2017 THE ALMOND CONFERENCE

THE SCIENCE AND PRACTICE OF INTENTIONAL RECHARGE IN ALMOND ORCHARDS

Room 312-313 | December 5 2017

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The Almond Conference

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- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- *Repeat this process for each session, and each day you wish to receive credits.*

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- Pickup verification sheet at conclusion of each session.
- Turn in your scantron at the end of the day at the last session you attend.

Sign in sheets and verification sheets are located at the back of each session room.

AGENDA

- **Daniel Mountjoy**, Sustainable Conservation, moderator
- **Helen Dahlke**, University of California, Davis
- **Peter Nico**, Berkeley National Laboratory
- **Aaron Fukuda**, Tulare Irrigation District

The Science and Practice of Intentional Recharge in Almond Orchards

Moderator: Daniel Mountjoy

Sustainable Conservation

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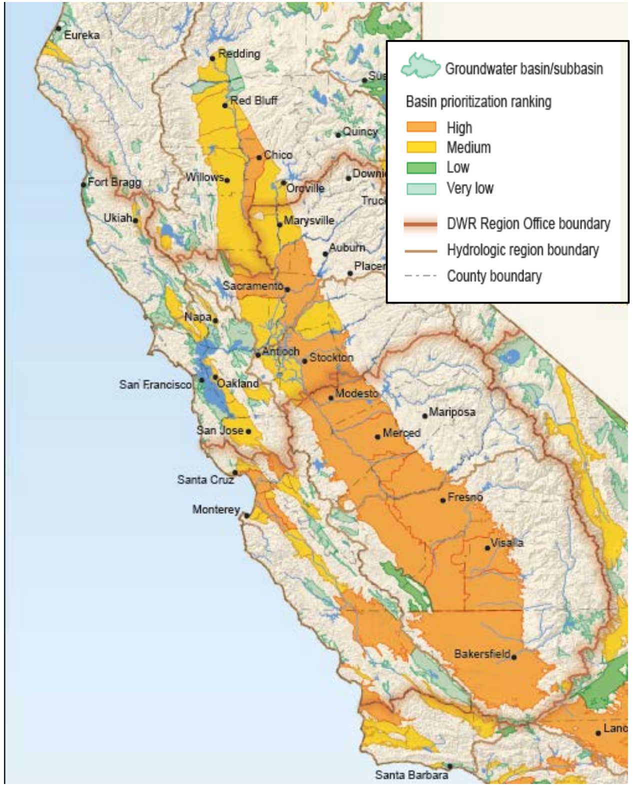
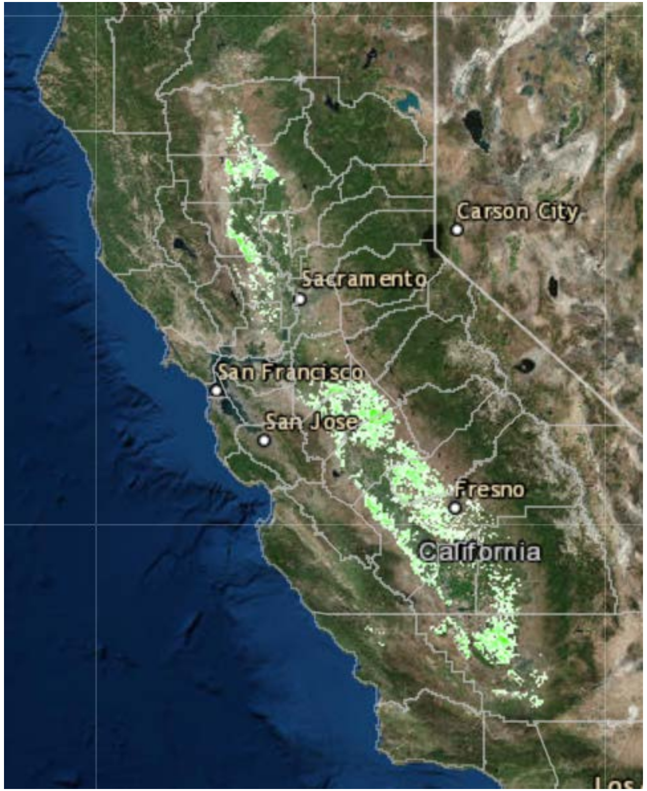
The Potential Role of Almond Acreage for Recharge in the SGMA Era

DWR CASGEM Basin Prioritization



2014 Almond Acreage - LandIQ



The Potential Role of Almond Acreage for Recharge in the SGMA Era

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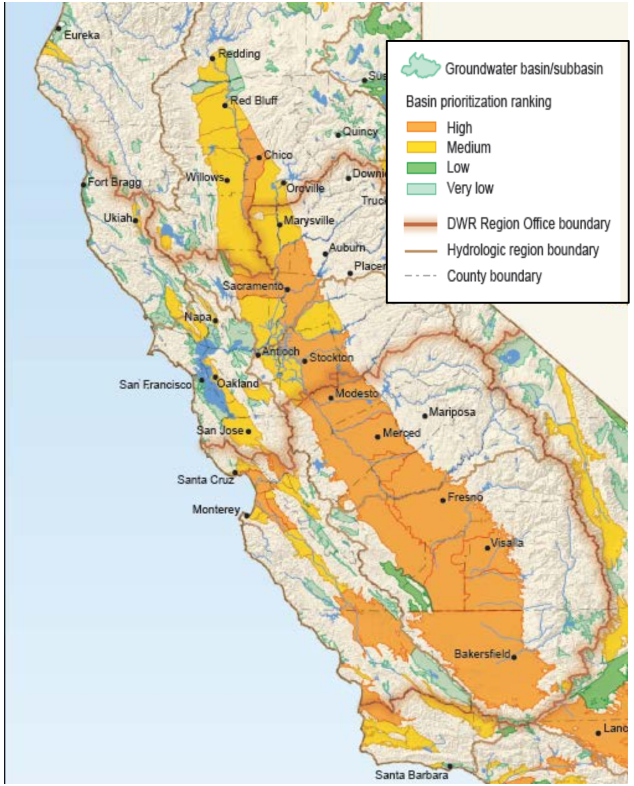
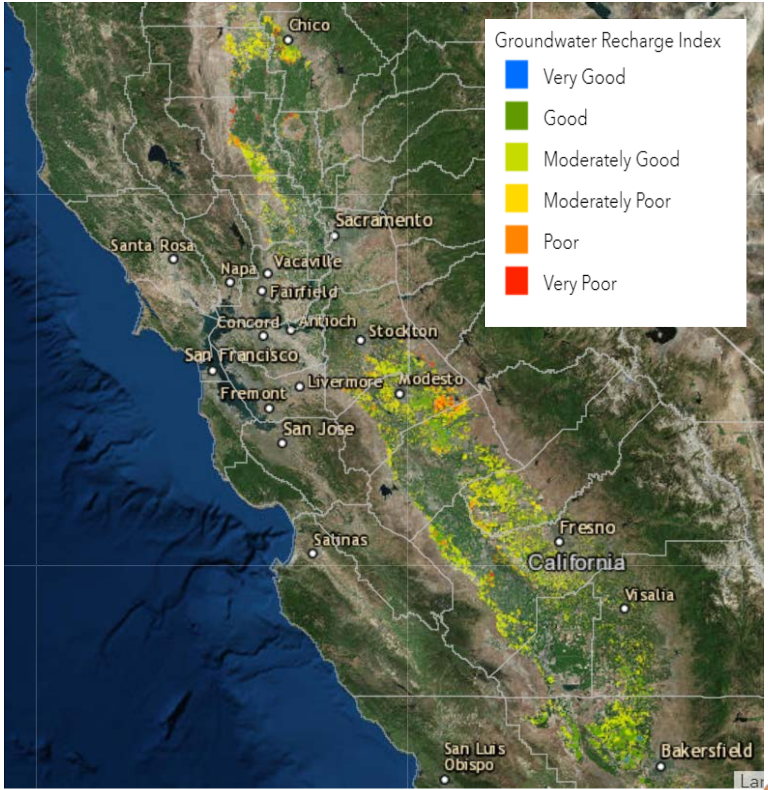


Almond Groundwater Recharge Suitability - LandIQ



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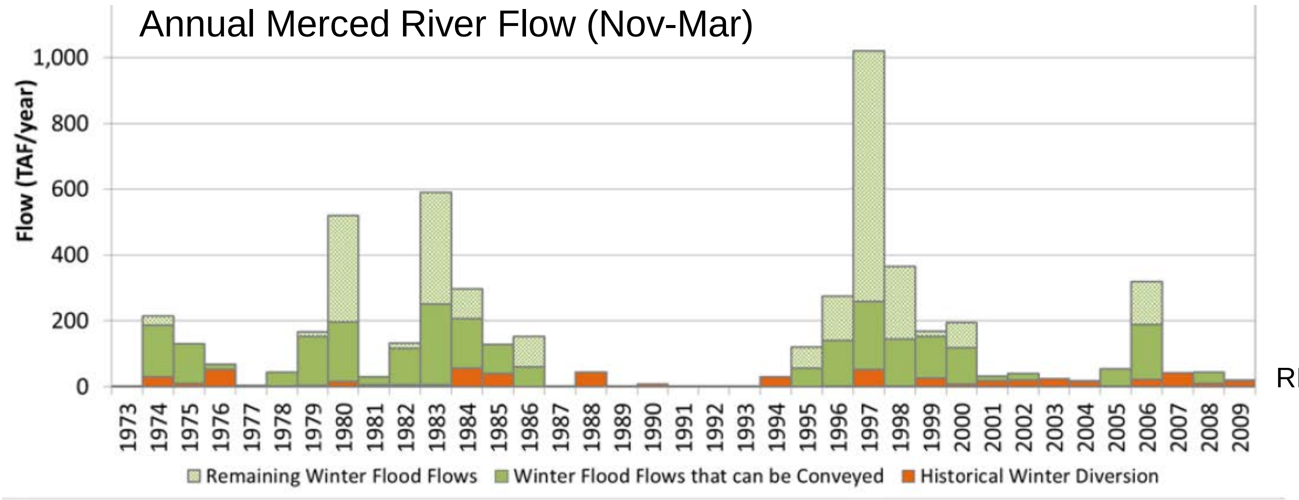
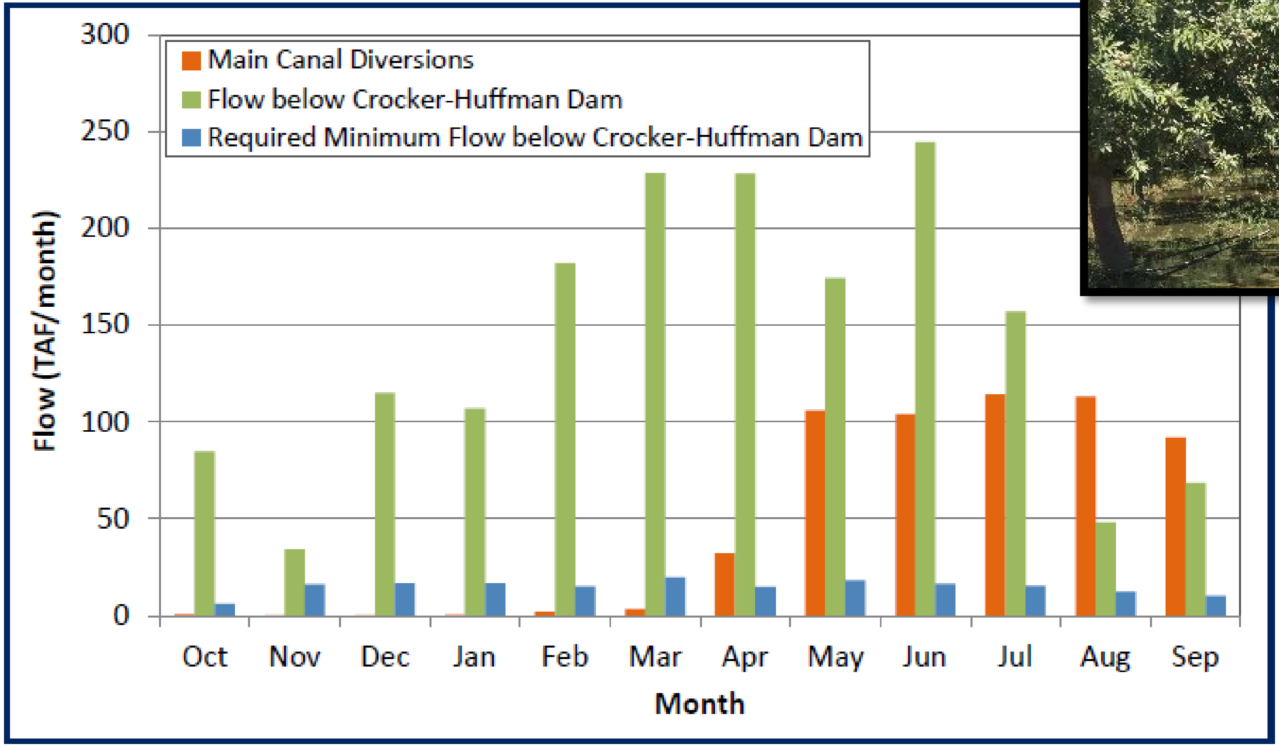
What is the most cost-effective way to capture high flow events?



RMC 2015

Timing of Water Availability for Recharge



Almonds June 2017

Monthly Wet Year Merced River Flow (Nov-Mar)

RMC 2015

Research Questions to determine almond suitability for recharge

- **Crop Compatibility**: response to extra water during dormancy, growing season, and after harvest
  - UC Davis research on dormant season response
  - Bachand and Associates with Sustainable Conservation on growing season compatibility

- **Nutrient Management**: leaching out of root zone to groundwater
  - UC Davis and other public and private partners

- **Site Suitability**: Soil type, underlying geology, and depth to groundwater
  - Lawrence Berkeley National Lab research on underlying geologic variation
  - Stanford University School of Earth Sciences

- **Recharge methods**: flood, drip, alternate rows
  - Grower practice and experience

- **Incentives**: rewarding grower participation - the role of Groundwater Sustainability Agencies
  - Tulare Irrigation District experience

Panel Presenters

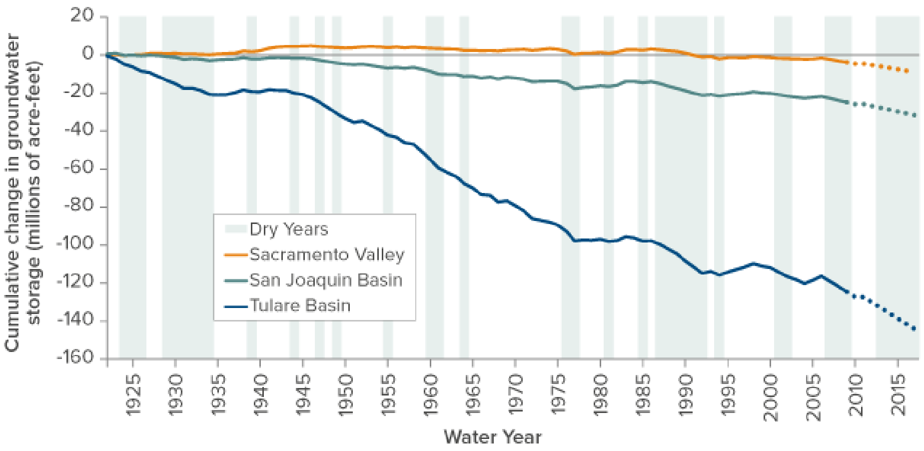
- **Helen Dahlke**, Assistant Professor in Physical Hydrology at the Department of Land, Air and Water Resources, UC Davis

- **Peter Nico**, Geologic Scientist, Lawrence Berkeley National Labs

- **Aaron Fukuda**, District Engineer, Tulare Irrigation District

Why study winter recharge in almonds?

- Since 1920s groundwater depletion has reached more than 160 million acre-feet of groundwater
- Sustainable Groundwater Management Act (SGMA) requires overdrafted groundwater basins to achieve balance by 2040
- Intentional recharge of flood water on agricultural land is a practice considered to achieve groundwater sustainability



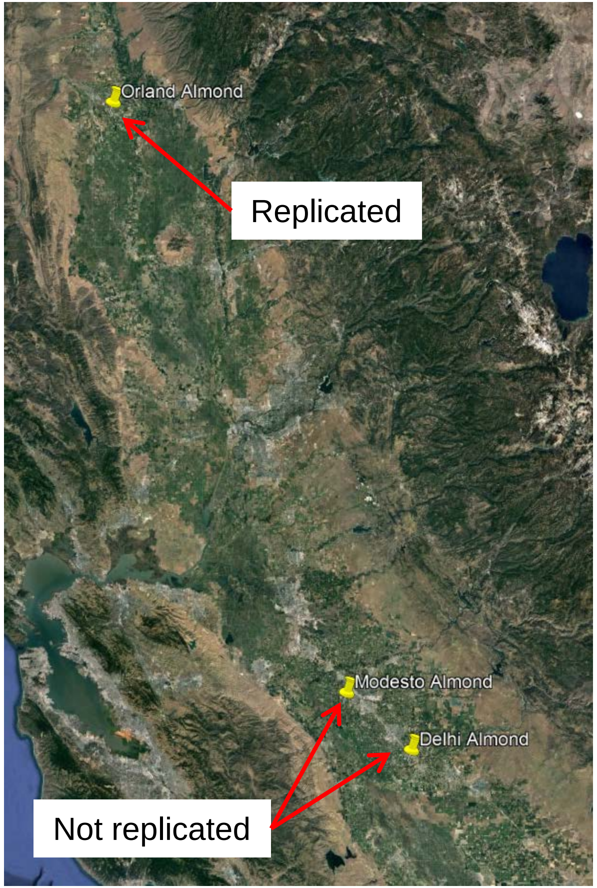
http://www.ppic.org/main/publication_quick.asp?i=1160

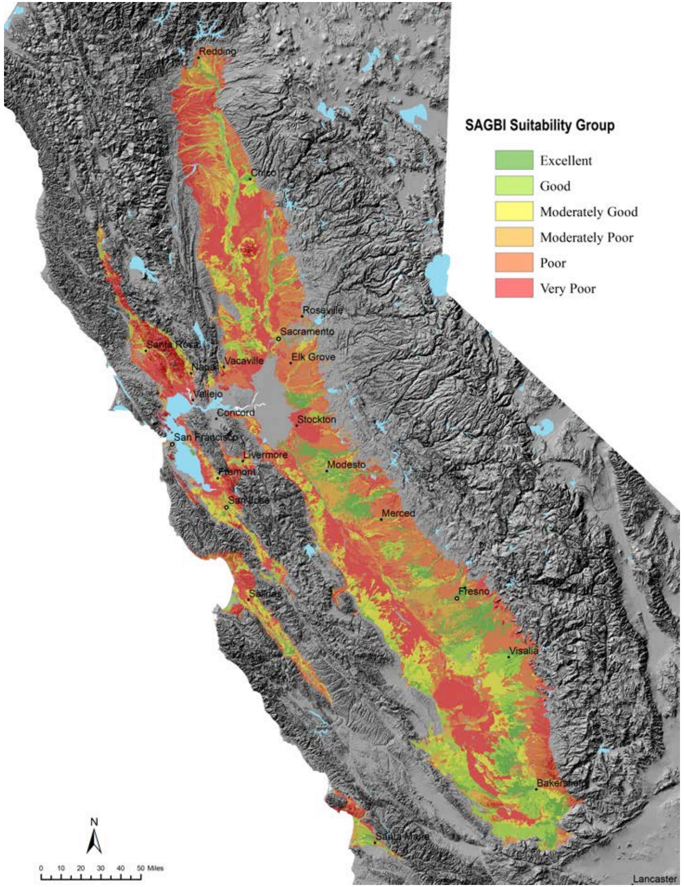
Goal and Experimental Design

- Winter water application:
  - 24" of water were applied in addition to rainfall in Dec-Jan of 2015/16 and 2016/17
- Water balance & recharge
  - How much, how fast, where?
  - Quality of water as it moves through the soil
- Impact on tree
  - Water status (stem water potential)
  - Root growth
  - Yield

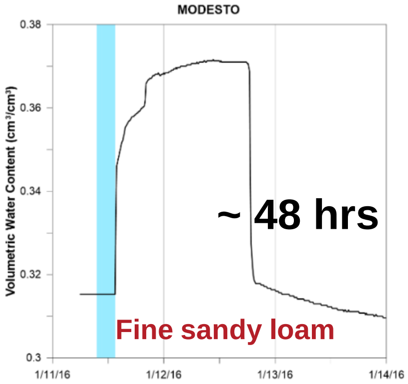
Site Information

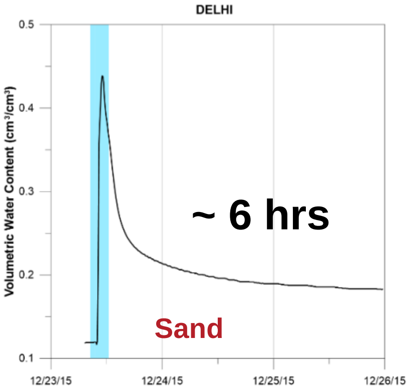
- **Modesto:**
  - Nonpareil, Monterey
  - Stand age: 20 years
  - Flood irrigated
  - Dinuba, fine sandy loam
  - SAGBI: moderately good
- **Delhi:**
  - Butte, Padre, on Nemaguard
  - Sprinkler irrigated
  - Stand age: 14 years
  - Dune land, sand
  - SAGBI: excellent
- **Orland:**
  - Butte, Padre, Mission
  - Stand age: 25 years
  - Flood irrigated
  - Jacinto, fine sandy loam
  - SAGBI: moderately poor

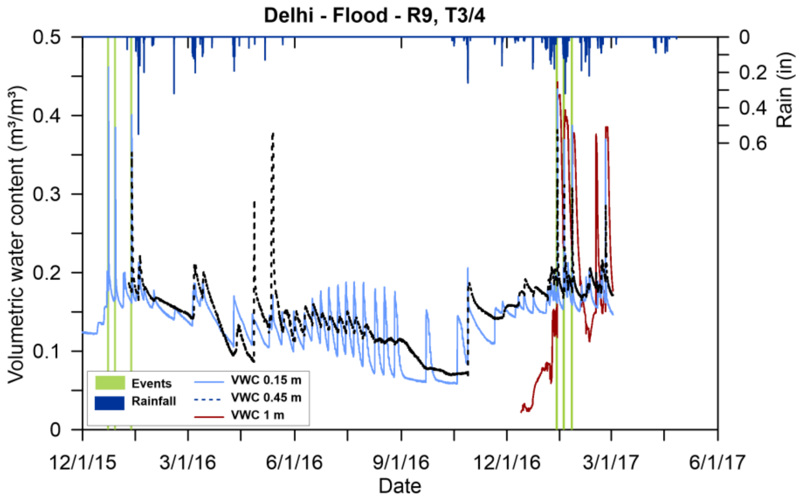


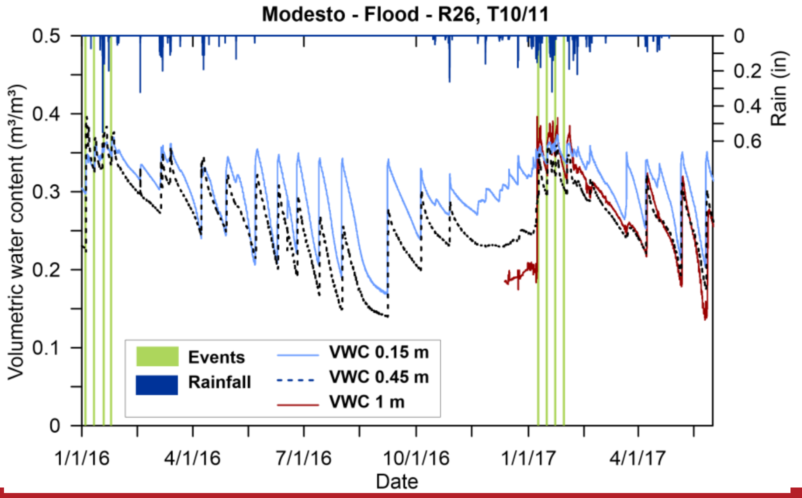


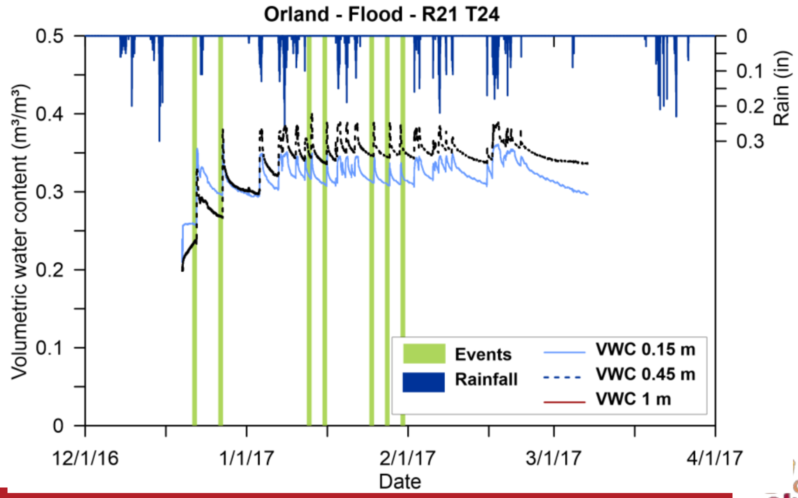
Root zone hydrology











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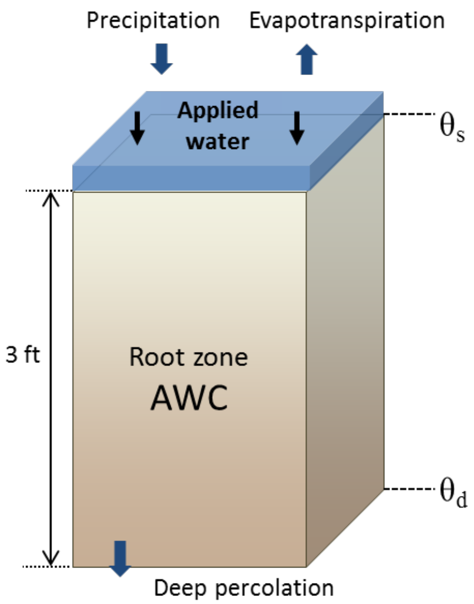
How much of applied water went to recharge?

Summary of water inputs (rain & applied water) for October-March.

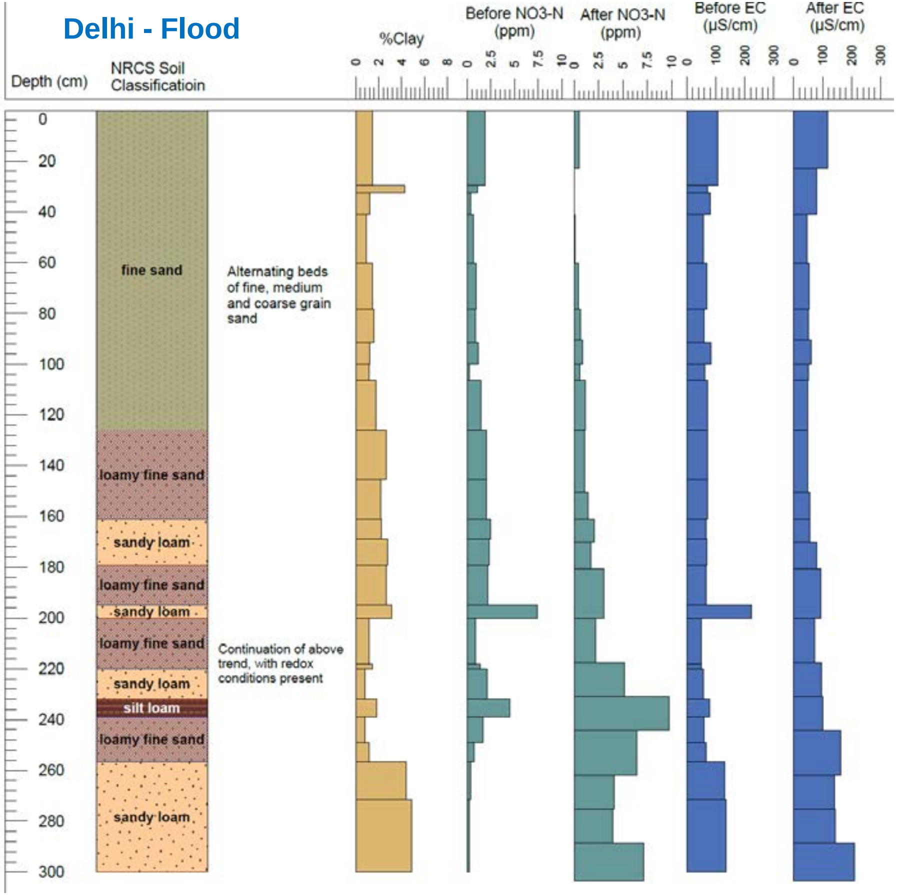
		Rain	Applied Water	Total deep percolation	Deep Percolation from rainfall	Deep Percolation of applied water		Loss of applied water to soil storage	
		inches	inches	inches	inches	inches	%	inches	%
2015/16	Delhi	12.94	26.15	29.09	4.79	24.30	93%	1.84	7%
	Modesto	9.91	24.00	21.90	2.55	19.35	81%	4.65	19%
2016/17	Delhi	17.44	25.80	33.03	7.43	25.60	99%	0.20	1%
	Modesto	12.46	24.00	27.94	4.78	23.16	96%	0.84	4%
	Orland	28.62	4.76	21.00	17.35	3.65	77%	1.11	23%



AWC = available water content

- ➢ At Modest and Delhi >80% of applied water went to deep percolation.
- ➢ Jacinto soil at Orland largely prevented deep percolation.

Soil Nitrate



How much residual soil nitrate is leached during groundwater recharge events?

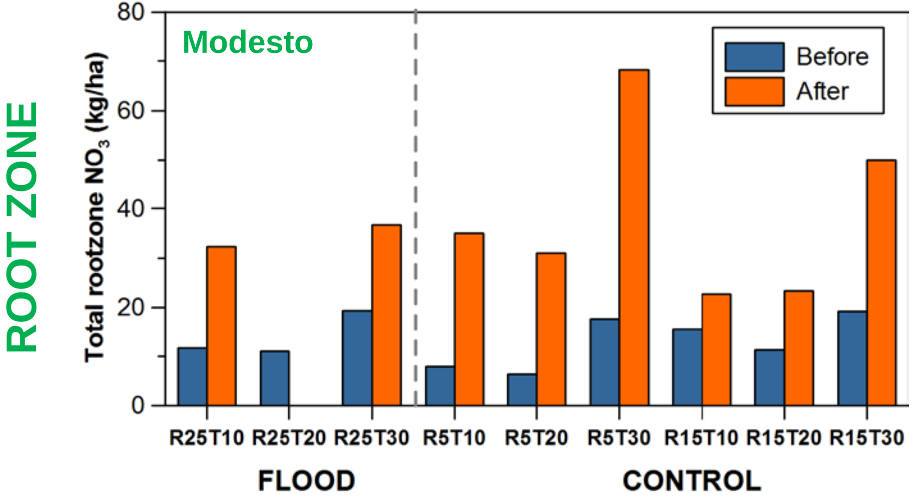
- Soil cores (12 ft) were taken before and after recharge events
- Soil analysis: texture, pH, EC, soil nitrate, DOC
- Water analysis: nitrate concentration in the applied water

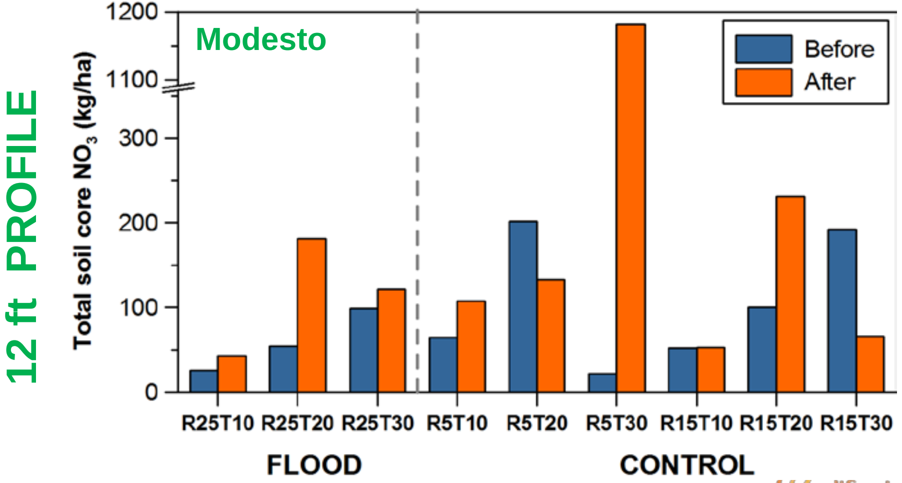
Soil Nitrate Leaching – 2015/16

- Root zone (upper 3 ft):
  - 167% ***increase*** across treatments
  - 56% ***increase*** in Flood treatment
  - 220% ***increase*** in Control

- Entire profile (12 ft):
  - 53% ***increase*** across treatments
  - 107% ***increase*** in Flood treatment
  - 20% ***increase*** in Control

➢ Most of the increase in soil nitrate occurred in the root zone as the result of nitrification





Soil Nitrate: 1 kg/ha = 0.89 lb/acre

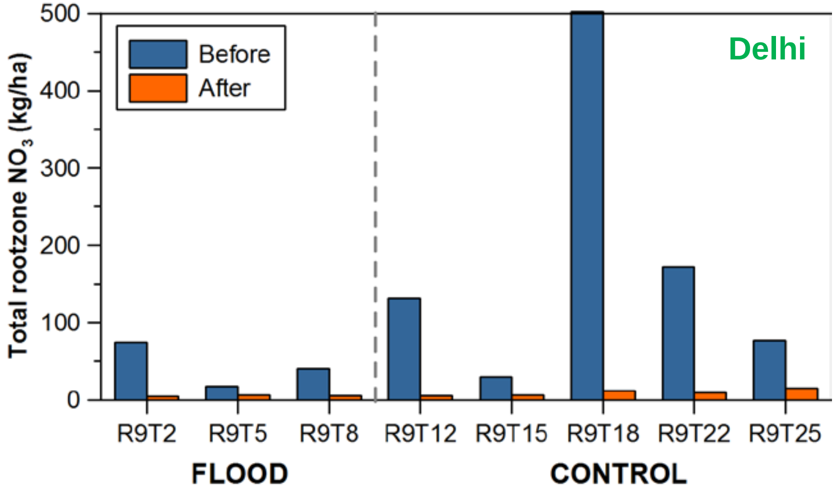
Soil Nitrate Leaching – 2015/16

- Root zone (upper 3 ft):
  - 88% ***decrease*** across treatments
  - 84% ***decrease*** in Flood treatment
  - 89% ***decrease*** in Control

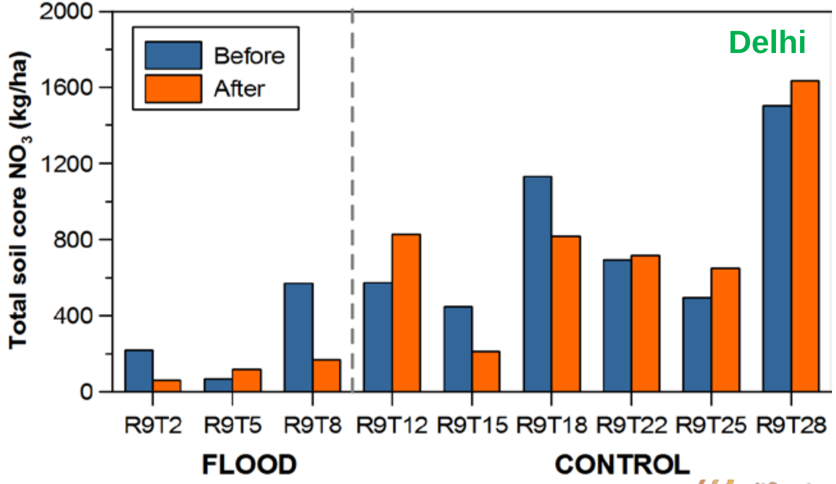
- Entire profile (12 ft):
  - 7% ***decrease*** across treatments
  - 23% ***decrease*** in Flood treatment
  - No change in Control

➢ Rainfall caused a similar decrease in nitrate from the root zone in Control as flooding did in Recharge treatment.

ROOT ZONE



12 ft PROFILE



Soil Nitrate: 1 kg/ha = 0.89 lb/acre

Yield Data

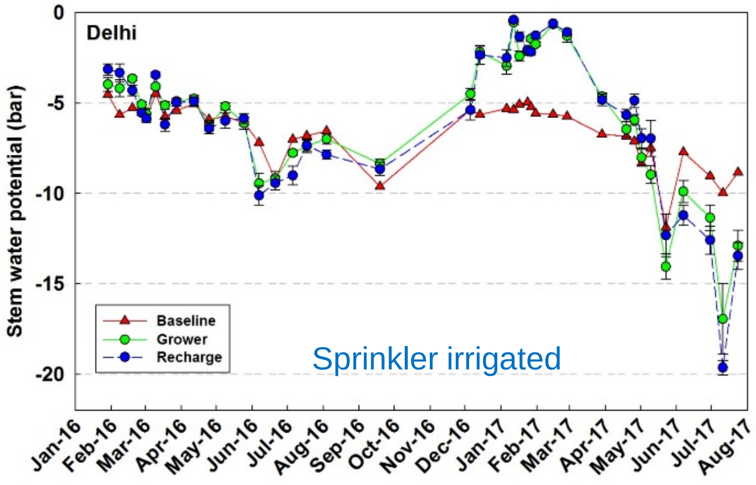
		Year		
Site	**Treatment**	**2015 (pre-treatment)**	**2016**	**2017**
Modesto	Grower	3220	3090	<u>3900</u>
	(Dry Winter)	3360	<u>3290</u>	2980
	Recharge	<u>3430</u>	3130	2990
Delhi	Grower	1230	<u>1250</u>	2200
	(Dry Winter)	1190	1140	2640
	Recharge	<u>1410</u>	1200	<u>3110</u>
Orland	Grower	DROUGHT		1640 ± 190
	Recharge			1520 ± 140

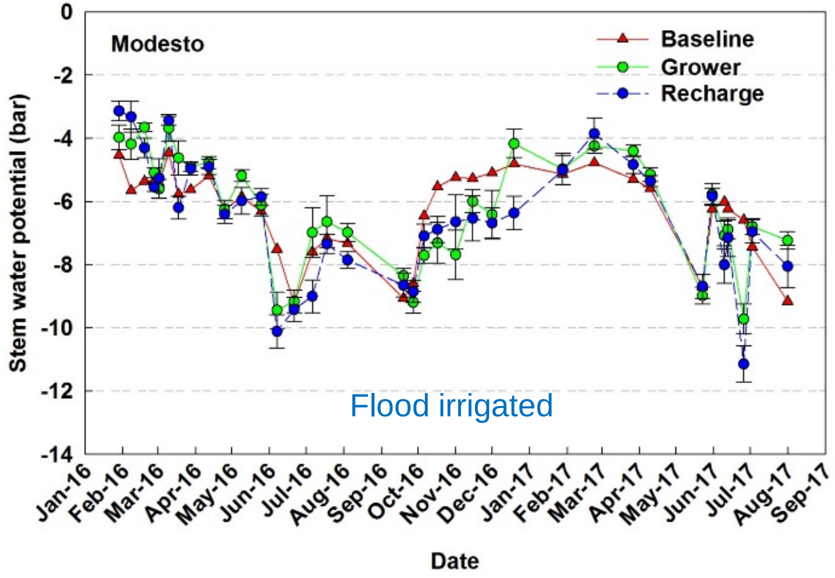
Benefit

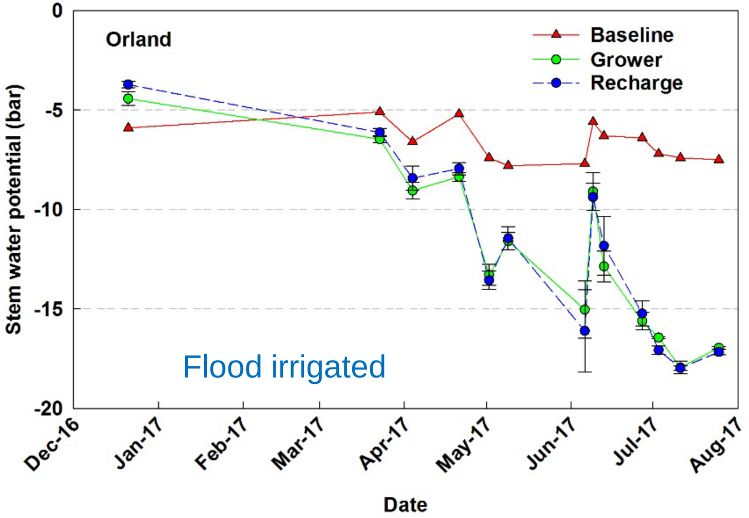
Underline = Max. yield per year

Stem Water Potential

- Midday stem water potential was slightly higher (wetter) in the recharge treatment than in the control at beginning of growing season (Modesto, Delhi)





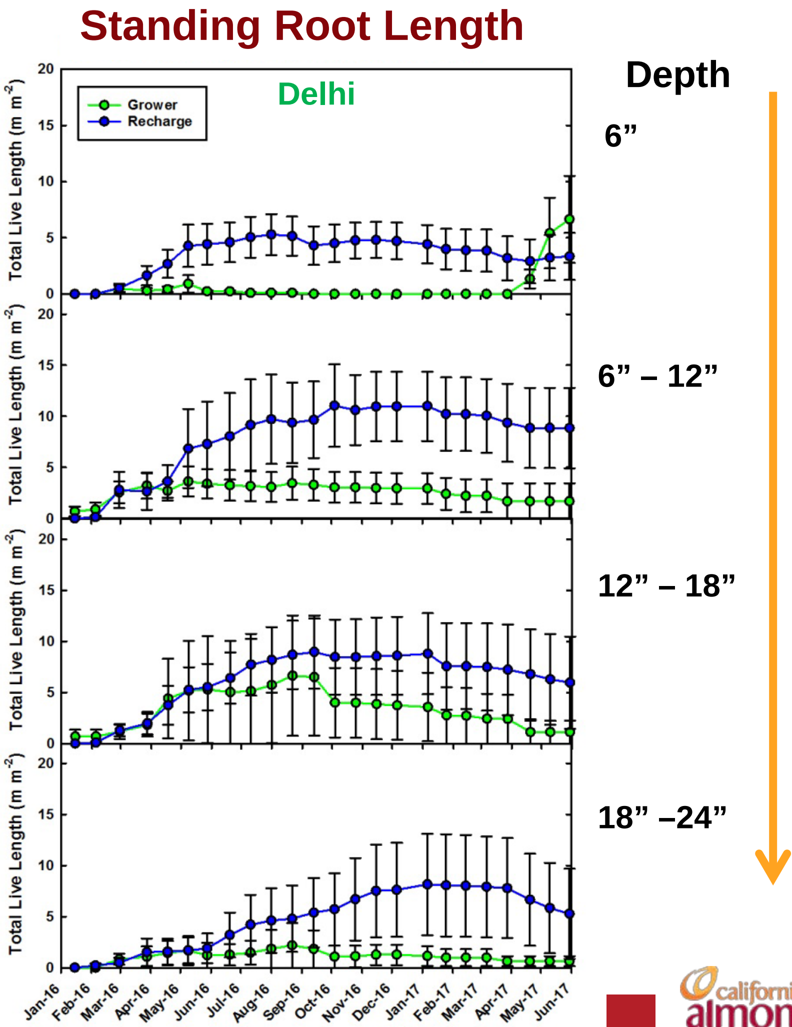


Root growth

- No difference in production of new roots (March-May) between treatments at Delhi and Modesto.

- Trees in Recharge treatment showed higher standing root length:
  - Standing root length: rate of root production minus rate of root death
  - Greater standing root length = longer root lifespan

- Median lifespan of roots was about 30-70% longer in the Recharge treatment than in the Control
  - Lifespan increased with depth except for 18-24” depth
  - Greatest difference between Control and Recharge treatment at 6-12” depth



Conclusions

- No obvious warning signs that winter irrigation (Dec/Jan) for groundwater recharge affects trees
- Sandy sites might benefit from winter flooding
- Moderately poor site turned out to perform poorly (no deep percolation possible)
- Sandy soils – clear nitrate loss from recharge
- Silt loams and complex soils with impeding layers – recharge might increase soil nitrate

- Winter recharge is <u>not</u> a suitable practice for every grower!
  – Check SAGBI map for soil suitability → know your soil!
- Undecided growers:
  – Keep your flood irrigation system if you have one
  – Talk to your irrigation/water district about options

Acknowledgements

- **Funding:**
  Almond Board of California

- **Farm advisors:**
  David Doll, Roger Duncan, Allan Fulton, and Danielle Lightle

- **Students and field helpers:**
  Seanna McLaughlin, Nicholas Murphy, Paul Martinez, Rebecca Scott, Colin Fagan, Juliana Wu

Importance of Subsurface Sediments on Water Movement

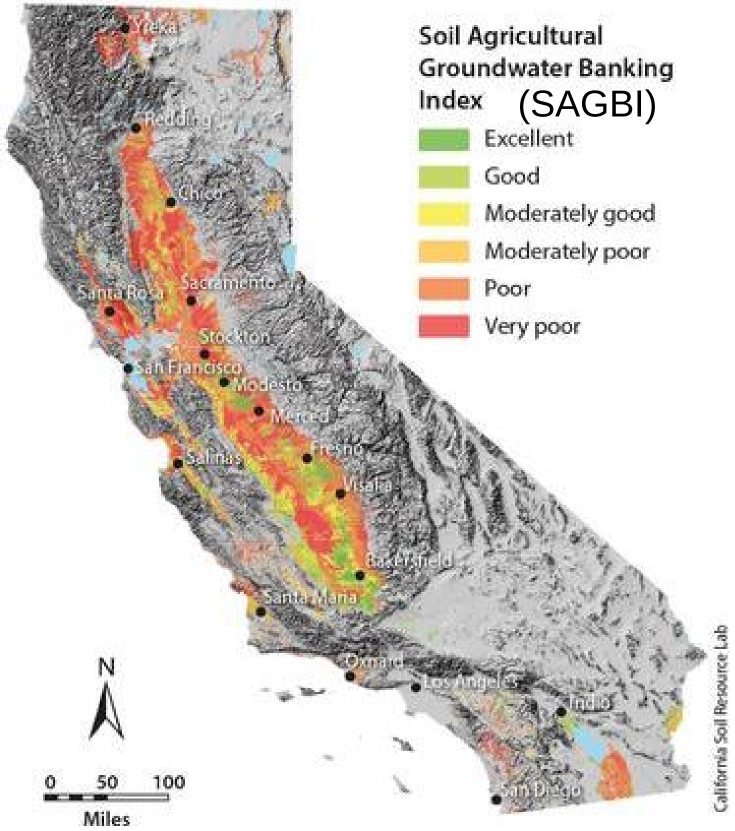
Peter S. Nico, Craig Ulrich, Yuxin Wu, Mark Conrad, Greg Newman, William Stringfellow, Christine Doughty and Yingqi Zhang
Lawrence Berkeley National Laboratory

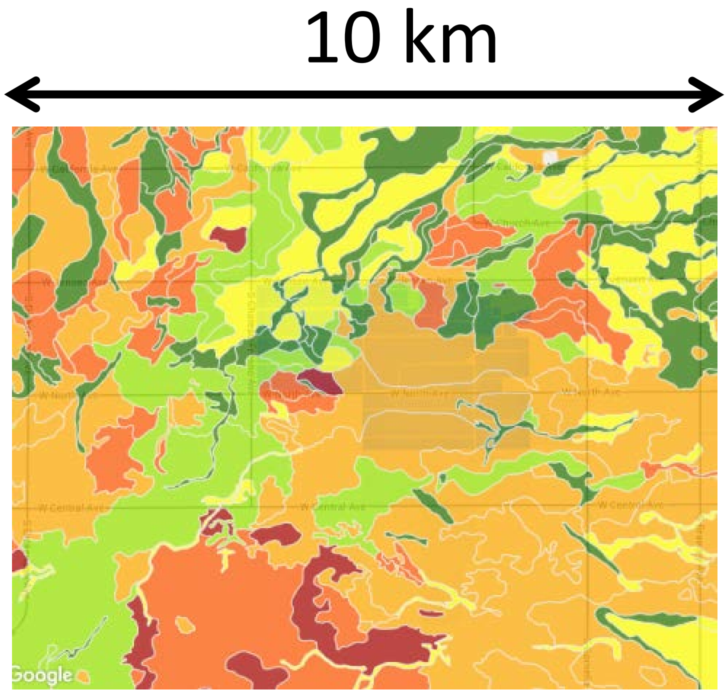
Taqi Alyousuf; Jamie Rector
University of California, Berkeley

Hannah Waterhouse, Helen Dahlke
University of California, Davis

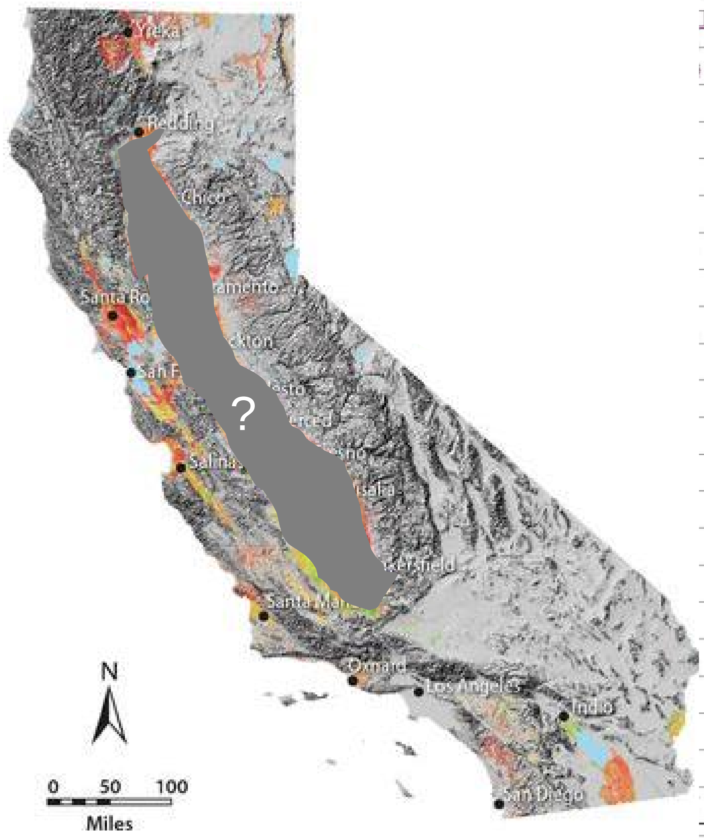
Nick Blom
The Arnold Farms
Roger Duncan and David Doll of UC ANR

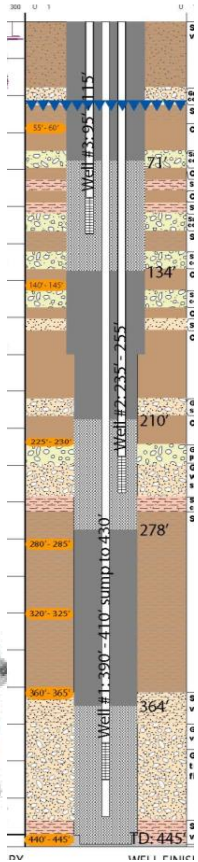
Surface Soils are Complex

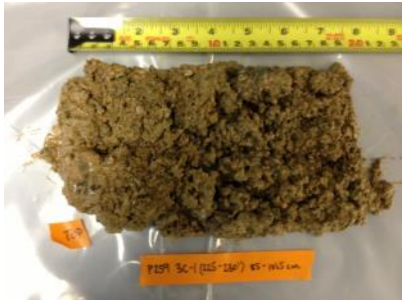


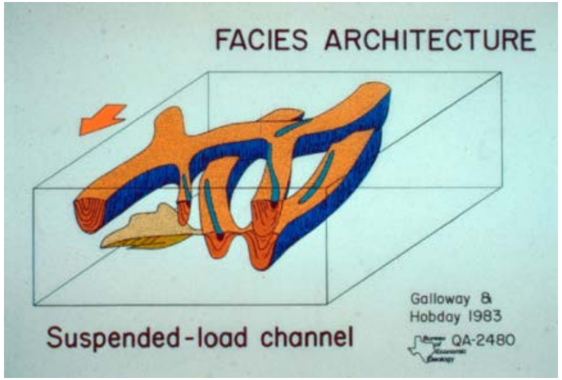


Subsurface as Complex as Surface Soil but Less Well Known

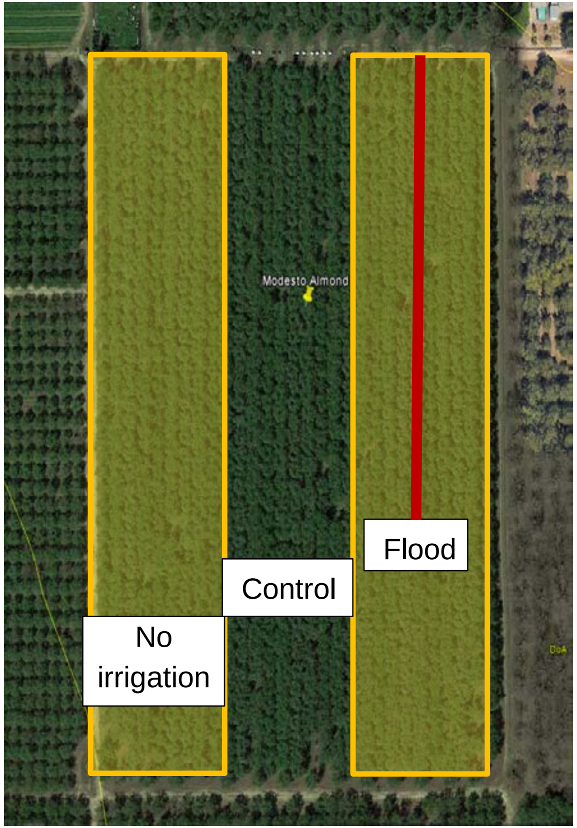


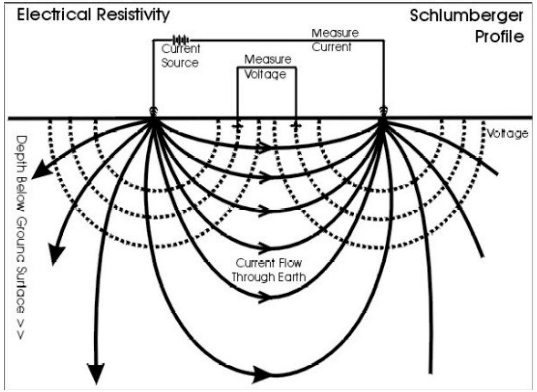






We Can Image What's Below Ground





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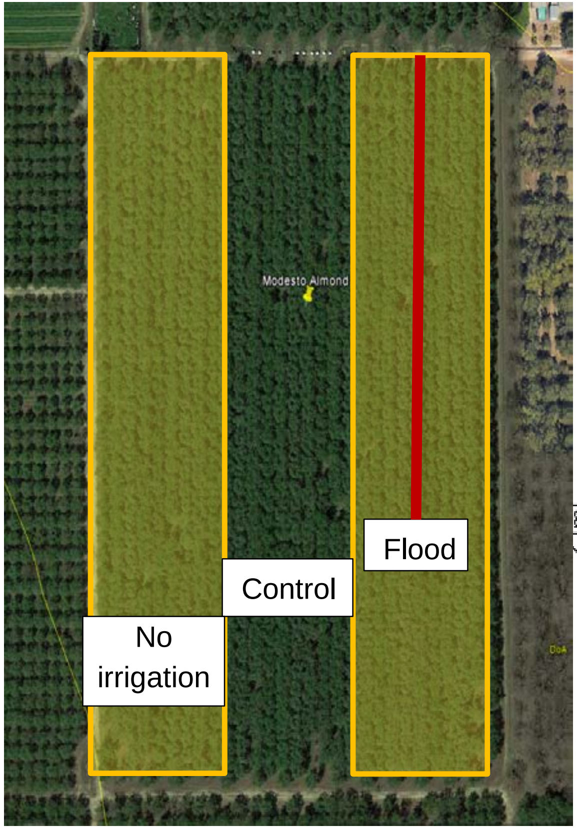
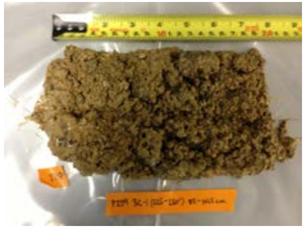


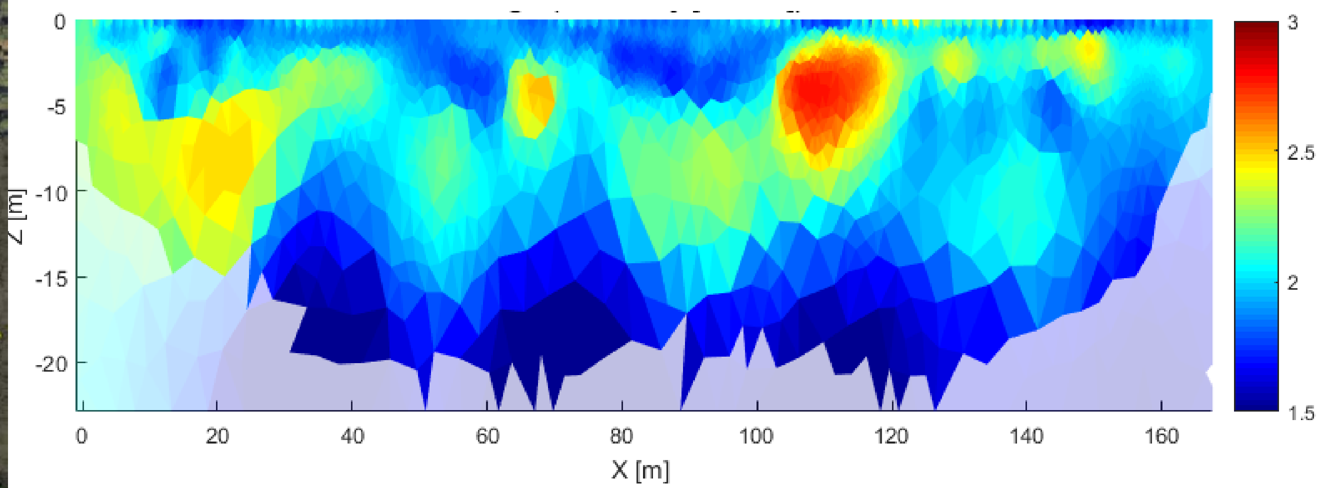
Coarser



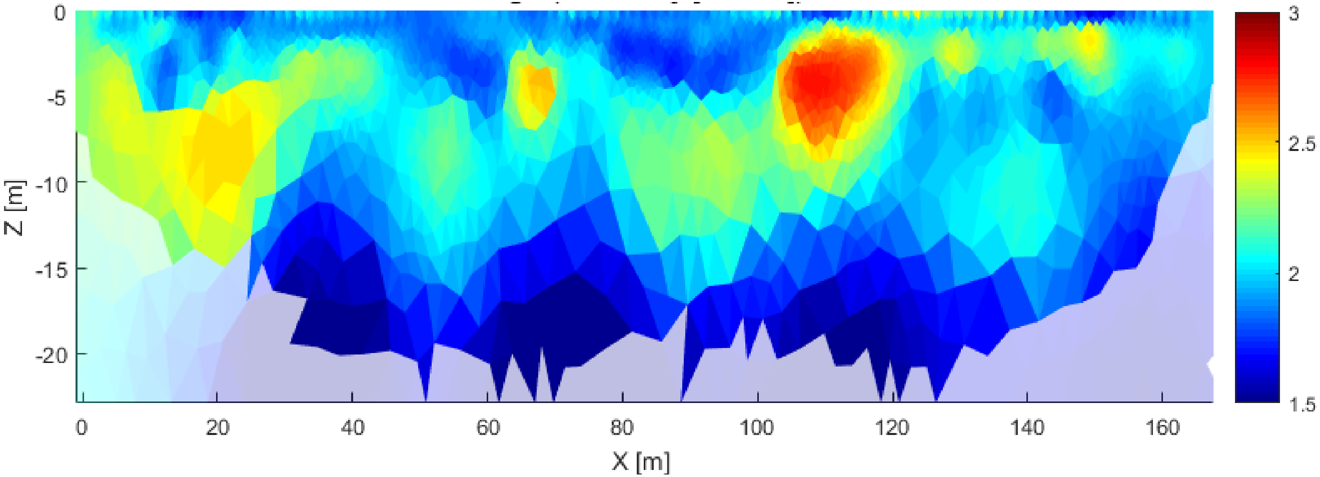
High Electrical Resistivity

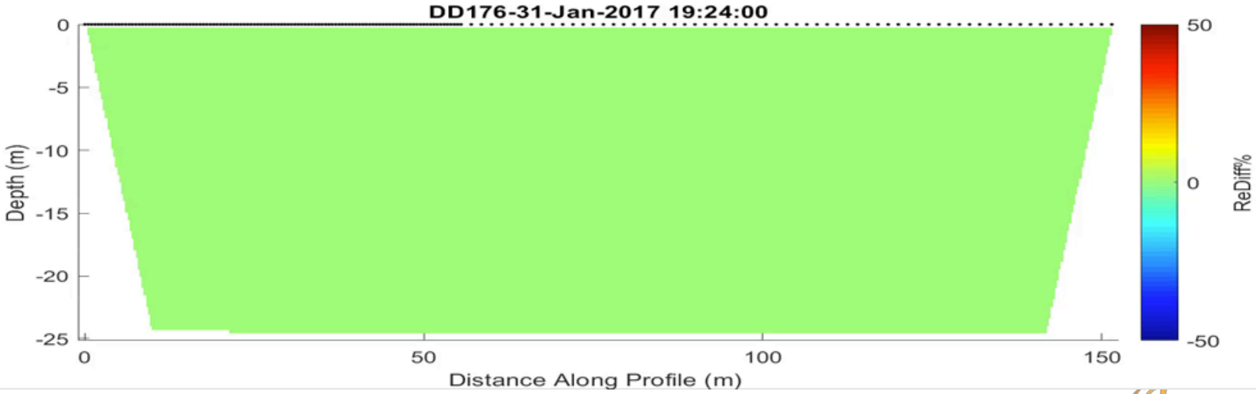
Finer

Low Electrical Resistivity



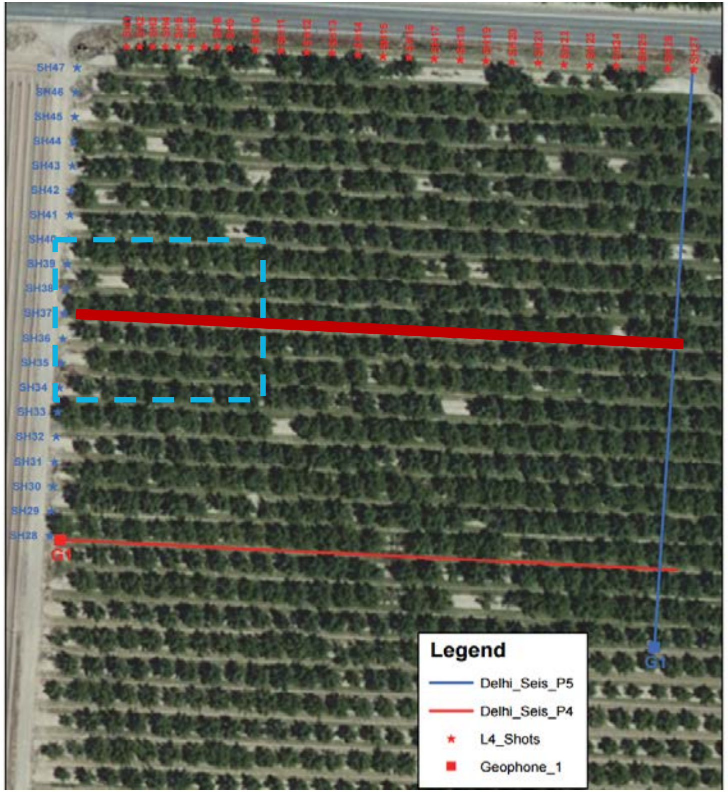
We Can Watch Water Move

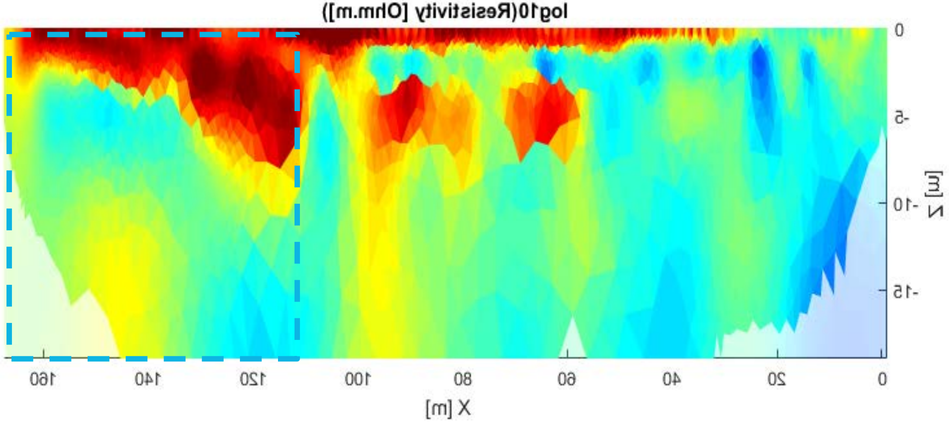


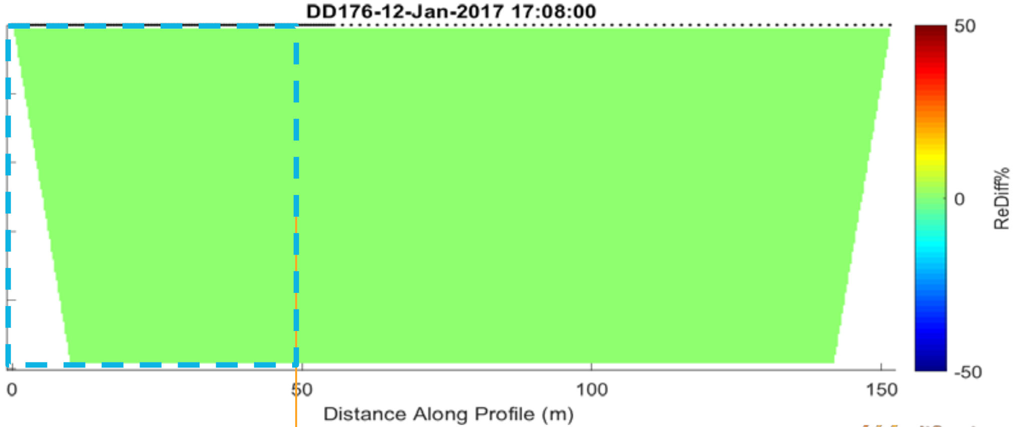


Water Doesn't Stay Where It is Put

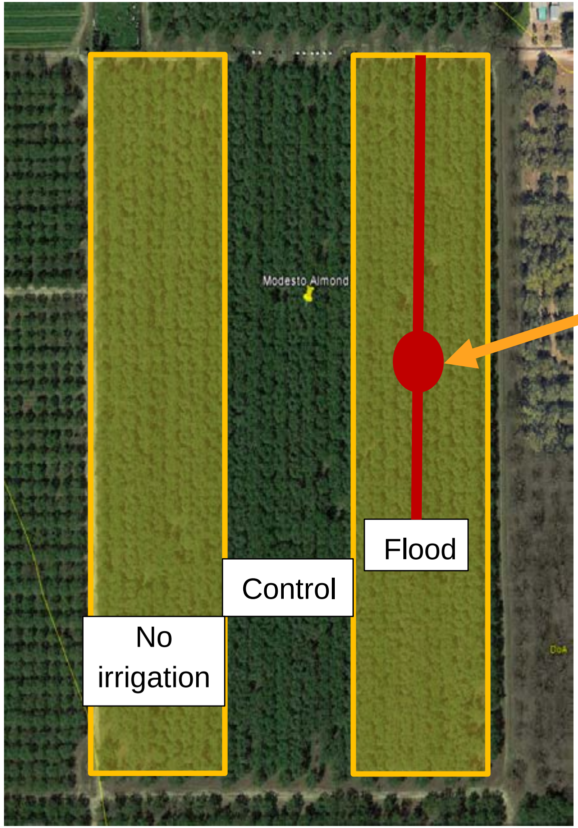
Delhi Orchard

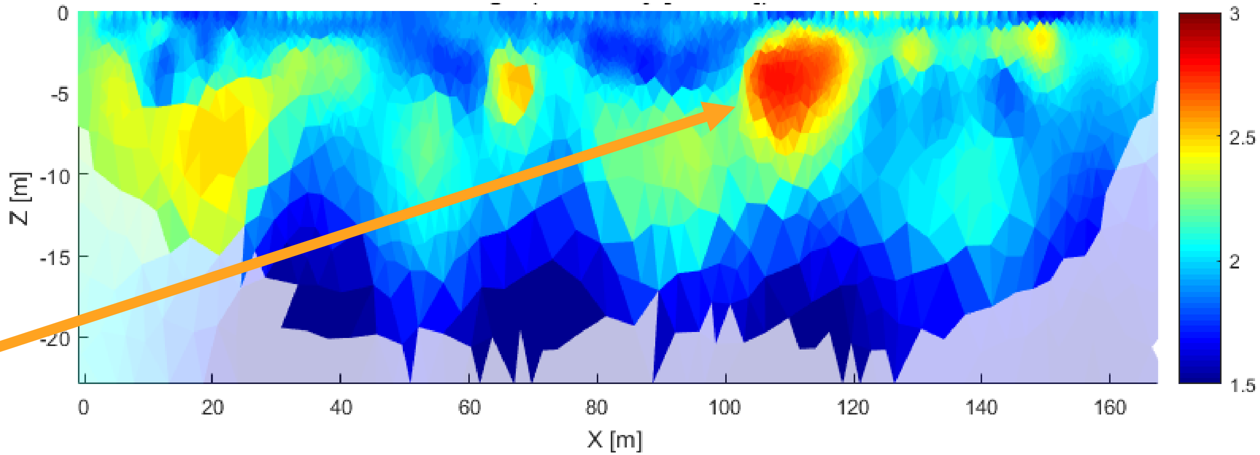






There is a Lot of Variation Even Over Small Distances





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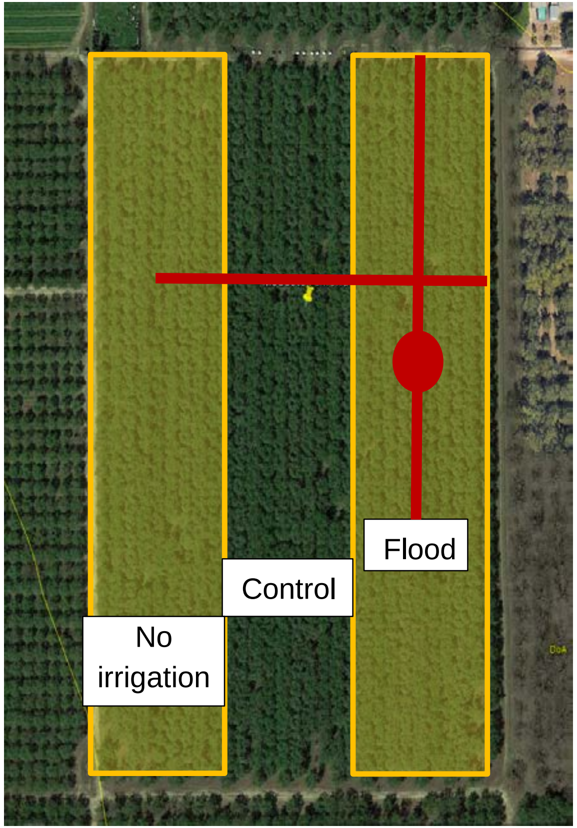

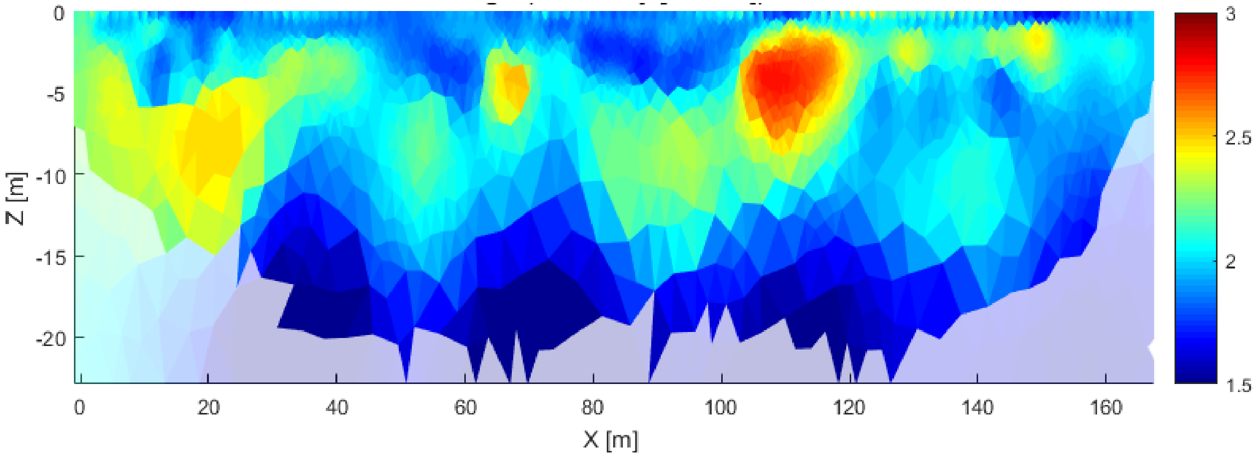

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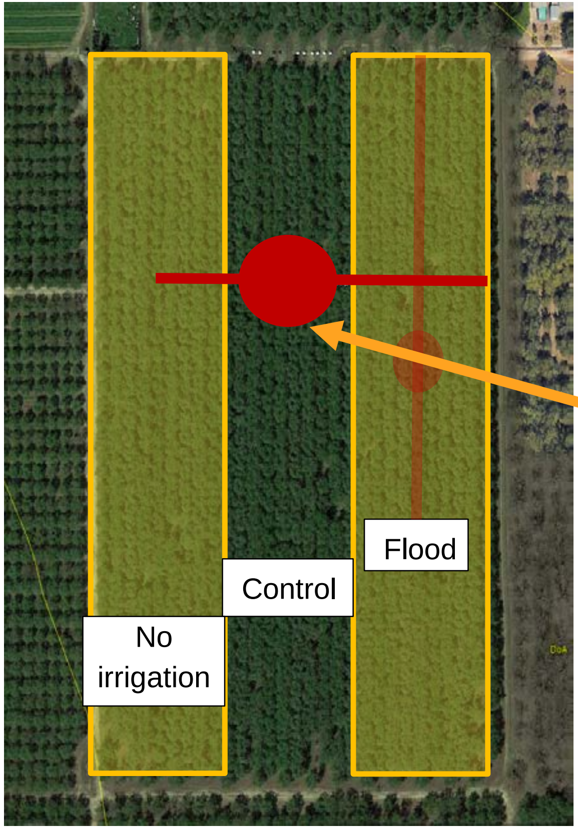
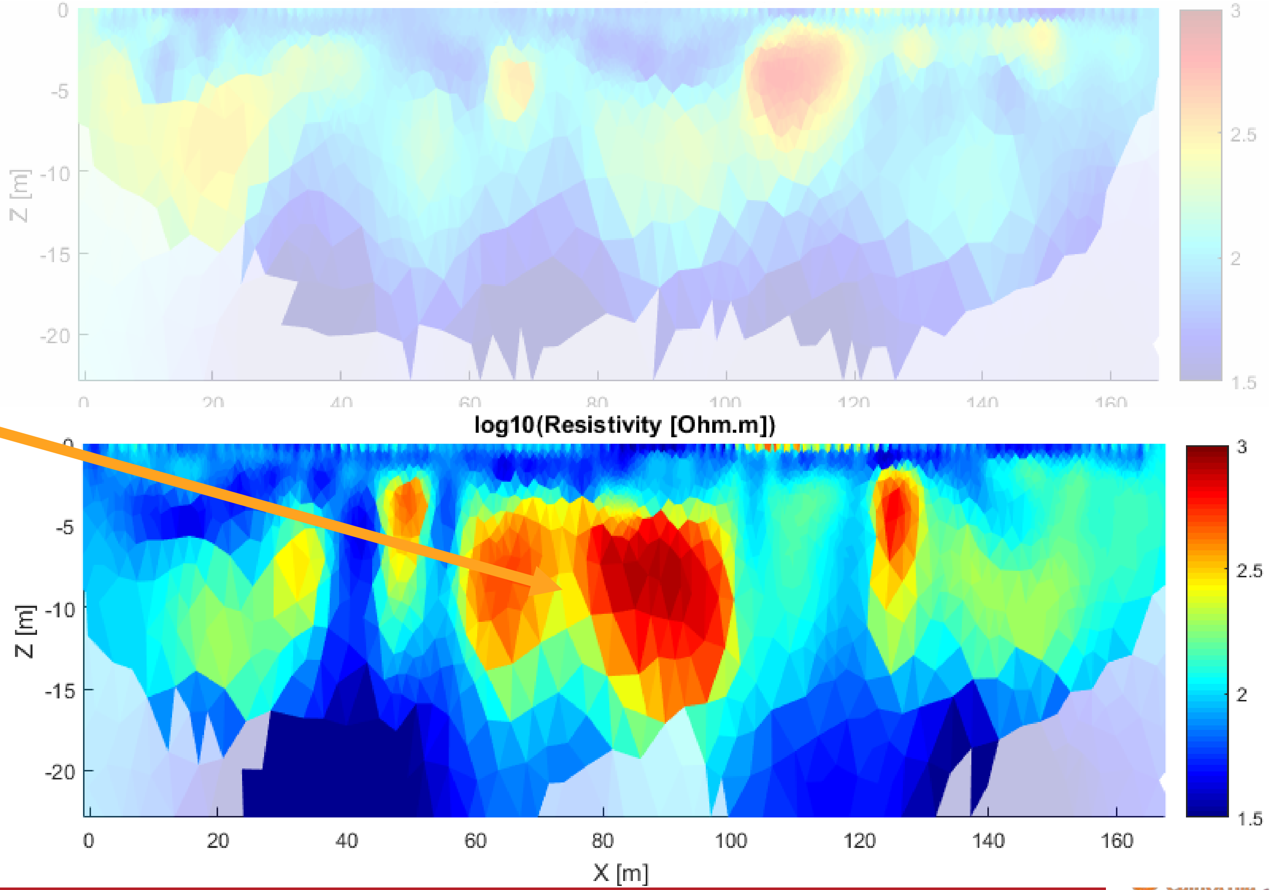
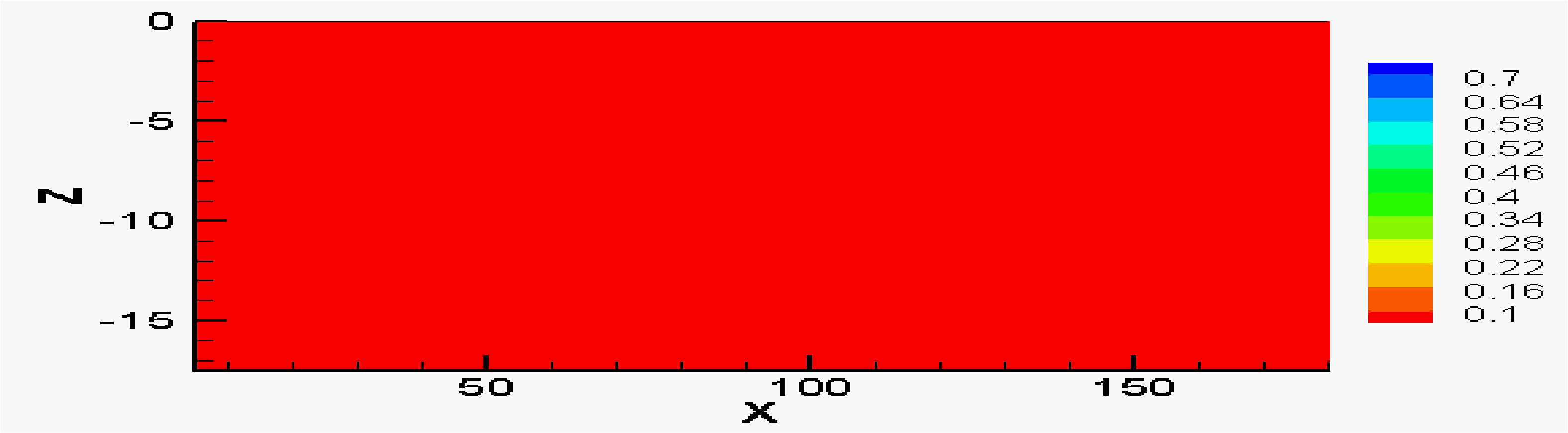




We Can Build Computer Models of Where the Water Goes



What if……

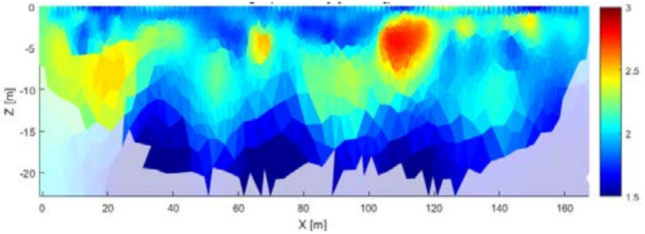
applied 6 inches of water?

applied 24 inches of water?

there was nitrate or salt?

you used a different part of the orchard?

how sensitive are the answers to uncertainty in the model……?



Conclusions

- There are lots of differences in the subsurface below what looks like similar soils
- Water movement can vary a lot from place to place within even a single part of an orchard
- There could be ways to optimize recharge effectiveness even within a single orchard
- Knowing where the water goes can help with predicting/preventing negative impacts, e.g. nitrate movement
- We are working on ways to image more area, more quickly

Thank You!

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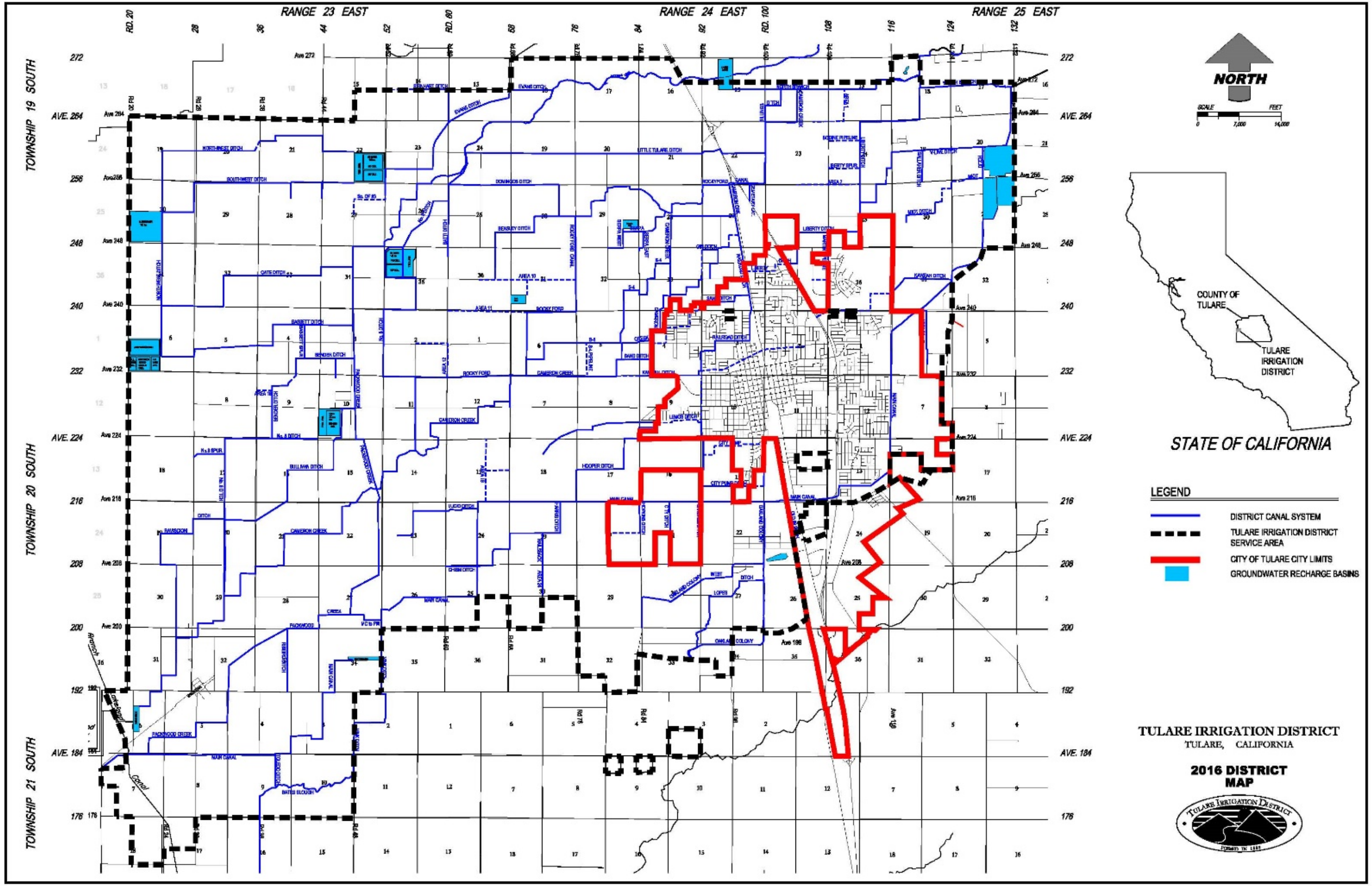
Tulare Irrigation District

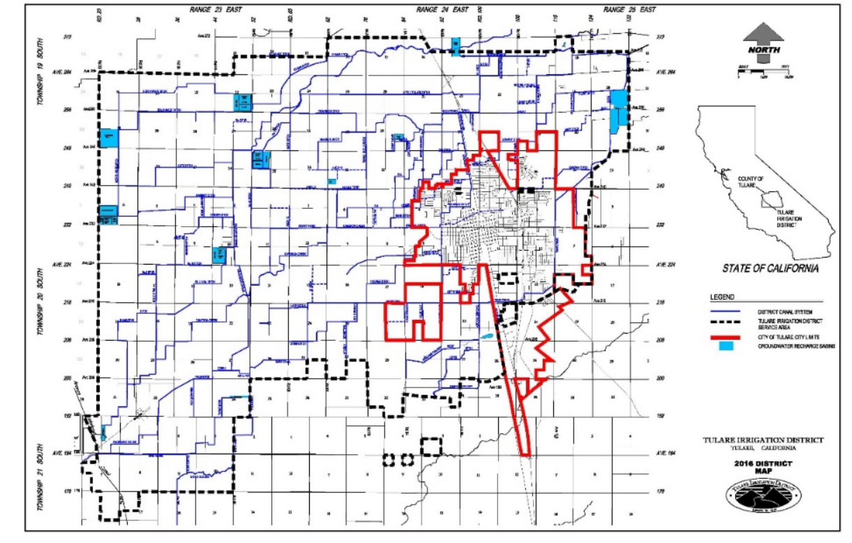
Grower On-Farm Recharge Program

Tulare Irrigation District

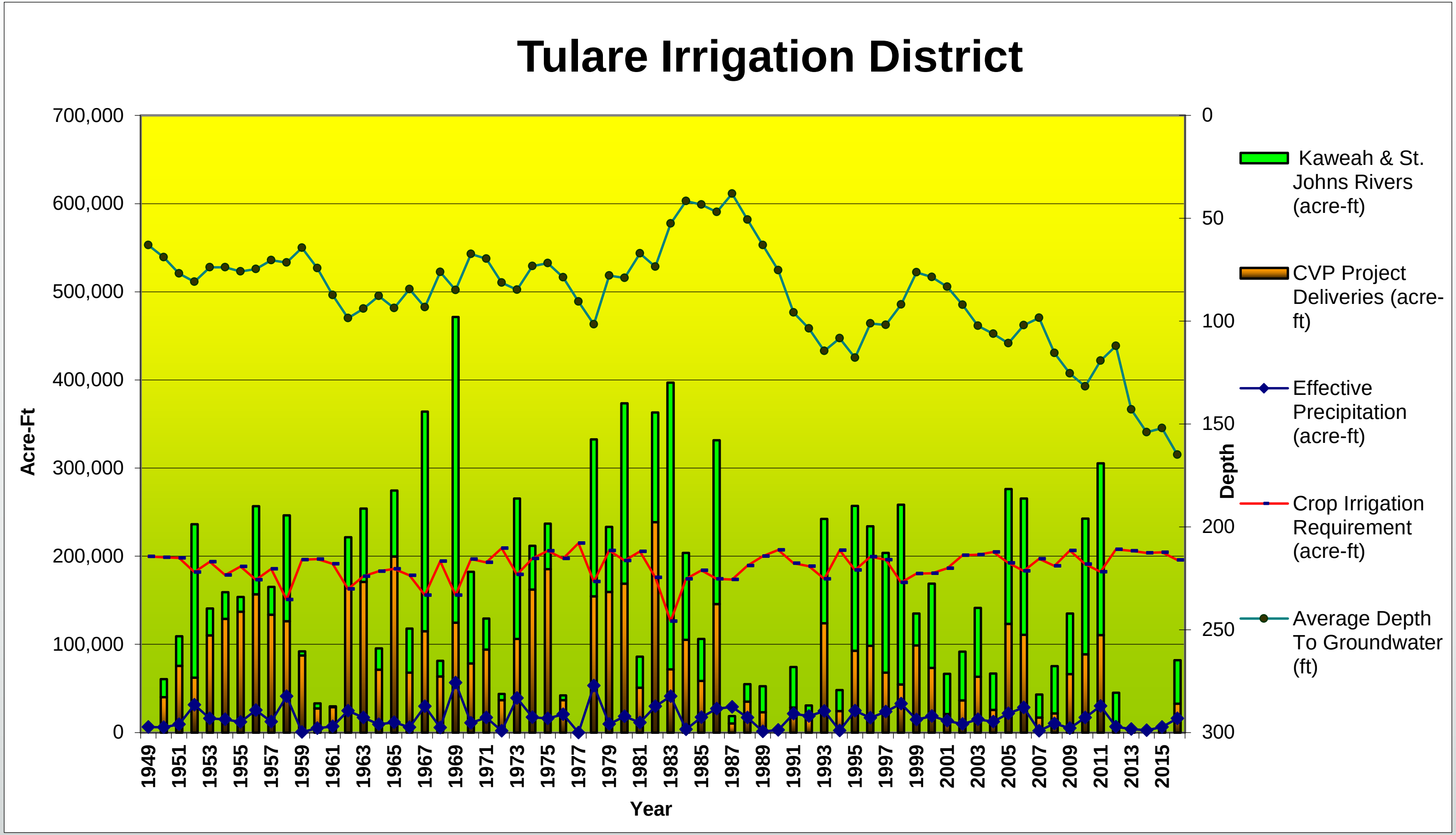


District Background

- 70,000 acres
- 300 miles of earthen canals
- 30 miles of pipeline
- 1,250 acres of recharge basins
- 190 users
- Crops: corn, wheat, alfalfa, walnuts, pistachios, almonds
- Water Supply:
  - 180,000 AF Surface Water
    - Pre-1914 water rights on the Kaweah River System
    - Friant Division of CVP (30,000 AF Class 1 & 141,000 AF Class 2)
  - 120,000 AF Groundwater
- Kaweah Subbasin (SGMA)
  - Member of Mid-Kaweah GSA



Groundwater Conditions



On-Farm Recharge

- 2011 – Concept
- 2016 – Pilot Program Initiated
- 2017 – Pilot Program Implemented
  - On-Farm Recharge
  - Reduce Rate Surface Water ($10/AF)
  - Private Pond Recharge

Total Number of Participants	14
On-Farm Field Participants	6
On-Farm Pond Participants	8
On-Farm Field Acreage	650 Acres
Total Recharge	6,800 Acre-Feet[3]
On-Farm Field Recharge	2,500 Acre-Feet
On-Farm Pond Recharge	4,300 Acre-Feet

2017 On Farm Conclusions

- Previous Recharge Capacity 350 CFS
- 2017 On-Farm Program = 650 CFS
  - Intake Capacity of 900 CFS
  - 250 CFS of increased recharge targeted
  - On-Farm achieved an average of 3.9 AF/Acre
- 2017 Water Year
  - 170,000 AF to Irrigation Turnouts
  - 190,000 AF to Groundwater Recharge

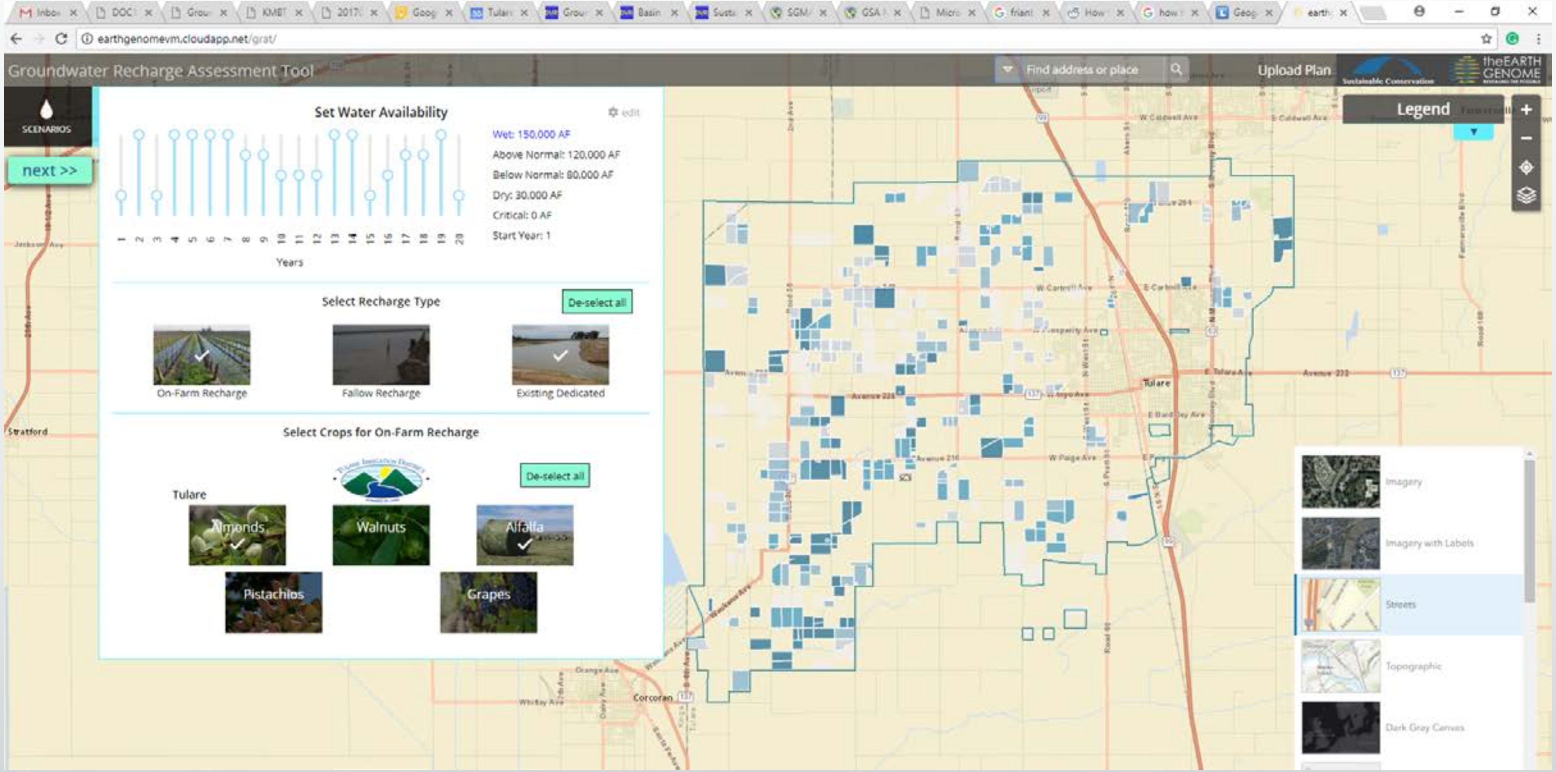
Future Landowner Participation / Costs in Groundwater Recharge

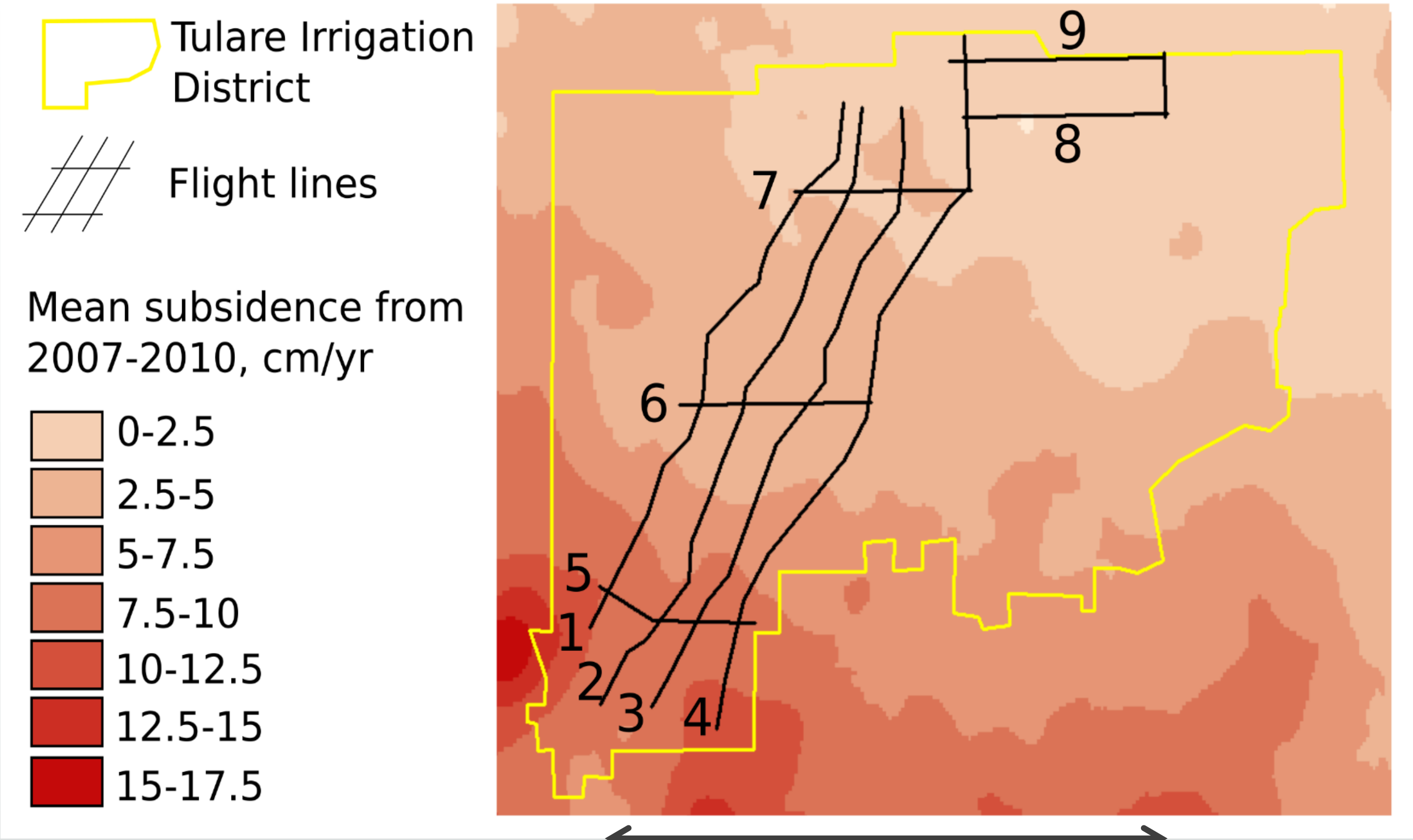
- Development of District Recharge Ponds
  - Landowner sells ground $20,000 - $35,000 per acre
  - Development costs are approximately $20,000 per acre
- Reduced rate winter surface water
- On-Farm Recharge
  - Current Approach: Free water in exchange for access for on-farm recharge
  - Future Approach: Reimburse landowner for access to field to “buy the crop”
    - Example: buy winter wheat planting @ $175 - $250 per acre

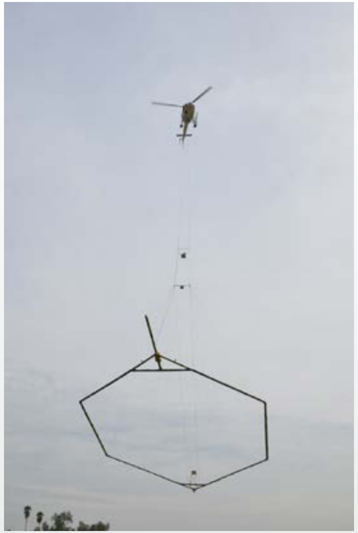


Finding the On-Farm Program

- Working with Sustainable Conservation we have developed the Groundwater Recharge Assessment Tool



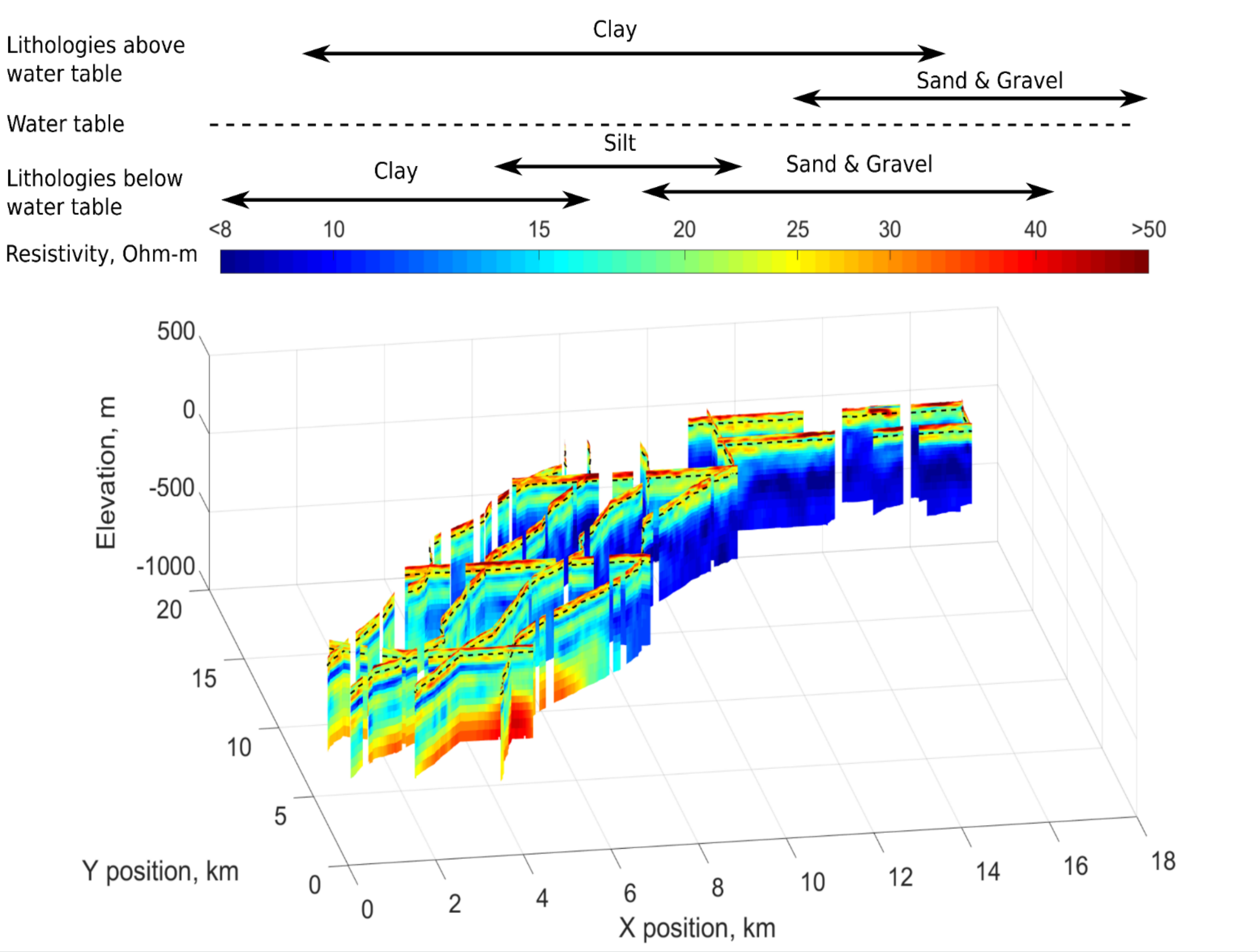


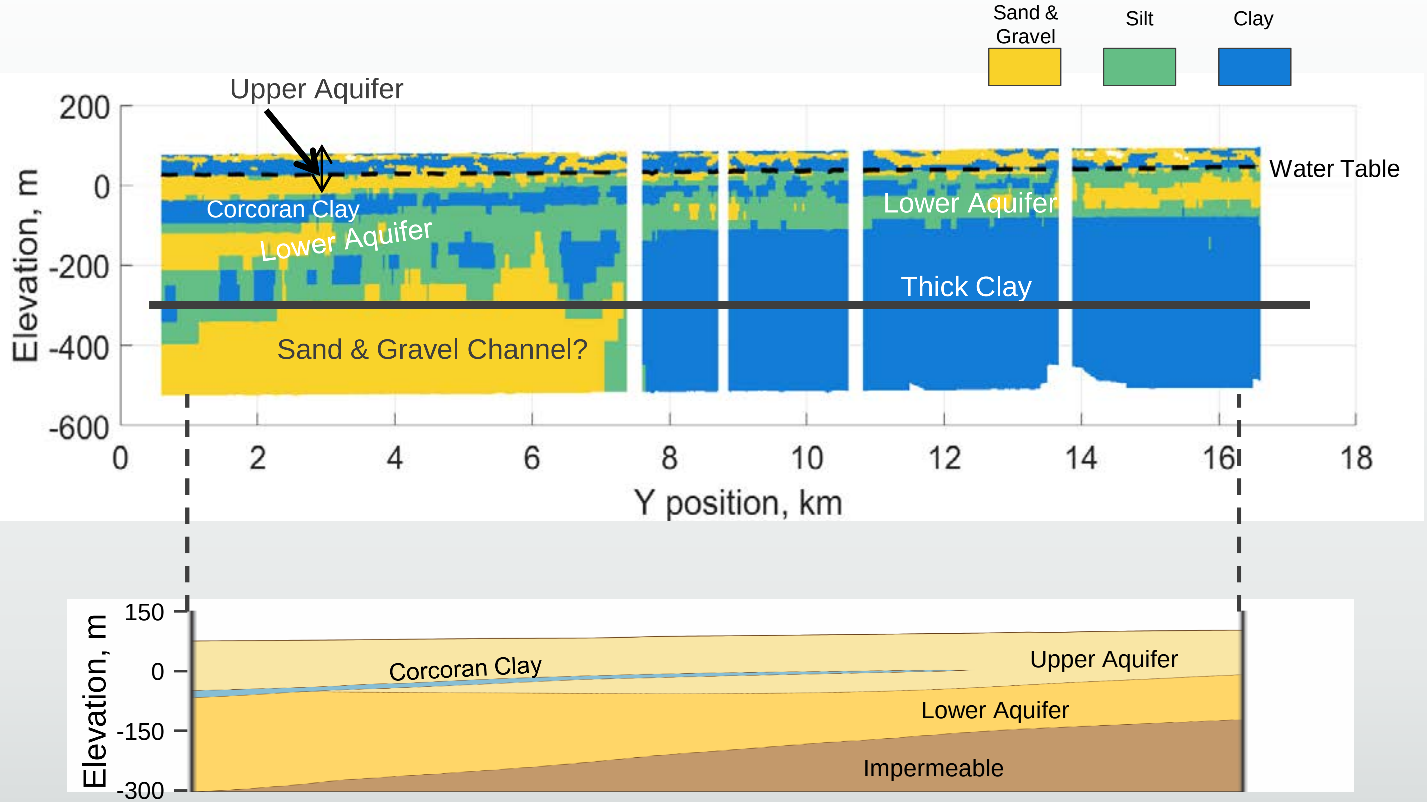


20 kilometers

Total of 104 line km (64 miles), 1 km (.6 mi) spacing between lines

Stanford University

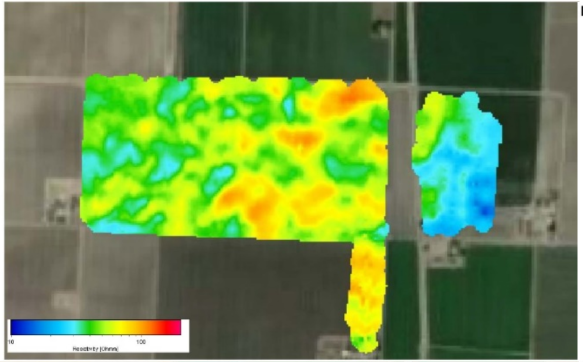

Lithologies above water table
Clay
Sand & Gravel
Water table
Lithologies below water table
Clay
Silt
Sand & Gravel
Resistivity, Ohm-m
<8
10
15
20
25
30
40
>50
Elevation, m
500
0
-500
-1000
Y position, km
20
15
10
5
0
X position, km
0
2
4
6
8
10
12
14
16
18



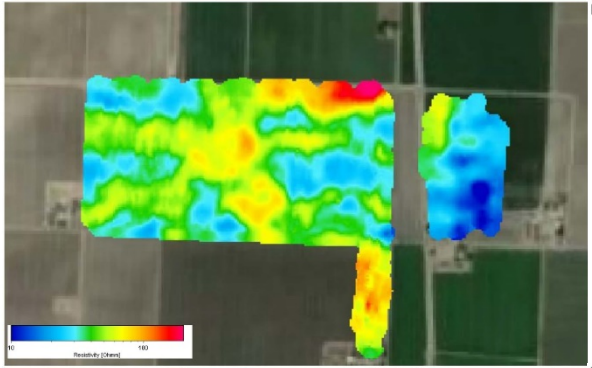
Cross-section provided by Kaweah Delta Water Conservation District

Tow-TEM

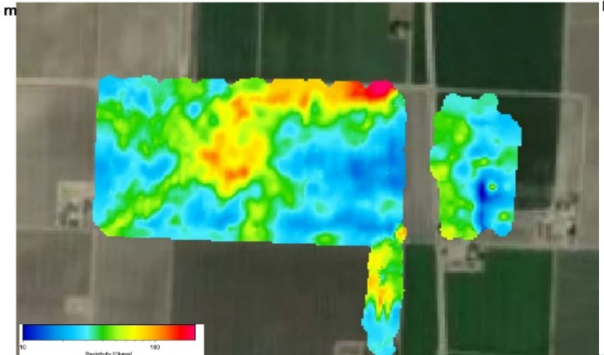
MR 0-5 m



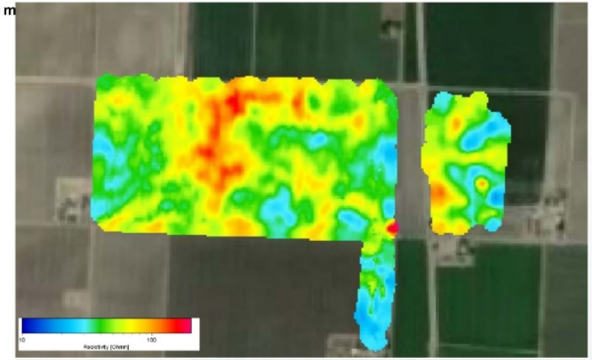
MR 5-10 m



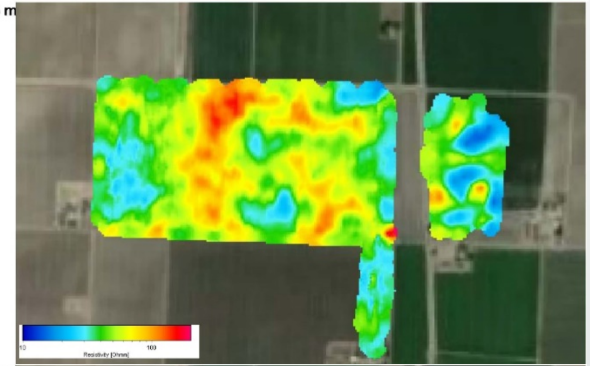
MR 10-15 m



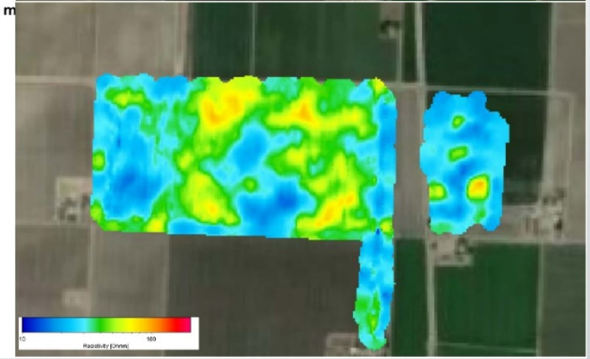
MR 15-20 m



MR 20-25 m



MR 25-30 m



Conclusions

- Transitioned from extreme drought to extreme wet conditions
  - Growers participated in recharge efforts
- With SGMA ahead of us, we quickly implemented an aggressive groundwater recharge season
  - On-Farm Recharge
  - Existing Recharge Basin
  - Reduced Rate Water
- On-Farm Recharge was a success with lessons learned and future opportunities
- New projects ahead such as Sky-TEM, Tow-TEM and GRAT will assist in our future recharge programs

Aaron Fukuda

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Tulare, California 93274

Phone: 559-686-3425
Email: akf@tulareid.org

Thank you!

What’s Next

Tuesday, December 5 at 3:00 p.m.

- Research Update: Soil Health, Aerial Almond Mapping and Almond Lifecycle Assessment – Room 312-313
- Come See What’s Happening in D.C.! – Room 306-307
- How to Manage a Young Orchard – Room 308-309
- Technology in the Food Safety World: Tools Such as Whole Genome Sequencing – Friend or Foe? – Room 314

CEUs – New Process

Certified Crop Advisor (CCA)

- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- *Repeat this process for each session, and each day you with to receive credits.*

Pest Control Advisor (PCA), Qualified Applicator (QA), Private Applicator (PA)

- Pickup scantron at the start of the day at first session you attend; complete form.
- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- Turn in your scantron at the end of the day at the last session you attend.

Sign in sheets and verification sheets are located at the back of each session room.

Research Poster Sessions

Wednesday, December 6
3:00 p.m. – 5:00 p.m.

Featured topics:
- Irrigation, nutrient management
- Breeding
- Soils, if related to organic matter input
- Sustainability, irrigation improvement continuum, life cycle assessment, dust
- Food quality and safety

Thursday, December 7
1:30 p.m. – 2:30 p.m.

Featured topics:
- Insect and disease management
- Fumigation and alternatives
- Biomass (including biochar-related efforts)
- Pollination
- Almond Leadership Program

2017 Research Update Book

- Pickup your copy at the ABC Booth in Hall A+B
- Includes a one-page summary of every current ABC-funded research project