Spencer Kenner (SBN 148930)
James E. Mizell (SBN 232698)
DEPARTMENT OF WATER RESOURCES
Office of the Chief Counsel
1416 9th St.
Sacramento, CA 95814
Telephone: +1 916 653 5966
E-mail: jmizell@water.ca.gov

Attorneys for California Department of Water Resources

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	REBUTTAL TESTIMONY OF JOEL KIMMELSHUE, PHD, CPSS (EXHIBIT DWR-85)

I Joel Kimmelshue do hereby declare:

I. INTRODUCTION

My name is Joel Kimmelshue and I am a Certified Professional Soil Scientist (license #18204) with the Soil Science Society of America. A true and correct copy of my Statement of Qualifications is attached as Exhibit DWR-25. A brief summary of relevant experience is summarized below.

My educational background includes a Bachelor of Science (1990) in Soil Science from California Polytechnic State University, San Luis Obispo with a concentration in Crop Science, a Master of Science (1992) in Soil Science with a concentration in Agricultural Engineering from North Carolina State University, and a Doctor of Philosophy (1996) in Soil Science with a concentration in Water Resources from North Carolina State University. My education included extensive coursework in soil and crop science (fertility, chemistry, physics, genesis and morphology, land use, agricultural production, etc.) irrigation management (irrigation systems, irrigation design, irrigation management, etc.) and drainage management (agricultural drainage systems, unsaturated flow, saturated flow, agricultural drainage modeling, etc.). My MS thesis was entitled, “Nitrogen Mineralization of ^{15}N Labelled Corn Residue as Influenced by Water Management. My PhD dissertation was entitled, “The Influence of Drainage Management and Nitrogen Fertility Practices on Nitrate Leaching.” Both research efforts assessed the influence of high water tables on nitrogen dynamics in agricultural systems.

I was raised on a diversified irrigated agricultural operation in northern California. This farm still exists today and we have grown and/or currently grow almonds, walnuts, dry edible beans, sugar beets, wheat, safflower, and other crops. For 13 growing seasons, I conducted and/or lead irrigation management and decisions on these various crops for multiple fields/orchards ranging from 10 to 250 acres. I am fully experienced in the operation and management of both gravity and pressurized irrigation systems.

Since completion of my research-based PhD in 1996, I have been working in the private consulting industry as an agricultural science specialist. My areas of expertise include:

- Soil and water salinity management for agriculture
- Production agricultural systems
- Soil/water/plant relations in arid climates
- Irrigation and drainage management
- Land use assessments and crop identification
- Crop consumptive use estimates
- Expert witness testimony
- Soil and land use evaluations for the implementation of irrigation systems and crop production
- Water resources
- Soil nutrient interactions and environmental issues in soils

- Agricultural land application and reuse systems for various liquid and solid byproducts
- Dust and Erosion Control
- Water quality for irrigated agriculture
- Regulatory support and negotiation for agriculture
- Policy, regulatory, and environmental influences on agricultural production systems
- Soil and water conservation
- Agricultural research

Currently, I am a Principal Soil and Agricultural Scientist with Land IQ and a founding co-owner in the firm. I have over two decades of technical experience in agricultural and water resources consulting in the western United States (especially California), and agricultural research and crop production throughout the United States. My consulting experience includes practical and applied solutions for development of water/soil management systems and agricultural systems, specifically with irrigated agriculture. Prior to opening my own agricultural sciences firm, I worked for CH2M. While there, I served as the firm-wide Agricultural Services Technology Director. My responsibilities included leading a group of 25-30 scientists in the areas of agricultural technologies (both science and engineering) as related to the work we performed.

Approximately 80 percent or more of the work that I perform on a daily basis, and for over the past 21 years, centers around salinity, nutrient, and irrigation and drainage management in agricultural production systems. Throughout this time, I have been the lead scientist on approximately 70-80 projects in the states of California, Arizona, New Mexico, Texas, Montana, Nevada, Oregon, Washington, Utah, and Iowa and in the countries of Israel, Turkey, and Egypt, the science of which are directly related and applicable to this testimony. The vast majority of my salinity and irrigation management technical work has taken place in California, specifically in the Central Valley. Specific examples of these projects can be found in my Statement of Qualifications. [Exhibit DWR-25.]

I was asked to review the testimony, cross examination, and technical exhibits of witnesses Dr. Michelle Leinfelder-Miles and Mr. Terry Prichard. My written rebuttal testimony will address the opinions of both witnesses with the common major technical themes in their testimonies including:

- Existing scientific knowledge of salinity management
- Leaching requirements and actual leaching fractions
- Farm management practices, including
  - Irrigation management
  - Drainage management
- Localized studies
- Impact of precipitation on soil salinity.

Within each of the categories above, the foundational accepted science as reported in peer reviewed literature will be referenced. Then existing witness written and oral testimony and exhibits are addressed. In particular, I will be providing my opinions in response to the Dr. Leinfelder-Miles and Mr. Prichard testimonies.

II. SUMMARY OF TESTIMONY

I have reviewed the Dr. Leinfelder-Miles and Mr. Prichard testimonies and associated work products as it relates to the water rights proceedings for the California WaterFix. This written rebuttal testimony directly responds to those testimonies, and states concerns with those testimonies and their methodologies. I also address misleading, uncharacterized and, in some cases, incorrect statements.

It is important to note that the testimony of Dr. Leinfelder-Miles is a building block for the testimonies of Mr. Prichard and other testimony on economics and hydrology, etc. Specifically, Mr. Prichard relies on Dr. Leinfelder-Miles analysis to use a 5% leaching fraction to compute his crop damages.[1] Then Dr. Michael uses the crop damages computed by Mr. Prichard to compute his alleged economic damages.[2] Thus, both the Mr. Prichard and Dr. Michael testimonies[3] depend upon the accuracy of the Dr. Leinfelder-Miles analysis.

The testimonies provided by witnesses Leinfelder-Miles and Prichard, in relation to other, more comprehensive studies, and my professional experience pose unclear, unsubstantiated, and in some cases inaccurate results. Below is a summary of the key issues with the Leinfelder-Miles and related Prichard testimonies, analyses, and supporting materials. In particular, the testimony, and associated studies, by Dr. Leinfelder-Miles:[4]

- do not account for or provide adequate recognition of the occurrence of salinity increases during drought conditions during the growing season.[5]
- fail to recognize the significant impact of natural leaching of salts during the winter season caused by precipitation and that associated variability by year.
- provide limited recognition of the significant impact of irrigation method and management on leaching of salts below the root zone.
- do not adequately recognize the potential salinity contributions sources from shallow groundwater.[6]
- show uncharacteristically low leaching fractions.[7]
- incorrectly applied standard leaching fraction calculations.[8]
- draw conclusions from research that has not been independently peer reviewed.[9]

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[1] Exhibit SDWA 92, pp. 3:19-4:7.

[2] Exhibit SDWA 134-R, p. 5:1-15.

[3] Exhibit SDWA 92; Exhibit SDWA 134-R

[4] Exhibit SDWA 140 (Leaching Fractions Achieved in South Delta Soils under Alfalfa Culture, Project Report Update August 2016, by Michelle Leinfelder Miles); Exhibit II-14; Exhibit II-13 (Testimony of Leinfelder-Miles).

[5] Exhibit SDWA 140.

[6]Exhibit SDWA 140.

[7] Exhibit SDWA 140; Exhibit II-14.

[8] Exhibit SDWA 140; Exhibit II-14.

[9] Exhibit SDWA 140;

- do not report actual sampling locations for multiple studies for correlation to site specific soil type, drainage systems, surface waterways, subsurface water intrusion, and other impactful variables.[10]
- do not report the presence or absence of surface or sub-surface drainage systems and the corresponding management of those systems for salinity management.
- do not propose any grower management options to mitigate any increase in salinity regardless of water quality used for irrigation or environmental conditions.[11]

In particular, the testimony and work from Mr. Prichard:

- Uses erroneous leaching fraction estimates to calculate yield losses.[12]
- Uses erroneous values in the spreadsheet calculator to determine yield impacts.[13]
- Only highlights years with calculated possible yield loss associated with dry precipitation conditions. Does not fully recognize wet year contributions to reduction of soil salinity levels and full production.[14]

III. BACKGROUND

The following background is responsive material to the many specific rebuttal points made in this testimony but is consolidated here as a single scientific explanation for clarity.

Several specific factors influence the potential for soil salinization, including soil physical properties, soil chemical properties, land use or crop type, irrigation methods, precipitation, and water table elevation. Crops vary in their tolerance to salinity, and recently crop varieties (especially alfalfa) have been developed to tolerate more saline and

[10] Exhibit SDWA 140; Exhibit II-14; Exhibit II-13.

[11] Exhibit SDWA 140; Exhibit II-14; Exhibit II-13.

[12] Exhibit SDWA 92; (Testimony of Prichard).

[13] Exhibit SDWA 92.

[14] Exhibit SDWA 92.

drought conditions. Agricultural soil salinity is managed by applying more water than is required by the crop to grow. This water carries salts in the root zone to depths below the root zone.

To manage salt ions in the root zone, excess irrigation water is applied to leach salt ions lower in the profile and drain past the root zone. The additional water needed (or required) to sufficiently remove the salts is known as the **leaching requirement**. The leaching requirement can be calculated if the salinity of irrigation water and the crop salt tolerance is known.

The **leaching fraction**, a term which is sometimes mistakenly used interchangeably with leaching requirement, is the water amount that passes through the root zone, not the required amount to achieve a particular salinity. Theoretically, if the leaching fraction is less than the leaching requirement, salts will build up in the root zone. However, this may not always be the case because there are multiple factors that influence the extent of salinization, including soil type, irrigation and drainage methods and management, crop type/variety, the frequency/magnitude/duration of precipitation, and the effect of crop growth and other management practices on overall soil salinity. The leaching requirement can be roughly estimated using charts that plot the results of this calculation for different irrigation water salinities and crop salt tolerances. An example is shown in Figure 1.

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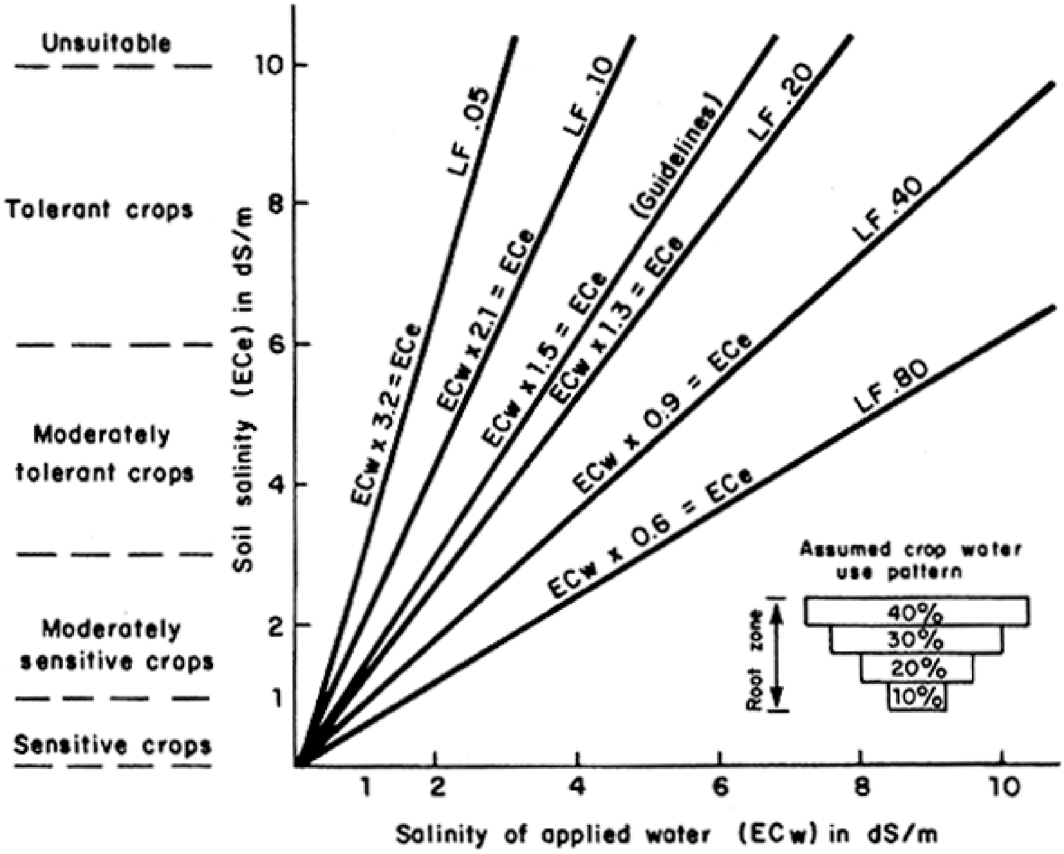

Figure 1. Effect of applied water salinity (ECw) upon root zone soil salinity (ECe) at various leaching fractions (LF). Source: Ayers and Westcot 1985.

Salinity in agricultural soils has been studied in the California Delta since 1979 (Hildebrand, 1993; Hildebrand, 2005; Hoffman, 2010; Hoffman, et al., 1979; Hoffman, et al., 1983; Meyer, et al., 1979). These early studies were mainly conducted to determine corn salt tolerance. Since these early studies, models and additional field studies have been used to estimate the maximum salinity of irrigation water that can be used to irrigate the most sensitive Delta crop varieties without harm.

Ayars, et al., (2012) reviewed general leaching concepts for salinity management and the accuracy of various models that estimate irrigation water quality and quantity necessary for leaching requirements. One of the conditions that precludes a steady state condition is poor irrigation water distribution uniformity. The report further notes that accounting for non-uniformity of irrigation to estimate the leaching requirement has not been addressed to date. Growers have the option of applying enough water to ensure that the leaching requirement is met throughout the field, or accepting some reduction in yield in parts of the field rather than over-irrigate most of the field, neither of which is ideal.

Of particular importance is that these authors reviewed the impact of high water tables and upward water flux on leaching requirements, and stated that "*The ultimate salinity distribution in the soil profile will depend on whether the water table was static, as in a lysimeter study, or was dynamic, as would be found in field studies.*" Though crops can use some of this water coming from lower depths in the root zone, "*soils with a shallow water table frequently depress yields due to reduced soil aeration and inhibited root extension. If the shallow groundwater is saline, yields may be further reduced.*" (Ayars, et al., 2012, p. 389.)

Of particular importance, a comprehensive literature assessment and south Delta-specific study (Hoffman, 2010) was commissioned by the State Water Resources Control Board, Division of Water Rights. This study not only summarized plentiful and applicable historic literature, but also arrived at the following repeatable conclusions[15] pertinent to this rebuttal of points raised in the Dr. Leinfelder-Miles and Mr. Prichard testimonies:

- Based on the analysis of a range of water quality (0.1-1.4 dS/m) from 1990 to 2006, no impact on any crop production systems is expected (Hoffman, 2010; p. 98).
- Model results indicate that water quality standards could be increased (0.9-1.1 dS/m) without any adverse effects on yields (Hoffman, 2010; p. 101).
- Of particular note is the minimum threshold standards for alfalfa and beans based on dated literature (Ayers and Westcot, 1985). As with other crops, newer varieties (especially alfalfa) have been developed to not only provide higher yields, but also to increase resilience to environmental impacts such as moisture, nutrient, and salinity stressors.

[15] Repeatable conclusions are necessary to validate field study results. The strength of a scientific study is related to independent validation of that study through repeatable and similar results. This is especially common and true in natural systems research.

- Saline soils were identified in 1992 on approximately 5% of all ground in the south Delta indicating that existing conditions only promote salinity build up in marginal soils (Hoffman, 2010; p. 98).

- Soil types (even though finer textured in some areas) do not pose a restriction on the ability of a grower to implement leaching fractions in response to a possible leaching requirement. This was also viewed in soils in the Imperial Valley (Hoffman, 2010; p. 98). This conclusion is inconsistent with conclusions of Dr. Leinfelder-Miles.[16]

- It is necessary to couple precipitation with actual leaching fractions to determine the potential impact of water salinity on crop production and correction measures where necessary (Hoffman, 2010; p. 100).

- In the south Delta, average border irrigation efficiency (commonly used on alfalfa) is 78%, furrow irrigation 70%, sprinkler 75%, and micro 87% (Hoffman, 2010; p. 99. CA DWR Crop Survey, 2007).

- Leaching fractions are critical in determining guidelines for moving salts through soil to below the root zone. The lowest leaching fractions identified involved a small number of fields growing alfalfa. As a result, if a leaching fraction of 7% were ever encountered, it would be in very constrained and minor areas even within fields. Leaching fractions in the south Delta averaged between 21% and 27%. More typical minimum leaching fractions ranged from 11% to 22% (Hoffman, 2010; p. 100).

- Surface and sub-surface tile drains have been installed in the Delta where drainage management is deemed necessary to produce crops. Not only do drainage systems function to remove water from the root zone to avoid water-logging conditions, but also serve as a mechanism to control salinity (Hoffman, 2010; p. 99).

The key take home message from the Hoffman study demonstrates that crop production has not been impacted by current irrigation water salinity levels and will not be impacted by anticipated future salinity levels. This contradicts Prichard's opinion that impacts to crop production is assumed to occur from salinity.[17] Repetitive and objective conclusions throughout the Hoffman study support this over-arching conclusion.

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[16] Exhibit SDWA 140; II-14; II-13.

[17] Exhibit SDWA-92, p. 14:3-5.

IV. SUBSTANTIVE REBUTTAL

Questionable Studies Relied Upon by Dr. Leinfelder-Miles, and therefore Mr. Prichard and Dr. Michaels

This rebuttal testimony presents foundational objective opinions in response to Dr. Leinfelder-Miles original testimony, and supporting materials.[18]

The explanation and description of salinity management and plant growth is summarized in the initial testimony of Dr. Leinfelder-Miles. She mentions that her work in the Delta focused on salinity management and her testimony was predicated/explained by a series of studies designed to assess the potential impact on crop production. These studies (overall, and with various components) are referred to below.

A. Tomato, Alfalfa, Grape, and Pear Studies, Sampling Events, and Variables

1. Tomato Study

My opinion is the study results produced from the tomato study and testified to by Dr. Leinfelder-Miles are questionable because they do not fully recognize the impact of natural precipitation or the shift in irrigation method.[19] Precipitation frequency, intensity, and duration is a key factor in determining soil salinity as I will describe below. The tomato study should only be used for demonstrating increases in salinity due to a change in irrigation method (surface gravity to pressurized drip) and drought conditions. As it is reported, the study tends to create a biased opinion of salinity build up due to water quality concerns, when in reality, it is an artifact of a past irrigation method with higher leaching fraction as compared to a new irrigation method with a lower leaching fraction and drought conditions.

Failure to Properly Account for Precipitation

Overall, the conclusions of the tomato study indicated that over the three-year study, average root zone salinity increased from 0.79 dS/m to 1.31 dS/m. The timeframe of this

[18] Exhibit SDWA 140, Exhibit II-14, Exhibit II-13.

[19] Exhibit II-13, p. 4:4-19; Exhibit II-14, p. 9.

study occurred from the spring of 2013 through the fall of 2015.[20] This same timeframe concurred with one of the most severe droughts that our state has seen in decades.[21] The winter precipitation prior to the 2013 spring sampling event experienced rainfall in November and December 2012 of 3.39 and 4.11 inches respectively.[22] These are significant amounts in a relatively short period of time (2 months) which would provide a natural leaching fraction resulting in correspondingly low soil salinities. Essentially, precipitation events, as described above, would have the effect of resetting the soil salinity in the root zone. This effect is shown in the tomato study results of Leinfelder-Miles (Figure 1 below).

Alternatively, the fall of 2015 shows relatively higher soil salinity. The Twitchell Island CIMIS weather station recorded a total of 2.59 inches of rainfall from January through September of 2015, approximately 3 times lower than average for this 9-month period.[23] From this point forward during the study, it is not surprising that an increase in soil salinity occurred during this same timeframe of lower precipitation, and it is entirely feasible that the majority of the increase in salinity can be attributed to a naturally reduced leaching due to fewer precipitation events. Had natural precipitation events not occurred, this reclamation reduction in soil salinity could have also been achieved through dedicated grower management based on leaching requirements.

It would be interesting to continue this same sampling regime on the tomato fields in the spring of 2017 to determine the salinity levels at that time considering the significant rainfall the Delta has experienced in the 2016-2017 winter. Overall, the likely conclusion is that the predictable and significant leaching attributable to precipitation has occurred and soil salinity levels in these fields are correspondingly low.

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[20] Exhibit II-13, p. 4:4-19; Exhibit II-14, p. 9.

[21] See waterboard.ca.gov/waterrights/water_issues/programs/drought/index.shtml

[22] http://www.cimis.water.ca.gov/Stations.aspx

[23] http://www.cimis.water.ca.gov/Stations.aspx

Dr. Leinfelder-Miles presented a compelling figure showing salinity build up in drip irrigated tomato fields (Figure 1). Again, precipitation impacts and irrigation method change should be recognized as significant contributing factors to the perceived increases. It is true that precipitation is unpredictable; however, when a number of years occur with lower than average precipitation and salinity increases occur, growers would recognize this and manage their agricultural systems accordingly.

II_14

Delta Research Projects

1. Drip-irrigated tomato field

Electrical Conductivity, ECe (dS/m)

Spring 2013

Depth (cm)	Bed Center			Furrow
0 - 10	0.84	0.74	1.24	
10 - 20	0.93	0.84	0.75	0.72
20 - 30	0.81	0.84	0.92	0.74
30 - 40	0.94	0.84	0.73	0.76
40 - 50	0.67	0.92	0.74	0.79
50 - 60	0.64	0.76	0.74	0.79
60 - 70	0.68	0.79	0.75	0.71
70 - 80	0.82	0.77	0.79	0.71
80 - 90	0.83	0.77	0.74	0.73
90 - 100	0.81	0.80	0.78	0.66

Fall 2015

Depth (cm)	Bed Center							Furrow
0 - 10	2.50	2.51	2.97	2.34	2.67	2.27	2.76	2.69
10 - 20	1.37	1.17	1.12	1.02	1.05	0.96	2.51	4.49
20 - 30	0.85	0.85	0.85	0.86	0.90	1.08	0.81	1.04
30 - 40	0.87	0.94	0.99	0.92	0.95	0.87	0.74	0.76
40 - 50	1.12	0.89	1.26	1.15	0.99	0.86	0.85	0.71
50 - 60	1.06	1.05	1.37	1.08	0.89	0.84	0.61	0.71
60 - 70	0.94	0.96	1.52	1.16	1.09	0.88	0.71	0.87
70 - 80	0.83	0.94	1.32	1.49	1.21	1.11	1.01	0.87
80 - 90	1.15	1.17	1.46	1.51	1.58	1.56	1.43	1.21
90 - 100	1.47	1.75	1.66	1.68	1.67	1.68	1.68	1.51

Legend* 2.5 3.5 5.0 7.6 13.0

Figure 1. Drip irrigated tomato field results [Leinfelder-Miles, II-14, p. 9.]

Failure to Account for a Shift in Irrigation Method

Equally exacerbating was the conversion to a pressurized drip irrigated systems in tomatoes, which was previously a gravity surface irrigation system. In my opinion, soil salinity levels would increase with the combination of severe drought conditions and highly efficient irrigation systems. Drip irrigation has been somewhat recently (over the past 5-10 years) implemented in processing tomato production primarily due to the ability to achieve higher yields and better quality. It was stated in Dr. Leinfelder-Miles' cross examination that drip irrigation was implemented following furrow irrigation at the start of this study.[24] Drip irrigation is generally considered more efficient as compared to surface irrigation methods. One common drawback of drip irrigation is the usual inability to apply water at volumes that provides an adequate leaching fraction to maintain soil salinity. This was also stated by Dr. Leinfelder-Miles in her testimony.[25] Using drip irrigation is a grower choice, and tradeoffs need to be recognized and managed accordingly. Salinity is building up in these systems under current conditions, however most likely due to a combination of differences in precipitation and irrigation methods and management rather than water quality.

2. Alfalfa Study:

In Dr. Leinfelder-Miles' testimony, the reported result of the alfalfa study was that over three years, four out of seven fields had ECe levels that exceeded 10 dS/m at 90 cm (3 feet).[26] Dr. Leinfelder-Miles also references a study (Brown and Niederholzer, 2007) and states that salinity may build up at 60 cm (2 feet) and may be even shallower in annual cropping systems.[27]

Dr. Leinfelder-Miles does not mention the source of salinity at 90 cm (3 feet) or deeper. In other testimony by Dr. Leinfelder-Miles, she indicates that salinity in some areas of the Delta can originate from shallow groundwater.[28] She also states that she believes the underlying groundwater depths have resulted in a "barrier" to leaching.[29] The fact that measured soil salinity levels in the alfalfa study were elevated to a relatively high value at 10 dS/m at some points during the study at 3 feet indicates that this salinity may originate from sources of groundwater salinity rather than leaching of salts from above (e.g. brackish

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[24] November 3, 2016 Transcript Vol. 26, p. 155:2-4.

[25] November 3, 2016 Transcript Vol. 26, pp. 155:15-156:6.

[26] Exhibit SDWA 140, p. 9; Exhibit II-13, p. 4:13-19.

[27] Exhibit II-13, p. 4:13-19.

[28] November 3, 2016 Transcript Vol. 26, pp. 150:20-151-:1.

[29] November 3, 2016 Transcript Vol. 26, pp. 157:20-158:3.

water intrusion into the shallow groundwater). Dr. Leinfelder-Miles does not divulge the locations of the 7 fields she evaluated, let alone the sampling locations within those fields and the proximity to surrounding water sources. If these locations were revealed, then proximity to other potential salinity sources could be evaluated.

The Leinfelder-Miles study entitled, "Leaching Fractions Achieved in South Delta Soils under Alfalfa Culture: Project Report Update 2016" (Leinfelder-Miles, 2016) states the following:

1. "At some sites, there may be the potential to decrease salinity with irrigation management. This is most evident at Site 6, where the top of the profile is being leached fairly well, but the middle and bottom sections are not. Lengthening the run-time so that water sits longer on the middle and bottom sections could be a management option, particularly because this soil has a higher infiltration rate relative to the other sites."[30]

This conclusion drawn by Dr. Leinfelder-Miles provides an example of a grower management action that can, and has been proven many times, to result in reclamation and management of saline profiles through dedicated leaching events. She admits that grower management (if necessary) is a key variable in managing any cropping system potentially affected by periodic salinity increases due to low precipitation and other variables.

2. "Alfalfa yields at these sites met or exceeded the average yield for California alfalfa and was not correlated with leaching fraction, suggesting that other factors like pest pressure, stand quality, or market forces may have been more influential on yield during the 2013 and 2014 growing seasons. Despite the lack of correlation between salinity and yield, salinity at these sites is increasing down the soil profile to unsuitable levels, which could challenge alfalfa yield in the future, preclude the growing of other salt-sensitive crops, or reduce agricultural longevity of these fields."[31]

This conclusion indicates that there is not necessarily a correlation between yield and soil salinity levels. Rather, it suggests that other variables explain the differences. The statement related to increasing salinity down the profile again, could be very well correlated

[30] Exhibit SDWA 140, p. 13.

[31] Exhibit SDWA 140, p. 14.

to drought conditions and grower management of irrigation systems rather than the water quality itself.

3. "Recent studies have emphasized the importance of rainfall for leaching (Platts and Grismer, 2014; Weber et al., 2014), suggesting that irrigation water during the season cannot substitute for low winter rainfall. Low winter rainfall results in inadequate leaching unless other measures are taken, such as replenishing the soil profile with irrigation water after harvest in the fall (Weber et al., 2014) or irrigating before a storm in order to leverage the rainfall and optimize winter leaching. Such measures may be necessary to sustain soil longevity and agricultural productivity in the Delta where the achieved leaching fraction is low, particularly in low rainfall years."[32]

This conclusion demonstrates the need for growers to recognize historic rainfall and soil salinity levels to better manage their cropping systems. It accurately states that "[s]uch measures may be necessary to sustain soil longevity and agricultural productivity…." It also implies that high rainfall years provide the natural leaching requirement necessary for a "reset" of the soil salinity profile – and when that does not occur, grower intervention with leaching activities is necessary.[33] This is the only direct mention of precipitation in all of the Leinfelder-Miles studies. Her conclusions are correct in this case, but this absolutely significant variable should be recognized more as a separate section of her work; both in low and high rainfall years.

In the Leinfelder-Miles testimony, she indicates that 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.[34] This observation contradicts the conclusions of the alfalfa study which show no correlation between yield and soil salinity (see conclusion #2 above).

The following items are also of concern from the Leinfelder-Miles alfalfa study (SDWA 140)

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[32] Exhibit SDWA 140, p. 14.

[33] Exhibit SDWA 140, p. 14.

[34] Exhibit SDWA 140, pp. 1-2; Exhibit II-13, p. 4:21-23.

- No indication exists that this study has gone through a formal and independent peer review process.

- Although soil series were provided, individual map units were not identified. Variation does occur within a broad reaching soil series description, whereas individual map units are more representative of more localized conditions. All soils are described as being artificially drained for agricultural production (USDA/SCS, 1992 – Soil Survey of San Joaquin County). Of key note, the soil series identified (Merritt, Grangeville, and Ryde) have saturated hydraulic conductivities of 0.6, 3.0, and 5.2 inches/hour, respectively (NRCS, SSURGO). Even the Merritt soil at 0.6 inches/hour has adequate rates of conductivity whereby the argument that dedicated leaching cannot take place due to the time required is not supported.

- Specifics on actual drainage systems (surface or sub-surface) or operational parameters of those systems at the evaluated sites are not presented in the study. Without this information, the results of the study cannot be adequately interpreted for validity or reliability.

- The alfalfa study showed no correlation to yield loss due to some fields having elevated salinity or not. This suggests that other variables are impacting yields and that irrigation management in this surface irrigated system satisfies leaching requirements. This may be due to the choice of alfalfa variety.

- The alfalfa varieties were not mentioned in the study. New varieties of some crops have been developed specifically for salt tolerance. For example, the historic recommended salt threshold for alfalfa is 2 dS/m; however, Benes et al. (2014) demonstrated that newer varieties of salt-tolerant alfalfa can be grown in soil with an EC of 6.5 dS/m with no yield loss. Without knowing the varieties, a clear distinction of whether yield loss should be expected cannot be ascertained.

- No exact location of the study sites or sampling locations was provided. Thus, there is no way to spatially correlate to variables such as water supply routing, drainage systems, groundwater levels, trends in groundwater quality, proximity to water ways, field elevations, drainage systems, etc. All of these variables can significantly impact results and are critical factors to consider when interpreting any differences in salinity levels.

- Of particular concern are the leaching fractions calculated in the alfalfa study. It is interesting to note that sites 3 and 5 have significantly higher leaching fractions than do the other five sites. The ECe at the root zone depth is relatively low compared to other sites at similar depths, yet no conclusions were drawn as to why this was the case (e.g. soil type, existence or absence of drainage systems, irrigation management, previous crop, alfalfa age, sampling location, etc.)

- The majority of the leaching fractions calculated were below 10% (e.g. 2%, 3%, 5%, 6%, 7%, etc.). These levels of leaching fractions are not common in even the most efficient surface irrigated systems (Howes, D. 2017 – Personal

Communication). By definition, the leaching fraction is determined as the ratio of the salinity of the applied irrigation water to the salinity of the soil solution extract below the root zone (Ayers and Westcott, 1985). Its development was predicated on well drained soils without high water tables. Peer reviewed research has shown that this empirical ratio does not apply to high water table soils. (Sreenivas and Reddy, 2008.) Key to this ratio, and its validity, is the source of the salt content of the soil immediately below the root zone. It is expected that the salt content in the soil immediately below the root zone has originated from that salt contribution on the surface of the soil (i.e. salinity in irrigation water and soil amendments). Contributions of salt from other sources (e.g. groundwater salinity) should not be included in the leaching fraction as it originates from a different source of salt. The Leinfelder-Miles work mentions sampling of groundwater for salinity and not necessarily the soil salinity below the root zone. The study does not indicate the source of salinity in the groundwater below the root zone. Therefore, if the groundwater is elevated in salinity due to intrusion of another salt source, the calculations of leaching fractions are incorrect and underestimating the actual leaching fraction. The inappropriate use of this basic ratio has been made elsewhere in high water table soils with higher salinity (Grattan, 2017 – Personal Communication).

3. Vineyard and Pear Studies

Per testimony, soil samples were taken at one time in August of 2016.[35] One sample does not, in any way, constitute a scientifically valid study. All conclusions should be taken with caution. Also, samples were taken at the peak of potential salinity build up (August, 2016) near the end of the growing season and following three years of drought conditions. Given the timing and that only one sample was taken, it is not surprising to see somewhat elevated salinity in grapes. This is not the case in pears, however.

The vineyard was drip irrigated.[36] Conclusions from the study state that, "the ECe pattern suggests that the wetting front is pushing salts to approximately 90 cm from the vine row and 90 cm deep."[37] This bulb-like wetting pattern is classic for drip irrigation systems, and is likely the extent to which the irrigation system is capable of wetting the soil profile. Therefore, this extent of salt migration is not surprising considering the irrigation method used. Also, it is mentioned in other testimony that deficit irrigation is commonly

[35] November 3, 2016 Transcript Vol. 26, p. 158:4-7.

[36] Exhibit II-13, p. 6:3-4.

[37] Exhibit II-13, p. 6:3-4.

practiced on wine grapes to increase quality.[38] This is a clear example where a highly efficient irrigation method (e.g. drip) and management practices (e.g. deficit irrigation) very likely result in increased soil salinity levels. If managed differently, the applied water quality is more than suitable for grape production.

To counter these impacts, an alternative irrigation method, if possible (e.g. border-check flooding) periodically can be implemented to provide the adequate leaching fraction necessary to maintain suitable soil salinity levels. This is a conclusion drawn by Dr. Leinfelder-Miles as well.

The pear study was sprinkler irrigated.[39] The single sampling event resulted in soil salinity levels ranging from 0.25 to 1.18 dS/m down the profile, with an average profile salinity of 0.74 dS/m.[40] Pear yields are reduced when average root zone salinities reach 2.5 dS/m.[41] The conclusion was drawn that salinity at this site would not appear to impact yield.[42]

The testimony states that the Ksat at depth of the pear orchard according to USDA/NRCS map unit analyses was 10 mm/hr to a depth of 152 cm for the pear orchard and 5 mm/hr to a depth of 152 cm for the vineyard.[43] The conclusion from Leinfelder-Miles was that soil type had a significant impact on salt accumulation. The Ksat of these soils are actually somewhat similar (a 2x difference). In reality the range of Ksat can be hundreds or thousands of times different from one soil to another. What determines Ksat is predominantly texture and soil structure. Here texture is discussed but soil structure is not.

Although the Ksat rate is half as much in the vineyard, it is still at a level at which leaching can occur if managed correctly – even concurrent with normal irrigation practices.

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[38] November 4, 2016 Transcript Vol. 27, p. 36:17-22.

[39] Exhibit II-13, p. 4:14.

[40] Exhibit II-13, pp. 6:25-7:2.

[41] Exhibit II-13, pp. 6:25-7:2.

[42] Exhibit II-13, pp. 6:25-7:2.

[43] Exhibit II-13, p. 5:9-13.

Any increase in salinity in the vineyard soil is more likely the result of irrigation method and management than soil type or irrigation water salinity.

In a separate study, Aergerter and Leinfelder-Miles (2016) had the following conclusions:

1. Claimed that salts are accumulating in Delta soils, despite relatively good quality water (particularly compared to groundwater quality in other regions of the state) being used for irrigation. In their study of tomatoes under buried drip, they observed that "with high quality surface water, the average ECe increased slightly over the three years. We saw localized leaching that was less downward than what was observed in the studies conducted on the west side of Fresno County. Salts were moved out of the soil that was lateral to the drip tape. Some of the salt was pushed to the surface of the bed and furrow."

Again, this does not take into account the extreme drought conditions that were experienced during this timeframe, and does not relay the clear fact that highly efficient irrigation systems (e.g. buried drip) do not usually provide adequate leaching fractions alone.

2. Results from both the tomato and alfalfa projects showed that in gravity-fed irrigation systems (furrow, flood), the top end of the field, where irrigation water enters, may be more easily leached than the bottom end of the field. The top of the field has a longer opportunity time for water to infiltrate and percolate through the root zone. Irrigating over a longer run time may provide for better leaching at the bottom of the field; however, longer run times will also increase runoff from the field and could result in standing water on clay soils.

This conclusion shows the definite need to understand within what field, in what soil type, and exactly where in the field the sampling took place. Location of sampling significantly matters with consideration of soil salinity.

3. Additionally, shallow groundwater may be restricting leaching in the Delta. Monitoring soil and water salinity and understanding soil and groundwater characteristics will help growers optimize leaching and agricultural productivity.

This supports the fact that unless one is completely sure of the resultant salinity below the root zone, then results from formulas used to calculate leaching fractions may be incorrect.

V. Leaching Fractions and Requirements

In the testimony of Dr. Leinfelder-Miles, she provides the classic definitions of leaching fractions and leaching requirements as outlined in traditional literature sources (e.g. Ayers and Westcott, 1985).

The complicating variable for use of these approaches is high water table systems that may carry salts with them from alternative sources. For example, if salinity contributions to groundwater are a result of tidal influences, or simply with salinity derived from other sources, elevated salinities will occur. In Dr. Leinfelder-Miles' testimony, and in particular the alfalfa study, it is unclear as to the source of salinity in the shallow groundwater. This is a significant concerning factor.

The relatively low leaching fractions (e.g. reported as low as 2%) in a surface irrigated system are highly uncommon, if achievable at all (Howes, D. 2017. Personal Communication). The method of calculating leaching fractions in this study is determined by a comparison of the EC of the irrigation water (ECw) and the EC of the drainage water (ECdw). It is important to understand if a portion of the shallow groundwater salinity originates from non-ag sources. If salinity originates from any source other than that applied to the surface of the soil through irrigation water sources, the formula used from Ayers and Westcot, 1985 will have resulted in erroneous leaching fraction values. Comparatively, comprehensive research (Hoffman, 2010) did not witness or calculate leaching fractions anywhere near these low values. Also, it is explicitly stated in Ayers and Westcott, 1985, that the formulas presented for calculating leaching fraction based on the salinity of the irrigation water as compared to the salinity below the root zone in high, potentially saline water tables will be in error. As a result, the leaching fractions reported by Leinfelder-Miles should be suspect. Higher leaching fractions (e.g. >10%) as shown by Hoffman, 2010, and in the Prichard testimony (Exhibit SDWA 92), show no or limited adverse impact on crop yields.

Irrigation water quality is only one of several factors to be considered in the management of soil salinity. High water tables and inadequate drainage also affect soil salinity. Inadequate drainage can lead to the accumulation of salts within the soil profile. Even when good quality irrigation water is applied, salts may accumulate to detrimental levels.

At page 6, Exhibit SDWA 140, "Leaching Fractions Achieved in South Delta Soils under Alfalfa Culture Project Report Update August 2016" references "Water Quality for Agriculture, FAO Irrigation and Drainage Paper 29," 1985 (Paper 29) to explain the assumptions upon which the calculation of leaching fractions are based. Under Site Conditions, Paper 29 provides that "[d]rainage is assumed to be good, with no uncontrolled water table present within 2 metres of the surface" (Table 1, Assumptions in the Guidelines). It further provides that "The guidelines in Table 1 and the remainder of the discussion in this paper assume that all salts accumulating in the crop root zone come from the applied water. This means that drainage is adequate and salinity management is a significant part of irrigation management." (Section 2.4.1 Drainage, page 23.)

"The traditional approach to estimating leaching fractions and leaching requirements assumes that salt in the irrigation water is the sole contributor to root zone salinity, but where saline water tables are present, shallow groundwater may contribute substantially to crop water use. This is particularly true for many field crops such as cotton, safflower and alfalfa. Since the salinity of this water is normally much higher than that of the irrigation water, crop use of the groundwater can cause a significant increase in soil salinity compared with only using irrigation water. Traditional methods of estimating leaching fractions and leaching requirements may therefore underestimate the leaching fraction. No method has yet been developed to adjust the traditional estimating methods for the effect of shallow groundwater on soil salinity." (Blaine Hansen, Stephen Grattan and Allan Fulton, *Agricultural Salinity and Drainage, Division of Agriculture and Natural Resources Publication 3375*, U.C. Irrigation Program, U.C. Davis, revised 2006, page 107.)

The conditions at the sites used in Michelle Leinfelder-Miles' study *Leaching*

Fractions Achieved in South Delta Soils under Alfalfa Culture, Project Report Update August 2016 show that the water table is high, and the groundwater is more saline than the surface irrigation water. [44]

Table 1. Average groundwater depth (Dep), electrical conductivity (ECgw), and chloride ion concentration (Clgw) across seven south Delta alfalfa sites in fall and spring, 2013 and 2014.

	Spring 2013			Fall 2013			Spring 2014			Fall 2014		
Site	Dep (cm)	ECgw (dS/m)	Clgw (meq/L)	Dep (cm)	ECgw (dS/m)	Clgw (meq/L)	Dep (cm)	ECgw (dS/m)	Clgw (meq/L)	Dep (cm)	ECgw (dS/m)	Clgw (meq/L)
1	117	10.7	77.5	148	7.8	49.5	117	11.0	76.4	183	7.0	45.0
2	177	9.6	72.3	153	10.6	76.5	132	12.2	92.3	117	14.3	108.7
3	198	3.7	19.2	208	2.3	7.6	232	3.0	13.2	200	2.7	11.2
4	197	5.7	36.1	192	6.2	52.2	218	5.1	33.4	212	5.7	37.9
5	168	5.2	29.9	177	4.8	25.3	157	6.0	33.5	177	4.4	23.4
6	155	3.6	18.7	182	3.0	14.5	162	2.8	13.9	163	3.6	18.3
7	185	3.0	12.1	102	3.5	12.6	135	2.7	11.1	155	3.6	15.6

In the table above, groundwater levels are between one and two meters in 23 out of 28 measurements. This is the level associated with salinity problems mentioned in *FAO 29*.

Sites 1 – 4 are located on soil mapped as Merritt silty clay loam. Sites 5 and 6 are located on soil mapped as Grangeville fine sandy loam. Site 7 is located on soil mapped as Ryde clay loam. Although sites 1 – 4 are mapped on the same soil series, the electrical conductivities of the groundwater are quite varied and always considerably higher than salinities of the applied irrigation water (see Table 2, below).[45]

[44] Exhibit SDWA 140, p. 8 [Table 2]

[45] Exhibit SDWA 140, p. 7 [Table1]

Site	Water Source	ECw(dS/m) Range	ECw(dS/m) Average	Clw (meq/L) Range	Clw (meq/L) Average
1	San Joaquin River	0.2-0.7	0.6	0.7-3.9	2.8
2	Old River	0.5-1.0	0.8	1.6-4.6	3.1
3	San Joaquin River	0.2-0.7	0.6	0.6-3.0	2.2
4	Middle River	0.3-0.8	0.5	1.2-3.6	2.0
5	Paradise Cut	0.3-2.8	1.8	5.4-13.5	8.1
6	Grant Line Canal	0.6-1.1	0.9	2.5-4.7	3.8
7	North Canal	0.3-0.4	0.4	1.1-2.0	1.4

Table 2. April-October 2013 average irrigation water salinity as electrical conductivity (Ecw) and chloride ion concentration (Clw)

Considering the groundwater levels recorded for this study, the sources of salt accumulating within the soil profile could be from both applied irrigation water and water moving upward into the soil profile from shallow groundwater.

VI. Irrigation and Drainage Management

Although the north Delta single sampling events and the south Delta three-year tomato studies are different in many ways (e.g. crop types, soil types, etc.), one similarity exists. Regardless of crop type (i.e. grapes or tomatoes), they are drip irrigated and both the single sampling and 3-year study took place during extreme drought conditions. Both show indications of elevated salinity (grapes as compared to pears, and tomatoes over time). In both cases, the drip irrigation methods generally do not have the capacity to apply water at rates to achieve adequate leaching fractions when necessary. This, coupled with limited rainfall, only accelerates salinity increases.

The pear study (irrigated with pressurized sprinkler systems) showed no impactful soil salinity concentrations.

Very little information is provided in any of Dr. Leinfelder-Miles' testimony or cross-examination as to the presence, operation and maintenance, and effectiveness of subsurface drainage systems within the Delta. Drainage systems that are developed to lower water tables can either be periodic surface drainage ditches or actual installed perforated drain tubing at various intervals depending on soil texture, Ksat, and other hydraulic related variables of the soil system.

Growers install drainage systems to generally keep water tables out of the root zone of a crop. Drainage systems are typically either allowed to drain by gravity or are pumped to maintain an aerated root zone. This aerated root zone is not only to allow for effective rooting depths but also to allow for leaching efforts when necessary. If the drainage system is effective in removing water from the root zone for optimum crop production, it should be equally effective in removing water from the root zone during dedicated leaching efforts.

Also, no information was provided regarding the actual locations of the fields sampled and the areas sampled within the fields. Until this information is provided, no independent verification of this work can be accomplished.

In addition to the salinity of the applied irrigation water, other factors could have affected the soil salinity of these fields, and additional data could have been collected to provide a better understanding of salinity conditions in the fields included in this study.

As noted above, a high water table and the lack of adequate drainage can affect the calculated leaching fraction. Documentation of drainage systems and maintenance practices are important to include in a study on leaching fractions. The soil salinity at the bottom of the root zone may have contributions from the shallow water table in addition to salts from applied irrigation water. In the *Soil Survey of San Joaquin County, California*, 1992, the Merritt soil description states “The effective rooting depth of the crops commonly grown in the county is limited by an apparent water table that has been lowered to a depth of 4 to 6 feet through drainage systems that require continual maintenance.” It goes on to say “This unit is suited to irrigated crops. The main limitation is the high water table. Areas adjacent to levees are subject to lateral seepage in wet years when the water level is high. Careful applications of irrigation water are needed to prevent the buildup of a high water table. Tile drainage can lower the water table if a suitable outlet is available.”

Additional data that would have clarified the factors affecting the pattern of salts in the soils at the study sites are the quantities of water applied and the irrigation schedules, the distribution uniformities of the irrigation systems, the evapotranspiration of the alfalfa over the season, the timing of alfalfa cuttings and changes in canopy, and a determination of the alfalfa rooting depths. Additional questions related to the study that might be answered using data that was collected are "How was precipitation incorporated into the calculation of leaching fractions?" and "What was the pattern of soil moisture by depth, over time, shown by the soil moisture sampling?" Without additional data, it is unknown to what extent the high water table contributed to meeting the evapotranspiration of the alfalfa or to what extent the high water table contributed to soil salinity. It is also unknown whether the quantity of applied irrigation water was sufficient to meet the evapotranspiration needs of the crop. Thus, the information needed to determine the appropriate leaching fraction is not included.

VII. Modeling Results

The study on leaching fractions conducted by Dr. Leinfelder-Miles during 2013 and 2014 [Exhibits SDWA 139; SDWA 140] provided the basis for calculating crop yield reductions and economic impacts related to irrigation water salinity in Mr. Prichard's testimony [Exhibit SDWA 92] and in Dr. Michael's testimony [Exhibit SDWA 134-R]. Thus, it is important to look closely at how Dr. Leinfelder-Miles' study was conducted and the limitations it has when applied for this purpose.

One of the fundamental components of Mr. Prichard's testimony and cross-examinations centers on a model (spreadsheet calculator) used to predict yield loss under varying irrigation water qualities and assumed leaching fractions. [Exhibit SDWA-92, p.4:6-7.] Of particular importance are the leaching fractions assumed. Mr. Prichard clearly states in his testimony and during cross-examination that although he uses a range of leaching fractions, he supports the leaching fraction estimates developed by Dr. Leinfelder-Miles in her alfalfa study. (Id.) It has been previously explained why these leaching fractions developed by Dr. Leinfelder-Miles are suspect at best and therefore, the modeling results by Mr. Prichard should be considered suspect as well until the leaching fractions are verified.

He says that modifying inputs on a model would give an indication of what would happen in the field, then says that "such differences between model runs should not be understood to indicate what conditions will actually result" [Exhibit SDWA-92, p.2:15-16.] Other significant concerns related to the Prichard testimony include the following:

- Only two crops (of many) produced in the Delta (beans and almonds) were explored in more depth. Other crops were not considered in as much detail and likely should be.
- It is stated that there is insufficient time to practice the necessary leaching fractions. No mention of pre-irrigation practices (commonly a time to implement leaching fractions – especially in bean production) was mentioned.
- It is stated that varying degrees of soils, drainage, crops, channel water quality, etc., impact resultant soil salinity, yet the analysis was narrowed down to two crops with two scenarios. It is uncertain as to whether or not these limited scenarios represent the true conditions in the Delta.
- Mr. Prichard states, "[h]owever in years like 1977, 1979, 1985, and 1987, we see that the H3 scenario results in significant crop reductions beyond those for the NAA." [Exhibit SDWA-92, p.5:25-26.] It is clear there are increases in these years, but there are also decreases in other years (e.g. 1988, 1989, 1990, and 1991). This is not correspondingly explained and not correlated to the obvious driver of soil salinity, which is rainfall in the off-season. Regardless of increases or decreases, there is no analysis of the statistical significance of these differences.
- At Page 5, line 27 through Page 6, line 2, Mr. Prichard provides testimony as to why in certain years he believes growers were injured. [Exhibit SDWA-92, pp.5:27-6:2.] He does not mention other years when his modeling shows otherwise. It is important to understand that these systems are dynamic in nature and always have been. Salinity will increase, and salinity will decrease. The fact that crops are currently being grown successfully indicates this balance is sufficient for acceptable production.
- Leaching fractions are estimated by relating salinity of water applied to the salinity of the soil water below the root zone. Because the source of the salinity in the latter component is unknown and the witnesses admit as much, it is unclear why a mobile lab was not contacted to assess irrigation efficiency and associated leaching fractions.
- Statements such as "huge impacts," "…impacts could be very much worse," and "virtually no leaching occurs" are all relative and unsubstantiated statements. They should be ignored as they have no quantifiable measure. For example if "virtually no

leaching of salts" has actually been occurring, then the soils would have already salinized beyond a point of profitable crop production.

Another example is the statement at Exhibit SDWA-92, p.9:7-8 that "[w]hen on-site conditions limit the ability of applied water to move through the soil profile, virtually little leaching occurs…[and u]nder such circumstances virtually little of the applied salt moves out of the root zone and all of the salt in that applied water remains in the root zone."

If this were actually true, salinization of the ground would have already occurred and no agricultural production would be taking place. Therefore, the leaching fraction must be of some significance to continue to allow for crop production to continue to occur, even with ever increasing irrigation efficiencies.

- The positive impacts of precipitation on managing salinity naturally are essentially ignored. Even the model results show these impacts; however, the contributions are not discussed. The soils in the Delta are very productive agricultural systems and salinity (for the most part) has not affected crop production. It is in some sort of equilibrium, because if it was not, soils would have salinized beyond a point where crop production would occur.
- At Exhibit SDWA-92, pp.13:26-14:1, Mr. Prichard states, "…current information indicates that leaching fractions less than 5% occur in many areas of the southern Delta. If this is the case and has been for a number of years, some of this ground would have salinized to the point of non-production already. This has not been the case; however, because the leaching fraction is inherently more than 5% and very likely more than 10%, which has been stated in the testimony to be the minimum target and has been verified in other research (Hoffman, 2010). Where leaching fractions are on the edge of this limit, it is clear that growers have adapted their systems to mitigate this potential problem.
- The high water tables found in this study described in SDWA 140 could be a source of secondary salinization of the soil profiles, especially when periods of high evapotranspiration are associated with low infiltration rates. No measurements of applied irrigation water were made in this study, so whether the quantity of applied water was greater than the crop evapotranspiration is unknown.
- It appears that erroneous values (ECw rather than ECe) in the spreadsheet model used to estimate yield losses according to irrigation water salinity and soil salinity were used (Tables 3 (erroneous) and Table 4 (corrected)). It also appears as if Dr. Michael used these erroneous values as well in determining economic impacts. Also included in these yield loss estimate tables is a scenario for a 15% leaching fraction. This leaching fraction results in little, if any yield loss under most all water quality variables. The 15% leaching fraction (or higher) is likely what should be expected in these conditions as previously explained and in various studies (Hoffman, 2010; Ayars, et al., 2012, Ayers and Westcot, 1985; Grattan, 2016; Howes, 2016).

Table 3. Original yield reduction calculations included in testimony by Terry Prichard (SDWA 92)

15% leaching fraction results added for comparison purposes

	bean	corn	alfalfa	tomato	almond	grape
ECe Threshold	1.0	1.7	2.0	2.5	1.5	1.5
ECe at 0% yield reduction	1.0	1.7	2.0	2.5	1.5	1.5
ECe at 100% yield reduction	4.2	6.7	10.0	8.4	4.5	7.9
b	31.3	20.0	12.5	16.9	33.3	15.6

Leaching Fraction 5%

ECi	Average Soil Ece	%yield reduction bean	corn	alfalfa	tomato	almond	grape
0.2	0.65	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.3	0.97	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.4	1.3	9.4%	0.0%	0.0%	0.0%	0.0%	0.0%
0.5	1.62	19.4%	0.0%	0.0%	0.0%	4.0%	1.9%
0.6	1.95	29.7%	5.0%	0.0%	0.0%	15.0%	7.0%
0.7	2.27	39.7%	11.4%	3.4%	0.0%	25.7%	12.0%
0.8	2.6	50.0%	18.0%	7.5%	1.7%	36.7%	17.2%
0.9	2.92	60.0%	24.4%	11.5%	7.1%	47.3%	22.2%
1.0	3.25	70.3%	31.0%	15.6%	12.7%	58.3%	27.3%

Leaching Fraction 10%

ECi	Average Soil Ece	%yield reduction bean	corn	alfalfa	tomato	almond	grape
0.2	0.41	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.3	0.62	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.4	0.82	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.5	1.03	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%
0.6	1.23	7.2%	0.0%	0.0%	0.0%	0.0%	0.0%
0.7	1.44	13.8%	0.0%	0.0%	0.0%	0.0%	0.0%
0.8	1.64	20.0%	0.0%	0.0%	0.0%	4.7%	2.2%
0.9	1.85	26.6%	3.0%	0.0%	0.0%	11.7%	5.5%
1.0	2.05	32.8%	7.0%	0.6%	0.0%	18.3%	8.6%

Leaching Fraction 15%

ECi	Average Soil Ece	%yield reduction bean	corn	alfalfa	tomato	almond	grape
0.2	0.32	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.3	0.48	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.4	0.64	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.5	0.80	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.6	0.96	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.7	1.12	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%
0.8	1.28	8.8%	0.0%	0.0%	0.0%	0.0%	0.0%
0.9	1.44	13.8%	0.0%	0.0%	0.0%	0.0%	0.0%
1.0	1.60	18.8%	0.0%	0.0%	0.0%	3.3%	1.6%

Table 4. Revised Yield Reduction Calculations (Figures 3 and 4 from SDWA 92)

Using ECe corresponding to 100% yield reduction from ***FAO Irrigation and Drainage Paper 29***
to replace ECw corresponding to 100% yield reduction from ***FAO Irrig and Drainage-Paper 29***, Table 4, p 31-33.
15% leaching fraction results added for comparison purposes

	bean	corn	alfalfa	tomato	almond	grape
ECe Threshold	1.0	1.7	2.0	2.5	1.5	1.5
ECe at 0% yield reduction	1.0	1.7	2.0	2.5	1.5	1.5
ECe at 100% yield reduction	6.3	10.0	16.0	13.0	6.8	12.0
b	18.9	12.0	7.1	9.5	18.9	9.5

Leaching Fraction 5%

ECi	Average Soil Ece	%yield reduction bean	corn	alfalfa	tomato	almond	grape
0.2	0.65	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.3	0.97	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.4	1.3	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%
0.5	1.62	11.7%	0.0%	0.0%	0.0%	2.3%	1.1%
0.6	1.95	17.9%	3.0%	0.0%	0.0%	8.5%	4.3%
0.7	2.27	24.0%	6.9%	1.9%	0.0%	14.5%	7.3%
0.8	2.6	30.2%	10.8%	4.3%	1.0%	20.8%	10.5%
0.9	2.92	36.2%	14.7%	6.6%	4.0%	26.8%	13.5%
1.0	3.25	42.5%	18.7%	8.9%	7.1%	33.0%	16.7%

Leaching Fraction 10%

ECi	Average Soil Ece	%yield reduction bean	corn	alfalfa	tomato	almond	grape
0.2	0.41	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.3	0.62	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.4	0.82	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.5	1.03	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
0.6	1.23	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%
0.7	1.44	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%
0.8	1.64	4.0%	0.0%	0.0%	0.0%	1.0%	1.7%
0.9	1.85	5.4%	1.5%	0.0%	0.0%	2.4%	4.2%
1.0	2.05	6.6%	3.5%	0.8%	0.0%	3.7%	6.6%

Leaching Fraction 15%

ECi	Average Soil Ece	%yield reduction bean	corn	alfalfa	tomato	almond	grape
0.2	0.32	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.3	0.48	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.4	0.64	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.5	0.80	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.6	0.96	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.7	1.12	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%
0.8	1.28	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%
0.9	1.44	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%
1.0	1.60	3.8%	0.0%	0.0%	0.0%	0.7%	1.2%

VIII. CONCLUSION

The entirety of Mr. Prichard and Dr. Michael's testimony rely on the use of a 5% leaching fraction supplied by Dr. Leinfelder-Miles. As detailed above, my opinion is that the leaching fraction developed by Dr. Leinfelder-Miles is not supportable. A higher leaching fraction should be expected as outlined in various peer reviewed scientific articles summarized as well as personal communications with experts in the field. Compounding this uncharacteristically low leaching fraction estimate, Mr. Prichard's error in calculation of potential yield loss is concerning. Also, in my opinion it is troublesome that the work done by Dr. Leinfelder-Miles has not been peer reviewed with rigor for scientific publication. It is also my opinion that a single soil sampling event (i.e. the Ryer Island pear and grape work), especially in August following one of the most severe droughts the state has seen, does not constitute results to establish reliable conclusions. Furthermore, the work performed by Leinfelder-Miles downplays the effects of precipitation, and ignores management decisions made by growers to commonly mitigate normal soil salinity fluctuations.

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Joel Kimmelshue

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