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LETTER TO THE EDITOR:

Appropriate Use of Numeric Chemical Concentration-Based Water Quality Criteria: Supplemental Discussion

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Morrisey, Williamson, and Roper (1995) were critical of our (Lee and Jones-Lee, 1995) suggested approach as to how numeric chemical water quality criteria should be used in a water pollution control program. They correctly state that we propose biological effects based criteria as more reliable predictors of impact of chemical constituents than chemical-specific numeric criteria. They argue that this is not necessarily the case, since laboratory-based toxicity tests do not provide an adequate prediction of effects of contaminants under field conditions.

In fact, chemical-specific water quality criteria are, in general, based on the same type of laboratory testing as we propose to use to investigate whether regulated or unregulated chemical constituents are toxic in the waters of concern. However, such criteria do not properly consider the aqueous environmental chemistry and toxicology of the constituents of concern that leads to many constituents becoming nontoxic in ambient waters.

Morrisey *et al.* further argue that under conditions where there is a lack of site-specific information, and where regulatory agencies must make decisions on the likely impacts of a particular activity: "*Generic, chemical-based criteria often represent the best immediately-available syntheses of relevant information in such situations.*" This argument is not valid and is part of a syndrome that exists in the field "just give me a chemical-specific number and we will regulate by it," independent of whether the numeric values properly incorporate aquatic chemistry and toxicology into the regulatory process.

A far more reliable approach to determine whether regulated or unregulated chemicals are toxic is to ask appropriately sensitive organisms in a toxicity test whether the system being tested is toxic to them. While this approach does not address all possible adverse impacts (neither does the chemical-specific approach), adopting it will be a major step toward developing technically-valid, cost-effective approaches for regulating chemical constituents over the chemical-specific approach that is being used today. Further, while the toxicity testing based impact evaluation approach has not traditionally been used, it can be less expensive and will yield more definitive, useful information than the mechanical approach advocated by Morrisey *et al.* of comparing chemical-specific criteria and standards to ambient water concentrations.

Morrisey *et al.* cite the example of the "*unavoidable need to apply chemically based criteria*" to regulate the stormwater runoff of chemical constituents from urban area development. They specifically mention the use of Long and Morgan's (1991) so-called "effects ranges" covering the accumulation of stormwater-derived constituents from urban areas in assessing the ecological impacts of the predicted buildup of contaminants in the receiving water sediments. The Long and Morgan (1991) "effects ranges" do not, in fact, represent effects related to the chemical concentrations that are represented by these so-called "effects ranges" (Lee and Jones-Lee, 1996).

Further, the Long and Morgan values are based on a fundamentally flawed approach involving the use of total concentrations of chemical constituents in sediments rather than biologically available toxic forms. It is well known that, for most chemical constituents in sediments, large parts are in nontoxic, nonavailable forms. To the extent that New Zealand is influencing urban development based on the Morrisey *et al.* approach, New Zealand is using technically invalid approaches to assess the potential impacts of stormwater runoff associated constituents that tend to accumulate in aquatic sediments.

Morrisey *et al.*'s statement, "*the use of numerical sediment- and water-quality criteria is essentially an attempt to predict environmental impacts*" represents a technically invalid approach that can lead to massive waste of public and private funds where regulated chemicals are over-regulated and the unregulated chemicals are not addressed at all. New Zealand and others who are following this bureaucratically simple, but technically invalid approach should abandon this approach in favor of focusing on biologically-based assessments of the impacts of chemical constituents on the beneficial uses of waters.

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

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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.

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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. Decrease in Lake Tahoe's Annual Average Secchi Depth (After Goldman, 1988)

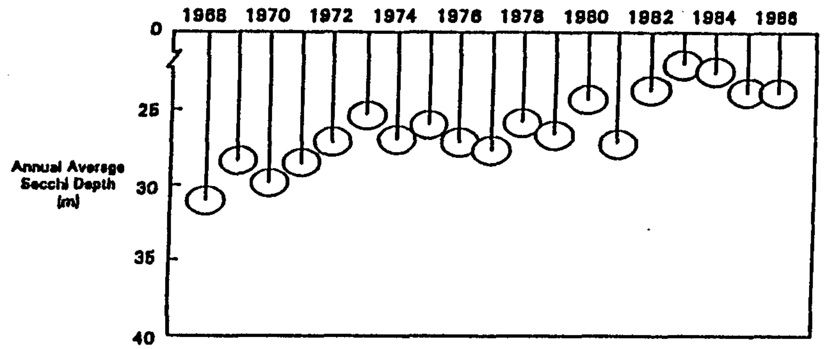
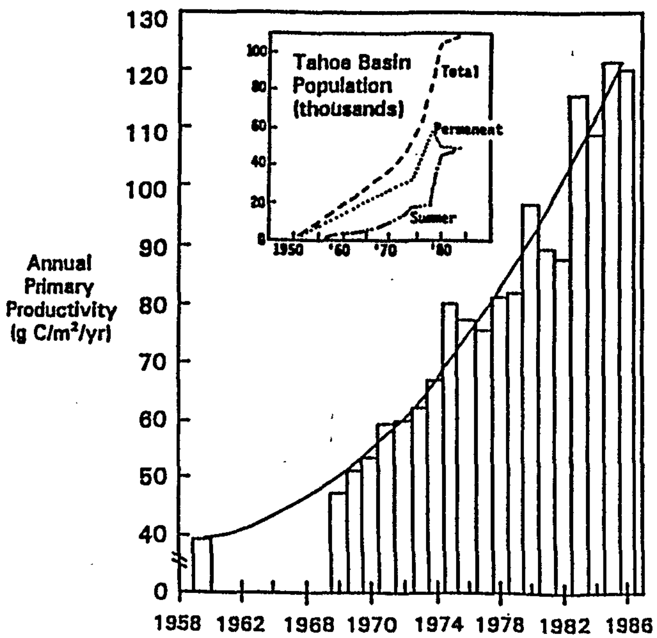


Figure 2. Increase in Lake Tahoe's Primary Productivity (After Goldman, 1988)



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.

Managing Lake Tahoe's Water Quality

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, 1991)

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, 1991)

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

Source: Air Resources Control Board, 1987

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

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Example of Inappropriate Approaches for Establishing Stormwater Runoff BMP's
- Control at Source
- Structural BMP

Presented at ASCE National Conference on Environmental Engineering, "Critical Issues in Water and Wastewater," Boulder, CO, July (1994)

Characteristics of Lake Tahoe

◂ One of the World's Distinctive Waterbodies ▸

Lake Surface Area: *$5x10^8$ m^2*
Dimensions: *35 km Long; 20 km Wide*
Watershed Surface Area: *$1.3x10^9$ m^2*
  Small Watershed Given Lake Surface Area
Volume: *$1.6x10^{11}$ m^3*
Mean Depth: *313 m*; **Maximum Depth:** *501 m*
Hydraulic Residence Time: *700 yrs*
Elevation: *1897 m above Sea Level*
Complex Physical Limnology: *Some Years Does Not Mix Completely*
Trophic State: *Ultra-Oligotrophic*
  Water Clarity (Secchi Depth): *~25 m; Decreasing*
  Chlorophyll: *< 1 µg/L*
Algal Growth Limitation: *Nitrogen; P Limitation also Occurring*
Human Populations: *Permanent Residents • Visitors*
  Intensively Used for Water-Based Recreation; Casinos

Nutrient-Related Water Quality Problems

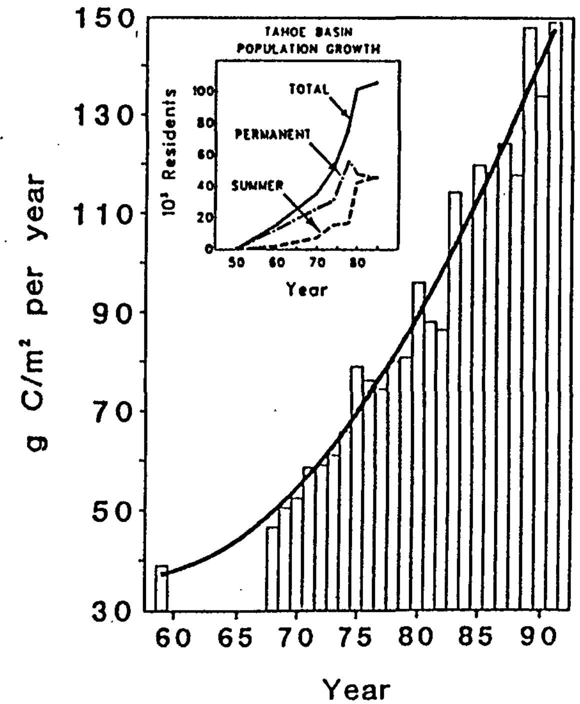
Nutrients of Concern:

Nitrogen (NH_3 & NO_3^-) • Phosphorus (Soluble O-P)

Nearshore Water Quality Problems
- Periphyton (Attached Algae) "Green Slime"
- Algae-Derived Tastes and Odors in Water Supplies

Open Water Quality Problems
- Decreased Water Clarity (Secchi Depth) Due to Planktonic Algae

Annual Algal Growth



(from Goldman, 1993)

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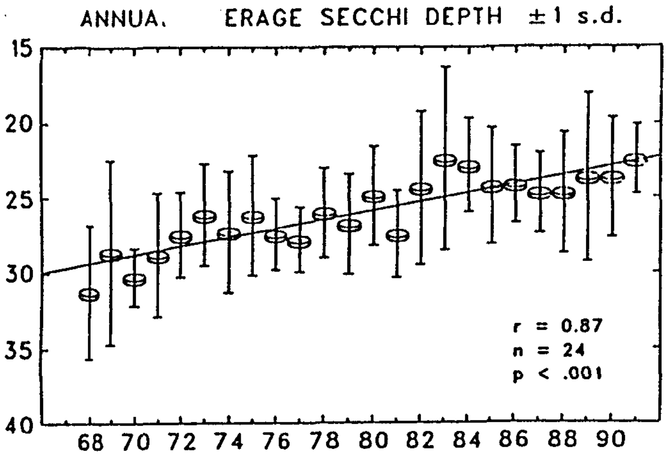

(from Goldman, 1993)

Approaches Used to Try to Manage Lake Tahoe Water Quality

Domestic Wastewaters

Prior to 1962 Used Septic Tanks and Spray Irrigation for Wastewater Disposal

1970 - Diverted All Domestic Wastewaters Out of Lake Tahoe Watershed

Important Step in Protecting Lake Water Quality

Legacy of Polluted Groundwaters Moving to Lake

(continues)

Approaches Used to Try to Manage Lake Tahoe Water Quality (continued)

Non-Point Source Nutrient Control

Focus on Land Use Control

Individual Parcel Evaluation System (IPES)

Social Engineering to Limit New Development

Erosion Control and Land Disturbance
Erosion Important - Scaring of Hillsides
Siltation Not a Problem in Most of Lake

Not Valid Approach to Control Nutrient Input

Lake Water Clarity Decreasing 1.5 feet/year

Individual Parcel Evaluation System

Components
- Relative Erosion Hazard
  - Frequency and Duration of Rainfall
  - Gradient of Terrain
- Runoff Potential
  - Water Infiltration
  - Ground Cover
- Access to Building Site
  - Need to Construct Roads, Parking Area, Etc.
- Stream Environment Zones
  - Proximity to a Stream
- Condition of Watershed
  - Ability of Watershed Area to Deliver Nutrients and Sediments
  - Precipitation, Soil Characteristics
- Ability to Revegetate
  - Slope, Elevation
- Need for Water Quality Improvement in Area
  - Need for Paving Roads
  - Stabilizing Slopes
  - Installing Storm Drains
- Distance from Lake
  - Removal of Nutrients and Sediments in Stream

IPES (continued)

Purpose Is to Protect Lake Tahoe Water Quality
- Arbitrary Score Assigned to Each Component
- Property with IPES Score above an Arbitrary Selected Value Given Low Priority for Development

Technical Validity
- Based Primarily on Erosion Control Issues - Land Disturbance
  - Land Disturbance and Erosion of Limited Impact on Lake Tahoe Water Quality
  - Not Technically Valid for Estimating Erosion Due to Land Disturbance in Some Parts of Lake Tahoe Basin
- Does Not Consider Available Forms of Nutrients
- Does Not Consider Groundwater Transport of Nutrients to Lake
- Does Not Reliably Consider Nutrient Transport and Transformations in Lake Tahoe Basin

Basically IPES Is a Social Engineering Quasi-Technical Approach for Limiting Further Development of Land in the Lake Tahoe Basin

Will Not Protect Lake Tahoe Water Quality from Nutrient Related Problems

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Estimated N Loads to Lake Tahoe (tonnes N/yr)
(after Jones and Lee, 1991)

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

Estimated Contributions of NOX from Motor Vehicles to Lake Tahoe Basin
(after Jones and Lee, 1991)

	tonne NOX/yr
Automobiles	800
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Heavy Duty Trucks	1160
Total	2500

Source: Air Resources Control Board, 1987

Sources of Atmospheric Nitrogen to Lake Tahoe

In-Basin: Lake Tahoe Watershed

Out-of-Basin: San Francisco Bay Area and San Joaquin Valley

Regulatory Agencies Claim Out-of-Basin Sources of Atmospheric Nitrogen

Not Properly Evaluated and Not Likely Valid

Identification & Control of Atmospheric Sources of Nitrogen

Currently Not Being Addressed by Regulatory Agencies

New Focus on Control of Land Sources of Nutrients with Construction of Stormwater Runoff BMP's

Detention Basins
- Limited Value in Controlling Input of N and P That Stimulate Algal Growth in Lake
  - Available Forms Pass through Basins
  - Siltation/Filling of Lake Not Significant Problem

Construction of Wetlands
- Wetlands Remove Nutrients at Low Flow
- Of Little Nutrient Control Value at High Flow and during Non-Growing Season

Management of Algal-Related Water Quality Nearshore

Nutrient Sources
- Surface Runoff
- Groundwater Input to the Lake
  - Lawns • Golf Courses
  - Residuals from Historic Use of Septic Tanks and Wastewater Spray Irrigation

To Control Nutrient Input May Need to
- Ban Use of Lawn and Yard Fertilizers and Watering
- Pump and Treat Groundwater to Remove Nutrients

Lessons from Lake Tahoe Non-Point-Source Control Program

- Do Not Assume That Current "Off-the-Shelf" Stormwater Runoff BMP's Will Address Real Water Quality Problems
- Identify Specific Water Quality Problems of Concern
  Do Not Confuse *Perceived* Problems with *Real* Problems
- Define the Specific Causes of Water Quality Deterioration in the Waterbody Receiving the Stormwater Runoff
- Identify the Specific Sources of the Specific Contaminant Forms Causing the Real Problems
- If Possible, Control Contaminants at Source
- Construct Appropriate Structural BMP's for Removal of Specific Forms of Contaminants Causing Real Water Quality Problems
- Define Improvement in Water Quality/Beneficial Uses That Will Be Effected by Control Measures

Conclusions

- Past and Proposed Nutrient Control Programs Aimed at Non-Point Sources (Stormwater Runoff BMP's) Will Not Be Effective in Controlling Nutrient-Induced, Water Quality Deterioration in Lake Open (Water Clarity) or Nearshore
- Must Determine if Atmospheric Nitrogen Load to Lake Significantly Derived from Vehicular Exhaust (NOX)

  If Important Source,
  Control Vehicle Use in Lake Tahoe Basin - Park Autos Out of Basin and Use Light Rail