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.

This annual *Tahoe: State of the Lake Report* presents data from 2013 in the context of the long-term record. While the focus is on data collected as part of our ongoing, decades-long measurement programs, this year we have also included sections summarizing current research on establishing a novel, basin-wide Nearshore Water Quality Network, the monitoring of algal growth potential in the nearshore, climate change (from the past and into the future), dissolved oxygen loss from the deepest parts of the lake, the wave environment of Tahoe, wetland design guidelines, and nearshore clarity changes due to storms.

The UC Davis Tahoe Environmental Research Center (TERC) has developed sophisticated computer models that help scientists better predict and understand how Lake Tahoe's water moves and how the entire ecosystem behaves. Long-term data sets are an essential element in constantly refining the accuracy of those models and in developing new models as knowledge increases and new challenges arise. These models could be used to address a variety of questions – where would a contaminant spill be carried?; what are the likely next locations for the spread of invasive species within the lake?; will lake oxygen be depleted by climate change; and what will the consequences be?

With respect to **weather**, 2013 saw the continuation of dry conditions for a second year at Lake Tahoe. The winter of 2012-2013 had 80 percent of the long-term average precipitation. The fraction of precipitation that fell as snow continued the downward trend at 32 percent. While December 2012 was exceptionally wet, January through April 2013 were all well below the long-term mean. Air temperatures were colder in winter and warmer in summer than the long-term average. The number of days with below-freezing temperatures was close to the long-term trend line of declining below-freezing days. As a consequence, the peak in the timing of the snowmelt was also close to the long trend line of earlier occurrence of spring conditions, occurring on May 15.

Lake level rose by only 6" during the spring snowmelt, one of the lowest increases on record. The elevation difference between peak lake level and the lowest lake level in 2013 was 2.73 feet, falling at an average rate of decline of 1.1 inches per week. The volume-

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[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 2014 report, water year data are from Oct. 1, 2012 through Sept. 30, 2013. Calendar year data are from Jan. 1, 2013 through Dec. 31, 2013.

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averaged lake temperature rose again in 2013. Following the cooler temperatures of the last decade, it is now close to the long-term trend of increasing temperature. July surface water temperatures were the highest recorded in 5 years, at 65.6 deg. F, an increase of 1.8 deg. F over the previous year. Other consequences of climate change could also be seen in the rising temperature of the deep waters of the lake. In the last 38 years bottom temperatures have increased by over one deg. F.

Lake Tahoe did not **mix** to its full depth in 2013, the second consecutive year in which this has not happened. Instead, the maximum depth of mixing was only 590 feet, reached in March. The lack of mixing was due to a second year of above average lake stability. The upper 330 feet of the lake stayed stratified for 187 days, three weeks longer than what was typical when the record began.

River releases from Lake Tahoe to the Truckee River occur at the dam in Tahoe City. Water temperature has been monitored there by the USGS since 1993. Though the data set is incomplete, there is evidence that the summertime release temperatures have increased significantly over that period, suggesting potential impacts on downstream fish spawning. Summer (July-September) water releases have increased for the last two years, despite falling water levels in both of those years.

The input of **stream-borne nutrients** to the lake was low again in 2013 due to the low precipitation and subsequent run-off. Both phosphorus and sediment inputs from the streams were even lower than 2012, although still larger than the loads during the drought years of the early 1990's.

Overall **in-lake** nitrate concentrations have remained relatively constant over the 33 years of record. By contrast, in-lake phosphorus concentrations display a downward trend over the same period, having decreased by almost 50 percent.

Biologically, the primary productivity of the lake continued its long-term increase in 2013, with the annual average value of 230.9 grams of carbon per square meter. The reasons for this increase are believed to be linked to a long-term shift towards smaller algal species that have the ability to process nutrients faster. Despite the increase in lake productivity, the concentration of chlorophyll in the lake has remained relatively constant over time. In 2013 there was a decrease in the abundance of diatom cells in the lake, down from the peaks experienced in 2009 to 2011. In particular the concentration of *Cyclotella* was reduced. This small-sized diatom can exert a large influence on lake clarity. Higher numbers of this group over the last six years compared to historical values had been linked to climate change and had resulted in summertime clarity reductions. This year's reduction

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coincided with an improvement in clarity.

Periphyton, or attached algae, on the rocks around the shoreline continues to show variability from site to site. The long-term monitoring program has helped identify those areas of the shoreline that are consistently displaying periphyton levels that are undesirable. Lake Tahoe agencies are now keenly aware of the need for further investment in science to better understand the root causes of nearshore degradation in general. A recent report prepared by researchers from TERC, DRI and UNR laid out a strategy for nearshore monitoring that would provide a minimum level of status and trend analysis. A more detailed set of studies to explain what is causing nearshore degradation, focused on the known problem areas, will elucidate the processes and mechanisms that are controlling nearshore conditions. While some of the strategies utilized for restoring midlake clarity will also benefit the nearshore, a focus on projects that directly affect the urban nearshore are important. TERC's new real-time nearshore water quality network will play a crucial role in those efforts by creating a link between nearshore water quality and measured meteorology, streamflow and stormwater flow.

This year the annual average **Secchi depth**, a measure of lake clarity, was consistent with the long-term halt in clarity degradation. While the annual clarity value was 5 feet lower than last year (a degree of inter-annual variability that is not unexpected), this was mainly due to the high precipitation that occurred in the early winter. Year-to-year fluctuations are the norm, and the long-term goal must be seen as attaining a level of clarity which on average meets the basin's standards. Summer clarity was almost identical to the previous year at 63.8 feet, and continues the recent cycle of improvement. It has improved by over 13 feet from values that were measured just 2 years ago.

In **new research**, TERC is launching the Real-time Nearshore Water Quality Network in August 2014. This unique partnership between private property owners and science will see the deployment of advanced instruments at 20 sites around the shoreline. The instruments will provide minute-by-minute data on the key water quality indicators of nearshore health and will allow researchers to begin exploring solutions that agencies can implement.

Climate change research continues to be a major focus. Using a combination of our long-term data sets and powerful modeling techniques, it is possible to quantitatively examine how climate change has affected Lake Tahoe in the past and will continue to affect it through the present century. Changes in the length of the seasons will alter the way in which water moves in

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the lake, leading to the possible loss of dissolved oxygen at the bottom of the lake. To measure this threat and to prepare mitigation measures, TERC is conducting autonomous measurements of dissolved oxygen from the deepest parts of the lake. These types of data are unique, and are of value to understanding the threats to freshwater ecosystems worldwide as well as here at home.

Understanding how best to control **invasive species**, particularly Asian clam, is an ongoing priority. TERC and its research partner UNR are continuing to work with agency staff on an experiment to control the satellite population of this invader at the mouth of Emerald Bay. The site has presented new challenges that are unique to Emerald Bay compared with other regions of the lake. These include strong currents, complex sub-surface conditions that permit oxygen-rich water to reach deeply buried clams, and cold water conditions that our divers need to contend with in winter. Despite the challenges, there has been clear evidence of some success, including clam mortality of about 90%. This project is a great example of the growing collaboration between science and resource managers.

Stormwater monitoring and the designing of new infrastructure to help control lake clarity has been a major focus. Working with agencies in the basin we are monitoring the loads of fine particles that are delivered to the lake by drains and culverts every time it rains. We have also developed LiDAR based maps that are being used to identify small depressions in the landscape that can be used to locate hundreds of "distributed detention basins" that have the capacity to store and infiltrate stormwater before it reaches the lake. Constructed wetlands are another important tool, and student research has provided important data on how they should best be designed.

The **waves** we often see on the lake have also been shown to impact the lake. While they are the most important factor in resuspending sediment in the nearshore region, research has shown that the sediment there is coarse and it quickly settles back down. On the other hand, the waves produced by large winter storms can generate tremendous damage to nearshore infrastructure and property. New modeling tools now allow us to predict these waves for any set of storm conditions.

This report is available on the UC Davis TERC website (http://terc.ucdavis.edu/stateofthelake/).