Clear Lake Watershed and Lake Remediation

Funding: State of California Natural Resources Agency

BRC Meeting, September 12, 2024

UC DAVIS
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science for a changing world

clearlakerehabilitation.ucdavis.edu

Why Was This Project Necessary?

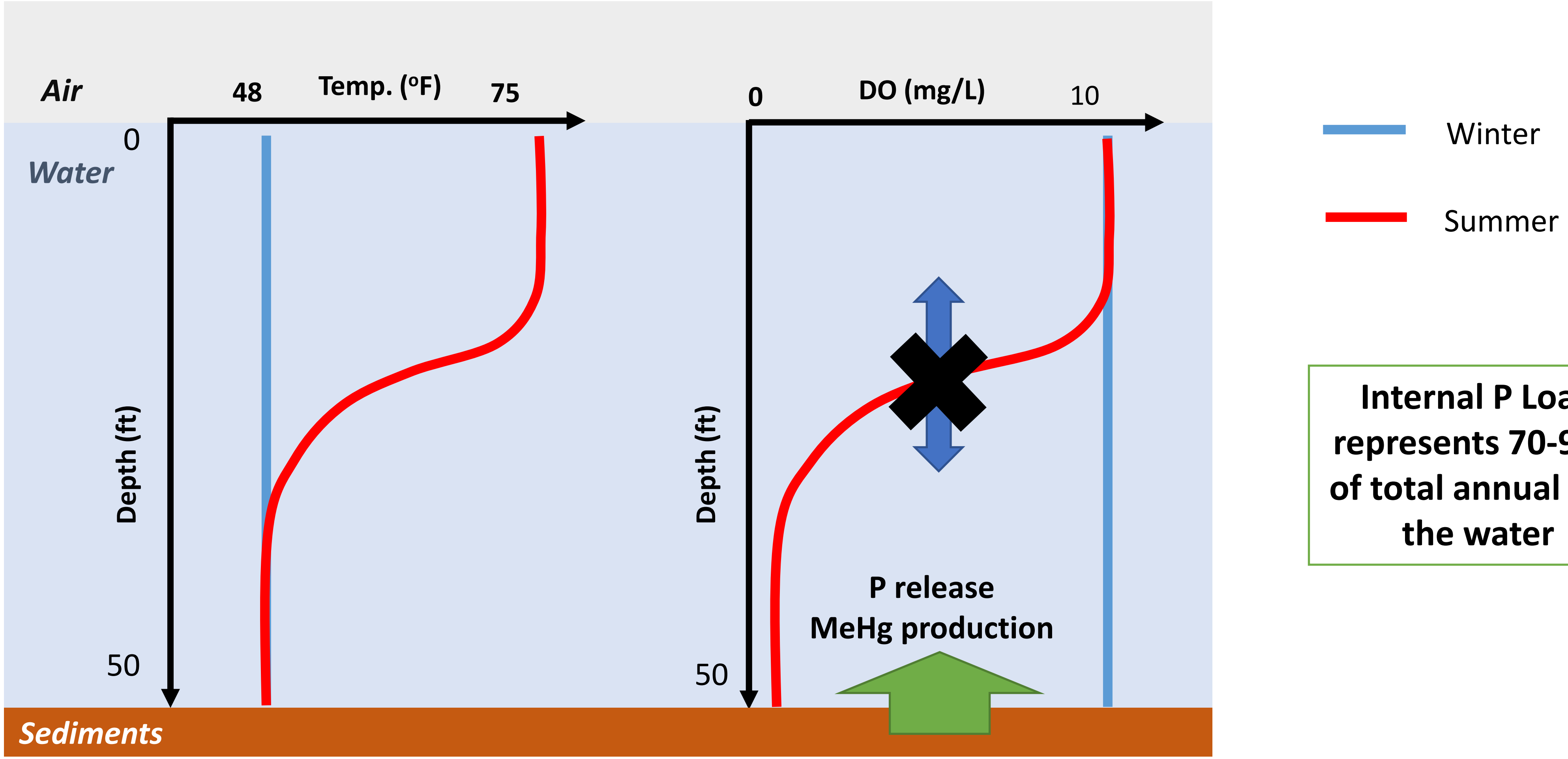
Studies into Clear Lake since 1970

by DWR, Lake County, UCD, and many others

BUT

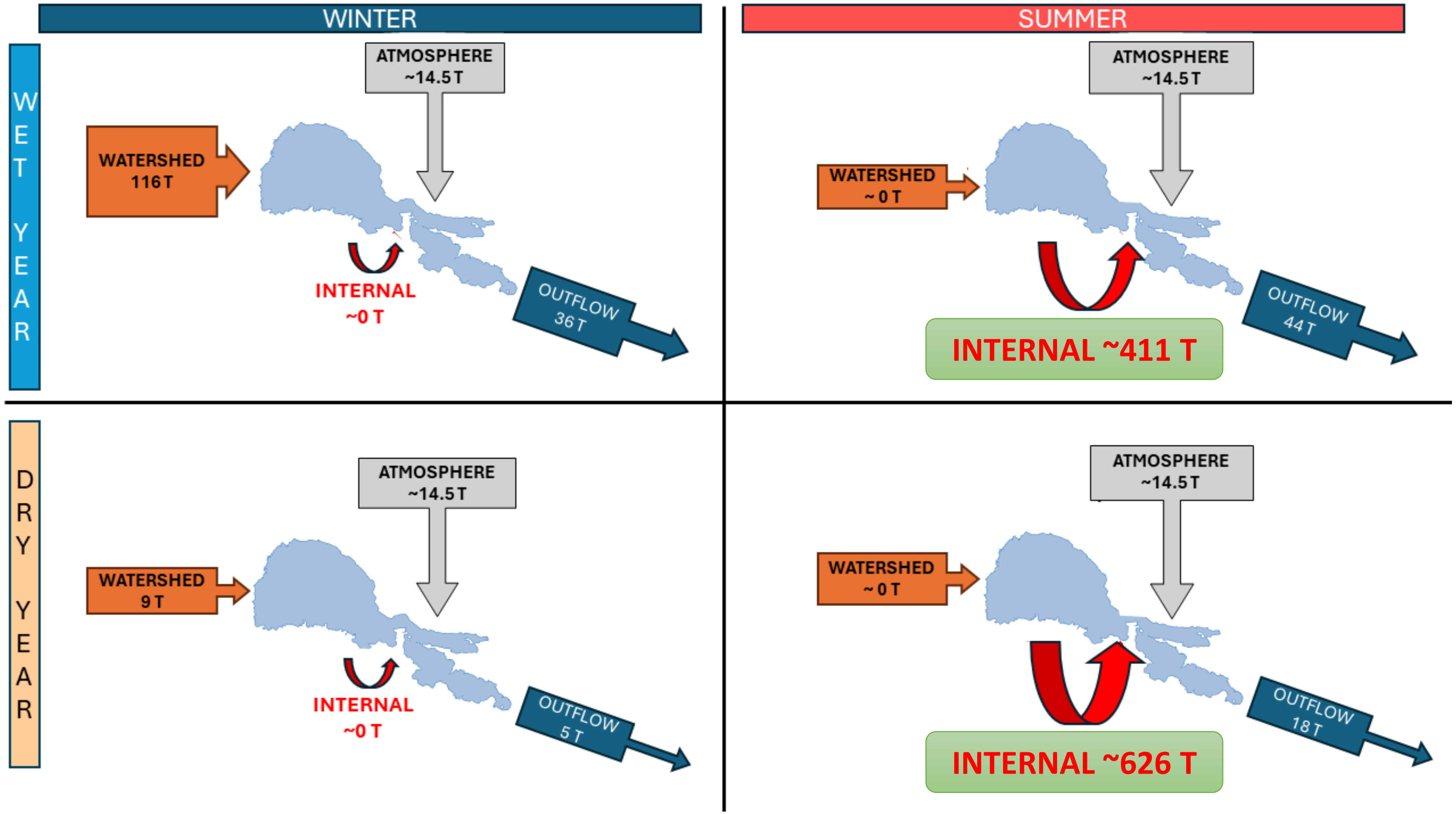
- *Focused on **historical** analysis, not the driving **mechanisms** of water quality decline*
- *We all know that **the future will not be a simple extension of the past***
- ***Predictive tools (i.e. models) based on the driving mechanisms** were needed to explore restoration strategies in a time of climate change, mega-fires, extreme events….*
- *A **measurement program that identified the driving mechanisms** in the lake (and the watershed) was required to construct and to validate the model(s)*

Lake Temperature, Dissolved Oxygen (DO), and Internal Load



Internal P Load represents 70-95% of total annual P in the water

Phosphorus Budget: External or Internal Load?



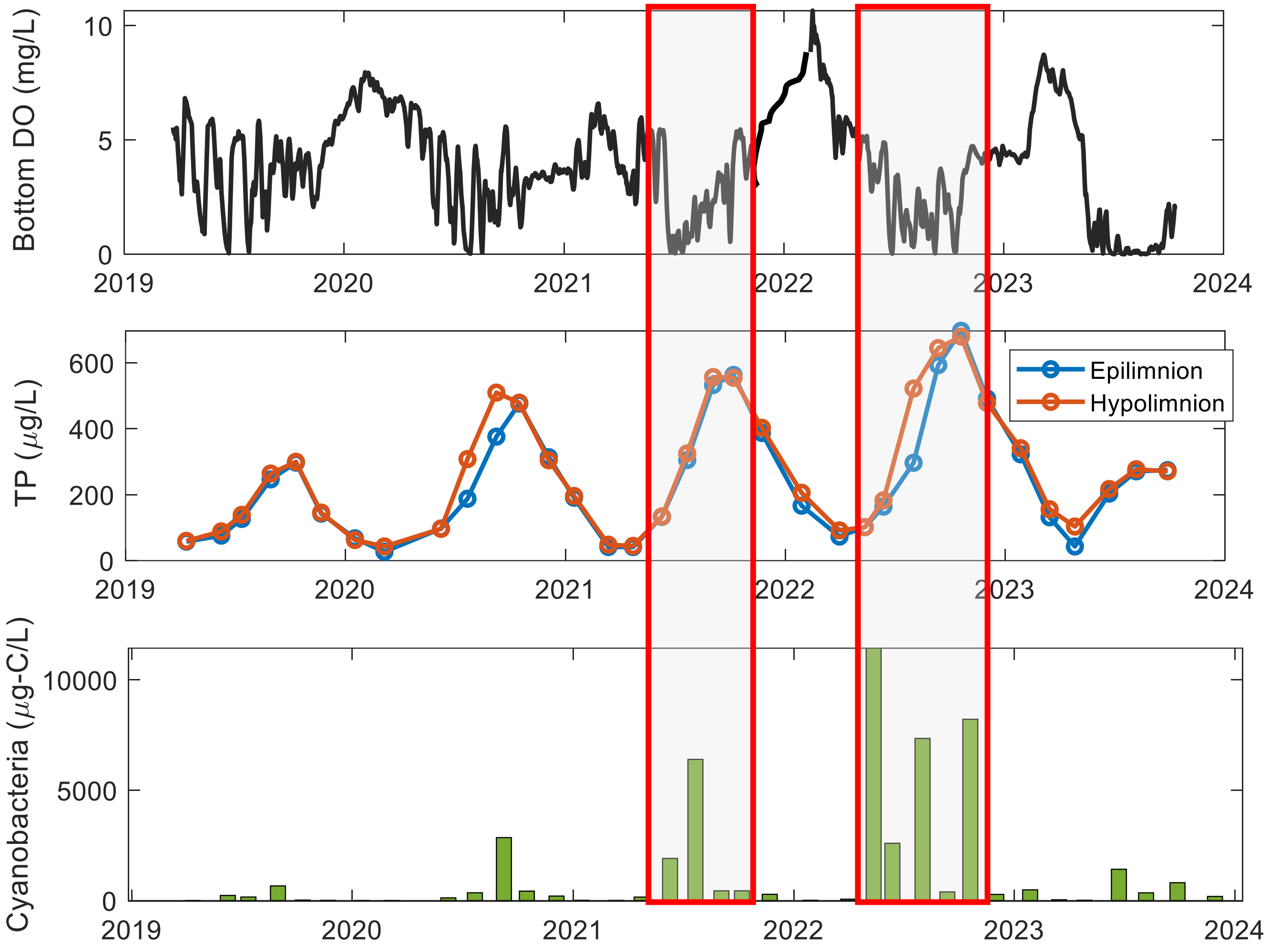
Seasonal Variability

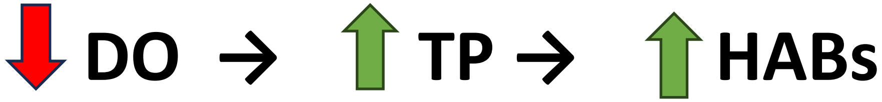
More P in the lake when **creeks are dry (summer)**

Interannual Variability

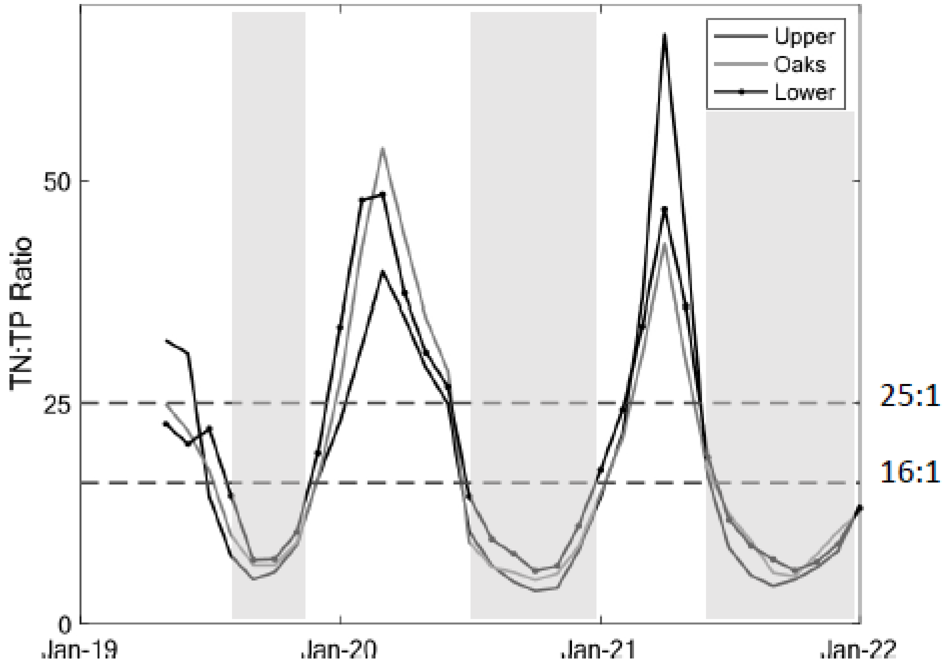
More P in the lake during **dry years**

Dissolved Oxygen, P Load, and Harmful Algal Blooms (HABs)





Why Does Internal P Load Promote HABs?



↑TP → ↓TN:TP → ↑N_2 fixers

Summer Internal P Load causes a **shift in nutrient limitation (i.e., P >> N),** which causes a relative deficit in nitrogen for all algae. This favors HABs, that are capable of "fixing" atmospheric nitrogen.

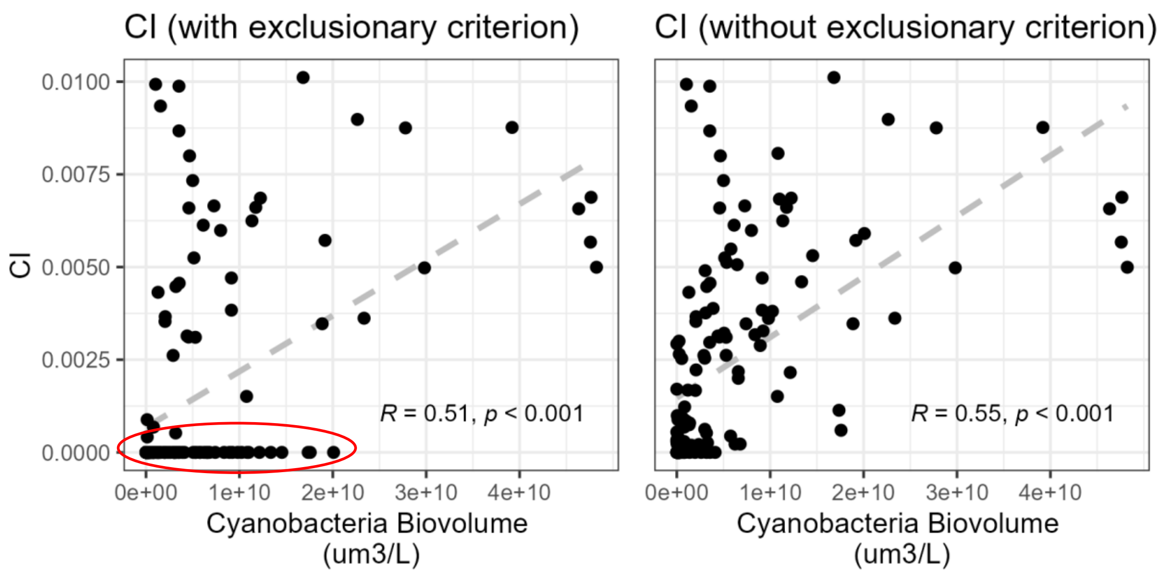
Swann, M. et al. 2024. ***Internal phosphorus loading alters nutrient limitation and contributes to cyanobacterial blooms in a polymictic lake****. Aquat Sci 86, 46*

Remote Sensing and HABs

The current Cyanobacteria Index (CI) from **the SFEI tool (fhab.sfei.org) does not always "see" blooms** occurring in Clear Lake.

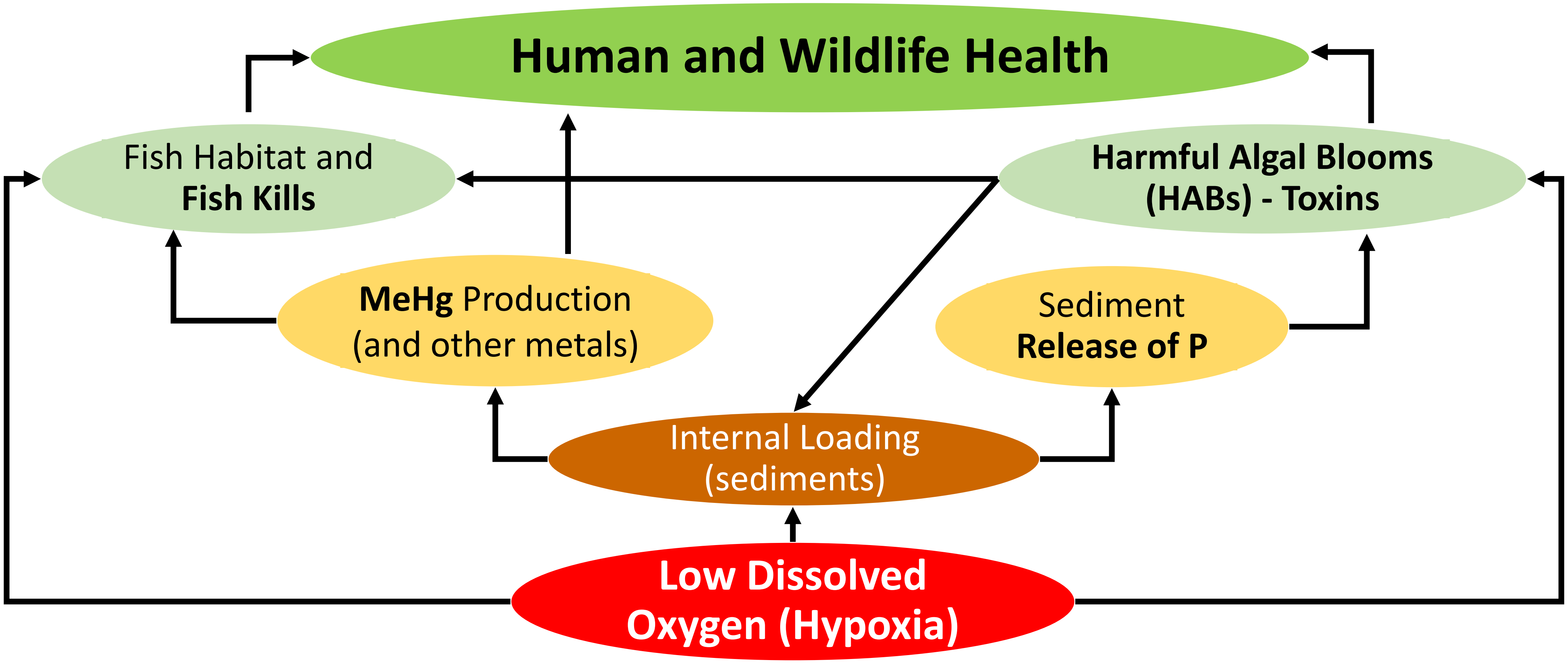
↓

We adopted the <u>original CI algorithm</u> to "see" them

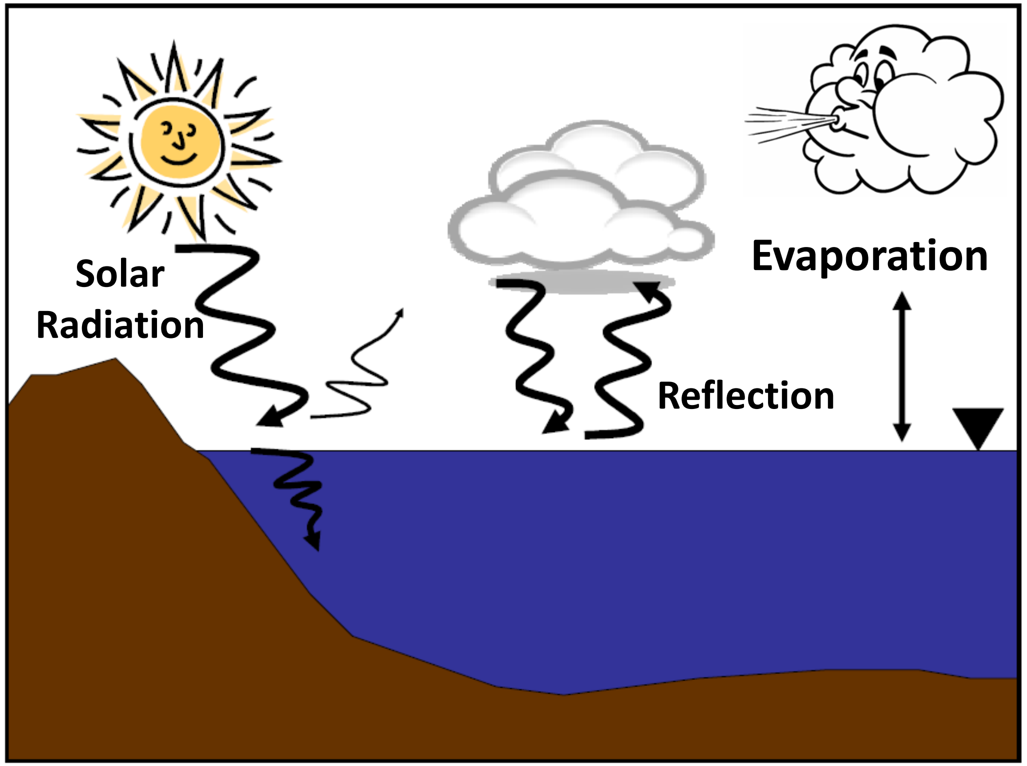


See Sharp, et al. (2021). ***Quantifying Scales of Spatial Variability of Cyanobacteria in a Large, Eutrophic Lake Using Multiplatform Remote Sensing Tools****. Frontiers in Environmental Science, 9, 612934.*
https://doi.org/10.3389/fenvs.2021.612934

Causes of Poor Water Quality at Clear Lake



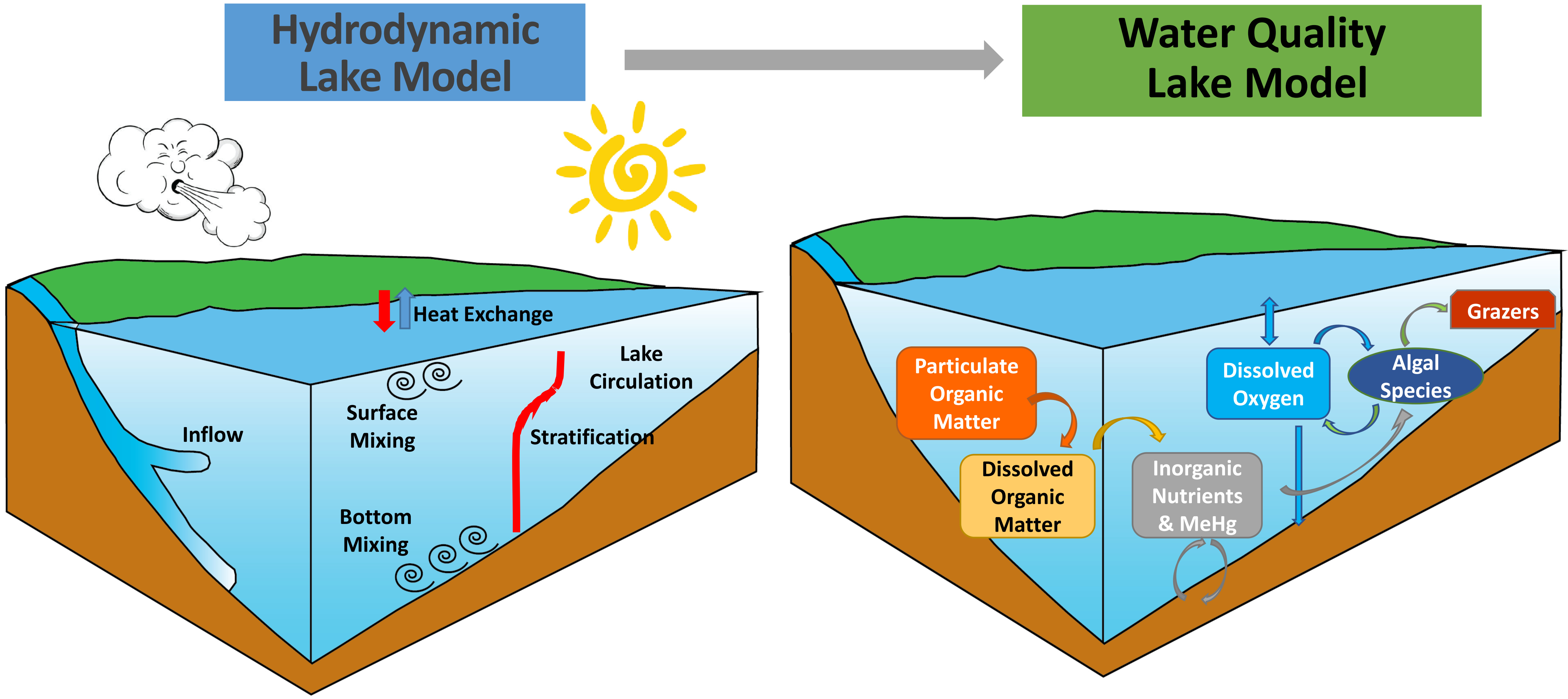
Predicting Hypoxic Events from Meteorological Conditions



Cortés, A. et al.. 2021. ***Prediction of Hypoxia in Eutrophic Polymictic Lakes****. Water Resources Research, 57(6)*

- Solar Radiation
- Air Temperature
- Relative Humidity
- Wind Speed
- Lake Surface and Bottom Temperatures

Predictive Tool of Hypoxic Events based on how much the Lake heats and cools - provides an early warning of bad things to come

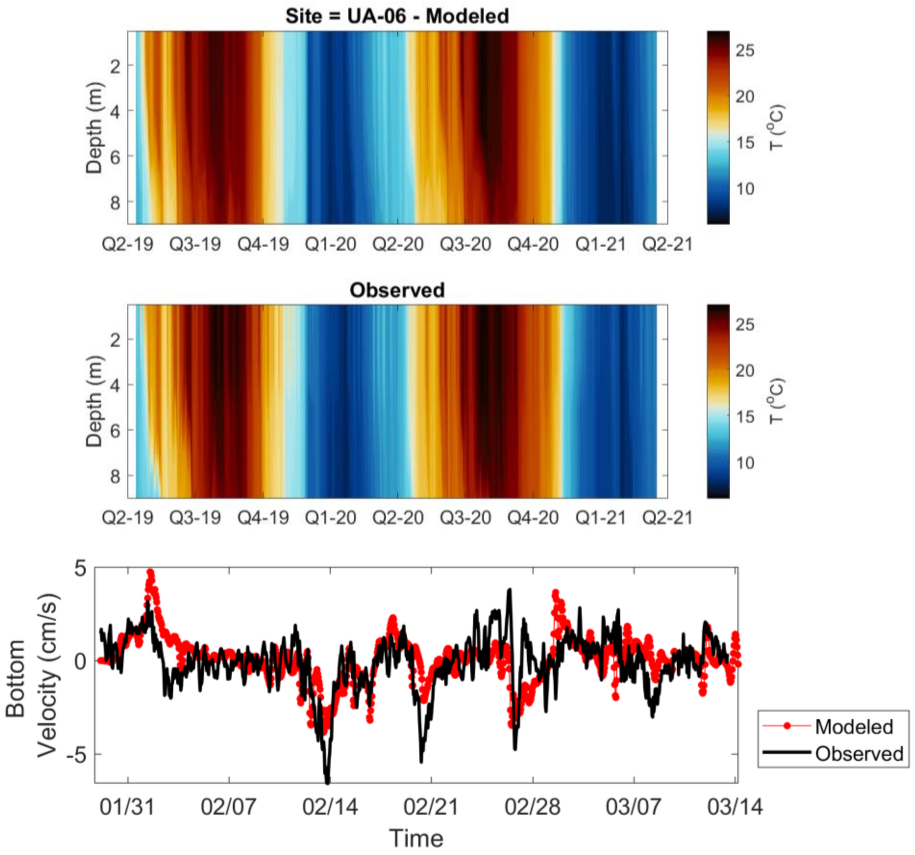


How does the water move?
Simulate the velocity, temperature

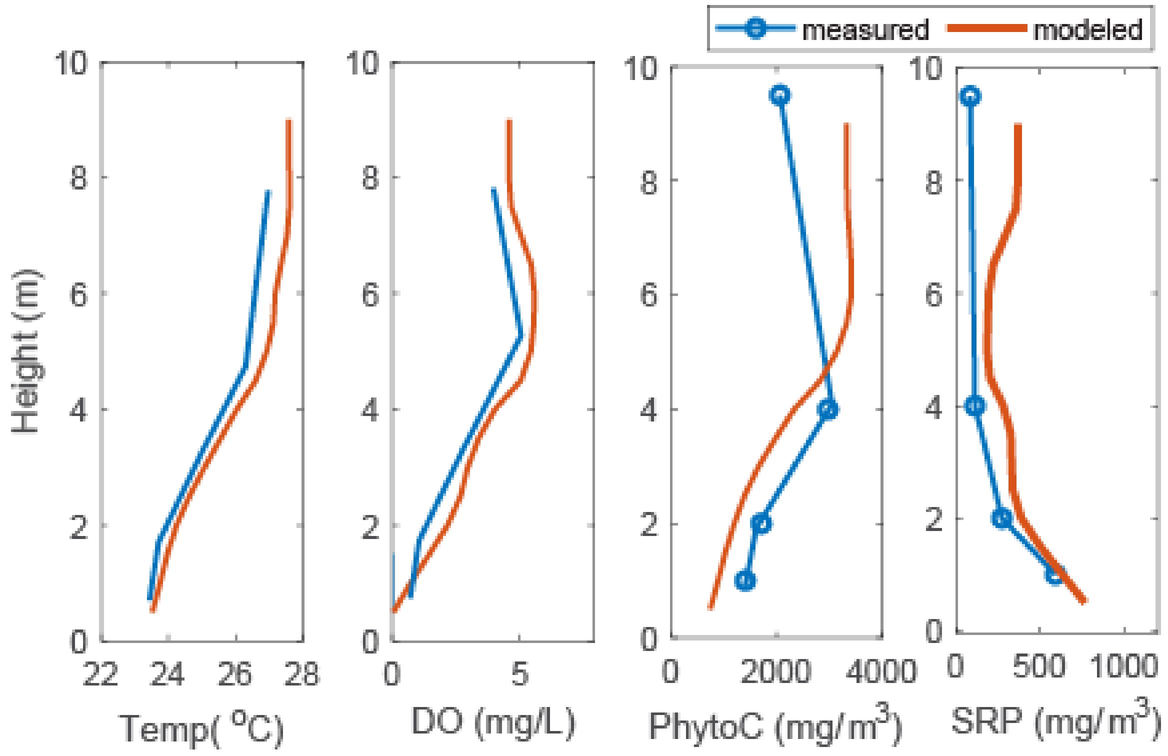
How does the lake production change?
Simulate nutrients, oxygen, algae

Validated Accuracy of the Lake Models

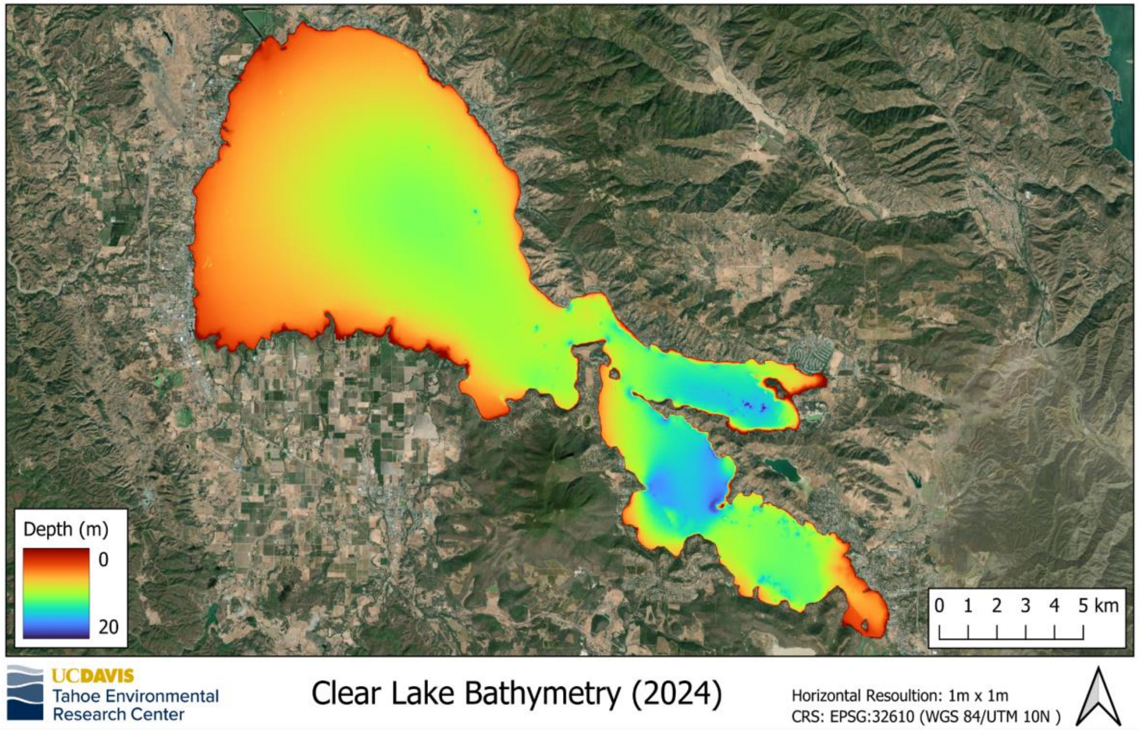
Comparison of Modeled and Observed Lake Temperature (top) and Bottom Currents (bottom)

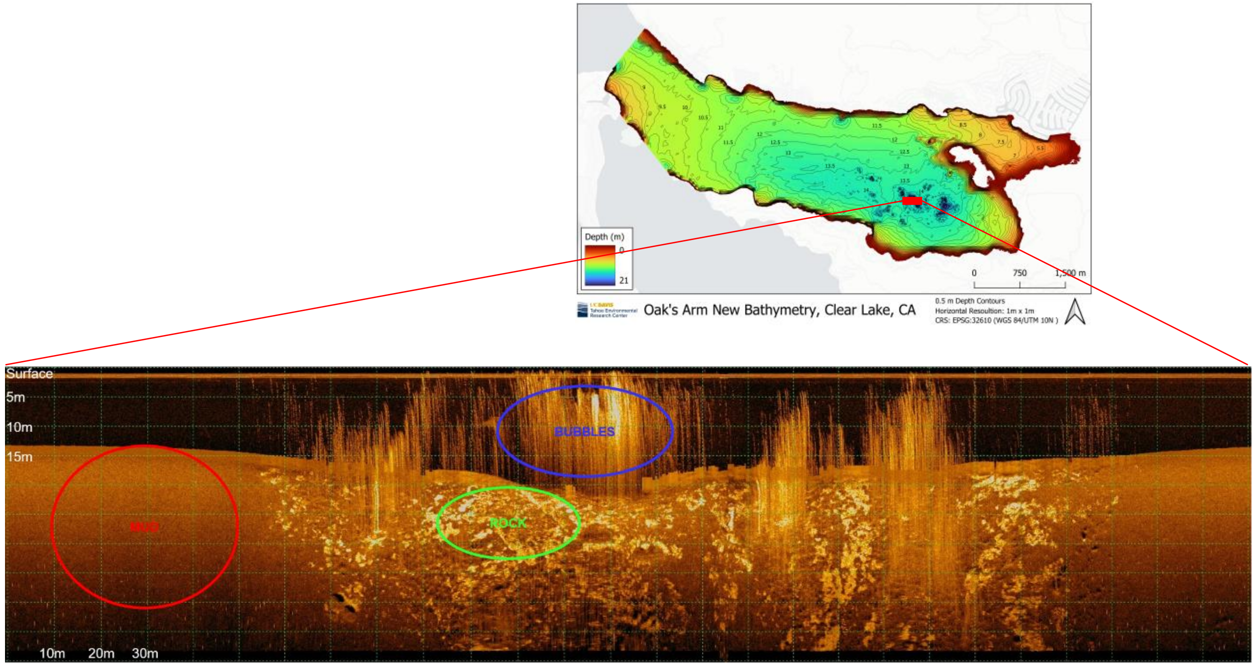


Comparison of Modeled and Observed Lake WQ variables



Updated Bathymetry (Lake Bottom) and New Products (substrate, gas vents)





Sidescan sonar cross-section of gas vents in the Oaks Arm

Using the New Predictive Model to Evaluate Capital Investments

Lake Modeling
(Future **Predictions**)

→

Restoration Strategies to Mitigate Harmful Algal Blooms (HABs)

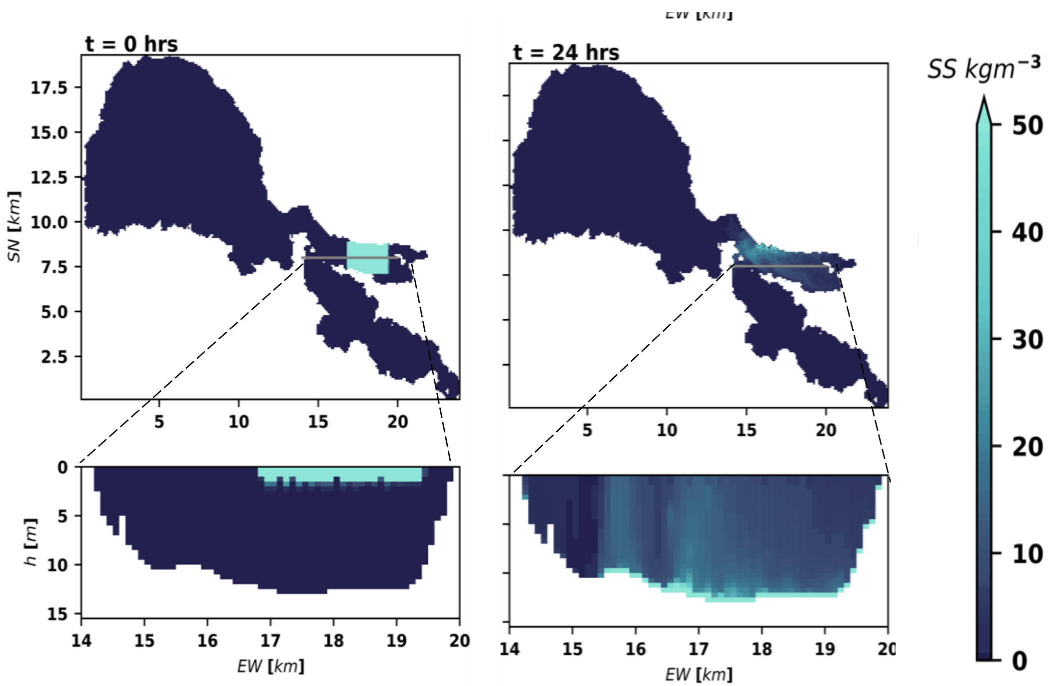
- Sediment Capping (EutroPHIX)
- Algae and Nutrient Harvesting (AECOM)
- Ultrasonic Algae Control (LG Sonic)
- Hypolimnetic Oxygenation (TERC)

Preliminary** results with **assumptions!

Model Evaluation: Sediment Capping

- **Pilot project** on **7% of the lake surface** (~2,750 acres, ~10 km^2)
- **Model Results showed:**

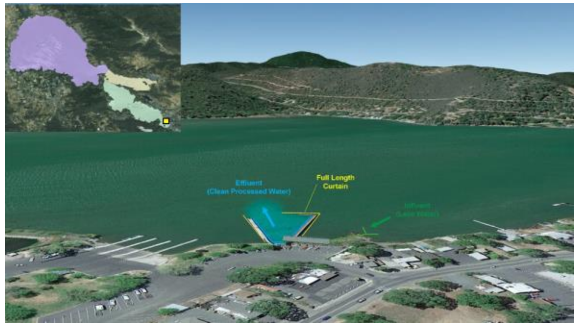
  Lake Processes will compromise efficacy:
  - **High velocity lake currents** will rapidly resuspend and redistribute the cap material
  - 1/3 of product resuspended by currents
  - Less product reaching the target location



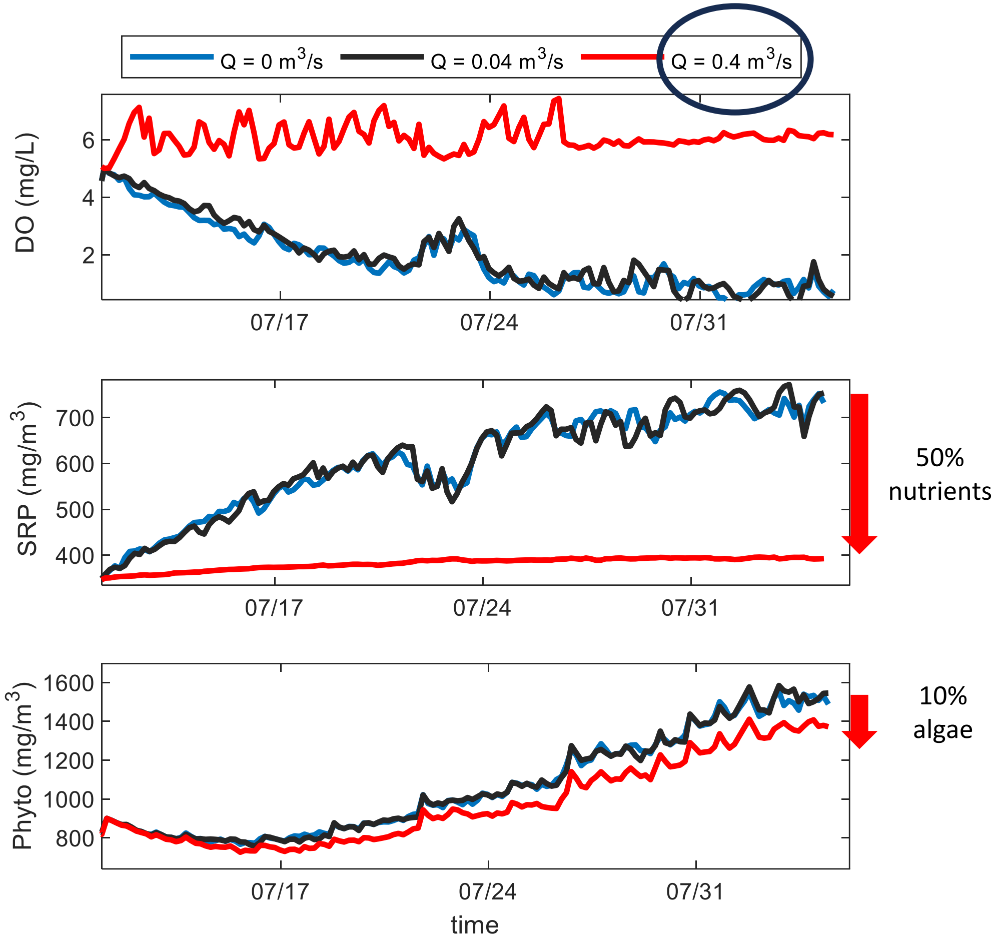
Model Evaluation: Algae and Nutrient Harvesting

- <u>**Pilot Project:**</u>
  - **0.1% of the total lake surface** (50 acres, 0.2 km^2 near Redbud Park)
  - 1-million-gallon per day (**0.04 m^3/s**) harvester for **3 weeks in mid-summer** to early fall

- <u>**Model Results Showed**</u>: May **need ~10 times the treatment capacity** to reduce nutrients (by 50%) and algae (by 10%) due to currents



Credit: AECOM

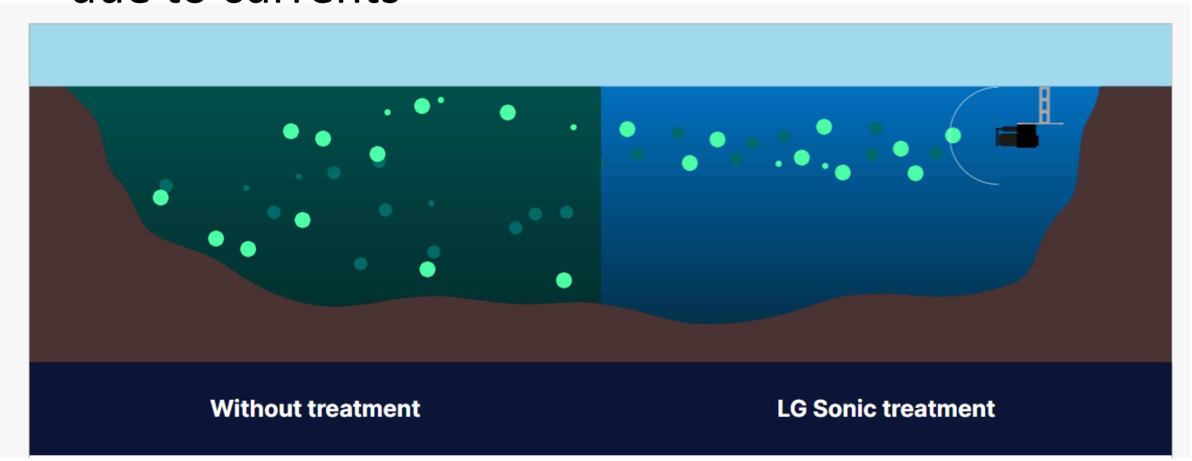


Averaged values across the treated area

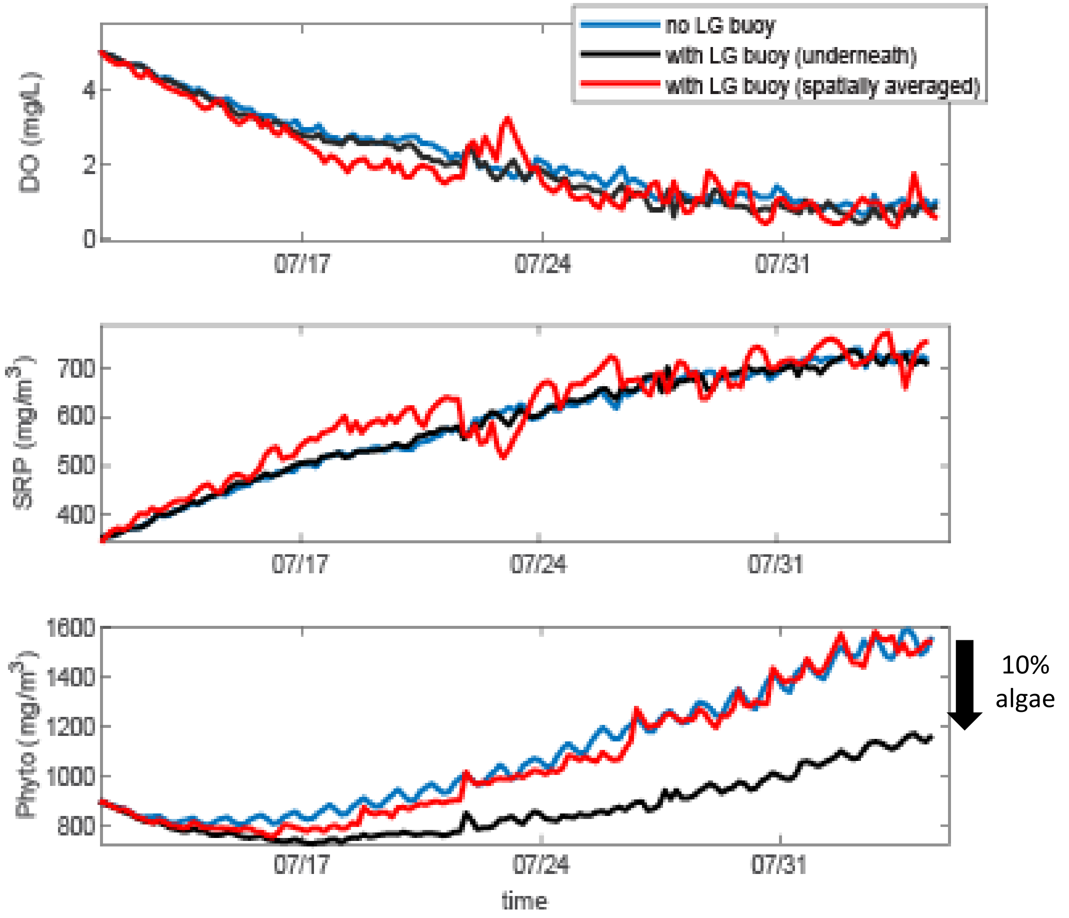
Model Evaluation: Ultrasonic Algae Control

- **Pilot project** on **0.1% of the total lake surface** (50 acres, 0.2 km^2 near Redbud Park)

- **Model Results Showed**: Algae reduction only apparent directly below the buoy, but not across the treated area due to currents



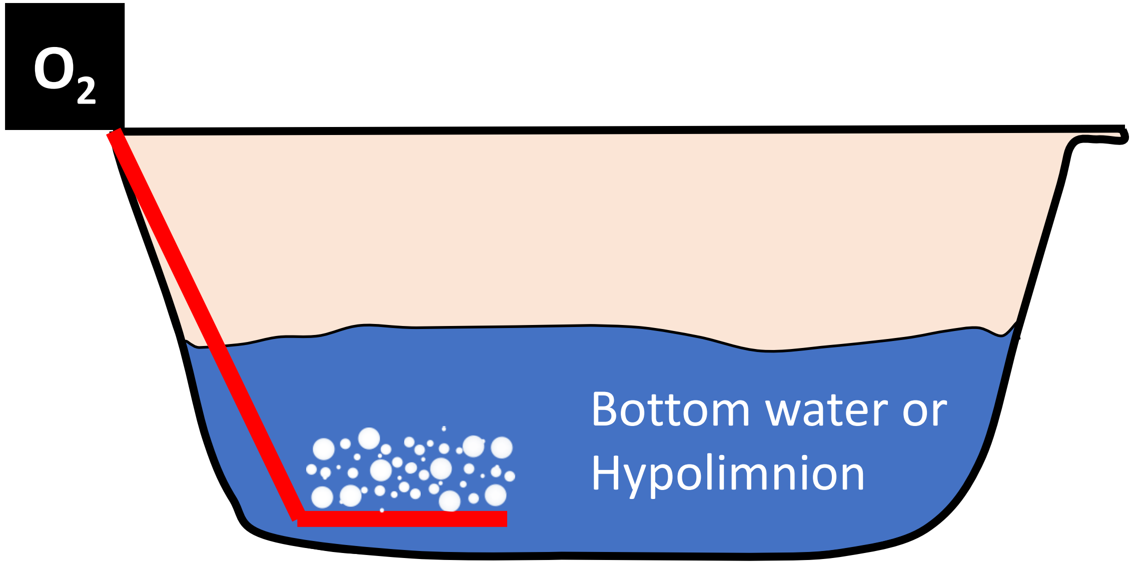
Credit: LG Sonic



Averaged values across the treated area

Hypolimnetic Oxygenation (HO)

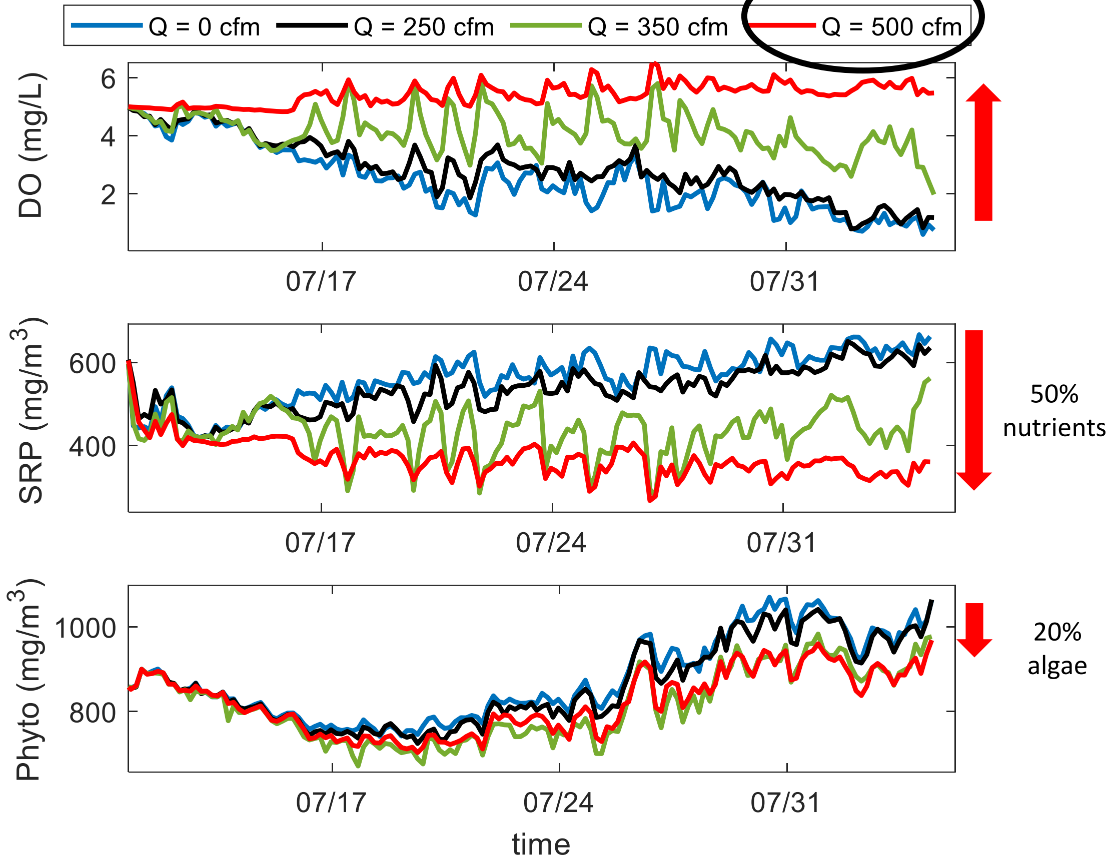
Direct addition of very fine bubbles of pure oxygen to the hypolimnion



Pilot Project in the Oaks Arm
10% of the total lake surface
(3,500 acres, 14 km^2)

Pilot Project partially funded by CNRA (planning phase) and ongoing conversations with USEPA for the execution phase (construction, injection, monitoring)

Hypolimnetic Oxygenation (HO): Model Results



DO > 3.5 mg/L

Concentration reduced by 50%

Concentration reduced by 20%

Averaged values across the treated area

Full Lake Restoration Strategies – Estimated 10 Yr Costs

Pilot Project Required to Confirm

Lake surface area = 37,000 acres

Technology	Cost of Pilot Project - one unit (Millions $)	Surface area treated by the Pilot Project (acres)	Number of additional units for full lake remediation	Capital cost per additional unit (Millions $)	Capital cost of the full lake project including pilot project (Millions $)
Hypolimnetic Oxygenation	4.0	3,500	7	2.5	22
Algae and Nutrient Harvesting	1.3	50	740	1.5	1,111
Sonic algae control	1.5	50	740	1.0	742
Sediment capping	3.4	2,000	20	3.4	71

Technology	Annual O&M cost per unit (Millions $)	Annual Monitoring (Millions $)	O&M and Monitoring for 10 years full lake project (Millions $)	Total capital investment + 10 years O&M and Monitoring
Hypolimnetic Oxygenation	0.3	0.2	26	48

Take-home Messages

Root Cause of Poor Water Quality → Low Dissolved Oxygen near the Sediments

Prediction → Hypoxic Events

Prediction → HABs and MeHg

Remediation (solution) → H.O. – most economical in short and long term

Thank you for letting us be a part of Clear Lake's rehabilitation

https://clearlakerehabilitation.ucdavis.edu/

Pomo of Upper Lake Habematolel

Scotts Valley Band of Pomo Environmental

Elem Indian Colony 1852 Pomo

Big Valley Rancheria

Robinson Rancheria Pomo Indians California

KOI NATION

Middletown Rancheria of Pomo Indians of California

County of Lake Water Resources

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