Conjunctive Use of Oilfield Produced Water for Irrigation in the Southern San Joaquin Valley of California

Tackling the Drought: Exploring Safe, Innovative Water Sources

Originally for PRODUCED WATERS WORKSHOP
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Hung Le – Irrigation Manager, Paramount Farming Co.
Here in California's thirsty farm belt, where pumpjacks nod amid neat rows of crops, it's a proposition that seems to make sense: using treated oil field wastewater to irrigate crops.

Oil giant Chevron recycles 21 million gallons of that water each day and sells it to farmers who use it on about 45,000 acres of crops, about 10% of Kern County's farmland. State and local officials praise the 2 decadeold program as a national model for coping with the region's water shortages. As California's fouryear drought lingers and authorities scramble to conserve every drop, agricultural officials have said that more companies are seeking permits to begin similar programs. The heightened interest in recycling oil field wastewater has raised concern over the adequacy of safety measures in place to prevent contamination from toxic oil production chemicals.

By Julie Cart  July 1, 2015

Results of the most recent testing of recycled oil field wastewater that Chevron sells to Kern County farmers for irrigation showed no traces of methylene chloride, an industrial solvent that had appeared in previous testing conducted by a clean water advocacy group.

Chevron sells 21 million gallons of treated oil field wastewater per day to the Cawelo Water District, which provides water to 90 Kern County farmers. Before releasing it to the district, Chevron treats the wastewater in settling ponds and other processes designed to remove contaminants.
3-POINT SERMON

1. WATER SUPPLY
2. CHANGING CROP DYNAMICS
3. SALT
The Global Perspective: Paul Ehrlich’s “Population Bomb” has not disappeared

- Global food production will need to increase by 38% by 2025 and 57% by 2050.
- It is estimated that about 15% of the total land area of the world has been degraded by soil erosion and physical and chemical degradation, including soil salinization.

CA groundwater depletion: 1962-2003

KERN REGIONAL DEMAND

- **OLD STANDARD:** 2.75 ac-ft/ac, 33 inches
  - **WHY:** Cotton was king – 450,000 acres, ET 29 in.

- **KERN REQUIREMENT (@ 850,000 ac):**
  - 2.3 to 2.5 MAF/yr

- **AVERAGE PROJECTED SUPPLY:**
  - Kern River: 650,000 ac-ft
  - USBR Friant (Eastside Sierra): 800,000 ac-ft
  - State Water Project (Westside): 900,000 ac-ft

  **TOTAL:** 2.35 MAF
2002 KCWA & Ag Comm Estimates of Crop Acreage Breakdown for Kern

- **Fruit/Nut Crops**: 350,000 Acres
- **Cotton**: 300,000 Acres
- **Other Field Crops**: 150,000 Acres
- **Alfalfa**: 100,000 Acres
- **Silage/Winter Forage**: 100,000 Acres
- **Vegetable Crops**: 90,000 Acres
- **Winter Grains**: 60,000 Acres

**Ag Commissioner**
- Total Acres: 866,226

**Kern County Water Agency**
- Total Acres: 884,100

**Comparison**
- **Difference**: 17,874 Acres

**Legend**
- Ag Commissioner
- Kern County Water Agency
Despite the picture that most people have of San Joaquin Valley growers when it comes to water use efficiency...
...they have proven very innovative by switching to higher value permanent crops, maximizing the efficiency of older irrigation systems and...
developing new methods needed to maximize yields and stay in business while paying $70 to $1000/ac-ft for irrigation water.
UC Kern County Irrigation/Grower Irrigation Projects Fall 2000 to Fall 2005

- 11,781 acres over 136 fields
- 30 different growers
- 14 different crops
- 11 soil textures
- 9 different irrigation system types
ALMOND IRRIGATION MONITORING SUMMARY

- Blocks instrumented: 42 total, 34 >6th leaf
- Average available water to 6 feet: 56%
- Average soil moisture “tension”: -52 centibars
- 2002-2005 average applied water: 46.8 inches
- Calculated CIMIS ET: 47.9 inches
- Average neutron probe ET: 45.7 inches
- Average Water Use Efficiency: 97%
Kern Oilfield Locations (50 total, the other half of the Kern economy)
West Kern Belridge Oilfield, Produced Water Percolation Ponds and Surrounding Ag Fields
Old Percolation Ponds for Westside Kern Belridge Produced Water & Nearby Water Quality

Sample: WATER  Date Sampled: 7/1/04;  Grower/Location/Project: Starrh Wells

<table>
<thead>
<tr>
<th>WELL</th>
<th>pH</th>
<th>EC</th>
<th>SAR</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>Cl</th>
<th>B</th>
<th>HCO3</th>
<th>CO3</th>
<th>SO4</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-4 NW (1 mile E)</td>
<td>7.3</td>
<td>7.36</td>
<td>10</td>
<td>26.7</td>
<td>10.4</td>
<td>43.0</td>
<td>53.1</td>
<td>20.4</td>
<td>3.2</td>
<td>&lt;0.1</td>
<td>23.8</td>
</tr>
<tr>
<td>9-3 Well (6 mi SE)</td>
<td>7.6</td>
<td>4.38</td>
<td>5</td>
<td>18.3</td>
<td>11.2</td>
<td>20.1</td>
<td>24.7</td>
<td>11.2</td>
<td>1.6</td>
<td>&lt;0.1</td>
<td>24.0</td>
</tr>
<tr>
<td>CA Aqueduct</td>
<td>7.4</td>
<td>0.48</td>
<td>2</td>
<td>1.1</td>
<td>1.1</td>
<td>2.3</td>
<td>1.8</td>
<td>0.3</td>
<td>1.7</td>
<td>&lt;0.1</td>
<td>0.9</td>
</tr>
</tbody>
</table>

- **EC 35 dS/m**
- **B 53 ppm**
Sacramento River water salinity

= 0.11 ton / ac-ft  (0.13 ds/m EC, 83 ppm tds)

CA Aqueduct water salinity

= 0.46 ton / ac-ft  (0.53 ds/m EC, 339 ppm tds

= 73.6 t/ac @ 4 ac-ft/yr * 40 years

= 2.87 dS/m increase in EC over 10 ft depth of soil)

Friant-Kern water salinity  (Kern County data)

= 0.06 ton / ac-ft  (0.07 ds/m EC, 45 ppm tds)

(CA Water Plan Update 2009: Vol2 Chap18: Salt and Salinity Management)
10. Additional options for salt collection, salt treatment, salt disposal and long-term storage of salt should be developed. University researchers should work with regulatory agencies and stakeholders to identify environmentally acceptable and economically feasible methods of closing the loop on salt for areas of the state that do not currently have sustainable salt management options. Funding for this sort of research should be prioritized to ensure that areas with the greatest needs (i.e. high salt and few or no feasible management options) are targeted first. (See also Recommendations 2 through 7, 11 and 12.)
CAWEO WATER DISTRICT

Total Acreage Distribution of Service & Non-Service Area in Cawelo WD

- Poso Creek Bed: 222 acres
- Recharge Reservoirs: 931 acres
- Dry/Fallow/Misc: 8,155 acres
- M&I: 1,961 acres
- Row Crops: 271 acres
- Veg Crops: 260 acres
- Tolerant Trees: 4,782 acres
- Sensitive Trees: 11,101 acres
- Grapes: 17,636 acres

Water Requirement of Service & Non-Service Area in Cawelo WD

- Total Area in District (acres): 45,317
- Total Requirement (ac-ft): 116,578
- 2001-5 Avg Deliveries (ac-ft): 90,222
- Effective Rainfall (0.25 ac-ft/ac): 944
- Potential Deficit (ac-ft): 25,412
INCREASING COSTS AND DEMAND REQUIRE INNOVATIVE SOLUTIONS

• CAWELO WD & CHEVRON/TEXACO PARTNERSHIP
Produced water is collected across thousands of acres of well field and eventually transported through a 16 inch pipe…

… and discharged into Regulation Reservoir B (~25 acres) for mixing with Kern River and project water.
Reservoir B where produced & canal water are blended

June 2003 aerial
Cawelo canal
Rolling hills, Eastside oil fields
Fresh water from the Lerdo canal is boosted 1.7 miles to Reservoir B, blended with produced water then delivered by gravity via canal and buried laterals.
Almonds and grapes predominate the district.
Most water is delivered by buried laterals running downslope from canal.

Nearly all permanent crops are now irrigated with microsprinklers or drip.
<table>
<thead>
<tr>
<th>ENTITY / USE</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEVRON / TEXACO</td>
<td>22,259</td>
<td>19,988</td>
<td>17,910</td>
<td>20,181</td>
<td>17,096</td>
</tr>
<tr>
<td>VALLEYWASTE</td>
<td>879</td>
<td>585</td>
<td>1,065</td>
<td>2,853</td>
<td>3,812</td>
</tr>
<tr>
<td>SCHAEFER</td>
<td>1,186</td>
<td>1,274</td>
<td>1,457</td>
<td>1,441</td>
<td>1,293</td>
</tr>
<tr>
<td>TOTAL PRODUCED WATER</td>
<td>24,324</td>
<td>21,847</td>
<td>20,432</td>
<td>24,475</td>
<td>22,201</td>
</tr>
<tr>
<td>TOTAL WELLS TO DISTRICT</td>
<td>13,058</td>
<td>10,055</td>
<td>5,425</td>
<td>11,203</td>
<td>2,661</td>
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<tr>
<td>TOTAL IMPORTED CANAL</td>
<td>47,807</td>
<td>55,955</td>
<td>62,396</td>
<td>54,248</td>
<td>75,025</td>
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<tr>
<td>TOTAL SUPPLY</td>
<td>85,189</td>
<td>87,857</td>
<td>88,253</td>
<td>89,926</td>
<td>99,886</td>
</tr>
<tr>
<td>BANKING AND CONVEYANCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOSSES</td>
<td>8,711</td>
<td>6,598</td>
<td>7,584</td>
<td>11,197</td>
<td>18,837</td>
</tr>
<tr>
<td>TOTAL TO LANDOWNERS</td>
<td>76,479</td>
<td>81,259</td>
<td>80,669</td>
<td>78,729</td>
<td>81,049</td>
</tr>
<tr>
<td>PRODUCED / TOTAL (%)</td>
<td>28.6%</td>
<td>24.9%</td>
<td>23.2%</td>
<td>27.2%</td>
<td>22.2%</td>
</tr>
</tbody>
</table>
PRODUCED WATER FLOW
Average 23,000 ac-ft/yr
= 63 ac-ft/day
= 488,986 bbl/day
= sufficient irrigation for 5,750 acres
@ 4 ac-ft/ac
= 13.8 million pounds of almonds
@ 2,400 lb/ac
= 3.2 bbl water/4 oz can of almonds
# Average Water Quality

(quarterly samples 2001-5, except as noted)

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC (dS/m)</th>
<th>Ca (meq/l)</th>
<th>Mg (meq/l)</th>
<th>Na (meq/l)</th>
<th>HCO3 (meq/l)</th>
<th>Adj SAR (%)</th>
<th>Cl (meq/l)</th>
<th>B (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lerdo Canal</td>
<td>8.5</td>
<td>0.19</td>
<td>0.82</td>
<td>0.28</td>
<td>0.82</td>
<td>1.03</td>
<td>1.11</td>
<td>0.50</td>
<td>0.13</td>
</tr>
<tr>
<td>Produced</td>
<td>7.7</td>
<td>0.89</td>
<td>1.40</td>
<td>0.38</td>
<td>6.93</td>
<td>4.34</td>
<td>12.78</td>
<td>3.92</td>
<td>0.96</td>
</tr>
<tr>
<td>Current Blend</td>
<td>8.0</td>
<td>0.51</td>
<td>0.96</td>
<td>0.30</td>
<td>3.94</td>
<td>2.72</td>
<td>7.05</td>
<td>2.26</td>
<td>0.52</td>
</tr>
<tr>
<td>Quarterly C.V.</td>
<td>3.1%</td>
<td>41%</td>
<td>30%</td>
<td>44%</td>
<td>48%</td>
<td>40.9%</td>
<td>52.2%</td>
<td>50.6%</td>
<td>51.3%</td>
</tr>
<tr>
<td>PreBlend (1995)</td>
<td>0.34</td>
<td>0.78</td>
<td>0.06</td>
<td>2.50</td>
<td>1.40</td>
<td>3.95</td>
<td>0.47</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

**FAO 29 "Sensitive" Crop Thresholds**

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>HCO3</th>
<th>Adj SAR</th>
<th>Cl</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.7</td>
<td>3.0</td>
<td>5*EC</td>
<td>4.0</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**June 2004 grab samples for subsurface drip Almond Block 3050**

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>HCO3</th>
<th>Adj SAR</th>
<th>Cl</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>District Plus Gypsum</td>
<td>7.9</td>
<td>1.77</td>
<td>17.17</td>
<td>0.46</td>
<td>1.98</td>
<td>4.30</td>
<td>0.67</td>
<td>0.90</td>
<td>0.57</td>
</tr>
<tr>
<td>Well</td>
<td>7.9</td>
<td>1.11</td>
<td>5.74</td>
<td>0.13</td>
<td>5.22</td>
<td>0.70</td>
<td>3.05</td>
<td>6.20</td>
<td>0.21</td>
</tr>
</tbody>
</table>
Almond Block 3050 (planted 1998)
-Irrigated with blended and some well water
-Cawelo Water District
-Subsurface drip irrigation

Almond Block 3680 (planted 1998)
-Always irrigated with fresh canal water
-North Kern Water District
-Microsprinkler irrigation

Aerial Pictures
June 2003
The Observation: some orchards visibly stress and defoliate just before harvest...
Westside Almond Irrigation & N trial – Yields, applied water, & 2003 soil moisture.

**Full Irrigation**
- 57.6 Total for 2003
- 3.2” Dormant Refill
- 54.4” In-Season

**Reduced Irrigation**
- 47.9 Total for 2003
- 2.9” Dormant Refill
- 45.0” In-Season

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### Soil Moisture Tension Over Season

#### Entire Rootzone
- **1’**
- **3’**
- **5’**

**STORED SOIL MOISTURE**

#### Neutron Probe Water Content Over Season

**Available Water Stored in Rootzone**
- Entire Rootzone
- **1’**
- **3’**
- **5’**

**Water Content @ Depth (in/ft)**
- **0%**
- **20%**
- **40%**
- **60%**
- **80%**
- **100%**
- **120%**

**Water Content @ Depth (in/ft)**
- **1/19**
- **2/16**
- **3/16**
- **4/13**
- **5/11**
- **6/8**
- **7/6**
- **8/3**
- **8/31**
- **9/28**
- **10/26**
- **11/23**

**Soil Moisture Tension (cb)**
- **18”**
- **36”**
- **60”**

---

### Nonpareil Yields (lb/ac) by applied irrigation & N fertilizer treatment (lb/ac) for 5th-9th leaf almonds, Belridge.

<table>
<thead>
<tr>
<th>Year</th>
<th>Full Irrigation</th>
<th>Reduced Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(in)</td>
<td>N~250</td>
</tr>
<tr>
<td>2002</td>
<td>48.5</td>
<td>1922</td>
</tr>
<tr>
<td>2003</td>
<td>57.6</td>
<td>3004</td>
</tr>
<tr>
<td>2004</td>
<td>59.7</td>
<td>2838</td>
</tr>
<tr>
<td>2005</td>
<td>53.6</td>
<td>2227</td>
</tr>
<tr>
<td>Total</td>
<td>219.4</td>
<td>11917</td>
</tr>
</tbody>
</table>

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### Watermark® Soil Moisture Tension Over Season

**Nonpareil Almond**
- Full Irrigation – 57.6 inches

**Millham Sandy Loam**
- **18”**
- **36”**
- **60”**

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**Nonpareil Almond Irrigation & N trial** – Yields, applied water, & 2003 soil moisture.

**Full Irrigation**
- 57.6 Total for 2003

**Reduced Irrigation**
- 47.9 Total for 2003

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**Westside Almond Irrigation & N trial** – Yields, applied water, & 2003 soil moisture.
Water quality is the starting point! Notice burn on leaves sprayed with this marginally high salinity (1.1 dS/m) water.
Chloride Toxicity: often accompanied by excess salinity and sodium. Marginal toxicity results in cupped leaves, slight yellowing and eventual burning of the margins... at severe levels leaves will desiccate with obvious gummosis and sometimes cracking along trunk.
Summary of published tolerance limits for various permanent crops.  S = sensitive, <5-10 meq/l.  MT = moderately tolerant, <20-30 meq/l (Ayers and Westcott, 1989, ¹Sanden, et al., 2004)

<table>
<thead>
<tr>
<th>Crop</th>
<th>EC&lt;sub&gt;thresh&lt;/sub&gt; (dS/m)</th>
<th>Slope (%)</th>
<th>Sodium (meq/l)</th>
<th>Chloride (meq/l)</th>
<th>Boron (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almond</td>
<td>1.5</td>
<td>19</td>
<td>S</td>
<td>S</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Grape</td>
<td>1.5</td>
<td>9.6</td>
<td>10-30</td>
<td></td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Orange</td>
<td>1.7</td>
<td>16</td>
<td>S</td>
<td>10-15</td>
<td>0.5-0.75</td>
</tr>
<tr>
<td>Pistachio¹</td>
<td>9.4</td>
<td>8.4</td>
<td>20-50</td>
<td>20-40</td>
<td>3-6</td>
</tr>
</tbody>
</table>

Almond Block 3050 (SDI) June 2004 Soil Samples

<table>
<thead>
<tr>
<th>Location</th>
<th>EC dS/m</th>
<th>pH</th>
<th>Ca meq/l</th>
<th>Mg</th>
<th>Na</th>
<th>Cl</th>
<th>ESP%</th>
<th>B ppm</th>
<th>NO₃ ppm</th>
<th>P ppm</th>
<th>K ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>20&quot; under edge of Berm next to hose</td>
<td>1.7</td>
<td>5.4</td>
<td>3.3</td>
<td>0.4</td>
<td>13.1</td>
<td>4.3</td>
<td>25.4</td>
<td>0.27</td>
<td>350</td>
<td>67</td>
<td>76</td>
</tr>
<tr>
<td>30&quot; under tree</td>
<td>2.8</td>
<td>7.1</td>
<td>7.1</td>
<td>1.6</td>
<td>21.8</td>
<td>16.0</td>
<td>25.3</td>
<td>0.37</td>
<td>205</td>
<td>21</td>
<td>98</td>
</tr>
<tr>
<td>20&quot; under Mid of row 4' from SDI hose</td>
<td>0.8</td>
<td>7.2</td>
<td>1.9</td>
<td>0.6</td>
<td>5.7</td>
<td>2.0</td>
<td>17.9</td>
<td>0.18</td>
<td>290</td>
<td>22</td>
<td>126</td>
</tr>
<tr>
<td>48&quot; under Mid of row</td>
<td>3.8</td>
<td>7.7</td>
<td>10.0</td>
<td>1.8</td>
<td>30.0</td>
<td>16.6</td>
<td>19.2</td>
<td>0.30</td>
<td>205</td>
<td>15</td>
<td>144</td>
</tr>
</tbody>
</table>
Mean EC$_e$ of Block 3050 samples = 2.28 dS/m

Mean blended EC$_{irr}$ irrigation water = 0.51 dS/m

Long-term EC$_{rootzone}$ $\sim 6*EC_{irr}$ @ <5% LF
Long-term EC$_{rootzone}$ $\sim 3*EC_{irr}$ @ 10% LF
Long-term EC$_{rootzone}$ $\sim 2*EC_{irr}$ @ 15% LF

(Adapted from Hoffman, G.J. 1996)
Almond Relative Yield = \( 100 - \text{slope}(EC_{\text{thresh}} - EC_e) \)

Relative Yield \( EC_e \) @ 2.28 dS/m
\[
= 100 - 19(2.28 - 1.5) = 85.2\%
\]

POINT:
A 10-15% leaching fraction is required to maintain adequate soil water quality
## Almond Block 3050 after winter leaching using microsprinklers and 12 inches of District water (Saturated paste extract and fertility March 2005 soil samples)

<table>
<thead>
<tr>
<th>Location</th>
<th>EC (dS/m)</th>
<th>pH</th>
<th>Ca (meq/l)</th>
<th>Mg (meq/l)</th>
<th>Na (meq/l)</th>
<th>Cl (meq/l)</th>
<th>ESP (%) (CEC)</th>
<th>B (ppm)</th>
<th>NO3 (ppm)</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 0-1ft</td>
<td>0.4</td>
<td>7.2</td>
<td>1.1</td>
<td>1.0</td>
<td>1.5</td>
<td>0.7</td>
<td>8.8</td>
<td>0.90</td>
<td>2</td>
<td>18</td>
<td>--</td>
</tr>
<tr>
<td>1-2 ft</td>
<td>0.2</td>
<td>7.8</td>
<td>0.5</td>
<td>0.2</td>
<td>1.6</td>
<td>0.2</td>
<td>9.0</td>
<td>1.19</td>
<td>2</td>
<td>6</td>
<td>--</td>
</tr>
<tr>
<td>2-3 ft</td>
<td>0.8</td>
<td>8.6</td>
<td>0.5</td>
<td>0.1</td>
<td>7.4</td>
<td>0.2</td>
<td>20.5</td>
<td>1.77</td>
<td>2</td>
<td>5</td>
<td>--</td>
</tr>
<tr>
<td>3-4 ft</td>
<td>0.3</td>
<td>8.2</td>
<td>0.5</td>
<td>0.2</td>
<td>2.3</td>
<td>0.2</td>
<td>19.2</td>
<td>1.24</td>
<td>2</td>
<td>2</td>
<td>--</td>
</tr>
<tr>
<td>B 0-1ft</td>
<td>0.4</td>
<td>7.6</td>
<td>1.1</td>
<td>0.3</td>
<td>2.4</td>
<td>0.2</td>
<td>5.6</td>
<td>0.50</td>
<td>2</td>
<td>9</td>
<td>--</td>
</tr>
<tr>
<td>1-2 ft</td>
<td>0.8</td>
<td>8</td>
<td>0.9</td>
<td>0.2</td>
<td>7.2</td>
<td>0.6</td>
<td>11.7</td>
<td>0.64</td>
<td>2</td>
<td>9</td>
<td>--</td>
</tr>
<tr>
<td>2-3 ft</td>
<td>1.0</td>
<td>8.3</td>
<td>0.9</td>
<td>0.2</td>
<td>8.5</td>
<td>0.9</td>
<td>16.4</td>
<td>0.57</td>
<td>2</td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>3-4 ft</td>
<td>0.9</td>
<td>8.6</td>
<td>0.8</td>
<td>0.2</td>
<td>7.4</td>
<td>1.5</td>
<td>12.6</td>
<td>0.53</td>
<td>2</td>
<td>1</td>
<td>--</td>
</tr>
</tbody>
</table>
So we knocked the salt down, finally, with some relief from the 2001-4 drought. Should we NOT use the produced water and irrigate with 42” instead of 52”? (Actually, not an option.)
Westside Almond Irrigation & N trial – Yields, applied water, & 2003 soil moisture.

Full Irrigation
57.6 Total for 2003
3.2” Dormant Refill
54.4” In-Season

Reduced Irrigation
47.9 Total for 2003
2.9” Dormant Refill
45.0” In-Season

Nonpareil yields (lb/ac) by applied irrigation & N fertilizer treatment (lb/ac) for 5th-9th leaf almonds, Belridge.

<table>
<thead>
<tr>
<th>Year</th>
<th>Full Irrigation</th>
<th>Reduced Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(in) N<del>250 N</del>125</td>
<td>(in) N<del>250 N</del>125</td>
</tr>
<tr>
<td>2002</td>
<td>48.5 1922 1275</td>
<td>38.8 1593 1215</td>
</tr>
<tr>
<td>2003</td>
<td>57.6 3004 2030</td>
<td>47.9 2352 1901</td>
</tr>
<tr>
<td>2004</td>
<td>59.7 2838 2752</td>
<td>47.9 2307 2209</td>
</tr>
<tr>
<td>2005</td>
<td>53.6 2227 1493</td>
<td>44.5 1758 1536</td>
</tr>
<tr>
<td>Total</td>
<td>219.4 11917 9448</td>
<td>179.1 9989 8853</td>
</tr>
</tbody>
</table>

Available Water Stored in Rootzone

19.4% yield reduction with 18.4% less applied water
24% yield reduction with 30% less applied water (dashed line)
Goldhamer PFC Study (in-house) 2005-8

Kernel Yield; 5% H2O; 4 Yr. Mean

25.3% yield reduction with 30% less applied water (dashed line)
UC Cooperative Extension / Almond Board
Almond ET Production Function Trial 2013-17
Uniform Driver sandy loam soil, no hardpans

Cooperators/Contributors:
Paramount Farming Company
Jain Irrigation
Galcon
“CONDUCTANCE” AERIAL IMAGERY SHOWING WATER STRESS USING CANOPY TEMP & RELATIVE HUMIDITY CALCULATION

6/3-9/30/14 average almond plot water conductance by 2014 applied irrigation (9 flyovers)

Canopy Temp/Water Stress by Irrigation Treatment
(CERES Spectral Imaging 6-3-14, Shackel, et al. Yield Production Function Trial)
Possible oil scum in drip pattern 6/4/2015
End 2014 soil salinity compared to end 2015

\[ y = 0.3071x + 3.8886 \]

\[ R^2 = 0.135 \]

CERES “Conductance” (stress) as a function of end 2015 soil salinity
Quick review of current findings on almond ET and yield impacts in Kern County

Crop coefficient (Kc)-ET curve & individual tree ET/Yields (Brown fertility trial)

Westside Longevity trial (15th leaf 2013)

Interactions and 95.0 Percent LSD Intervals

Nonpareil Kernel Yield (lb/ac)

Crop coefficient (Kc) - ET curve & individual tree ET/Yields (Brown fertility trial)

Means and Standard Errors (actual turnout)

A 70% B 80% C 90% E 100% F 110%

G - Soil Moisture

H - Canopy Temp

2700
2900
3100
3300
3500
3700
3900

15% less water reduced yield 9%

15% less water reduced yield 15%

30% less water reduced yield 21%

Eastside ET Irrigation Trial (8th leaf 2013)

Irrig (inch) 38 43 48 53 58

CIMIS ET 70% 80% 90% 100% 110

20% less water reduced yield 15%
Do you get 6,000 lb/ac with 60” ET? (Data from Brown Fertility Trials)
FANJET Chloride Concentration (saturation extract, meq/l)

Depth (feet)

2/7/08
11/19/08
12/15/09
1/4/11

FANJET Soil EC (saturation extract, dS/m)

Depth (feet)

2/7/08
11/19/08
12/15/09
1/4/11

DRIP Chloride Concentration (saturation extract, meq/l)

Depth (feet)

2/7/08
11/19/08
12/15/09
1/4/11

DRIP Soil EC (saturation extract, dS/m)

Depth (feet)

2/7/08
11/19/08
12/15/09
1/4/11
Individual tree yield by average rootzone salinity (0 to 3 foot rootzone)
Individual tree yield by average rootzone salinity (0 to 5 foot rootzone)

<table>
<thead>
<tr>
<th>EC</th>
<th>Avg Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=1.5</td>
<td>4,560</td>
</tr>
<tr>
<td>1.5 – 3</td>
<td>4,082</td>
</tr>
<tr>
<td>&gt;3</td>
<td>4,070</td>
</tr>
</tbody>
</table>

Relative Yield
Average Rootzone ECe to 1.5 m (dS/m)
2008 2009 2010

FAO Yield
ECONOMICS OF SUPPLY

• 81,049 ac-ft @ $120 grower cost: $9.73 M
  – VALUE OF PRODUCED WATER
  – 22,201 ac-ft of Produced Water @ $120: $2.66M
  – Payment for Produced Water @ $12: $0.27M

– NET BENEFIT TO DISTRICT: $2.39M
– SERVICE AREA @ 33,247 ACRES
  • NET BENEFIT / ACRE: $71.89
ECONOMICS OF SUPPLY

• VALUE OF WATER IN CROP EQUIVALENT

• NET BENEFIT / ACRE: $71.89

• Equivalent orange boxes @ $10: 7 boxes
• Equivalent grape boxes @ $8: 9 boxes
• Equivalent almond meats @ $3/lb: 24 lbs

10% almond yield loss/acre @ max yield of 3,500 lb/ac, 350 lbs, and $3/lb: $1,050

Alternatively 54” vs. 45” applied water increased yield 679 lbs (19.4%), @ $3/lb: $2,037
POINT:
Growers, engineers and water managers cannot stick their heads in the sand to either hide from the issue or fool themselves into thinking one quick look and a spot shot solution will fix the problem ...

Where is your salt going?
WATER CONSERVATION PLANNING IN THE WEST:

- Which one is the farmer and which one is the water policy planner?