Efforts to recharge California's groundwater

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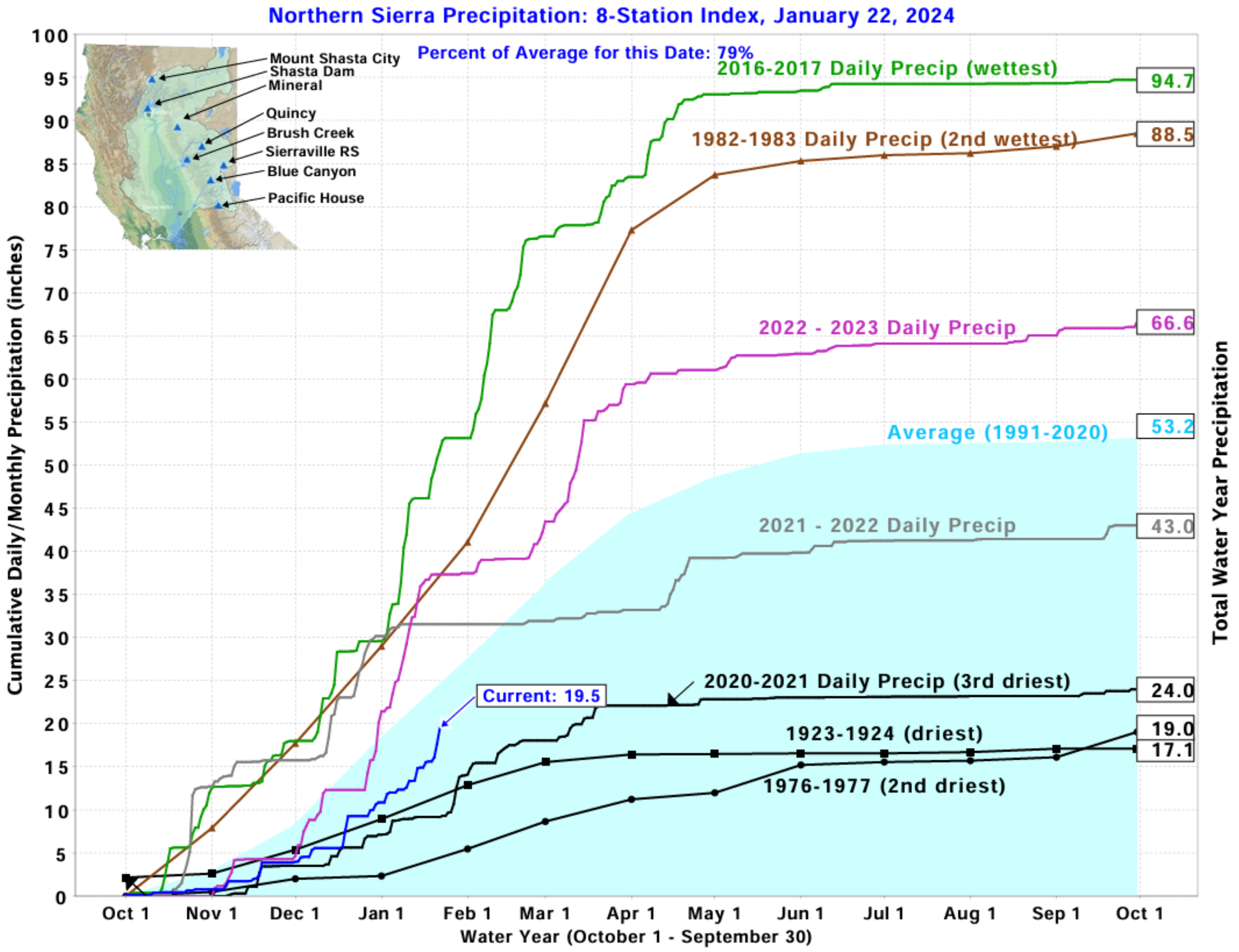
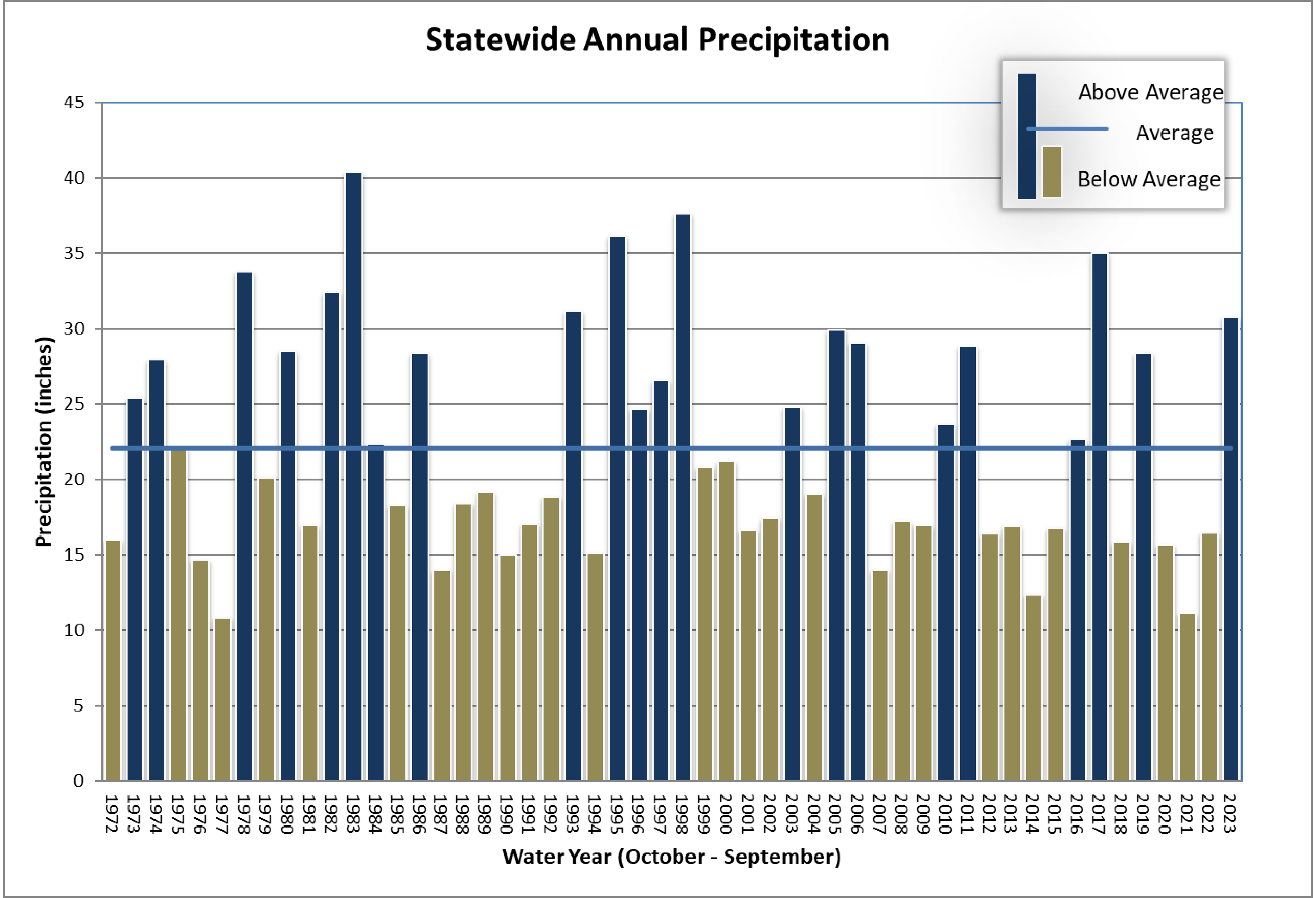
UC DAVIS DEPARTMENT OF LAND, AIR AND WATER RESOURCES

Current surface water & groundwater situation





Statewide Annual Precipitation
Above Average
Average
Below Average
Precipitation (inches)
0
5
10
15
20
25
30
35
40
45
1972
1973
1974
1975
1976
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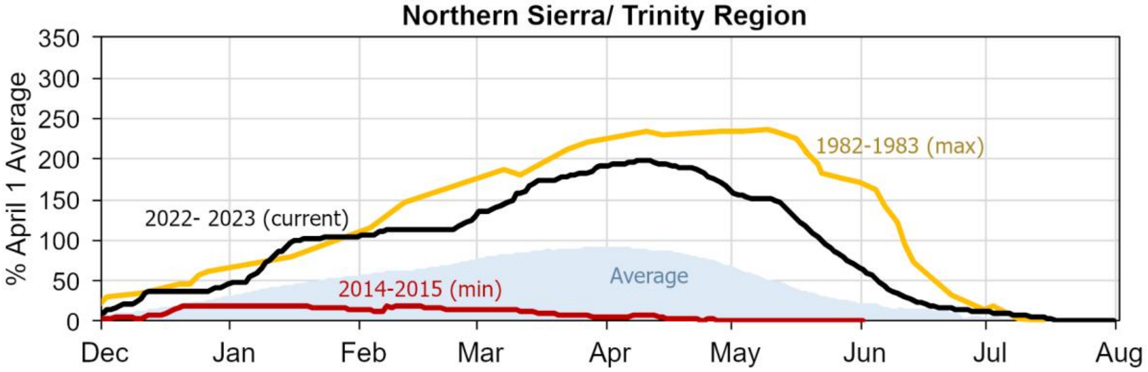
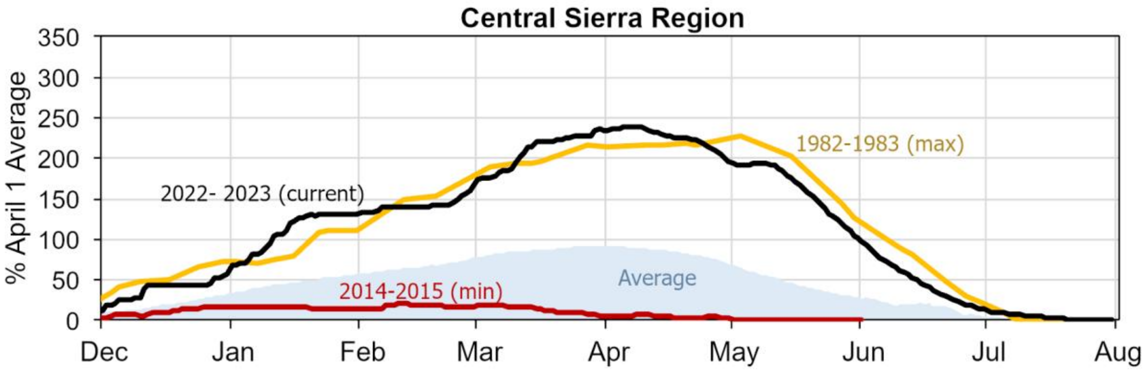
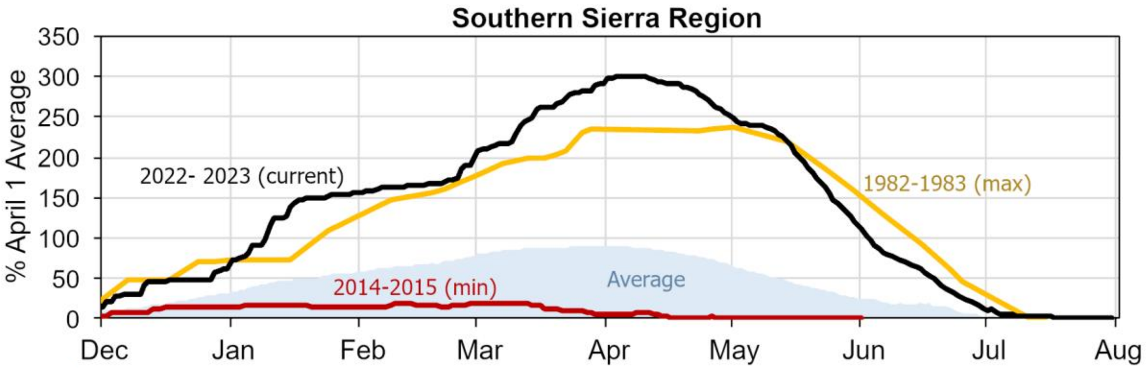
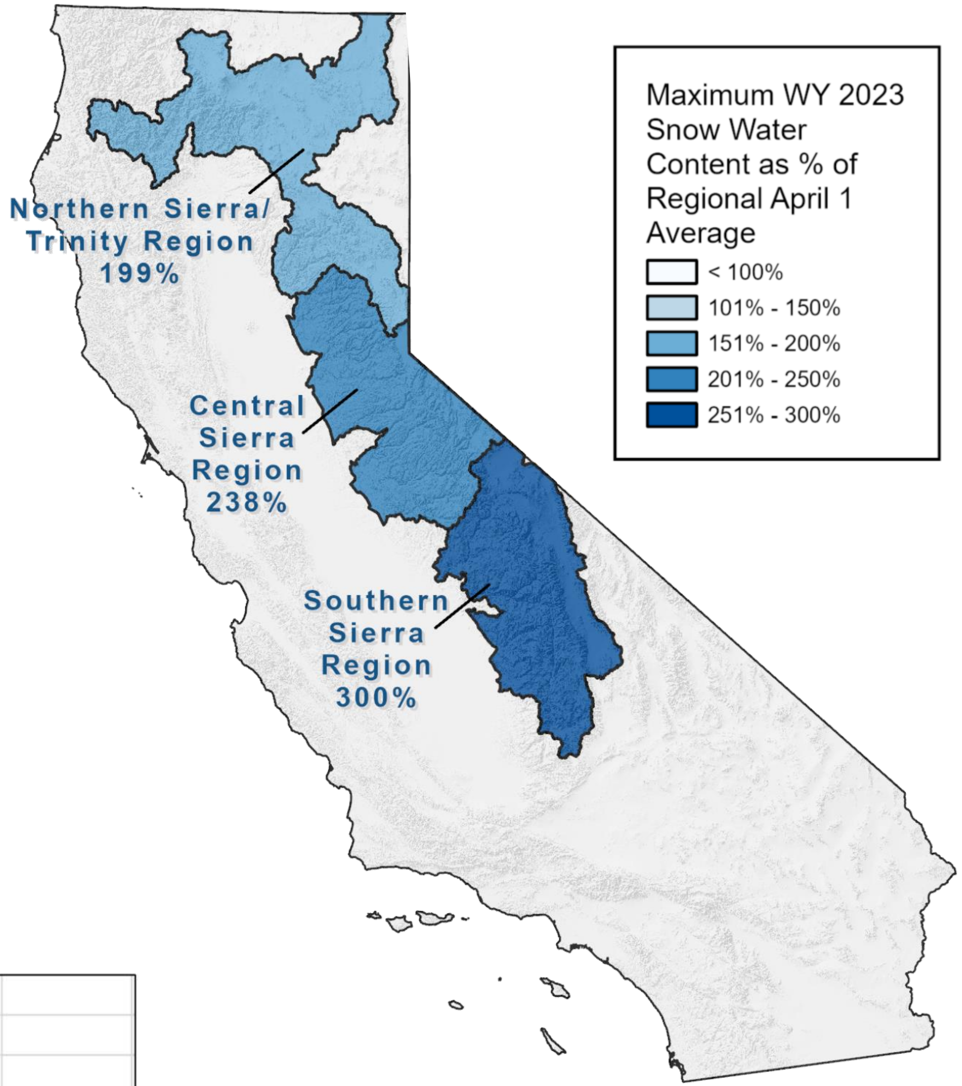
2018
2019
2020
2021
2022
2023
Water Year (October - September)

2023 Water Year Snow Water Content

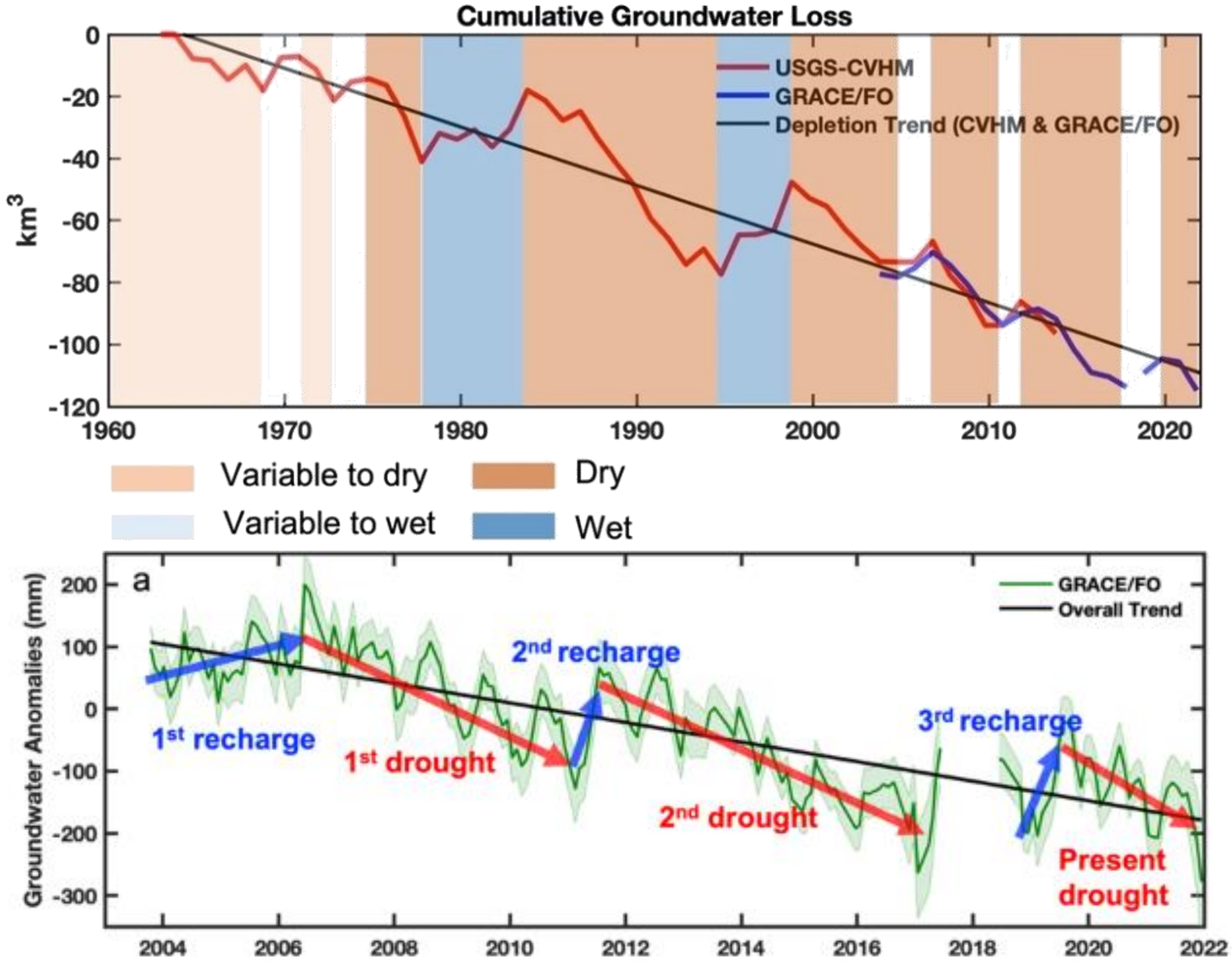








What do we need to catch up on?



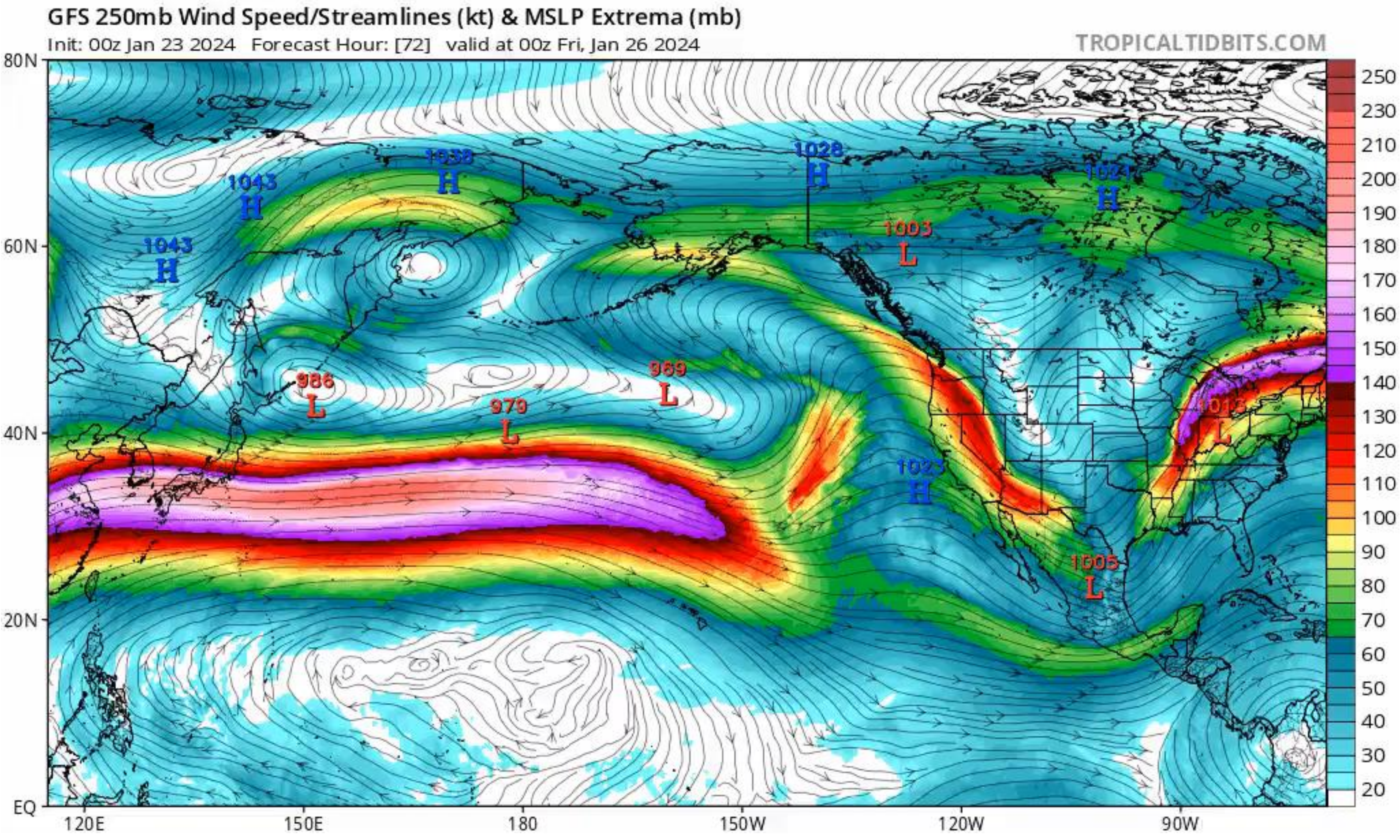
Central Valley overdraft rates:

1961–2021: 1.51 MAF/yr

2003–2021: 1.95 MAF/yr

2019–2021: 6.95 MAF/yr

Liu et al., 2022, Nature Communications



GFS 250mb Wind Speed/Streamlines (kt) & MSLP Extrema (mb)
Init: 00z Jan 23 2024 Forecast Hour: [72] valid at 00z Fri, Jan 26 2024
TROPICALTIDBITS.COM
80N
60N
40N
20N
EQ
120E
150E
180
150W
120W
90W
1043 H
1043 H
1038 H
1028 H
1021 H
1023 H
1003 L
986 L
979 L
969 L
1005 L
250
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110
100
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50
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30
20

Groundwater Recharge – how to do it?

Recharge Ponds

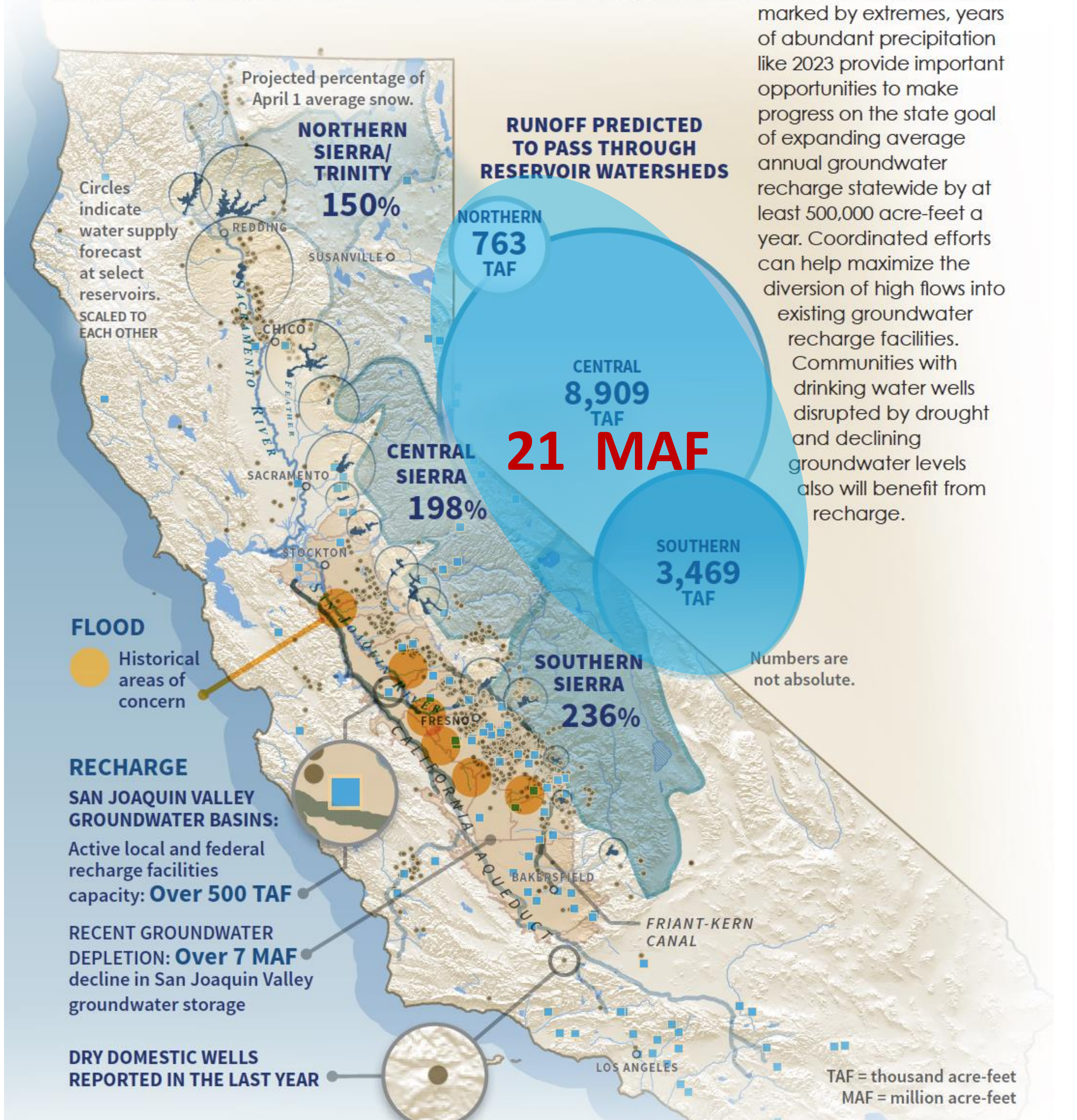
Flooding unlined earthen canals

On-farm Recharge


Water Year 2023

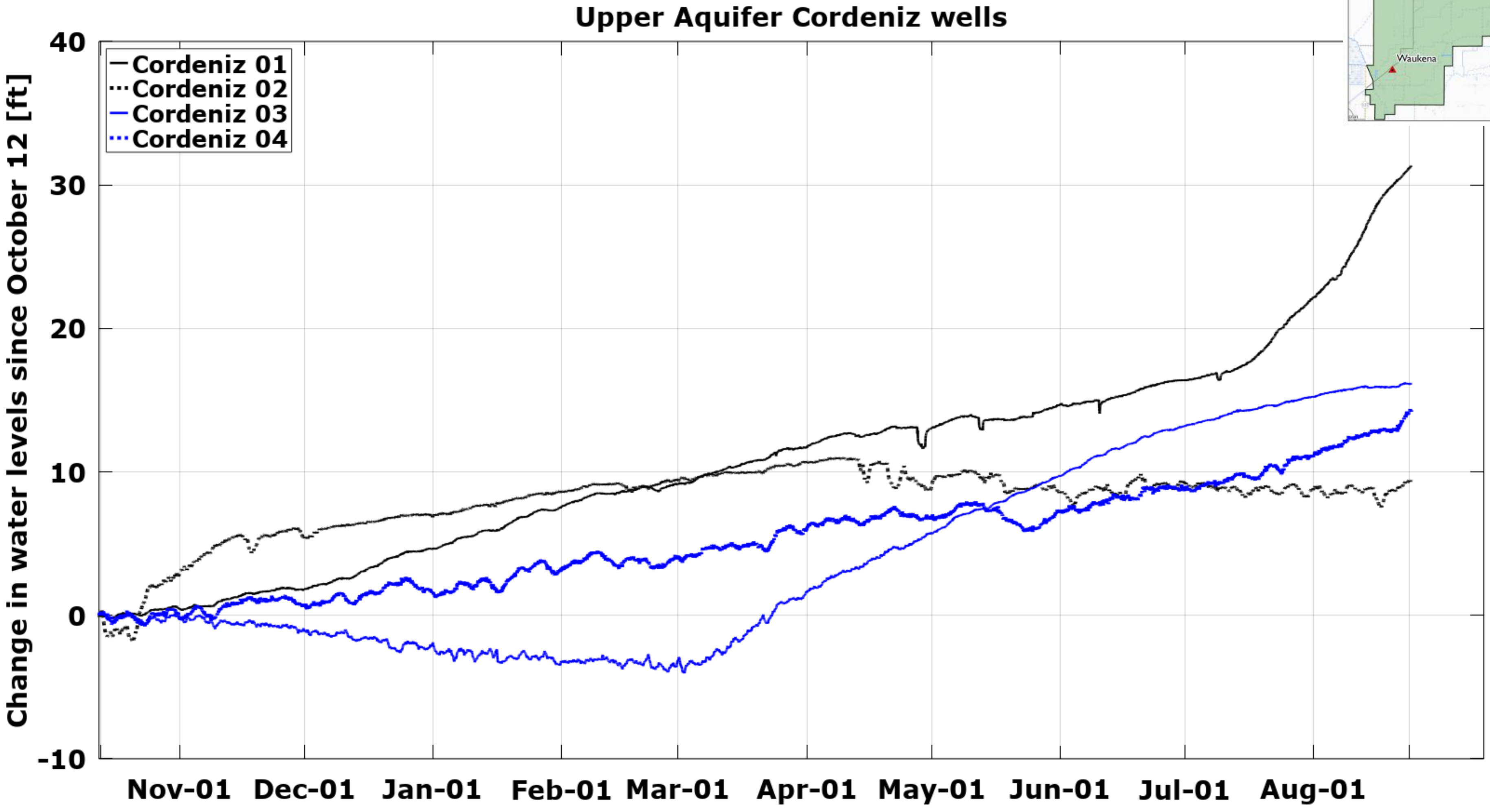
Achievements

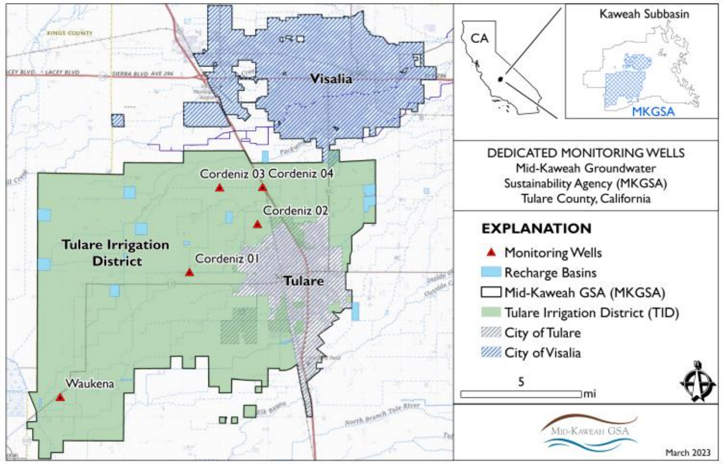
- During 2023 water year, DWR estimates **3.8 MAF of water has been recharged**.
- Water Board permitted 11 applications authorizing >**180,000 AF** to capture floodwater for groundwater recharge.
- Executive orders N-4-23 and N-7-23
- Recharge created flood relief for downstream communities
- Recharge created a rebound in groundwater levels
- Lots of recharge everywhere but mostly uncounted/uncredited



Map from March 10, 2023

Regional effect on groundwater

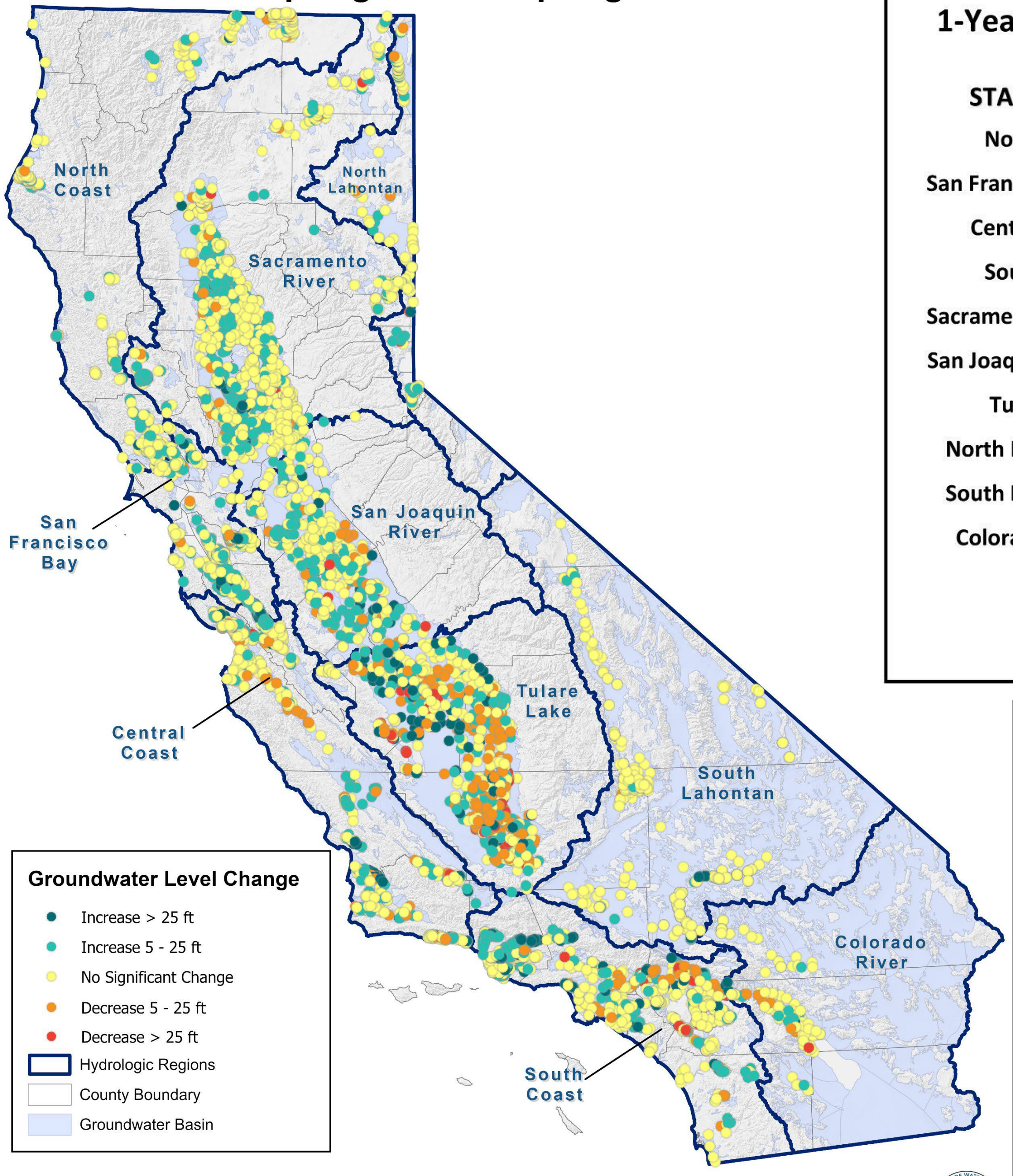


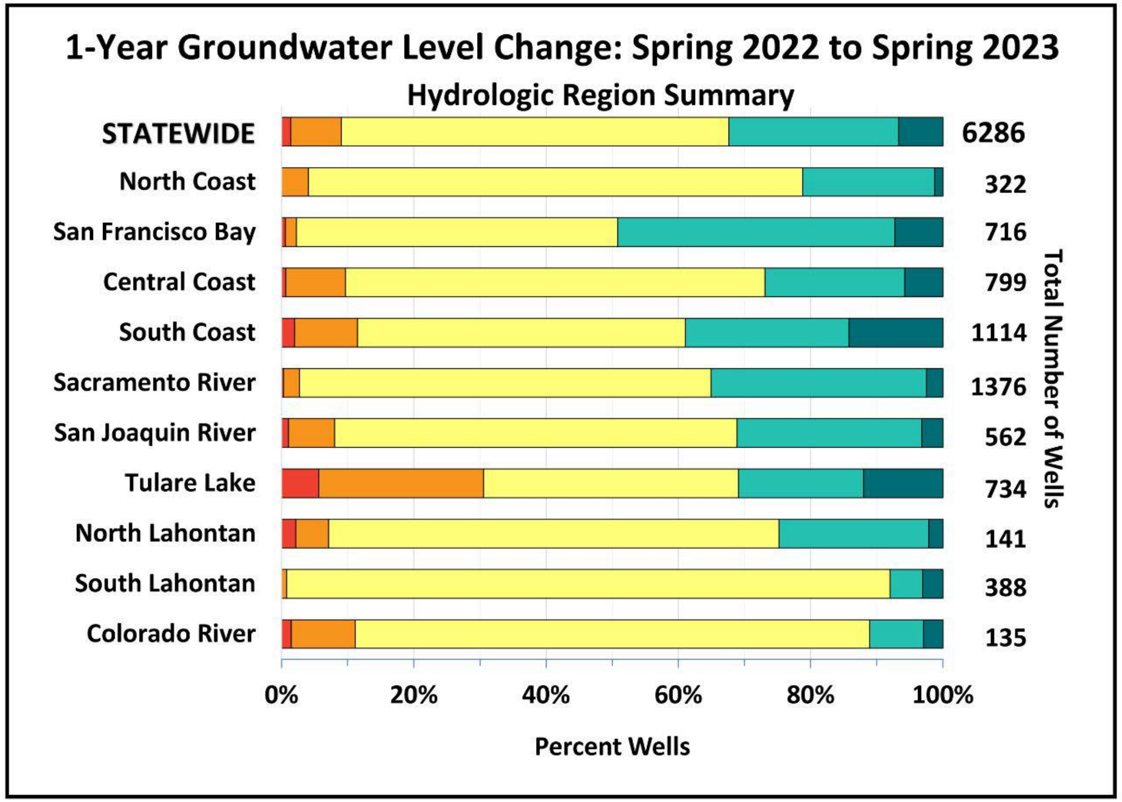


Tulare Irrigation District

Figure from Aaron Fukuda

One-Year Groundwater Level Change
Spring 2022 to Spring 2023





Groundwater Level Change

- Increase > 25 ft
- Increase 5 - 25 ft
- No Significant Change
- Decrease 5 - 25 ft
- Decrease > 25 ft

How do we capture more flood water for drought years?

California Flood-MAR program

waterboards.ca.gov/waterrights/water_issues/programs/applications/...

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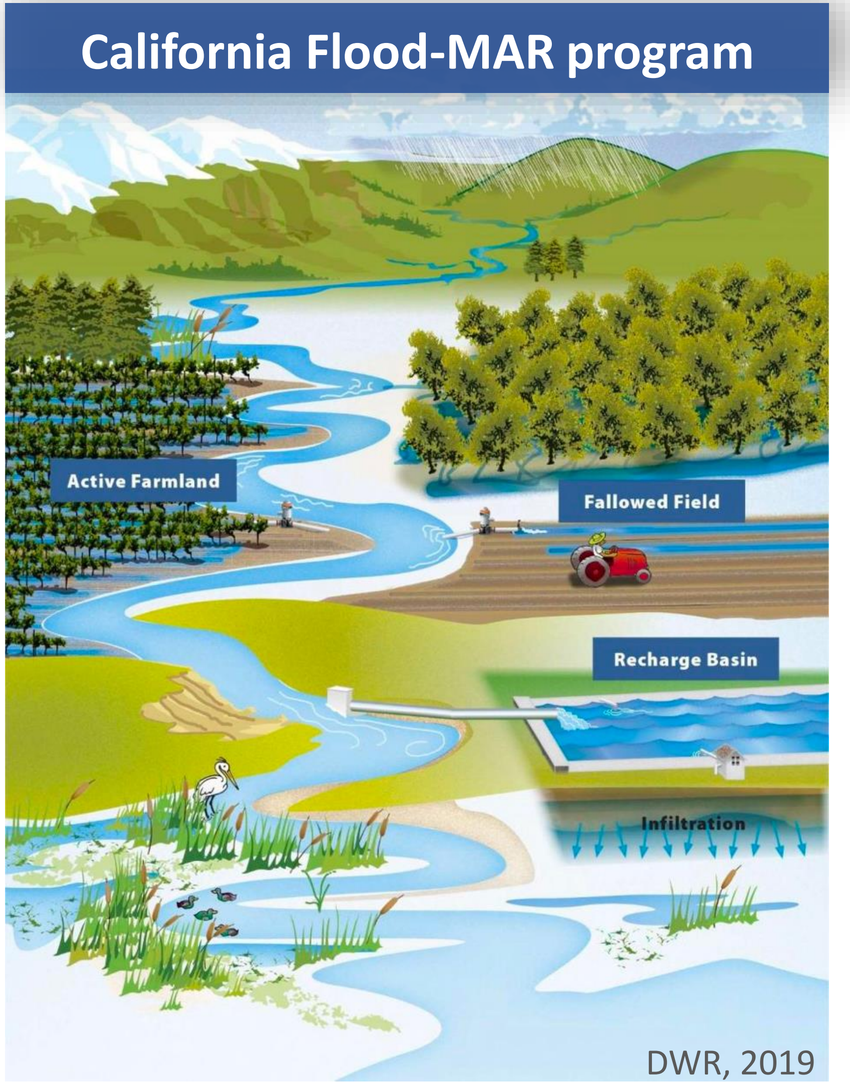
Home | Waterrights | Water Issues | Programs | Applications | Groundwater Recharge | Streamlined Permits

Streamlined Processing for Standard Groundwater Recharge Water Rights

QUICK LINKS

- Home
- Application Types
- FAQs
- Fact Sheets
- Groundwater Recharge Applications
- SGMA Home

The state legislature enacted the Sustainable Groundwater management Act (SGMA) to address widespread overdraft and other undesirable results caused by groundwater conditions in California's groundwater basins. SGMA requires local agencies in high and medium priority basins to develop plans that achieve sustainability in the basin within 20 years of implementation. Groundwater recharge is likely to be an important part of achieving sustainability in groundwater basins, but local agencies may lack the water rights to divert and use that water later. The streamlined permitting process for diversion of high flows to underground storage was developed, in part, to assist local agencies to obtain necessary water rights. Those water rights will, in turn, help Groundwater Sustainability Agencies (GSAs) reach their sustainability goals more quickly.

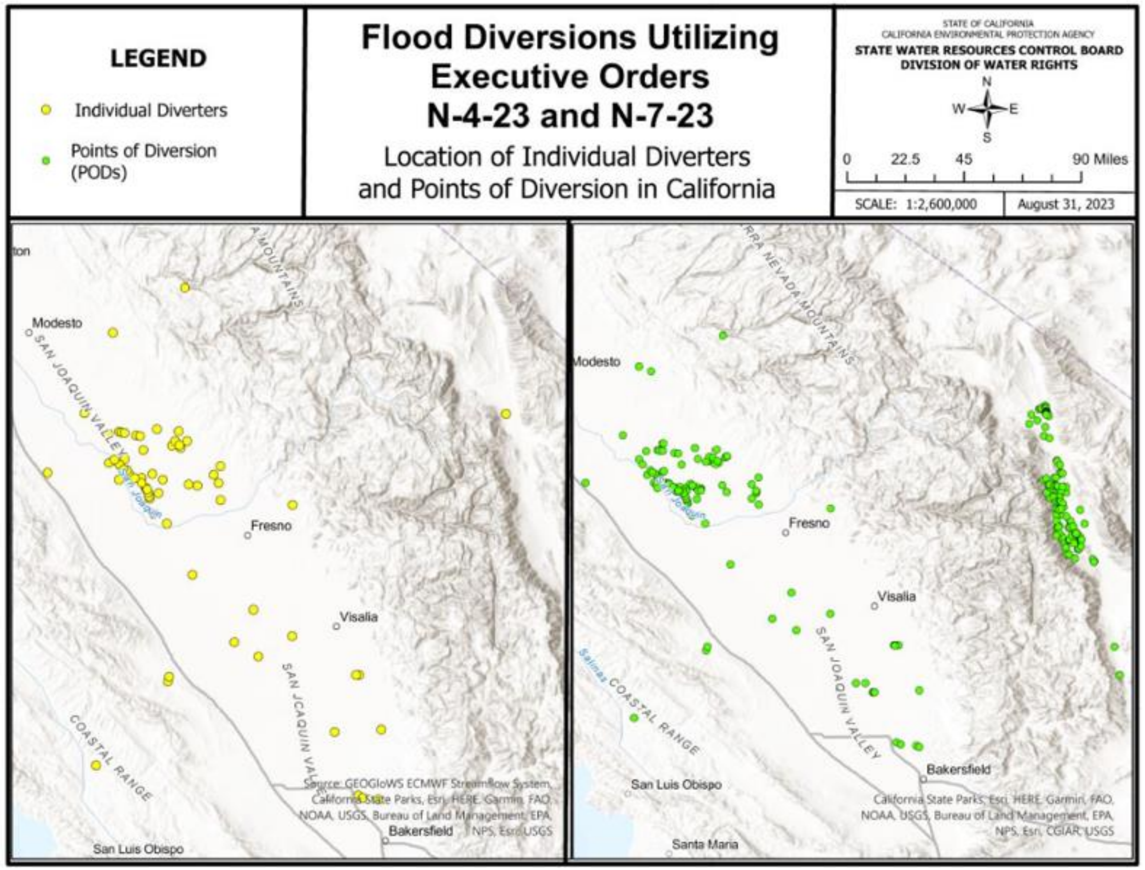


DWR, 2019

Executive orders N-4-23 & N-7-23

Allowed for diversion and recharge of flood flows with stipulations

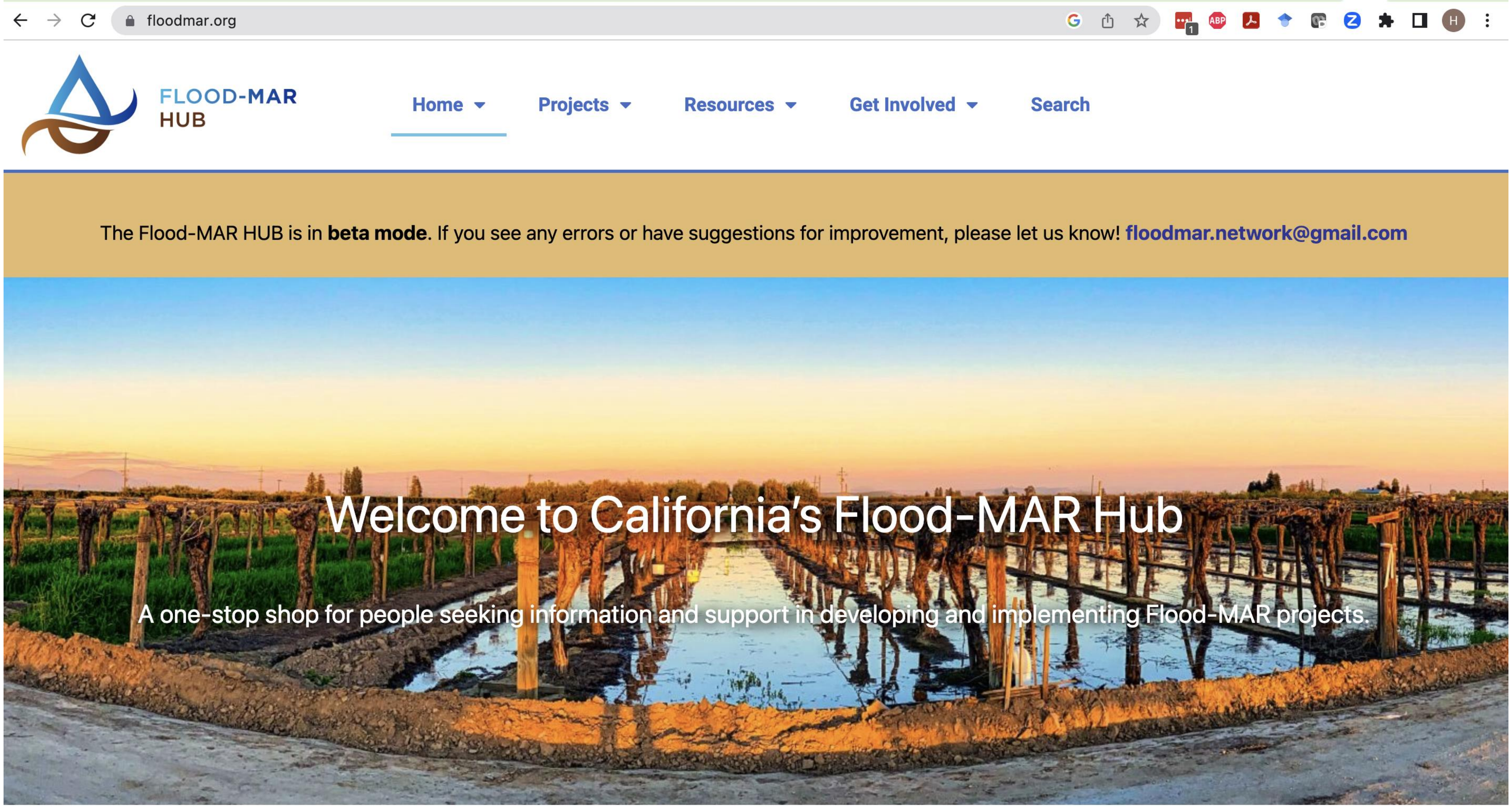
- An agency must declare flood conditions in the region
- Must not apply to dairy lands, parcels with pesticide applications within 30-days, non-ag parcels, areas that could impact critical facilities
- Landowner must report diversions to State Water Resources Control Board (SWRCB) & the local Groundwater Sustainability Agency (GSA)



SB 122 – Trailer Bill

- Recharge done with flood flows does not require an appropriative water right *(under certain conditions)*
- Similar requirements to Executive Order
- Sunsets on Jan. 1, 2029
- State is not liable for damages from the application of flood flows
- SWRCB must post diversions
- Recharger does not claim a water right

Join the Flood-MAR network



https://floodmar.org

FRESHWATER

BirdReturns

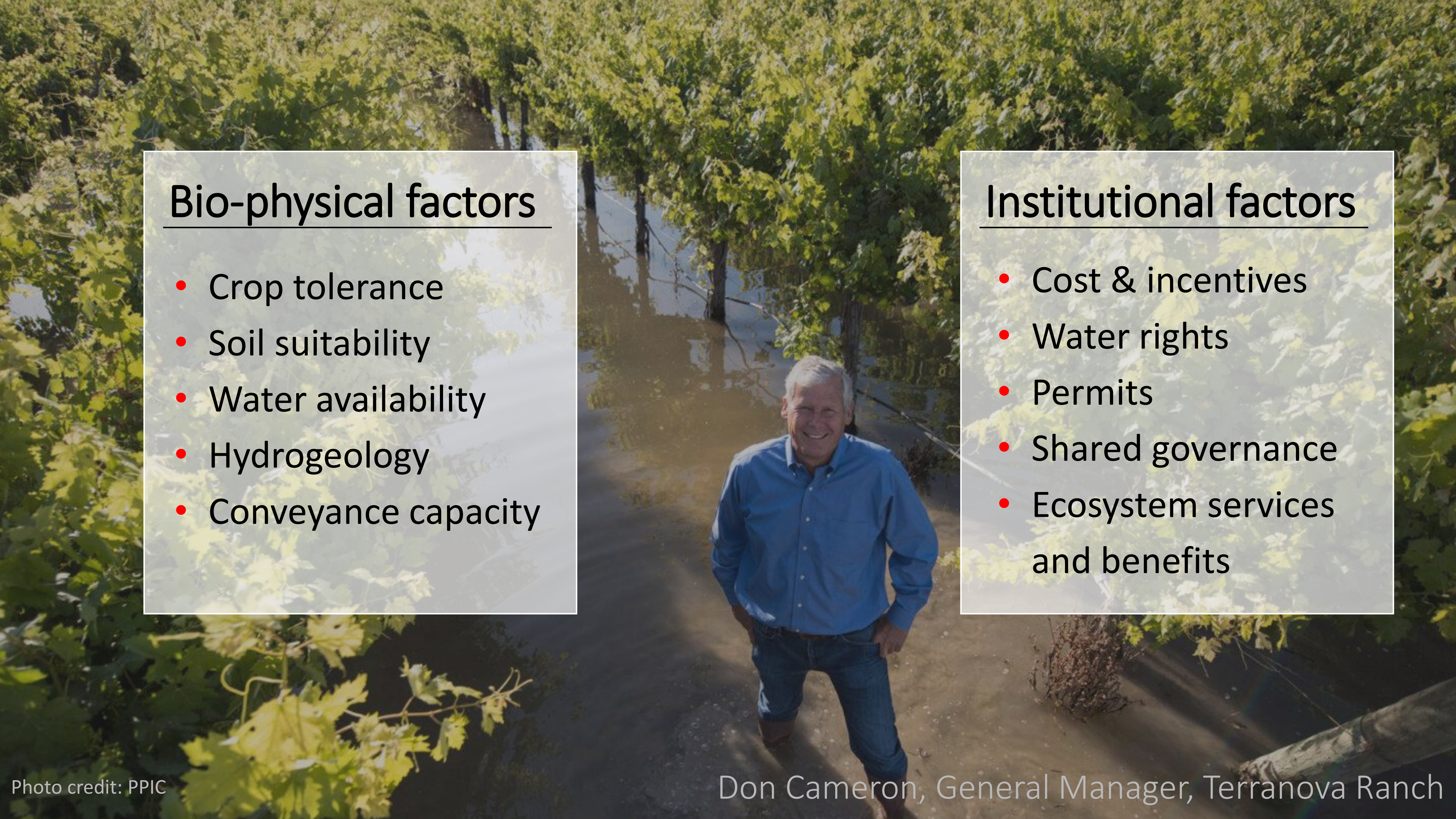
How can we get water in the right place at the right time to help migrating birds?

Flocks of Dunlin use this flooded rice field as a place to rest during their long seasonal migrations. Farmers in the Great Central Valley of California are being paid to create temporary wetland habitat like this, at times that our models predict birds will need it most. Photo: © Drew Kelly

BirdReturns pairs birding and farmland management with innovations in big data, crowd-sourcing and online auctioneering.

On-farm recharge


Photo credit: PPIC
Don Cameron, General Manager, Terranova Ranch



Bio-physical factors

- Crop tolerance
- Soil suitability
- Water availability
- Hydrogeology
- Conveyance capacity

Institutional factors

- Cost & incentives
- Water rights
- Permits
- Shared governance
- Ecosystem services and benefits

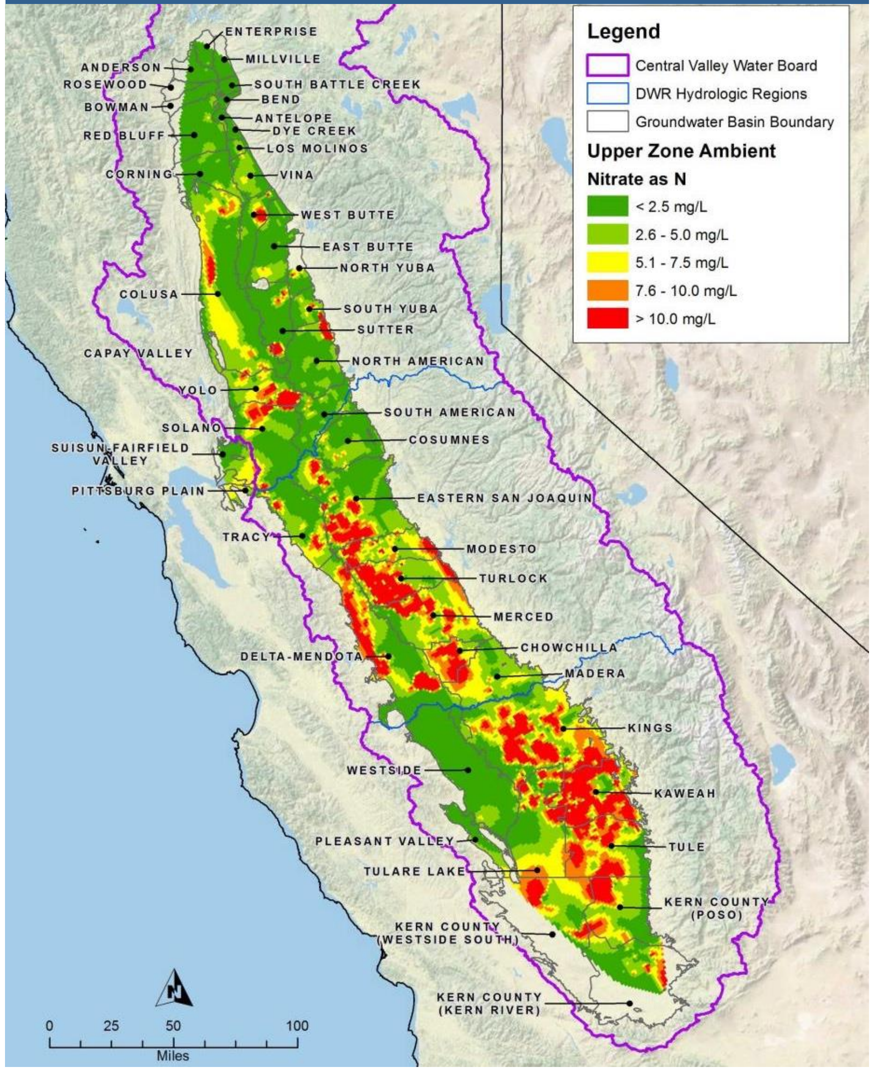
Photo credit: PPIC

Don Cameron, General Manager, Terranova Ranch

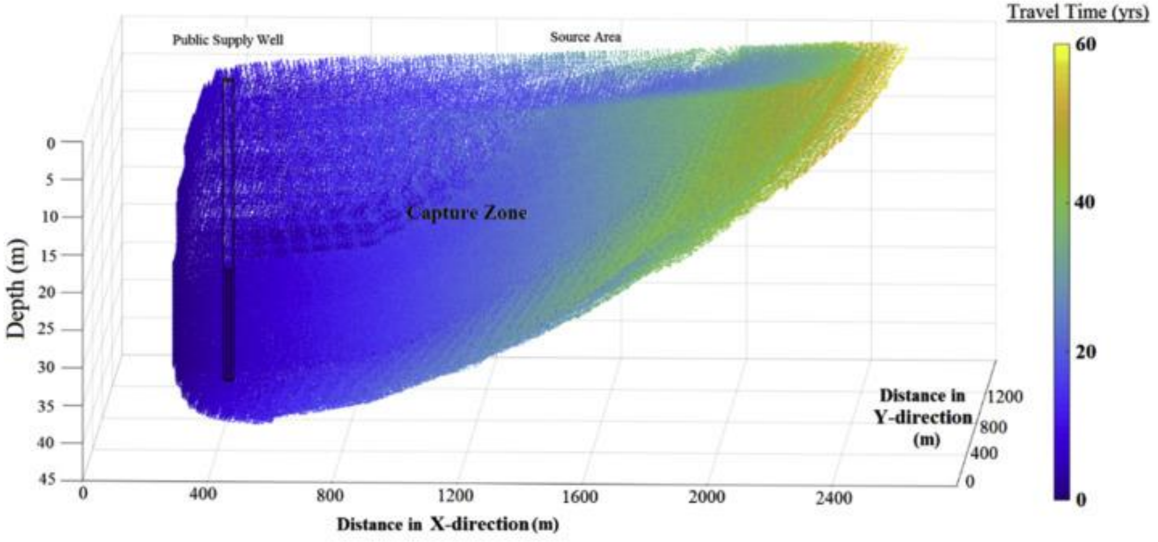

Effect of Ag-MAR on groundwater nitrate?

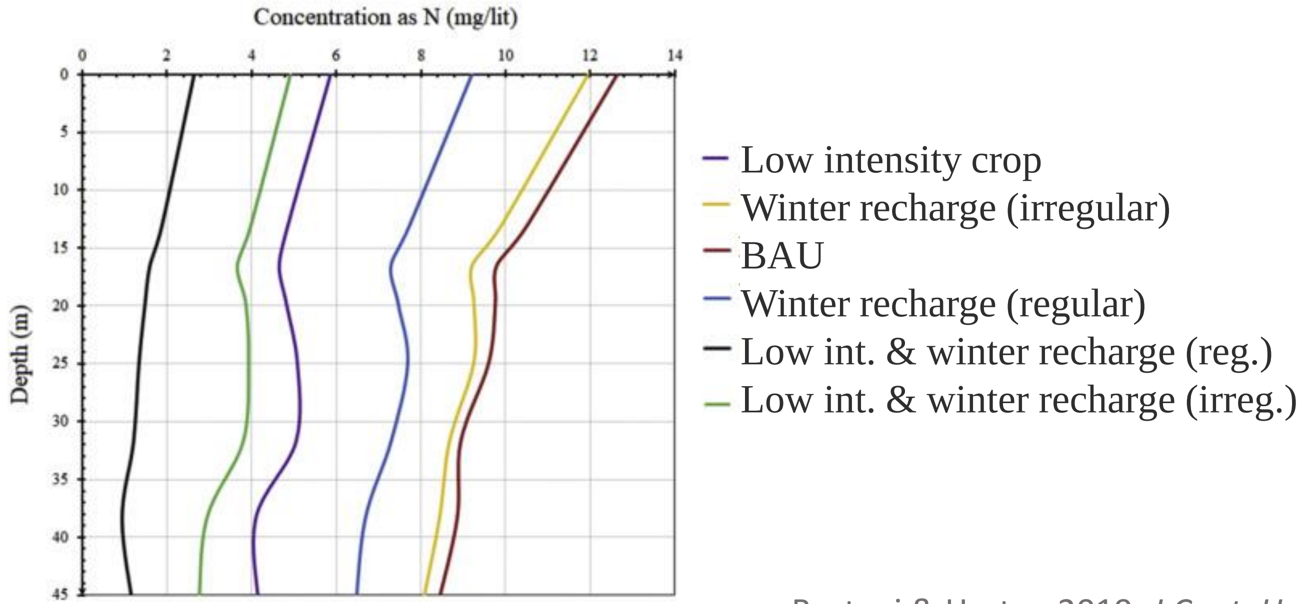
Risk of groundwater contamination

Nitrate in shallow groundwater

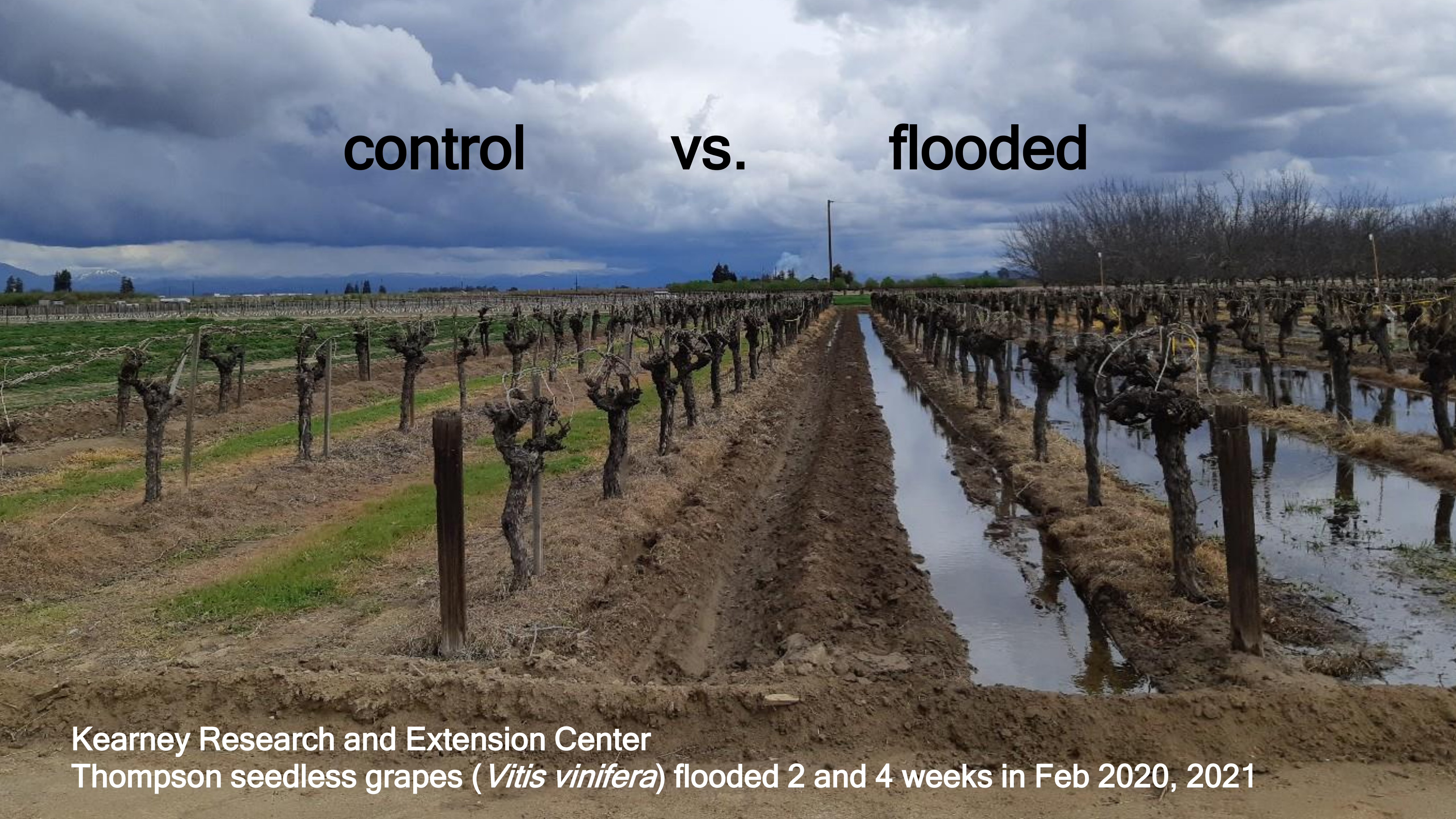


Source: CV-Salts Coalition



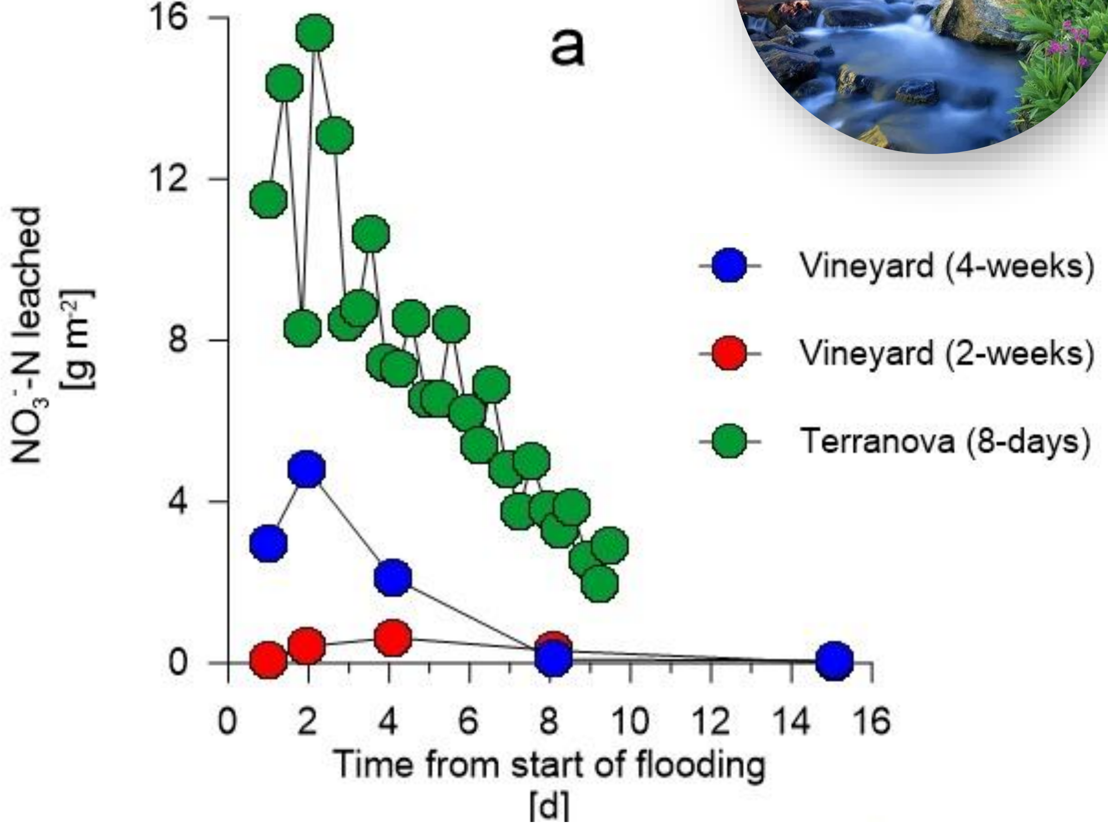


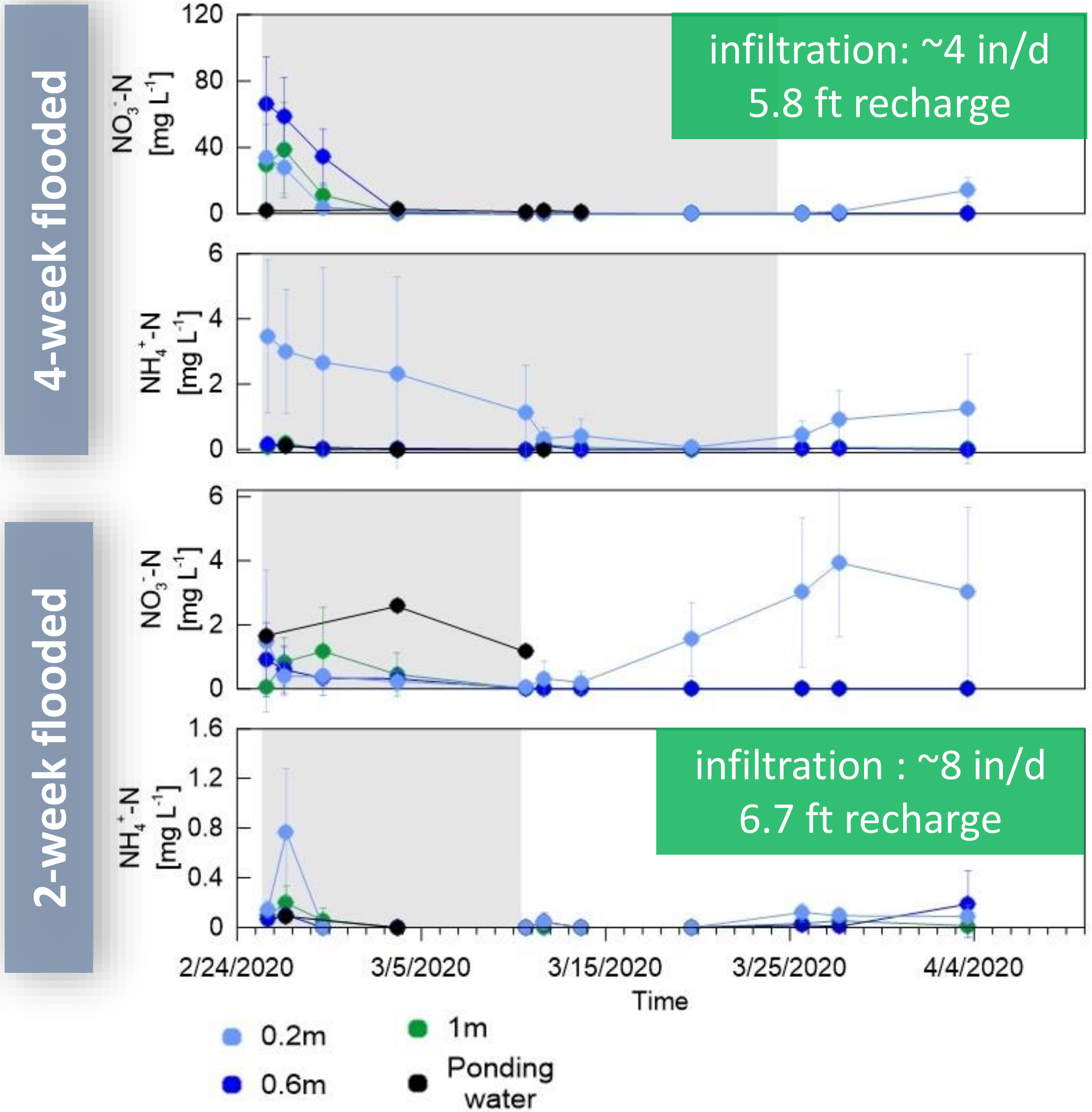
Bastani & Harter, 2019, *J Cont. Hyd*


control
vs.
flooded
Kearney Research and Extension Center
Thompson seedless grapes (*Vitis vinifera*) flooded 2 and 4 weeks in Feb 2020, 2021

Site-specific nitrogen management

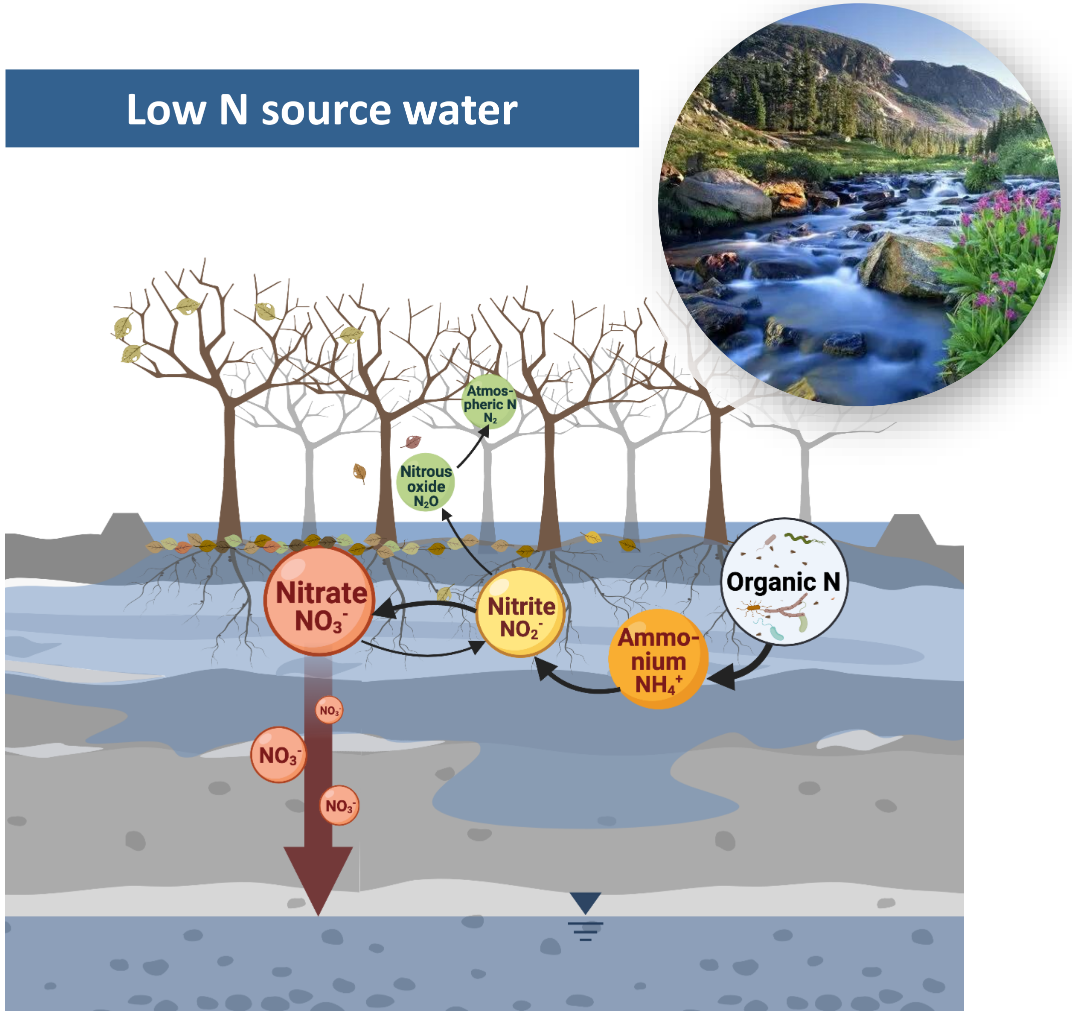
Low N source water

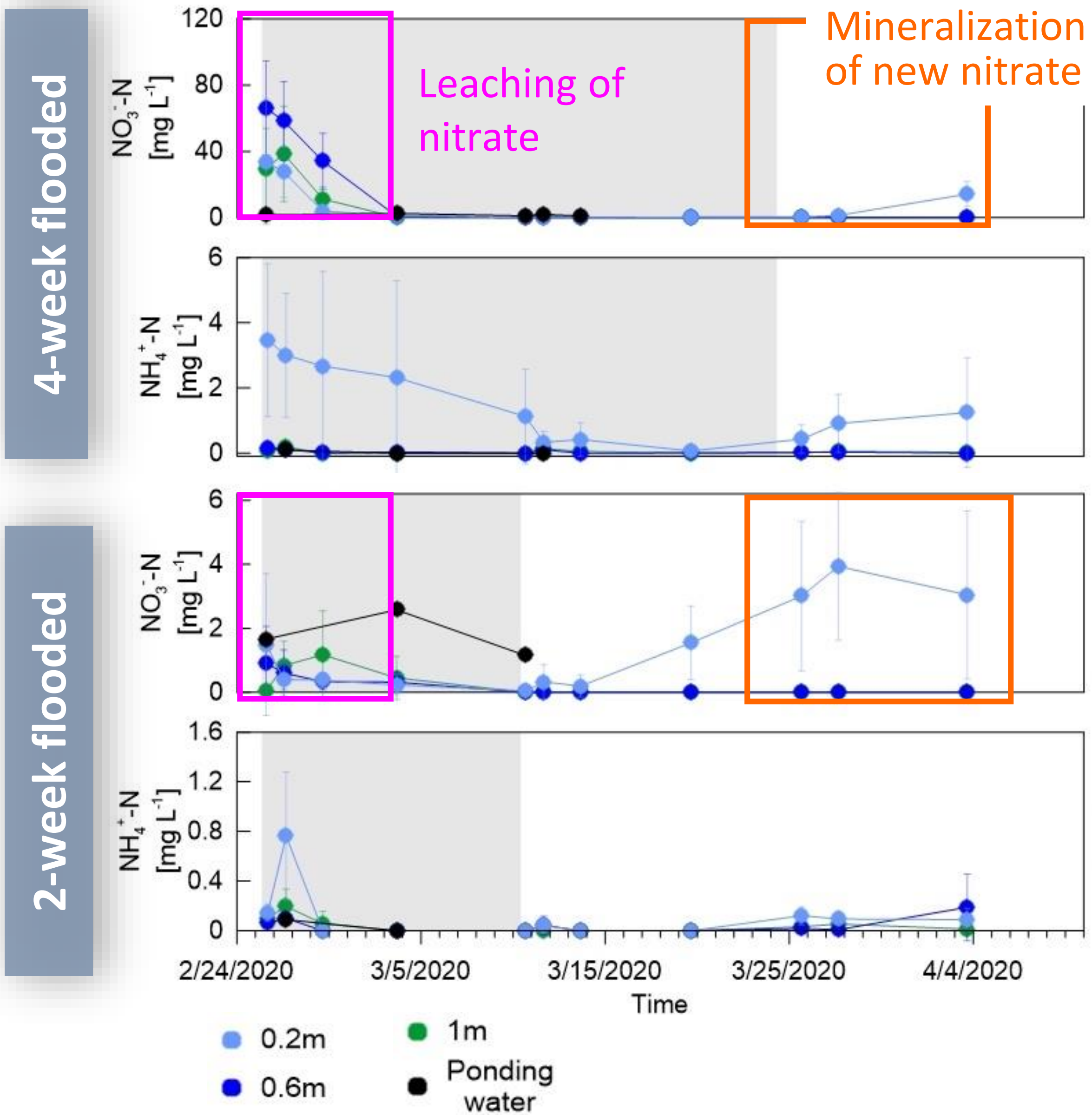




Levintal et al. 2023, *ES&T*

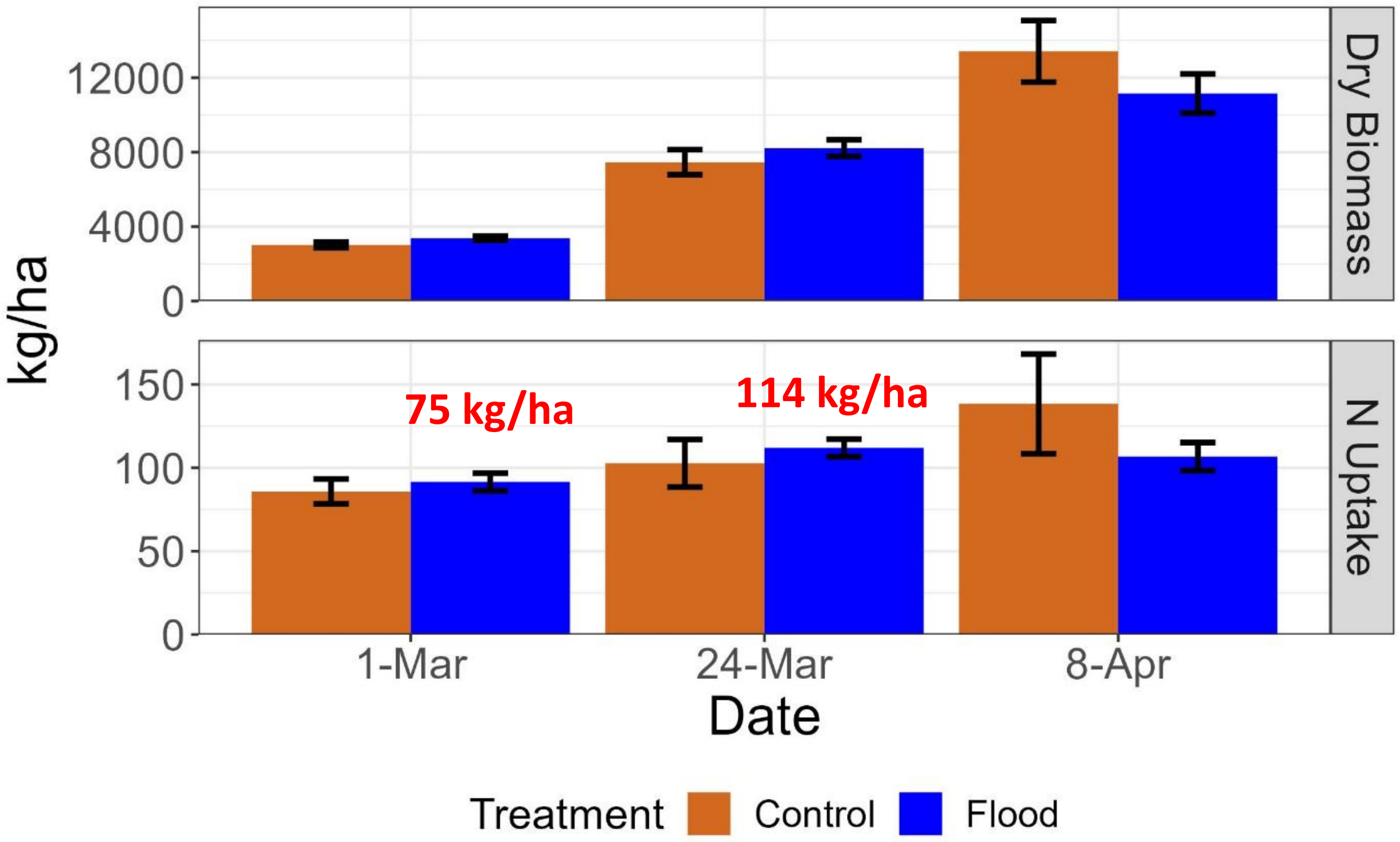
Site-specific nitrogen management





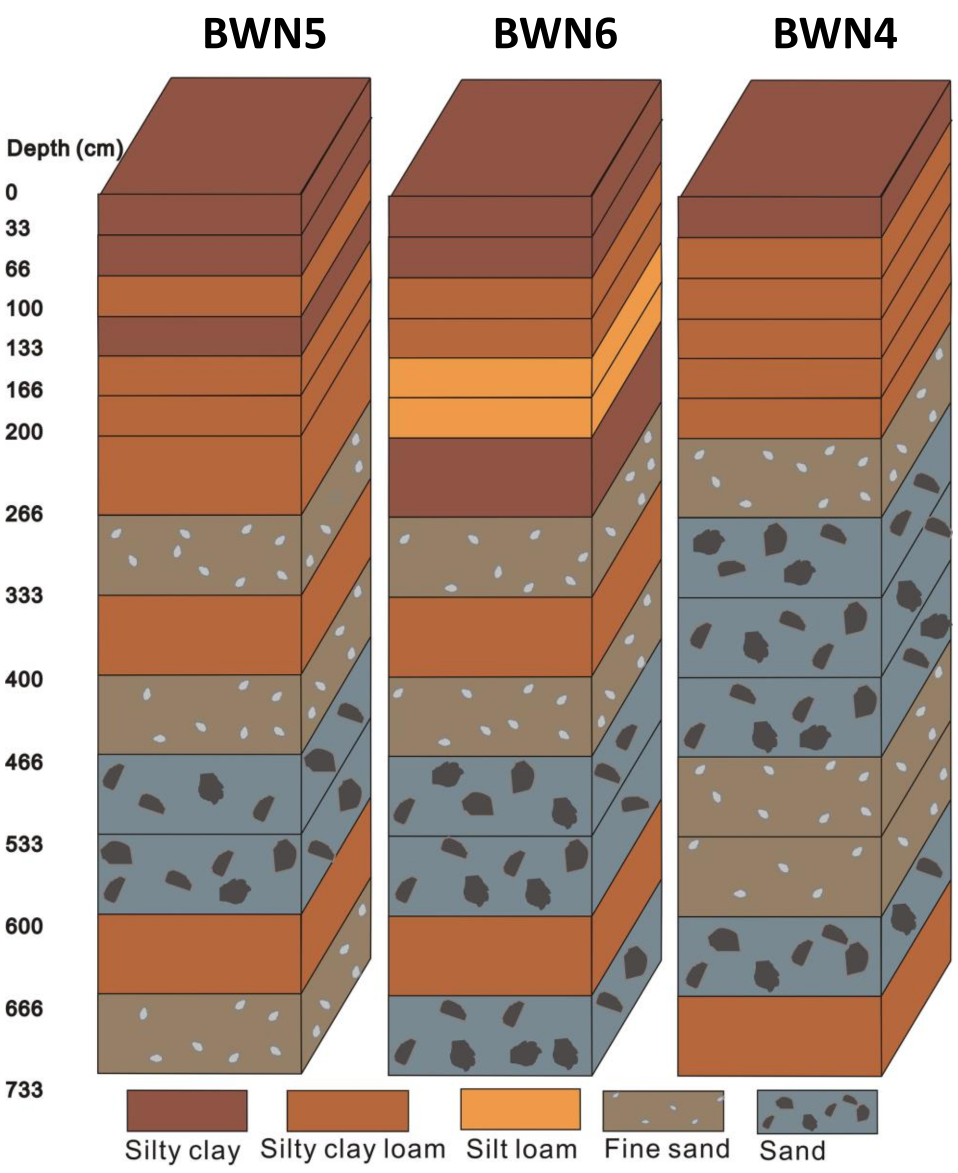
Murphy et al. 2021, *VZJ;* Levintal et al. 2022, *Crit. Rev ES&T*

Cover cropping

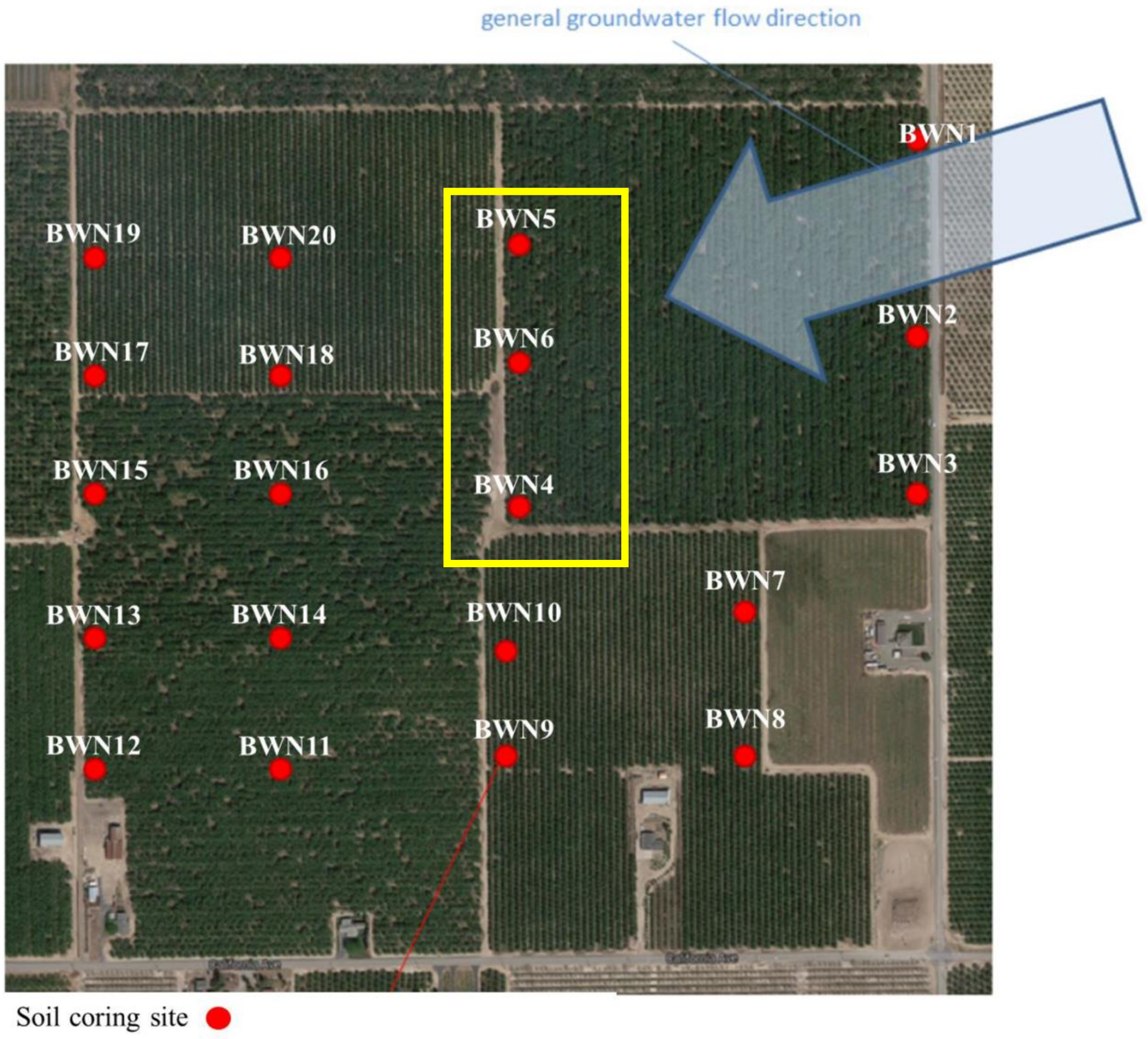


- Triticale TRICAL® 2700 planted on Nov. 15
- Flooding occurred from March 9-23, 2021
- Flooding did not affect the triticale's biomass production
- 75 kg/ha nitrogen uptake prior to flooding
- Nitrogen uptake continued during flooding

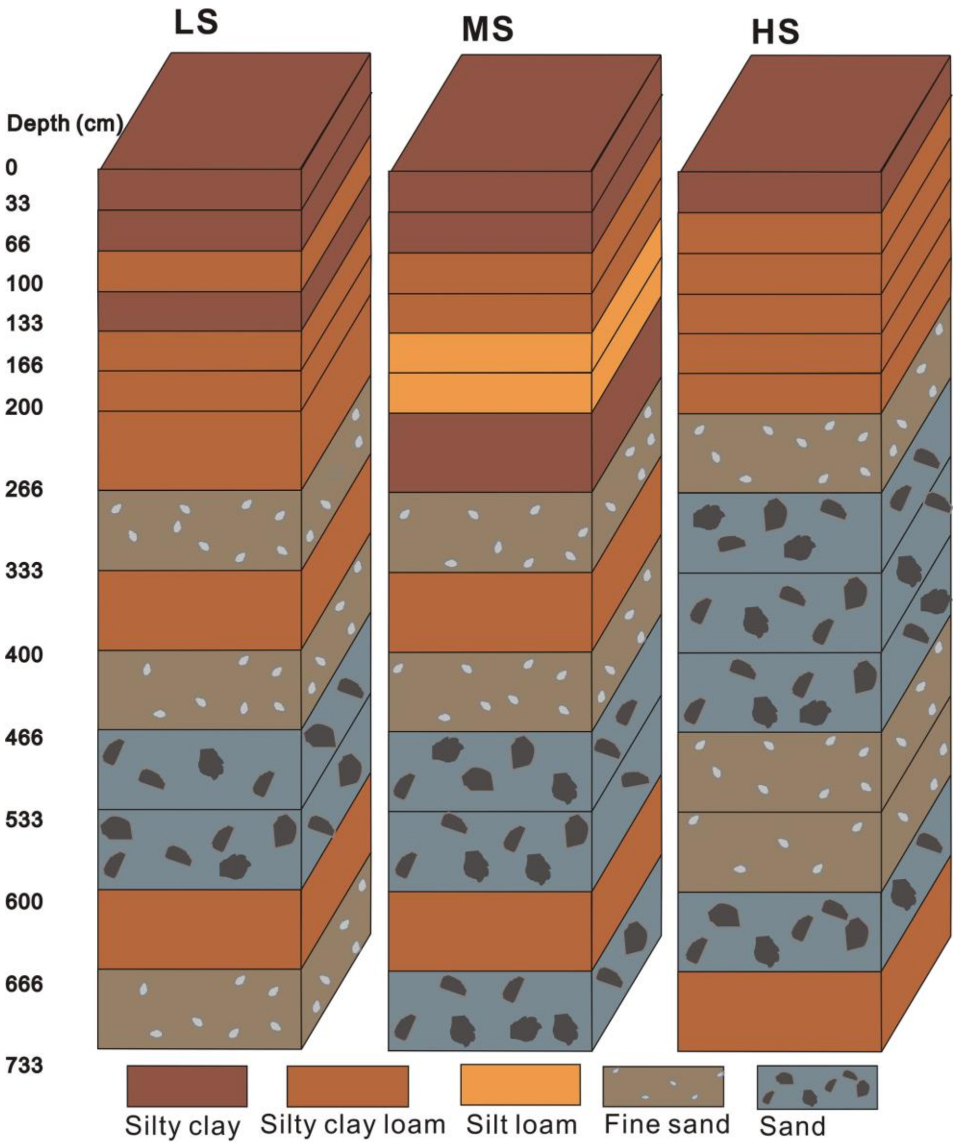
Recharge plot instrumentation

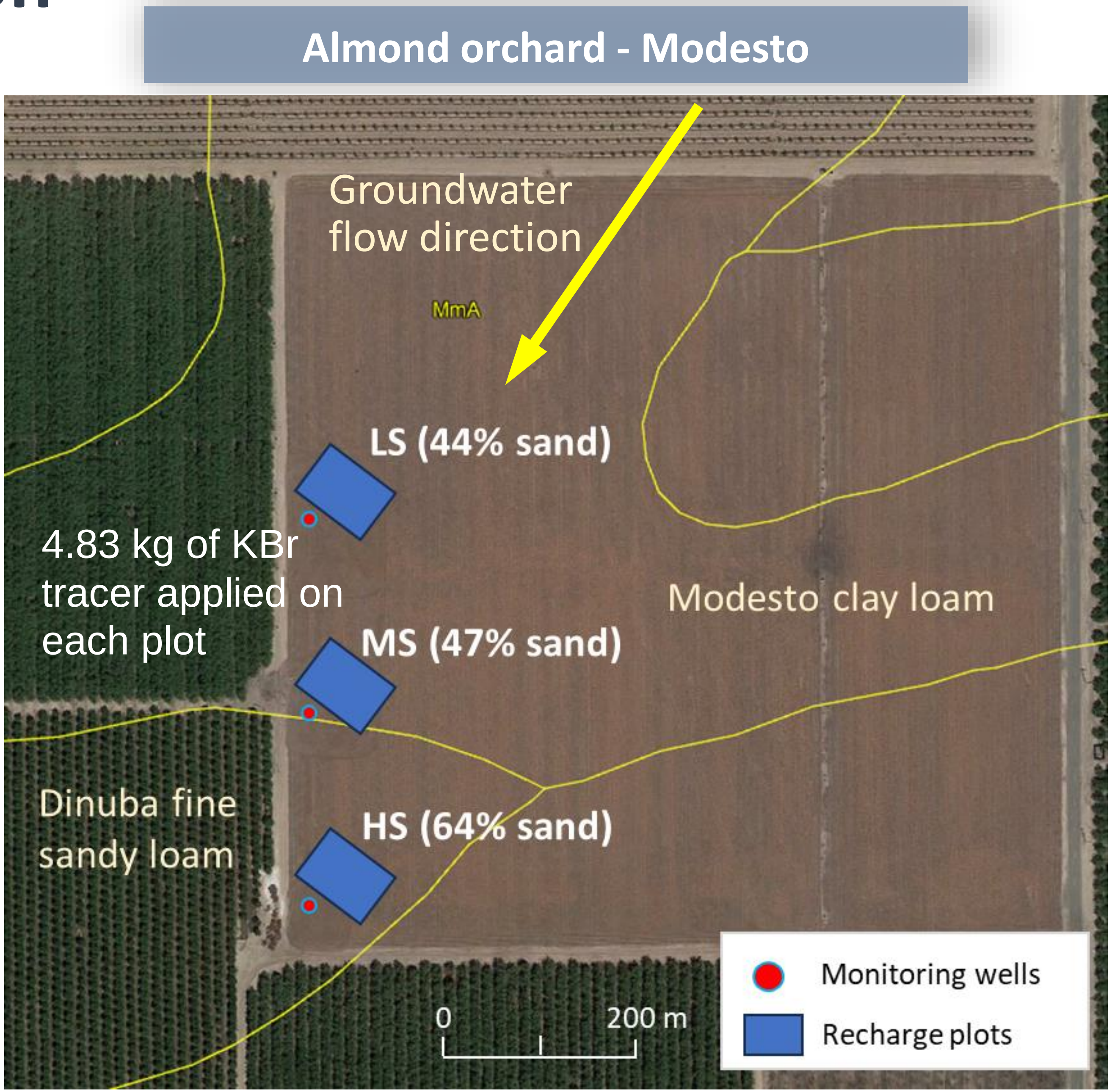


Almond orchard - Modesto



Recharge plot instrumentation





Recharge plot instrumentation

Depth (ft/in)	Depth (cm)
8 in	20 cm
2 ft	60 cm
3.3 ft	100 cm
9.8 ft	300 cm
16 ft	500 cm

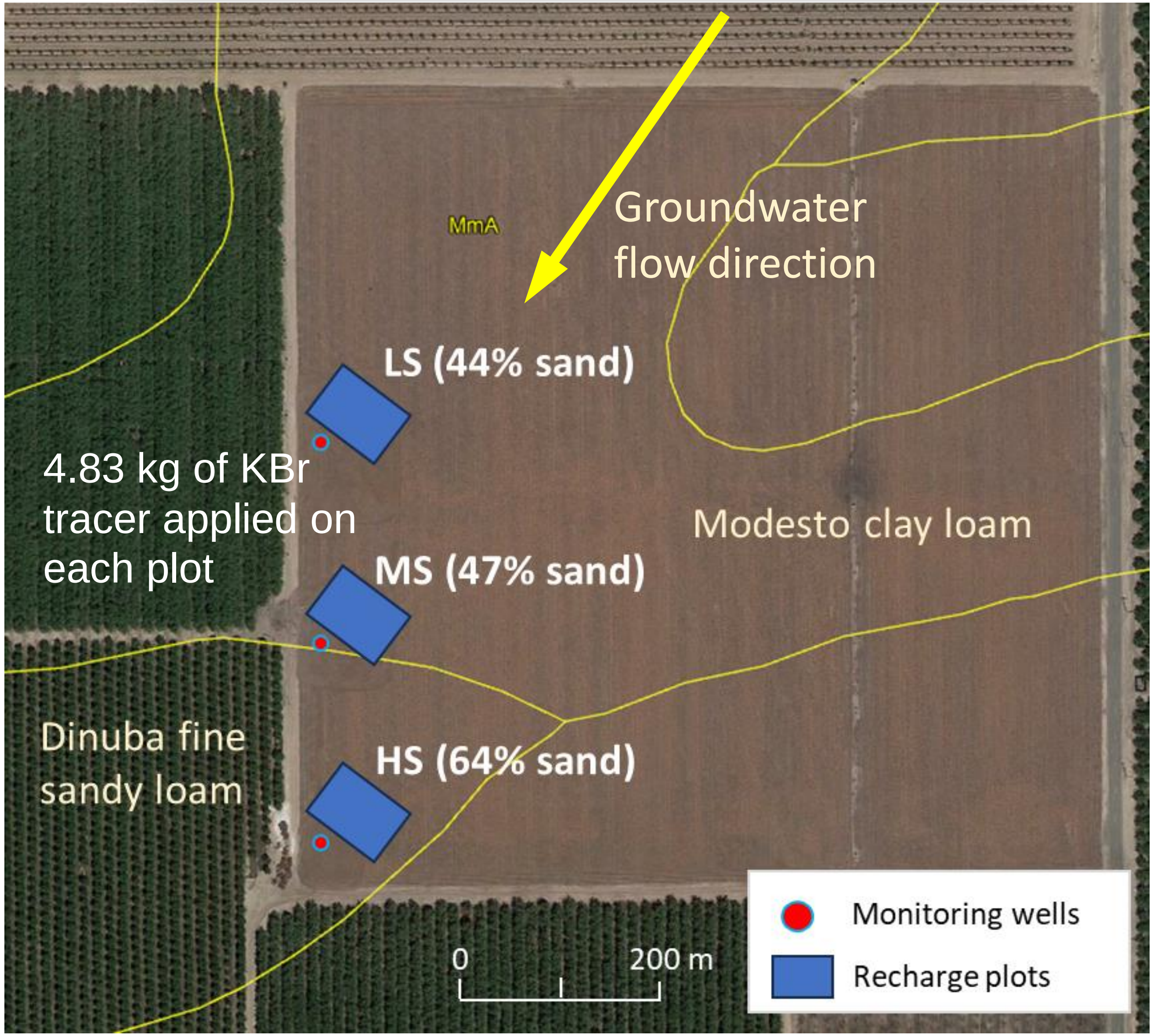
Flooding
- 4-weeks
- 3 plots, 2170 m^2
- About 30 ft recharge

Sensors
- Soil water content, EC, temperature
- O_2
- Redox potential
- Ponding depth
- Groundwater level

Suction cups
- Soil samples
- Soil pore water
- Groundwater

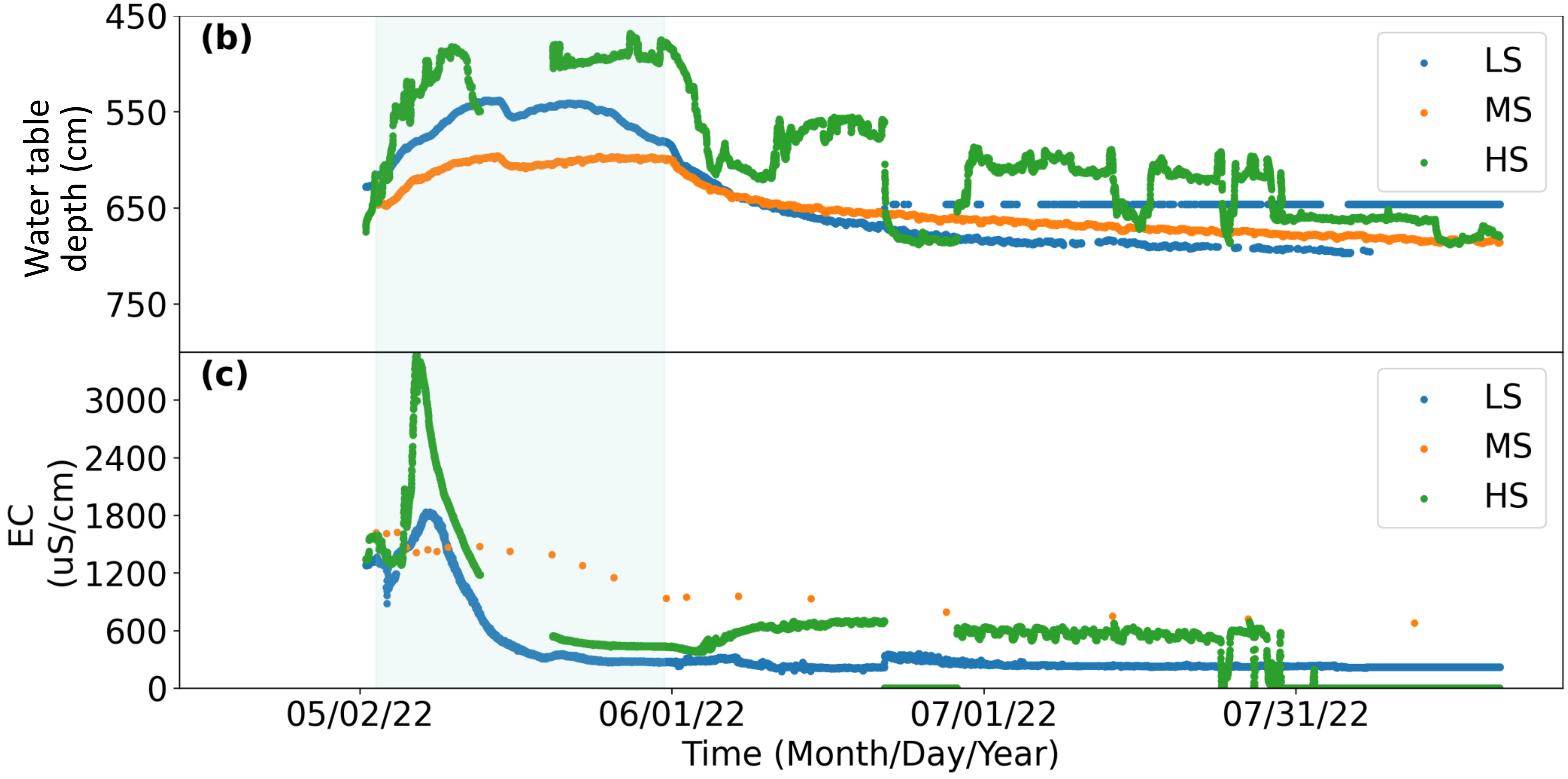
Depth to groundwater: 21 ft in May 2022

Almond orchard - Modesto

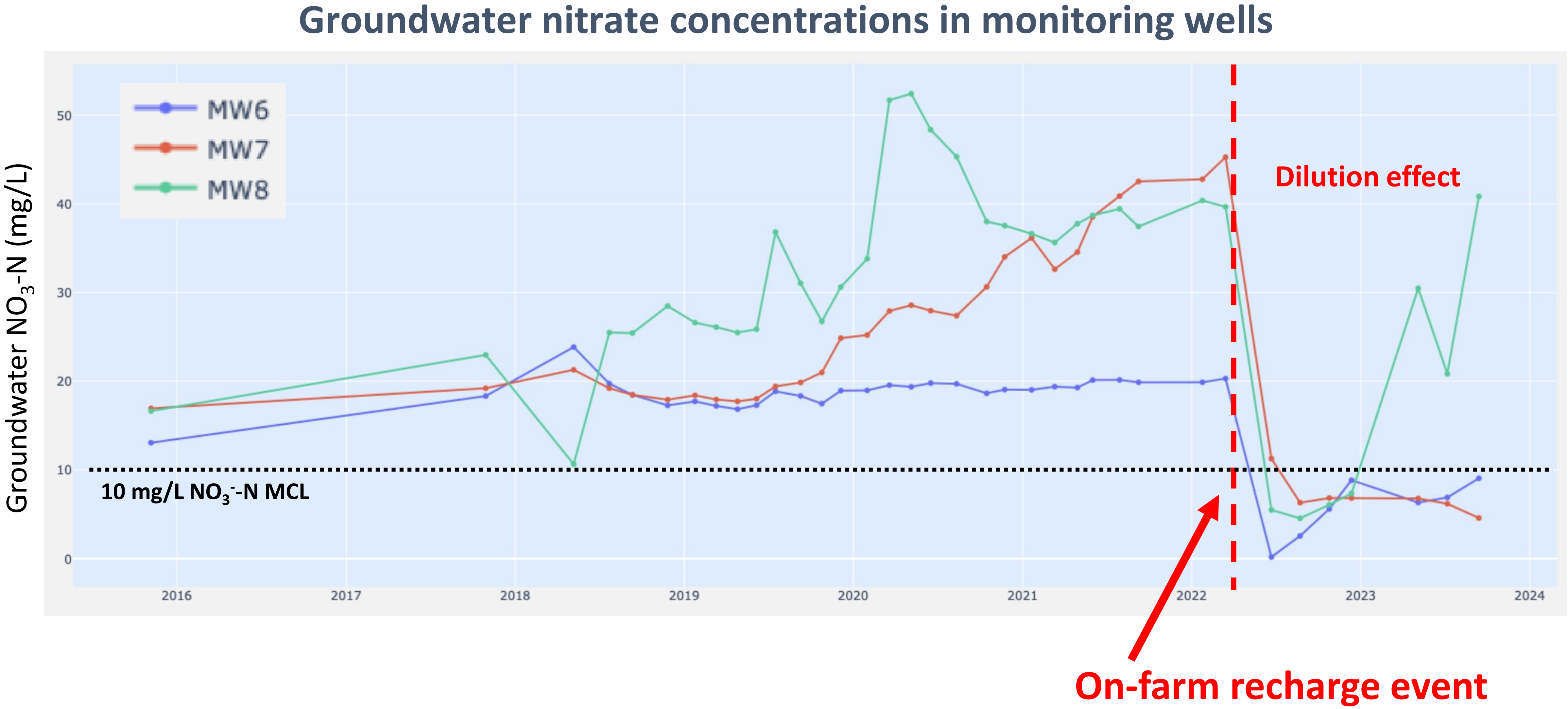



~ 16 ft horizontal
distance to well

Groundwater response

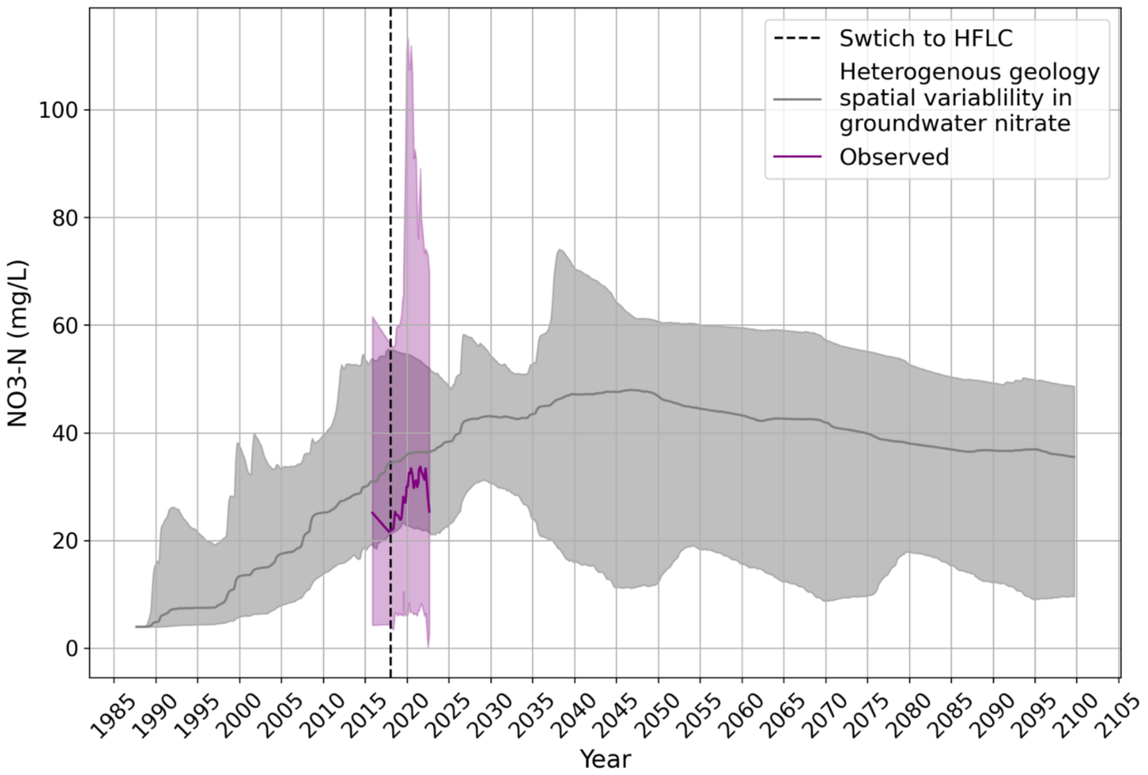


Nitrate leaching to groundwater

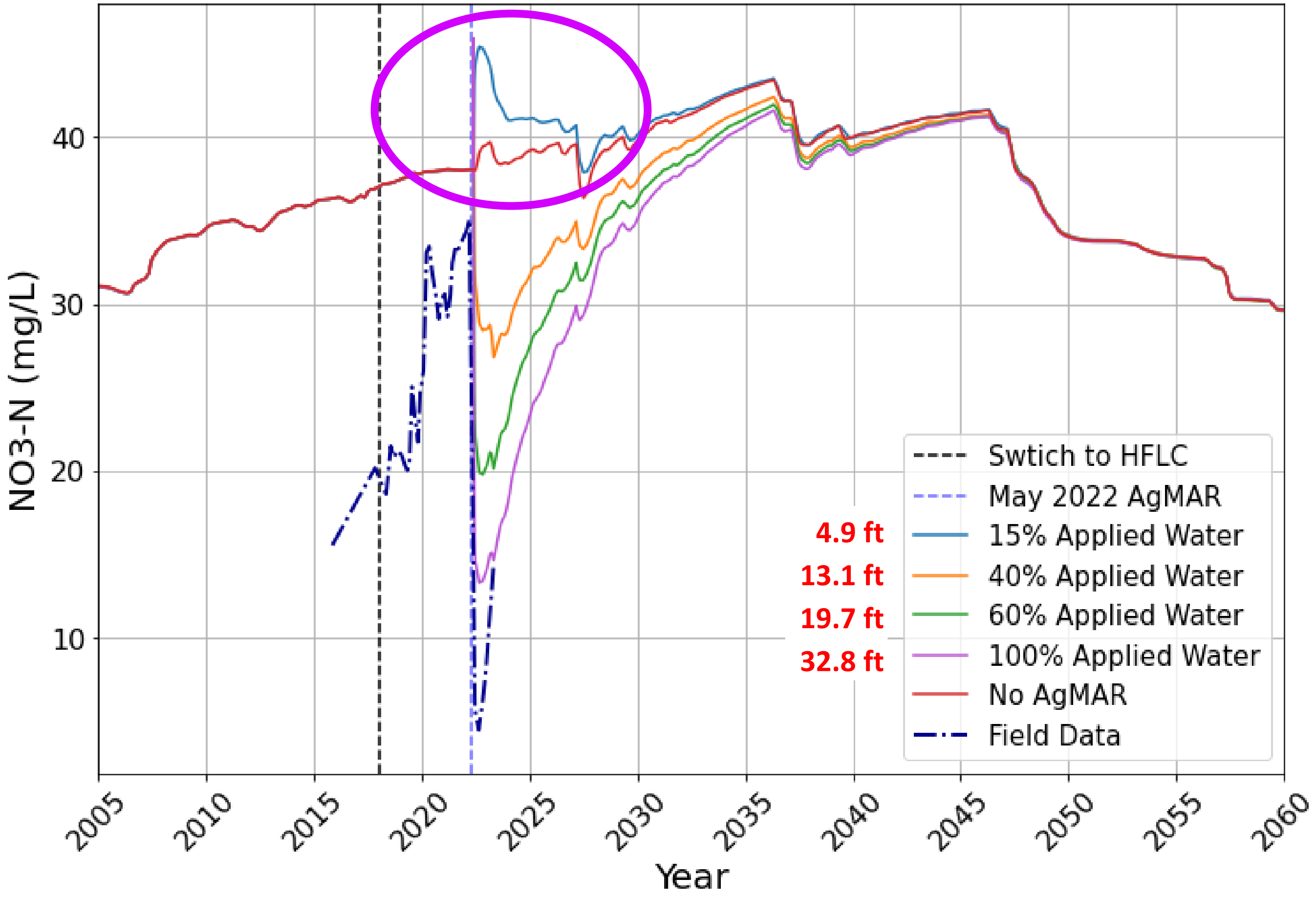


Data from Thomas Harter & Spencer Jordan

MODFLOW modeled and observed groundwater NO_3-N concentrations across orchard

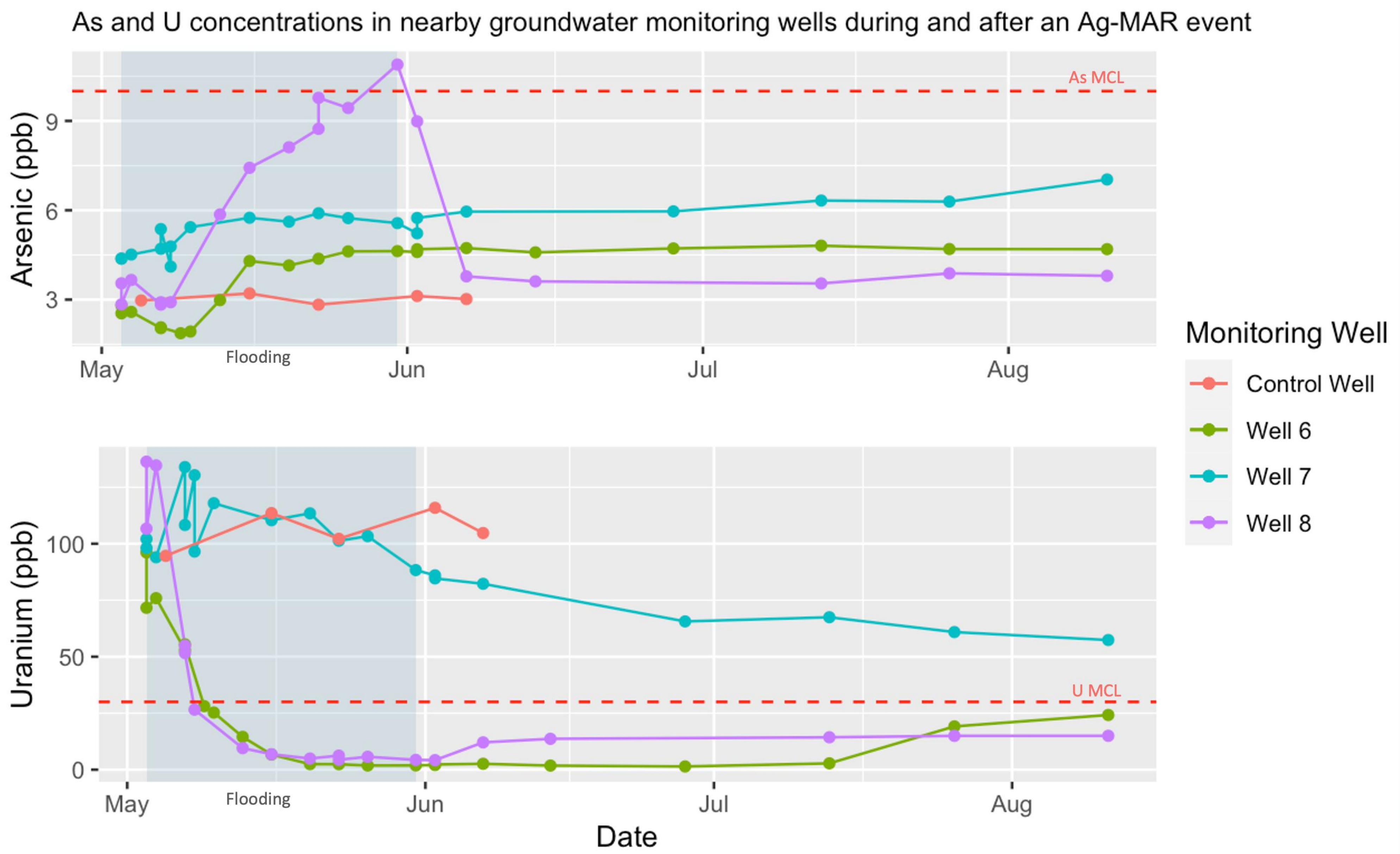


HYDRUS modeled NO_3-N concentrations at wells LS, MS, and HS with 15%, 40%, 60%, 100% applied water



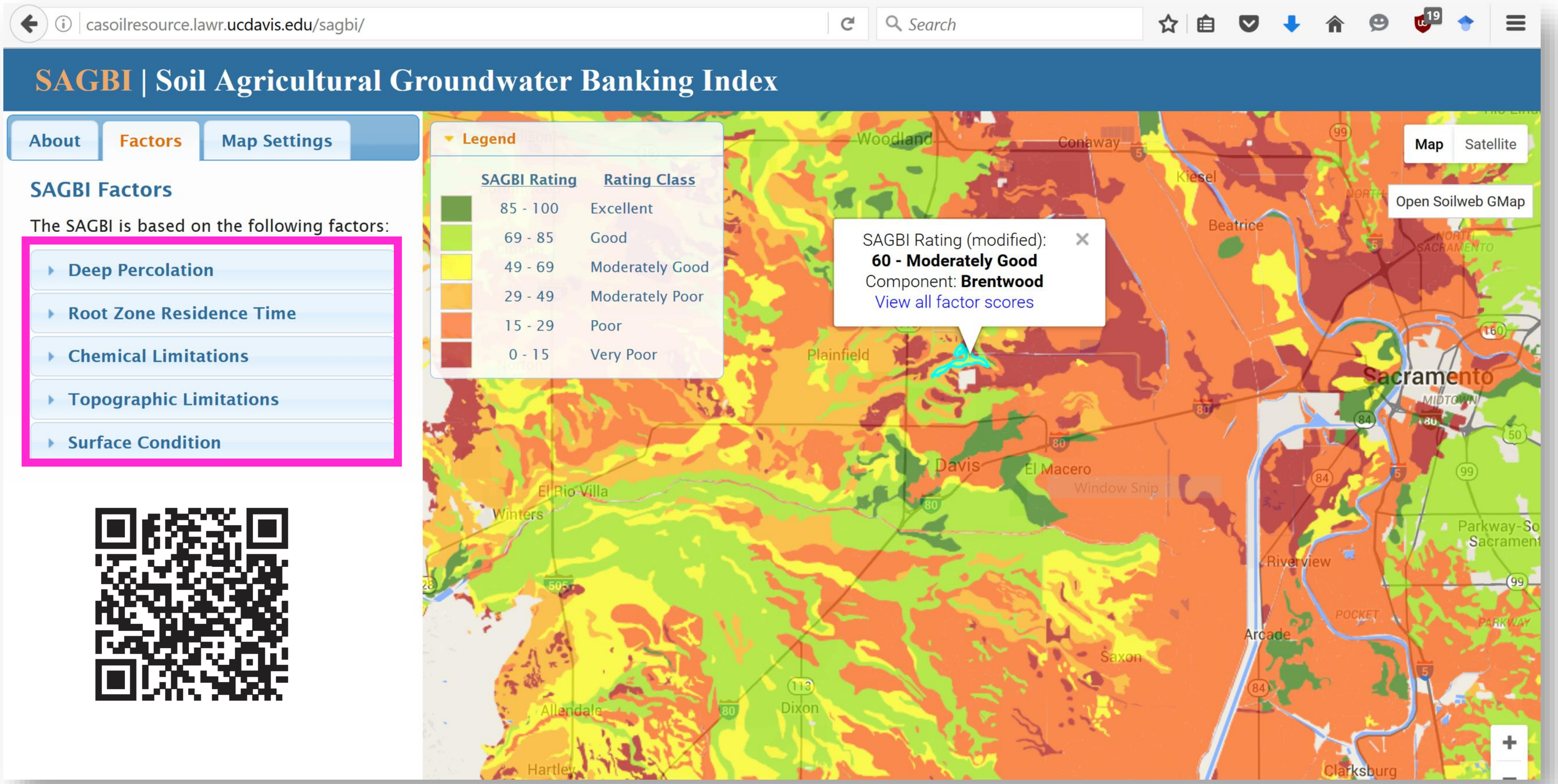
Data and model results from Spencer Jordan, Hanni Haynes, Thomas Harter

Mobilization of geogenic contaminants

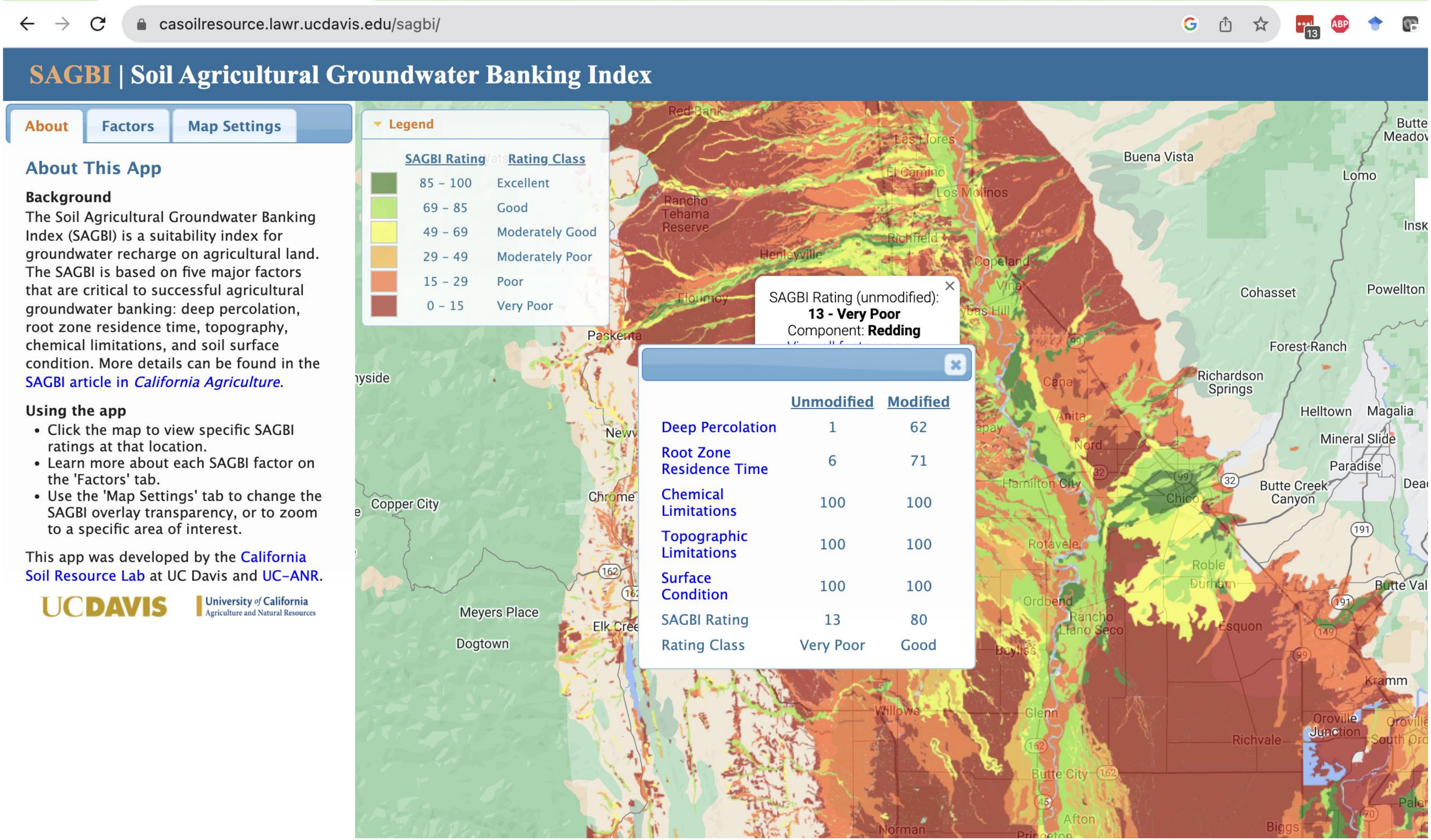



DECISION SUPPORT TOOLS
How to site the best Ag-MAR locations?

Decision support



O’Geen et al. 2015, CalAg


casoilresource.lawr.ucdavis.edu/sagbi/
SAGBI | Soil Agricultural Groundwater Banking Index
About
Factors
Map Settings
About This App
Background
The Soil Agricultural Groundwater Banking Index (SAGBI) is a suitability index for groundwater recharge on agricultural land. The SAGBI is based on five major factors that are critical to successful agricultural groundwater banking: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. More details can be found in the SAGBI article in California Agriculture.
Using the app
• Click the map to view specific SAGBI ratings at that location.
• Learn more about each SAGBI factor on the 'Factors' tab.
• Use the 'Map Settings' tab to change the SAGBI overlay transparency, or to zoom to a specific area of interest.
This app was developed by the California Soil Resource Lab at UC Davis and UC-ANR.
UC DAVIS
University of California Agriculture and Natural Resources
Legend
SAGBI Rating
Rating Class
85 – 100 Excellent
69 – 85 Good
49 – 69 Moderately Good
29 – 49 Moderately Poor
15 – 29 Poor
0 – 15 Very Poor
SAGBI Rating (unmodified):
13 - Very Poor
Component: Redding
Unmodified
Modified
Deep Percolation 1 62
Root Zone Residence Time 6 71
Chemical Limitations 100 100
Topographic Limitations 100 100
Surface Condition 100 100
SAGBI Rating 13 80
Rating Class Very Poor Good
Red Bank
Las Flores
El Camino
Los Molinos
Rancho Tehama Reserve
Henleyville
Richfield
Copeland
Vina
Flournoy
Paskenta
Buena Vista
Lomo
Cohasset
Powellton
Forest Ranch
Richardson Springs
Helltown
Magalia
Mineral Slide
Paradise
Butte Creek Canyon
Cana
Anita
Nord
Hamilton City
Chico
Copper City
Chrome
Rotavele
Roble
Durham
Ordbend
Rancho Llano Seco
Esquon
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Bayliss
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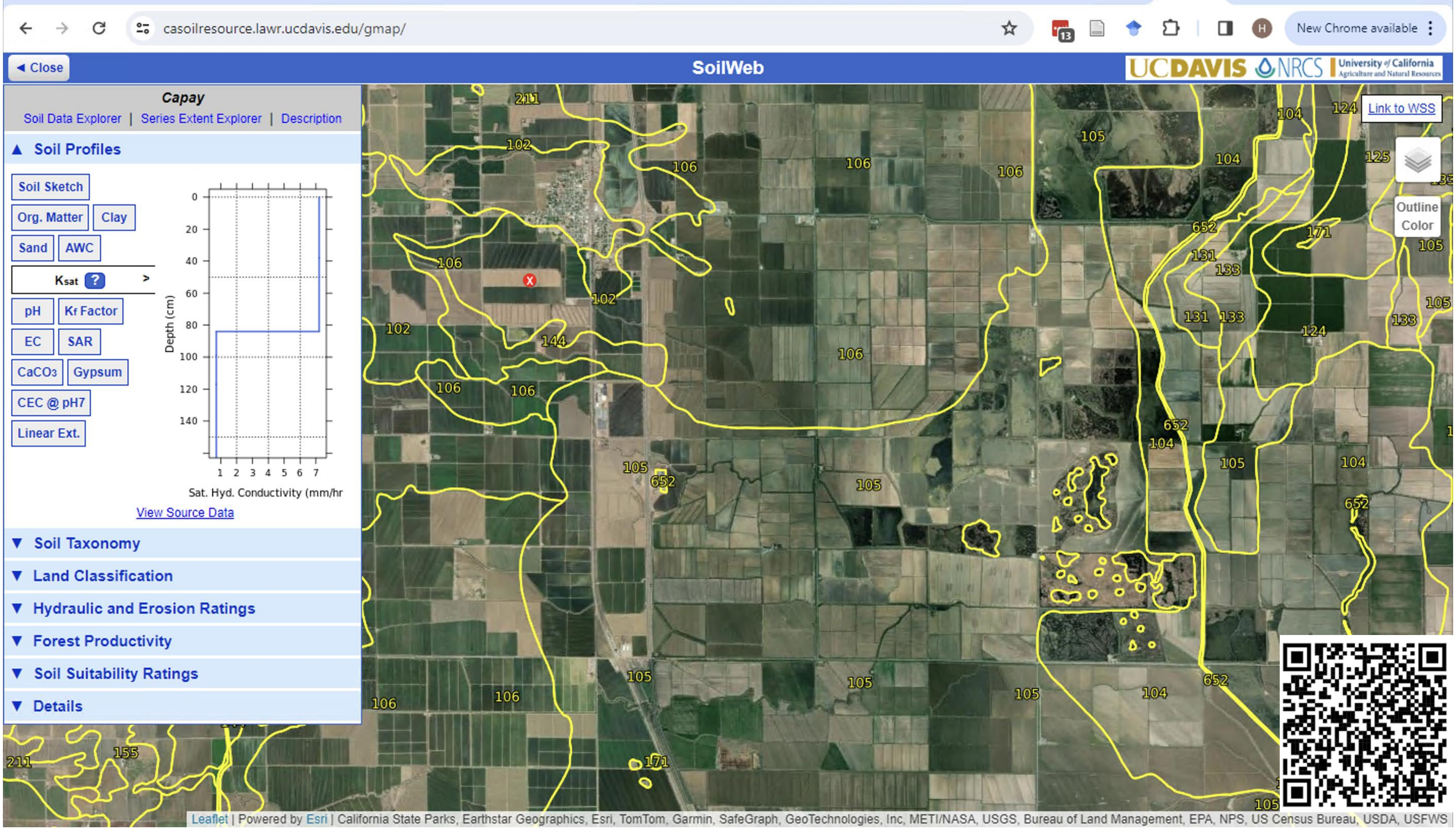
Norman
Biggs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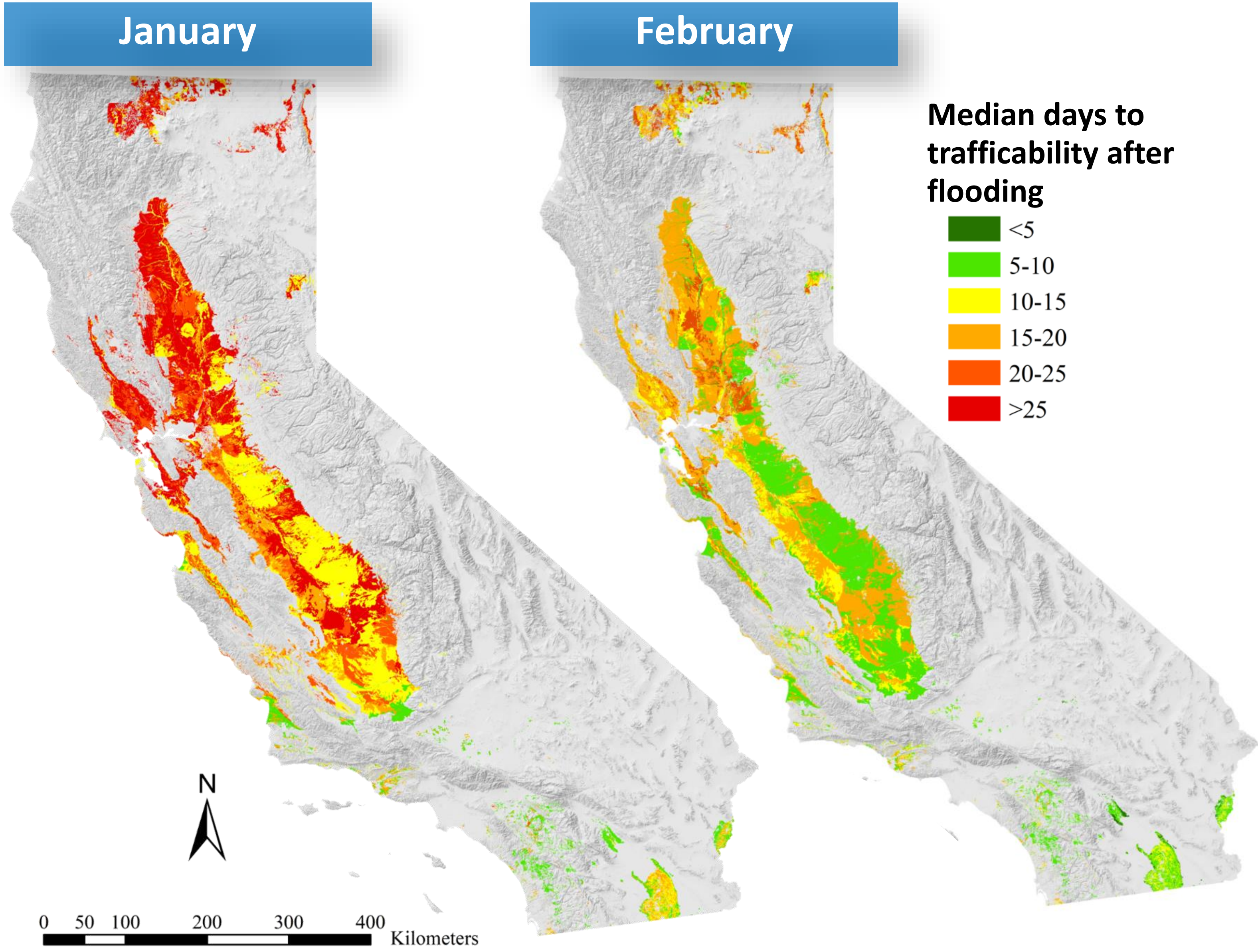
pH
Kf Factor
EC
SAR
CaCO3
Gypsum
CEC @ pH7
Linear Ext.
Depth (cm)
Sat. Hyd. Conductivity (mm/hr
View Source Data
Soil Taxonomy
Land Classification
Hydraulic and Erosion Ratings
Forest Productivity
Soil Suitability Ratings
Details
Link to WSS
Outline Color
Leaflet | Powered by Esri | California State Parks, Earthstar Geographics, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, USFWS

Soil trafficability after deep wetting

Trafficability and risk of soil compaction



Devine et al. 2021, J. of Soil & Tillage Research

Soil trafficability after deep wetting

Time-to-trafficability after deep soil wetting

ABOUT | SOIL TRAFFICABILITY

▲ Background

The *time-to-trafficability* SoilWeb product is intended to help California growers identify when fields are generally *trafficable* after *deep soil wetting* during crop dormancy or winter fallow periods. The tool applies to wetting situations such as managed aquifer recharge projects and large rain or flood events. The primary objective of the app is to help growers avoid physical soil damage by agricultural vehicles, so estimates are relatively conservative.

See the topics below to better understand this SoilWeb product.

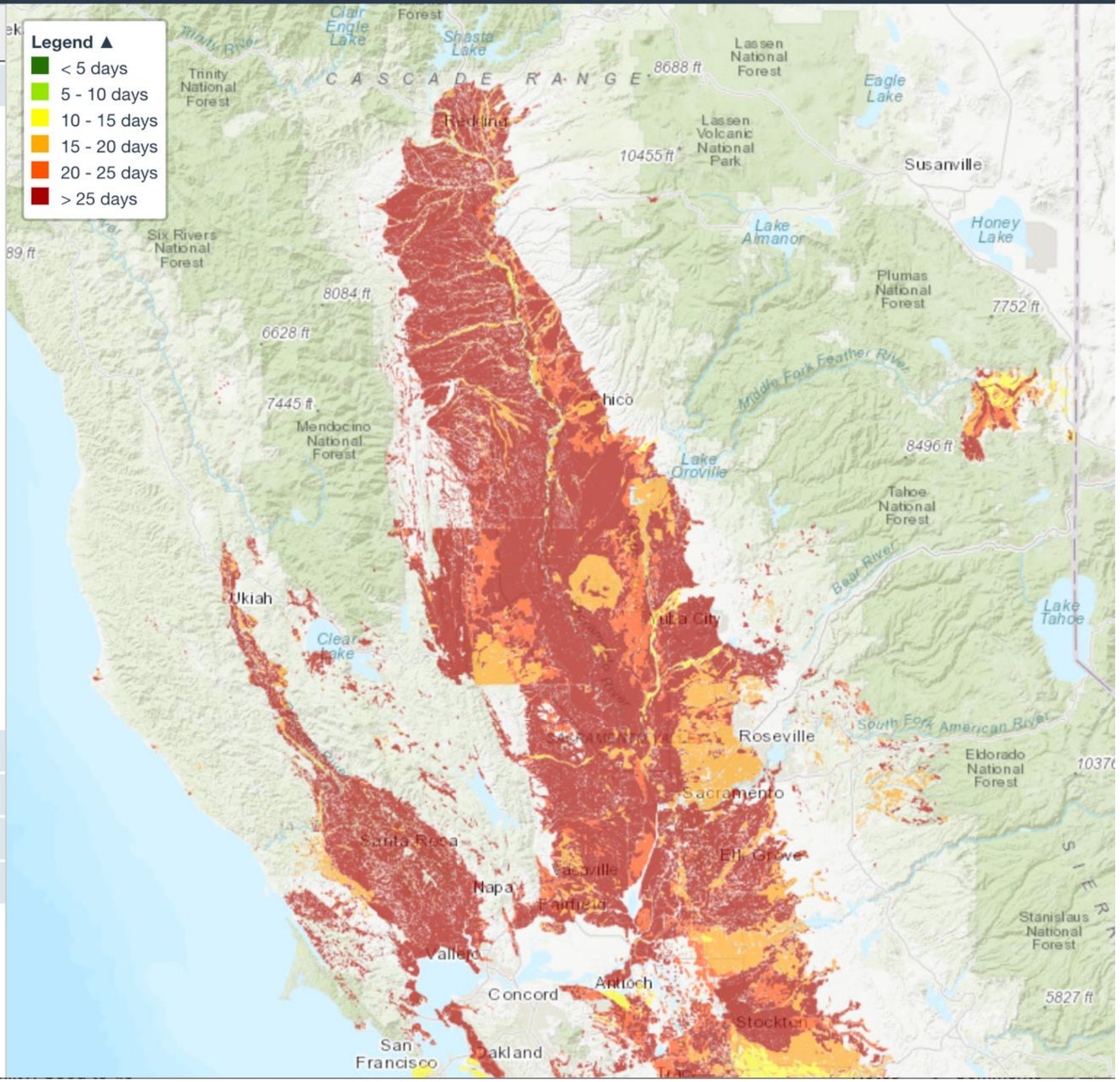
Use the "Soil Trafficability" tab to modify the trafficability estimate and map settings.

▼ Definitions

▼ How to Interpret

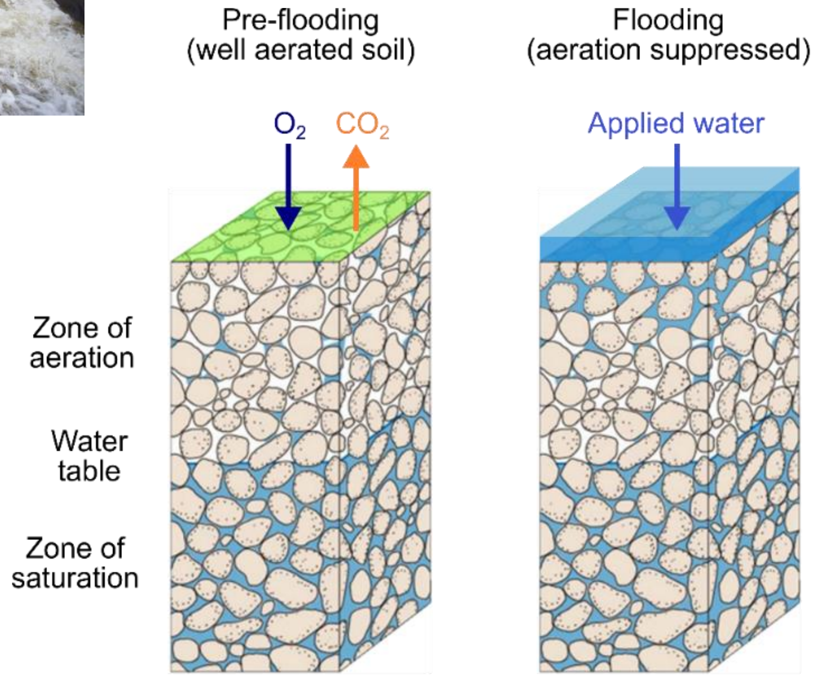
▼ Assumptions

▼ Feedback



https://soilmap2-1.lawr.ucdavis.edu/soil-trafficability/

Safe water application calculator



Ganot & Dahlke, 2021 *AgWaterMgt*

https://soilmap2-1.lawr.ucdavis.edu/root-zone/

Thank you!

NSF

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NIFA

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MOORE
FOUNDATION

NRCS
Natural Resources Conservation Service

ERS
ECONOMIC RESEARCH SERVICE
United States Department of Agriculture

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RECLAMATION
Managing Water in the West

california almonds
Almond Board of California

References

- Levintal, E., Kniffin, M.L., Ganot, Y., Marwaha, N., Murphy, N.P., and H.E. Dahlke. 2022. Agricultural managed aquifer recharge (Ag-MAR) – a method for sustainable groundwater management: A review. Critical Reviews in Environmental Science and Technology. https://doi.org/10.1080/10643389.2022.2050160
- Marwaha, N., Kourakos, G., Levintal, E., and Dahlke, H.E. 2021. Identifying agricultural managed aquifer recharge locations to benefit drinking water supply in rural communities. Water Resources Research, https://doi.org/10.1029/2020WR028811
- Ganot, Y. and H.E. Dahlke. 2021. A model for estimating Ag-MAR flooding duration based on crop tolerance, root depth, and soil texture data. Agricultural Water Management, https://doi.org/10.1016/j.agwat.2021.107031.
- Ganot, Y. and H.E. Dahlke. 2021. Natural and Forced Soil Aeration during Agricultural Managed Aquifer Recharge (Ag-MAR). Vadose Zone Journal, https://doi.org/10.1002/vzj2.20128.
- Kourakos, G., Dahlke, H.E., Harter, T. 2019. Increasing Groundwater Availability and Baseflow through Agricultural Managed Aquifer Recharge in an Irrigated Basin. Water Resources Research, https://doi.org/10.1029/2018WR024019
- Murphy, N.P., H. Waterhouse, and H.E. Dahlke. 2021. Influence of Agricultural Managed Aquifer Recharge on nitrate transport – the role of soil type and flooding frequency. Vadose Zone Journal, https://doi.org/10.1002/vzj2.20150.
- Dahlke, H.E., Brown, A.G., Orloff, S., Putnam, D., A. O'Geen. 2018. Managed winter flooding of alfalfa recharges groundwater with minimal crop damage. California Agriculture, https://doi.org/10.3733/ca.2018a0001
- Kocis, T.N. and H.E. Dahlke. 2017. Availability of high-magnitude streamflow for groundwater banking in the Central Valley, California. Environmental Research Letters, https://doi.org/10.1088/1748-9326/aa7b1b.
- O'Geen et al. 2015. A Soil Survey Decision Support Tool for Groundwater Banking in Agricultural Landscapes, California Agriculture Journal, https://doi.org/10.3733/ca.v069n02p75

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