Models clarify Tahoe clarity loss

Phil Schermeister

Tahoe is one of the most beautiful lakes in the world, with such clear blue water that you could once see to depths of more than 100 feet. But Lake Tahoe's extraordinary clarity has declined for half a century and today you can usually only see to depths of about 70 feet.

While the water has gotten less clear, UC researchers have elucidated one important thing: the causes for the murkiness. Just about anything in the Tahoe Basin from eroded soil to air pollutants can end up in the lake, so restoring its clarity will require basinwide management. To help guide this process, UC Davis researchers have developed a model that accounts for what gets into the lake, where it goes once it's in the lake, and finally how it all affects clarity.

"The model connects land-use and policy decisions to what's actually going on in the lake," says Ted Swift, who worked on the lake clarity model while at UC Davis and is now an environmental scientist at the Department of Water Resources in Sacramento.

Lake Tahoe is so clear because it is very deep and the water that goes into it is very pure. The lake reaches a depth of about 1,650 feet, making it among the 10 deepest worldwide and one of the deepest nationwide, second only to Oregon's Crater Lake, which reaches a depth of about 1,950 feet.

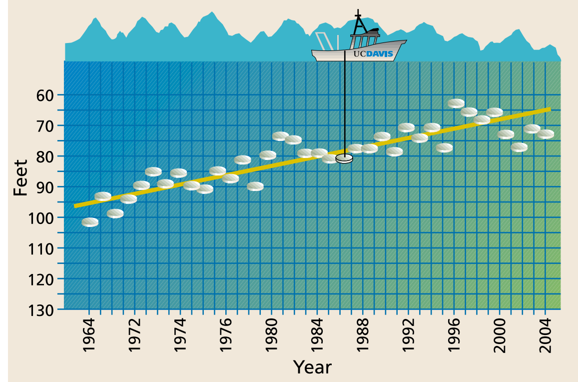
The water that goes into Lake Tahoe is so pure for two reasons, Swift explains. First, much of it falls directly into the lake as rain or snow because the watershed is small relative to the lake's surface area (roughly 300 square miles vs. 200 square miles). Second, the water that drains into the lake has historically been low in nutrients and sediments, Swift says, partly because the watershed is small and partly because it is mostly granite so the soils are relatively sterile.

Why is clarity declining?

"Old-timers say Lake Tahoe is not as clear and blue as it used to be. It's still beautiful but it is gradually getting milkier and greener," Swift says. The research documenting the lake's 30% clarity decline was pioneered by UC Davis limnologist Charles Goldman (see page 45), who in the late 1960s began systematically measuring its Secchi depths. This simple but powerful technique entails lowering an

John Stumbos

Historically, erosion into Lake Tahoe has been low because of the high percentage of granite and granitic soils in the watershed.



Above, **Using the white Secchi disk to measure water transparency, UC Davis scientists have documented a decline in Lake Tahoe's clarity.** ***Right,*** **Brant Allen (middle) of TERC and Jeremy Sokulsky (top) of the Lahontan water board lower the Secchi disk into Lake Tahoe. While visibility is sometimes as deep as 130 feet, the trend is toward declining clarity.**

8-inch white disk until it can no longer be seen by the naked eye, yielding annual averages based on more than 30 measurements taken regularly over the course of each year (see figure).

The two main culprits in the clarity decline are excess nutrients and sediments. Nutrients — particularly phosphorus but also nitrogen — increase the growth of algae, which in turn absorb and scatter light. The growth rate of algae near the lake surface has quadrupled over the last 35 years (see figure, page 46). Sediments both carry nutrients and scatter light themselves, and more than 10 tons of sediment are added to the lake each year from sources including erosion from development, road dust and engine exhaust.

Contaminants enter the lake in streamflow and fall directly onto its surface from the air — and then they persist because the lake has such limited outflow that water stays for an average of 700 years.

Lake Tahoe: From research to policy

Nearly 40 years after UC Davis limnologist Charles Goldman established the Tahoe Research Group, concern over the lake's diminishing beauty culminated in the Lake Tahoe Presidential Forum. "This place is amazing. It's a national treasure that must be protected and preserved," Vice President Gore told the forum on July 26, 1997. President Clinton then announced that he had just signed an executive order to ensure greater cooperation among the many groups working to protect the lake. Today, UC Davis and 10 affiliated research institutions as well as 19 federal, state and local agencies are participating in a concerted effort to restore Lake Tahoe's clarity.

Now called the Tahoe Environmental Research Center (TERC), the research group Goldman founded is part of the UC Davis John Muir Institute of the Environment, which is dedicated to solving environmental issues by bringing together researchers, regulatory agencies and the public. Besides serving as an umbrella for UC Davis's Tahoe research, TERC facilitates collaboration with researchers elsewhere, notably the University of Nevada, Reno; the Desert Research Institute in Reno; and the Scripps Institution of Oceanography in La Jolla. A biennial science conference on Lake Tahoe met last in 2004; five of the many studies presented are published in this issue of California Agriculture (see pages 53-82). Its next meeting is in October 2006.

TERC is currently housed in a former fish hatchery in Tahoe City, Calif., an outdated facility

Heather M. Segale, UC Davis TERC

Alan Heyvaert (left) of the Desert Research Institute and John Reuter of the UC Davis Tahoe Environmental Research Center (TERC) monitor construction of a new 45,000-square-foot Tahoe Center for Environmental Sciences in Incline Village. The wetland site of the old facility, a former fish hatchery in Tahoe City, will be restored.

Sylvia Wright/ UC Davis

it plunges toward the bottom. While contaminants can also settle to bottom, it takes years for the smallest particles to get there. And even then, they can come back up.

The analysis of satellite data has revealed that water jets rise from the depths and go shooting across the lake. The jets are several miles wide and "can go clear across the lake in half a day," says Geoffrey Schladow, a UC Davis environmental engineer who directs the Tahoe Environmental Research Center (TERC). "It took us by surprise." Driven by winter winds, these water jets typically mix the lake only about three-fifths of the way down, but every few years they mix it completely to the bottom.

For more info:

Pathway 2007 factsheet:
www.tiims.org/tiimswebsite/ContentProjects/Pathway2007/factsheets/Pathway2007.pdf

Tahoe Environmental Research Center:
http://terc.ucdavis.edu/index.html

Role of lake mixing

Equally important is where all the contaminants go once they are in the lake. "The muck we see is in the top 300 feet," Swift says.

The destination of contaminant-laden streamflow depends on its temperature relative to the lake: when the streamflow is warmer, it shoots across the surface; when the streamflow is colder,

Contaminants and visibility

The next step is determining how the contaminants affect visibility in the surface waters of Lake Tahoe. Swift and colleagues developed an optical model of the lake that predicts Secchi depths based on factors including algae and sediments (Aquatic Sciences, in press). The model showed that sediments account for more than half of the lake's clarity loss, and that the smallest particles (less than 8 microns) have the biggest impact.

In addition, the optical model accurately predicts seasonal dips in clarity that are observed in

For the first time, agencies are now coordinating their 20-year plans for Lake Tahoe

that has only 1,000 square feet of laboratory and office space. "Charles Goldman used to say, 'We're doing first-class research in a third-class facility'," says Heather Segale, TERC education and outreach coordinator.

But soon the researchers will also have a first-class facility, the Tahoe Center for Environmental Sciences, a joint project between UC Davis and Sierra Nevada College that is scheduled to be completed in August 2006 in Incline Village, Nev. Designed to be environmentally friendly, with features including plenty of natural light and solar panels, the 45,000-square-foot center also has ample common space to foster collaboration and the exchange of ideas among researchers.

To help inform policy, UC Davis and its affiliated institutions formed the Tahoe Science Consortium, which in August 2005 signed an agreement to work more closely with the federal and state resource-management agencies responsible for protecting Lake Tahoe. "At the science end, all the scientists will report to a representative board; the same is true at the policy end," Segale says. "Then the two boards will get together so the policymakers can ask key management questions, and the scientists can provide answers and direct research."

The agencies are also working more closely with each other, in a process called Pathway 2007. The main agencies overseeing Lake Tahoe are the Tahoe Regional Planning Agency, which was created by Congress in 1969 to regulate development on both the California and Nevada sides of the lake; the USDA Forest Service; the Lahontan Regional Water Quality Control Board, which is responsible for water quality on the California side; and the Nevada Division of Environmental Protection, which is responsible for water quality on the Nevada side.

Adding to the mix, this spring UC will hire a Cooperative Extension natural resource advisor to conduct programs in the basin.

"For the first time, agencies are now coordinating their 20-year plans for Lake Tahoe," Segale says. — *Robin Meadows*

December and June. During winter, the top 150 or so feet of water cools and the wind then mixes the lake, bringing algae, nutrients and sediments up from deeper waters. During summer, the streamflow is relatively warm and so spreads across the lake's surface waters, concentrating the fine particles it carries there. "The small volume of stream water has an amplified effect on clarity," Swift says.

Based on the various factors that affect visibility, from contaminants to lake mixing to optics, TERC researchers developed a comprehensive clarity model that predicts Tahoe's Secchi depths. Contaminants from streams are estimated based on monitoring a subset of the 63 streams that feed into the lake, while contaminants from the air are monitored by the California Air Resources Board. Lake mixing is driven by the local weather, which is monitored by TERC. So far, the lake clarity model has been tested on Secchi depths that have already been observed. "The model agrees very well with the last 3 to 4 years of data," Schladow says. "Next we'll project the lake's clarity over the next 20 years under various management scenarios."

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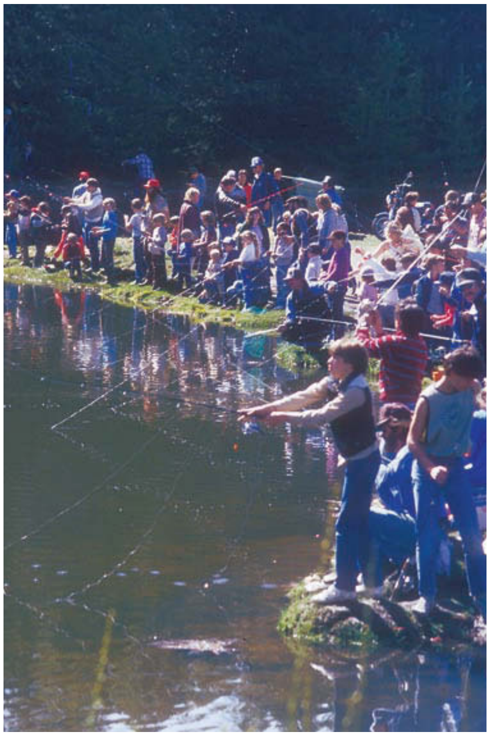

Lake Tahoe's popularity as a tourist destination has increased substantially since the 1950s, bringing with it increased pressure on its limited resources. *Above*, a fishing derby at Sawmill Pond.

Restoring clarity

The current management goal, which was set by the Tahoe Regional Planning Agency (see sidebar, page 50), is to restore the lake's clarity to that of the early 1970s, when the Secchi depth was about 95 feet. However, whether this goal can be reached remains to be seen. "I think it's achievable to stop the decline and improve the clarity," Schladow says. "I don't know if we can reach 95 feet. It depends on what the model shows about the sources [of contaminants]."

One barrier to restoring Lake Tahoe is that the contaminant sources and their relative impacts are not yet fully understood. For example, while recent research shows that the atmospheric nutrients in the lake are primarily from within the Tahoe Basin (see page 53), the primary atmospheric sources of fine sediments remain unknown. If the latter are mostly from the Central Valley, they will be harder to control than if they are mostly from within the Tahoe Basin. "We need to identify where gains can be made," Schladow says.

Similarly, the relationships between Tahoe Basin land uses and lake clarity are not well understood. TERC researchers are currently investigating the effects of land uses — from forests (see page 65) and wetlands to development and ski areas. Recent research shows that local urban forests may affect biodiversity and ecosystem function (see page 59).

Another big unknown is how climate change will affect the lake's clarity. Temperatures in large lakes worldwide are rising about twice as fast as those in oceans, and UC Davis ecologist Robert Coats has found that Lake Tahoe has warmed nearly 0.9° F over the last 30 years. Warmer waters could mean less mixing, which could make clarity either better or worse: the former by keeping more nutrients in the depths, and the latter by not diluting sediments in the surface. "There are two competing processes," Schladow says. "We're learning not to be foolish enough to say 'this is going to happen next year'."

Warming could also favor different kinds of algae than those that currently dominate Lake Tahoe. While the lake has hundreds of algal species, only about a dozen dominate during any given time period and they can have very different effects on clarity. At its clearest, the lake was dominated by diatoms, which are compact and so scatter light less, but now the lake has lots of algae that have long filaments and so scatter light more.

Reasons for hope

Despite the progressive decline in clarity and the many unknowns, hope remains for restoring Lake Tahoe. There are still days when the lake is so clear that you can see to depths of 130 feet or more, and the annual clarity improves by as much as 3 feet during drought years, when streamflow and thus nutrient and sediment levels are low. This suggests that controlling erosion could have a huge impact, which makes sense because the lake has a natural cleaning process in that sediments eventually do settle to the bottom.

Encouragingly, erosion control may indeed be feasible in the Tahoe Basin. Recent research shows that fine sediments in runoff can be reduced by a combination of soil restoration and pine needle mulch (see page 72) as well as other treatments (see page 77). In addition, most of the wetlands around the lake have been lost to development, and restoring them is a promising way to keep sediments and nutrients from reaching the lake. "If we can bring these levels back down, the lake has a fair chance of regaining much of its fabled clarity," Swift says.

— *Robin Meadows*