visually or audibly reached. The water was allowed to equilibrate in the hole before measuring the depth to groundwater and collecting a sample (200-mL). Water was stored in a cooler (37 degrees C) until analyzed.

Because the vineyard is drip irrigated, the wetting pattern from irrigation would be quite different and less uniform than the wetting pattern in the pear orchard. For this reason, we sampled two grid patterns in the vineyard, from vines that are approximately 20 rows apart. The grid pattern consisted of samples taken from 30 cm, 60 cm, 90 cm, and 120 cm from the vine row, in 30-cm increment depths, down to 150 cm, for a total of 20 samples from each of the two grids. The vine rows were spaced approximately 240 cm apart, so the 120-cm sample marked the mid-point between vines. Both grid samplings were taken from the Egbert soil series. Soil moisture samples were taken for each grid pattern at 30 cm from the vine row, following the aforementioned procedures. It was assumed that at this point in the season, since irrigation had ceased for the season, that soil moisture between 30 cm and 120 cm from the vine row would not be profoundly different. Groundwater was also sampled from both grid patterns following the aforementioned procedures.

The samples were processed for salinity by oven-drying at 38 degrees C and grinding to pass through a 2-mm sieve. Soil salinity was determined by measuring the electrical conductivity (EC) of the saturated paste extract, where higher EC indicates higher levels of dissolved salts in the soil. To conduct these procedures, a saturated paste extract was made by saturating a soil sample with deionized water until all pores were filled but before water pooled on the surface (II-41, Rhoades, 1996). When saturation was achieved, the liquid and dissolved salts were extracted from the sample under partial vacuum. The EC of the saturated paste extracts (ECe) was measured in the laboratory of UC Cooperative Extension in San Joaquin County using a conductivity meter (YSI 3200 Conductivity Instrument). The groundwater samples were vacuum-filtered for clarity and analyzed with the same conductivity meter.

The bulk samples from the pear orchard had ECe readings ranging from 0.25 to 1.18 dS/m down the soil profile. The groundwater was at a depth of 1.65 m and had an EC of 0.35 dS/m. Based on these data, the average root zone salinity at this orchard was 0.74 dS/m. Brown and Niederholzer (2007)(II-22) indicate that pear yields have been reduced when the average root zone salinity reached 2.5 dS/m; thus, the salinity at this site would not appear to be currently impacting yield.

In the vineyard, which is drip irrigated, the ECe pattern suggests that the wetting front is pushing salts to approximately 90 cm from the vine row and 90 cm deep. This region of both grids has some of the highest salinity of the profile, at or above 4.0 dS/m. The saturation percentage (SP) at the 90-cm depth exceeded 90 percent at both sampling grids. The SP of a soil correlates well with soil texture, and when the SP ranges from 65-135 percent, the soil is characterized as clay (II-19, Neya et al., 1978). Clays are fine textured soils that have low permeability; thus, the salts appear to be accumulating at the 90-cm depth where infiltration is inhibited by inherent soil characteristics.

The average root zone salinity of the two grids is approximately 1.9 and 3.1 dS/m for the north and south grids, respectively. The groundwater was at a depth of 2.21 m and 2.84 m at the north and south grids, with corresponding ECs of 0.21 dS/m and 0.97 dS/m. (II-15, Ayers and Westcot (1985)) present salinity crop tolerances and yield potential for grapes. To attain 100 percent yield potential, the average root zone salinity should not exceed 1.5 dS/m. Likewise, for 90, 75, 50, and 0 percent yield potential, the average root zone salinity should not exceed 2.5, 4.1, 6.7, and 12 dS/m, respectively. While certain management practices, varietal differences, and environmental factors may impart a higher level of tolerance among certain vineyards, there is the potential for the salinity conditions at this site to impact yield, unless the soils are leached of the salts.

VI. SALINITY MANAGEMENT BY LEACHING

The primary management strategy for combating salinity is leaching, and leaching must be practiced when soil salinity has the potential to impact yield (II-15, Ayers and Westcot, 1985). Leaching occurs when water is applied in excess of soil moisture depletion due to evapotranspiration (ET) (II-16, Hanson et al., 2006), or the amount of water that is evaporated from the soil and transpired by the plant. Leaching may occur during the winter season when fields are fallow or crops are dormant, or leaching may occur whenever an irrigation event occurs.

The leaching fraction (Lf) is the fraction of the total applied water that passes below the root zone. This can be expressed as:

$$Lf = ECw/ECdw \qquad \text{(Equation 1)}$$

where ECw is the electrical conductivity of the applied water, and ECdw is the electrical conductivity of the drainage water at the bottom of the root zone, which is equal to 2ECe (II-15, Ayers and Westcot, 1985).

The leaching requirement (Lr) is the minimum amount of the total applied water that must pass through the root zone to prevent a reduction in crop yield from excess salts. Rhoades (1974) (II-21) proposed the following equation for the Lr:

$$Lr = ECw/(5ECet - ECw) \qquad \text{(Equation 2)}$$

where ECet is the average soil salinity, as measured by saturated paste extract, that a crop can tolerate. Thus, there are two factors necessary to estimate the Lr. One factor is the salt concentration of the applied water, which can vary substantially in the Delta based on time of year and location. The other factor establishing the Lr is the salt tolerance of the crop. Some crops are more tolerant of salinity than others. Alfalfa is a widely planted crop in the Delta and is considered moderately sensitive, so the following derivation uses salinity tolerance levels for alfalfa as an example. Beyond an average root zone soil salinity threshold (ECet) of 2.0 dS/m and a seasonal average applied water salinity threshold (ECw) of 1.3 dS/m, alfalfa yield reductions are expected (II-15, Ayers and Westcot, 1985). This relationship between ECe and ECw, where ECe = 1.5ECw, holds under the following assumptions: there is a 15-20 percent Lf and a 40-30-20-10 percent plant water uptake pattern from the upper quarter of the root zone to the lower quarter. Using these values in Equation 2, the Lr is calculated to be 15 percent. When ECet is given at 2.0 dS/m but ECw ranges from 0.5-2.0 dS/m, the Lr ranges from 5-25 percent.

The average ECw for this range of values is 1.3 dS/m, and the average Lr is 15 percent. The yield potential guidelines in Ayers and Westcot (II-15, 1985) assume a 15 percent Lf. Using these guidelines to predict crop response from a given applied water salinity requires an achievable Lf of 15 percent, and when ECw is higher than 1.3 dS/m, the Lf must be higher than 15 percent.

While a 15 percent Lf is a general rule of thumb in agricultural systems (II-19, Neya et al., 1978), given the Delta's unique circumstances and constraints, a 15 percent Lf may not always be possible. Soil permeability may be low, water tables are typically around 2 meters from the soil surface, and groundwater quality may be near the salinity thresholds for maintaining crop yield potential. Additionally, perennial crops such as alfalfa, pears and grapes have a high annual ET demand. It can be difficult to apply enough water to meet the ET and Lr of these crops, particularly on low permeability soils like the ones on Ryer Island.

Using soil salinity data gathered on Ryer Island and water salinity data from the California Data Exchange Center (II-42, CDEC, 2016) at Rio Vista – a water quality monitoring station near to the vineyard irrigation water intake on Ryer Island – a Lf can be calculated for the vineyard. Because the seasonal average salinity of the applied irrigation water was not tested as part of the Ryer Island project, hourly CDEC data for the period of April 1, 2016 to August 10, 2016 (ranging from 102-298 μS/cm or 0.102-0.298 dS/m) was averaged to derive an ECw for the vineyard, 142 μS/cm (0.142 dS/m). The bottom of the drip irrigation wetting front was assumed the bottom of the root zone, having average ECe values of 3.55 dS/m and 4.56 dS/m for the two grids (ECdw equal to 7.1 dS/m and 9.12 dS/m, respectively). Using Equation 1, the Lf at both vineyard locations was 2 percent. Using the same ECw, a grape ECet value of 1.5 dS/m, and Equation 2, the Lr for maintaining 100 percent yield potential for grapes is 2 percent. Thus, in 2016, the achieved Lf at the vineyard was equal to the Lr for maintaining yields. What this means is that we would not expect to see yield declines due to salinity in this situation because the achieved Lf met the Lr for maintaining yields. Had the Lf been lower than the Lr, yields may have been affected.

In 2015, using CDEC (II-42) data for the same time period that ranged from 148-3,627 μS/cm (0.148-3.627 dS/m), the average seasonal irrigation water salinity was an ECw of 509 μS/cm (0.509 dS/m). Again, using Equation 2 to calculate the Lr for this higher seasonal applied water salinity, we need a Lr of 7 percent to maintain 100 percent yield potential for grapes. This illustrates that as the seasonal average applied water salinity increases, a higher Lr will be required in order to maintain crop yields. If it is not possible to apply enough water to achieve a 7 percent Lf due to poor soil permeability, proximity of groundwater, or other agronomic considerations (such as crop disease susceptibility exacerbated by standing water), then this higher applied water salinity in 2015 compared to 2016 would suggest detrimental effects on crop yields, increases in the salt load of the soil, or both.

VII. CONCLUSIONS

Leaching is the primary means of managing salinity and must be practiced when there is the potential for salinity to impact yield. Soil sampling data from Ryer Island illustrate the inherent low permeability of certain Delta soils, the build-up of salts in the soil to levels that have the potential to affect crop yields, and a low achieved Lf. The Delta's unique growing conditions, including low permeability soils and shallow groundwater, coupled with unpredictable winter rainfall, put constraints on growers' ability to manage salts by leaching and achieve a Lf that meets the Lr to sustain crop yields. Higher surface water salinity would result in a higher Lr. Thus, salinity – a pervasive issue in the Delta – will continue to impact Delta agriculture, especially under conditions of higher surface water salinity.

I declare under penalty of perjury under the laws of the State of California that the foregoing statements are true and correct.

Executed on the 1st Day of September at Stockton, California.

Michelle Leinfelder-Miles

Michelle Leinfelder-Miles

REFERENCES

Ayers, R. S. and D. W. Westcot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. FAO, United Nations, Rome. 174 p.

Brown, P.H. and F.J.A. Niederholzer, 2007. Nutrition. In: Mitcham, E.J. and R.B. Elkins (eds.), 2007. Pear Production and Handling Manual. Publication 3483. University of California Agriculture and Natural Resources. Oakland, CA.

California Data Exchange Center (CDEC), California Department of Water Resources. Accessed August 2017. Rio Vista (RIV) station data. http://cdec.water.ca.gov/cgi-progs/queryF?s=RIV.

Hanson, B., S.R. Grattan, and A. Fulton, 2006. Agricultural Salinity and Drainage. Publication 3375. University of California Agriculture and Natural Resources. Oakland, CA.

Neya, R.A., R.S. Ayers, and A.N. Kasimatis, 1978. Salinity Appraisal of Soil and Water for Successful Production of Grapes. Leaflet 21056. University of California Division of Agricultural Sciences. Berkeley, CA.

Natural Resources Conservation Service (NRCS), United States Department of Agriculture. Accessed August 2017. Soil Survey Geographic (SSURGO) Database for San Joaquin County, California. Accessed via SoilWeb Apps: http://casoilresource.lawr.ucdavis.edu/drupal/node/902.

Rhoades, J. D. 1974. Drainage for salinity control. In: J. van Schilfgaarde (ed.), Drainage for Agriculture. Agronomy Monograph No. 12. SSSA, Madison, WI. p. 433-461.

Rhoades, J.D. 1996. Salinity: Electrical conductivity and total dissolved solids. In: Sparks, D. L., A. L. Page, P. A. Helmke, R. H. Loeppert, P. N. Soltanpour, M. A. Tabatabai, C. T. Johnston, and M. E. Sumner (ed.). 1996. Methods of soil analysis, part 3, chemical methods. Soil Science Society of America, Inc. and American Society of Agronomy, Inc. Madison, WI.

STATEMENT OF SERVICE

CALIFORNIA WATERFIX PETITION HEARING
Department of Water Resources and U.S. Bureau of Reclamation (Petitioners)

I hereby certify that I have this day submitted to the State Water Resources Control Board and caused a true and correct copy of the following document(s):

to be served **by Electronic Mail** (email) upon the parties listed in Table 1 of the **Current Service List** for the California WaterFix Petition Hearing, dated July 11, 2016, posted by the State Water Resources Control Board at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/service_list.shtml

I certify that the foregoing is true and correct and that this document was executed on July 12, 2016.

Signature: ______________________
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