Evaluation and Management of Non-Point Source Pollutants in the Lake Tahoe Watershed*

G. Fred Lee, PhD, PE, DEE (Member)[1] and Anne Jones-Lee PhD (Member)[2]

Abstract

Lake Tahoe, California-Nevada, one of the most oligotrophic lakes in the world, is experiencing decreased water clarity and increased periphyton growth, and water supplies drawing from the lake are experiencing increased algal-related tastes and odors. The growth of algae in Lake Tahoe is primarily limited by the nitrogen (nitrate and ammonia) loads to the lake, which have been increasing over the years. The nitrogen that is causing the increased fertilization of the lake is primarily derived from atmospheric sources through precipitation onto the lake's surface. A potentially highly significant source of atmospheric nitrogen in the Lake Tahoe Basin is automobile, bus, and truck engine exhaust discharge of NOx. The fertilization of lawns and other shrubbery, including golf courses, within the Lake Tahoe Basin is also leading to significant growths of attached algae in the nearshore waters of the lake. The fertilizers are transported via groundwater to the nearshore areas of the lake.

In order to prevent further deterioration of Lake Tahoe's eutrophication-related water quality, there is immediate need to control atmospheric input of nitrate and ammonia to the lake's surface, and to control use of fertilizers on lawns, shrubbery, and golf courses in the watershed. The states of California and Nevada, and the Tahoe Regional Planning Authority need to focus considerable attention on the determination of whether restricting NOx emissions from vehicular traffic within the basin would have a significant beneficial impact on Lake Tahoe's water clarity

*Reference as: Lee, G. F., and Jones-Lee, A., "Evaluation and Management of Non-Point Source Pollutants in the Lake Tahoe Watershed," Proc. 1994 National Conference on Environmental Engineering, "Critical Issues in Water and Wastewater Treatment," American Society of Civil Engineers, New York, NY, pp. 516-523, July (1994).

1 President, G. Fred Lee & Associates, 27298 E. El Macero Dr., El Macero, CA 95618-1005

2 Vice-President, G. Fred Lee & Associates

Introduction

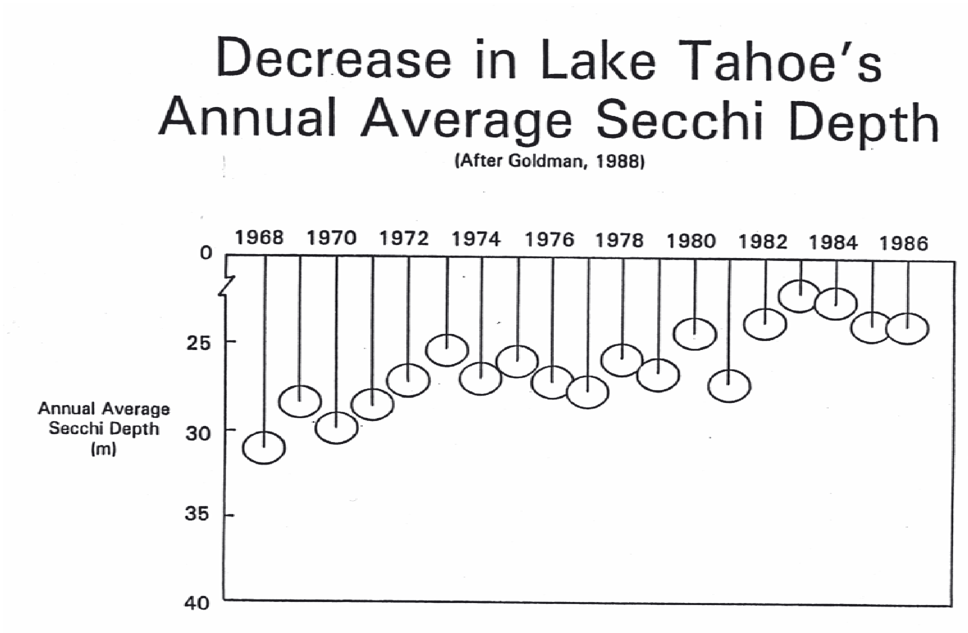
The extremely high clarity of its waters and the natural beauty of its setting make Lake Tahoe, California-Nevada one of the unique lakes of the world. However, the water quality in this lake has been deteriorating at a significant rate over the past 20 years (Figure 1). The rate of deterioration matches the rate of increase in urbanization and use of the lake's watershed by permanent residents and visitors (Figure 2). Even with the diversion of all point-source wastewater discharges out of the Lake Tahoe Basin a number of years ago, the water clarity has been decreasing at an average rate of 1 to 2 ft/yr. While the Secchi depth was on the order of 30 m in 1970, today it is on the order of 20 m (see Figure 1). The decreasing water clarity has been caused by the increasing input of aquatic plant nutrients to the lake that stimulate planktonic algal growth.

Lee *et al.* (1978) and Rast and Lee (1978) developed a relationship between planktonic algal chlorophyll in lakes and reservoirs and Secchi depth (water clarity) where increased algae causes reduced light penetration. They also quantitatively related the Secchi depth to the normalized nutrient loadings to waterbodies; that relationship was expanded by Jones and Lee (1986). It is clear from the data of Goldman and others that while Lake Tahoe is ultra-oligotrophic and is one of the clearest lakes in the world, increased algal growth is occurring in this lake that is significantly reducing light penetration in the watercolumn.

It has been established that planktonic algal growth in Lake Tahoe is primarily limited by nitrogen in the forms of nitrate and ammonia. The increase in input of algal-available nitrogen, however, has resulted in a more balanced ratio of nitrogen to phosphorus with respect to the ratio needed by algae for growth. The result is that both nitrogen and phosphorus are often limiting algal growth in the lake today.

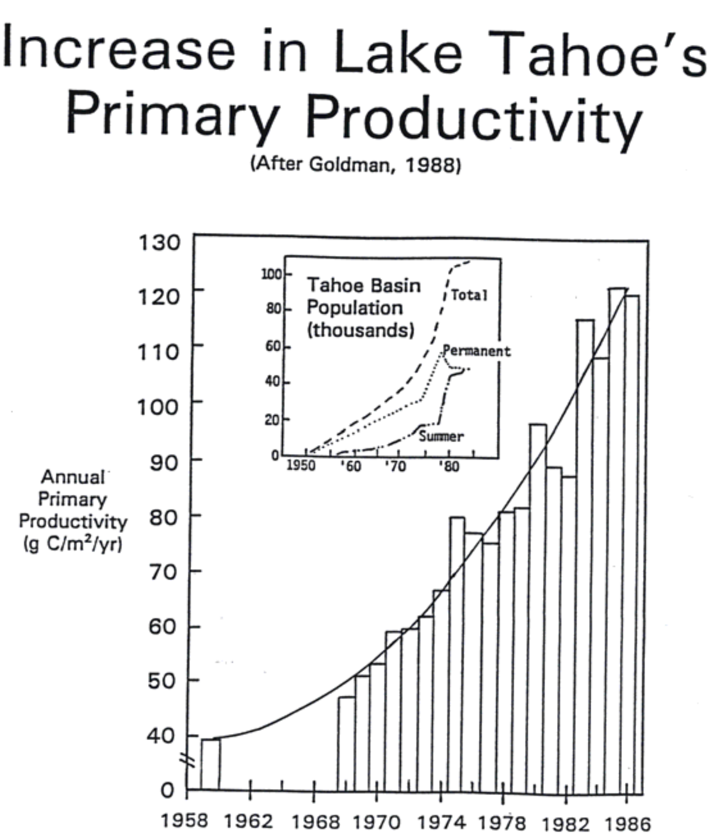
There has been considerable controversy over the years about how to best manage the non-point sources of nutrients that are causing the excessive growth of planktonic algae in Lake Tahoe. Several years ago the Tahoe Regional Planning Authority (TRPA) adopted the Individual Parcel Evaluation System (IPES) as a means of trying to control the deterioration of Lake Tahoe water quality based on an attempt to control nitrogen input to the lake from property development. IPES is a multi-parameter scoring system in which the property ground slope and other erosion-related parameters are assigned an arbitrarily developed score. The individual IPES parameter scores are summed to give a total score to rank properties for priority for development. A critical examination of the components of IPES and its application shows that it is an arbitrary approach for limiting development in the Lake Tahoe watershed, using a pseudo-technical approach for social engineering in the Lake Tahoe Basin. The underlying purpose of IPES was to control the rate of development of undeveloped properties in the Lake Tahoe watershed. It is clear that IPES is a technically invalid approach that will not

Figure 1*



* Please see updated figure attached to this paper for more recent information.

Figure 2



significantly control the input of available nitrogen and phosphorus to the lake to reduce the rate of decrease in water clarity due to planktonic algal growth.

While controlling property development will limit the input of algal nutrients to the lake to some extent, the IPES approach is basically flawed in addressing the primary causes of increased algal growth in the lake. In order to gain an understanding of the relative significance of various sources of nitrogen that are leading to increased growth of planktonic algae in Lake Tahoe, an estimate of the nitrogen sources for the lake was made and is presented in Table 1. It is apparent that the key to the increase in planktonic algal growth in the lake is the increase in atmospheric nitrogen that enters the lake through its surface. It is also clear that the development of property and the associated erosion that has occurred in the Lake Tahoe watershed has not been a significant factor in the increased nitrogen input to the lake relative to the inputs that have occurred from atmospheric sources.

In order to determine if the input of atmospheric nitrogen to the lake is potentially controllable, it is necessary to understand its origin. There are both in-basin and out-of-basin sources of atmospheric nitrogen. In 1987 the California Air Resources Control Board determined that about 2500 mt (metric tons) of nitrogen oxides (NOx) are emitted to the atmosphere in vehicular exhaust in the Lake Tahoe watershed (Table 2). That 2500 mt NOx/yr in-basin atmospheric input of nitrogen could contribute significantly to the 100 mt N/yr nitrogen input to the lake surface.

<u>Managing Lake Tahoe's Water Quality</u>

Presented below are a series of actions that should be considered for management of water quality in Lake Tahoe.

NOx-Nitrogen Control

There is an urgent need to immediately significantly curtail the nitrogen inputs to Lake Tahoe. Jones and Lee (1991) recommended that in order to begin to effectively slow the rate of deterioration of the lake's water quality that is related to algal growth in the open and nearshore waters of the lake, aggressive action should be immediately taken toward greatly reducing, if not essentially eliminating, the use of internal combustion engine-based automobiles, trucks, and buses within the Lake Tahoe watershed. This recommendation is based on the finding that the exhaust from these vehicles could be a significant source of atmospheric nitrogen for the lake. In order to evaluate the full significance of this source, there is need to conduct studies to properly define the relative roles of in-Tahoe-Basin atmospheric nitrogen sources and out-of-basin atmospheric nitrogen sources that lead to entrance into the lake of forms of nitrogen (nitrate and ammonia) that could stimulate algal growth within the waterbody.

Table 1
Estimated N Load to Lake Tahoe (tonnes N/yr)
(After Jones and Lee, 1990)

Source	Pre-Development	Now
Atmosphere – onto Lake Surface	2.5	~100
Surface Water Runoff	4	16
Groundwater	0.5	2
Total N Loads	7	118

Table 2
Estimated Contributions of NOX
From Motor Vehicles
(After Jones and Lee, 1990)

	Tonne NOX/yr
Automobiles	800
Light & Medium Trucks	630
Heavy Duty Trucks	1160
Total	2500

Recently, a light rail system was proposed for the Yosemite Valley in order to reduce the traffic congestion and pollution of that area. A similar system needs to be adopted for the Lake Tahoe Basin in which automobiles and other vehicles are parked outside of the basin and people and goods are transported into the basin via a non-internal combustion engine-based transportation system.

Nearshore Lake Water Quality

Jones and Lee (1991) recommended that all lawns, including golf courses, and fertilized shrubbery be banned in the Lake Tahoe watershed. They feel that the basin should be allowed to return to native vegetation that does not require fertilization and/or irrigation. Adoption of this approach would significantly reduce nitrogen inputs to the nearshore waters of Lake Tahoe and thereby reduce the periphyton growth in some areas.

While at this time domestic wastewater disposal is not allowed within the Lake Tahoe watershed, i.e., the system is sewered with the wastewaters exported out of the watershed, it is highly likely that previous wastewater disposal practices could be significant sources of nutrients for some nearshore areas of Lake Tahoe, contributing to localized algal related problems in these areas. Nutrients derived from the previous use of septic tank wastewater disposal systems and wastewater spray irrigation disposal systems are, or could be, significant sources of nutrients which stimulate algal growth in some parts of the nearshore waters of Lake Tahoe.

Jones and Lee (1991) suggested that additional work needs to be done to determine the potential significance of past wastewater and solid waste (landfill) disposal practices within the Lake Tahoe Basin as a source of nutrients for nearshore water quality problems. If there is interest in controlling excessive periphyton growth in a particular part of the nearshore area of the lake where the nutrients contributing to the excessive growth in that region are significantly derived from past wastewater or solid waste disposal practices, it may become necessary to intercept the groundwater before it reaches the lake by pumping and treating the groundwater to remove the nutrients.

IPES Validity

Jones and Lee (1991) concluded that the Lake Tahoe Regional Planning Agency's Individual Parcel Evaluation System (IPES), which is being used in an attempt to control population growth in the basin, is technically invalid with respect to protecting the lake's water quality. The IPES score is a growth-limiting mechanism used by TRPA for the purpose of "protecting" lake water quality. However, the IPES score on a property is not related to the amount of nitrogen or, for that matter, other forms of algal-available nutrients that ultimately reach the lake from that property.

Erosion Control

It should be recognized that erosion control is very important in the Lake Tahoe Basin for reducing the scarring of the terrestrial resources of the area. The TRPA should abandon the use of the current IPES for regulating population growth in the basin. In its place, a more reliable approach for limiting erosion due to development should be formulated and used. It should further be recognized, however, that erosion control has little impact on the lake's water quality and that a significantly different approach, based on a proper evaluation of the nutrient sources for the lake that contribute algal-available forms of nutrients to the lake waters, is needed to address the lake's water quality problems.

Conclusions

The increased fertilization of Lake Tahoe is causing several highly significant water quality problems, including algal-related tastes and odors and decreased water clarity.

In order to reduce the frequency and severity of algal-related domestic water supply water quality problems in Lake Tahoe, it appears that it will be necessary to significantly curtail the use of automobiles and other vehicles powered by internal combustion engines in the Lake Tahoe watershed and to ban the use of lawn and shrubbery fertilizers and watering within the lake's watershed. It may be necessary to ban all watered lawns and shrubbery in the Lake Tahoe watershed and allow the basin to return to native vegetation. There is no doubt that unless action is taken to limit NOx emissions within the basin, the lake's open water clarity will continue to decrease, and ultimately, the highly unique character of Lake Tahoe (i.e., its water clarity) would be lost. It is imperative that highly aggressive action be taken now to reverse the changes in water quality that are occurring today.

The key issue that needs to be addressed to reverse and/or control the Lake Tahoe water clarity decrease is whether or not a restriction in use of internal combustion engines in the Lake Tahoe Basin could reduce the nitrogen input to the lake sufficiently to stop the deterioration of the lake's water clarity. It would be possible to require that most of the visitors to the lake park their vehicles out of the lake basin and use a light-rail or other system for transport to and within the lake watershed, and to control commercial traffic. The states of California and Nevada and the TRPA need to focus considerable attention on the determination of whether restricting vehicular traffic within the lake basin and the attendant reduction in the NOx emissions would have a significant beneficial impact on Lake Tahoe water clarity.

It is important to properly evaluate the impacts of contaminants in non-point sources on water quality in the waters receiving runoff from these sources. Failure to make such evaluations can readily lead to the initiation of inappropriate management programs for non-point sources that do not properly address the causes of real water quality problems, and can lead to substantial waste of public funds without an improvement in the designated beneficial uses of the receiving waters.

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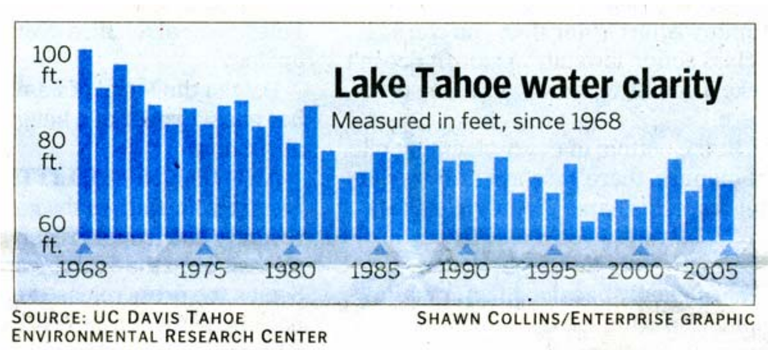
Additional Information

On October 8, 2006, *The Davis Enterprise*, a city of Davis, California, local newspaper, published an article on Lake Tahoe, in which the following figure was included on the changes in the lake's water clarity. Figure 1 in the paper above provided water clarity information through 1986. The Figure presented below provides an additional 19 years of data on water clarity as measured by Secchi depth. While there is year-to-year variability, the overall trend over the last 20 years is decreasing water clarity. It is the authors' finding that little progress has been made over the past 20 years in controlling the sources of nitrogen that are leading to increased algal production within the lake, which is affecting water clarity. The Tahoe Research Group is now indicating that in-basin nitrogen is a potentially significant source, which was pointed out in our 1991-1992 review of this issue.



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