Environmental Problems Facing Lake Tahoe

Algal Growth

TERC research has shown that the rate of algal growth has been steadily increasing over the past 40 years. In fact, the rate of algae growth in Lake Tahoe has quadrupled since 1959. This trend continues to increase at a rate of approximately 5 percent to 6 percent per year (see annual algal growth chart). This increase in growth is believed to be due to a reduction in the size of the phytoplankton in the lake, and a faster turnover rate of nitrogen and phosphorus in the Lake. These two nutrients have become unnaturally abundant in the lake because of human caused (anthropogenic) disturbances. The primary anthropogenic sources are accelerated erosion, fertilizer use, car exhaust and urban runoff.

Sediment Erosion

Erosion of soil and sediment occurs naturally by water and wind but recently accelerated erosion has been occurring due to human caused disturbances. Driving on roads, motor vehicles on dirt trails, and development are all sources of erosion and soil disturbances. These activities grind up soil and sediment into microscopic particles. The extremely small particles (1 – 10 microns) are especially harmful to water clarity. These small particles get into the lake via the air, storm drains and tributaries. Some particles are so small that they stay suspended in the water column and are believed to be the major contributor to Lake Tahoe's long term clarity loss (Swift et al. 2005).

Pollution

Pollution, primarily from the more urbanized areas around the lake has become a problem for Lake Tahoe. Pollution takes many forms, and can include litter, sediment, nutrients, oil and grease, and pathogens. Lake Tahoe suffers from increased loads of fine sediment and dissolved nutrients. The nutrient inflows, mostly phosphorus and nitrogen, are literally fertilizers, which support the growth of free-floating and attached algae.

Eutrophication

Eutrophication refers to the effects of an overabundance of nutrients. Eutrophication occurs naturally as part of the overall aging of a lake. The normal life cycle of a lake begins with clear water that becomes progressively browner/greener due to sedimentation and algae growth. Over time the layers and layers of dead organisms and sediment will fill up the lake, turning it into a marsh and then finally into a meadow. This process normally occurs over millions of years; however, we are seeing the effects of eutrophication happening at an accelerated rate. This accelerated eutrophication of Lake Tahoe is primarily due to the nutrients and the sediments that are entering the lake at rates higher than what would naturally occur at Lake Tahoe. If we do not make a conscious effort to reduce these inputs, we could witness catastrophic changes within our lifetimes.

Cultural Eutrophication

Cultural eutrophication refers to the acceleration of the natural process of eutrophication by anthropogenic changes. These changes can include such things as disturbed watersheds from roads and urbanization. The pavement, rooftops and other impervious surfaces shed over 90 percent of all precipitation. Instead of being filtered by the soil, the water runs off the surface rapidly. Surface runoff typically concentrates in ditches and gullies, causing soil erosion. When these higher-than-natural flows reach streams, increased streambank erosion occurs. Cumulatively, these alterations lead to greater loads of fine particles and nutrients to the lake.

Changes in the Food Web

Species diversity in Lake Tahoe has been greatly affected by the intentional and unintentional introduction of exotic species, and many communities of both plant and animal life have undergone significant change since studies began. In the case of phytoplankton, these communities have a direct impact on lake clarity. For other species, changes have affected the lake's food web and consequently have altered its fishery. Mysis shrimp were introduced into Lake Tahoe with the intention of providing additional food for the fish to increase fish size; however, this introduction had major effects on the aquatic food web.

Introduction of Non-Natives

In attempts to improve the Lake Tahoe's fishery, many fish and invertebrate species have been introduced into Lake Tahoe and surrounding waters, most with limited success. These non-natives cause changes in the food web and in food web energetics.

Invasive Species

During the last 130 years numerous nonnative fish, invertebrate, and plant species have been introduced to Lake Tahoe. Invasive species such as Asian clams, Eurasian watermilfoil, Curly-leaf pondweed, and fish species such as bigmouth bass, smallmouth bass, bluegill and carp are now found regularly in Lake Tahoe. Whether intentional, accidental or illegal, these species introductions have had profound negative effects on the lake's food web, native species assemblages, and have greatly altered native habitats. Current management efforts are aimed at preventing the introduction of Quagga or Zebra mussels into the lake. Mandatory boat inspections are currently required for all boats entering the lake.

Destruction of Wetlands

Lake Tahoe historically had natural wetlands that acted as filtration systems to remove excess nutrients from stream water before the runoff would reach the lake. This is one of the many reasons for Lake Tahoe's famously clear and pristine waters. Unfortunately, the value of wetlands was not fully known prior to the heavy development that began in the mid-1950s. For example, the Tahoe Keys was built on one of the largest wetlands in the Lake Tahoe basin. Research has shown that the wetlands of South Lake Tahoe used to remove tons of sediment and nutrients. The detrimental impact of this development can be easily seen during heavy runoff when plumes of sediment cause the waters to turn cloudy.

Examples of TERC Research Activities in the Lake Tahoe Basin

Researchers at Lake Tahoe have been gathering data since 1958 and have produced one of the longest continuous data sets available for a sub-alpine lake. This long-term record along with the research and analysis of these data contributes to the knowledge base on sub-alpine lakes worldwide and to the well-being of Lake Tahoe itself.

Ongoing Research and LTIMP Monitoring

An ongoing monitoring program is essential to water quality protection in the Lake Tahoe region. The goal of monitoring is to characterize water quality and the degree of support for beneficial uses on both temporal and spatial scales. 'Baseline' data can be used to set standards for water bodies that currently do not have site-specific standards. 'Trend' information defines the need for, and allows prioritization of, restoration and/or regulatory actions. Monitoring can also document compliance with permit conditions, and the success (or failure) of remedial activities. The UC Davis Tahoe Environmental Research Center has been an active member and committed partner in the Lake Tahoe Interagency Monitoring Program or "LTIMP." The mission of LTIMP is to develop integrated water quality research and monitoring strategies to support regulatory, management, planning and research activities in the Lake Tahoe Basin.

The current LTIMP monitoring projects conducted by TERC staff include the following:

Lake Tahoe profile monitoring is conducted every 7-10 days to determine changes in lake clarity and water column properties. This includes conducting Secchi disk measurements at the mid-lake and index station (off west shore near Homewood), measurements of primary productivity (see section on primary productivity sampling), profiles of temperature, conductivity, dissolved oxygen, light transmission and light attenuation using a "Seabird-SBE25", profiles of particle size and concentration using a LISST-100X, and water sampling for nutrient analysis and phytoplankton counts from discrete depths. Zooplankton samples are collected using a net pulled from 150 meters depth up to the surface. The zooplankton samples are stored and counted in Davis and include species such as Diaptomus and Epischura.

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Primary Productivity (PPr) sampling occurs every 30 days to measure the primary production in Lake Tahoe. Samples of water are collected from the surface down to 105 meters using a Van Dorn sampler for varied depth collection. Samples are then split into glass bottles, injected with an isotope of Carbon (C14), and then sent back down to the depth in which they were collected. After the samples are allowed to incubate for four hours, measurements can determine how much of this "labeled" carbon was "taken up" by the algae. This measures the instantaneous growth rate of algae.

Contact: Brant Allen, bcallen@ucdavis.edu

Monitoring of Periphyton: Brant Allen and Scott Hackley regularly don their wetsuits to collect samples of the attached algae that grows along Tahoe's shoreline. Attached algae, or periphyton, are good indicators of localized nutrients entering the lake. Researchers have been studying the attached algae in the shore zone of Lake Tahoe for the past 25 years. While the steady loss in lake clarity is sometimes difficult to visualize, the proliferation of periphyton is a readily apparent indicator to the public that the lake is changing in a detrimental way. The monitoring has indicated that there is a greater amount of growth in lakeshore areas where the upland is more developed. This green "ring around the collar" is a tell-tale indicator that Tahoe is changing.

Contact: Scott Hackley or Brant Allen, shhackley@ucdavis.edu or bcallen@ucdavis.edu

Stream Monitoring: TERC researcher Scott Hackley monitors three streams along the west shore of Lake Tahoe (Ward, Blackwood and General Creeks and the Truckee River just downstream of the dam at Tahoe City) in collaboration with the U.S. Geological Survey. Regular sampling is done monthly with more frequent sampling during the spring runoff and rain events. Water samples are analyzed for nutrients, suspended sediment, temperature and dissolved oxygen. Information from this monitoring is used to estimate the annual nutrient loads from streams and to discern trends in tributary water quality. Hackley also collects samples from Ward, Blackwood and General Creeks for a TERC project which is studying the particle contribution from tributaries. Fine particles contributed from tributaries and other sources have a significant direct negative impact on lake clarity.

Contact: Scott Hackley, shhackley@ucdavis.edu or Nancy Alvarez (USGS) nalvarez@usgs.gov

Atmospheric Deposition Monitoring: Atmospheric deposition of nitrogen (and to a lesser extent phosphorus) is an important source of nutrients to the lake. TERC currently monitors atmospheric deposition at four stations within the Tahoe basin. Two stations are located in Ward Valley and two are located on research buoys near the middle of the lake. Data collection from the stations on land in Ward Valley includes precipitation amount, timing, nutrient (N and P) content and pH. From the lower Ward Valley station, both "wet" deposition (rain and snow) and "dry" deposition (deposition occurring during dry periods) are collected using an Aerochem Metrics Wet/Dry sampler. At the Upper Ward station, "bulk" (wet plus dry precipitation) is collected. Bulk deposition data is collected from the two buoy stations using special buckets partially filled with deionized water as collectors (these mimic the lake water collection surface). A passive plastic-lined PVC sampler is also located on one buoy to collect wet and dry precipitation. Atmospheric deposition data from the lake buoys has provided important information on atmospheric deposition directly to the lake surface. The atmospheric deposition monitoring program provides ongoing information on nutrient loading via this important source of nutrients to the lake.

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Algal Bioassay Monitoring: Routine bioassays are done about six times per year to determine the nutrient or nutrients which most limit the growth of phytoplankton in Lake Tahoe. These are laboratory experiments in which treatments with known amounts of nitrogen (N), phosphorus (P), or N and P are added to flasks containing lake water and natural phytoplankton. The phytoplankton are incubated for six days in a laboratory incubator at ambient lake temperature and daily light cycles. During this time, algal growth is monitored. Increased growth caused by an N or P treatment relative to the control (a set of untreated flasks) after six days provides evidence of nutrient limitation by the nutrient added. The bioassay results can be useful in helping guide efforts for lake restoration. For instance, in the early 1980's a shift from N and P colimitation to predominant P limitation was observed. This highlighted a need for an expanded erosion control strategy, to control release of sediments and associated P to the lake.

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Current Research Projects

In addition to the routine monitoring that is undertaken by TERC there are a variety of ongoing, ever-changing research projects funded by national and state agencies. These are in areas as diverse as invasive species control, lake currents, remote sensing of lake water quality, sediment resuspension dynamics, lake food webs, computer modeling, landslide risk and wetlands performance. This research is conducted by TERC's graduate students, post-doctoral scholars, visiting scientists and our professional staff. Details of many of these projects are included on TERC's webpage, http://terc.ucdavis.edu.

State of the Lake

Please see the State of the Lake Report at http://terc.ucdavis.edu/stateofthelake/ for information about how Lake Tahoe is changing. In the *UC Davis Tahoe: State of the Lake Report*, we summarize how natural variability, long term change and human activity have affected the lake's clarity, physics, chemistry and biology. We also present the data collected in the previous year. The data reveals a unique record of trends and patterns – the result of natural forces and human actions that operate at time scales ranging from days to decades.

Each year different research areas emerge as the most topical in the *State of the Lake Report*. In past years we have focused on topics such as the Angora Fire, Climate Change, and the emergence of Asian clams as a major threat to Lake Tahoe's ecosystem. In 2011, we looked at changes in lake clarity, the issue that has most symbolized Lake Tahoe in the eyes of the world. Recent changes in lake clarity highlight the complexity of natural systems, and the extent to which monitoring is needed to understand and best protect our natural resources.

Lake Tahoe Vocabulary List

Terminology commonly used by scientists and researchers at Lake Tahoe:

Atmospheric deposition: Pollution from the air may deposit into water bodies and affect water quality in these systems. Airborne pollution can fall to the ground in raindrops, in dust or simply due to gravity. As the pollution falls, it may end up in streams, lakes, or estuaries and can affect the water quality there.

Bathymetry: the measurement of water depth at various places in a body of water

Best Management Practices (BMPs): structural BMPs include infiltration devices, ponds, filters and constructed wetlands and non-structural BMPs include low impact development practices and management measures such as maintenance practices, street sweeping, public education and outreach programs. Section 208 of 1972 Clean Water Act requires every state to establish effective BMPs to control nonpoint source pollution.

Erosion: the group of natural processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is worn away from the earth's surface.

Eutrophic: having waters rich in mineral and organic nutrients that promote a proliferation of plant life, especially algae, which reduces the dissolved oxygen content and often causes the extinction of other organisms. Used of a lake or pond.

Eutrophication: the process by which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Infiltration: to enter, permeate, or pass through a substance or area by filtering; infiltration is the process by which water on the ground surface enters the soil

Limnology: the scientific study of bodies of freshwater (as lakes); the scientific study of the life and phenomena of fresh water, especially lakes and ponds

Non-point Source Pollution (NPS): pollution coming from many small sources

Nutrients: a source of nourishment, especially a nourishing ingredient in a food; specifically, nitrogen and phosphorus

Oligotrophic: lacking in plant nutrients and having a large amount of dissolved oxygen throughout a pond or lake; having a deficiency of plant nutrients that is usually accompanied by an abundance of dissolved oxygen (as in a clear oligotrophic lake)

Phytoplankton: tiny (minute) free-floating aquatic plants; planktonic plant life (in Lake Tahoe these include diatoms, Chrysophytes, Chlorophytes, Cryptophytes and Dinoflagellites)

Plankton: microscopic organisms (see also phytoplankton and zooplankton); the passively floating or weakly swimming usually minute animal and plant life of a body of water

Micron: a unit of length equal to one millionth (10^{-6}) of a meter

Chlorophyll: any of a group of green pigments that are found in the chloroplasts of plants; the green photosynthetic pigment found in plants

Electrical conductivity: the ability to transmit electricity; conductivity is the ability of water to conduct an electrical current (dissolved ions in the water are conductors); conductivity is measured by an electronic probe, which applies voltage between two electrodes

Secchi Disk: an instrument commonly used for measuring the lake's clarity. It is a round, dinner-plate size desk that is lowered into the water. Once it can no longer be seen in the deep water, a scientist measures how far down in was lowered to determine the water's clarity.

Streamflow: discharge of water from a stream; the amount of water flowing in a stream or river

Total Maximum Daily Load (TMDL): Section 303(d) of the 1987 Water Quality Act requires the states to list those water bodies that are not attaining water quality standards including designated uses and identification of relative priorities among the impaired water bodies. States must also develop TMDLs (Total Maximum Daily Loads) that quantify the pollutant load or the
impairing pollutants that will bring the waterbody back into attainment.

Thermocline: the region in a thermally stratified body of water which separates warmer surface water from cold deep water and in which temperature decreases rapidly with depth. As you go down farther and farther into the lake, the water stays about the same temperature as at the surface. But once you reach a certain depth boundary (the thermocline), the water's temperature starts decreasing rapidly with depth

Urban Runoff: storm water or non-storm water from urbanized areas (city streets, gutters, etc.) that is dirty and polluted. This water runs down the lake and contributes to the lake's loss of clarity.

Water Clarity: The depth to which light penetrates water. A lake that is composed of clear, clean water will have a much higher level or clarity than one that is polluted.

Zooplankton: plankton composed of animals; tiny aquatic animals that live in bodies of water, they are usually microscopic and are an important part of the food chain in water habitats (in Lake Tahoe these include Diaptomus, Epischura, Bosmina, Daphnia, Mysis shrimp, and several types of rotifers)

Lake Tahoe Facts

How did Lake Tahoe form?

Three to five million years ago, the valley that would become the Tahoe Basin sank between parallel fractures in the Earth's crust as the mountains on either side continued to rise. A shallow lake began to form in the resulting valley. Two to three million years ago, erupting volcanoes blocked the outlet, forcing the lake to rise hundreds of feet above its current elevation, and eventually eroding down to near its current outlet. Between one million and 20,000 years ago, large masses of glacial ice covered the west side of the Tahoe Basin. Current geologic theory suggests an earthen berm (moraine) left by a receding glacier near Squaw Valley acted as a dam, causing the lake level to rise and then draw down rapidly when the dam catastrophically failed. Between 7-15 thousand years ago, a four-mile segment of the West Shore collapsed into the Lake causing a massive submerged debris avalanche, widening the Lake by three miles, and creating McKinney Bay.

How high is the Tahoe Basin?

The surface of the Lake is at an elevation of 6,225 ft. above historical sea level. The surrounding mountain peaks vary from 9,000 to nearly 11,000 ft. Only 16 other large lakes in the world are higher.

How pure is the Lake and why?

The water is 99.994% pure, making it one of the purest large lakes in the world. The Lake owes it extraordinary purity to the relatively small watershed, the large amount of precipitation falling directly on the lake's surface, the dilution effect of the massive volume of water it contains and purification of runoff by adjacent wetlands.

Why is the Lake so blue?

The lake water appears blue in color as other colors in the light spectrum are absorbed and blue light is scattered back. In addition, under the right conditions, the Lake surface can reflect the color of the sky.

How clear is the water?

Clarity is determined by measuring the water depth at which an eight-inch diameter white disk disappears from view. In 2007, clarity averaged 70.1 ft., far less than the maximum 105 ft. of clarity measured in 1968.

How large and deep is the Lake?

The Lake's surface is 22 mi. long by 12 mi wide and 191 sq. mi. (122,200 acres) in area. The shoreline length is 75 mi. The average depth is 1,000 ft. A maximum depth of 1,645 ft. makes Tahoe the second deepest lake in the USA, third deepest in North America and 11th deepest in the world.

How much water is in the Lake?

The Lake holds about 40 trillion gallons of water, enough to cover the state of California to a depth of 14 ½ in. Between the regulated high and low water levels, the volume of water in Tahoe can vary by 243 billion gallons. Tahoe is the largest lake by volume above 600 ft. elevation in the USA.

Where does the water come from?

Snowmelt from 63 tributaries in the 315 sq. mi. watershed adds 65% of the water. Another 35% falls as precipitation directly on the Lake. Typically, 212 billion gallons of water enter the Lake this way each year.

Where does all the water go?

About one-third of the water flows into the Truckee River through the dam at Tahoe City for downstream use with any remaining water flowing to the river terminus at Pyramid Lake. The remaining two-thirds of water evaporate from the lake surface at an annual average rate of 0.1 inch per day. In a normal year, Lake Tahoe will see a net rise of 15 in. from spring runoff.

What is the weather like?

Average high temperature is moderate, ranging from the high 20's in winter to high 60's in summer. At least seven months per year, daily maximum temperatures reach the outdoor comfort zone. Sunshine occurs over 75% of the time during daylight hours each year. From November through March, 78% of the yearly precipitation occurs, mostly as snowfall. Typically, at lake level in Tahoe City, 14 ft. of snow falls over winter and accumulates to a maximum snowpack depth of 2.8 ft.

How cold is the Lake?

Below an average depth of 600 ft, water temperature is a near constant 40˚F. During July and August, surface temperature can reach 75˚F. In the coldest months, the lake surface temperature lowers to 40˚F.

Does the Lake ever freeze?

The main body of Lake Tahoe does not freeze. The stored heat in the Lake's massive amount of water compared to its relative surface area prevents the Lake from reaching freezing temperature under the prevailing climatic conditions. On rare occasions, Emerald Bay has developed full or partial ice cover and thin ice sheets can form on shallow near shore waters under very cold and calm conditions.

Does pollution endanger Lake Tahoe?

Tahoe has lost about one-third of its world-renowned clarity since 1968. The major component of clarity loss is fine particles, with nearly three-quarters originating from development-impacted watersheds. Another important pollutant is nitrogen, over one-half of which comes from atmospheric fallout created by vehicle exhaust and pollution blown in from surrounding urban areas. A third critical pollutant is phosphorus, with disturbed and natural watersheds contributing two-thirds of the load. All wastewater is treated and exported from the Basin.

Interesting Facts

- Nearly 80% of yearly precipitation occurs during the five months of November through March
- The chance of getting more than 0.1 in. of precipitation between the May 1 and October 15 is 10% or less.
- The name Tahoe comes from a mispronunciation of the Washoe name for Lake Tahoe, *da ow a ga*, which means, "edge of the lake."
- The sun shines on average 75% of the time during daylight hours.
- There are about 270 sunny and partly sunny days each year.
- Lake Tahoe water is 99.994% pure.
- The Lake Tahoe water surface averages 6,225 ft. above historical sea level.
- The Lake water appears blue due to absorption of all other colors in the light spectrum and backscattering of the remaining blue light back to an observer.

- On average, an observer can see a submerged eight-inch white disk at 70 ft. depth.
- At Tahoe City, an average of 14 ft. of snow falls, accumulating to a snowpack depth of 2.8 ft.
- A maximum depth of 1,645 ft. makes Lake Tahoe the second deepest lake in the USA, third deepest lake in North America and 11th deepest in the world.
- The elevation of Carson City, Nevada is 85 ft. higher than the deepest part of Lake Tahoe.
- If Sears Tower, the tallest building in the USA, was dropped into Lake Tahoe at its deepest point, the top would still be submerged by 194 ft. of water.
- By volume, Lake Tahoe is the sixth largest natural lake in the USA, the largest lake over 600 ft. in elevation in the USA and the 17th largest lake in the world at or above this elevation.
- The average daily evaporation of water from the lake surface would serve the daily needs of 3.3 million Americans.
- Lake Tahoe is nominally 22 miles long and 12 miles wide with 75 miles of shoreline and a surface area of 191 square miles.
- Lake Tahoe does not freeze due to its volume, surface area and prevailing climate.
- At the surface, Lake Tahoe water temperature varies between 75˚F in summer to 40˚F in winter.
- Over a 40-year period, loggers clear-cut 95% of the forest to supply lumber for Virginia City, Nevada mines and the transcontinental railroad.
- The Lake contains about 40 trillion gallons of water – enough to cover the State of California to a depth of at least 14 ½ in.
- Ancestral Native Americans began inhabiting the Tahoe region as far back as 10,000 years ago. The Washoe Tribe occupied the Tahoe Basin for 1300 years preceding the 20th Century.
- Lake Tahoe is 3-5 million years old and is the result of faulting and volcanism.
- The Truckee River at Tahoe City, California is the only surface outlet of Lake Tahoe and flows 140 miles to its terminus at Pyramid Lake in Nevada.
- A dam at Tahoe City on the Lake's surface outlet regulates the upper 6.1 ft. of Lake Tahoe above the low water mark.

- In 1861, Mark Twain hiked 12 miles from Carson City to Lake Tahoe in search of a timber claim, camped on the North Shore and accidently started a wildfire.
- The first recorded sighting of Lake Tahoe was by Brevet Captain John Fremont and his topographer, Henry Preuss, on February 14, 1844 from Red Lake Peak near present day Carson Pass.
- Each year, Lake Tahoe fills with 212 billion gallons of water from 63 streams and direct precipitation on the surface of the lake.
- Tsunamis up to 300 ft. high have occurred on Lake Tahoe in the past 15,000 years.
- Due to global warming, Lake Tahoe surface water temperature has increased an average of 1.6˚F since 1968.
- The surface elevation of Lake Tahoe is in the sub-alpine zone.

David C. Antonucci is an environmental engineer and 33-year Tahoe resident. He is available for paid professional speaking engagements on Lake Tahoe natural history, Mark Twain at Lake Tahoe and the 1960 Winter Olympics. For more information and booking arrangements, contact him at 530-525-5410 or dcantonucci@msn.com. Lake Tahoe Facts were prepared in cooperation with the UC Davis, Tahoe Environmental Research Center.

Protecting Lake Tahoe

Learn from Science

- 50 years of research has shown that Lake Tahoe is threatened by loss of water clarity, an increase in non-native species, changes in the food web, and risk of catastrophic wildfire
- Research allows for wise public policy decisions
- Lake Tahoe provides a living laboratory for studying freshwater lakes and their ecosystems.

Think Blue

- Consider how your actions will impact the lake and surrounding watershed.
- Never dump anything into the storm drains. The underground storm drain system leads directly to roadside ditches, streams and eventually to the lake.
- Prevent soil erosion by covering bare soil in your yard, by staying on trails and by parking in designated areas.
- Fertilize wisely – Fertilizers contain the nutrients (nitrogen and phosphorus) that feed plants, including algae, which harm the lake.
- Pick up after your pet.

Be Green

- Ride a bike, take public transportation, walk or carpool – Excessive automobile use degrades air quality and contributes to the decline in Tahoe's clarity.
- Consider low-impact recreational opportunities like hiking, biking, kayaking, and cross-country skiing.
- Reduce your ecological footprint – Increasing open space on private property helps the lake.
- Conserve energy and recycle.
- Conserve water, it is a limited resource.

Practice Good Stewardship of Lake, Land and Sky

- Do not litter: dispose of trash properly.
- Be careful with fire.
- Stay on trails and avoid fragile areas – Straying from the trail causes excessive erosion.
- Practice "Leave No Trace" outdoor ethics: "Pack it in, pack it out."
- Protect sensitive areas such as stream zones and meadows.
- Respect plants and wildlife.

Start in Your Backyard: Tahoe Locals Have Responsibilities

- Complete the required Best Management Practices (BMPs) and Defensible Space projects on your property.
- BMPs improve water quality by reducing soil erosion and capturing polluted water before it enters Lake Tahoe. The intent of BMPs are to help designed landscapes better mimic the natural ecosystem, reducing the amount of dirt and sediment the flows into Tahoe.
    - Typical BMPs include armored drip line under roof eaves, slotted channel drains in driveways, slope stabilization, and infiltration basins.

    - Pave your driveway. Sediments from compacted dirt driveways wash into the nearest storm drain and into Lake Tahoe during rainfall or snowmelt.
    - For more information about BMPs, visit www.tahoercd.org (California) or www.ntcd.org (Nevada).
- Tahoe's forests have become overgrown and put us at high risk for high-intensity fires that destroy neighborhoods, impact watersheds and take human lives; therefore, it is important to implement defensible space practices to increase the likelihood of your home's survival.
    - Rake your pine needles! Rake them in the Spring, let them fall in the Fall.
    - Thin trees. Trees less than 14 inches in diameter can be removed without a permit as one step to creating defensible space.
    - Trim low limbs and think brush. These limbs and brush or "ladder fuels" allow fire to travel along the forest floor and to climb into the forest canopy.
    - Maintain a 5-foot noncombustible zone. Keep a fire safe buffer free of combustible material around structures year round to combine erosion control with wildfire defense practices.
    - For more information on defensible space, visit www.tahoefiresafe.com.

Keep it Native

- Use native and adapted plants which are easier to maintain and require little irrigation and fertilizer.
- Never plant non-native invasive ornamentals on your property. Invasive weed infestations can permanently alter the environment and cost millions of dollars to manage, making early detection and rapid response the most effective tools in the fight against invasive weeds. Watch out for hoary cress, Dalmatian toadflax, spotted knapweed, and Scotch broom. For a complete list of priority weeds, visit www.tahoeinvasiveweeds.org.
- Watch out for invasive aquatic species such as Quagga mussels, Zebra mussels, New Zealand mudsnails, Eurasian watermilfoil and Curlyleaf pondweed which hitch rides on boats, trailers and equipment. Check boat propellers, bilge and bait buckets to help prevent the spread of invasive species that can have devastating long-term effects on Lake Tahoe and its streams. Ensure your boat is clean, drained and dry after every outing and have your boat inspected prior to launch. For more information, visit www.tahoeboatinspections.com.

Protect Native Wildlife

- Never feed bears or leave food out for pets, or wild creatures, to lure them up close for that perfect photo. Bears and other animals will return in an attempt to get another free meal after you have gone home. Often the next visitor has to deal with a problem which you may have created.
- Dispose of your trash in bear proof containers, if available. do not overfill or stack garbage outside of the container. Be sure that the latches engage after closing the door. If bear proof containers are not available, store your garbage in your garage or similar structure until trash day. Put your trash out on the morning it will be picked up, not before.

Conserve. Clearly.

- Everyone has a role to play to protect Tahoe's clarity.
- Support the Lake Tahoe Environmental Improvement Program (EIP).
  - The EIP consists of hundreds of projects that are designed to restore Lake Tahoe's clarity and environment.
  - Write to your elected officials to let them know the EIP is important for preserving Lake Tahoe for future generations.

Lights Out!

- Point your home's outdoor lights down so that they don't cause light pollution and dim the night's starry skies.
- Use energy efficient bulbs outside and inside to conserve energy and turn off outdoor lights when not in use.

Watch the Volume!

- Enjoy the tranquil beauty of the region by choosing non-motorized options such as kayaking, sailing, biking or walking.
- Be considerate - Please let others enjoy peace and quiet, especially in the forest.
- Remember that carbureted 2-stroke engines aren't allowed on motorboats or watercraft on Lake Tahoe because they pollute. There's also a 600-foot no-wake zone to help reduce boating noise, to prevent shoreline erosion and to help protect wildlife.

Get Involved

- Volunteer for a program, organization or effort to protect the Tahoe Basin.
- Participate in local citizen monitoring or restoration efforts – Citizens can collect valuable information about water quality and assist on restoration projects.
- Support the Tahoe Environmental Research Center and other research institutions by contributing financially, including cash contributions to the donation box for specified research projects, or through in-kind contributions.

Lake Tahoe: Four Decades of Change

By Charles R. Goldman,
Distinguished Professor Emeritus of Limnology, UC Davis
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Lake Tahoe was first observed by General John Fremont and his tired group of cavalry from a mountain top located southwest of the Lake. Since that time of those early western settlers, development for the next century proceeded slowly with stage coaches and summer visitors finding their way gradually to the shore of the Lake. When Mark Twain visited the Lake Tahoe, he was extremely impressed by its cobalt blue waters and commented in his book, Roughing It, that the lake was the "fairest sight the whole earth affords".

Once the discovery of gold and silver in the Comstock Load at Virginia City was made, the first of the major disturbances of the Lake Tahoe basin occurred. This was the clear cutting of most of the Tahoe basin's timber to shore up the mines of the Comstock. The timber was required for the boxed scaffolding that supported the mine shafts as the miners went ever deeper into Nevada's earth. When the mines ran out of silver, most of the old growth timber in the Lake Tahoe basin was also gone. White fir and brush grew back in dense, over crowded stands which have created a major fire hazard in the basin today. This period of re-vegetation was important, however, in slowing the high soil erosion rates which characterized the peak logging period. The high losses of soil, which is chronicled in the sediments, dropped back to less than a quarter of those that occurred during that time of excessive lumbering activity.

Lakes are, in fact, reservoirs of history in the sense that they are able to record in their bottom sediment, an indelible record of what has occurred on the land, in the air and in the water. Sawdust from the saw mills at Glenbrook along the east shore is still perfectly preserved in the sediment samples extracted from the lake bottom. A unique chemical record also exists in the sediments from the ethyl lead used in gasoline as well as mercury from the California gold rush and various sources of industrial atmospheric pollution. Even the fossil remains of invertebrates and fish scales can provide forensic evidence of the past glacial history of Lake Tahoe.

With the return of forests to the basin, Tahoe recovered its pristine quality as one of the clearest large lakes in the world. John le Conte, in 1887, measured the lake's transparency at over 100 feet. This lake revival provides the hope that the lake can once more recover from the current period of high development activity. Over seventy percent of the Tahoe basin is US Forest Service land under the control of the Federal government. Despite this dominant ownership, there was ample room for extensive development around the Lake shore. Post World War II construction of roads and buildings, for the most part, had proceeded using the flatland technology of the less sensitive lower elevations. Adding to this situation, the problems associated with development on steep slopes contributed to the degradation of the fragile soils and the limited vegetation cover of the sub-alpine Tahoe basin.

In the late 1950's, when the value of wetlands was not well understood, the Dillingham Corporation was allowed to construct a marina development by digging up the Pope Marsh. This single largest wetland in the Sierra Nevada was transformed into an extensive marina development at the south end of the lake known as the Tahoe Keys. In so doing, the important filtering capacity of Pope Marsh was lost forever. To make things worse, the major tributary to the lake, the upper Truckee River, was canalized along the east side of the Tahoe Keys. Because of this, nutrients and sediment are directly delivered to the lake without the filtering benefits of the former wetland. The Keys became a habitat whose water was warmer than that of the lake and has served as refuge for a number of invasive plants and animals. Unfortunately, over the years, people transported aquarium plants and fish to the Keys. Rather than taking them home at the end of the summer, they dumped them into the Keys. These invasive species, now exemplified by the spread of the notorious waterweed *Eurasian watermilfoil,* have gradually spread from the Keys to other areas around the lake. Warm-water fish introduced to the Keys have been able to move with the *Eurasian watermilfoil* to the new, warmer micro environments that the weeds have created. Other invasive fish, particularly the cold water tolerant Smallmouth Bass, may eventually threaten the very existence of the native minnow, trout and salmonid populations.

The invasion of these exotic organisms will be further aided by the gradual warming of the lake. Tahoe's enormous volume of 156 cubic kilometers of water has already increased a half of a degree in temperature over the last twenty years through climatic change and global warming. Unfortunately this warming trend appears very likely to continue.

Although development along the lake shore was slowed by World War II, the construction of casinos at the state line on both the north and south ends of the lake, together with a developing summer boating and winter ski industry, Tahoe gradually attained the status of a resort destination. So popular is the Lake in summer that it is not unusual to record a million vehicle miles around the lake in a single day. Selection of Tahoe for the 1960 Winter Olympics gave it global publicity and greatly increased the visitor traffic to the basin. The beauty of Lake Tahoe is now world renowned, but like most of the world's lakes, human impacts are gradually taking their toll.

Since my studies began in 1959, the lake has lost a third of its remarkable transparency and algal growth rate has increased by about five percent per year. Small particles of dust and sediment remain suspended in the water column for years adding to the gradual but relentless transparency loss. Air pollution is no stranger to the Tahoe basin and nitrogen pollution of the lake is greater from the atmospheric deposition than it is from stream water input.

The limnology studies which started in 1959 were instrumental in convincing a consulting group of eminent civil and environmental engineers in the 1960's to require the total export of both treated and untreated sewage from the Tahoe basin. Although the availability of a basin wide sewage system was probably stimulation for additional near-shore development, had this export not been achieved, the clear water picture which appears at the beginning of this article would not have been possible. A major factor in achieving the sewage diversion was the growing realization that Tahoe was revered for its remarkable cobalt blueness and that keeping Tahoe blue was a difficult, but achievable goal.

An extremely effective activist group, the League to Save Lake Tahoe, was instrumental in passing the scientific data collected by the Davis faculty of the University of California's Tahoe Research Group to the public at large. This translation of scientific data to layman's terms was particularly important. As the League's membership grew, so did the public's awareness of the growing threats to Lake Tahoe's water quality. "Keep Tahoe Blue" bumper stickers began to appear all across the states of California and Nevada. Another important activist, Alfred Heller, published a journal entitled "Cry California" which dealt with the many contemporary problems of the state. This provided the author with an opportunity to publish two articles on the plight of Lake Tahoe and compare it with the nearly undeveloped great Siberian Lake Baikal. Some years later the Tahoe Baikal Institute was founded to provide student exchange between the two lakes each year.

Reflecting on the important decisions that have been made since my arrival at Lake Tahoe in 1958, several stand out; creation of the Tahoe Regional Planning Agency, for example, brought a lake divided by two states and five different counties, various municipalities, agencies and local governments under a single central authority. I accompanied League to Save Lake Tahoe leaders in successful meetings with governors Paul Laxalt of Nevada and Ronald Reagan of California to urge creation of the gestate agency, to be charged with protecting the lake's unique environment. This Federal mandate was unpopular in some circles, since it imposed Federal control of an area split by two states and five counties, but it provided an essential unification of purpose. The objective was simply to preserve the environmental quality by regulating future development and repairing the damage that had already been done. Federal Judge Garcia issued a landmark decision to halt the development in the basin for two years until control measures could be adequately established to protect the resources.

I have participated in successfully defending the Tahoe Regional Planning Agency from various legal assaults over the years. Strong scientifically based arguments have been the decisive factor in winning these cases for the Agency. A milestone event which greatly influenced the future of Lake Tahoe was a political meeting at the Lake in 1997, referred to as the "Lake Tahoe Summit". Both President Bill Clinton and Vice President Al Gore attended this meeting at Lake Tahoe at the invitation of Nevada's well- known Senior Senator Harry Reid. As Director of the Tahoe Research Group, I had the opportunity to show both the President and the Vice President, first hand, the condition of Lake Tahoe from aboard our University of California research vessel, the "John le Conte". They spent almost an hour aboard, examining the lake's water quality before returning to shore to sign a declaration for Lake Tahoe's protection. This event was unique for a President and Vice President of the United States and was fully covered by news papers and world-wide television. The Tahoe Summit has now become an annual event. A few years later, when President Clinton was on a post-Presidential speaking tour at the Davis Campus of the University of California, he began his speech by saying how he remembered this lake expedition and getting his biology course from me!

I was invited to accompany J.T. Ravize', an outstanding Tahoe color photographer, when he displayed his photographic artistry and his wife's poetry in Washington D.C., at the U.S. Senate Rotunda. The exhibition was instrumental in focusing attention_in the nation's Capital on one of the country's most valuable and scenic resources.

Senior Senators Harry Reid of Nevada and Dianne Feinstein of California have continued their essential leadership in championing the cause of helping to protect Lake Tahoe from further degradation. To further this cause , in the fall of 2006, the UC Davis Tahoe Environmental Research Center will be moved into a new world-class facility to support research and help provide the important science-based decisions for management of the Tahoe basin for this and future generations. Over a century and a half of development and environmental abuse have occurred since the Lake first became known to the western settlers. Tahoe remains an extraordinarily beautiful and remarkably clear lake. It is one of the West's most treasured resources. We have now moved beyond most of the conflicts of the past and it is generally agreed between developers and conservationist alike that everyone loses if Tahoe's water quality and scenic beauty is allowed to deteriorate. There has been a growing public understanding of the value of this unique natural resource and a growing willingness to do whatever is necessary to protect Lake Tahoe for this and future generations.