2022 Annual Research Update for the Blue Ribbon Committee Clear Lake Watershed and Lake Remediation Project

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Table of Contents

PART A: UC Davis Tahoe Environmental Research Center (TERC): Lake Monitoring and Modeling in Clear Lake

1. UC Davis TERC Accomplishments in 2022

1.1. Continued data collection for lake, meteorology, and streams

We continued the high-resolution data acquisition for (1) stream properties at three locations (Middle, Scott, and Kelsey Creeks), (2) meteorological data at seven locations around the perimeter of the lake, and (3) lake temperature and dissolved oxygen at multiple depths and locations across the lake (six permanent water quality stations). In addition, we made measurements of particle size in the water during each of the routine monitoring events as part of our ongoing research on the impact of wildfire smoke on lakes. We also measured nutrient concentrations and multi-variable profiles throughout the water column and across all three lake basins during eight sampling events in 2022 (January 28th, April 1st, May 13th, June 13th, August 2nd, September 12th, October 20th, and December 2nd). The water samples were analyzed for dissolved and particulate forms of nitrogen, phosphorus, and carbon; chlorophyll; particle size distribution; phytoplankton and zooplankton identification and quantification. A new laboratory staff member (Helen Fillmore) has been successfully on-boarded, who helped greatly with data analysis. All of these data are critical for the ongoing development of the numerical models of physical transport and lake production and for a better understanding of the range of solutions that may be applied in the future.

Water samples were also collected for the Big Valley Band of Pomo Indians for their cyanobacteria monitoring program. During most of 2022, data collection has been particularly challenging due to the low lake levels and the difficulties this presents in launching research vessels. We are particularly grateful for the assistance provided by Lake County.

We also continue our collaboration with the US Geological Survey (USGS) to find a surrogate for mercury that can be monitored continuously using high-resolution sensors, such as the YSI-EXO probes. These instruments have been installed since spring 2020 in our permanent water quality station in the Oaks Arm to develop regressions between time series of colored dissolved organic matter (CDOM) and mercury.

1.2. Publicly available data

In 2022, we launched a new TERC-Clear Lake website, with a publicly available data repository for all our data. This website also includes a brief description of our field monitoring plan, displays data interactively, shows field observation animations, stores photos and publications, and posts updates on a blog. We continue to improve this website with the support of the IT Department of the College of Engineering at UC Davis.

1.3. Continued watershed monitoring collaboration (USGS-TERC-Lake County)

In addition to the in-lake monitoring, we are collaborating with USGS and Lake County Water Resources Department (LC-WRD) to conduct a 3-year upper watershed monitoring study. Fall 2022 has been the beginning of the second sampling year. We have developed a new protocol for storm sampling at Clear Lake. Flow permitting, we are planning to sample up to 15 tributaries (natural creeks and culverts) up to 12 times a year. USGS and LC-WRD will be responsible for the sampling and filtering. The analytical constituents will vary depending on the sample, but they can be filtered and unfiltered nutrients (N and P), mercury species, and metals. Analyses will be run both at USGS and TERC's labs.

1.4. Participation in BRC and Technical meetings

We participated in quarterly BRC meetings and monthly Technical BRC meetings. We have also participated in the "Clear Lake October Fest 2022" meeting organized by the USGS Volcano Hazards Program to provide an update on the TERC Clear Lake project and the BRC Open House on December 13th. Alicia Cortes presented work conducted at Clear Lake during her Invited Speaker talk at the Joint Aquatic Sciences Meeting (JASM) in May 2022 (Grand Rapids, Michigan).

1.5. Approved hypolimnetic oxygenation pilot project in the Oaks Arm

Historical monitoring data and more recent monitoring, experiments, and modeling by UC Davis TERC have shown that periods of low dissolved oxygen next to the lakebed sediments are a major factor in the poor water quality and ecological health of Clear Lake. Hypolimnetic oxygenation is a technique that has been used nationwide (and in California) in impaired water bodies. It entails the direct injection of pure oxygen into the lake's hypolimnion (the lower stratum of the lake) during the summer months (Fig. 1). TERC has suggested a pilot research project that consists of the design, construction, implementation, monitoring, water testing, and scenario testing of Hypolimnetic Oxygenation (HO) in the Oaks Arm of Clear Lake.

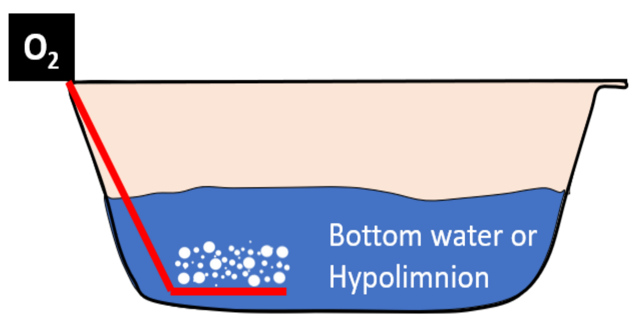

Fig. 1. Sketch of an ideal hypolimnetic oxygenation system

This project has been approved by the Blue Ribbon Committee. Our proposal will be forwarded to the California Natural Resources Agency (CNRA) for funding in the Fiscal Year (FY) 2023/24 California State Budget. If the project is funded by the State of California, it will be conducted between July 2023 and July 2025, with the first year focusing on permitting, design, outreach, and construction, and the second year dedicated to oxygen injection in the lake, monitoring, and final report

1.6. Summary report on metals and metalloids in Clear Lake based on historical data (TERC-USGS)

This report addressed concerns raised about possible toxicity threats from metals in Clear Lake if the proposed Hypolimnetic Oxygenation (HO) pilot project in the Oaks Arm is executed. The HO comprises the addition of oxygen to the bottom waters of the lake when it falls to low levels (hypoxia), which typically occurs during the summer months. During the rest of the year, when the lake is actively mixing, Clear Lake has more than 5 mg/L in the bottom waters (oxic conditions). Thus, we can learn much about how the concentration of various metals responds to changes in dissolved oxygen (DO) concentrations by analyzing existing historic data. Here, we analyzed the long-term data for metals and metalloids in Clear Lake collected monthly across the lake by the California Department of Water Resources (DWR) during the last 50 years to infer if oxic conditions result in the release of metals. Results from this report confirmed that metal concentrations (except for nickel, at environmentally low levels) do not increase during oxic periods. This strongly supports the hypothesis that increasing summer DO concentrations using hypolimnetic oxygenation will improve lake water quality and pose no new threats (Fig. 2).

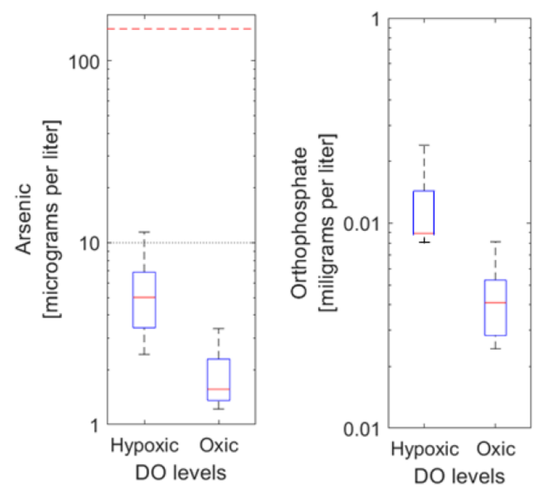

Fig. 2. Boxplots for arsenic and orthophosphate concentrations under hypoxic and oxic conditions in Clear Lake

1.7. Interactions with Clear Lake Tribes and stakeholders

Interactions with Clear Lake tribes and other stakeholders continue to be a high priority.

- In 2022, in addition to the previously mentioned cyanobacteria sample collection, some members from the Big Valley Band of Pomo Indians community have joined our sampling crew (Alix Tyler, Amida Verhey).
- We have helped the Lake County Department of Water Resources to set up a filtering station for the stream water samples collected during the watershed monitoring program.
- We also had conversations with Temashio Anderson (Robinson Rancheria) and Eddie Crandell (Lake County Supervisor) to identify their concerns about our lake remediation recommendation.
- We delivered our first outreach presentation of the Hypolimnetic Oxygenation Pilot Project in the Oaks Arm at the Clearlake Homeowners Association meeting on September 24th, 2022.

We are still in touch with this community while developing remediation strategies for their specific problems.

- Our graduate student Kanarat Pinkanjananavee is collaborating with Buckingham Park Water District to analyze disinfection by-products.

1.8. Internal loading and cyanobacteria blooms in Clear Lake

Graduate student Micah Swann has completed a new laboratory experiment to evaluate the release rates of nutrients from the sediments during early summer in the Upper Arm (referred to as Incubation Experiment 3.0). This new experiment aimed to (1) evaluate if nutrient release rates in early summer were the same as in the fall, and (2) evaluate the effect of pH on oxic release rates. The collection of the sediment samples was successfully conducted on June 29th. The sediment samples were subject to anoxic and oxygenated conditions in the laboratory (incubation) during the whole month of July and samples were sent to TERC lab for analysis of nutrients, pH, metals, and redox. Preliminary results confirmed the phosphorus release rates observed in previous incubation experiments under anoxic conditions (2019 and 2020). Nutrient release rates under oxygenated conditions were not as high as expected for high pH values.

Micah Swann has also completed the first draft of his scientific manuscript "Drivers of cyanobacteria blooms in a polymictic lake", where he combined data from a range of sources to determine the internal and external nutrient fluxes and their connection to the magnitude of the summer cyanoHAB season in Clear Lake (Fig. 3).

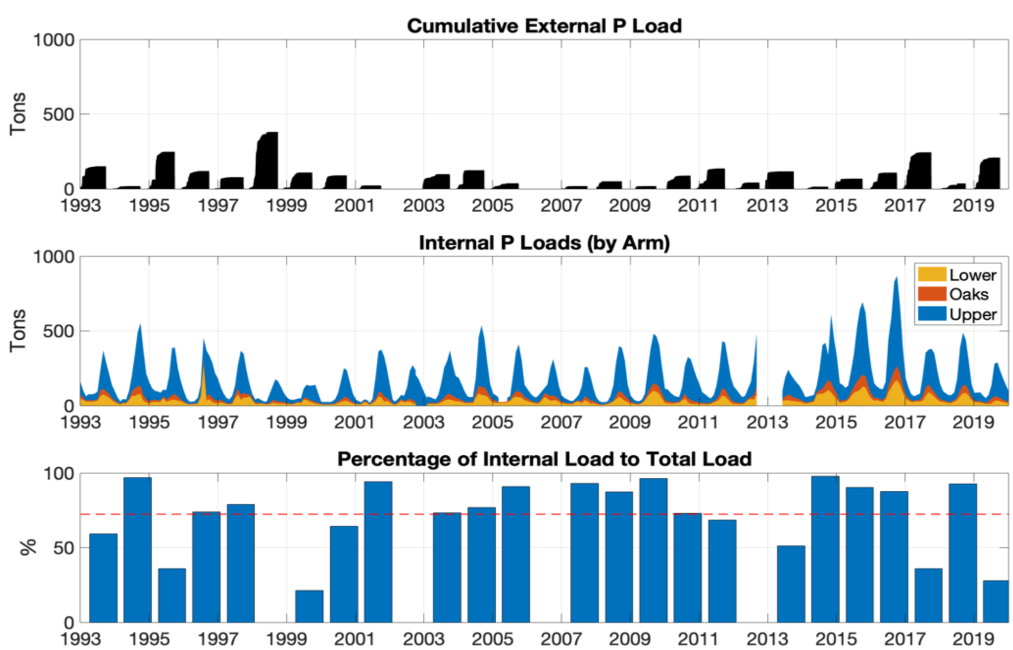

Fig. 3. Time series of cumulative external P load, internal P load by arm, and percentage of internal load to total load (external plus internal) between 1993 and 2020

Former graduate student, Nick Framsted. completed his MS thesis, half of which focused on nutrient-release experiments from Clear Lake sediments. He is currently working on a peer-reviewed publication describing his findings.

1.9.Remote sensing and cyanobacteria blooms

We have continued our efforts to measure cyanobacteria blooms in Clear Lake using a variety of remote sensing methods, led by our graduate student Samantha Sharp. Satellite-based remote sensing of cyanobacteria blooms is emerging as a useful tool for researchers and water managers because of the high spatial coverage and the frequent data availability. However, a limitation of currently available multispectral cyanobacteria algorithms is that they detect the presence and abundance of cyanobacteria but do not tell you whether a bloom contains cyanobacteria species that produce cyanotoxins. With the upcoming launches of satellites with hyperspectral sensors, higher spectral resolution data will be readily available. These rich datasets will allow for new algorithms to be developed based on detailed spectral differences between targets. With the prospect of these upcoming hyperspectral satellite missions, Samantha's research focuses on exploring the use of hyperspectral data to distinguish algal bloom types, with the goal that the dominant genera of cyanobacteria may be distinguished to determine if cyanotoxins may be present in an algal bloom, which has public health repercussions. During the summer and fall of 2022, Samantha Sharp collected hyperspectral data and phytoplankton samples coincident with DESIS image collections to refine remote sensing tools for algal species at Clear Lake (Fig. 4).

Fig. 4. Hyperspectral image collected during a DESIS flight in October 2022

1.10. Numerical Modeling: progress on water quality modeling

The field and laboratory measurements are essential to build, calibrate, and validate a three-dimensional (3-D) numerical lake model. The processes the model simulates are organized into two groups: those that characterize how the water moves (i.e. *hydrodynamic*) and those that modify nutrients and algae in the lake (i.e. *water quality*). In 2021 we completed the calibration and validation of the hydrodynamic model. Root mean square errors for temperature are less than 1^{o}C between modeled and observed lake temperatures for a two-year simulation in all Clear Lake basins. We are concurrently developing a water quality or biogeochemical model to simulate the evolution of different constituents, such as dissolved oxygen, nitrogen species, phosphorus species, phytoplankton, and suspended solids. This model will include cyanobacteria as one of the phytoplankton groups (Fig. 5). This module needs the same type of calibration/

validation described for the hydrodynamic module. So far, we have conducted the following tasks:

- We have worked on the development of algorithms to represent the different nutrient cycles (P, N, C) and dissolved oxygen at Clear Lake.
- We have worked on the input files to run the Water Quality Model for Clear Lake.
- We have run the developed 3D Aquatic Ecological Model (AEM) for nutrients and phytoplankton and compare results with data collected in the summer of 2020 when the highest data quality is available so far.

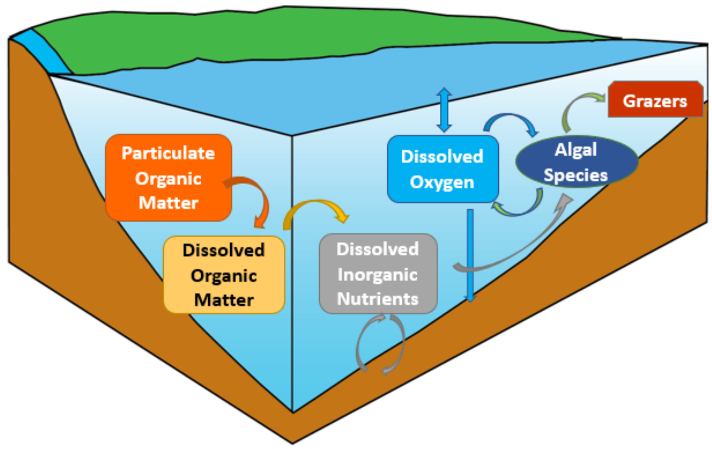

Fig. 5. Conceptual diagram of the biogeochemical model developed for the 3D Clear Lake model

- We have started monthly meetings with USGS watershed modeling team members (Michelle Stern and Dina Saleh) to coordinate the modeling products of this project (watershed and lake).

1.11. Bathymetrical survey update

In early 2022, we successfully onboarded a research staff member dedicated to the collection of bathymetry data at Clear Lake. We also integrated the necessary survey equipment onto the research vessel. The project team conducted over three weeks of field operations at Clear Lake in May/June 2022. In late June 2022, we ceased survey operations on Clear Lake due to water levels being too low to launch our survey vessel (<-0.5 ft Rumsey). Data collected during the 3-week initial survey showed some data quality artifacts due to hardware and software interferences (Fig. 6).

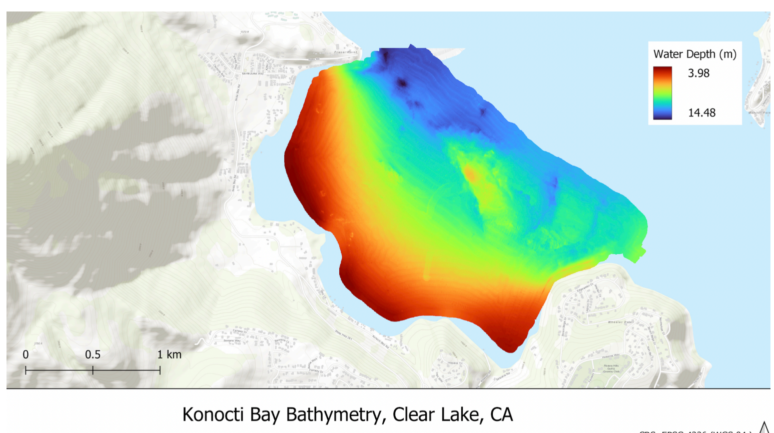

Fig. 6. Konocti Bay bathymetrical map, Clear Lake

Over the summer we resolved the hardware/software issues of our sonar equipment by troubleshooting in Lake Tahoe. As a result, we are confident that we can collect high-quality bathymetric data efficiently once water levels rise enough to resume the survey. The troubleshooting process revealed many sub-optimal system configurations. This includes both software settings and physical locations of instruments on our vessel. The instrumentation has now an adequate mount and location on the vessel to minimize interference. We plan to purchase software that allows us a more accurate data collection and post-postprocessing of the raw data. The software allows us to maintain higher (on the order of 10 cm or better) horizontal resolution more consistently using proprietary triangulation algorithms. The software will also correct for vessel motion (pitch, roll, head) with the required accuracy after the data has been collected.

We are appreciative of the support provided by the USGS Volcanology Section for this work.

2. UC Davis TERC Next Steps in 2023

2.1. Continue bathymetrical survey

We are developing an efficient workflow to make sure that raw data can be organized, backed up, and processed readily as soon as it is collected in the field. That will ensure final products from the sonar survey are produced in a timely fashion. The lead sonar operator is attending a week-long, immersive, training course in early December 2022 to ensure optimal workflows and facilitate the training of other staff. Progress on the sonar survey depends on water levels at Clear Lake. Once the Rumsey gauge is above -0.5 ft Rumsey, we can launch our survey vessel with the modified equipment configuration and updated software. We estimate that this will happen and, hence, we will be able to start surveying again before spring 2023.

2.2. New Proposal: ‘Early warning system for HABs’

During the next cycle of proposals for consideration of the BRC in 2023, TERC would like to present a new project about an early warning system for HABs, which consist of a model-based early warning system, that comprises a one-dimensional model to provide an initial risk index and a three-dimensional lake model forecast of HAB location for the coming three days. The three-dimensional lake model will use daily remote sensing data for initial conditions and a combination of measured meteorological data and National Weather Service forecast meteorological data to “drive” the model. Three-day lake forecasts will be published daily on a public website. This forecasting tool will provide water purveyors, members of the tribes, and the general public with lead time to respond to episodic HAB events.

2.3. Link 3-D model to mercury model (USGS)

A new contract is being established with CNRA for mercury modeling, to involve USGS, private consultants, and TERC. The project team has started planning for the project which is anticipated to commence in January 2023. The addition of a mercury model to the lake 3D model will provide projections of mercury levels throughout the lake and would be the basis for developing a food web model for predicting levels of methylmercury in fish and other biota.

2.4. On-going work on wildfire smoke impacts

In the fall of 2020, TERC was awarded an NSF RAPID grant to measure the impacts of wildfire smoke and particulates on the productivity of lakes in the western US. During the wildfires that occurred in our region in 2022, we have continued our post-fire sampling to investigate the smoke impacts in Clear Lake and other lakes such as Lake Tahoe affected by the wildfires. We have also conducted multiple data analysis tasks with the data collected during the last two years.

PART B: U.S. Geological Survey (USGS): Watershed Monitoring and Modeling in Clear Lake Tributaries

1. USGS Accomplishments in 2022

1.1. Four stream gages installed

USGS constructed stream gages and began monitoring stream flow, water temperature and turbidity at four new locations in Clear Lake tributaries. The links in the table below are to real-time data for the parameters indicated.

USGS Station	Station Name	Flow	Turbidity	Temperature
11449255	Scotts Cr at Hwy 29 nr Upper Lake	G	A	A
11449235	Clover Cr bypass at Elk Mtn Rd nr Upper Lake	G	A	A
11449820	Cole Cr at Kelseyville CA	G	A	A
11449370	Molesworth Cr nr Old Hwy 53	G	A	A

G = Gage height only (pending rating curve)
A = Active

Because of the lengthy permitting process, the four gages listed above were not activated until late September 2022.

USGS also operates and maintains three other stream gages on Clear Lake tributaries.

USGS Station	Station Name	Flow	Turbidity	Temperature
11449500	Kelsey C nr Kelseyville	D	--	--
11448750	SF Scotts C nr Lakeport	D	A	A
11448800	Scotts C bl SF Scotts C nr Lakeport	D	A	A

D = Discharge
A = Active
– Not measured

Operation and maintenance of the gages on Scotts Creek and South Fork Scotts Creek are funded by the Bureau of Land Management (BLM). Station 11448800 also has an ISCO autosampler and the USGS computes daily sediment loads.

1.2. Water-Quality Sampling

The USGS team carried out water-quality sampling at nine Clear Lake Tributary locations during Water Year 2022 (October 2021 through September 2022). Sampling at the three sites in Scotts Creek drainage was funded by the BLM. The number of samples at each location is summarized below in Table 1.

USGS Station Number	USGS Station Name	WY 2022 samples	Filtered and unfiltered nutrients (UCD TERC lab)	Filtered and unfiltered nutrients (USGS lab)	Filtered and unfiltered mercury species (USGS lab)
11449235	CLOVER C BYPASS A ELK MTN RD NR UPPER LAKE CA	6	6		6
11449500	KELSEY C NR KELSEYVILLE CA	7	7		
390030122502101	KELSEY C AB SODA BAY RD BR NR KELSEYVILLE CA	6	6		6
391057122544301	MIDDLE C A RANCHERIA RD BR NR UPPER LAKE CA	7	7		7
391227122553101	MIDDLE C BL ELK MOUNTAIN RD BR NR UPPER LAKE CA	4	4		
391448122565601	MIDDLE C NR VANN CA	4	4		
11448750	SF SCOTTS C NR LAKEPORT CA *	8	1 #	8	
390236122575901	SCOTTS C A SCOTTS C ROAD NR LAKEPORT CA *	8	1 #	8	
390544122574201	SCOTTS C AB EICKHOFF RD BRIDGE NR LAKEPORT CA *	8	1 #	8	
	Totals	**58**	**37**	**24**	**19**

* BLM funding — # Inter-lab comparison

(Note that USGS station number 390236122575901 is located about one mile downstream of USGS gaging station 11448800.)

The USGS team coordinated with UC Davis and Lake County regarding water sampling. Lake County staff collected water samples at some of the same sites during 2022 (at different times) and some additional sites. Water samples collected by Lake County were transported by USGS to Davis, where they were filtered at UC Davis and then submitted to the UCD TERC lab.

1.3. Sediment Fingerprinting

USGS collected streambed, streamside, soil, roadside ditch, and integrator samples throughout the Clear Lake tributary watersheds (Table 1). The tributaries that are being sampled for this work are: Adobe Creek (ADB), Burns Valley and Molesworth Creek (BVM), Clover Creek (CLV), Cole Creek (COL), Kelsey Creek (KEL), Manning Creek (MAN), Middle Creek (MID), Schindler Creek (SCH), and Scotts Creek. Scotts Creek is subject to the highest density of sampling and was discretized into the following sub-watersheds: Benmore Creek and South Fork Scotts Creek (BSF), Black Oak Springs and Lyons Valley Creek (BLV), Blue Lakes (BLL), Cooper Creek and Dayle Creek (CDC), Middle Scotts Creek (SCB), Scotts Creek Main (SCM), Tule Lake (TLL), and Willow Creek and Eight Mile Valley (WEM). Much of the work performed in the

Scotts Creek watershed was supported by Bureau of Land Management (BLM) funding, to fingerprint and track sediment and nutrient sources coming from BLM's South Cow Mountain Off-Highway Vehicle (OHV) Recreation Area. Sampling methods and analyses from the BLM-funded work coincide with those applied to the rest of the Clear Lake tributary samples so a common dataset will be established for all Clear Lake tributaries.

To balance the study design and sample collection efforts throughout the Clear Lake watershed, many of the tributary watersheds were paired together based on proximity, regional lithologies, land use, and other similarities. The final configuration was: ADB and MAN, BVM and SCH, CLV and MID, COL and KEL, Upper Scotts Creek (BSF, BLV, SCM, WEM), Middle Scotts Creek (SCB), and Lower Scotts Creek (BLL, CDC, TLL). Each of the tributary watersheds, including all Scotts Creek sub-watersheds, were assigned 'integrator' sites, which will be sampled multiple times over approximately a one-year period to evaluate possible seasonal effects on some parameters being measured.

The overall sediment fingerprinting study design calls for 750 samples to be taken – 75 each from 10 watersheds or subwatersheds; the 75 samples from each area will be distributed as 15 of each of the 5 sample types indicated in Table 1. As of December 2022, a total of 386 sediment fingerprinting samples have been collected to date (Fig. 1); to date, about half of the samples have been shipped to USGS Sample Control in Denver, CO for sample preparation (drying and sieving), and the rest will follow during early 2023.

Table 1: A summary of sediment fingerprinting samples collected in the Clear Lake tributaries. Samples organized by tributary and sample type.

Tributary	**Streambed sediment**	**Streamside**	**Soil**	**Roadside ditches**	**Integrator**	**Totals**
ADB + MAN	10	10	3	3	8	34
BVM + SCH	0	0	0	0	8	8
CLV + MID	7	4	7	1	15	34
COL + KEL	15	14	2	2	8	41
Scotts Creek	61	62	49	57	40	269
Totals	93	90	61	63	79	386

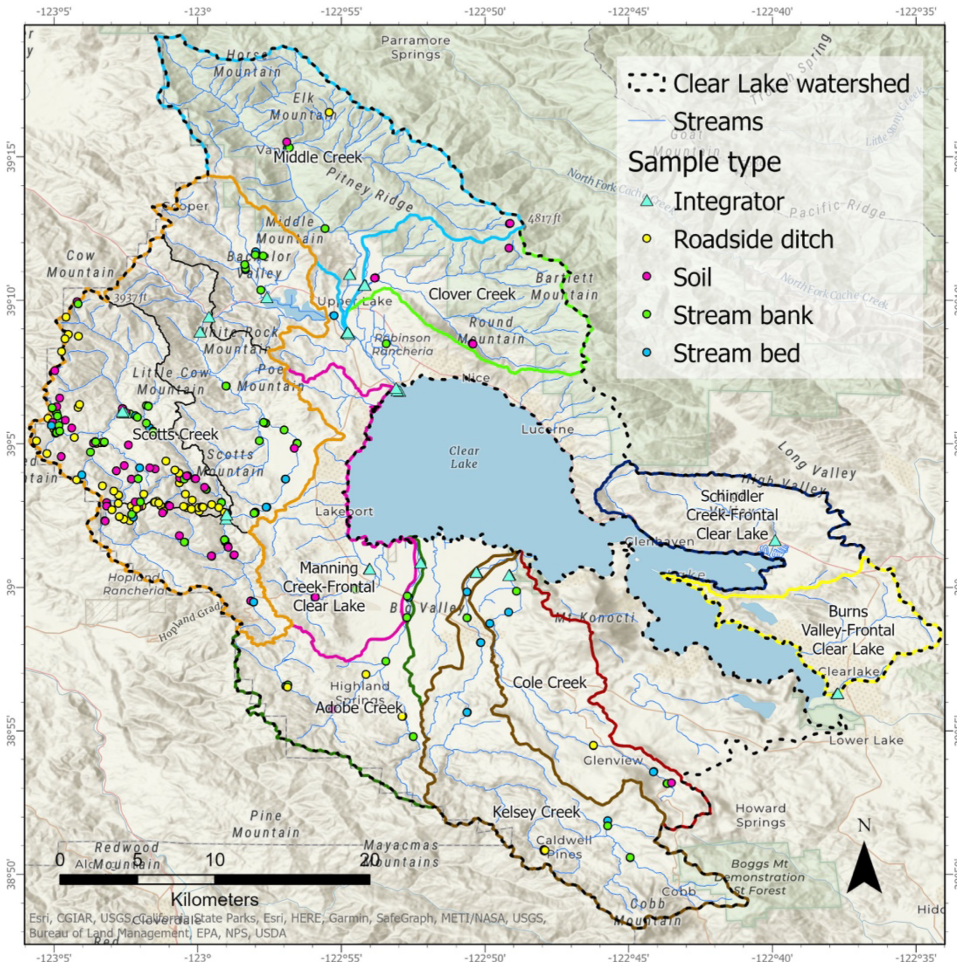

Fig. 7: Map of the Clear Lake watershed depicting tributaries and samples collected in 2022.

1.4. Rainfall-Runoff Modeling (HSPF)

We collected hourly weather data from 33 precipitation and 24 air temperature sensors in and surrounding the Clear Lake study area. Quality assurance/ quality control procedures were run to remove erroneous and extreme outliers. These stations will be interpolated (Figure 7) to produce gridded hourly climate grids that drive the HSPF and SPARROW models.

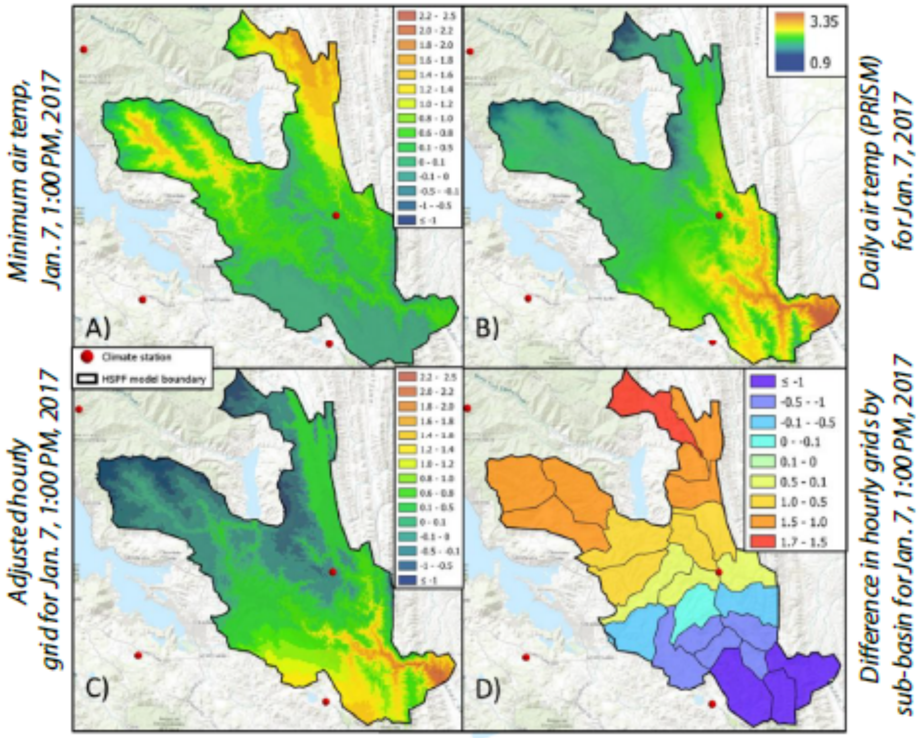

Fig. 8: Interpolation steps from hourly station data to gridded weather grids for Cache Creek, CA.

We worked with Task 2C lead Dina Saleh to use consistent sub-watershed basins for both models. Initial models were built for each tributary that flows into Clear Lake using the BASINS software, including sub-watershed delineation and stream network processing. Initial parameters were set up for each model and sub-basin, and GIS layers of soil properties, land use, elevation, and geology were downloaded and clipped to the study area for further parameter development. We began individual model testing and troubleshooting. We attended meetings with our UC Davis colleagues to coordinate model input and output requirements and to develop a timeline for completing major milestones. We also attended the Blue Ribbon Committee Clear Lake Open House meeting on December 13, 2022.

1.5. Mass-balance Modeling (SPARROW, Spatially Referenced Regression on Watershed attributes)

We are developing a SPARROW model to represent the sources, fate, and transport of nutrients and suspended sediment in streams in the Clear Lake watershed during 2022-2024 time period. The model will estimate mean seasonal total nitrogen, total phosphorus, and suspended sediment loads and yields in monitored and unmonitored stream reaches. The model will also quantify the relative contribution of different sources to total nitrogen, total phosphorus, and suspended sediment loads and yields. We compiled detailed historical datasets that describe water-quality conditions in all of the sub basins during the 2012 water year obtained from Wise

(2019) (https://pubs.er.usgs.gov/publication/sir20195112), to evaluate the hydrologic conditions during that time period. These databases include agricultural practices (fertilizer and manure application), atmospheric deposition, geology, soils, and land-use data, and other datasets that affect the fate and transport of nutrients and suspended sediment in the watershed (Fig. 9).

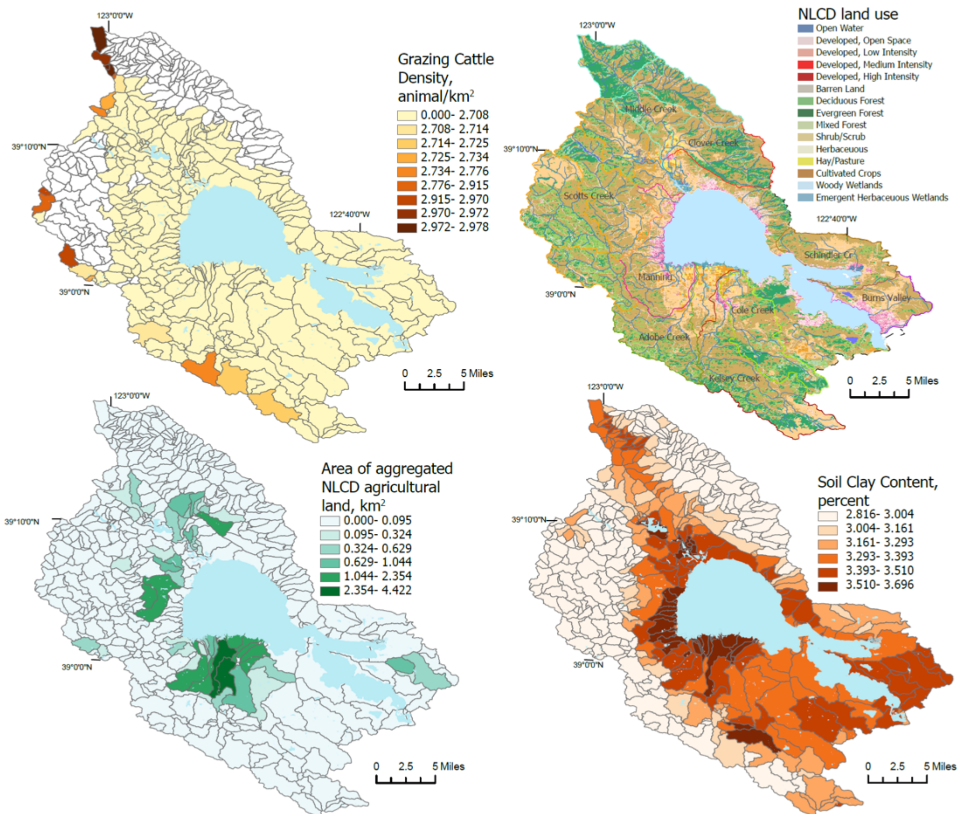

Fig 9. SPARROW data sets

Some of these datasets (for example, fertilizer and manure applications) will be updated for the 2022-2024 time period. These datasets will be used in developing the SPARROW model and used either as nutrient or sediment source terms or as delivery terms that transport nutrients to downstream portions of the watershed or the lake. We accumulated and verified stream reach attributes for the Clear Lake watershed from the NHD-Plus dataset (https://www.usgs.gov/national-hydrography/nhdplus-high-resolution). These attributes include a comprehensive set of digital spatial data that contain information about surface water features such as lakes, ponds, streams, and rivers, as well as the sub basin watershed boundaries. These data sets were formatted into the SPARROW input file for the first time period, and we will continue to format the entire 2022-2024 time period on a seasonal time step.

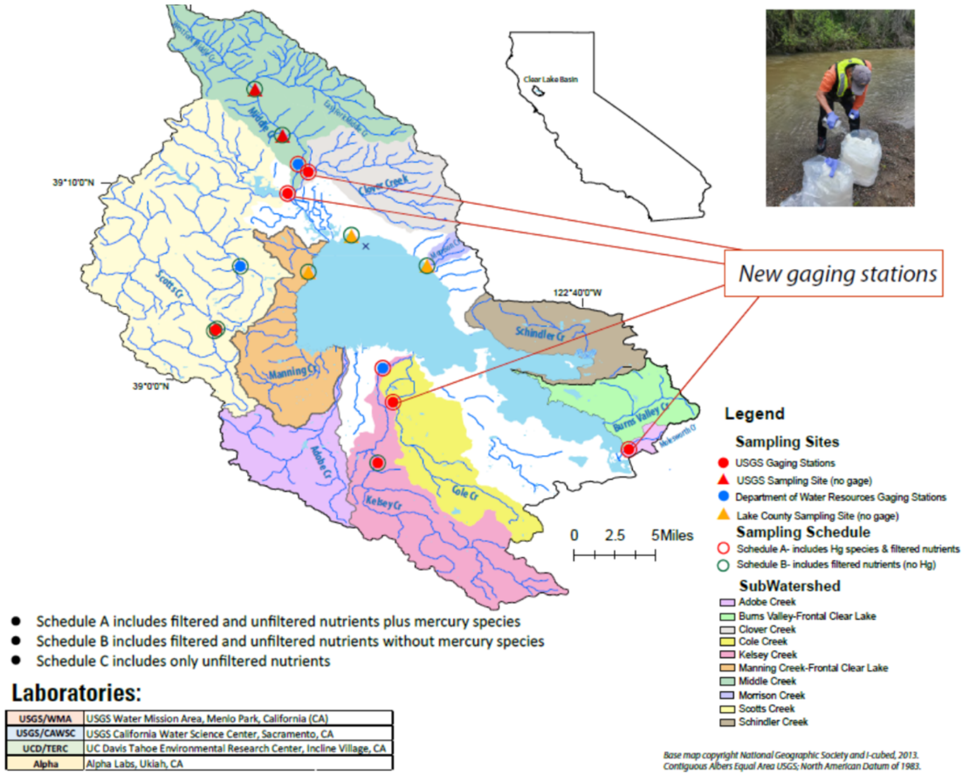

Fig. 10. Water-sampling locations for Clear Lake tributaries.

We retrieved historic streamflow data from 3 USGS and 3 California Department of Water Resources (DWR) gaging stations (Fig. 10). Data from 4 new USGS gaging stations (Figure 9) will be retrieved when available. We also retrieved historic water quality data from the DWR sites. All this data was formatted to be used for load calculations and will be used to calibrate the SPARROW model.

Updates to the Dynamic SPARROW model were obtained from the USGS National SPARROW team. This new model was evaluated, applied, and calibrated to a different watershed to give us a better understanding of the new model and how to apply it to the Clear Lake watershed.

1.6. Web portal with data access

USGS has developed two public Internet sites to allow for overall information on the project and to view water quality and discharge for the individual stream sites monitored for this study. The first site (https://www.usgs.gov/centers/california-water-science-center/science/hydrologic-and-aquatic-ecology-studies-clear-lake) provides general information about the water quality and aquatic ecology studies in progress at Clear Lake. From this site, the user can click on the Web Tools link which will then direct the page to the Watershed Monitoring in Clear Lake Tributaries page. A direct link to the monitoring Internet page is (https://www.usgs.gov/tools/watershed-monitoring-clear-lake-tributaries). This page directs the viewer to a map of the watershed which shows boundaries of individual stream watersheds and monitoring sites. The monitoring sites include USGS stream gaging stations where water-quality samples are also collected, California Department of Water Resources stream gaging stations where water-quality samples are also collected, and additional locations for water-quality sampling without stream gaging stations both for USGS and Lake County. The viewer can click on an individual station where further information on each site can be accessed, such as river discharge and/or water quality.

1.7. Participation in BRC and Technical meetings

Members of the USGS team participated in quarterly BRC meetings and monthly BRC Technical Subcommittee meetings. The USGS team participated in the BRC Open House on December 13th by making a short oral presentation and providing a booth with posters explaining the USGS role in the project and a computer monitor with access to the new public web sites described above.

2. USGS Next Steps in 2023

2.1. Operation and Maintenance of Stream Gages

The USGS stream gages will continue to be operated and maintained throughout Water Year 2023 (October 2022 – September 2023) and will continue through Water Year 2024 (October 2023 – September 2024). Flow is typically seasonal at most of the sites; no flow is expected during May to September.

2.2. Water-Quality Sampling

Water sampling of Clear Lake tributaries during Water Year 2023 will continue to be coordinated among USGS, UC Davis, Lake County, and other stakeholders.

2.3. Sediment Fingerprinting

USGS will continue sample collection efforts in the next year. In addition to the 750 samples planned from the tributaries, an additional 45 samples are planned from the lakebed. The goal is to collect the remaining streambed, streamside, soil, roadside ditch, and lakebed samples by Spring of 2023. The integrator sites will be sampled periodically until each integrator location has a total of 15 samples. Most of the sample locations on public land have been collected. The next phase will require coordinating with many private landowners in Lake County. We will continue to build a working relationship with the local landowners and private citizens as we move toward completing the field work portion of this task.

Samples will be submitted to USGS Sample Control in Denver for processing by late Spring or early Summer. We expect to work closely with our colleagues in Denver to ensure the processed samples are received by laboratories for analysis in a timely manner. Planned analyses include: major and trace elements; nutrient species (forms of nitrogen and phosphorus); forms of carbon (organic, inorganic, and pyrogenic); stable isotopes of carbon, nitrogen, and strontium; and grain-size distribution.

We expect to receive laboratory data for all submitted samples by late 2023. Once data are received it will go through a process of QA/QC and subsequently be published in a USGS data release. The data will be used for sediment fingerprinting calculations to determine sediment sources by watershed and land use / vegetation type.

2.4. Rainfall-Runoff Modeling (HSPF)

Over the next year, USGS will develop the gridded weather inputs and calculate potential evapotranspiration to run the models. The initial HSPF model parameters for streamflow, sediment, and nutrients will be enhanced using land use, soil properties, elevation, and geology. The initial HSPF models will be calibrated in three steps: 1) streamflow will be calibrated using available stream gage data, 2) sediment will be calibrated using sediment data collected at gages and parameterized using any available data from the sediment fingerprinting task, and 3) nutrients (nitrogen and phosphorus) will be calibrated in a similar method to the sediment calibration with any available nutrient data. Model outputs will include hourly streamflow, sediment transport, and nutrient loads. As new data are collected at each of the gages and from the sediment fingerprinting task, model calibration and validation will be performed iteratively as necessary. We will work closely with the SPARROW and UCD modeling teams to ensure communication about model outputs and future climate and land-use scenarios.

2.5. Mass-balance Modeling (SPARROW)

Over the next year, the USGS will continue to develop the input data set (Data1 file) needed to run the SPARROW model on a seasonal time step for the 2022-2024 period. This data set will include updated agricultural inputs based on county and state estimates of fertilizer applied to agricultural land and from livestock manure waste from confined animal operations, and from unconfined animals on farms, pastures, and rangelands; streamflow, runoff and recharge data obtained from the HSPF model developed in task 2B; climate data (temperature, and precipitation), and land use classifications obtained from the 2016 National Land Cover Database (NLCD) (http://www.mrlc.gov/nlcd.php). We will continue to collect nutrient and suspended sediment data from all USGS and DRW gaging stations.

2.6. Enhancement of web portal

The water quality portal will be enhanced during 2023 with continuous updates on water quality collected over the time frame of the project and some historical water quality. Additional enhancements will include graphical information on when water quality samples were collected relative to stream flow at individual sites, as well as improved coordination regarding nutrient data collected and analyzed at the UC Davis Tahoe Environmental Research Center with uploads to the USGS National Water Information System. Further enhancements will include results for the mass-balance and rainfall-runoff modeling described above.

2.7. Participation in BRC and Technical meetings

Members of the USGS team will continue to participate in quarterly BRC meetings and monthly BRC Technical Subcommittee meetings, as well as future BRC Open House meetings.

References

Wise, D.R., 2019, *Spatially referenced models of streamflow and nitrogen, phosphorus, and suspended sediment loads in streams of the Pacific region of the United States (ver. 1.1, June 2020):* U.S. Geological Survey Scientific Investigations Report 2019-5112, 64 p., https://doi.org/10.3133/sir20195112.