TAHOE REGIONAL PLANNING AGENCY

Threshold Update

VEHICLE MILES TRAVELED THRESHOLD STANDARD

APRIL 26, 2019

CONTENTS

THRESHOLD UPDATE INITIATIVE

BACKGROUND

The vehicle miles traveled (VMT) threshold standard was adopted in 1982. At the time the standard was proposed, the study report explained, “Nitrates deposited from the atmosphere originate from automobile emissions generated within the basin and from sources upwind of the basin. Nitrates contribute to algal growth which affect the clarity of Lake Tahoe (TRPA 1982a).” At the time, increased algal growth was thought to be the primary driver of declining lake clarity[1].

The VMT standard was one of a suite of standards adopted to address loading of algal nutrients to the lake. While the motivation for the VMT standard was the clarity of the lake, the standard was adopted in the air quality category to reflect the pathway (the air) through which the nutrients reached the lake.

While still a concern, TMDL science revealed that the algal component forming the basis for the VMT threshold was of lesser importance than particulate matter for lake clarity. In the mid-2000s, over $10 million was invested in science to better understand declining lake clarity and to formulate a management response. That work established the foundation for the Lake Tahoe Total Maximum Daily Load (TMDL), the science-based plan to restore Lake Tahoe’s historic clarity. TMDL development science found that fine sediment particles were responsible for approximately two-thirds of the lost clarity, and algae was responsible for the remaining third (Lahontan & NDEP 2010). Based on these findings and a thorough review of implementation opportunities, the TMDL established pollutant load reduction targets to be implemented over 65 years to restore the historic clarity of the lake. The TMDL implementation plan’s primary focus is to reduce the load of the primary pollutant of concern, fine sediment particles from urban runoff sources. The TMDL is now in its sixth year of implementation. The Lake Tahoe TMDL Program 2018 Performance Report released in August 2018, found that local governments and highway departments collectively met or exceeded their 2017 water year pollutant load reduction targets. Pollutant controls reduced fine sediment particulate load by over 12 percent, total phosphorus by almost 10 percent, and total nitrogen loads by over seven percent.

While TMDL implementation focuses on reduction of fine sediment load, nitrogen remains a pollutant of concern in the Lake Tahoe Basin (Lahontan & NDEP 2010). The TMDL identified atmospheric deposition as the primary source (55 percent) of nitrogen reaching the lake (Lahontan & NDEP 2010).

[1] In 1982, a VMT standard was also adopted as a part of the sub-regional visibility standard (TRPA 1982b). The VMT standard was removed as a measure of sub-regional visibility as part of the 2012 threshold updates, when it was replaced with four direct measures of particulate matter concentration (AQ 9-12), that more closely measured the human health and regional visibility values for which the standard was adopted (TRPA 2012a, 2012b).

Emissions from on-road mobile sources were estimated to account for between 37 percent and 46 percent of nitrogen emissions in the Tahoe Basin (Pollard et al. 2012).

The adopted standards sometimes deal with emissions (source specific) and other times address deposition (multiple sources). The connection between regional NOx emissions, deposition, and associated VMT has been an issue since initial discussions of the VMT standard. At the time the VMT standard was proposed, the League to Save Lake Tahoe (League) submitted comments objecting to the establishment of 10 percent reduction in VMT as a threshold standard (League To Save Lake Tahoe 1982). The League wrote, “A 10% reduction is <u>not</u> a threshold standard. The threshold standard is the total number of miles traveled that maintains the nitrate deposition level below that which adversely affects the water quality of the lake and its tributaries (League To Save Lake Tahoe 1982).”

WHAT IS VMT?

Vehicle miles traveled (VMT) is a measure of the number of miles driven on roadways in a specified area and period of time. Estimates of VMT are generally approximations of actual vehicle miles traveled, based on estimates of trip distance and frequency (Salon et al. 2012). VMT could be precisely measured using car odometers, but rarely is because of the difficulty in obtaining the information (Salon et al. 2012) and the challenge of determining where the vehicle travel occurred. VMT is influenced by a complex set of interconnected factors and synergies between individual factors. For example, higher fuel prices reduce regional VMT, but the response at the household level is influenced by household location and income (Salon et al. 2012, 2013). Nationally, VMT has generally increased as the population has grown, the economy has expanded, and car ownership has increased. The Federal Highway Administration (FHWA) forecasts suggest that nationwide VMT will continue to grow by 1.07 percent annually through 2035. The FHWA forecast is influenced by projections for population growth, economic growth, and increased disposable income, all of which are positively associated with VMT (FHWA 2017).

VMT in the Tahoe Region is a function of the complex interplay of a variety of factors including population (both inside and outside the Region), gas prices, employment rates, local housing costs, demand and access for recreational opportunities in the Region, and access to alternative forms of transportation. Higher unemployment, higher fuel prices, increased congestion, work from home programs, employer car pool programs, and concentration of development in centers are all linked to reductions in VMT. While population growth, higher household income, higher employment rates, increased fuel economy and greater roadway capacity are all linked to increasing VMT. Increasing access to transit services, access to bicycle and pedestrian facilities, and the relative desirability of alternative modes of transportation in comparison to the use of the personal automobile can reduce VMT.

NITROGEN RELATED THRESHOLD STANDARDS

The VMT standard was one of a package of threshold standards that establish goals for nitrogen emissions or loading. The overlap in nitrogen load reductions standards was identified as a potential issue in the assessment of threshold standards(TRPA 2017a, 2017b). Addressing overlapping standards, and development of a more straightforward threshold standard system, that clearly articulates what the Region's goal is with respect to nitrogen loading is one of the goals for the threshold update initiative.

Among the standards adopted in 1982, two standards were adopted to reduce nitrate deposition onto the lake (TRPA 1982a):

AQ13) Reduce the transport of nitrates into the Basin and reduce oxides of nitrogen (NOx) produced in the Basin consistent with the water quality thresholds.

AQ14) Reduce vehicle miles of travel in the Basin by 10 percent of the 1981 base year values.

A third standard established a goal of stabilizing NOx emissions to address ozone concentrations. Ozone is formed through a photochemical reaction between atmospheric oxygen, hydrocarbons and/or carbon monoxide, oxides of nitrogen, and sunlight:

AQ4) Maintain oxides of nitrogen (NOx) emissions at or below the 1981 level.

Like many elements of the threshold standards system, numerous threshold standards TRPA adopted address concerns related to nitrogen loading. Two additional threshold standards were adopted in the water quality category that establish goals for reduction of nitrogen and nitrogen species:

WQ36) Reduce total annual nitrogen load to achieve long-term pelagic water quality standards (WQ1 and WQ2) and littoral quality standards (WQ5 and WQ6).

WQ41) The most stringent of the three dissolved inorganic nitrogen load reduction targets shall apply:

i. Reduce dissolved inorganic nitrogen loads to pelagic and littoral Lake Tahoe from[2]
   a) surface runoff by approximately 50 percent of the 1973-81 annual average,
   b) groundwater approximately 30 percent of the 1973-81 annual average, and
   c) atmospheric sources approximately 20 percent of the 1973-81 annual average.

ii. Reduce dissolved inorganic nitrogen loading to Lake Tahoe from all sources by 25 percent of the 1973-81 annual average.

iii. To achieve littoral water quality standards (WQ5 and WQ6).

VMT AND NOx

The relationship between VMT and NOx emissions has changed significantly over the last 40 years as a result of increasingly stringent tailpipe emissions standards. Nationally, VMT continues to increase while NOx emissions have drastically declined. Nationally, NOx emissions have decreased by 57 percent since 1980 despite a 49 percent increase in VMT since 1990 (TSAC 2018a). Locally these changes mean that a 14-fold increase in VMT from 1981 levels would be required to generate 1981 NO_x emissions levels.

Nitrogen in the Atmosphere

Molecular nitrogen (N_2) accounts for nearly 80% of the earth's atmosphere and is relatively stable. Nitrogen in the atmosphere occurs in smaller quantities in a variety of other forms, including nitrogen oxides (NOx), gaseous ammonia, organic nitrogen, particulate nitrate and ammonium compounds, and nitric acid vapor. Human activities have enriched the atmospheric concentrations of NOx, ammonia, and ammonium. Unlike $N_{2,}$ both NOx and ammonia are reactive and are readily deposited onto terrestrial and aquatic systems enriching nitrogen concentrations.

NOx is a general term for a suite of nitrogen-based compounds that are air quality pollutants of concern, including nitrates. NOx are also precursors to the formation of ozone, which is harmful to human health and can damage trees and crops at elevated concentrations. The majority of NOx emissions originate from the transportation and power generation sectors as a byproduct of fuel combustion. There are a few natural sources of $NO_{x,}$ such as lighting, but they do not add a substantial portion of global NOx emissions.

Application of nitrogen-based fertilizer on agricultural crops and keeping of livestock are responsible for 80% of ammonia emissions in the US. Ammonia and ammonium are produced naturally as a result of activity of soil microorganisms and account for 20% of global emissions. Atmospheric nitrogen is reactive and can be converted to nitric acid vapor or particulate nitrate, which are both readily deposited on land during precipitation events (NDAP 2001).

NOx Emissions

The California Air Resources Board (CARB) estimates that NOx emissions from mobile sources in the California side of the Region have decreased from 5.7 tons per day in 2000 to two tons per day in 2015 (Figure 1). The trend suggests that current emissions are approximately 25 percent of emissions in 2000. Current forecasts suggest that NOx emissions will continue to decrease to 0.6 tons per day by 2030 (CARB 2016).

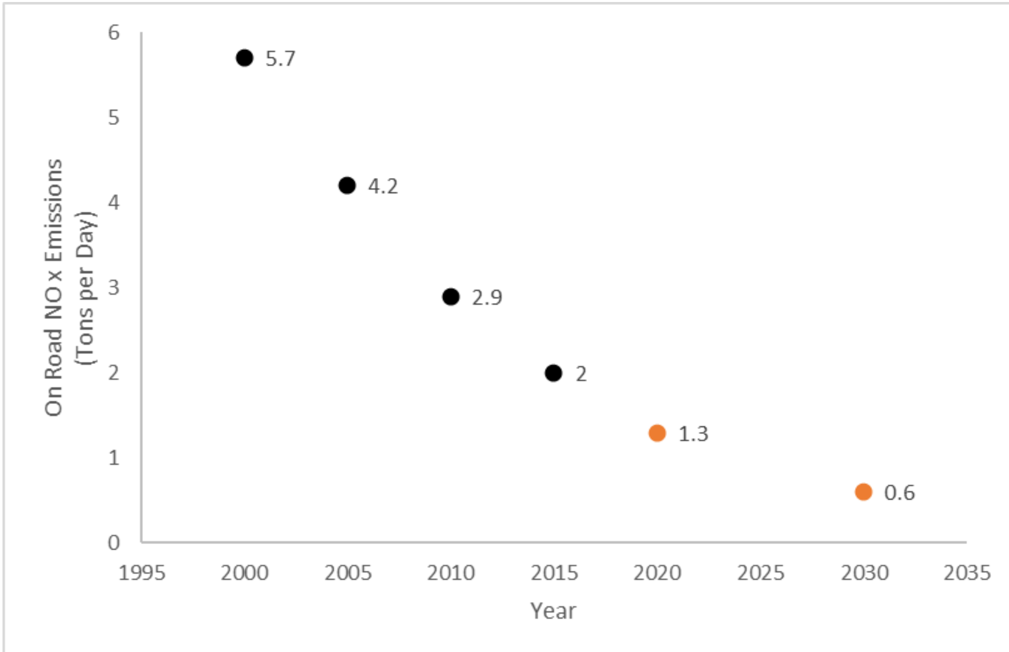

FIGURE 1: ON ROAD DAILY NO_x EMISSIONS IN THE TAHOE BASIN. SOURCE: CARB 2016

The reduction in transportation sector related NO_x emissions is the result of reduced tailpipe emissions from automobiles. In the 1950s, the average new car released 3.6 grams of NO_x for each mile it traveled (EPA 2018). The U.S. Environmental Protection Agency (EPA) established the first NO_x emission standard (3.1 grams per mile of NOx) for cars and light duty trucks in 1975 (EPA 1999). Since that time, NO_x emissions standards per mile have become increasingly strict (Figure 2).

EPA tier 3 emission standards began in the 2017 vehicle model year, and grouped NO_x emissions regulation with regulation of non-methane organic gases (NMOG). The new fleet average emission standards establish an immediate 46 percent reduction from the tier 2 requirements and become increasingly stringent over the next seven years leading to a 81 percent reduction by 2025 (EPA 2014).

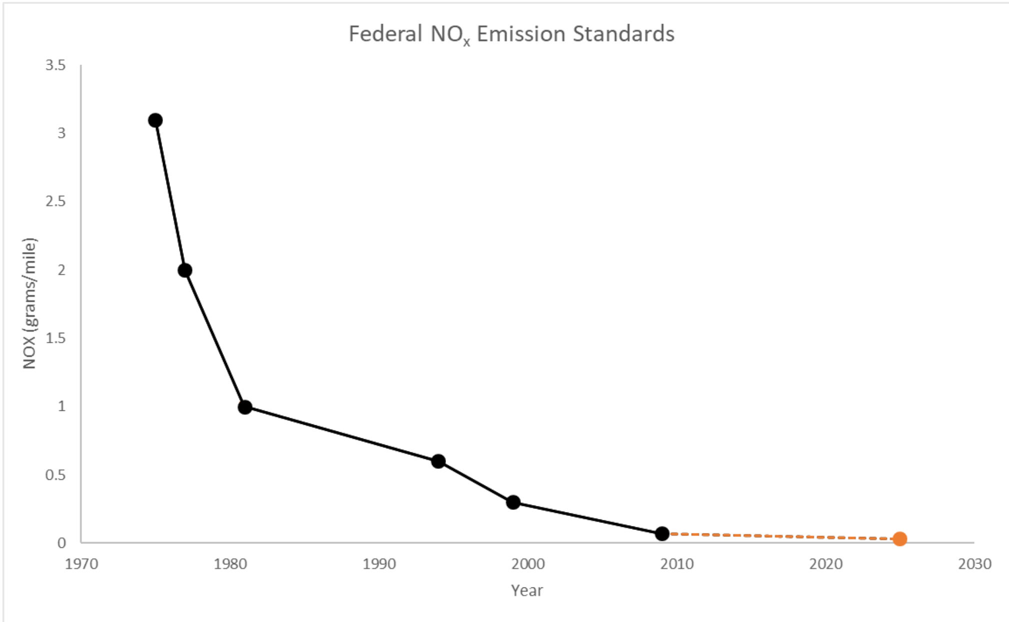

FIGURE 2: ON ROAD DAILY NO_x EMISSIONS IN THE TAHOE BASIN. SOURCE: CARB 2016

The majority of vehicle miles traveled in the Region are traveled by passenger cars and light duty trucks, which collectively account for nearly 80 percent of VMT, but account for just over half of NOx emissions in the Region (CARB 2016). On a per mile basis, NOx emissions from passenger cars and light duty trucks is less than a third of what it is from heavier vehicles. Thus, a 10 percent reduction in passenger cars' and light duty trucks' VMT would be expected to reduce NOx emissions by 5.2 percent.

NITROGEN DEPOSITION

The relationship between nitrogen emissions (local and non-local) and deposition in the Region is complex and governed by an interconnected set of factors. Deposition occurs in both dry and wet forms and in different species of nitrogen. Wet deposition is associated with precipitation events, while dry deposition refers to nitrogen deposited through interactions between airborne nitrogen species and the surface of rocks, plants, buildings, soil, and water (NDAP 2001). Nationally, nitrogen deposition is monitored by the National Atmospheric Deposition Program/National Trends Network. Monitoring suggests that there has been no significant change in nitrogen deposition in the Region over the last thirty years. The available lines of evidence are summarized below.

National Trends

Despite increasingly stringent emission standards over the last two decades of the 20th century, there was no observed response in deposition of nitrogen until 2000. Since 2000, there has been an "unprecedented decrease in NOx deposition" across the United States, with the highest observed reductions occurring on the east coast where loading is substantially higher (Lloret & Valiela 2016; TSAC 2018a). Between 1990 and 2011, a 19 percent reduction in nitrogen deposition was observed in both California and Nevada (Lloret & Valiela 2016). Deposition rates in California decreased steadily (at roughly one percent annually) throughout the entire period of record, while deposition in Nevada increased between 1990 and 1999, but has been decreasing since 2000 by approximately three percent annually (Lloret & Valiela 2016).

Tahoe Region

Two sources of data are available for nitrogen deposition in the Tahoe Region, UC Davis Tahoe Environmental Research Center (TERC) and the National Atmospheric Deposition Network.

Tahoe Environmental Research Center

TERC has monitored nitrogen deposition onto the lake for last twenty years. The historic record includes water years 1994, 1998, 2000-2017 (TERC 2018). The monitoring program collects information on total nitrogen and dissolved inorganic nitrogen. Figures 3 and 4 are reproduced from the TERC summary of monitoring through 2017 (TERC 2018). While the red trend lines show an apparent downward trend in observed deposition, there is no statistically significant trend in deposition of either total nitrogen or dissolved organic nitrogen over the period of record.

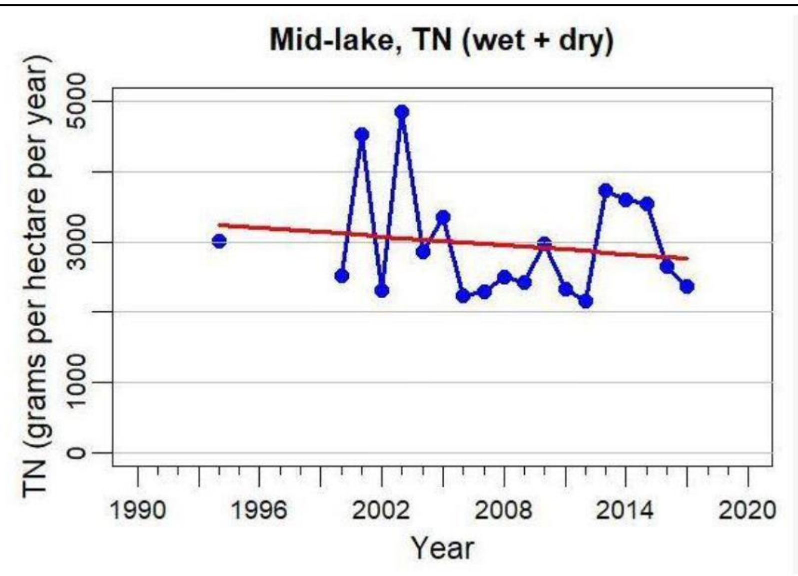

Figure 4. Annual total nitrogen (NO_3-N + TKN) loading at the mid-lake station WY1994, 2000-2017. Red line is GAM statistical line of fit. The results of the GAM analysis indicated there was no statistically significant trend for TN in atmospheric deposition at mid-lake for the period of record at the $p \leq 0.05$ level (r^2= -0.0313, p=0.509, n=19, K=3).

FIGURE 3: TOTAL NITROGEN DEPOSITION ON TO LAKE TAHOE (WATER YEARS 1994, 2000-2017). SOURCE: TERC 2018

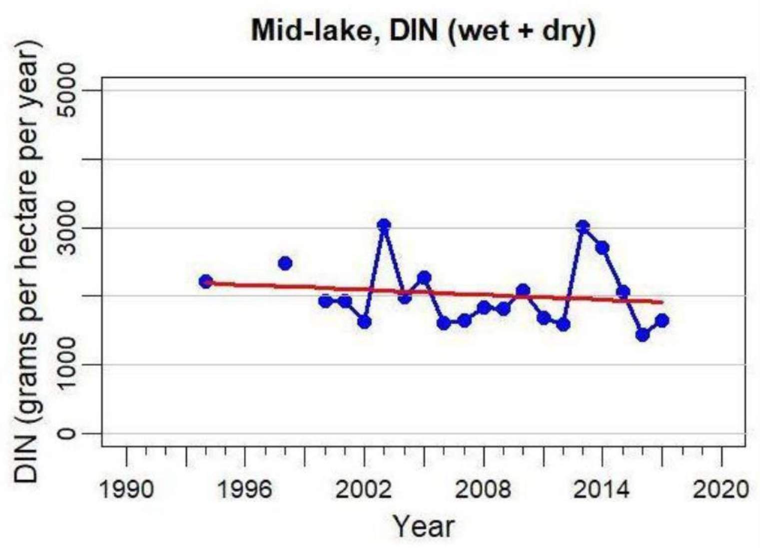

Figure 2. Annual Dissolved Inorganic Nitrogen "DIN" (NO_3-N + NH_4-N) loading at the mid-lake station WY1994, 1998, 2000-2017. Red line is GAM statistical line of fit. The results of the GAM analysis indicated there was no statistically significant trend for DIN in atmospheric deposition at mid-lake for the period of record at the $p \leq 0.05$ level ($r^2 = -0.0262$, $p=0.482$, $n=20$, $K=3$).

FIGURE 4: DISSOLVED INORGANIC NITROGEN DEPOSITION ON TO LAKE TAHOE (WATER YEARS 1994, 1998, 2000-2017). SOURCE: TERC 2018

National Atmospheric Deposition Network

Wet deposition data were summarized from the National Atmospheric Deposition Program/National Trends Network (NDAP). To represent regional deposition trends, NDAP uses data collected from its network of sites and spatial interpolation and modelling to estimate wet deposition across the entire country. There are no NDAP sites in the Tahoe Region, but four NDAP sites exist in the greater region (NTN Site CA88 -Davis, CA / NTN Site CA99, Yosemite NP / NTN Site CA50 North of Truckee / NTN Site NV03, Smith Valley, NV).

Estimated average annual concentration of NO_3 in wet deposition within the Tahoe basin was summarized from NDAP data and is presented in Figure 5. The observations are consistent with the TERC data, the trend appears to be a decline, but the trend is not statistically significant.

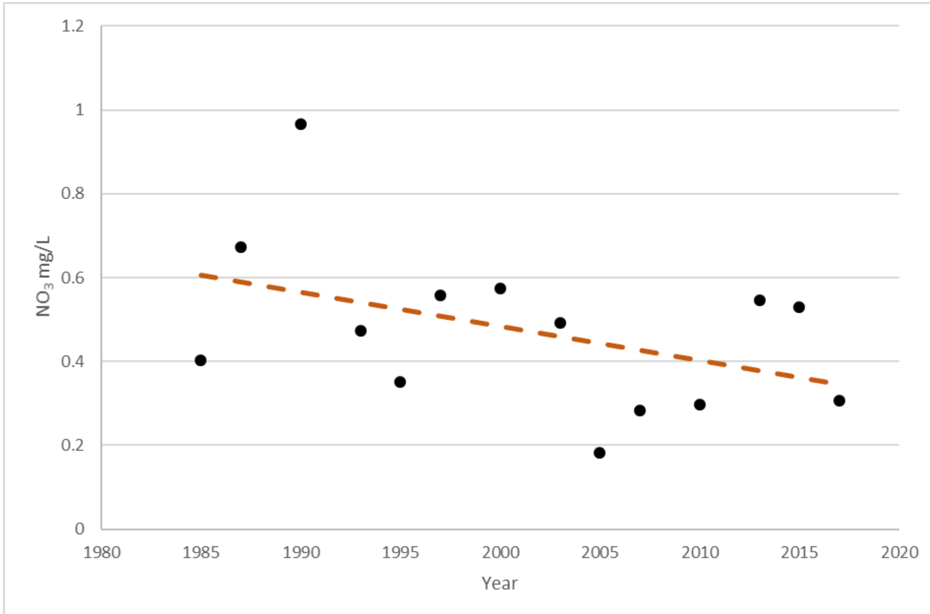

FIGURE 5: AVERAGE CONCENTRATION OF NO_3 IN WET DEPOSITION THE TAHOE BASIN. SOURCE: NADP/NTN 2018

The NADP National Trends Network (NTN) also provides estimates of total deposition (wet and dry), by leveraging air quality monitors and the Community Multiscale Air Quality (CMAQ) modeling system to estimate dry deposition (NDAP 2018). Estimates of total N deposition are available from 2000 – 2017. Estimated deposition within the Tahoe basin was summarized from NDAP data and is presented in Figure 6. In contrast to the TERC measurements and the NDAP wet deposition, total estimated total N deposition appears to be increasing, but like the other two measures, the trend is not statistically significant.

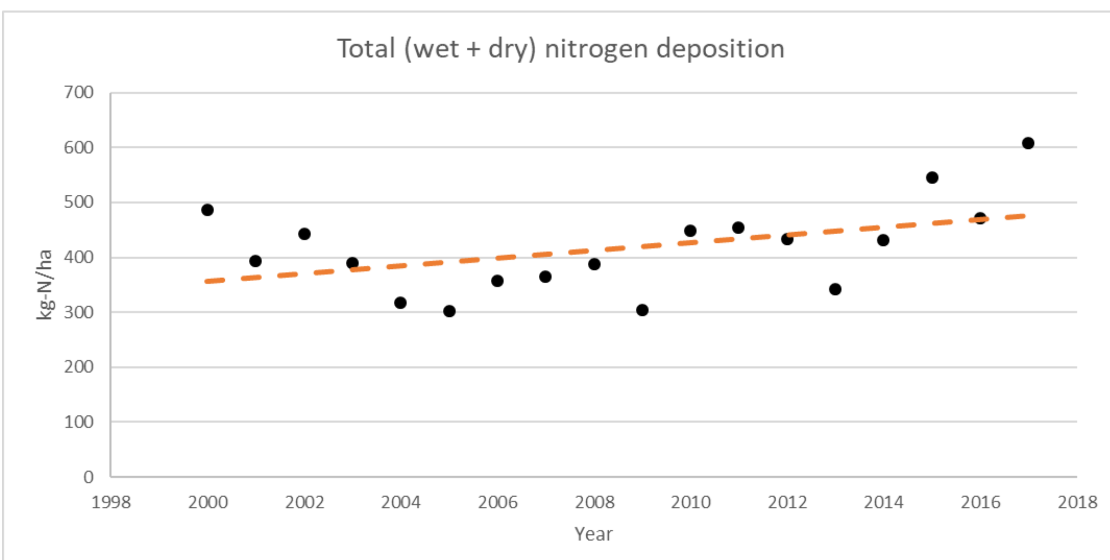

FIGURE 6: TOTAL N DEPOSITION IN THE TAHOE BASIN. SOURCE: NADP/NTN 2018 (VERSION 2018.02)

NITROGEN DEPOSITION AND EMISSIONS

The relationship between local emissions and deposition is complex as described above. While no significant pattern has been observed in deposition of total nitrogen or dissolved inorganic nitrogen onto the lake between 2000 and 2016, in basin emissions from mobile sources have declined by two-thirds over the same period (Figure 7, CARB 2016; TERC 2017).

In 2017, TRPA asked the Tahoe Science Advisory Council (TSAC) to investigate the relationship between vehicle miles traveled in Tahoe Region and pollutant loading to Lake Tahoe. Researchers at The Desert Research Institute, Division of Atmospheric Sciences used a series of model simulations to explore the impact of VMT reduction on nitrogen deposition in the Region. The preliminary research suggests that vehicles in the Region account for 20 percent of the nitrogen deposited in the Region. The research estimated that if emissions per mile were constant, nitrogen deposition would decline by 2.5 percent to 2.8 percent as a result of the 15 percent VMT reduction observed between 1981 and 2014. Actual emissions per mile have decreased significantly over the last 30 years, but exploring that change was beyond the scope of the TSAC research. The preliminary research findings suggest that if mobile emissions in the Region were reduced to zero, atmospheric deposition would be reduced by 13 percent to 14 percent (TSAC 2018b).

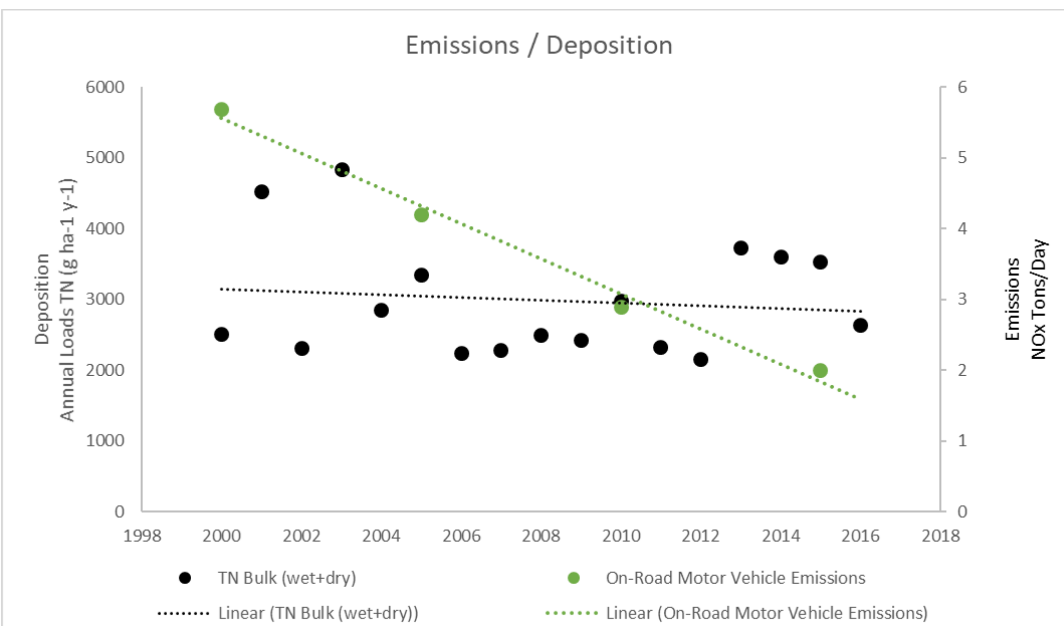

FIGURE 7: IN BASIN NITROGEN EMISSIONS AND DEPOSITION (2000-2016). SOURCE: TERC 2017, CARB 2016.

LAKE TAHOE TMDL

The Lake Tahoe Total Maximum Daily Load (TMDL) establishes the 65 year strategy to restore the historic clarity of Lake Tahoe (Lahontan & NDEP 2010). To restore that clarity, the TMDL identified three pollutants of concern (fine sediment particles, nitrogen, and phosphorus) and the sources and associated loads of those pollutants. The TMDL establishes the load reduction targets necessary for each pollutant of concern (a 65 percent reduction in fine sediments, a 10% reduction in nitrogen, and 35% reduction in phosphorus) to restore the historic clarity of the lake. The more ambitious load reduction target for fine sediments, reflects both the primary importance of fine sediments as a driver of clarity, and the cost effectiveness of load reduction opportunities.

Nitrogen Load Reduction

The TMDL target for reduction in total nitrogen load from all sources is 10 percent by 2076. Atmospheric deposition of nitrogen was estimated to account for 63 percent of total nitrogen load to the lake. The TMDL target for nitrogen load reduction from atmospheric sources is one percent by 15 years of implementation and two percent by 2076 (Lahontan & NDEP 2010). The Lake Tahoe TMDL Pollutant Reduction Opportunity Report analyzed pollutant load reductions and the costs associated with those controls (Lahontan & NDEP 2008).

The Lake Tahoe TMDL Program 2018 Performance Report estimated that TMDL implementors reduced nitrogen load from urban areas by 7.3 percent in the 2017 water year (Lahontan & NDEP 2018). The U.S. Geologic Survey, TERC, and independent statisticians analyzed over 30 years of stream loading data for the 2015 Threshold Evaluation Report. They found that over the 30 year period there had been 52.1 percent reduction in flow weighted nitrite, but found no significant trend in flow weighted total nitrogen load (TRPA 2016). Inter-annual variability in local weather and the resulting amount, timing, and type of precipitation have a strong influence on stream inflow and pollutant load. Flow weighted load analysis accounts for the variability in inflow and provides an estimate of the nutrient load carried by a set amount of water.

Fine Sediment Load Reduction

Fine sediment particle (FSP) accumulation is primarily responsible for declining clarity and reducing fine sediment load is the primary focus of the TMDL. TMDL development considered a number of options for fine sediment load reduction. Preliminary studies conducted for the TMDL also explored the efficacy of VMT reduction as a strategy to reduce atmospheric fine sediment loading. The preliminary findings of the TMDL work suggested that VMT reduction would likely not be a cost-effective strategy for FSP load reduction. The work estimated that a 25 percent reduction in VMT would reduce FSP loads by less than half of one percent (Lahontan & NDEP 2008).

CONCLUSION

The VMT standard was originally adopted as a policy to reduce emissions of nitrogen from mobile sources in the Region, and thereby reduce loading to the Lake. The understanding of the relationship between in-region nitrogen emissions and atmospheric deposition has progressed as a result of empirical observations over the last 30 years.

- Current in-basin NO_x emissions from mobile sources are substantially below 1981 levels.
- A 14-fold increase in VMT from 1981 levels would be required to equal the 1981 NOx emissions levels.[2]
- The goal established by the VMT standard, a 10% reduction in NOx emissions from in-basin mobile source, was likely achieved more than 15 years ago.
- NO_x emissions are likely to continue to decline even further as a result of increasingly strict tailpipe emissions standards.
- Atmospheric deposition of nitrogen hasn't changed significantly in the last 20 years.
- Nitrogen emissions from mobile sources in the Region have declined by >66%, far in exceedance of the standard's goals. Despite this decline, no significant change in atmospheric deposition of nitrogen has been observed.

Understanding of the drivers of clarity loss has improved significantly since the standards was adopted in 1982. The motivating concern at the time was algal growth in the lake which was thought to be primarily responsible for declining clarity.

- The TMDL demonstrated that clarity loss is primarily driven by fine sediment particle accumulation.
- The TMDL found that excess algal growth is responsible for roughly a third of clarity loss.
- TMDL implementation focuses on reduction of FSP load
- Preliminary TMDL science suggested that VMT reduction was unlikely to be a cost-effective strategy to reduce nitrogen loading.

The declines in emissions from mobile sources means that functionally the VMT standard no longer provides additive water quality benefits to the load reduction targets established by Air Quality standard 13 and Water Quality standards 36 and 41, which directly address nitrogen from all sources.

[2] Calculations based on the difference between 1981 and 2009 model year tailpipe emissions standards. Using the 2025 model year emissions standard the necessary increase would be a 33 increase in VMT.

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TAHOE REGIONAL PLANNING AGENCY

P.O. Box 5310
Stateline, NV 89449
fax 775-588-4527
www.trpa.org

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