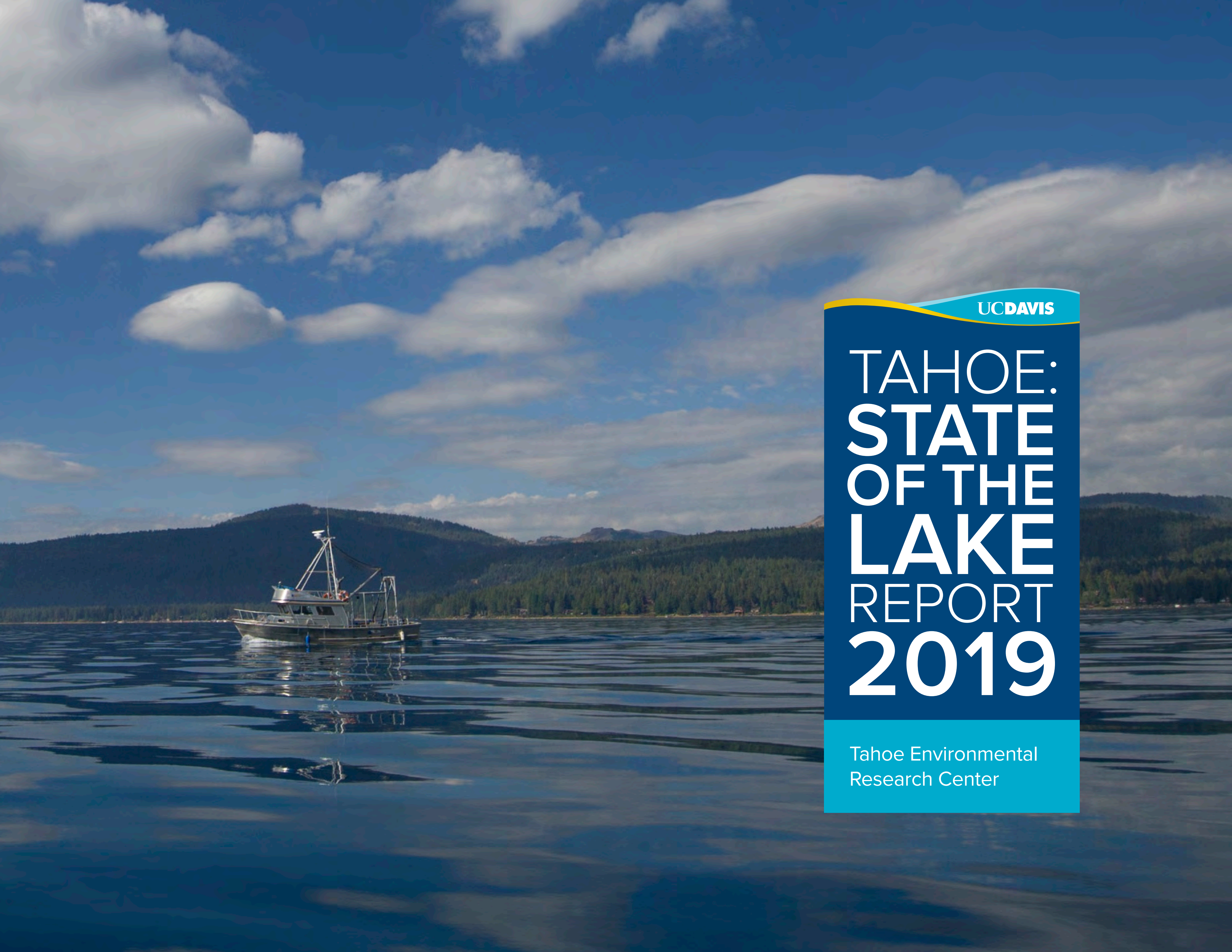

UC DAVIS

TAHOE: STATE OF THE LAKE REPORT 2019

Tahoe Environmental Research Center

FUNDING TO ASSEMBLE AND DISTRIBUTE THIS REPORT WAS PROVIDED BY THE FOLLOWING SPONSORS:

California Environmental Protection Agency
Lahontan Regional Water Quality Control Board

California Tahoe Conservancy

Tahoe Fund
Together Creating a Legacy

Tahoe Regional Planning Agency

Tahoe Lakefront Owners' Association

$5000 and above

Lake Tahoe Marina Association

Keep Tahoe Blue
League to Save Lake Tahoe

Nevada Division of Environmental Protection

parasol
Tahoe Community Foundation

Tahoe Water Suppliers Association
TWSA
Protect the Source
www.tahoeh2o.org

$1000 to $2500

Incline Village
Waste Not

under $1000

TABLE OF CONTENTS

(CONTINUED ON NEXT PAGE)

TABLE OF CONTENTS, CONTINUED

INTRODUCTION

The University of California, Davis has conducted continuous monitoring of Lake Tahoe since 1968, amassing a unique record of change for one of the world's most beautiful and vulnerable lakes.

In the UC Davis Tahoe: State of the Lake Report, we summarize how natural variability, long-term change and human activity are affecting the lake's clarity, physics, chemistry, and biology. We also present part of the data collected in 2018 – presenting all of it would be a monumental task. While Lake Tahoe is unique, the forces and processes that shape it are the same as those acting in most natural ecosystems. As such, Lake Tahoe is an indicator for other systems both in the western United States and worldwide.

Our goal is to understand the lake's complexity and to use the knowledge gained to provide the scientific underpinnings for ecosystem restoration and management actions. Choosing among those options and implementing them is the role of management agencies that also need to take into account a host of other considerations. This annual report is intended to inform non-scientists about variables that affect lake health. One indicator of Lake Tahoe's health status, the annual clarity is reported earlier each year. In this report we publish many other environmental and water quality factors that all provide indications of the lake's condition and help explain the lake's changing clarity.

This report sets the context for understanding the changes that are seen from year to year and those that are observed over time scales of decades. We also present updates on current research taking place independently of the long-term monitoring. This highlights some of the most exciting and promising findings of work that is still in progress, and will be reported on fully in the months and years to come.

The data we present are the result of efforts by a great many scientists, engineers, students, and technicians who have worked at Lake Tahoe throughout the decades since sampling commenced. I would, however, like to acknowledge (in alphabetical order) the contributions of Brant Allen, Jonathan Arthur, Karen Atkins, Brandon Berry, Brooke Boeger, Mike Bruno, Tom Burt, Luciana Cardoso, Sudeep Chandra, Danny Cluck, Bob Coats, Stephanie Coppeto, Mark Enders, MJ Farruggia, Alex Forrest, Nick Framsted, Susan Frankel, Drew Friedrichs, Charles Goldman, Nick Gomez, Cordie Goodrich, Scott Hackley, Karen Hagerman, Tina Hammell, Bruce Hargreaves, Simon Hook, Camille Jensen, Yufang Jin, Jackson Kuzmik, Kwungwoo Lee, Anne Liston, Patricia Maloney, George Malyj, Elisa Marini, Jasmin McInerney, Devin Middlebrook, Patricio Moreno, Siya Phillips, John Reuter, Bob Richards, Will Richardson, Gerardo Rivera, Derek Roberts, Steve Sadro, Goloka Sahoo, Heather Segale, Katie Senft, Steven Sesma, Samantha Sharp, Roland Shaw, David Smith, Sheri Smith, Adrianne Smits, Drew Stang, Erin Suenaga, Jae Sung, Micah Swann, Lidia Tanaka, Raph Townsend, Alison Toy, Sean Trommer, Seung Tae, Sergio Valbuena, Aaron Vanderpool, Shohei Watanabe, Andy Wong, and Carmen Woods to this year's report. In particular, Shohei Watanabe was responsible for the majority of the data analysis and Alison Toy led the compilation of the final report.

Funding for the actual data collection and analysis has come from many sources over the decades. While many additional water quality variables could be tracked, funding ultimately limits what we measure and report on. Current funding for the long-term monitoring and analysis is provided by the the California Tahoe Conservancy, Lahontan Regional Water Quality Control Board, Tahoe Regional Planning Agency, U.S. Geological Survey, and UC Davis.

Funders for current projects include the following: California Tahoe Conservancy, Institute for Museum and Library Services, Nevada Department of Tourism and Cultural Affairs, Nevada Division of Environmental Protection, Nevada Division of State Lands, Tahoe Fund, and Tahoe Truckee Community Foundation.

Our monitoring is frequently done in collaboration with other research institutions and agencies. In particular, we would like to acknowledge the Desert Research Institute (DRI), the National Aeronautics and Space Administration (NASA), the Tahoe Resource Conservation District (TRCD), the U.S. Forest Service (USFS), the U.S. Geological Survey (USGS), and the University of Nevada, Reno (UNR).

We are very proud to recognize the funding support for the actual production of this annual report from the following organizations: California Tahoe Conservancy, Incline Village Waste Not Program, Lahontan Regional Water Quality Control Board, Lake Tahoe Marina Association, League to Save Lake Tahoe, Nevada Division of Environmental Protection, Parasol, Tahoe Fund, Tahoe Lakefront Owners Association, Tahoe Regional Planning Agency, and Tahoe Water Suppliers Association. We sincerely thank these organizations for their dedication in supporting science to save the lake.

Sincerely,

Geoffrey Schladow, director
UC Davis Tahoe Environmental Research Center
291 Country Club Drive

EXECUTIVE SUMMARY

The long-term data set collected on the Lake Tahoe ecosystem by the University of California, Davis and its research collaborators is an invaluable tool for understanding ecosystem function and change. It has become essential for responsible management by elected officials and public agencies tasked with restoring and managing the Tahoe ecosystem. This is in large part because it provides an independent basis for assessing the progress toward attainment of Tahoe's restoration goals and desired conditions, while at the same time building our understanding of the natural processes that drive the ecosystem.

The UC Davis Tahoe Environmental Research Center (TERC) is increasingly using new approaches to enrich the long-term data record for Lake Tahoe. These include real-time measurements at over 25 stations around the basin; remote sensing from autonomous underwater vehicles, satellites, and aerial drones; and the deployment of a suite of numerical models. These tools are all focused on quantifying the changes that are happening; and, at the same time, understanding what actions and measures will be most effective for control, mitigation, and management.

This annual Tahoe: State of the Lake Report presents data from 2018 in the context of the long-term record. While we report on the data collected as part of our ongoing, decades-long measurement programs, we also include sections summarizing current research that is being driven by the important questions of the day. These include: the continuing decline of lake clarity during the summer months and a potential ecological approach to restoring it; the vastly different climate that Tahoe basin will experience in the coming decades and what this could mean for current planning and management activities; the direct linkage between the alga *Cyclotella* and clarity; new findings on the physical processes that occur in the lake based real-time measurements in the nearshore; and growing threats to Lake Tahoe's aspens. The impact that TERC's researchers are having at locations far from Tahoe are also highlighted.

Summer clarity has been declining in the long term at Lake Tahoe, and largely offsetting the gains made in winter clarity. With projections of future climate change indicating accelerating warming and earlier runoff from streams, the decline in summer clarity is expected to continue, threatening the progress that has been made in the last 20 years. Recent results suggests that a novel ecological approach, focused on the removal of the Mysis shrimp that was introduced in the 1960s, may be able to restore the lake's native zooplankton, increase the clarity at to levels not seen in decades, and in the process "climate proof" the clarity of the lake. Increased clarity and the return of the native zooplankton carries with it the additional benefits of rapid growth of native fish and a natural impediment to the growth of invasive fish and plants.

Climate change is expected to impact all aspects of the Tahoe basin in the coming decades. The most serious of these changes are likely to be driven by changes in the physical processes, not simply the change in air temperature. The temperature

(CONTINUED ON NEXT PAGE)

[1]*"Previous year" for some parameters means data collated in terms of the water year, which runs from October 1 through September 30; for other parameters, it means data for the calendar year, January 1 through December 31. Therefore, for this 2019 report, water year data are from Oct. 1, 2017 through Sept. 30, 2018. Calendar year data are from Jan. 1, 2018 through Dec. 31, 2018.*

EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.1)

distribution in the lake will suppress mixing, critical for oxygenation of the deep waters. At the same time, the continuing transition from a snow-based to a rain-based climate will result in the peak stream-flows occurring months earlier than they historically have. Aside from consequences for fish spawning, the loss of snowpack water storage will also mean a drying of the forests and the consequent elevated wildfire risk.

In 2018 the tiny diatom, a type of algal cell, *Cyclotella* again impacted summertime clarity levels. Even though *Cyclotella* biomass was relatively smaller in 2018, its small size and its dominance in the surface waters means that it comprises the largest number of algal cells above the level of the Secchi disk.

Five years ago, a novel monitoring program was commenced with the installation of eleven real-time water quality stations around the periphery of the lake. Over that time, an entirely new set of insights and knowledge about Lake Tahoe have been developed. Aside from quantifying water quality in different parts of the nearshore, we have been able to create predictive tools for turbidity and periphyton sloughing all around the lake, better understand the conditions under which stream inflows mix as they enter the lake, and– most importantly– have discovered a new "wave" that propagates around the boundary of Lake Tahoe. The existence of this wave had previously been inferred, but now the measurements and the model results have confirmed its existence and its importance.

Though the devastation wrought on Tahoe's forests by the recent drought seem to have passed from our memory, new threats to the health of the forests have emerged. The most prominent of these is the threats white satin moth, which is defoliating stands of Aspen in parts of the basin. Some of these trees are considered "heritage trees" as carvings on their trunks can be dated to an earlier era when Basque sheepherders brought their flocks into the basin. With successive cycles of defoliation these trees will eventually die.

Meteorologically, 2018 was a very uneventful year. Air temperature and precipitation were similar to what the long-term trend lines. Similarly, the percentage of snow in the total precipitation was 31.5 percent, almost identical to the previous year, but down from one hundred years ago when it was closer to 50 percent. The snow depth on March 29, 2018 was 121 inches, a very average year, far below the values this year when on March 29, 2019 it was 198 inches.

Lake Tahoe has been warming since regular measurements commenced in 1968. Surface water temperatures in particular have been increasing. For 2018, the average surface water temperature was 53.2 °F (11.8 °C). This is the second warmest surface temperature year recorded. The maximum daily summer surface water temperature was one of the highest observed at 77.5 °F, which was recorded on August 6, 2018. Over the month of July, surface water temperature averaged 67.3 °F, the third warmest July on record. The warming of the surface prevents the lake from fully mixing in winter. In 2018, Lake Tahoe mixed to a depth of 935 feet. This lack of deep

(CONTINUED ON NEXT PAGE)

EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.2)

mixing most likely contributed to the warm surface temperatures, and the continuing buildup of nitrate in the lake.

Nutrient inputs via streams are a major source for nitrogen and phosphorus, and the total load typically varies with the annual precipitation. With 2018 being an average precipitation year, nutrient inputs were closer to average than the previous very wet year. Within the lake, nitrate concentration was at an all-time high of 20.9 micrograms per liter, the result of the seventh successive year in which deep mixing did not occur. Phosphorus, measured as total hydrolysable phosphorus (THP), was at its highest level since 1989 for the same reason.

Biologically, the primary productivity of the lake has increased dramatically since 1959. By contrast, the biomass (concentration) of algae in the lake has remained relatively steady over time. The annual average concentration for 2018 was 0.65 micrograms per liter. For the period of 1984-2018, the average annual chlorophyll-a concentration in Lake Tahoe was 0.70 micrograms per liter. From an abundance viewpoint, diatoms were the most common algal group (60 percent of the cells). Of these, *Synedra* and *Nitzschia* were the most common during every month of the year. *Cyclotella* was a lower fraction of the diatoms in 2018, but it still had a large impact on clarity. The peak biovolume in 2018 was 320 cubic millimeters per cubic meter, almost double the biovolume in the last three years, a reflection of the increase in *Synedra* and *Nitzschia.* The attached algae (periphyton) on the rocks around the lake were particularly heavy in 2018, based on a synoptic survey of 53 observations. This was in part due to the relatively steady water level. Ironically, the four individual sites that are annually used to compare year to year variations were all abnormally low.

In 2018, the annual average Secchi depth was 70.9 feet (21.6 m), a 10.5 foot increase over the previous year. The highest individual value recorded in 2018 was 100.0 feet (30.5 m) on March 6 and the lowest was 50.0 feet (15.2 m) on July 27. The increase this year is attributed to a return to more normal conditions, following the five-year drought and the heavy snow year that ended it. While the average annual clarity is now better than in preceding decades, it is still short of the clarity restoration target of 97.4 feet. The winter (December - March) clarity value of 73.5 feet was a decrease of 5.2 feet. This was largely the result of the previous year's extremely low clarity conditions. Summer (June-September) clarity was 61.7 feet, an 8.2 foot increase from 2017. The cause of the improvement was a return to more normal summer conditions.

This report is available on the UC Davis Tahoe Environmental Research Center website (http://tahoe.ucdavis.edu/stateofthelake).

ABOUT LAKE TAHOE AND THE TAHOE BASIN

- Maximum depth: 1,645 feet (501 meters), making it one of the deepest lakes in the world and second deepest lake in the United States
- Average depth: 1,000 feet (305 meters)
- Lake surface area: 191 square miles (495 square kilometers)
- Watershed area: 312 square miles (800 square kilometers)
- Length: 22 miles (35 kilometers)
- Width: 12 miles (19 kilometers)
- Length of shoreline: approximately 75 miles (120 kilometers)
- Volume of water: 39 trillion gallons, plus or minus
- The daily evaporation from Lake Tahoe (half a billion gallons) would meet the daily water needs of 5 million Americans
- The number of algal cells in Lake Tahoe is approximately 30 million trillion
- Number of inflowing streams: 63, the largest being the Upper Truckee River
- Number of large lakes worldwide with annual clarity exceeding Tahoe's: 0
- Number of outflowing streams: one, the Truckee River, which exits at Tahoe City, California, flows through Truckee and Reno, and terminates in Pyramid Lake, Nevada.
- Length of time it would take to refill the lake: about 600 years
- Average elevation of lake surface: 6,225 feet (1,897 meters)
- Highest peak in basin: Freel Peak, 10,891 feet (3,320 meters)
- Latitude: 39 degrees North
- Longitude: 120 degrees West

ABOUT THE UC DAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER (TERC)

The UC Davis Tahoe Environmental Research Center (TERC) is a world leader in research, education and public outreach on lakes and watersheds, providing critical scientific information to help understand, restore, and sustain the Lake Tahoe Basin and other systems worldwide. Since 1968 UC Davis has undertaken the continuous scientific monitoring of Lake Tahoe, creating the foundation on which to base restoration and stewardship efforts.

TERC's activities are based at permanent research facilities in the Tahoe Basin and at the University's main campus in Davis, California, about 90 miles west of the lake.

Our main laboratories and offices are in Incline Village, Nevada, on the third floor of the Tahoe Center for Environmental Sciences building.

On the first floor, we operate the Tahoe Science Center, an educational resource for K-12 students and learners of all ages, that is free and open to the public.

In Tahoe City, California, we operate a field station (housed in a fully renovated, former state fish hatchery) and the Eriksson Education Center. Tahoe City is also the mooring site for our research vessels, the John LeConte and the Bob Richards.

Our secondary laboratories and offices are located on the UC Davis campus at the Center for Watershed Sciences and in Wickson Hall.

At locations throughout the basin, we have sensors continuously reporting on the health and well-being of the lake and its environs, making Lake Tahoe the smartest lake in the world.

Our website (http://tahoe.ucdavis.edu) has more information about our programs, including:

- Information for potential students, staff, faculty, research collaborators and visitors;
- Access to near-real-time data gathered by our growing network of sensors;
- An extensive list of Tahoe research publications;
- Exhibits and events at the Education Centers; and
- Information about supporting our research and learning programs.

TAHOE BASIN DATA COLLECTION SITES