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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 DR. CHRISTOPHER THORNBERG (EXHIBIT DWR-84)

I, Dr. Christopher Thornberg, do hereby declare:

Qualifications

I am the Founding Partner of Beacon Economics, LLC and an expert in economic forecasting, regional economics, employment and labor markets, economic policy, and industry and real estate analysis, Since 2006, I have served on the advisory board of Wall Street hedge fund Paulson & Co. Inc. In 2015, I was named to California State Treasurer John Chiang's *Council of Economic Advisors*, the body that advises the Treasurer on emerging strengths and vulnerabilities in the state's economy. Between 2008 and 2012, I was a chief economic advisor to the California State Controller's Office and served as Chair of then State Controller John Chiang’s Council of Economic Advisors.

I regularly present to leading business, government, and nonprofit organizations across the globe. These groups include Chevron, The New Yorker, City National Bank, REOMAC, the California State Association of Counties, Colliers International, State Farm

Insurance, the City of Los Angeles, and the California and Nevada Credit Union League, among many others. I have testified before the U.S. Congress House Committee on Financial Services on municipal debt issues, and before the California State Assembly Committee on Revenue and Taxation regarding changes related to Proposition 13.

I have been involved in a number of special studies measuring the effect of important events on the economy. These include the NAFTA treaty, the California electricity crisis, port security, California's water transfer programs, and the terrorist attacks of September 11, 2001.

I currently serve on the Residential Real Estate Committee at the University of San Diego's Burnham-Moores Center for Real Estate. I am a panel member of the National Association of Business Economists ' quarterly outlook, a contributor to the consensus outlook of the *Journal of Business Forecasting*, and a contributor to the monthly economic polls published by *Reuters*. I also serve on the boards of the Los Angeles Area Chamber of Commerce, the Central City Association (Los Angeles), the Asian Real Estate Association of America, and America's Edge, a nonprofit organization focused on strengthening the economy through public investments in youth and education. Additionally, I am member of the Los Angeles Chapter of Lamda Alpha International, the honorary society for the advancement of land economics, and serves on the Advisory Committee of United Ways of California's coming *California Financial Stability Report*.

Prior to launching Beacon, I was an economist with UCLA's Anderson Forecast where I regularly authored economic outlooks for California, Los Angeles, and the East Bay.

I hold a Ph.D in Business Economics from The Anderson School at UCLA, and a B.S. degree in Business Administration from the State University of New York at Buffalo. Attached as Exhibit DWR-23 is a true and correct copy of my Statement of Qualifications.

Summary of Findings

I have extensively reviewed the analysis and testimony of Dr. Jeffrey Michael, Michael Machado, and Ed Whitelaw (collectively Michael et al.) regarding their estimates of the economic losses the California WaterFix project would supposedly inflict on the Sacramento Delta region. Overall, I have found a series of significant flaws in this work, flaws that—in my opinion—cause their damage estimates to be highly inflated over any realistic level. Indeed, my own analysis would tend to suggest that true damages to the delta economy would be very small, if measurable at all.

There are four primary, overarching conclusions to the testimony of Michael et al.

1. The construction of the WaterFix tunnels will significantly increase the average salinity level of soil in the Delta
2. This increase in Delta salinity will negatively impact productivity (in terms of yield reduction and revenue) for certain crops
3. The decrease in yield will cause the agricultural community to shift production to lower value crops
4. The estimated agricultural losses would in turn cause significant lasting harm to the broader economy of the region

The first claim is beyond the scope of this analysis but is addressed by the testimony of Dr. Joel Kimmelshue [Exhibit DWR-85 and Dr. Parviz Nader Tehrani Exhibit DWR-79]. Regarding conclusions 2 through 4, I find the following:

I find little evidence that increase in Delta salinity will negatively impact crop productivity (in terms of yield per acre) within the range of salinity increases that might reasonably be expected because of the operation of the tunnels.

The model used by Michael et al to estimate the yield losses from the higher salinity levels is based upon misinterpretation and misapplication of a now outdated and now largely discredited agricultural study. Dr. Michael’s yield estimates are based on field sites that are not representative of the whole Delta and crop choices that do not reflect the true impact on agricultural economic activity in the Delta. Dr. Michael also assumes that crops will be more uniformly salt-sensitive than newer studies of field sites have suggested. A reasonable read of newer studies applied correctly would show a very small potential impact.

This opinion is backed up by the empirical evidence. Because of the nature of California's rain cycles, there are a wide range of salinity levels from year to year in the Delta—generating a natural experiment. I find that while Delta salinity levels vary from year to year, those salinity levels have not had any statistically significant impact on average crop yields.

The operation of the tunnels will not cause a shift to lower value crops

The fact that I found level relationship between yields and levels of salinity in the Delta is, by itself, sufficient to negate the claim that the tunnels will cause the agricultural sector to shift to lower value crops.

Nevertheless, I looked closely at the model created and used by Dr. Michael to estimate these losses. The results he has obtained are based on an empirical analysis that has many flaws. To start with, he does not adequately distinguish between what is a high value crop versus what is a low value crop. Crops are categorized into unusual combinations (e.g. truck crops) that do not reflect comparable salt tolerance. Dr. Michael's use of revenues as a representation of value is not as strong as the use of profits or multiplier effects might be.

There are also econometric problems with the model itself, including significantly the omission of certain years of data and a failure to account for potential autocorrelation issues. As such his results are simply not reliable.

Again, this opinion is backed up by the actual data. A simple analysis shows that in years of higher water salinity levels, acreage of salt sensitive crops actually increased.

Agricultural losses are overestimated and would not cause in turn significant lasting harm to the broader economy of the region

I found that Dr. Michael overestimates the negative impact of the WaterFix due to lost farmland in the Delta region while underestimating the positive impact of construction and operations of the WaterFix on the Delta economy. Dr. Michael also mistakenly finds that WaterFix will have a negative impact on the logistics sector but he simultaneously overestimates the impact of the logistics sector on the overall Delta region's economic growth.

Dr. Michael incorrectly determines that the WaterFix comes at the expense of Delta levee upkeep. Dr. Michael finds comparatively small negative economic impacts due to factors such as traffic congestion relative to the highly positive impact of construction and operations of the WaterFix.

Finally, I found that Ed Whitelaw establishes far too high a standard of avoiding injury to in-Delta water users such that it would be nearly impossible to implement any infrastructure project that would not entail an "injury" to these water users. Even then, Dr. Whitelaw ignores the possibility of providing payments to compensate for any potential injury.

In all, I found that conclusions 2 through 4 all fail in the face of a thorough analysis of data, ultimately negating the claims of Dr. Michael, Michael Machado, and Ed Whitelaw in their analyses and testimony.

I. Overview of Analysis

I reviewed the analysis and testimony of Dr. Jeffrey Michael, Michael Machado, and Ed Whitelaw (collectively Michael et al.) regarding the impact of the California WaterFix on agriculture in the region.[1] I found substantial flaws in their work that negate their claims that significant economic harm will be done to Delta farmers by implementing the WaterFix.

[1] [See Exhibits SDWA-134-R; SDWA-135-R; RTD-301; RTD-305; RTD-30 Erratum; RTD-31; and CWIN-6.]

The deepest analysis and the center of my investigation is on the work of Dr. Michael. Dr. Michael's claims specifically can be summarized as follows: the WaterFix will cause an increase in salinity in the Delta, which will in turn harm the agricultural economy in the region. These losses are, in theory, caused by both a loss in productivity and a resultant shift in the use of crops in the region, with the shift in crops leading to lower agricultural revenues.[2]

"The WaterFix will reduce agricultural production in the Delta in two ways: a) water quality degradation, and b) land loss. Higher salinity in the Delta could reduce yields for Delta farmers, prevent them from planting more lucrative but salt-sensitive crops, or shift existing fields to lower-revenue crops with higher salt tolerance over time."[3]

"The BDCP Statewide Economic Impact Report examines a scenario in which the Delta tunnels cause a 1.1% increase in average salinity… this small change in salinity due to the tunnels would result in a $1.8 million decrease in crop revenue in the Delta just from shifts to lower-value crops over time."[4]

There are several links in this chain of causality suggested by Michael. If any link in the chain breaks, then the model being used to estimate the negative impact of the tunnels by Dr. Michael is no longer valid and these results are not credible. His links in the causal chain are:

1. The construction of the WaterFix tunnels will significantly increase the average salinity level of soil in the Delta[5]
2. This increase in Delta salinity will negatively impact productivity (in terms of yield reduction and revenue) for certain crops[6]

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[2] [Exhibit SDWA-134-R,p.3:3-8.]
[3] [Exhibit SDWA-134-R,p3:2-5.]
[4] [Exhibit SDWA-134-R,p.4:11-12,15-17.]
[5] Michael referenced Thomas Burke's work, which states that "some locations could experience a greater than 25% increase in salinity in some years due to the WaterFix and even greater increases when analyzed over shorter durations during irrigation season." [Exhibit SDWA-134-R,p.6:20-22.)
[6] [Exhibit SDWA-134-R,p.5:1-15, citing (decrease in yield when referencing Terry Prichard's work [SDWA-92]); Exhibit SDWA-134-R,p.6:8-16.]

3. The decrease in yield will cause the agricultural community to shift production to lower value crops[7]

4. The estimated agricultural losses would cause in turn significant lasting harm to the broader economy of the region[8]

While link number one is outside my scope of analysis, I do consider links 2 through 4. My efforts show that each of these links fails to hold up under scrutiny, and as such the loss estimates are, at best, highly overstated. The flaws in the testimonies of Michael Machado and Ed Whitelaw have weaknesses of their own that only serve to further undermine the logical chain above.

Part 1 of my analysis will show weaknesses in the estimate of the negative impact of increased salinity on agricultural productivity. I will analyze this from both a theoretical as well as an empirical basis.

Part 2 of my analysis will use regression results to demonstrate that salinity levels have not impacted crop choices in the Delta region.

Part 3 of my analysis I will demonstrate other positive impacts of the WaterFix that have been overlooked in the testimony of Dr. Michael and Dr. Whitelaw, and how Ed Whitelaw's interpretation of the no injury rule does not make sense from an economic perspective.

II. Part 1. Agricultural (Direct) Economic Damages

According to Dr. Michael's analysis and testimony, the WaterFix will cause higher salinity levels that will in turn reduce yields for Delta farmers.[9] This reduction in yield is then suggested to impact crop choices by local farmers—an issue I will discuss in depth in the second part of this rebuttal. However, it is worth discussing the odd structure of his analysis. In terms of the impact of higher salinity on yield, Dr. Michael relies solely on the

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[7] [Exhibit SDWA-134-R,p.3:3-5.]

[8] In Exhibit RTD-301, Michael describes his multinomial logit model (on crop choice) "generates estimates of the probability of observing a given crop type in each specified field over a long-term time horizon." [Exhibit RTD-301, p.123.] The long-run agricultural revenue forecast is then presented in Table 19. [Exhibit RTD-301, p.125.] A critique of his model is discussed more in-depth under section "Model Problems."

[9] [Exhibit SDWA-134-R, p.3:2-4.]

estimates derived from results of a single older agricultural science study on the impact of salinity on yield in one portion of the Delta region. In other words, his estimate is being derived theoretically. This contrasts with his approach on the shift in crop mix in which Dr. Michael uses actual crop data within an empirical analysis.

To be clear, the use of theoretical models to measure the economic impact of specific events is not unusual. But it is not the only or even preferred type of economic analysis, since the impact is being assumed to be occurring. Another, sometimes preferable, method is to find what economists would refer to as a natural experiment. A natural experiment refers to a study of some historical event that provides an analog for the event of interest. By studying the actual impact in the past, I can create better estimates for the future.

When I consider the theoretical underpinnings of Dr. Michael's analysis I find him to be using a result of just one study—importantly a study that produces results that seem to be extreme within a broader line of scientific study, and not relevant to the situation at hand. In short, he seems to be cherry picking estimates from the broader literature that support a specific desired conclusion rather than using a truly impartial look at the research.

Such a view is supported by the results of my own empirical analysis. Due to normal climatic variations (the range of wet and dry years typically found in California's year to year weather patterns) there is a natural fluctuation in the salinity of the Delta waters. In dry years, the water tends to have a far higher salinity level than in wet years.[10] This provides my with a natural experiment—by looking at the history of crop yields over these year-to-year fluctuations in salinity I should be able to find a negative correlation in crop yields if they truly exist. A cursory look at the data fails to show any such historic pattern for the vast majority of crops I considered—in other words, at least within the range of salinity seen in Delta waters in the past, there is very little evidence of a negative impact on yields.

[10] The Water Quality Control Plan requires the SWP/CVP to meet a water quality standard of .7 EC April through August and 1.0 EC September through March. Exhibit DWR-404 summarizes the various Bay-Delta standards as currently exist under D-1641.

I start by discussing the theoretical framework used by Michael et al to estimate crop yield reductions that would occur because of increased salinity. Michael did not state how much salinity the tunnels would cause; instead he claimed total decrease in San Joaquin County revenue from crop yield loss for scenario of 0.1 EC (electro conductivity)[11] increase in salinity to base EC ranging from 0.4 to 0.6. would be as follows:[12]

Table 1. Dr. Michael Estimate of Crop Yield Reductions

		0.4	0.5	0.6	Total
Almond	Deciduous	$167,453	$627,950	$1,074,632	$1,870,035
Corn/Alfalfa	Field	$0	$445,838	$1,319,679	$1,765,517
Grape	Vineyard	$100,577	$376,093	$643,585	$1,120,255
	Total	$268,030	$1,449,881	$3,037,896	$ 4,755,807

There are two components – 1. Terry Prichard's crop reduction table and 2. Michael's multinomial logit model - of Prichard's calculations on the reduction in crop yields due to increased salinity levels. The first component, based on work from Terry Prichard, is based on the following resources:

- Leaching fractions from Dr. Michelle Leinfelder-Miles' study on alfalfa [Exhibit SDWA-140.]
- Salt tolerance levels of crops from Table 4 of Food and Agriculture Organization Paper no. 29,[13] which are mostly compiled from a 1977 study by Maas and Hoffman[14] [15]
- Soil salinity leaching requirement guidelines from Ayers and Westcot (1985)[16]

It is important to note that Terry Prichard's calculations on crop yield reductions, which Dr. Michael presented in his testimony,[17] are wrong. Although the formula is correct,

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[11] Water and soil salinity are measured by passing an electric current between the two electrodes of a salinity meter in a sample of soil or water.

[12] [Exhibit SDWA-134-R, p.6:8-15.]

[13] See URL < http://www.fao.org/docrep/003/T0234E/T0234E03.htm>

[14] Maas, E. V. and Hoffman, G. J. (1977). "Crop Salt Tolerance – Current Assessment." J. Irrig. And Drainage Div., ASCE 103(IR2): 115-134.

[15] Note that since 1977, many new varieties of crops that are more resistant to drought and salinity have been developed. Therefore, this reference should be considered as a very conservative one.

[16] Ayers, R.S., Westcot, D.W. (1985). "Water Quality for Agriculture." FAO Irrigation and Drainage Paper 29. Food and Agriculture Organization of the United Nations, Rome, p. 174.

[17] [Exhibit SDWA-134-R,p.5:4-15.]

the inputs are not.[18] As described in the testimony of Joel Kimmelshue, Prichard incorrectly used the ECw instead of the ECe, which resulted in overstated yield reductions. The table with the incorrect calculations is reproduced in Table 1a below:

Table 1a: Percentage Reduction in Yield for Leaching Fraction of 5% (Prichard)

ECi	ECe	Bean	Corn	Alfalfa	Tomato	Almond	Grape
0.2	0.65	0.00	0.00	0.00	0.00	0.00	0.00
0.3	0.97	0.00	0.00	0.00	0.00	0.00	0.00
0.4	1.3	9.38	0.00	0.00	0.00	0.00	0.00
0.5	1.62	19.38	0.00	0.00	0.00	4.00	1.88
0.6	1.95	29.69	5.00	0.00	0.00	15.00	7.03
0.7	2.27	39.69	11.40	3.38	0.00	25.67	12.03
0.8	2.6	50.00	18.00	7.50	1.69	36.67	17.19
0.9	2.92	60.00	24.40	11.50	7.12	47.33	22.19
1.0	3.25	70.31	31.00	15.63	12.71	58.33	27.34

The corrected calculations are presented in Table 1b below[19]:

Table 1b: Percentage Reduction in Yield for Leaching Fraction of 5% (Corrected)

ECi	ECe	Bean	Corn	Alfalfa	Tomato	Almond	Grape
0.2	0.65	0.00	0.00	0.00	0.00	0.00	0.00
0.3	0.97	0.00	0.00	0.00	0.00	0.00	0.00
0.4	1.3	5.66	0.00	0.00	0.00	0.00	0.00
0.5	1.62	11.70	0.00	0.00	0.00	2.26	1.14
0.6	1.95	17.92	3.01	0.00	0.00	8.49	4.29
0.7	2.27	23.96	6.87	1.93	0.00	14.53	7.33
0.8	2.6	30.19	10.84	4.29	0.95	20.75	10.48
0.9	2.92	36.23	14.70	6.57	4.00	26.79	13.52
1.0	3.25	42.45	18.67	8.93	7.14	33.02	16.67

Below in table 1c is the incorrect calculation and in table 1d is the corrected calculation of economic loss.

Table 1c: Original Impact table

Crop	0.4	0.5	0.6	Total
Almond Deciduous	$167,453	$627,950	$1,074,632	$1,870,035
Corn/Alfalfa Field	$0	$445,838	$1,319,679	$1,765,517
Grape Vineyard	$100,577	$376,093	$643,585	$1,120,255
Total	$268,030	$1,449,881	$3,037,896	$4,755,807

[18] These errors were further compounded in the testimony of Dr. Michael, as he used them in his calculation of the economic impacts. [Exhibit SDWA-134.]

[19] The corrected crop loss calculations are provided in the testimony of Dr. Joel Kimmelshue [Exhibit DWR-85].

Table 1d: Revised Impact Table

Crop	0.4	0.5	0.6	Total
Almond Deciduous	$94,785	$355,443	$608,282	$1,058,510
Corn/Alfalfa Field	$0	$268,577	$785,648	$1,054,225
Grape Vineyard	$61,304	$229,238	$392,280	$682,822
Total	$156,089	$853,258	$1,786,211	$2,795,558

As you can see, Michael's use of the incorrect crop yield reduction from Prichard resulted in overstating the economic impacts. This is assuming I agree with his methodology, which I don't as I describe below.

Looking through his methodology I found that Dr. Michael's estimate of the impact to Delta agriculture due to salinity have been largely overstated, driven in turn by a number of incorrect assumptions used within his framework. Specifically, I found problems with the following.

1) His model is based on a sample of field sites in South Delta that is not representative of the entire Delta region. Each area of the Delta has very unique requirements regarding crop growth and yields. The field sites are too concentrated in a portion of South Delta (the field sites located between Tracy, CA and Manteca, CA) to make any valid claims about the Delta region as a whole.[20]
2) His analysis is based on a sample of crops that are not representative of the overall Delta economy. The Delta is home to hundreds of crops and the six crops selected in no way accurately represent the agriculture in the Delta.[21] Thus, he overestimates the economic impact on the region if these crops were to be reduced.
3) His analysis is based on leaching fractions (the ratio of the quantity of water draining past the root zone to that infiltrated into the soil's surface) of a small sample (only 7 field sites) to generalize leaching fractions of the greater Delta area.[22] Leaching fractions are different depending on factors such as soil type and leaching

[20] [Exhibit SDWA-140, p. 6.]
[21] The six crops selected are beans, corn, alfalfa, tomatoes, almonds, and grapes. [See Exhibit SDWA-134-R,p.5:5.]
[22] "Seven south Delta alfalfa fields were selected for this study, representing three soil textural and infiltration classes." [Exhibit SDWA-140, p.1.]

requirements (the amount of water each crop needs to keep salinity levels tolerable) are different for each crop, and thus a small sample of fractions cannot be extrapolated to the Delta region in general.

Incorrect Generalization Based on a Small Geographical Region

Dr. Michael's calculation of crop yield [Exhibit SDWA-134-R.] relies on Terry Prichard's testimony [Exhibit SDWA-92], both of which relied on a study of alfalfa by Dr. Michelle Leinfelder-Miles [Exhibit SDWA-140].[23] [24] Although Mr. Prichard claimed that Dr. Leinfelder-Miles study and the leaching fractions Leinfelder-Miles calculated are scientifically reliable,[25] there are several problems with using Dr. Leinfelder-Miles' study as a reference point[26]:

1) The study uses salinity levels from a few field sites in a small but unspecified part of the South Delta to generalize salinity levels for the entire Delta region. The alfalfa study outlined in SDWA-140 pertained to site locations between Tracy, CA and Manteca, CA.[27] In other words, Dr. Leinfelder-Miles' study pertains to only a small portion of the South Delta region (Conservation Zone 7). It is problematic to use the result from a portion of the South Delta to generalize to the entire Delta region - especially since salinity in South Delta tends to be higher compared to the rest of the Delta region - as the South Delta has different soil salinity levels, elevation, soil type, and temperature as well as other factors, all of which affect crop yields differently. Dr. Michael claimed that "studies by Michelle Leinfelder of alfalfa irrigation and soil salinity in the Delta have found a median leaching fraction."[28] This is misleading, as it is phrased in such a way

[23] [Exhibit SDWA-92,p.3:21-27,p.4:1-7.] Furthermore, although Prichard claimed to have "consulted with Dr. Leinfelder-Miles on the design, implementation and analysis of the study" [Exhibit SDWA-92,p.4:1-2], Prichard admitted that he did not know why the fields in the studies done by Dr. Leinfelder-Miles identified in SW -- SDWA-139 and 140 did not identify the fields" (November 18, 2016 Transcript Vol.30,p. 68:23-25 and p. 69 lines 1-2, from 2016-11-18-_final_cwfpethearing.pdf).

[24] Michael, 4, lines 24-26 and p. 5, lines 1-3, from SDWA-134-R.

[25] [Exhibit SDWA-92,p.4:7.]

[26] The testimony of Dr. Joel Kimmelshue [Exhibit DWR-85] has additional detail regarding the use of the Leinfelder-Miles leach fractions.

[27] [SDWA-140, p. 6.] "We used California Irrigation Management Information System (CIMIS) data, averaged between the Manteca and Tracy locations for the 2014-2015 precipitation season, as the water applied as rainfall. Data from these two locations were averaged because the seven field sites were located between these stations."

[28] [Exhibit SDWA-134-R,p.4:24-26.]

that Dr. Leinfelder-Miles' study applies to the entirety of the Delta. In fact, her study only covered a portion of the South Delta. Dr. Michael's analysis should have accounted for differences in leaching requirements as a result of geographical variations if the entire Delta region was being assessed. He did not appear to do so.

2) Both Dr. Michael and Mr. Prichard compounded their mistakes by using the median leaching fraction of the field sites (i.e. the median of the actual leached amount in the field) and applying the leaching fraction for other crops. The seven sites in the Leinfelder-Miles study shows that leaching fraction varies considerably among sites;[29] therefore one cannot assume a uniform leaching fraction in the Delta. Furthermore, in agriculture, I understand that a "leaching requirement" is the amount of water needed to pass through the ground in order to keep salinity levels at a tolerable and nourishing level. Each crop has a different leaching requirement, and thus a different amount of salinity that can be tolerated while still producing optimum yields. Therefore, what is tolerable for alfalfa (alfalfa's leaching requirement) is not necessarily tolerable for another crop. Alfalfa's leaching requirement cannot be used to extrapolate the leaching requirements of other crops.

3) Finally, Dr. Michael and Mr. Prichard's conclusions that salinity level plays a pivotal role in crop yield are in direct contrast of Dr. Leinfelder-Miles' own conclusion. Dr. Leinfelder-Miles stated explicitly that "in this study, alfalfa yield was not correlated with average root zone salinity, suggesting that other factors, like pest pressure, stand quality or economic factors, were more influential on yield during these growing seasons."[30] Moreover, the real focus of this study was concerned with the impact of surface water quality and rainfall on the leaching fraction, not on the leaching fraction's effect on crop yields. Thus, they erroneously cite this study a second time, as it is not germane to the topic at hand.[31]

[29] The leaching fraction results are detailed in Leinfelder-Miles, p.11, Table 3: Root zone depth (RZ Dep), soil salinity (ECe, Cle), and leaching fraction (Lf) at the base of the root zone at seven south Delta alfalfa sites in Fall 2013 and 2014, from SDWA-140.pdf.

[30] [Exhibit SDWA-140, p. 12.]

[31] There are several other issues with the Leinfelder-Miles analysis, which are discussed more thoroughly in Dr.

Incorrect Choice of Crops to Examine Salt Tolerance Levels

Dr. Michael and Mr. Prichard's estimates on crop yield reduction relied on crop salt tolerance levels from Table 4 of the Food and Agriculture Organization Paper no. 29,[32] which is based on a 1977 study by Maas and Hoffman.[33] However, exact salt tolerance data for many major crops currently grown in the Delta region are missing. In Mr. Prichard's testimony, he selected six "common delta crops" – beans, corn, alfalfa, tomatoes, almonds, and grapes[34] – to present his crop yield reduction calculation. While corn, alfalfa, tomatoes, grapes and almonds are indeed asserted to be the most common and important crops by acreage[35] [36] and value (or revenue),[37] [38] Mr. Prichard should not have claimed the same for beans. While the State Water Board used beans and alfalfa as the basis of measuring the southern Delta electricity conductivity levels, it is not certain why Mr. Prichard specifically picked beans as part of his representative sample as it is neither a high yield crop nor a crop with high acreage.

According to the acreage and value tables from both RTD-301 and RTD-305, crops such as wheat and asparagus are both more common than beans in terms of both acreage and value. Therefore, the crops Mr. Prichard selected do not constitute the best representative sample given that beans (ranked outside of top 20 in terms of value and ranked 10 in terms of acreage) and almonds (ranked 12 in terms of value and ranked 16 in terms of acreage)[39] are not as common and would not show the biggest economic impacts due to salinity.

While the Maas and Hoffman (1977) paper is pivotal for many crop salt tolerance studies, the data is several decades old and is not immune to criticism. For example, in

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Kimmelshue's rebuttal testimony [Exhibit SDWA-85.]

32 URL < http://www.fao.org/docrep/003/T0234E/T0234E03.htm>.

33 Maas, E. V. and Hoffman, G. J. (1977). "Crop Salt Tolerance – Current Assessment." J. Irrig. And Drainage Div., ASCE 103(IR2): 115-134.

34 [Exhibit SDWA-92, Figure 3 Salinity coefficients for six common delta crops, 9 – 10.]

35 [Exhibit RTD-301, Table 8: Top 20 Delta Crops by Acreage, 2009, 111.]

36 [Exhibit RTD-305, Table G-1 Detailed Crop Acreage, G-3.]

37 [Exhibit RTD-301, Table 10: Top 20 Delta Crops by Value, 2009, 114.]

38 [Exhibit RTD-305, Table G-2 Detailed Crop Revenue, G-4.]

39 Based on rankings in Tables 8 and 10 of RTD-301.

response to Dr. Hoffman's updated study in 2010, which reviewed previous literature relating to the effect of salinity on a variety of irrigated crops, San Joaquin River Group Authority and State Water Contractors pointed out that the 1977 analysis is "not based on a strong data set and is likely over conservative."[40] In response to Comment #7.3, Dr. Hoffman agreed that "salt tolerance values for bean may be conservative"[41] and recommended to "conduct a field experiment to establish the salt tolerance of bean using current cultivars and under the field conditions representative."[42] Another possible caveat of using the metrics established in the Maas and Hoffman study, which Michael et al. never mentions, is that scientific advances have allowed many new varieties of crops that are more drought and salt tolerant to be developed. This strongly supports the need of new and updated crop salt tolerance data.

Incorrect Use of Past Studies Regarding Leaching Requirements

~~I understand that soil with higher salinity requires a higher leaching requirement for salinity control of crops regularly grown on drainage- and salinity-impaired soils. Much of the discussion of soil salinity, irrigation water salinity, and leaching fractions are based on the steady model in Ayers and Westcot (1985). Like the critique of the Maas and Hoffman (1977) paper, the guidelines are subject to revisions by later studies. A later study by Hanson et al. (2006) had suggested different leaching requirements, which suggested lower soil salinity levels.[43 44] Letey et al. (2011) summarize the comparisons below:~~

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[40] Hoffman, G. J. (2010). "Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta." Report for California Environment Protection Agency. Comment #7.3, Comment Letter #7.3, p. 123.

[41] Ibid.

[42] Ibid.

~~[43] Hanson, B. R., Grattan, S. R., and Fulton, A. (2006). "Agricultural Salinity and Drainage." Division of Agriculture and Natural Resource Publication 3775.~~

~~[44] Letey, J., Hoffman, G. J., Hopmans, J. W., Grattan, S. R., and Suarez, D. L. (2011). "Evaluation of soil salinity leaching requirement guidelines." Biological Systems Engineering: Papers and Publications. Paper 215.~~

Table 2. The Average ECe/ECw as a Function of the 5% and 10% Leaching Fractions (LF)[45]

LF	Ayers and Westcot (1985)	Hanson et al. (2006)
5%	3.2	1.9
10%	2.1	1.4

Hanson et al.'s guidelines are considerably lower than those of Ayers and Westcot. The lower figures imply that Ayers and Westcot's guideline could be overestimating the impact. Retabulation of crop yield reduction, which incorporates Hanson et al.'s guidelines, at 5% leaching fraction is shown below:

Table 3. Percentage Reduction in Yield For Leaching Fraction of 5% (Hanson 2006b)

ECi	ECe	Beans	Corn	Alfalfa	Tomatoes	Almonds	Grapes
0.2	0.38	0.0	0.0	0.0	0.0	0.0	0.0
0.3	0.57	0.0	0.0	0.0	0.0	0.0	0.0
0.4	0.76	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.95	0.0	0.0	0.0	0.0	0.0	0.0
0.6	1.14	2.6	0.0	0.0	0.0	0.0	0.0
0.7	1.33	6.2	0.0	0.0	0.0	0.0	0.0
0.8	1.52	9.8	0.0	0.0	0.0	0.4	0.2
0.9	1.71	13.4	0.1	0.0	0.0	4.0	2.0
1.0	1.9	17.0	2.4	0.0	0.0	7.5	3.8

Tables 4 shows corresponding crop yield reduction with Hanson et al.'s guidelines at 10% leaching fraction:

Table 4. Percentage Reduction in Yield For Leaching Fraction of 10% (Hanson 2006b)

ECi	ECe	Beans	Corn	Alfalfa	Tomatoes	Almonds	Grapes
0.2	0.28	0.0	0.0	0.0	0.0	0.0	0.0
0.3	0.42	0.0	0.0	0.0	0.0	0.0	0.0
0.4	0.56	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0
0.6	0.84	0.0	0.0	0.0	0.0	0.0	0.0
0.7	0.98	0.0	0.0	0.0	0.0	0.0	0.0
0.8	1.12	2.3	0.0	0.0	0.0	0.0	0.0
0.9	1.26	4.9	0.0	0.0	0.0	0.0	0.0
1.0	1.4	7.5	0.0	0.0	0.0	0.0	0.0

Even though Mr. Prichard's tabulations included leaching fractions at 5% and 10%, Dr. Michael only presented the 5% leaching fraction scenario in his testimony. As

[45] Ibid.

discussed in detail in the rebuttal testimony of Dr. Kimmelshue, the 5% leaching fraction is not justified. (DWR 000). His justification was that "studies by Michelle Leinfelder of alfalfa irrigation and soil salinity in the Delta have found a median leaching fraction of 5.5%, half of the Delta locations in her study sample had leaching fractions at or below 5%."[46] The 5.5% median leaching fraction is based on the leaching fractions of the seven sites in 2013 and 2014.[47] Sites 3 and 5 had high leaching fractions in both years (21% in 2013 and 18% in 2014 for Site 3 and 25% in 2013 and 26% in 2014 for Site 5) and as a result the average (mean) leaching fraction would be 9.6%, which is significantly higher than the median leaching fraction of 5.5%. The table below summarizes the leaching fractions of the field sites in 2013 and 2014 and the mean and median calculated to show that Michael's claim of the median leaching fraction of 5.5% is the average of the median leaching fraction of both years.

Table 5. Leaching Fraction (LF) at Seven South Delta Alfalfa Sites in Fall 2013 and 2014[48]

Site	LF (2013)	LF (2014)
1	3	3
2	3	5
3	21	18
4	3	2
5	25	26
6	6	5
7	7	8
Mean	9.71	9.57
Median	6.0	5.0

Not only did Dr. Michael not mention the higher mean leaching fraction, he also showed only the worst possible scenario, overstating the severity of the effect of salinity on crop yields. In essence, a leaching fraction is the amount of water required in irrigating a

[46] [Exhibit SDWA-134-R, p.4:24 – 26; p. 5:1.]
[47] [Exhibit SDWA-140, p. 11, Table 3: Root zone depth (RZ Dep), soil salinity (ECe, Cle), and leaching fraction (Lf) at the base of the root zone at seven south Delta alfalfa sites in Fall 2013 and 2014, from SDWA-140.pdf.]
[48] Ibid.

crop so that a tolerable salinity level is maintained. The lower the leaching fraction, the higher the impact of salinity level has on crop yield reduction for a given crop. A 5.5% median leaching fraction entails a higher salinity level than does a 9.6% mean leaching fraction. If the mean is used instead of the median, the impact of salinity on crop yield reduction would more resemble what is presented in Table 4 (10% leaching fraction) than Table 3 (5% leaching fraction). Thus, by presenting only the median leaching fraction, Dr. Michael gave the impression that salinity levels were much higher than they actually were.

Most importantly, I understand that there are many different types of soil, all with different leaching fractions. Therefore, I believe it is inappropriate to attribute the soil (and leaching) characteristics from Dr. Leinfelder-Miles' study to the entire Delta. Just about five miles south of Tracy, CA, and Manteca, CA, is the New Jerusalem Water District. Table 3.11 of Hoffman (2010) shows the calculated leaching fraction for applied water of 0.7 dS/m for the New Jerusalem Drainage District from 1977 to 2005 based on results from Belden et al. (1989)[49] and Westcot (2009).[50] Hoffman found that the average leaching fraction was 27% and leaching fraction had been stable during the sampled years, ranging from 22% to 29%.[51]

The takeaway point is that leaching fractions differed greatly within what is considered to be a small part of the South Delta. As a result, I believe it is incorrect to assume a uniformly low leaching fraction across an even wider area, namely the entire Delta region.

It is my belief that the models used by Michael et al overstate the true potential impact of increased salinity levels on agricultural production yields. For instance, Machado reports, "The model estimated an 18 percent decrease in truck crop revenue for a 25 percent rise in salinity, as well as a 33.4 percent decrease in truck crop revenue for a 50

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[49] Belden, K. K., Westcot, D. W. and Waters, R. I. (1989). Quality of agricultural drainage discharging to the San Joaquin River and Delta from the western portion of San Joaquin County, California. April 1986 to May 1988. California Regional Water Quality Control Board, Sacramento, CA. p. 25.

[50] Westcot, D. R. (2009). Attachment #2, New Jerusalem Drainage District Data. Personal communication.

[51] Hoffman, G. J. (2010). "Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta." Report for California Environment Protection Agency.

percent rise in salinity. Doubling salinity in the South Delta would result in an estimated 57.3 percent decrease in truck crop revenue, and for a 200 percent increase in salinity, an 83 percent drop in estimated truck crop revenue."[52]

To verify my suspicions, I have another tool at my disposal—historical data analysis. As it turns out there have been wide fluctuations in water salinity over time in the Delta region, typically but not exclusively related to the amount of rainfall in the state. This fluctuation over time allows for what economists refer to as a natural experiment. By controlling for other potential drivers of crop yields within a panel time series data analysis, I should be able to statistically identify the negative impact of salinity on crop yields during periods of time when salinity levels have been high in the past.

As mentioned in Part 1, Dr. Michael attempted to show the impact of increased salinity in irrigation water on crop yields via two ways: a simple calculation by Terry Pritchard on yield reduction based on leaching fractions of five percent.[53] Mr. Pritchard selected six "common delta crops" – beans, corn, alfalfa, tomatoes, almonds, and grapes[54] – to present his crop yield reduction calculation. All of the crops selected are considered in the literature to be either moderately salt sensitive or salt sensitive.

For my analysis I chose to examine a much broader array of crops found in the Delta, as determined by the San Joaquin County Crop Report. Crops were chosen based on harvested acres and revenues from San Joaquin County crop data. The crop data was collected from the National Agricultural Statistics Service (NASS).[55] Specifically, this data is based on the annual Crop Reports published by the California County Agricultural Commissioners. I used the year range from 1991-2015 for the analysis. The only significant crop that was omitted, due to lack of data in some years, was blueberries. It is worth noting that this crop is salt tolerant and thus this omission should not bias my results. The final crop list included: almonds, asparagus, beans, cherries, corn, cucumber, wine

[52] [Exhibit RTD-30-Erratum, p.8:23 – 27.] (The result of the MNL model are based on RTD-301, p. 131, Table 20; RTD-304, p. 1).
[53] [Exhibit SDWA-134-R,p.3:4-15.] Table "Percentage Reduction in Yield Fore Leaching Fraction of 5%."
[54] [Exhibit SDWA-92,p.9-10, Figure 3 Salinity coefficients for six common delta crops.]
[55] https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/Detail/index.php

grapes, hay, peaches/pears, bell peppers, potatoes, pumpkins, tomatoes, walnuts, watermelon, and wheat.

Table 6. 2015 San Joaquin County Crop Acreage & Revenue

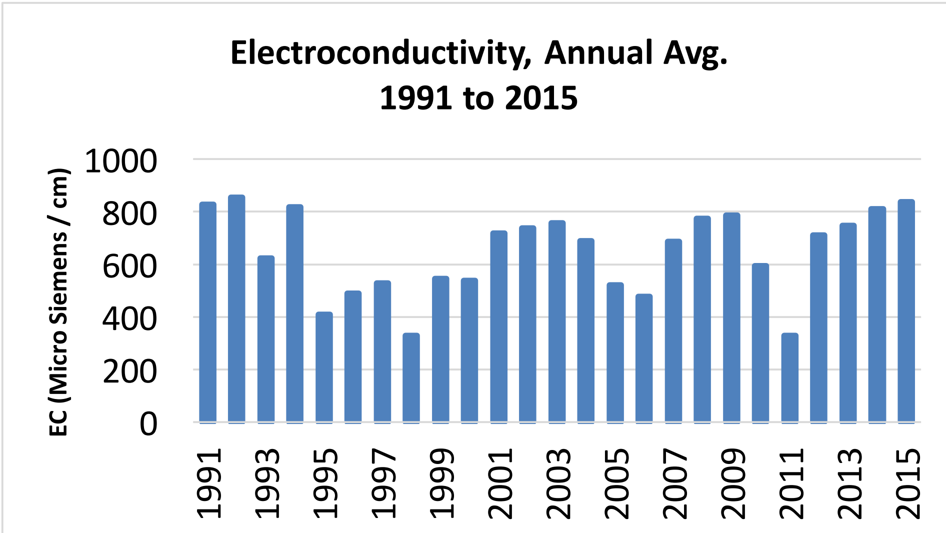
Crop	Harvested Acres	Revenue	Revenue Per Acre
Potatoes	4,020	62,484,000	15,543
Bell Peppers	270	3,454,000	12,793
Watermelons	2,660	32,327,000	12,153
Asparagus	2,820	32,718,000	11,602
Cherries	20,300	181,152,000	8,924
Pumpkins	2,620	21,259,000	8,114
Peaches/Pears	1,874	14,399,000	7,684
Almonds	65,300	433,484,000	6,638
Walnuts	64,100	319,723,000	4,988
Tomatoes	37,230	148,846,000	3,998
Wine Grapes	97,900	351,453,000	3,590
Beans	10,190	18,247,000	1,791
Hay	61,610	71,781,000	1,165
Cucumbers	2,800	3,026,000	1,081
Corn	92,340	92,948,000	1,007
Wheat	18,600	13,151,000	707
Total	484,634	1,800,452,000	3,715
% of County Total	64.7	90.7	-

Salinity data was collected from WRO Order 2006-0006 Exhibit WR-8 (DWR sources)[56] and from the California Data Exchange Center (CDEC).[57] In particular, I used data from the San Joaquin River at Brandt Bridge (BDT), Old River at Tracy Road (OLD), and Union Island (UNI) stations. The annual average of the three sensor zones was used. Although these measures come from different stations, there is a high degree of correlation between the levels of salinity. For instance, the correlation coefficient between EC measured at UNI and EC measured at BDT is 0.86, the correlation coefficient between

[56] http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/salinity.shtml

[57] http://cdec.water.ca.gov/

OLD and BDT is 0.78, and the correlation coefficient between UNI and OLD is 0.75. For my analysis, I used annual data from 1991-2015.



The data shows that the most recent years have seen the highest levels of salinity, due likely to the serious drought. The crop reports from 2010 to 2015 for the five Delta counties do not support the argument that a decrease in Delta inflow that would lead to higher salinity levels, which would in turn reduce crop yield. Despite higher salinity due to the recent drought, crop yields from 2010 to 2014 actually increased for all counties. Crop values actually peaked in 2014, which was one of the driest years.[58] Although crop values decreased in 2015 for all Delta counties except for Contra Costa County, crop values generally had been trending up. San Joaquin County, which comprised almost half of the Delta, is shown below as an example.

Before running a regression, it is helpful to examine the data and consider the historical patterns of water salinity yield per acre for the various crops.

First, I look at the data for almonds, which are known to be salt-sensitive.

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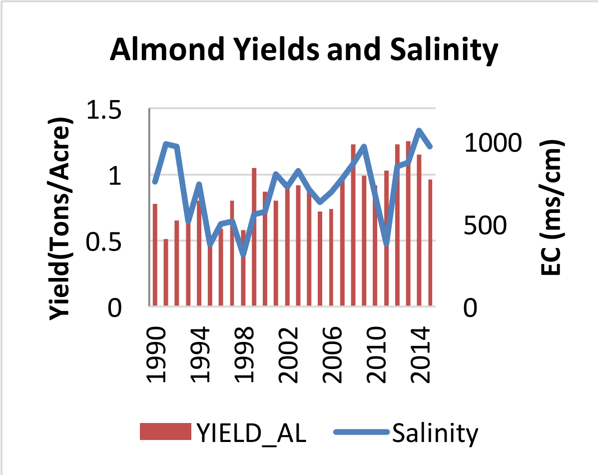
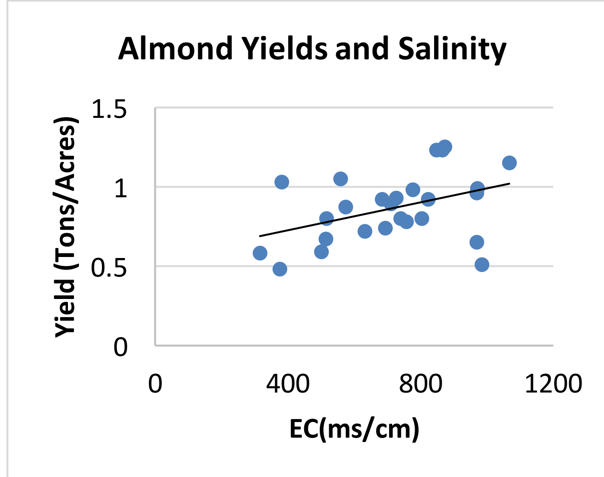
58 United States Drought Monitor. Retrieved January 26, 2017. Available at < http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx>





The graph on the right demonstrates yearly almond yield data on the y-axis with the corresponding salinity level on the x-axis. A best-fit trend line was inserted in order to illustrate the correlation between salinity and yield. In this case, the trend line has a positive slope. The fact that the slope is positive directly contradicts Michael et al's claim that an increase in salinity should automatically lead to a significant decrease in yield. If Michael et al's claim were true, then I would see a negative slope instead of a positive slope.

Interestingly, similar simple analyses of other salt-sensitive crops such as beans, almonds, cherries, peaches/pears yielded a positive slope as well. Furthermore, crops identified as moderately salt-sensitive (i.e. hay (alfalfa), corn, tomatoes, and walnuts) also show a positive relationship between salinity and yield. The graphs for all of these crops are provided in the appendix. It is evident from the charts that none of these crops, identified as sensitive to salinity, have a negative relationship between crop yield and salinity, which means that an increase in salinity did not lead to a significant decreased in yield. This is likely due to other factors as described below.

It is important to note that I am not claiming that increased salinity has a positive effect on yields. This simple analysis only suggests that there are other, clearly far more important, factors at play. There is a reasonable explanation for this relationship seen in so many of the crops. Salinity tends to be higher in sunnier years when there is less precipitation. Ordinarily a lack of rain would seem problematic, but easy irrigation offsets the problem and the plants largely benefit from greater hours of sunlight. I also have to acknowledge that there may be general trends in productivity that are creating a spurious correlation with the general increase in salinity in the delta over the time period in question.

This suggests that a more rigorous empirical effort needs to be undertaken. As such I use two types of statistical analysis. First, I look to create a time series regression for each crop yield history, where I use a variety of controls including lagged variables (variables that reflect effects occurring at earlier times) to control for non-stationary aspects of the data. In order to improve the efficiency of the results, I then place the data in a SUR-type (seemingly unrelated regression, described below) panel regression.

The first analysis analyzes crop yields on a crop by crop basis. A typical log-log time series analysis was used (in which the independent (or "cause") variable is a logarithm as is the dependent (or "effect") variable), including lagged dependent and control variable. A variety of potential variables were used in the equations, with insignificant variables dropped for a final form equation. Data available for the crops includes: yield (tons/acre), harvested acres, price per unit (tons), and total output (tons).

Table 7. Regression Variables Defined

Variable	Description	Units
ec	Annual electroconductivity average, 1990-2015. This is the covariate of primary interest, and is the average of the current and previous year to take into account the additive impact of salt	Micro Siemens / cm
yield	Output per Acres. This variable serves as a measure of crop productivity. This is my dependent variable in my regression analysis.	Tons/Acres
price	Price per unit. Price is included since it affects planting choices by farmers.	$/Ton
tmax	Average Annual Maximum Temperature. This variable is used as a proxy for heat stress that may affect crop productivity.	Fahrenheit
tmin	Average Annual Minimum Temperature. This variable is used as a proxy for cold stress that may affect crop productivity.	Fahrenheit
prec	Precipitation.	Inches
ppi	Producer Price Index for agriculture. Used as a proxy for farmer's input costs.	N/A
un	Unemployment Rate. This variable serves as a proxy for labor availability.	%

The full results of these regressions are included in an appendix. The salinity elasticity[59] estimate from these equations is shown in Table 8 below.

Table 8. Salinity Impact Elasticity Estimate by Crop

Crop	Elasticity	t-stat	
Alfalfa (Hay)	0.243	1.80	*
Almonds	0.152	0.542	
Asparagus	-0.059	-0.368	
Beans	0.062	0.593	
Bell Peppers	0.311	0.797	
Cherries	0.537	1.75	*
Corn	0.286	1.78	*
Cucumbers	0.424	1.33	
Wine Grapes	0.014	0.082	
Peaches / Pears	0.044	0.374	
Potatoes	0.013	0.093	
Pumpkins	-0.014	-0.079	
Tomatoes	0.127	1.43	
Walnuts	0.122	0.728	
Watermelons	-0.096	-0.358	
Wheat	0.043	0.253	

For no crops does there appear to be any truly significantly negative correlation with water salinity levels—for watermelons and pumpkins. On the other side there are 3 crops that seemingly have a significantly positive correlation of yields with salinity levels—alfalfa, cherries, and corn. As noted—these correlations may well be due to the inability to fully capture weather patterns or other environmental variables. It clearly shows that increases in salinity have little impact on overall agriculture productivity within the range of the data.

The data I am using is limited by the number of years of data available as well as

[59] A log-log model gives us regression coefficients that should be interpreted as the elasticity of the dependent variable with respect to the covariate in question. In this case, the elasticity coefficient should be interpreted as a percentage change. For instance, if the coefficient for the covariate log(EC + EC(-1)) is 0.05 and our dependent variable is log(yield), then this means that a 1% change in log(EC) will lead to a 0.05% change in log(yield), all else equal.

some issues with data quality. In order to undertake a more rigorous approach, I used a panel data model. The dataset consisted of 16 crops that were observed over 25 years (1991-2015)[60]. There are a total of 400 (16x25) observations. The regression method employed was pooled estimated generalized least squares (Pooled EGLS) with a cross-section seemingly unrelated regression (SUR) framework. The cross-section SUR weights were used in order to allow for contemporaneous correlation between the error terms for each crop (i.e. the cross-sectional components). In other words, if there are other forces at play, these can be better controlled for by looking for correlations in the patterns of errors over time, in order to prevent this potential omitted variable bias (in which a regression is being biased by forces unaccounted for in the regression) from influencing the coefficient on salinity.

As with the first set of regressions, the independent variables are used as controls. Iused max temperature (source: NOAA),[61] which is the maximum monthly average temperature in a given year. I also used change in harvested acres (source: NASS; San Joaquin County Crop Reports), precipitation (source: NOAA) and county unemployment (source: California EDD) as a proxy for labor availability/cost. Moreover, I used a lag dependent variable to control for auto correlation. Note, I also tried minimum temperature, peak salinity, PPI for agricultural commodities as a cost of farming, and crop price changes.

Most variables were transformed via logarithms as in the individual equations. This is done so that my regression coefficients could be interpreted as the elasticity of the dependent variable with respect to the covariate in question (a so-called log-log model). In this case, the elasticity coefficient should be interpreted as a percentage change. For instance, if the coefficient for the covariate log(ec + ec (-1)) is 0.05 and our dependent variable is log(yield), then this means that a 1% change in log(ec + ec (-1)) will lead to a 0.05% change in log(yield), all else equal. For our model, the dependent variable was log(yield). Our independent variables were: log(ec + ec (-1)), log(max temperature),

[60] https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/Detail/index.php
[61] https://www.ncdc.noaa.gov/cdo-web/

log(precipitation), unemployment, and a lagged dependent variable to control for autocorrelation issues.

The regression coefficients for water salinity levels are presented in the table below.

Table 9. SUR Regression Salinity Impact Coefficients

Crop	Coefficient
Alfalfa (Hay)	0.128**
Almond	0.027
Asparagus	0.349 **
Beans	0.128
Bell Peppers	0.25
Cherries	0.471*
Corn	0.222
Cucumber	0.624***
Peaches/Pears	0.06
Potatoes	-0.048
Pumpkins	0.133*
Tomatoes	0.076*
Walnuts	0.061
Watermelon	-0.106
Wheat	-0.069
Wine Grapes	0.174

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This model does seem to help, inasmuch as many of the positive correlations seen between salinity and crop yields disappear. Despite this—and no matter the type of analysis, the data is clear—around the range of salinity outcomes seen in the Delta, the actual impact on crop yields was statistically insignificant, or statistically significant and positive, for all the various crops.

III. Part 2. Higher Salinity Levels and Shifts in Crops

Dr. Michael claimed that "higher salinity in the Delta could reduce yields for Delta farmers, prevent them from planting more lucrative but salt-sensitive crops, or shift existing fields to lower-revenue crops with higher salt tolerance over time."[62] Part of his analysis estimates the supposed cost of such a shift to the local economy, derived from Dr. Michael's multinomial logit (MNL) model, which estimates how sensitive cropping patterns in the Delta are to salinity and other factors over a nearly 10-year period.[63]

As shown, I find that Michael et al's estimates of yield reduction to be highly overstated—both in terms of the model they use to estimate it, as well as looking at the history of crop yields in years of high and low water salinity. Such a result largely undermines any claim of damages created by crop-shifting. Without any significant loss in yields, salinity becomes a moot point in terms of crop choices.

The fact that Dr. Michael claims to find a crop choice impact could be seen to contradict my work detailed in the previous section. Yet a closer examination of these efforts shows many of the same flaws seen in their estimates of the loss in yield due to higher salinity levels—flaws that appear to highly exaggerate the actual potential economic impact of higher salinity levels. The problems I find include the following:

- The model used suffers from not having a clear discussion of what is being measured, or why. Specifically, the idea of "high" and "low" value crops seems to fly in the face of basic land use economics.
- The data used for the analysis also seems odd. Michael uses strange aggregates of crops in his empirical analysis that do not seem to match up with his previous definitions of high and low value.
- The empirical methodology used by Dr. Michael is not typically very efficient to use with small noisy datasets such as is available for the Delta Ag region. It is extremely sensitive to even small changes in specifications. Additionally the structure of the model itself seems to have many flaws. This suggests that the results are likely to be purely spurious and will disappear with even small changes in the structure of the model.

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[62] [Exhibit SDWA-134-R, p.3:3-5.]
[63] [Exhibit SDWA-134-R, p. 4:2-3.]

- Lastly the results seem to fly in the face of a basic look at the actual data.

Michael describes his model in Exhibit RTD-305. Michael classifies Delta crops into six groups – deciduous, field, grain, pasture, truck, and vineyard – which are the dependent variables in the model. To test the impact of salinity on these crop groups, Michael uses four specifications, which each with a different set of independent variables. The independent variables used are as follows: salinity (specifications 1, 2, 3, and 4), time and regional fixed effects (specifications 2, 3, and 4), field acreage (specifications 3 and 4), and geophysical characteristics (specification 4).[64] Salinity is measured in EC, which is May-August EC average from 2001 to 2010 and geophysical characteristics include Soil Storie Index, elevation, average annual maximum temperature, and slope.[65]

Data Issues

As noted- there are two major issues with how the data was accumulated for analysis. The first problem is the odd aggregation of crops for the analysis. As for Dr. Michael's multinomial logit model, he classified Delta crops into six categories – deciduous, field, grain, pasture, truck, and vineyard. His model shows there would be $23.8 million to $123.1 million of crop revenue loss depending on the level of salinity increase, which ranged from 25% to 200%.[66]

There was little explanation on the crop classification decision and why salinity impact on crops is examined in crop groups instead of individually. Michael considers deciduous, truck, and vineyard crops to be salt sensitive whereas grain and pasture crops are considered to be salt tolerant.[67] In one instance, Michael claims "truck crops and vineyards, with the notable exception of asparagus, are sensitive to salinity."[68] This claim is not entirely true, however. For example, I understand from the literature that blueberry, which is classified as a truck crop,[69] is actually salt tolerant.

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64 [Exhibit RTD-305, p.G-7, Table G-7.]
65 [Exhibit RTD-305, p.G-7, Table G-5.]
66 [Exhibit RTD-301, p.131, Table 20: Forecasted Crop Revenue Impacts from Increasing Delta Salinity.]
67 [Exhibit RTD-301, p.132.]
68 [Exhibit RTD-301,p. 126.]
69 [Exhibit RTD-305, p.G-5, Table G-3 Detailed Crop Categories.]

Also problematic is the idea of high vs low value crop. Based on Michael Machado's testimony (Exhibit RTD-30-erratum, p. 4:4-12), which heavily references Exhibit RTD-301, Dr. Michael classified crop value by type of crop.[70] Namely, truck, vineyard, and deciduous crops are considered to be higher-value crops, whereas field and grain crops are considered to be lower-value crops. It is unclear what Dr. Michael did not clarify what he meant by "more lucrative". I have to surmise that he means that higher revenue per acre crops, since it is true that the top four crops by value – tomatoes, grapes, corn, and alfalfa – are moderately salt sensitive (Exhibit RTD-301, p. 114, Table 10). Throughout Mr. Machado's testimony, he used the term "revenue" 25 times. Clearly, Mr. Machado measured Delta farmers' wellbeing using revenue.

But revenue is a poor metric of true economic value. From an economic perspective, there are two appropriate measures of "value". The first is the value for the farmer or profit per acre, revenues minus the cost of growing the crops. Some crops may be high in revenue, but also very high in costs. Asparagus is a classic example of a high revenue / high cost crop Its cultivation is very labor intensive compared to other forms of agriculture such as growing corn.

Another metric might be the multiplier effects, as driven by the supply chain. From this perspective revenues may well be a decent metric, as if I assume that expected profit margins are largely equivalent across crop types (as would be profit maximizing from the farmer's perspective) then indeed the multiplier effects could be roughly correlated with revenues. But it still isn't a complete picture. Multiplier effects are a function of the types of inputs needed. There is no effort on the part of Michael to estimate a more specific estimate.

Then there are other sorts of supply chain effects. For example, many of the lower-value grain and field crops are critical to other agricultural (e.g. livestock and poultry) and non-agricultural sectors. For example, corn (a field crop) is an essential livestock fodder.

[70] Mr. Machado claims, "Much of the south Delta area also shows many lower revenue-per-acre… allowing north Delta farmers to invest in higher revenue-per-acre…"

Even if I think revenue per acre is a good measure- there are still issues. Normalizing crop value based on acreage shows that the top five crops with the highest value per acreage are:

- Blueberries
- Turf
- Potatoes
- Asparagus
- Pears

Based on Dr. Michael's own data from Table 10 of RTD-301, the value per acre for blueberries ($23,022.71 per acre) was almost three times as much as the next highest value per acre crop, turf ($8,709.98 per acre). Of the top five crops, blueberries and asparagus are salt tolerant, whereas potatoes are moderately salt sensitive and pears are salt sensitive.[71]

In summation, I cannot take the model results seriously, as I don't have a full picture of what a high or low value crop is—either in terms of the aggregates used or what the "values" are that are attached to the crops. Although the model yields statistically significant coefficients, there is no way of inferring anything insightful about the economic significance of these results.

Model Problems

The data that exists at the core of Dr. Michael's analysis is suspect. So too is the methodology he uses as well. Regarding Dr. Michael's multinomial logit model, "[it] is used to predict agricultural land allocation, conditional on its current land use and other exogenous variables, including soil quality, a multi-year average of irrigation water salinity, temperature, slope, elevation, field size, and dummy variables for year and conservation zone to capture fixed effects."[72]

Dr. Michael's data is in effect panel data, where the behavior of multiple sites (cross

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[71] No salt tolerant data exists for turf based on FAO Paper No. 29 Tables 4 and 5.

[72] [Exhibit RTD-301, p. 123.]

sectional component) is observed across several years (time series component). There are three areas of concern regarding Dr. Michael's assumptions and methodologies:

1) Treatment of fixed-effects
2) Model specifications
3) Robustness checks of the model

The first issue pertains to Dr. Michael's treatment of the years in the data, and it stems from two additional problems:

1) Excluding an entire year's worth of observations
2) Not accounting for autocorrelation issues (that there is correlation between the variables of some observations at different points of time)

First, the data spans from 2002 to 2004 and from 2006 to 2010; 2005 was excluded because reliable data was not available.[73] There was no explanation why data for 2005 was not reliable, raising the question of whether the data was omitted for other possible reasons. Given that 2005 was not a drought year, inclusion of 2005 data would likely decrease the impact of salinity.

Dr. Michael accounted for time-fixed effects, there was no indication that he controlled for autocorrelation, which is a very prevalent problem with time series and panel data. In time series data, autocorrelation is a delayed correlation by itself, which means there is a correlation between two values of the same variable at different time periods. Standard treatment typically involves including lagged terms of said variables in the model.

The second issue pertains to more subtle components within the multinomial logit model itself: if Delta farmers make crop choices due to urbanization, then there is an endogeneity issue with land use change decisions and crop choices (Hua, Hite, and Sohngen, 2004).[74] An important assumption of econometric analysis is that the modeled independent variables are not correlated with the error (unobserved) term. In other words,

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[73] [Exhibit RTD-301, p. 123.]
[74] Hua, W., Hite, D. and Sohngen, B. (2004). "Assessing the Relationship Between Crop Choice and Land Use Change Using a Markov Model." Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005

endogeneity leads to incorrect conclusions regarding causation.

For example, observing that an increase in sales of ice cream corresponds with an increase in drowning incidences, one could incorrectly conclude that eating ice cream causes drowning. In other words, correlation doesn't equal causation. The endogeneity problem in this example is that the true cause, summertime, is unobserved. Dr. Michael's methodology, which was presented in Exhibit RTD-305, does not provide enough information to tell whether he accounted for that endogeneity issue in his model.[75]

The most critical issue with Dr. Michael's multinomial logit model concerns with the absence of a full discussion of the model. There was no discussion of the ranges of the data in Appendix G in Exhibit RTD-305; there was no complete set of model results; how many total observations were in the raw dataset; or how many observations were dropped from the multinomial logit model. Finally, there does not appear to be a discussion regarding the assumptions of the model structure, making it impossible to determine whether fundamental assumptions for a multinomial logit model were satisfied.

A Brief Look at the Data

A multinomial logit model is a complicated piece of econometric work. Yet while Dr. Michael displays and discusses his econometric results, there is a serious omission in his efforts—he spends no time discussing even basic trends in the underlying data.

As noted, the natural fluctuations in salinity in the Delta provides me with a natural experiment. If high salinity levels impact certain crops negatively, this in turn should lead to a reduction in acres planted. To see if the data shows any such trends, I compare harvested acres over two period of times for crops that are supposedly salt tolerant, salt

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[75] The multinomial logit model does not allow for violations of assumption II(A): independence of irrelevant alternate choices. On the other hand, models such as multinomial probit and nested logit relax this assumption. For example, suppose a farmer chooses between asparagus (a salt tolerant crop) and cabbage (a moderately salt sensitive crop) and his preference is split equally between asparagus and cabbage. Suppose there exists a third crop (e.g. broccoli) that the farmer can choose to plant. If the farmer's new preference is 1:1:1 ratio between the three crops then there is no violation of assumption II(A). However, if the farmer's new ratio is, say, 50% asparagus, 25% cabbage, and 25% broccoli, then there is a violation because the introduction of broccoli altars the ratio between the original two crops.

sensitive and highly salt sensitive.[76] The two periods in question are 1997 to 2000 when salinity levels were quite low. I then compare that to the 2012 to 2015 data when, because of the drought, salinity levels were 60% higher. These results are show in Table 10 below.

Table 10. Delta Water Salinity & Crop Acreage

	Water Salinity	Acres of Salt Tolerant Crops (a)	Acres of Salt Sensitive Crops (b)	Acres of Highly Salt Sensitive (c)
97-00	484.6	61,225	312,446	117,140
12-15	776.5	29,208	316,811	153,082
Change	60.2%	-52.3%	1.4%	30.7%

(a) Asparagus and wheat
(b) Alfalfa, corn, cucumber, pepper, potato, pumpkin, tomato, watermelon, grapes
(c) Beans, almonds, cherries, walnuts,[77] peaches and pears

Interestingly the pattern of crop acreage is exactly opposite of what has been suggested by Dr. Michael. Acres of salt tolerant crops declined by over 50%. On the other hand, despite higher salinity levels acres of salt sensitive crops rose by over 30%. From my perspective, this seems to completely contradict the results of Dr. Michael's model.

There are plenty of other reasons why farmers may shift their crops. Price changes is likely to be one of the largest. The cost of inputs—particularly labor—probably plays an important role as well. What is clear is that salinity within these ranges plays at best a small and likely an insignificant role.

IV. Part 3: Non-Agricultural Economic Impacts

Beyond some of the questionable claims made above regarding the impacts of salinity due to the WaterFix on crop revenues, there are several claims that do not hold up using basic economic data or theory.

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[76] The relative salt tolerance based on Table 5 of FAO Paper No. 29, which draws data from Maas (1984).

[77] Walnuts are the only crop that has no established relative salt tolerance level in Table 5 of FAO Paper No. 29. However, walnuts are considered to be similar to almonds in terms of salinity tolerance. For example, see: Fulton, A. E., Oster, J., and Hanson, B. (1997). Walnut production manual. UCANR Publications, pp. 58.

The arguments below, made by Dr. Michael or Dr. Whitelaw, either exaggerate economic harm caused by construction of the WaterFix ~~or underestimate the economic benefits of the WaterFix.~~

First, Dr. Michael claims that the WaterFix, by reducing farmland in the Delta, would cause harm to the Delta economy. ~~However, the perceived negative economic impact is very small, while the expected benefits to the local economy due to the WaterFix will be very high (construction could add substantial numbers of jobs and spending to the Delta economy).~~

Second, Dr. Michael exaggerates the impact of the logistics sector in the Delta economy and unreasonably suggests that WaterFix construction would significantly harm the sector, causing a negative impact on the Delta economy.

Third, Dr. Michael incorrectly suggests that WaterFix expenditures would come at the expense of levee upkeep expenditures. ~~The funding for each respective construction project would actually come from different sources and could work together, as a result.~~

~~Fourth, Dr. Michael significantly underestimates the high impacts on economic output, jobs, and wages to the whole economy of California due to the multiplier effects from over $15 billion in WaterFix construction and operations spending.~~

Fifth, Dr. Whitelaw sets an impossibly high standard of satisfying a “no injury” standard due to the WaterFix, such that even useful, seemingly harmless actions such as harvesting more crops could be said to “injure” existing Delta water users. Even then, his claims overlook the possibility of compensatory payments to water users to make up for any perceived injury that would be done.

Ultimately, these five points exaggerate negative consequences due to the WaterFix or overlook key benefits about the WaterFix that could be explained through a better examination of the economics of the Delta region.

Incorrect Assumption that WaterFix Would Harm the Delta Economy by Reducing Farmland

Dr. Michael also claimed that there would be land loss and “the larger community would still suffer an economic loss from the reduced economic activity from land that was no longer farmed due to the surface impacts of WaterFix construction."[78]

Dr. Michael found that the WaterFix would permanently reduce agricultural-related employment in the Delta by about 146 jobs and reduce income by $10.3 million in 2009 dollars or about $11.6 million in current dollars."[79] Dr. Michael also found that "loss of farmland to construct the conveyance facility is estimated to generate an additional $10 to $15 million in crop losses per year."[80]

Even without the implementation of the WaterFix, land loss has been occurring gradually due to factors such as urbanization and subsidence. ~~In addition, Dr. Michael overlooked the substantial economic impact of construction, operations, and maintenance of the WaterFix. A massive construction project would be required to implement the WaterFix, while operations and maintenance costs ($15 billion) would generate substantial economic output statewide, as that spending moves through the state economy. Much of the spending and hiring would occur locally, particularly for operations and maintenance. The Delta economy would in effect receive "new" spending, as water agencies – many as far away as Southern California – receiving SWP and CVP supplies from Delta would fund WaterFix.~~

Consequently, the net benefit to the Delta economy due to construction, operations, and maintenance of WaterFix would likely be much higher than losses Michael cites of 146 jobs and $11.6 million. In addition, the economic output and jobs supported by the WaterFix in areas outside the Delta would be enormous.

Incorrect Assumption that WaterFix Would Harm the Delta Economy by Impairing the Local Logistics Sector

Much of the debate surrounding the WaterFix is based on misunderstandings about the project and its impacts. In particular, Jeff Michael claims that the WaterFix will have a negative impact on infrastructure services, which are implied to be transportation,

[78] [Exhibit SDWA-134-R, p. 7:11-14.]
[79] [Exhibit SDWA-134-R, p.7:21-27.]
[80] [Exhibit RTD-301, p. 107.]

warehousing, and utilities (the logistics sector). Michael claims, "Particularly when you look at the Delta economy, some of these key infrastructure sectors, transportation and energy, these are actually the highest-paying, best jobs in -- in the Delta, and local water infrastructure. So they're critically important to the -- to the Delta economy."[81] Yet, the diversity of the logistics sector in San Joaquin County, coupled with the ability of the WaterFix to generate business activity in that sector, would render the impact of the WaterFix neutral on San Joaquin County logistics, if not positive.

Underpinning Dr. Michael's line of argument is the notion that there is a growing interdependence between the Delta region and the Bay Area, which Michael claims will be impeded by the construction of the WaterFix. In fact, Michael states, "The County's economic growth is dependent upon efficient transportation of goods and people with the Bay Area. Several of the important transportation corridors are in the Delta, and their importance to the economy is likely to increase in the future. Critical transportation corridors include state highways (4 and 12), rail, and Stockton shipping channel. The *Draft BDCP Statewide Economic Impact Report* estimated that traffic delays resulting from tunnel construction could result in costs as high as $28 million per year." [82]

However, it is unreasonable to claim that a single construction project, even one as large as the WaterFix, will have a significant effect on an entire industry and subsequently the economic growth of San Joaquin County. There are greater economic forces than potential traffic obstacles that affect supply and demand for the logistics sector, such as access to outside markets (abundant in the Delta region) and the strength of important complementary sectors such as construction, retail, or wholesale trade. This is especially true if San Joaquin County's economy is increasingly connected to the Bay Area economy, as Michael claims. If strong demand from the Bay Area—one of the strongest, fastest-growing economic centers in the United States—is helping grow the logistics sector in the Delta region, then there is no reason to believe that this will change due to traffic caused by

[81] [November 17, 2016 Transcript Vol.29, p.224:7-12.]
[82] [Exhibit SDWA-134-R, p. 11:11-17.]

the construction of the WaterFix. Moreover, the Delta economy is diverse, and thus negligible changes in the logistics sector should not affect the economic growth of the Delta region.

Although the logistics sector has grown rapidly in the past two years, it is not the only sector growing at a solid rate. Furthermore, it is not the largest sector in terms of overall employment. As a result, traffic delays from the WaterFix are not likely to be significantly detrimental to logistics in the Delta region. In turn, the general economic health of the Delta region will see little impact due to the WaterFix.

Furthermore, Dr. Michael aggrandizes the average wages earned in the logistics sector in San Joaquin County, exaggerating the importance of the industry to the health of the overall economy relative to other sectors. In particular, he claims that the transportation and energy sectors have the highest wages in the San Joaquin County. Data the Bureau of Labor Statistics' Quarterly Census of Employment and Wages demonstrate that the logistics sector is not the highest-paying industry in San Joaquin County.

Table 11. 2015 Annual Avg. Wage, San Joaquin County

Industry	2015 ($)
Prof.,Sci.,Tech., and Mgmt.	60,732
Wholesale Trade	55,905
Information	54,165
Fin. Svcs. and Real Estate	53,607
Logistics	**52,769**
Manufacturing	52,261
Health Care	46,850
NR/Construction	39,775
Education	37,919
Other Services	30,761
Retail Trade	28,877
Admin Support	28,253
Leisure and Hospitality	16,947

Source: BLS QCEW

This does not mean that logistics is not an important industry, but it is misleading for Dr. Michael to inflate the size of this industry in terms of the average wage. Ultimately, Dr.

Michael's interpretation of the impacts of the WaterFix construction on the Delta economy is based on a misleading portrayal of the logistics sector.

WaterFix Does Not Come at the Expense of Levee Upkeep

Dr. Michael maintains that construction of the WaterFix will leave fewer dollars available for maintaining and improving the Delta levee system. He also maintains that the WaterFix increases the risk of the Delta region suffering a multi-billion-dollar catastrophe. These assertions are baseless. I understand WaterFix would not take away any funding from restoring the Delta levee system, nor will it increase the likelihood of the Delta experiencing a major disaster.

Dr. Michael claims that the WaterFix would cause a direct decrease in the amount of funding available for levee upkeep. Specifically, he says: "…the WaterFix could also reduce future funding for levee maintenance and improvement since it would reduce the dependence of the SWP and CVP on the levee system."[83] This is simply not true. Funding for levee maintenance and improvements comes from many different sources at the federal, state, and local levels. ~~The WaterFix, on the other hand, will be funded entirely by the various water agencies that receive State Water Project and Central Valley Project water supplies.~~ The levee system and the WaterFix are separate entities with separate sources of funding.

Further statements by Dr. Michael include the assertion that, by focusing solely on water exports, proponents of the WaterFix will increase the risk involved in a major seismic event. He states: "Petitioners have chosen to focus investment on protecting water exports alone through the WaterFix rather than to address this risk through a collaborative approach to strengthen Delta levees and simultaneously protect water exports. Thus, the WaterFix increases the risk of the Delta economy suffering a multi-billion dollar catastrophe."[84] As mentioned previously, the levees are maintained and improved by

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[83] [Exhibit SDWA-134-R, p. 8:16-18.]

[84] [Exhibit SDWA-134-R, p. 9:4-8.]

different governmental agencies—it is not the function of the WaterFix to further bolster the levees.

Moreover, it is false to claim the WaterFix will increase the risk of the Delta area suffering a catastrophe. In fact, I understand WaterFix is proposed to actually mitigate the potential destruction of a major seismic event. A serious earthquake could cause substantial levee failure, destruction of property, loss of life, and a contaminated water supply. However, if the WaterFix were to be put in place, the threat of contamination would be mitigated by tunneling water from the proposed northern diversion point of the Delta. The WaterFix would effectively supply water that is safe from any potential contamination caused by an earthquake, as a supplement in the face of substantial Delta water supplies that might become unusable due to contamination. The existence of the WaterFix would not increase the Delta economy's exposure to catastrophic risk. ~~The WaterFix would lessen the destruction of a huge seismic event by supplying safe water to the rest of the state.~~

~~Negative Outcomes Do Not Outweigh Benefits of the WaterFix~~

~~Dr. Michael also overestimates the cost of traffic congestion and lost agricultural output in the Delta region relative to the highly positive benefits of job growth, economic output, and water supply reliability caused by construction of the WaterFix.~~

~~Traffic congestion is presented in economics literature as a very common negative externality. A negative externality exists when an action by an individual affects other parties, without payment or compensation for the cost or benefit affecting them. For instance, if one decides to go out for a leisure drive during rush hour, one typically only considers the benefit from being on the road as compared to costs such as fuel and time. However, being on the road imposes a cost to other drivers by increasing road congestion, which when aggregated is known as the social cost. It is of paramount importance to note that in this simple example, the decision to take a leisure ride is incurring a social cost but no social benefit.~~

~~This is the scenario Dr. Michael is envisioning when he discusses the negative~~

impacts of the WaterFix. Dr. Michael claims that the WaterFix construction will impose a negative externality in the form of traffic congestion.

Dr. Michael also claims that construction of the WaterFix, in eliminating roughly 4,000 acres from production, could cause a loss of roughly 146 jobs and $11.6 million in income ($12 million in total revenue loss).[85] Even assuming that this is the case, in the context of the overall economy of San Joaquin County, these losses are small. According to the U.S. Bureau of Economic Analysis, the total real gross regional product ("GRP") of the county stood at $22.0 billion, of which the Agriculture, Forestry, Fishing, and Mining industry represented 6.9%, or $1.5 billion. Consequently, a total revenue loss of $12 million represents less than 1% of total agricultural industry GRP, even if that $12 million loss were concentrated in a single year.[86]

Between 2001 and 2015, the GRP of San Joaquin County has grown by 75.1%, from $870 million to $1.5 billion, or roughly $46 million per year during that time. A $12 million loss, not concentrated in a single year, would not represent a substantial proportion of a single year's growth in the agricultural industry since 2001.[87]

Furthermore, Dr. Michael ignores much larger positive externalities from the project. This broader analysis of social benefits versus social costs is essential for economic decision-making regarding public infrastructure projects such as the WaterFix.

Public infrastructure projects such as the WaterFix are essential to many facets of the economy, thus typically providing a substantial social benefit. The construction of WaterFix could generate a substantial number of jobs in the logistics sector, as well as a range of other sectors, due to multiplier effects as spending made locally in connection to WaterFix construction moves through the San Joaquin County economy and in other regions of California.

As spending moves through the economy, businesses that earn revenue and

[85] [Exhibit SDWA-135-R, p.10:7.]

[86] U.S. Bureau of Economic Analysis, "Real GDP by metropolitan area (2009 chained dollars), Stockton-Lodi Metropolitan Area, 2015."

[87] U.S. Bureau of Economic Analysis, "Real GDP by metropolitan area (2009 chained dollars), Stockton-Lodi Metropolitan Area, 2001 & 2015."

workers that earn income from that spending in turn spend some portion of that revenue or income in the economy. Spending quickly moves throughout many sectors of the economy, generating additional spending that comes in the form of new hires, more pay for workers, renovations, or other goods or services. As a result, a project such as the WaterFix inputs so much money into the economy that it generates a substantial number of new jobs and economic activity, much of which will be concentrated in the Delta region. For instance, much of the construction materials involved in the WaterFix will need to be transported and stored in the Delta region.

Public infrastructure projects like the WaterFix are an essential part of the California's economy and have played an integral role in economic development across a range of sectors. Any costs, in terms of lost jobs or output, to the logistics sector or the agricultural sector are not as severe as Dr. Michael would suggest, particularly as those sectors are already strong in the local economy and continuing to grow.

Consequently, it is unreasonable to suggest that a construction project like the WaterFix will distort the economy of an entire sector and hinder the growth in San Joaquin County. If this were true, it would rarely make sense to go forward with major public infrastructure projects.

Throughout Michael's work there is substantial oversight of the impacts of the tunnel system that extend well beyond the Delta economy in the form of water supply reliability. Drought conditions could impair Delta water exports more severely. The negative economic impact of water export cutbacks would be felt statewide, in key markets such as the Bay Area, the Central Valley, and Southern California, where most of California's economic activity is concentrated. As described in the Final EIR/EIS for the WaterFix, restrictions to Delta water exports would force local water agencies to provide more water through potentially overdrawn sources like local storage and groundwater. (See Exhibit DWR-655, Appendix 5B, Responses to Reduced South of Delta Supplies.) Drought conditions in recent years have already demonstrated that these sources, particularly in areas such as Southern California, will not be able to sustain over the long term in the face of shortages from supplies such as the State Water Project.

Indeed, given the high cost of securing water to keep up with demand satisfied through Delta exports, there is a statewide economic benefit extending to potentially billions of dollars, depending on different expected export levels in the future without the WaterFix.

Economic Theory Does Not Support Dr. Whitelaw's Strict Interpretation of "No Injury" Rule

Dr. Whitelaw's interpretation of the "no injury" rule represents an economics perspective that is impossible to meet in reality. In his testimony, Dr. Whitelaw had a strict interpretation of the "no injury" rule, in which compliance with Water Rights Decision 1641 (D-1641) standards does not do enough to address injury to other legal users of water.[88] Dr. Whitelaw claimed that the D-1641 standards do not cover all aspects of quality or quantity conditions that might injure other legal users of water. Instead, Dr. Whitelaw argues for an overly simplistic rule of no economic impact, without assessing the legitimacy of the basis for a claim of injury. The biggest problem with Dr. Whitelaw's claim is that the actual "no injury" rule does not clearly translate to economic terms without such an assessment, which incorporates State policy decisions regarding the appropriate use of water.

By Dr. Whitelaw's definition, there could not be any impact whatsoever. Yet in economic theory, every action has an opportunity cost (that is, foregone potential benefits from other alternatives when one alternative is chosen). In turn, the goal of policy is to find solutions that maximize societal benefits, which often involve trade-offs between competing uses of resources. Dr. Whitelaw's interpretation of the "no injury" rule, however, is analogous to saying that a farmer cannot plant more crops or different crops than what he has currently, even in the face of a crop shortage, because that would increase his water consumption and he would be taking water away from other farmers.

In addition, Dr. Whitelaw concluded the D-1641 standards fail to cover all aspects of

[88] [Exhibit CWIN-6, p.4, Sect.B, ¶4.]

~~quality or quantity conditions that might injure other legal users of water.~~[89] ~~In the South Delta applied water salinity tends to be higher than in the North Delta. This creates a scenario where, entirely independent from WaterFix, demand from allegedly legal users outstrips supply. Ideally, the most economically sound decision would be to maximize societal benefits, an optimal allocation of water to Delta and non-Delta water users.~~

~~At the same time, any quality or quantity issues that might injure legal users of water – farmers in the Delta, in this case – could be addressed through compensating payments. This in itself is a kind of tradeoff that would help to achieve the optimal allocation of water to Delta and non-Delta water users. Any perceived injury to current Delta water users as a result of a project such as the WaterFix could lead to compensation that reduces the value of that negative impact to zero. For instance, payments might be made that could offset a cutback in crops due to reduced access to water.~~

V. Conclusion

Reviewing the analysis and testimony of Dr. Jeffrey Michael, Michael Machado, and Ed Whitelaw (hereafter Michael et al) regarding the impacts of the California WaterFix, I found a series of significant flaws that cause the findings of that analysis and testimony to break down with a substantive review.

Existing data and my own empirical analysis show that salinity levels have not had an impact on crop yields, and thus they would not have an impact on crop yields assuming salinity levels increase due to the WaterFix. Shortcomings in Dr. Michael's model also call into question that salinity would lead Delta farmers to shift to lower value crops. In fact, revenues are not even the best measurement of crop value, relative to profits or multiplier effects. Finally, Dr. Michael significantly overestimates the impacts of the WaterFix on areas such as total Delta farmland and the logistics sector, ~~while at the same time he substantially underestimates the positive effects of the WaterFix for the Delta region and indeed the whole state of California.~~ At the same time, Ed Whitelaw generates an

[89] ~~[Exhibit CWIN-6, Sect.B, ¶4 of Section B.]~~

unrealistically high standard of maintaining no injury to in-Delta water users, ignoring that even in the event of an injury, these water users could receive compensatory payments for that injury.

These flaws in Michael, Machado, and Whitelaw's claims negate their analyses and testimony and do not support the negative impacts of the WaterFix that they observe.

Executed on this 22 day of March, 2017 in Sacramento, California.

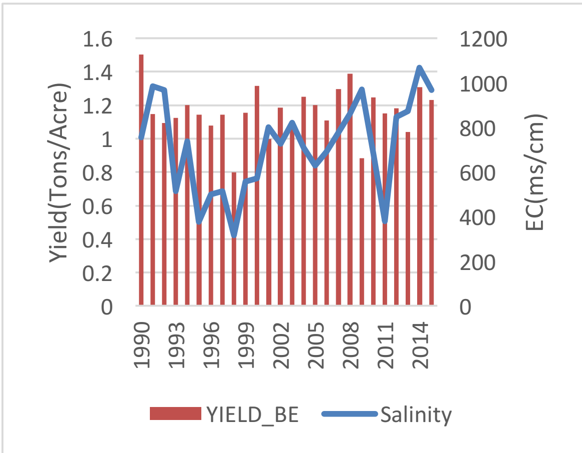
____
(Christopher Thornberg)

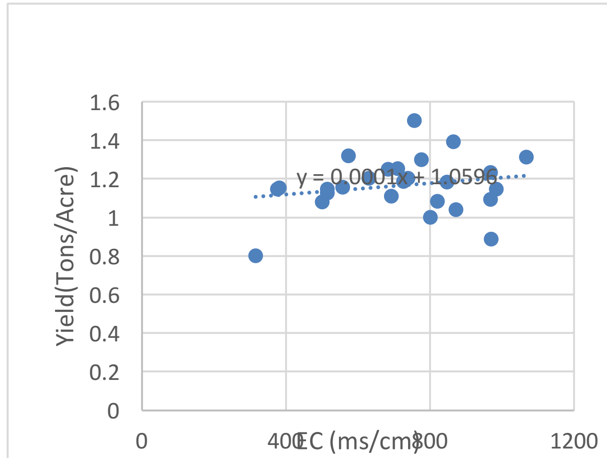
Testimony stricken per Oral Ruling Dated May 19, 2017, as shown in blue strike out text.

Appendix A:

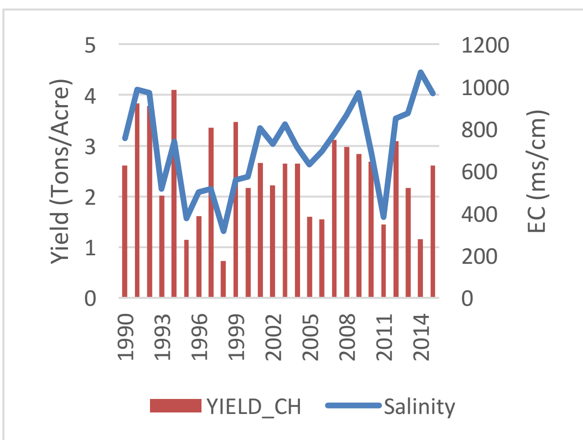
Sensitive Crops

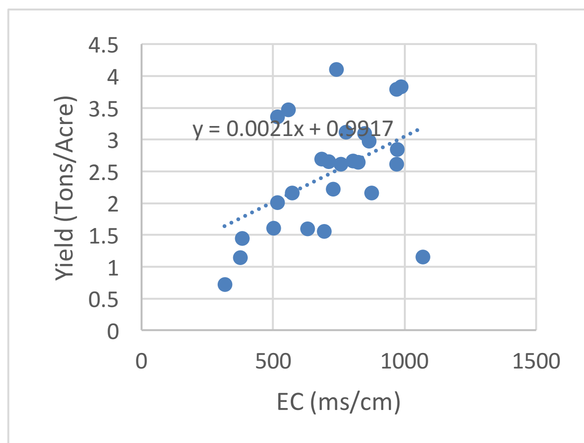
Beans:



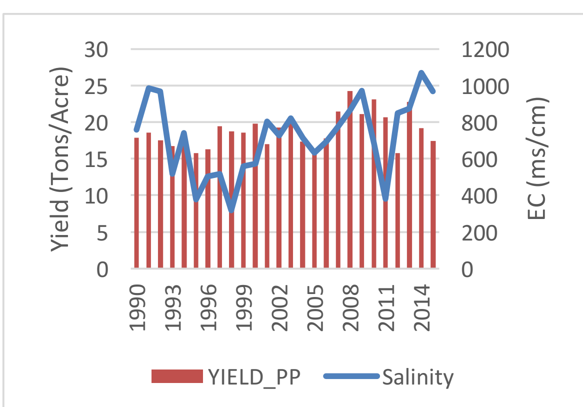


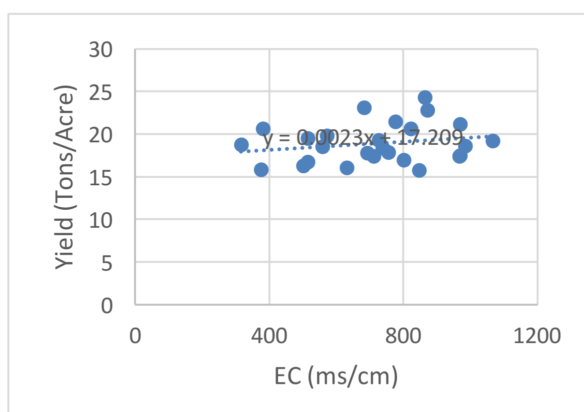
Cherries:





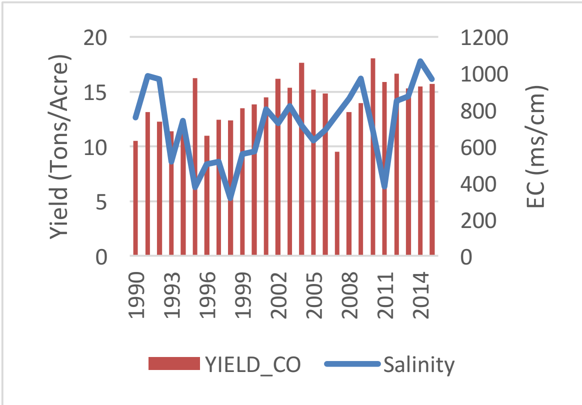
Peaches/Pears:

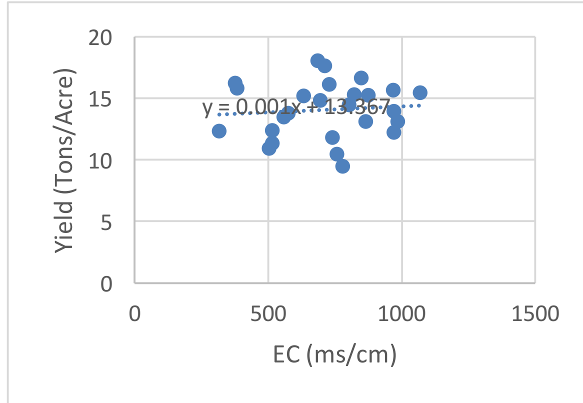




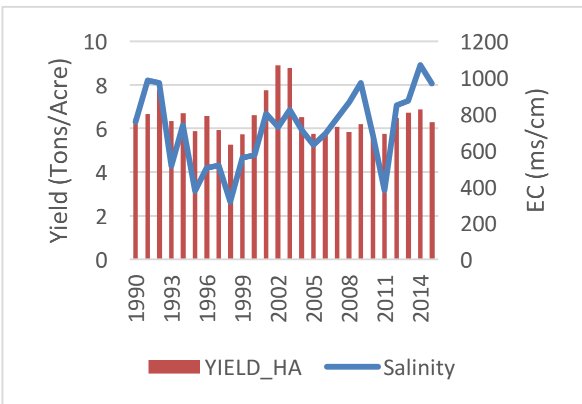
Moderately Sensitive Crops

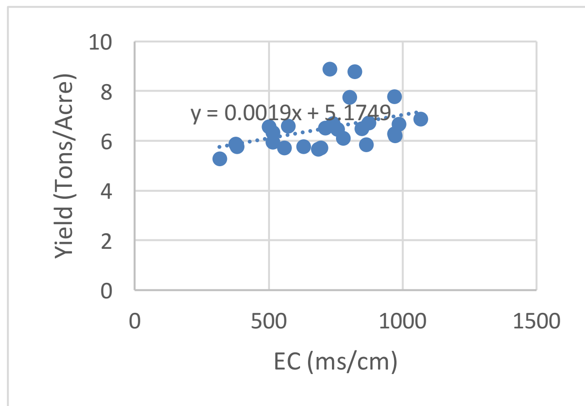
Corn:



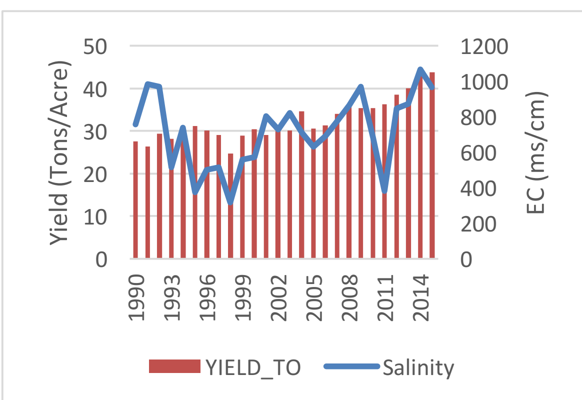


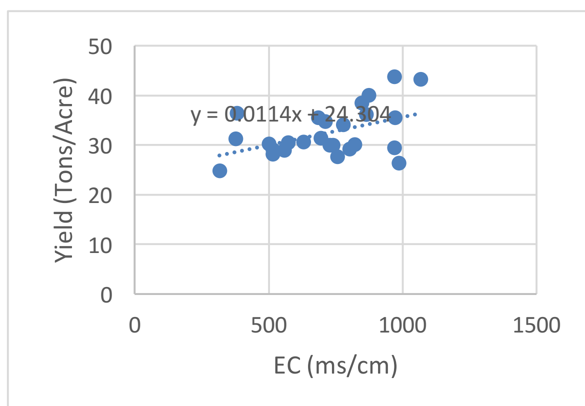
Alfalfa (Hay):



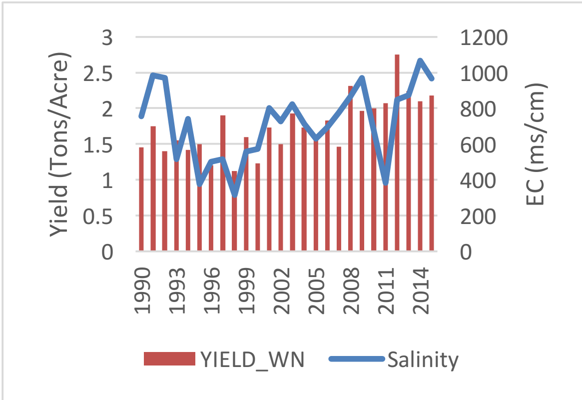


Tomatoes:

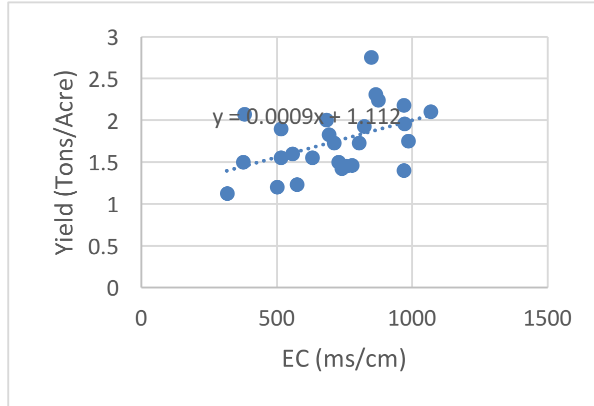




Walnuts:



Yield (Tons/Acre)
3
2.5
2
1.5
1
0.5
0
1200
1000
800
600
400
200
0
EC (ms/cm)
1990
1993
1996
1999
2002
2005
2008
2011
2014
YIELD_WN
Salinity



Yield (Tons/Acre)
3
2.5
2
1.5
1
0.5
0
y = 0.0009x + 1.112
0
500
1000
1500
EC (ms/cm)

Appendix B: Regression Results

Log-log time series analysis

Almonds

Variables	(1) log(yield)
log(ec + ec(-1))	0.152
	(0.28)
log(tmax)	-1.88
	(1.90)
log(prec)	-0.220**
	(0.094)
AR(1)	0.451*
	(0.251)
Constant	7.42
	(9.06)
R^2	0.56
F-Stat	5.81
Durbin-Watson	2.21

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Asparagus

Variables	(1) log(yield)
log(ec + ec(-1))	-0.059
	(0.161)
dlog(hacres)	-1.18***
	(0.245)
un	3.94***
	(0.974)
AR(1)	-0.278
	(0.241)
Constant	0.323
	(1.12)
R^2	0.67
F-Stat	9.01
Durbin-Watson	2.03

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Beans

Variables	(1) log(yield)
log(ec + ec(-1))	0.064
	(0.107)
dlog(Hacres)	-0.109
	(0.084)
log(prec)	-0.090
	(0.06)
AR(1)	-0.36
	(0.227)
Constant	-0.302
	(0.769)
R^2	0.27
F-Stat	1.64
Durbin-Watson	2.12

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Bell Peppers

Variables	(1) log(yield)
log(ec + ec(-1))	0.311
	(0.390)
log(tmin)	-0.826
	(0.560)
un	3.64
	(2.87)
AR(1)	0.27
	(0.286)
Constant	3.02
	(3.69)
R^2	0.40
F-Stat	3.02
Durbin-Watson	1.86

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Cherries

Variables	(1) log(yield)
log(ec + ec(-1))	0.54*
	(0.307)
log(tmax)	-2.85
	(3.43)
AR(1)	-0.415*
	(0.207)
Constant	9.94
	(15.6)
R^2	0.28
F-Stat	2.52
Durbin-Watson	2.11

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corn

Variables	(1) log(yield)
log(ec + ec(-1))	0.286*
	(0.161)
log(tmax)	-2.31*
	(1.40)
log(tmin)	0.612**
	(0.248)
dlog(hacres)	-0.408**
	(0.190)
AR(1)	0.393
	(0.231)
Constant	8.97
	(6.64)
R^2	0.52
F-Stat	3.64
Durbin-Watson	2.26

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Cucumbers

Variables	(1) log(yield)
log(ec + ec(-1))	0.424
	(0.319)
un	3.22
	(2.81)
AR(1)	0.451**
	(0.214)
Constant	-1.16
	(2.31)
R^2	0.39
F-Stat	4.09
Durbin-Watson	2.06

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Wine Grapes

Variables	(1) log(yield)
log(ec + ec(-1))	0.014
	(0.172)
AR(1)	0.239
	(0.216)
Constant	1.81
	(1.23)
R^2	0.06
F-Stat	0.59
Durbin-Watson	1.95

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Alfalfa (Hay)

Variables	(1) log(yield)
log(ec + ec(-1))	0.243*
	(0.135)
log(tmax)	1.93**
	(0.904)
AR(1)	0.639***
	(0.188)
Constant	-8.67*
	(4.38)
R^2	0.54
F-Stat	7.54
Durbin-Watson	1.51

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Potatoes

Variables	(1) log(yield)
log(ec + ec(-1))	0.013
	(0.140)
log(prec)	-0.154***
	(0.045)
AR(1)	0.561**
	(0.209)
Constant	2.78**
	(1.00)
R^2	0.58
F-Stat	8.83
Durbin-Watson	1.77

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Peaches/Pears

Variables	(1) log(yield)
log(ec + ec(-1))	0.044
	(0.119)
log(tmin)	-0.436*
	(0.211)
dlog(hacres)	-1.15**
	(0.468)
log(prec)	-0.09
	(0.056)
AR(1)	0.128
	(0.248)
Constant	4.22***
	(01.18)
R^2	0.50
F-Stat	3.40
Durbin-Watson	2.00

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Pumpkins

Variables	(1) log(yield)
log(ec + ec(-1))	-0.014
	(0.175)
log(tmin)	0.452*
	(0.24)
dlog(ppi)	-0.223
	(0.247)
AR(1)	0.608***
	(0.157)
Constant	1.27
	(1.60)
R^2	0.48
F-Stat	4.13
Durbin-Watson	2.19

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Tomatoes

Variables	(1) log(yield)
log(ec + ec(-1))	0.127
	(0.089)
log(tmax)	-1.39
	(0.838)
log(tmin)	0.130
	(0.137)
dlog(price)	0.056
	(0.105)
AR(1)	0.93***
	(0.12)
Constant	8.69**
	(3.79)
R^2	0.82
F-Stat	15.3
Durbin-Watson	2.15

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Wheat

Variables	(1) log(yield)
log(ec + ec(-1))	-0.043
	(0.169)
log(tmax)	-2.41*
	(1.37)
dlog(hacres)	-0.142
	(0.086)
AR(1)	0.336
	(0.233)
Constant	11.7*
	(6.39)
R^2	0.27
F-Stat	1.67
Durbin-Watson	2.1

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Watermelons

Variables	(1) log(yield)
log(ec + ec(-1))	-0.096
	(0.268)
log(tmax)	4.33**
	(1.70)
dlog(price)	0.135
	(0.131)
AR(1)	0.844***
	(0.130)
Constant	-15.5**
	(8.37)
R^2	0.76
F-Stat	14.5
Durbin-Watson	2.38

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Walnuts

Variables	(1) log(yield)
log(ec + ec(-1))	0.122
	(0.168)
un	1.87
	(1.09)
log(prec)	-0.322***
	(0.095)
AR(1)	-0.317
	(0.232)
Constant	-0.454
	(1.21)
R^2	0.45
F-Stat	3.70
Durbin-Watson	1.74

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Appendix C: Panel Data Model Results

Dependent Variable:	Covariates					
log(yield)	log(ec + ec(-1))	log(tmax)	log(prec)	un	AR(1)	c
Almonds	0.027	-0.429	-0.287***	0.392	0.259**	3.84
Asparagus	0.349**	-0.397	-0.057	2.78**	-0.146	1.65
Beans	0.128	-1.16	-0.022	-0.94	-0.184	6.81
Cherries	0.471*	-3.12	-0.119	-1.00	-0.335**	13.96
Corn	0.222	-1.72	0.085	0.734	0.29***	11.03
Cucumbers	0.624***	-2.9	0.248**	2.7	0.244***	12.81
Wine Grapes	0.174	1.53	0.003	0.409	0.507***	-4.16
Alfalfa (Hay)	0.128	2.43***	-0.064*	-0.481	0.673***	-7.86
Peaches/Pears	0.06	0.349	-0.109**	0.894	0.255**	3.05
Bell Peppers	0.259	2.23	-0.114	5.17**	0.363***	-7.63
Potatoes	-0.048	1.08	-0.194***	1.1	0.637***	0.394
Pumpkins	0.133	-0.014	-0.011	1.92	0.467***	3.86
Tomatoes	0.076*	-1.11***	-0.018	-0.707	0.989***	11.62
Walnuts	0.061	3.15***	-0.324***	2.6***	-0.529***	-12.23
Watermelons	-0.106	4.79***	0.019	-1.5	0.864***	-15.21
Wheat	-0.069	-0.243	-0.177***	0.52	-0.35***	4.79

*** p<0.01, ** p<0.05, * p<0.1

Model Statistics	
R^2	1.00
F-Stat	2067.6
Durbin-Watson	1.97