CHAPTER 4
Water Quality

The Lake's iconic transparency and stunningly blue waters are often the first thing that comes to mind when people think of the Tahoe Region. The lake's clarity has been regularly measured since 1968, when UC Davis first started lowering a Secchi disk into the lake, establishing one of the longest, unbroken clarity measurement records in the world. The Secchi depth measurements are perhaps the best known of all the indictors of the Region's environmental health. Between 1968 and 2000, the clarity of the lake regularly declined, but the long term decline in clarity observed in the end of the 20th century appears to have been halted about15 years ago. While this is an encouraging trend, there is still much work to be done, and is but one of many measures of the health of Region's aquatic systems.

The health of the aquatic system is assessed with respect to six threshold standards categories: 1) Lake Tahoe pelagic (deep) waters, 2) Lake Tahoe littoral (nearshore) waters, 3) tributaries, 4) surface runoffs, 5) groundwater, and 6) other lakes (i.e., lakes other than Lake Tahoe). Fine sediment particles ($\leq$ 16μm) and nutrients that support algal growth (nitrogen and phosphorus) are the primary pollutants of concern in the Region because of the negative impact on transparency (Lahontan & NDEP, 2010a) and, in the case of nutrients, the blueness of the lake (Watanabe et al., 2016). Additionally, many components of the aquatic system are thought to be adversely affected by these pollutants (Reuter et al., 2009).

The Bi-State Compact requires the Regional Plan to provide for the attainment and maintenance of federal, state, and local water quality standards. Resolution 82-11 sets out numerical standards, management standards, and policy statements for water quality. Some of these threshold standards are referenced to state standards. In other cases, Resolution 82-11 sets targets based on reference conditions related to specific periods, and can be found in the Study Report for the Establishment of Environmental Threshold Carrying Capacities (TRPA, 1982). The value statements were developed in 1982, that guided the development of threshold standards for water quality were:

- Attain levels of water quality in the lakes and streams within the basin suitable to maintain the identified beneficial uses of Lake Tahoe.
- Restrict algal productivity (rate of growth) to levels that do not impair beneficial uses or deteriorate existing water quality conditions in the Lake Tahoe basin.
- Prevent degradation of the water quality of Lake Tahoe and its tributaries to preserve the Lake for future generations.
- Restore all watersheds in the basin so that they respond to runoff in a natural hydrologic function.

Prior to the arrival of European settlers, fire, floods, and other natural disturbances (e.g., earthquakes, landslides, or avalanches) were the major drivers of pollutants like fine sediments and nutrients entering the lake. However, these were likely episodic in nature, with potentially substantial intervening periods between major events. More regular, low-intensity fires and a mature forest likely translated into low-nutrient stores on the forest floor. These were the watershed conditions that supported an ultraoligotrophic Lake Tahoe: a lake with a sustained level of exceptional water clarity (greater than or equal to 30 meters), a lake receiving low inputs of nutrients and therefore supporting low levels of primary productivity, and a lake containing a relatively simple food web that may have substantially relied on the recycling of nutrients and carbon, rather than new inputs from the surrounding watershed.

Urbanization and development altered the natural hydrologic regimes of many of the catchments in the Tahoe Region. Studies completed as part of the Lake Tahoe Total Maximum Daily Load (TMDL) show that urban areas are the primary source of fine sediment (the pollutant known to impact lake clarity) (Lahontan & NDEP, 2010a, 2010b). Much of the urban development has occurred along the edge of Lake Tahoe, meaning that in many cases, there is little or no buffer between the source of pollution and the Lake. The concentration of development also represents an opportunity for managers in the Region to mitigate impacts. For example, the Regional Transportation Plan focuses on ensuring that compact town centers are well served by transit, pedestrian and bicycle infrastructure, thus reducing reliance on cars, resulting less pollutant load reaching the lake. Reducing reliance on automobile is essential for addressing atmospheric deposition of nitrogen into the lake, which accounts for more than half of nitrogen loading (Lahontan & NDEP, 2010a, 2010b).

The nearshore of Lake Tahoe is an increasingly important focus for managers in the Region. It is the portion of the lake that visitors and residents most often interact with, and the presence of invasive species (e.g. Eurasian watermilfoil and curlyleaf pondweed) and anecdotal reports of change in nearshore conditions have heightened awareness of the nearshore. In 2012, the TRPA Governing Board adopted two new standards related to the nearshore environment, to address attached algae (periphyton) and aquatic invasive species. In October 2013, the Desert Research Institute, University of California at Davis, and the University of Nevada at Reno released the Lake Tahoe Nearshore Evaluation and Monitoring Framework Report (Heyvaert et al., 2013a). The report presents a conceptual understanding of nearshore environmental processes, highlights the heterogeneous nature of the nearshore, identifies deficiencies in the data available to characterize the environmental status of the Lake Tahoe nearshore, and proposed a set of monitoring metrics. The report also indicated that the actions implemented by partners in the Region to improve pelagic water quality are likely to benefit nearshore conditions. Pilot monitoring efforts were initiated in 2014 and 2015 to address specific data gaps identified in the report. The number of parameters of interest in the nearshore (including clarity, metaphyton, periphyton, toxins, and others) and spatial variability around the lake (conditions in one location are not necessarily indicative of conditions in other locations) complicate management of the nearshore. Building upon the report and recent monitoring efforts, management partners in the Region, including representatives from U.S. EPA, Lahontan, NDEP and TRPA, are developing a nearshore resource allocation plan (NRAP). The NRAP will be a comprehensive framework for allocating resources to enhance our understanding of the nearshore environment and more effectively targeting management actions to preserve the resource for future generations. A draft version of the NRAP is expected to be available in late 2016.

This chapter presents an evaluation of the water quality conditions and trends for the Region's aquatic system relative adopted standards (Table 4-1). However, the health of the Region's aquatic system is intimately linked to many of the components of the terrestrial system that are evaluated in other chapters of the report. The extent of impervious surfaces (soils chapter), the status vegetation and riparian areas (vegetation chapter), the condition of Region's streams (fisheries chapter), and atmospheric deposition of nitrogen (air quality chapter) all strongly influence the pollutant load reaching the Lake. Although these factors are evaluated in other chapters of this report, they provide the context necessary to interpret the findings of this chapter and guide management in the Region.

Table 4-1. *Water quality standards for the Tahoe Region aquatic system organized by the six major components of the Tahoe Region's aquatic system. Each component is considered a separate indicator reporting category.*

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Pelagic Lake Tahoe	Nitrogen loading	Numerical	Reduce dissolved inorganic nitrogen (N) loading from all sources by 25 percent of 1973 to 1981 annual average.	Annual mean total nitrogen concentration less than or equal to 0.15 to 0.23 milligrams per liter depending on the water body.	Total annual load	Concentration: milligrams/liter (mg/L) Load: kilograms/year (kg/yr)
	Phytoplankton primary productivity	Numerical	Maintain annual mean phytoplankton primary productivity at or below 52 grams of carbon per square meter per year. (gmC/m2/yr).	None	grams Carbon/m^2/yr.	grams/m^2/yr.
	Secchi depth	Numerical	The annual average deep water transparency as measured by Secchi disk shall not be decreased below 29.7 meters (97.4 feet), the average levels recorded between 1967 and 1971 by the University of California, Davis.	Transparency - Annual mean Secchi disk transparency: 29.7meters (California state standard)	Secchi disc depth	Meters (m)
	Vertical Extinction Coefficient	Numerical		The vertical extinction coefficient must be less than 0.08 per meter when measured at any depth below the first meter (California and Nevada state standard).	Vertical Extinction Coefficient	The percentage of the light absorbed or scattered in a meter-long vertical column of water

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Recognition of threshold standard exceedance	Policy	This threshold (numeric standard) is currently being exceeded and will likely continue to be exceeded until sometime after full implementation of the loading reductions prescribed by the thresholds.	N/A	N/A	N/A
	Pollutant loading	Management	Reduce the loading of dissolved phosphorus, iron, and other algal nutrients from all sources as required to achieve ambient standards for primary productivity and transparency.	Annual mean total phosphorus concentration less than or equal to 0.005 to 0.015 mg/L, depending on the water body. Annual mean iron concentration less than or equal to 0.01 to 0.03 mg/L, depending on the water body.	Total annual load	Concentration: mg/L Load kg/year

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Pollutant loading	Management	Reduce dissolved inorganic nitrogen loads from surface runoff by approximately 50 percent, from groundwater approximately 30 percent, and from atmospheric sources approximately 20 percent of the 1973 to 1981 annual average. This threshold relies on predicted reductions in pollutant loadings from out-of-Basin sources as part of the total pollutant loading reduction necessary to attain environmental standards, even though the Agency has no direct control over out-of-basin sources. The cooperation of the states of California and Nevada will be required to control sources of air pollution which contribute nitrogen loadings to the Lake Tahoe Region.	Annual mean total nitrogen concentration less than or equal to 0.15 to 0.23 mg/L depending on the water body.	Total annual load	Concentration: mg/L Load kg/year
Littoral Lake Tahoe	Nitrogen loading	Numerical	Reduce dissolved inorganic nitrogen (N) loading from all sources by 25 percent of 1973 to 1981 annual average.	Annual mean total nitrogen concentration less than or equal to 0.15 to 0.23 mg/L depending on the water body.	Total annual load	Concentration: mg/L Load kg/year

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Pollutant loading	Numerical	Reduce the loading of dissolved inorganic nitrogen, dissolved phosphorus, iron, and other algal nutrients from all sources to meet the 1967 to 1971 mean values for phytoplankton primary productivity and periphyton biomass in the littoral zone.	Annual mean total nitrogen concentration less than 0.15 to 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration less than 0.005 to 0.015 mg/L, depending on the water body. Annual mean iron concentration less than 0.01 to 0.03 mg/L, depending on the water body.	Total annual load	Concentration: mg/L Load kg/year
	Nearshore turbidity	Numerical	Decrease sediment load as required to attain turbidity values not to exceed three nephelometric turbidity units (NTU). In addition, turbidity shall not exceed one NTU in shallow waters of the lake not directly influenced by stream discharges	None	Turbidity	Nephelometric Turbidity Unit (NTU)

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Pollutant loading	Management	Reduced dissolved inorganic nitrogen loads from surface runoff by approximately 50 percent, from groundwater approximately 30 percent, and from atmospheric sources approximately 20 percent of the 1973 to 1981 annual average. This threshold relies on predicted reductions in pollutant loadings from out-of-basin sources as part of the total pollutant loading reduction necessary to attain environmental standards, even though the Agency has no direct control over out-of-basin sources. The cooperation of the states of California and Nevada will be required to control sources of air pollution which contribute nitrogen loadings to the Lake Tahoe Region.	Annual mean total nitrogen concentration less than or equal to 0.15 to 0.23 mg/L depending on the water body.	Total annual load	Concentration: mg/L Load kg/year

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Attached Algae	Management	Implement policy and management actions to reduce the areal extent and density of periphyton (attached) algae from Lake Tahoe's nearshore.	Not applicable	Areal extent and density of periphyton	Periphyton biomass index (PBI)

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Aquatic Invasive Species	Management	Prevent the introduction of new aquatic invasive species into the Region's waters and reduce the abundance and distribution of known aquatic invasive species. Abate harmful ecological, economic, social and public health impacts resulting from aquatic invasive species.	Not applicable.	Not applicable.	Not applicable.

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Tributaries	Attain applicable state standards	Numerical	Attain applicable state standards for concentrations of dissolved inorganic nitrogen, dissolved phosphorus, and dissolved iron. Attain a 90 percentile value for suspended sediment concentration of 60 mg/L.	California standard: attain a 90th percentile value for suspended sediment concentration of 60 mg/L. Annual mean total nitrogen concentration less than 0.15 to 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration less than 0.005 to 0.015 mg/L, depending on the water body. Annual mean iron concentration less than 0.01 to 0.03 mg/L, depending on the water body. Nevada standard: annual mean total phosphorus concentration less than or equal to 0.05 mg/L.	Same as most stringent state standard. Proportion of individual measurements that exceed 60 mg/L of suspended sediment.	Milligrams/liter (mg/L) for nutrients; percentage of individual measurements exceeding 60 mg/L for sediment
	Total annual nutrient and suspended sediment loads	Management	Reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe.	Annual mean total concentration of nitrogen, phosphorus, and suspended sediment.	Total annual load	Concentration: mg/L Load kg/year

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Surface Runoff (discharge to a water body)	Nutrient concentrations	Numerical	Achieve a 90 percentile concentration value for dissolved inorganic nitrogen (DIN) of 0.5 mg/L, for dissolved phosphorus (DP) of 0.1 mg/L, and for dissolved iron (DI) of 0.5 mg/L in surface runoff directly discharged to a surface water body in the Basin.	Annual mean total nitrogen concentration less than 0.15 to 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration less than 0.005 to 0.015 mg/L, depending on the water body. Annual mean iron concentration less than 0.01 to 0.03 mg/L, depending on the water body.	Proportion of individual measurements that exceed 0.5 mg/L (DIN), 0.1 mg/L (DP), and 0.5 mg/L (DI)	Percentage
	Sediment concentrations	Numerical	Achieve a 90 percentile concentration value for suspended sediment of 250 mg/L.	Attain a 90th percentile value for suspended sediment concentration of 60 mg/L.	Proportion of individual measurements that exceed 250 mg/L	Percentage
	Total annual nutrient and suspended sediment loads	Management	Reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe	Reduce loads of fine sediment particles, total nitrogen, and total phosphorus as established by Lake Tahoe TMDL.	Total annual load	kg/year

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Ground-water (discharge to)	Surface runoff infiltration	Management	Surface runoff infiltration into the groundwater shall comply with the uniform Regional Runoff Quality Guidelines as set for in Table 4-12 of the Draft Environmental Threshold Capacity Study Report, May, 1982.	California standard: Attain a 90th percentile value for suspended sediment concentration of 60 mg/L. Annual mean total nitrogen concentration less than 0.15 to 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration less than 0.005 to 0.015 mg/L, depending on the water body. Annual mean iron concentration less than 0.01 to 0.03 mg/L, depending on the water body. Nevada standard: Annual mean total phosphorus concentration less than or equal 0.05 mg/L.	Maximum concentration of constituent in waters infiltrated into soils: Total nitrogen = 5 mg/L; total phosphate = 1 mg/L; iron = 4 mg/L; turbidity = 200 NTU; grease and oil = 40 mg/L.	mg/L or NTU

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Surface-groundwater connection	Management	Where there is a direct and immediate hydraulic connection between ground and surface waters, discharges to groundwater shall meet the guidelines for surface discharges, and the Uniform Regional Runoff Quality Guidelines shall be amended accordingly.	California standard: Attain a 90th percentile value for suspended sediment concentration of 60 mg/L. Annual mean total nitrogen concentration less than 0.15 to 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration less than 0.005 to 0.015 mg/L, depending on the water body. Annual mean iron concentration less than 0.01 to 0.03 mg/L, depending on the water body. Nevada standard: Annual mean total phosphorus concentration less than or equal to 0.05 mg/L.	Maximum concentration of constituent in waters infiltrated into soils: Total nitrogen = 5 mg/L; total phosphate = 1 mg/L; iron = 4 mg/L; turbidity = 200 NTU; grease and oil = 40 mg/L.	mg/L or NTU
Other Lakes	Attain existing water quality standards	Numeric	Attain existing water quality standards	California standards for Fallen Leaf Lake: mean total nitrogen concentration (May to October) less than 0.087 mg/L. Annual mean total phosphorus concentration (May to October) less than 0.008 mg/L. Annual mean iron concentration (May to October) less than 0.005 mg/L. Annual mean Secchi depth (May to October) greater than or equal to 18.5 m.	Same as state standards	mg/L; meters (m)

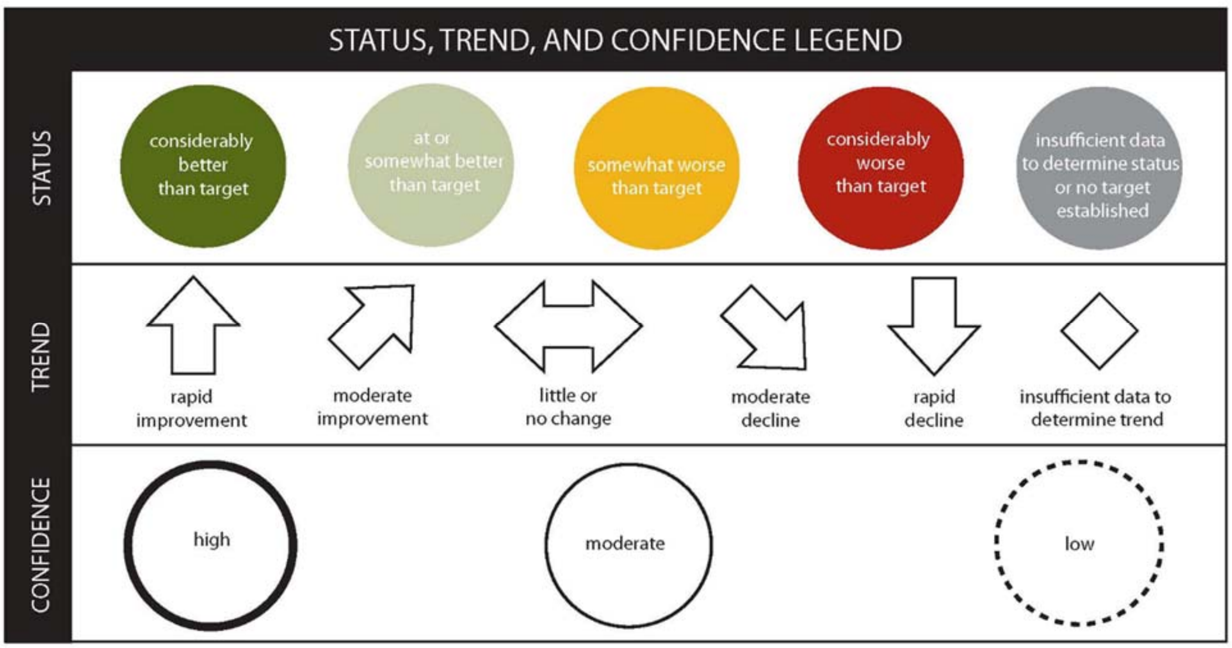
The results of the 2015 assessment are summarized in Table 4-2. The table also summarizes results from the 2011 Threshold Evaluation Report to facilitate comparison. Figure 4-1 and Table 4-3 provide a key to the symbols used to communicate status, trends, and confidence, and a detailed description of symbol is provided in the methodology section. The indicator sheets that follow contain a more detailed assessment of the status and trend of each indicator, provide descriptions of the methods used, and recommendations for modification of the standard or analytic approach used to assess the standard.

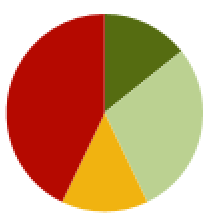
Table 4-2: *Summary of status and trend of water quality indicator reporting categories from the 2011 and 2015 Threshold Evaluation Reports. Following the convention of the 2011 Threshold Evaluation Report, icons for the groundwater and other lakes reporting categories are presented in Table 4-2 but indicator sheet are not included in the report.*

Standard	2011	2015
Pelagic Lake Tahoe		
Winter Average Secchi Disk Transparency (relative to interim target)		Removed (12-12-2012)
Secchi Depth (Clarity Challenge)		
Secchi Depth	Not assessed	
Phytoplankton Primary Productivity		
Clarity – Vertical Extinction Coefficient (VEC)	Not assessed	
Littoral Lake Tahoe		
Nearshore Turbidity (Stream Influence)		
Nearshore Turbidity (No Stream Influence)		
Nearshore Attached Algae	Not assessed	
Aquatic Invasive Species	Not assessed	
Tributaries		
Suspended Sediment Concentration		

Standard	2011	2015
Phosphorus Concentration		
Nitrogen Concentration		
Suspended Sediment Load		
Fine Sediment Load		
Phosphorus Load		
Nitrogen Load		
Surface Runoff		
Suspended Sediment Concentration		
Phosphorus Concentration		
Nitrogen Concentration		
Suspended Sediment Load		
Phosphorus Load		
Nitrogen Load		
Groundwater		
Nutrient Concentration Standards		
Sediment Concentration Standards		
Other Lakes		

Standard	2011	2015
Nutrients		
Secchi Depth		
Other Parameters		





In instances where there are too many standards and/or indicators to present each one in its own indicator sheet a pie chart showing the percentage of indicators in each status category are presented instead. The colors of the pie chart correspond to the status colors.

Figure 4-1: *A key to the symbols used to assess status, trends, and confidence levels.*

Table 4-3. *Key to the Reporting icon used to characterize the implementation status of management standards and policy statements.*

Status Category	Description	Reporting Icon
Implemented	The management standard or policy statement has been integrated into the Regional Plan and is consistently applied to a project design or as a condition of project approval as a result of project review process. Examples of programs or actions can be identified to support the management standard's implementation. Adopted programs or actions support all aspects of the management standard or policy statement's implementation, or address all major threats to implementation.	I
Partially Implemented	The management standard or policy statement has been integrated into the Regional Plan, but is not consistently applied during the project review process. No more than two examples of programs or actions can be identified to support the management standard's implementation and/or adopted programs or actions support some aspects of the management standard or policy statement's implementation, or address some major threats to implementation.	PI
Not Implemented	The management standard or policy statement has not been integrated into the Regional Plan and is not applied during the project review process. No examples of programs or actions can be identified to support implementation.	NI

Pelagic Lake Tahoe

Lake Tahoe's pelagic waters are the deeper waters of the lake. The TRPA Code of Ordinances defines the "lakezone" as all waters of the lake that are lakeward of the lake bottom elevation of 6,193-feet (1888m) Lake Tahoe Datum, or more than 350-feet (107m) from the shoreline. Lake Tahoe is designated as an "Outstanding National Resource Water" by both the federal and California governments and as a "Water of Extraordinary Ecological or Aesthetic Value" by the State of Nevada. In addition to aesthetic enjoyment, the exceptional quality of the lake's water supports a number of beneficial uses related to human and environmental health, including drinking water supply, water contact recreation, wildlife habitat, and aquatic life and habitat.

Attaining and maintaining a high level of clarity and exceptional water quality is a primary goal of the pelagic standards. Between 1968 and 2000, approximately one-third of Lake Tahoe's water clarity was lost. Declining clarity prompted the Lahontan Regional Water Quality Control Board and Nevada Division of Environmental Protection to lead the development of the Total Maximum Daily Load (TMDL) requirements for Lake Tahoe. The TMDL program is a science-based plan to reduce pollutant loads and restore deepwater transparency to historic levels. In 2011, the TMDL established an interim goal, referred to as the "Clarity Challenge", of 78 feet (23.8m) of clarity by 2031. Progress towards the Clarity Challenge goal is assessed with the five-year average Secchi depth, because of high inter-annual variability. In 2015, the five-year average Secchi depth increased to 73.1 ft (22.3m), the fifth consecutive year of improvement.

The Regional Plan contains policies and management strategies that complement the actions of TMDL implementers and support attainment of the pelagic threshold standards. These include:

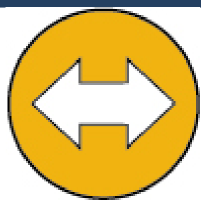
- Restoring and enhancing stream environment zones (SEZ).
- Limiting the rate and extent of urban growth.
- Implementing best management practices (BMPs) on developed properties to reduce nutrient and sediment discharge.
- Reducing private automobile use through improvements to public transit and alternative transportation modes with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment.
- Ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects.

More specific information about water quality improvement policies and regulations implemented through TRPA permit review processes can be found in the TRPA Regional Plan. Information about the implementation of environmental improvement projects and water quality mitigation programs is provided in the implementation and effectiveness chapter of this report (Chapter 12).

Two indicators are monitored to document the long-term status and trend of Lake Tahoe's pelagic waters relative to TRPA numerical standards: phytoplankton primary productivity and annual average lake transparency. The states of California and Nevada each have an adopted standard for clarity (measured by the vertical extension coefficient) that is also reported.

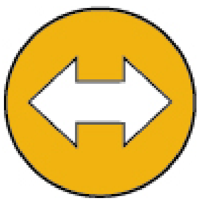
Pelagic Lake Tahoe: **Secchi Depth**

Status	Trend



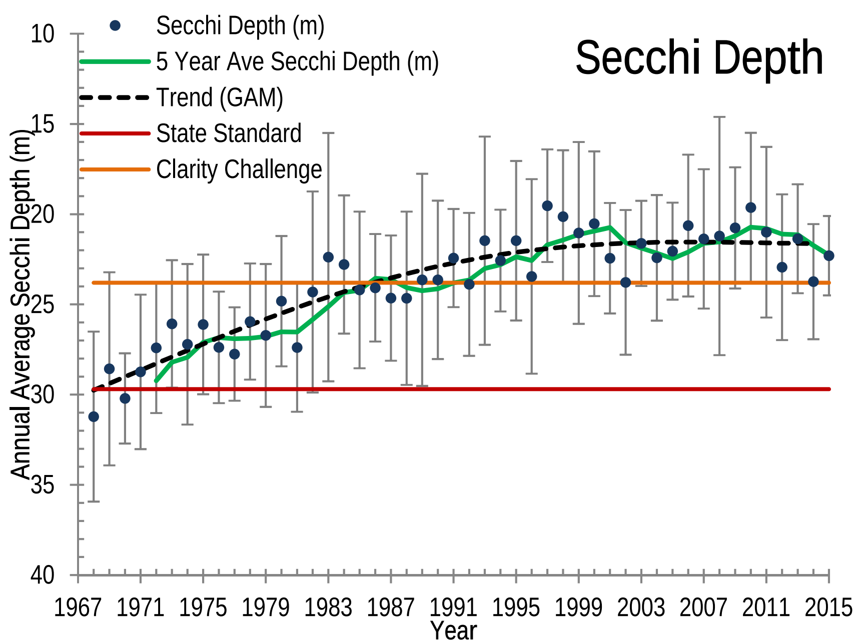
SECCHI DEPTH
(CLARITY CHALLENGE)

Status: **Somewhat Worse than Interim Target**
Trend: **Little or no Change**
Confidence: **Moderate**



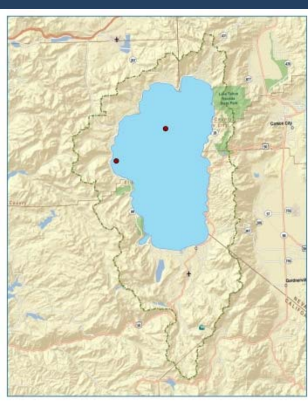
SECCHI DEPTH

Status: **Somewhat Worse than Interim Target**
Trend: **Little or no Change**
Confidence: **Moderate**



Annual average Secchi disk depth measurements recorded at the Lake Tahoe Index Station (1968 through 2015). Each annual value is an integrated average using 18 to 37 individual measurements taken throughout the year. Error bars indicate ±1standard deviation from the annual average. The trend line is determined statistically using a general additive model (GAM). The five-year running average (green line) between 2010 and 2015 was 22.3 meters (73.2 feet), 2.1m less than the TMDL Clarity Challenge target of 23.8 meters (78 feet) by 2026. Data from the UC Davis – Tahoe Environmental Research Center (TERC, 2015).

Map



Monitoring locations for Secchi depth and other water quality parameters. The index station is located along the west shore.

Data Evaluation and Interpretation

BACKGROUND

Relevance – This indicator tracks the transparency of Lake Tahoe as measured by the annual average Secchi depth at the Lake Tahoe Index Station. To restore Lake Tahoe's historic transparency and clarity and protect its special status designations, the states of California and Nevada collaborated to develop a water quality restoration plan and jointly administer the Lake Tahoe Total Maximum Daily Load Program (TMDL). The protection of Lake Tahoe's transparency is a key component of the Regional Plan, and a priority focus of the Environmental Improvement Program. Restoring Lake Tahoe's transparency is important to maintaining both ecological function, and its values to local and regional economies as a recreational destination and drinking water source. Additional information is available on the Lake Tahoe TMDL website (https://www.enviroaccounting.com/TahoeTMDL/Program/Home). This standard was established by the State of California in the early 1970's, and also is codified in the Bi-State Lake Tahoe TMDL.

TRPA Threshold Category – Water Quality

TRPA Indicator Reporting Category – Pelagic Lake Tahoe

Adopted Standard – The annual average deep water transparency as measured by Secchi disk shall not be decreased below 29.7 meters (97.4 feet), the average levels recorded between 1967 and 1971 by the University of California, Davis.

Type of Standard – Numerical

Indicator (Unit of Measure) – Between 18 and 37 individual Secchi depth measurements have been collected each year at an established index station. Values are aggregated over the calendar year to generate an estimate of the annual average. Individual measurements are recorded in meters.

Human and Environmental Drivers – Water transparency in Lake Tahoe is largely controlled by particles blocking light penetration either by scattering or by absorption (Swift et al., 2006). The decline in transparency is a result of additions of fine sediment particles and growth of phytoplankton (algae). The TMDL estimated that fine sediment particles (FSP) are responsible for about two-thirds of the overall decline in transparency. The primary source of fine sediment particles in the lake is stormwater runoff, which accounts for 72 percent of total load (Lahontan and NDEP, 2010a). Additional sources include atmospheric deposition (15 percent) and non-urban uplands (nine percent) and stream channel erosion (four percent) (Lahontan and NDEP, 2010a). Algal growth is stimulated by nutrient (nitrogen and phosphorus) loading from stream and stormwater runoff and atmospheric deposition (Lahontan and NDEP, 2010a). Drivers influencing the delivery of fine sediment and nutrients include urban development (including the transportation network and vehicle density), anthropogenic and natural disturbance in the undeveloped portions of the watershed, and local and regional climate (especially wind and precipitation). Below average stream inflows and stormwater runoff due to the continuing drought are substantial contributing factors in the recent improvement of lake transparency (TERC, 2015). The composition of diatom communities also influences clarity. When communities are dominated by smaller size diatoms, clarity is reduced because smaller diatoms remain in suspension longer, thus continuing to scatter light and decrease clarity (Winder et al., 2009). Lake mixing also influences clarity. The deeper waters of Lake Tahoe are very clear. During mixing events, when deep waters are brought up the surface, clarity is often quite high. However, mixing also brings nutrients to the surface which promotes algae growth which can reduce clarity. Climate change has the potential alter the depth and frequency of mixing(Sahoo et al., 2015, 2013). Altered mixing regime may further influence the algal composition in the lake

MONITORING AND ANALYSIS

Monitoring Partners – University of California at Davis, Tahoe Environmental Research Center, and TRPA.

Monitoring Approach – Measurements are taken in Lake Tahoe using a 25 centimeter, all white Secchi disk. The disk is lowered into the water column from a boat to a depth at which it is no longer visible by the observer, and then raised slowly until visible again. The midpoint of these two depths is called the Secchi depth. Between 18 and 37 individual Secchi depth measurements have been collected each year at an established index station. Values are aggregated over the calendar year to generate an estimate of the annual average. The measurements presented in this evaluation report are taken from the index station, where uninterrupted monitoring has occurred since 1967. Although this station appears close to the shoreline, lake depth at this location is greater than150 meters and is characteristic of open-water. Early studies by UC Davis show this location is representative of the lake's deep-water condition (Charles Remington Goldman, 1974).

Analytic Approach – Status is assessed by direct comparison of the most recent annual average value to the established interim target. Trend is determined using a generalized additive model (GAM). Since about year 2000, the rate of change in Secchi depth has decreased and recent Secchi depth measurements have been better than predicted by a long-term linear trend. Therefore, estimating the long-term trend using a linear estimate of change is no longer applicable to describe the observed pattern. Instead, a trend line was generated using a GAM, a more sophisticated statistical approach that shows the non-linear aspect of the observed trend in the data. The GAM permits a nonlinear relationship by fitting a smoothing function, which allows the trend analysis of recent years to be controlled more by recent measurements. The purpose of a GAM is to maximize the quality of prediction of a dependent variable from various distributions, by estimating unspecific (non-parametric) functions.

INDICATOR STATE

Status – Somewhat worse than interim target. In 2015, the annual average Secchi depth was 22.3 meters (73.2 feet), a decrease of 1.4 meters (4.6 feet) from the previous year. However, the reader is cautioned from placing too much importance on this year-over-year change. This amount of change between years is not extraordinary for the annual average Secchi depth. In 2014, an increase of 2.3 meters (7.5 feet) was observed from the previous year. The 2015 annual average Secchi depth is 75 percent of the adopted clarity standard which also reflects a status of somewhat worse than target. The five year average Secchi depth of 22.3 meters (73.2 feet), is 94 percent of interim target of 23.8 meters (78 feet) for 2026, reflecting a status of somewhat worse than target.

Trend – Little or no change. Since 2000, Secchi depth measurements have been better than predicted by the long-term trend of linear decline observed since 1968. Statistical analysis supports the observation that the decline in Lake Tahoe's transparency has slowed since 2000, and the overall trend is now better represented by a curve (see figure above), rather than a straight line. The line of best fit to describe the long-term trend was determined statistically using a generalized additive model (GAM). This reduction in the rate of decline in annual lake transparency over the last decade is a direct result of the improvement in the winter average Secchi depth. The mechanisms driving the improvement in winter Secchi measurement are not fully understood, but are potentially linked with a reduction in fine particles from urban stormwater (TERC, 2014). The summer average Secchi depth has shown a consistent linear decline since 1967, albeit with considerable inter-annual variability exhibiting a 10 to 15 year cyclical pattern (TERC, 2015). Factors that have contributed to slowing the rate of decline and recent improvements in lake transparency likely include, Regional Plan program and policies, Lake Tahoe TMDL implementation actions, the drought-induced stream flow and stormwater runoff reductions, a 2014 decline in small algal cell the concentration, and the shallow lake mixing depth during winter 2013/14 (TERC, 2015).

Confidence –

Status – High. There is high confidence in the status determination. Secchi depth measurements are used widely as a measure of water transparency in oceans and lakes; it is a highly reliable, relatively simple, and an inexpensive measurement of lake transparency. It is among the oldest limnological devices and was first used by Italian Professor P.A. Secchi in the 1860s. Jassby et al. (1999) evaluated the general precision of the method used in Lake Tahoe, and estimated the average precision based on two observers was $\pm$0.027 m (Jassby et al., 1999). A recent analysis of annual average Secchi depth readings (includes water conditions down to a depth of approximately 20 meters in recent years) and the vertical extinction coefficient (a more sophisticated electronic sensor for measuring light levels down approximately 100 meters), has shown these two measures of light penetration in Lake Tahoe to be well correlated over the entire period of record (UC Davis - TERC, 2011).

Trend– Moderate. Confidence in the long-term trend between 1968 and 2014 also is high. The long-term trend is estimated using a generalized additive model, which blends properties of generalized linear models and additive models. While the annual average Secchi depth in 2014 is highly encouraging, 2014 was among the driest years on record and should be considered in the context of three consecutive years of drought. It is still too early to determine if the recently observed increases are the result of actions taken to improve water quality or are primarily the product of recent weather. The intra-annual variability associated with each average annual estimate is expected as part of the normal ecosystem response due to year-to-year changes in precipitation, runoff, Lake mixing, and meteorology. Future weather conditions, particularly extreme conditions (i.e., droughts and floods) can have a substantial effect on pollutant loading and lake transparency.

Overall – Moderate. Overall confidence takes the lower of the two confidence determinations.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – The Regional Plan requires the use of best management practices (BMPs) for new residential and commercial development, and BMP retrofit regulations for developed properties. For example, section 60.4.6.A.1 of TRPA Code requires properties be able to infiltrate the 20-year, one-hour storm into groundwater. The Regional Plan is also designed to limit growth and shift development from sensitive to less sensitive lands. All of these requirements contribute to reducing fine sediment and nutrient runoff from developed areas. The Regional Transportation Plan complements these by encouraging use of public transit and alternative transportation modes, and reducing reliance on private automobile. Water quality mitigation fees, collected on projects that create new cover, support erosion and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel.
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road.
- Restored or enhanced 120 acres of disturbed forested uplands.
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles.
- Issued 18,076 BMP certificates to developed commercial, multifamily and single family residential properties.
- TRPA's grant funded Stormwater Management Program (SMP) focuses compliance and maintenance verification activities on priority commercial and large multi-family residential properties in coordination with local jurisdictions. In 2015, the SMP notified 2,441 parcel owners with BMP Certificates issued more than five years ago that maintenance was due and re-issued 186 BMP Certificates following maintenance verification.
- Completed street sweeping on 24,644 miles of roads.

The TRPA Stormwater Management Program leads broad professional and public education including annual BMP trainings for contractors, local jurisdictions and real estate professionals, articles in "Tahoe In-Depth" mailed to all property owners, and public workshops and events to increase BMP awareness and promote proper design, installation and maintenance. Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do to maintain a healthy environment including BMP completion. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

The Lake-Friendly Business Program highlights and encourages patrons to visit businesses that are doing their part to help protect Lake Tahoe by installing and maintaining their water quality BMPs. There are currently over fifty Lake-Friendly businesses in the Region.

The TMDL Management System Handbook guides the actions of agencies in the Region to reduce inputs of nutrients and sediments into Lake Tahoe (Lahontan and NDEP, 2014). As part of the TMDL implementation, each jurisdiction in the Region prepares a load reduction plan (pollutant load reduction plans in California and stormwater load reduction plans in Nevada) that detail the steps to achieve the specified load reductions. The Lake Tahoe TMDL estimated that a 50 percent reduction in nitrogen load from urban sources (8 percent of the total nitrogen load) would be required to achieve lake clarity standards (Lahontan and NDEP, 2010b).

The 2015 TMDL Findings and Recommendations memo identified wintertime traction abrasives as a primary source of ultra-fine sediment particles (less than 16 microns in stormwater runoff) (Larsen and Kuchnicki, 2015a). Managers and heavy equipment operators in the Tahoe Region continue to adaptively manage wintertime traction application practices to reduce adverse environmental impacts while ensuring safe roads. In the 2015/2016 winter season this included treating roadways with brine solution prior to storm events, which prevents ice from developing on roads and can reduce prior dry salt applications by as much as 86 percent (Wigart and Ferry, 2015b)(Wigart and Ferry 2015b). El Dorado County, the California Department of Transportation and the City of South Lake Tahoe are utilizing new wintertime traction abrasives that contain 90 percent less ultra-fine particles compared to previously used materials and also break down less into fine fractions from vehicle traffic. This new abrasive is sourced from a native granite material rather than the previously imported non-native volcanic cinders (Wigart and Ferry, 2015a)(Wigart and Ferry 2015a).

Effectiveness of Programs and Actions – Each year the actions of TMDL implementation partners are summarized and evaluated in the TMDL Performance Report (Larsen and Kuchnicki, 2015b).

A 2011 analysis found diminishing returns from increasing storm retention capacity beyond the 20-year, one-hour storm, the TRPA infiltration requirement (2ndNature and NHC, 2011). The synthesis found that doubling retention capacity required to handle the 20-year, one-hour storm would increase annual retention by only seven percent and at a significant cost (2ndNature and NHC, 2011).

Interim Target – An interim target of 23.8 meters (78 feet) Secchi disk depth in 2031 has been established through development of the Lake Tahoe TMDL. The interim target has been adopted by the Lahontan Regional Water Quality Control Board, California Water Resources Control Board, Nevada Division of Environmental Protection, and the U.S. Environmental Protection Agency. Evaluation of this target is based on the five-year annual average Secchi disk depth. The five-year average Secchi disk depth for the period from 2010 to 2015 was 22.1 meters (73.1 feet). The interim target for the 2019 Threshold Evaluation Report should be continued progress towards achievement of the 2031 Lake Tahoe TMDL "Clarity Challenge."

Target Attainment Date – 2031, the year identified in the Lake Tahoe TMDL "Clarity Challenge" (Lahontan and NDEP, 2014, 2010a). The TMDL estimates that the annual average Secchi depth standard (29.7 meters, 97.4 feet) would be achieved around 2076 if prescribed management actions are implemented and maintained (Lahontan and NDEP, 2010a). This estimate assumes that load reductions will slow after the first twenty years as load reduction opportunities become scarcer. The estimate does not account for impacts arising from global climate change or catastrophic events that may adversely affect clarity.

RECOMMENDATIONS

Analytic Approach – Daphnia are zooplankton that graze on phytoplankton. Reducing the abundance of phytoplankton in the water column increases clarity, and recent work in eutrophic systems has found that the loss of grazers contributed significantly to clarity loss (Walsh et al., 2016). Although early studies in Lake Tahoe suggested the loss of Daphnia did not significantly impact water quality due to the relative low Daphnia population (Elser and Goldman, 1991), increasing primary productivity in the Lake may require revisiting the working hypothesis that grazing does not significantly impact clarity. Recovery of Daphnia spp. and related filter feeding taxa like Bosmina have been documented in the Lake during years of high primary productivity (Byron et al., 1986) .

Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – No changes recommended.

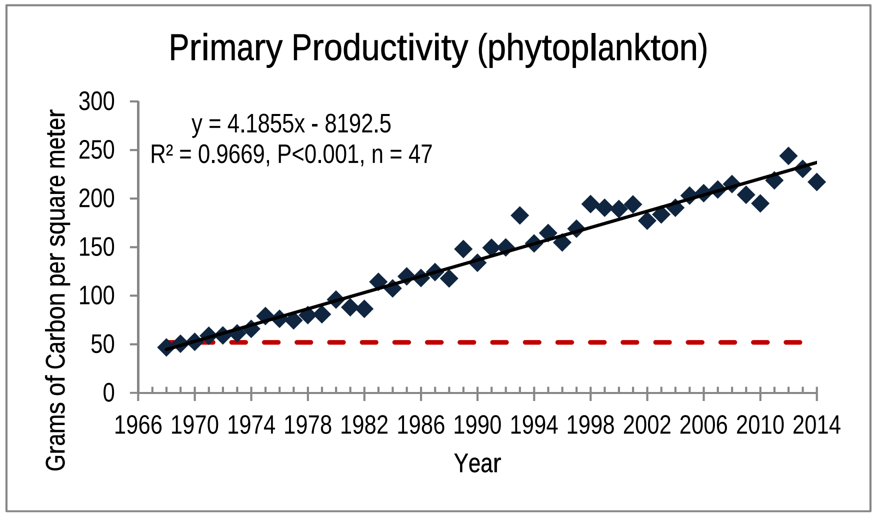
Attain or Maintain Threshold – Implementation of the Lake Tahoe TMDL and associated EIP water quality improvement projects have primarily focused on the control of fine sediment particles and attached nutrients from urban areas. This implementation strategy is pragmatic in that it focuses regulations and management actions on the largest source of fine sediment particles and on factors most directly controlled by humans: control of urban stormwater runoff, improved road maintenance and watershed restoration. Recent science suggests that preserving and restoring Lake Tahoe's clarity under a changing climate may require a greater emphasis on policies and management strategies that reduce the influx of nutrients from all sources (Sahoo et al., 2015). Further reducing the influx of nutrients into Lake Tahoe may require greater emphasis on the strategies and practices of the Regional Plan that focus on nutrient reduction, including stream environment zone restoration and reducing atmospheric deposition of nitrogen and phosphorus.

Pelagic Lake Tahoe: **Phytoplankton Primary Productivity**

Status	Trend

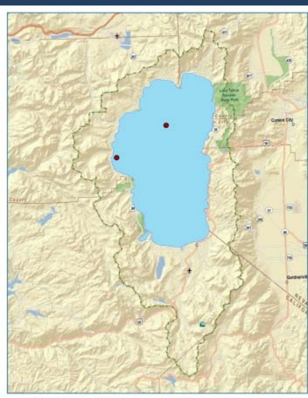
PHYTOPLANKTON PRIMARY PRODUCTIVITY

Status: **Considerably Worse than Target**
Trend: **Rapid Decline**
Confidence: **High**



Annual estimates of phytoplankton primary productivity from water samples collected at the Lake Tahoe Index Station, 1968 to 2014. Phytoplankton primary productivity has steadily increased (worsened) since 1968, although a slight decrease in primary productivity to 217.1 grams of carbon m^2 was measured in 2014 (TERC, 2015). Overall, primary productivity values have been well above the TRPA standard (red line) of 52 grams of carbon m^2, since before it was established in 1982.

Map



Monitoring locations for primary productivity and other water quality parameters. The index station is located along the west shore.

Data Evaluation and Interpretation

BACKGROUND

Relevance – Primary productivity is a measure of the rate at which solar energy is converted into chemical energy by photosynthetic organisms. Lake Tahoe is an ultraoligotrophic lake and management goals include maintaining this status due to its historic, cultural, economic, and aesthetic value. Monitoring work in Lake Tahoe include measurements of phytoplankton (free-floating algae) primary productivity (PPr). Phytoplankton occur naturally throughout Lake Tahoe, and they contribute to reductions in water transparency by absorbing light for photosynthesis, and by scattering light. From an ecological perspective, phytoplankton are a dominant and essential component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). At low levels, PPr can become a limiting factor in the population size of organisms that depend directly or indirectly on this source of food. Conversely, extremely high PPr can result in nuisance algal blooms, degradation of drinking water taste and odor, low dissolved oxygen, and fish kills.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category – Pelagic Lake Tahoe

Adopted Standards – Maintain annual mean phytoplankton primary productivity at or below 52gmC/m^2/yr.

Type of Standard – Numerical

Indicator (Unit of Measure) – Depth-integrated annual average phytoplankton primary productivity expressed as grams carbon per square meter per year (g C m^{-2} y^{-1}).

Human & Environmental Drivers – Nutrient (nitrogen and phosphorus) inputs from anthropogenic sources are considered the primary driver of increasing PPr in temperate lakes (Conley et al., 2009). It is suspected that activities associated with urbanization and watershed disturbance influence Lake Tahoe's PPr through the release of nutrients and subsequent transport in runoff, or through the atmospheric deposition of nutrients. The nutrient source analysis for the Lake Tahoe TMDL indicates that both urban and non-urban sources of nitrogen and phosphorus are important contributors of nutrients to Lake Tahoe (Lahontan and NDEP, 2010a; Sahoo et al., 2013). Meteorological conditions (e.g., wet vs. dry years) also affect PPr, due to changes in tributary loads of nutrients, and differences in the magnitude of physical processes within the Lake (e.g., deep lake mixing). However, the trend suggests these factors have not substantially influenced the overall trend. The source of nutrients that are driving the increase in PPr is currently unknown.

MONITORING AND ANALYSIS

Monitoring Partners – University of California at Davis–Tahoe Environmental Research Center (TERC), Tahoe Regional Planning Agency, and Lahontan Regional Water Quality Control Board.

Monitoring Approach – Phytoplankton PPr measurements at Lake Tahoe have been made following the same standard operating procedure since the first observations were made in 1967 (Winder et al., 2009). Lake water is collected at the TERC west shore index station, which was found to be representative of the lake's deepwater condition (Charles Remington Goldman, 1974). For each sampling event, water samples are collected from 13 different depths (between 0-105m) spanning the photic zone (i.e., the vertical zone in the water column exposed to sufficient sunlight for photosynthesis to occur), and analysed to determine carbon assimilation rates using very sensitive methods needed for pristine or oligotrophic waters (Charles Remington Goldman, 1974). Values from the various samples are aggregated to yield a depth-integrated PPr value. These depth-integrated values are aggregated over the calendar year to generate an estimate of annual average phytoplankton primary productivity. Between 1967 and 2006, measurements were taken, on average, every 10 to 14 days. In 2007, measurement frequency was reduced to once per month due to budget constraints. This reduction in the frequency of measurements was made only after a careful analysis of consequences to the long-term record confirmed that this change in measurement frequency was appropriate. The monthly measurements produced a very similar plot to the bi-monthly data (Winder and Reuter 2009).

Analytic Approach – Status is assessed by direct comparison of the most recent annual average value to the established standard. Trend is determined using a simple linear regression model. This analytical approach is considered appropriate for the data because the line of best fit explains approximately 97 percent of the variation in the data over the period of record. The slope of the line, which indicates a monotonic increase in PPr is significantly different from zero.

INDICATOR STATE

Status – Considerably worse than target. The PPr indicator is used to determine compliance with TRPA's Pelagic Lake Tahoe phytoplankton productivity standard of 52 g C m^{-2} y^{-1}. The threshold standard is based on measurements collected over four years (1968 to 1971) (Lahontan and NDEP, 2010a). Phytoplankton primary productivity has remained well above the standard since it was established in

1982. The current status (217.1 g C m^{-2} y^{-1}) of Lake Tahoe's phytoplankton primary productivity is considerably worse than the standard. The 2014 value is four times worse than the TRPA threshold standard.

Trend – Rapid decline. The line of best fit was determined statistically using a linear regression model. The data show phytoplankton PPr has steadily increased (worsened) since annual measurements began at Lake Tahoe in 1968. The maximum annual phytoplankton PPr was recorded in 2012 (243.9 g C m^{-2} y^{-1}). For the period of record (1968 to 2014) phytoplankton PPr has increased by 3.3 percent annually. The slope of the trend line for the entire period of record (1968 to 2014) yields an estimated rate of increase in phytoplankton PPr of 4.2 g C m^{-2} y^{-1}, which equates to an eight percent per year increase in PPr relative to the TRPA threshold standard. Thus, this indicator exhibits a rapidly increasing (worsening) trend relative to the adopted standard.

Confidence –

Status – High. There is high confidence in the determination of status and trend. The methodologies for data collection and analysis are well established and broadly accepted. Both the data and analyses have been used in a number of peer reviewed publications.
Trend– High. Monitoring protocols were established in 1967 and have been consistent since that time. The methodologies for data collection and analysis are well established and broadly accepted.
Overall – High.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – The Regional Plan requires the use of best management practices (BMPs) for new residential and commercial development, and BMP retrofit regulations for developed properties. For example, section 60.4.6.A.1 of TRPA Code requires properties be able to infiltrate the 20-year, one-hour storm into groundwater. The Regional Plan is also designed to limit growth and shift development from sensitive to less sensitive lands. All of these requirements contribute to reducing fine sediment and nutrient runoff from developed areas. The Regional Transportation Plan complements these by encouraging use of public transit and alternative transportation modes, and reducing reliance on private automobile. Water quality mitigation fees, collected on projects that create new cover, support erosion and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel.
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- Restored or enhanced 120 acres of disturbed forested uplands.
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles.
- Issued 18,076 BMP certificates to developed commercial, multifamily and single family residential properties.
- TRPA's grant funded Stormwater Management Program (SMP) focuses compliance and maintenance verification activities on priority commercial and large multi-family residential properties in coordination with local jurisdictions. In 2015, the SMP notified 2,441 parcel owners with BMP certificates issued more than five years ago that maintenance was due and re-issued 186 BMP certificates following maintenance verification.
- Completed street sweeping on 24,644 miles of roads.

The TRPA Stormwater Management Program leads broad professional and public education including annual BMP trainings for contractors, local jurisdictions and real estate professionals, articles in "Tahoe In-Depth" mailed to all property owners, and public workshops and events to increase BMP awareness and promote proper design, installation and maintenance. Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do to maintain a healthy environment including BMP completion. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

The Lake-Friendly Business Program highlights and encourages patrons to visit businesses that are doing their part to help protect Lake Tahoe by installing and maintaining their water quality BMPs. There are currently over fifty Lake-Friendly businesses in the Region.

Effectiveness of Programs and Actions – Each year the actions of the TMDL implementation partners are summarized and evaluated in the TMDL Performance report (Larsen and Kuchnicki, 2015a).

Interim Target – Reduce the rate of increase in PPr.

Target Attainment Date – 2019 threshold evaluation reporting period.

RECOMMENDATIONS

Analytic Approach – No changes recommended.

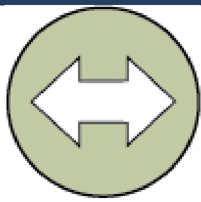
Monitoring Approach – The current monitoring method requires the use of a hazardous radioactive material. UC Davis is exploring alternative methods that do not require the use of hazardous materials.

Modification of the Threshold Standard or Indicator – No changes recommended.

Attain or Maintain Threshold – Understanding the source of nutrients that are driving the increase in PPr is critical to focusing management action where it will be most effective.

State Water Quality Standard: **Clarity – Vertical Extinction Coefficient (VEC)**

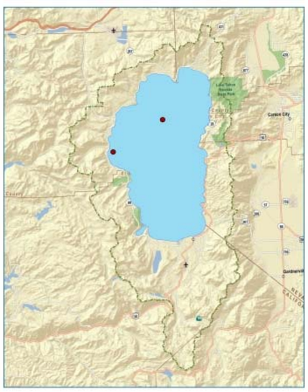
Status



CLARITY – VERTICAL EXTINCTION COEFFICIENT (VEC)

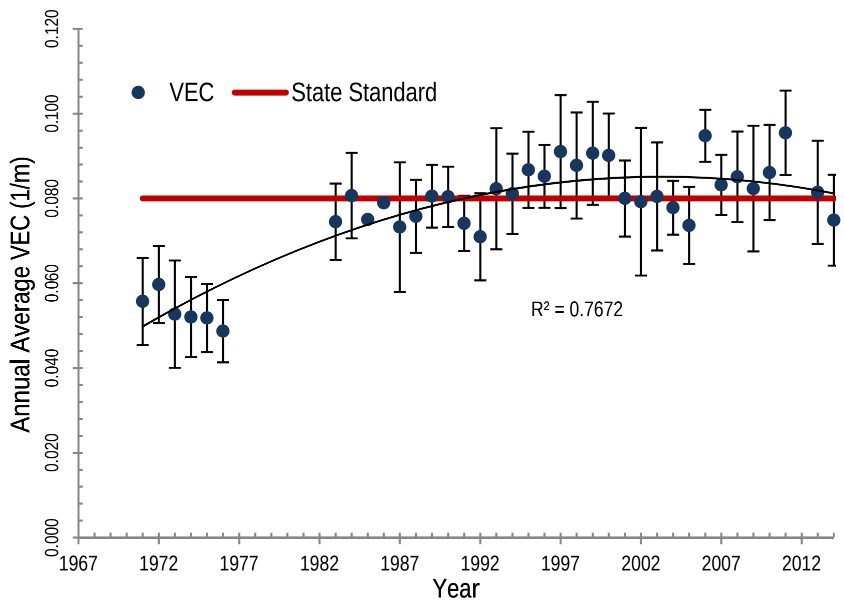
Status - **At or Somewhat Better than Target**
Trend – **Little or No Change**
Confidence - **Moderate**

Map



Locations of long-term monitoring sites for VEC and other water quality constituents. The Index Station is located along the west shore.

Trend



Annual average vertical extinction coefficient (VEC) recorded at the Lake Tahoe Index Station (1969 through 2014). No data was collected between 1977 and 1982 or in 2012. Each annual value is an integrated average using 17 to 37 individual measurements taken throughout the year. Black bars indicate +/- one standard deviation from the mean annual value. The trend, similar to Secchi measurements, shows a rapid worsening until around year 2000, when the trend leveled off.

Data Evaluation and Interpretation

BACKGROUND

Relevance – Both the vertical extinction coefficient (VEC) and the Secchi depth measure optical properties of Lake Tahoe. State standards define VEC as measure of clarity and Secchi depth as measure of transparency. VEC is related to Secchi depth, but the measure extends beyond the depth at which the Secchi Disc is visible, providing information on biological properties of the lake down to the bottom of the photic zone (approximately 50 to 60 meters). Light extinction results from one or more of the following factors: colored dissolved organic material, organic and inorganic particles and the water molecules themselves (Swift et al., 2006). The depth of one percent light transmission is typically considered the vertical extent of the photic zone. VEC can be interpreted as the amount of light extinguished as it passes through each meter of water. The mean annual VEC since 2000 has ranged from 0.07 to 0.09 m^{-1} meaning that seven to nine percent of the light is extinguished per meter of depth. VECs in some mesotrophic lakes can reach as high as 2.0 m^{-1} and in eutrophic lakes can approach 4.0 m^{-1} (Wetzel 1983).

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category – State water quality standard

Adopted Standards –The vertical extinction coefficient must be less than 0.08 per meter when measured at any depth below the first meter (California and Nevada state standard).

Type of Standard – Numeric

Indicator (Unit of Measure) – VEC. The percentage of the light absorbed or scattered in a meter-long vertical column of water.

Human & Environmental Drivers – Water clarity in Lake Tahoe is largely controlled by particles blocking light penetration either by scattering or by absorption (Swift et al., 2006). Particles in Lake Tahoe are composed of both microscopic, free-floating algae (phytoplankton) and fine sediment. Algal growth is stimulated by excess nutrient (nitrogen and phosphorus) loading from stream and stormwater runoff and atmospheric deposition(Lahontan and NDEP, 2010a). Fine sediment loading is also from stream and stormwater runoff and atmospheric deposition (Lahontan and NDEP, 2010a). Drivers influencing the delivery of fine sediment and nutrients include urban development (including the transportation network and vehicle density), anthropogenic and natural disturbance in the undeveloped portions of the watershed, and local and regional climate (especially wind and precipitation). The below average stream inflows and stormwater runoff due to the continuing drought, are substantial contributing factors in the recent improvement of lake transparency (TERC, 2015).

MONITORING AND ANALYSIS

Monitoring Partners – University of California at Davis- Tahoe Environmental Research Center, and the Tahoe Regional Planning Agency.

Monitoring Approach – VEC is measured at the Lake Tahoe Index Station at least 24 times annually and at least 12 times annually at the mid-lake station. VEC is measured by lowering a submersible photometer down through the water column.

Analytic Approach – Neither state standard provides guidance as to if determinations of attainment should be based on an annual average or a single sample. Attainment was assessed relative to the annual average VEC recorded in the most recent calendar year (2014).

INDICATOR STATE

Status – At or somewhat better than target. The annual average in 2014 was a Vertical Extinction Coefficient of 0.075, which means the standard is in attainment. However, 12 of 27 VEC measures in 2014 were above the state standard of 0.08.

Trend – Little or no change. Since around year 2000, VEC measurements have been better than predicted by the long-term trend of linear decline observed since 1969. Statistical analysis supports the observation that the decline in VEC has slowed since 2000, and the overall trend is now better represented by a curve (see figure above), rather than a straight line. The line of best fit to describe the long-term trend was determined statistically using a polynomial regression.

Confidence –

Status – Moderate. The annual average in 2014 was a Vertical Extinction Coefficient of 0.075, which means the standard is current in attainment. However, 12 of 27 VEC measures in 2014 were above the state standard of 0.08 per meter.

Trend – High. According to the standard methodology of this report, the trend is statistically significant $R^2 = 0.7672$, $P < 0.01$.

Overall – Moderate. Overall confidence takes the lower of the two confidence determinations.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – The TMDL Management System Handbook guides the actions of agencies in the Region to reduce inputs of nutrients and sediments into Lake Tahoe (Lahontan and NDEP, 2014). Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen, and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles
- Restored or enhanced 120 acres of disturbed forested uplands
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles
- Issued 18,076 BMP certificates to commercial, multifamily and single family residential

Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do maintain a healthy environment. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

Effectiveness of Programs and Actions – Each year the actions of the TMDL implementation partners are summarized and evaluated in the TMDL Performance Report (Larsen and Kuchnicki, 2015a).

Interim Target – No target set as the standard is in attainment.

Target Attainment Date – Standard is in attainment.

RECOMMENDATIONS

Analytic Approach –Consideration should be given to how attainment is assessed. Potential options include; 1) annual average, 2) multi-year average, and 3) with respect to individual measurements.

Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – The VEC standard is a state standard. See recommended changes for modification of the analytic approach.

Attain or Maintain Threshold – No changes recommended. Continue TMDL implementation.

Littoral Lake Tahoe

The littoral zone of Lake Tahoe is more commonly referred to as the "nearshore". The nearshore includes the area of the lake with a depth shallower than 30 feet, or to a minimum width of 350 feet from the shoreline (TRPA, 2012a). It is the area of the lake that people interact with most when visiting the Region and engaging in recreational activities such as viewing, wading, swimming, enjoying paddle sports, and boating. The TRPA Code of Ordinances emphasizes protection of the nearshore environment because of its exceptional scenic quality and significant recreational and ecological values (TRPA, 2012b).

Partners in the Region are implementing numerous policies and programs of the Regional Plan that will likely improve nearshore conditions including:

- Restoring and enhancing stream environment zones (SEZ).
- Limiting the rate and extent of urban growth.
- Ensuring road conditions are consistent with the road operations plan and road operations scenarios for reduction of pollutants.
- Implementing treatment and parcel best management practices (BMPs) on developed properties to reduce nutrient and sediment discharge from disturbed soils.
- Reducing private automobile use through improvements to public transit and alternative transportation modes with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment.
- Ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects.

The Lake Tahoe TMDL is primarily focused on restoration of the Lake's deep water transparency and clarity (Lahontan and NDEP, 2010a). To do so, the TMDL sets ambitious targets for the reduction of the primary pollutants that impact the pelagic environment (fine sediment, nitrogen and phosphorous). The pollutant load reductions of implementing partners of the TMDL are also likely to benefit nearshore water quality (Heyvaert et al., 2013a).

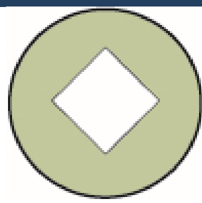
In October 2013, the Desert Research Institute, University of California at Davis, and the University of Nevada at Reno released the Lake Tahoe Nearshore Evaluation and Monitoring Framework Report (Heyvaert et al., 2013a). The report synthesized the findings of past research and presented a conceptual understanding of nearshore environment processes, highlighted existing data gaps, and proposed a set of monitoring metrics to assess the condition of the nearshore. The report emphasized that relative to the deep waters of the Lake, the nearshore is a highly heterogeneous environment, that may be best understood as a series of micro habitats within which the importance of individual drivers of condition are likely to vary in importance, and that management will likely have to be tailored to local situations. Pilot implementation of the biologic and optical (clarity and transparency) monitoring protocols suggested in the report were completed by the University of the Nevada-Reno and the Desert Research Institute in 2014 and 2015, with the support of the Nevada Division of State Lands (NDSL), Nevada Division of Environmental Protection (NDEP), California State Water Resource Control Board -Lahontan Region (Lahontan) and TRPA.

The number of parameters of concern in the nearshore (including clarity, metaphyton, periphyton, toxins, and others) and spatial variability around the lake (conditions in one location are not necessarily indicative of conditions in other locations) complicate management of the nearshore. Building upon the report and recent monitoring efforts, management partners in the Region, including representatives from U.S. EPA, Lahontan, NDEP and TRPA, are developing a comprehensive framework for allocating resources to enhance our understanding of the nearshore environment and more effectively target management actions to preserve the resource for future generations. A draft version of nearshore resource allocation plan (NRAP) is expected to be available in late 2016.

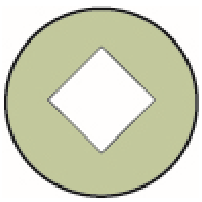
In 2012, the TRPA Governing Board added two new standards related to the nearshore environment, to address attached algae (periphyton) and aquatic invasive species. Assessments of three indicators are included to document the status and trend of conditions relative to a single numerical standard, nearshore clarity, and two management standards, nearshore attached algae, and aquatic invasive species.

Littoral Lake Tahoe: **Nearshore Turbidity**

Status



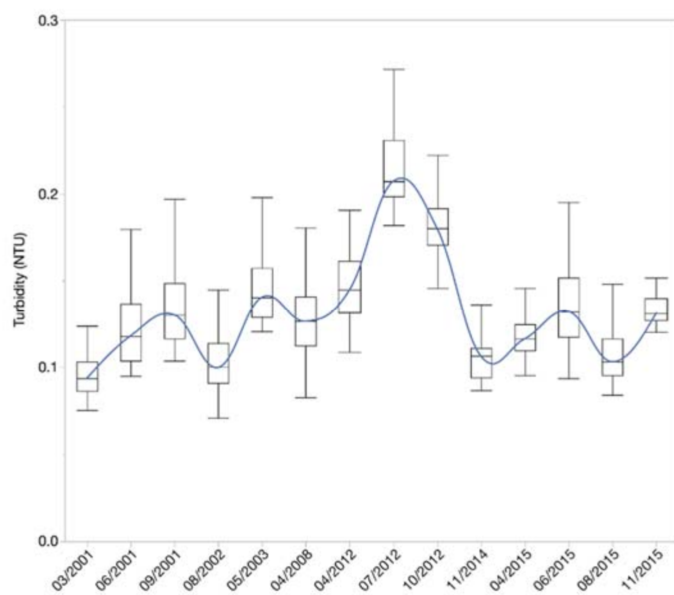
NEARSHORE TURBIDITY (NO STREAM INFLUENCE)
Status: **At or Somewhat Better than Target**
Trend: **Insufficient Data to Determine Trend**
Confidence: **Moderate**



NEARSHORE TURBIDITY (STREAM INFLUENCE)
Status: **At or Somewhat Better than Target**
Trend: **Insufficient Data to Determine Trend**
Confidence: **Moderate**

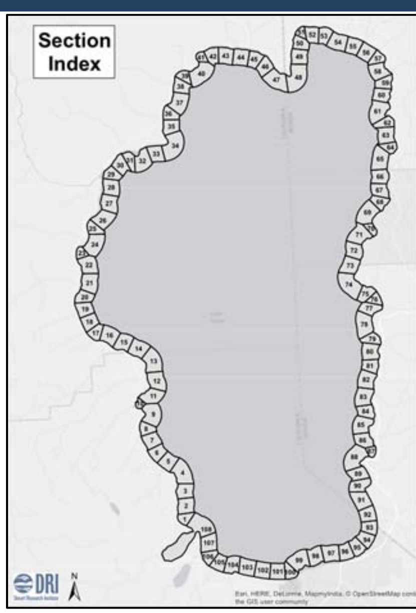
Trend

Nearshore Turbidity



Distribution of section average values obtained from individual nearshore clarity circuits at a seven meter depth (23 ft.) completed using equivalent methods since 2001. Survey re listed in chronological order on the x-axis (mm/yyyy format). Survey dates are non-continuous. The blue line follows median values from each circuit represented by quartile boxplots, with whiskers to outermost data points within 1.5 times the interquartile range.

Map



Lake Tahoe nearshore pilot study area divided into one-kilometer long Thiessen polygon sections for spatial analysis of clarity conditions.

Data Evaluation and Interpretation
BACKGROUND

Relevance – Water clarity refers to the transparency or clearness of water, and is a commonly used indicator for the health of a water body. Federal, state, and regional agencies have adopted regulations to protect Lake Tahoe's renowned clarity, which includes both the pelagic (deep water) and the littoral (nearshore) zones. The nearshore represents an important socioeconomic value because this is where most visitors and residents experience the lake first-hand. Both California and Nevada recognize the unique ecological and aesthetic values of the nearshore environment, and both have adopted standards to protect nearshore water clarity. Secchi disk transparency is measured in the pelagic zone of Lake Tahoe, but this approach does not work in the littoral (nearshore) zone where water depth is insufficient for the method. Instead, instrument measurements of turbidity and light transmissivity are used as indicators of nearshore clarity.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category – Littoral Lake Tahoe

Adopted Standards – Decrease sediment load as required to attain turbidity values not to exceed three nephelometric turbidity units (NTU). In addition, turbidity shall not exceed one NTU in shallow waters of the lake not directly influenced by stream discharges. TRPA has adopted the California standard.

Type of Standard – Numerical

Indicator (Unit of Measure) – The compliance indicator for this threshold is a measurement of turbidity, calibrated in NTUs.

Human & Environmental Drivers – Nearshore turbidity is primarily driven by the concentration and type of fine particulate materials suspended in water. Nutrient loading affects clarity by increasing phytoplankton growth (suspended organic particles). Suspended sediment loading affects clarity by contributing more fine inorganic particles. Both types of particulates cause nearshore clarity loss by scattering light and through light absorption (Swift et al., 2006; Taylor, 2002; Taylor et al., 2004). Heterogeneity of nearshore features leads to considerable variability in effects from environmental and anthropogenic drivers. Main drivers include seasonal runoff and lake water-column mixing, as well as episodic storm runoff and localized upwelling events. Deep-water zones close to the shoreline may mitigate the intensity of these effects by mixing offshore water with nearshore water and diluting clarity reducing constituents. Extended shallow-water shelves can accentuate impacts by retaining higher concentrations of nutrients and suspended sediment particles, as well as by providing warmer water conditions for increased biological activity and sediment resuspension from waves and boat wakes. Urban stormwater runoff generally contains much higher concentrations of nutrients and fine sediment particles than found in the lake or in runoff from undisturbed areas (Lahontan and NDEP, 2010b)(LRWQCB and NDEP, 2010). Urban stormwater discharges to the lake generally derive from impervious areas that include transportation routes and associated conveyance systems. They cause locally elevated concentrations of phytoplankton and suspended fine sediment particles that contribute to diminished nearshore clarity. Stream water concentrations of nutrients and sediments are naturally higher than pelagic lake water, so even streams from undisturbed watersheds contribute fine sediment particles and nutrients. Streams that pass through disturbed watersheds, however, contribute significantly higher concentrations of nutrients and fine sediment particles than streams from undisturbed watersheds. Inputs from groundwater seepage directly into the lake can increase concentrations of dissolved nutrients (e.g., nitrogen and phosphorus), which increase concentrations of the microscopic suspended algae that decrease nearshore clarity. Upwelling events and seasonal lake mixing deliver deep-lake waters to the nearshore. These waters often can be nutrient rich relative to nearshore conditions. Accumulated fine sediments that have settled in the nearshore may have an impact on transparency during times of high winds or when spring snowmelt increases lake levels and exposes newly submerged land surface to wave action. The cumulative effect of boat wakes during peak recreation periods can induce episodic sediment resuspension in the nearshore. Atmospheric deposition of fine sediments and adsorbed nutrients from road dust can have a disproportionately greater effect on the nearshore compared to deep lake sites due to proximity.

Long-term climate trends are likely to impact nearshore conditions as more precipitation arrives through rain rather than snow, with higher contributions of nutrients and fine sediments at some locations from increased runoff scouring of the landscape. Higher surface water temperatures from warming climate conditions may also increase nutrient cycling and phytoplankton production.

MONITORING AND ANALYSIS

Monitoring Partners – Desert Research Institute, Nevada Division of State Lands, University of California at Davis, Tahoe Environmental Research Center.

Monitoring Approach – A pilot monitoring program of nearshore turbidity began with the first circuit completed in November 2014, followed by similar nearshore circuits completed in April, June, August and November 2015. Measurements were made at a depth of seven meters. Routine boat operating speeds are typically around 10 kilometers per hour in the nearshore areas (Heyvaert et al., 2016). Beginning 1991, nearshore turbidity was measured offshore at the 25-meter depth contour for several locations, including 1) mouth of Upper Truckee River and Trout Creek; 2) El Dorado Beach; 3) mouth of Edgewood Creek; 4) Nevada Beach; 5) mouth of Incline Creek; 6) Burnt Cedar Beach; 7) mouth of Ward Creek; 8) Tahoe State Recreation Area; and 9) the mouth of Blackwood Creek. More recently, nearshore clarity has been measured at approximately the seven-meter contour following a continuous circuit around the lakeshore. This strategy is considered more representative of littoral conditions where people interact with the lake and where effects from nearshore impacts are not excessively diluted by mixing with offshore waters. Turbidity and transmissivity measurements were collected from nearshore water around the whole lake by continuously sampling from a bow-mounted probe about one half meter below the surface. This continuous sampling stream is pumped through an array of sensors including two laboratory-grade Hach turbidimeters and a WETLabs C-Star transmissometer. Campbell Scientific dataloggers are used to aggregate the two-second interval sample points in conjunction with real-time data from a global positioning system receiver. The desired boat track and incoming data are displayed in real-time to alert personnel of anomalous conditions that may require their intervention. Depending on boat speed, depth to bottom, and ambient lake conditions, the surveys typically consist of full-perimeter lakeshore circuits run over the course of two or three consecutive days. Turbidimeters are calibrated with primary formazin standards prior to each sampling period and these calibrations are verified before and after each day of surveying. A set path is followed during each survey for consistency; however, water levels, weather conditions and recreational traffic on the lake require that boat operators occasionally deviate from established pathlines.

Analytic Approach – Continuous data acquired from each nearshore run are merged into a contiguous line around the lake and then processed in ArcGIS to calculate distribution statistics and evaluate spatial autocorrelation. Output from the ArcGIS global autocorrelation analysis (Moran's I) indicates that samples are highly related over distances ranging from about 500 to 1500 meters. Therefore, samples averaged over one kilometer intervals minimize the effect of noise due to sensor measurement uncertainty and transient environmental effects, while preserving dominant local features of the dataset. The shoreline of Lake Tahoe was broken into one kilometer intervals that serve as midpoints for a set of Thiessen polygons that aggregate data within each interval (See map). The end result is that every nearshore sample point within the lake is assigned to a nearest Thiessen polygon midpoint along the shoreline (Heyvaert et al., 2013). Then quartile values, the mean, standard deviation and coefficient of variation are calculated from the sample data within each section. There are 108 sections (polygons) numbered sequentially around the nearshore, beginning just north of Emerald Bay and proceeding clockwise back to that starting point.

Status is assessed by evaluating the range of sample values represented within each nearshore section over a series of nearshore circuits. Data from previous years is aggregated to represent characteristic conditions of nearshore sections over that period, then compared to the range of turbidity values obtained more recently to evaluate localized changes relative to historical conditions. Trends are evaluated using a generalized additive model when a sufficient data record is available.

INDICATOR STATE

Status – At or somewhat better than target. Two standards exist for nearshore clarity: less than one NTU for areas not directly influenced by stream discharge and less than three NTU for areas directly influenced by stream discharge. Five complete nearshore circuits were completed as part of the pilot clarity monitoring project from November 2014 through November 2015. No single value exceeded the lower threshold standard of one NTU (Table 1). Evaluation against the less than three NTU standard, even the maximum recorded value in 2014/2015 was just 33 percent of the standard, resulting in a determination of considerably better than target. Evaluation against the less than one NTU standard found that the maximum recorded value was considerably better than target in three of the five sampling events and at or somewhat better than target for the two remaining events. No single value exceeded the lower threshold standard of one NTU (Table 1). Evaluation based on the mean sampled value yields a determination of considerably better than target for both standards in all sampling events. Results from data collected during these periods are summarized in Table 1, which shows that June 2015 and November 2015 circuits yielded higher overall turbidity than the other three sampling periods. Median, mean, and maximum values were nearly equivalent for these two higher turbidity periods. Processes driving these temporal conditions are likely associated with seasonal changes runoff and lake mixing. Additional monitoring will aid our understanding of the dynamics of nearshore clarity.

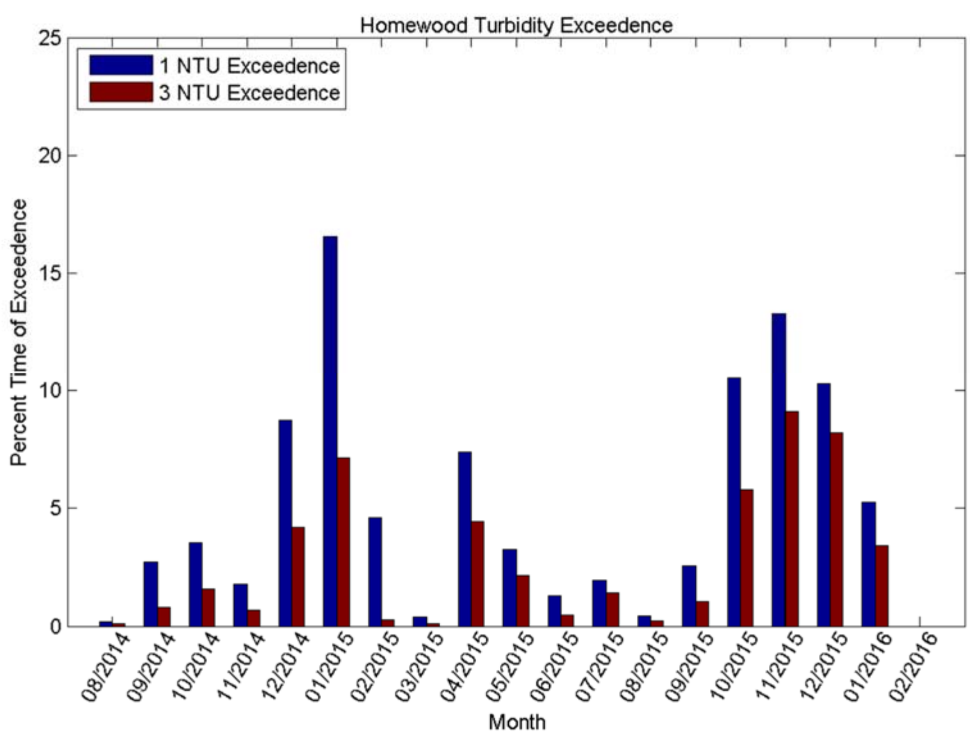
***Table 1**: Summary of nearshore turbidity measurements (NTU), 2014–2015 circuits.*

Nearshore Circuit ID:	November 2014	April 2015	June 2015	August 2015	November 2015
Maximum	0.187	0.640	0.937	0.685	0.999
75% Quantile	0.112	0.125	0.150	0.116	0.139
Median	0.106	0.117	0.131	0.103	0.131
25% Quantile	0.094	0.108	0.113	0.095	0.126
Minimum	0.081	0.092	0.086	0.083	0.115
Mean	0.106	0.122	0.139	0.114	0.141
Standard Dev	0.013	0.031	0.044	0.039	0.035
CV (%)	12.7	25.3	31.7	34.5	24.8

Table 2. Percent to target and status determination assessment for nearshore turbidity measurements based on 2014–2015 circuits. All observed values are below the respective standards of 3 and 1 NTU limits for areas influenced by stream discharge and not directly influenced by stream discharge. For not to exceed targets the percent to target reflects the percent of the maximum allowable value (lower percentages are more desirable).

Nearshore Circuit ID:	November 2015	April 2015	June 2015	August 2015	November 2015
3 NTU standard (Influenced by streams)					
Maximum	6%	21%	31%	23%	33%
Mean	4%	4%	5%	4%	5%
1 NTU standard (Not influenced by streams)					
Maximum	19%	64%	94%	69%	100%
Mean	11%	12%	14%	11%	14%

If evaluation were based solely on data collected to the pilot clarity monitoring project the status determination would be considerably better than target. UC-Davis TERC is in the process of deploying a network of sensors that will monitor nearshore conditions (chlorophyll, dissolved organic matter, wave height, temperature, conductivity and dissolved oxygen) in real-time. Early results from the network are just starting to become available and suggest significant temporal variability in turbidity at individual sites. The data shows some exceedances of the standards, but also show a strong correlation between wave height and turbidity (Figure 1). Both the one and three NTU standards are assessed because of uncertainty in delineating waters of the lake not directly influenced by stream discharges.



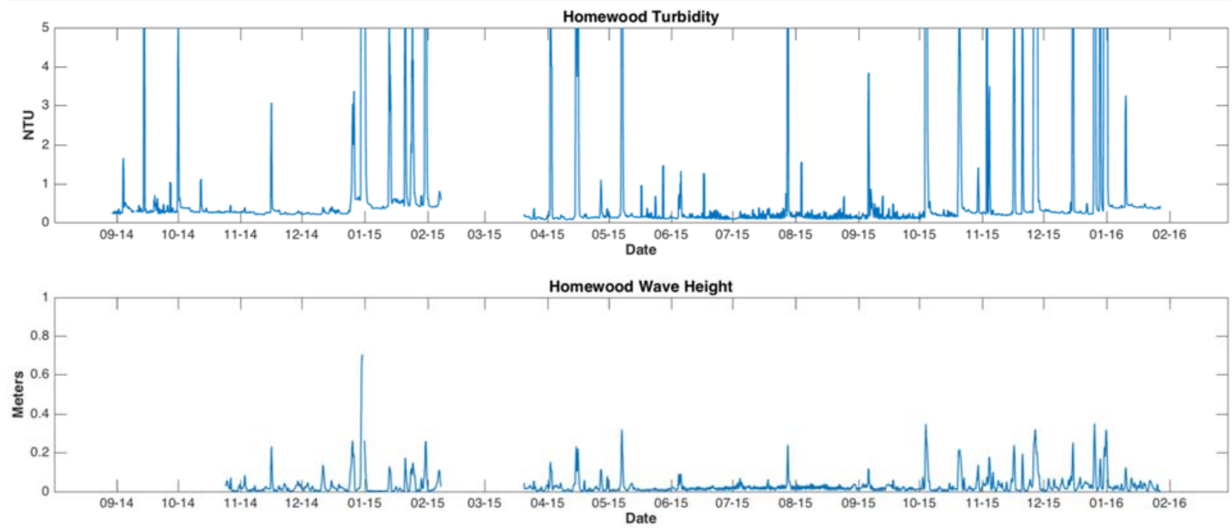


Figure 1: Nearshore turbidity and wave height measurements from UC-Davis TERC continuous monitoring station near Homewood*, CA. Turbidity measurements in the upper panel are classified relative to the 1 and 3 NTU standards and then summarized based on the proportion of measurements that exceed the standard. The lower panel displays measured turbidity and measured wave height associated with the turbidity measurements.*

There is no established method for assessing attainment of the turbidity standard, and the two different approaches to data collection clearly influence the perception of nearshore turbidity. For this evaluation, a determination of at or slightly better than target was made as a conservative middle ground between the observations of the two different monitoring methods. A status determination of at or slightly better than target reflects that the most comprehensive lake-wide measure of nearshore clarity had no exceedances of either standard, yet continuous monitoring at an individual site found exceedance rate of the one NTU standard could be as high as 15 percent of the time, during periods of high wave action.

Trend – Insufficient data to determine trend. The lack of a routine monitoring program precludes a detailed assessment of trend. Longer term data were extracted from previous nearshore circuits completed on an irregular basis as part of various research funded by different projects over the years since 2000. These data are compared to results obtained from the 2014–2015 pilot nearshore clarity monitoring program, with the range of section average values shown for each individual circuit completed since 2000. The clarity data from recent circuits in 2014–2015 show a fairly tight relationship in terms of data distribution when compared to previous years. This would suggest a trend determination of little to no change. No data are available for contiguous nearshore circuits prior to 2001. The distribution of nearshore turbidity data from two circuits completed in 2012 were both well above average. Potential contributing factors will be evaluated as the monitoring project continues, and trends will be evaluated over time using nonlinear regression techniques with smoothing functions that locally weight nearby circuits more heavily. In the meantime, there is no apparent trend in recent overall nearshore clarity conditions compared to the 2001–2008 period. This will be investigated more fully as data from additional circuits become available over time.

Confidence –

> **Status** - High. Confidence is high in the status of nearshore clarity conditions completed as part of contiguous circuits analyses in 2014 and 2015. Measuring turbidity reliably in relatively clear waters, such as Tahoe, is known to be challenging (Heyvaert et al., 2013a).
> **Trend** – Low. The lack of a routine monitoring data precludes a formal assessment of trend.
> **Overall** – Moderate. Overall confidence takes the middle of the two confidence determinations when high and low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road
- Restored or enhanced 120 acres of disturbed forested uplands
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles
- Issued 18,076 BMP certificates to commercial, multifamily and single family residential properties

Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do maintain a healthy nearshore environment. Between 2012-2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

Effectiveness of Programs and Actions – The nearshore is a heterogeneous environment and insufficient data exist to quantitatively evaluate the effectiveness or contribution of any individual policy, program or action.

Interim Target –The nearshore standard is currently in attainment.

Target Attainment Date – The nearshore standard is currently in attainment.

RECOMMENDATIONS

Analytic Approach – Data from contiguous circuits could be compared to spot measurements completed at specific locations on the 25-meter depth contour after 1991. A substrate identification study has been initiated to enhance analysis and interpretation of clarity results, in association with water depth and nearshore extent analysis. Ultimately, these analyses and the clarity data should be evaluated relative to onshore factors and other nearshore metrics as part of an integrated nearshore monitoring and assessment program (Heyvaert et al., 2013a). Continue to explore the relationship between transmissivity and turbidity. Transmissivity is likely a superior measurement of nearshore clarity in Lake Tahoe, where turbidity is so low. Establishing how these different measures correlate and why spatial differences in response sometimes appear is a research need.

Monitoring Approach – The differences in nearshore turbidity as assessed based on data collected from nearshore circuits relative to continuous site based measurements should be considered. The review should consider the strengths and weakness of each approach relative the information requirements of managing the nearshore. Refine nearshore survey route so that it is more routine for contiguous circuits, and follows a set of consistent pathlines. New high resolution turbidimeters are now available commercially, and could be evaluated within the context of current equipment and historical data. Additional recommendations related to survey circuits are detailed in (Heyvaert et al., 2013a).

Modification of the Threshold Standard or Indicator –Review of the threshold standards should consider the issues raised with respect to the existing standard. These include:

1. No formal method has been adopted for spatially delineating the two zones established in the standard: areas not directly influenced by stream discharge and areas directly influenced by stream discharge. Delineation of these areas is likely to require recognition that they are heavily influenced by stream flow and lake circulation patterns.

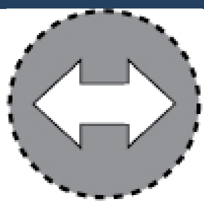
2. Concern that the current standard is adequate for protection of nearshore clarity and aesthetics. For example, a turbidity of only one NTU equates to a transparency (as Secchi depth) of about four feet, which does not seem to be good enough to be publicly acceptable (Taylor et al., 2004).
3. Data collection methodology and the precision and reliability of measuring turbidity in the relatively clear waters of Lake Tahoe. The 2013 nearshore monitoring report suggests: "Generally, turbidimeters are best suited for measurements in more turbid waters because their response is more stable and less variable at higher readings (near full scale). Transmissometers, on the other hand, are preferred for clear waters because they read near full scale (100 percent) in pristine conditions where particle concentrations are low and turbidimeter readings are suspect. (Heyvaert et al., 2013a)"
4. The nearshore environment as highly heterogeneous (Heyvaert et al., 2013a). Ambient levels of turbidity around the lake may vary considerably as a result of natural processes such as wind, wave action, depth, and substrate. Data collected by UC Davis near Homewood suggests a strong correlation between turbidity and wave height.

Modification of the standard should also consider focusing on the desired outcome (a specific level of nearshore clarity) rather than the presumed driver of that outcome (reduced sediment loading).

Attain or Maintain Threshold – No changes recommended.

Littoral Lake Tahoe: **Nearshore Attached Algae**

Status	Trend



NEARSHORE ATTACHED ALGAE

Status: **Insufficient Data to Determine Status**
Trend: **Little or No Change**
Confidence: **Low**

Time period	Observations	#	Mean	SD	Med	p	Trend
1982-2015		1293	28.6	31.1	18.5	0.46	None
	Lake Elevation >= 6225 ft.	723	24	31.3	13.5	0.33	None
	< 1000 day	537	21.4	29.4	11.4	0.04	Increase
	Lake Elevation <= 6225 ft.	570	34.4	30	25.2	<0.01	Decrease
	>= 1000 day	756	33.7	31.4	23.6	0.06	None
2000-2015		848	27.7	31.9	17.3	0.2	None
	Lake Elevation >= 6225 ft	441	24.1	32.6	12.9	0.19	None
	< 1000 day	304	22.1	33.2	10.5	<0.01	Increase
	Lake Elevation <= 6225 ft	407	31.5	30.7	22	0.87	N/A
	>= 1000 day	544	30.8	30.8	20.4	<0.01	Increase

Summary statistics (# observations, mean, median, std. dev.) for periphyton biomass (Chlorophyll a mg / m^2) and p-value for trend analysis for change in biomass. Trend analysis combine all routine sites to assess Lake-wide periphyton trends. Where analysis of trend indicated a significant trend, the direction of the trend is indicated. Observations where Lake Elevation >= 6225 ft or where the sampling depth has been submerged for less than 1000 days (< 1000 day) are thought to reflect trend in stalked diatoms and/or filamentous green algae. Observations where lake Lake Elevation <6225 ft or where the depth has been submerged for more than 1000 days (< 1000 day) are thought to be influenced by blue-green algae. Table adapted from (Hackley et al., 2016a).

Map

Periphyton monitoring locations.

Data Evaluation and Interpretation

BACKGROUND

Relevance – Attached algae or periphyton refers to a suite of organisms that grow attached to submerged surfaces (e.g. rocks, boats, buoys, piers). In Lake Tahoe these include stalked diatoms, filamentous green algae, and cyanophytes. The communities occupy different portions of the nearshore and exhibit different growth patterns. Stalked diatoms species and filamentous green algae dominate the shallow area between the low and high lake level (eulittoral zone) and grow rapidly in the spring in die off in the summer. Cyanophytes are more stable communities that dominate the deeper portions of the nearshore (Hackley et al., 2016b). Excessive periphyton growth impacts the aesthetic qualities, and impairs beneficial use of the shorezone. When periphyton dies off and breaks free each year, beaches can be fouled and water contact recreation affected. Periphyton growth can also be a safety concern for people attempting to navigate slippery algal covered surfaces.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category – Nearshore attached algae

Adopted Standards – 1) Reduce the loading of dissolved inorganic nitrogen, dissolved phosphorus, iron, and other algal nutrients from all sources to meet the 1967-71 mean values for phytoplankton primary productivity and periphyton biomass in the littoral zone. 2)Support actions to reduce the extent and distribution of excessive periphyton (attached) algae in the nearshore (littoral zone) of Lake Tahoe.

Type of Standard – Numerical and Management

Indicator (Unit of Measure) – Indicators measured include: 1) total yearly suspended sediment load (expressed in million metric tonnes/year); and 2) total annual stream flow (expressed in million cubic meters of water). The load for each day at each stream was estimated from multiple regression of measured values.

Human & Environmental Drivers –Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (Hackley et al., 2013). Phosphorus is a nutrient important to the growth and reproduction of plants, and is considered a pollutant of concern in the Lake Tahoe Region (Lahontan and NDEP, 2010b). It has also been hypothesized the excrement from crayfish in the lake augments periphyton growth (Heyvaert et al., 2013a). Stalked diatoms and green filamentous algae may be the most responsive to fluctuations in nutrient input (Hackley et al., 2016b). The stalked diatoms and filamentous green algae that inhabit the shallow waters grow rapidly in the spring with the influx of nutrients and die back rapidly during summer when nutrients are less abundant and waters warm (Hackley et al., 2016b). Biomass is generally higher on the north and west beaches and lower at the lower in the east and south, a pattern that has remained relatively stable over time (Hackley et al., 2016b). Lake level influences periphyton community composition, at lake elevations below 6225 feet blue-green algae contribute substantially to the periphyton levels, while at higher lake levels stalked diatoms and filamentous green algae dominate.

MONITORING AND ANALYSIS

Monitoring Partners –University of California at Davis-Tahoe Environmental Research Center and the Lahontan Regional Water Quality Control Board.

Monitoring Approach – UC Davis has monitored periphyton in Lake Tahoe since 2000. Monitoring also occurred between 1982 and 1985 and 1989 to 1993. The primary periphyton monitoring work are regular sampling work referred to "routine" sampling at nine sites annually (the number of locations has varied historically from six to ten). At each location algal biomass (as chlorophyll *a*) is sampled five times annually from natural rock surfaces at a depth of 0.5 meters below the water level at the time of sampling. A second type of sampling, referred to a "synoptic" monitoring occurs once a year at 40 additional sites. The timing of synoptic monitoring varies annually and is intended to capture biomass at its peak in the spring. The synoptic monitoring includes collection of chlorophyll *a* at a sub-set of the sites, as well as a rapid assessment method that quantifies a periphyton biomass index (PBI).

Analytic Approach – Status and trend assessment considered trends in periphyton biomass data for routine sites and spring synoptic sites. Individual trend analysis was done at multiple levels including site-level, regional, and Region and with respect to three explanatory covariates: upland development, lake level and length of time the site was submerged. Trend assessment was further segmented by time period considered in the assessment, first considering the full period of record 1982 to 2015 and second considering only the period of continuous sampling from 2000 to 2015. A Mann-Kendall test was used to asses for trend significance. Full details on the analytic methods are available in Hackley et al. 2016.

INDICATOR STATE

Status – Insufficient data to determine status. Neither the management standard nor the numerical standard have a defined numeric target, so it is not possible to assess attainment. The current standard references periphyton biomass as measured between 1967 and 1971 as the goal for biomass in the nearshore. This was the California state standard at the time the thresholds were established in 1982, but at the time of establishment, it was noted that, “there were no measurements of periphyton biomass between 1967-1971 (TRPA, 1982).”

Trend – Little or no change. Stalked diatoms and filamentous green algae are more likely to rapidly respond to changes in nutrients and are primary subject of this trend assessment (Hackley et al., 2016b). Lake wide there has been no significant change in periphyton biomass between 1982 and 2015 (considering all routine sites together). Two routine sites, Pineland and Incline West, exhibited statistically significant, but small increases in periphyton between 2000 and 2015. A significant decline in periphyton was observed at the Sugar Pine Point site between1982 and 2015. A significant negative trend was observed in both Chlorophyll A and PBI measured at the 50 spring synoptic sites. Because the spring synoptic sampling does not always catch peak biomass and sampling occurs only once a year, caution is urged in interpretation of the trend based on synoptic sampling at the regional level. For full details and additional results see Hackley et al. 2016.

Confidence –

Status – Low. Where insufficient data exists to determine status, confidence in the status determination is low. There is high confidence in the data presented in the assessment. Periphyton monitoring follows established techniques that produce reliable results. Sampling occurs at a single depth and measurements are likely influenced by lake level.

Trend – Low. No trends were identified at the lake wide level using the more reliable dataset for trend analysis (routine sites) and a declining trend was identified lake wide based on the synoptic data. These results are incongruent with the anecdotal reports of visitors and residents.

Overall – Low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – The heterogeneous nature of the nearshore environment mean that the drivers of periphyton growth are likely to vary importance around the lake. While the importance of drivers is likely to vary, it is generally thought that controlling nutrient inputs will help reduce periphyton growth (Heyvaert et al., 2013a). SEZ restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 that are likely to have resulted in reduced pollutant loads include have:

- Restored or enhanced 27,150 linear feet of stream channel
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road
- Restored or enhanced 120 acres of disturbed forested uplands
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles
- Issued 18,076 BMP certificates to commercial, multifamily and single family residential properties

The Lahontan Regional Water Quality Control Board is currently funding USGS and University of Nevada-Reno to explore the drivers of the periphyton biomass near Tahoe City. The results of the study will be available in early 2017 and will contribute to our understanding of what causes periphyton growth and what actions can be taken to limit that growth.

Effectiveness of Programs and Actions – Insufficient data exist to quantitatively evaluate the effectiveness of any individual policy, program or action implemented to reducing periphyton abundance or distribution.

Interim Target – Because neither the management standard nor the numerical standard has a specific target, one cannot reasonably establish an interim target.

Target Attainment Date – Because neither the management standard nor the numerical standard have defined numerical targets, one cannot reasonably establish a target attainment date.

RECOMMENDATIONS

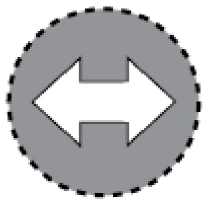
Analytic Approach – No changes recommended.

Monitoring Approach – Differences in periphyton community composition can confound the detection of trends in periphyton abundance and growth. The trend analysis presented above attempted to control for biomass changes driven by different periphyton communities by including both lake level and time submerged as covariates. The presence of more stable blue-green algae communities at some locations can confound periphyton trend detection, because when lake level drops blue-green algae communities contribute to elevated measures of periphyton. Consideration should be given to a monitoring design that accounts for these differences in data collection. Public perception is that there has been an increase in algae in recent years, yet synoptic sampling suggests that periphyton levels observed in 2015 were some of the lowest recorded. In addition to exploring different ways to monitor periphyton, additional emphasis should also be placed on understanding what is driving public perceptions of nearshore algae.

Modification of the Threshold Standard or Indicator – The management standard directs TRPA to "support actions" to reduce "excessive" periphyton but provides no further guidance or numeric target for assessing progress or attainment. The numeric standard references periphyton biomass as measured between 1967 and 1971 as the goal for biomass in the nearshore. This was the state standard at the time the thresholds were established in 1982, but at the time of establishment, it was noted that, "There were no measurements of periphyton biomass between 1967-1971 (TRPA, 1982)." Investigations of periphyton between 1967 and 1971 focused primarily on periphyton growth rates, but did provide two rough estimates of total biomass in the lake, which ranged from 147 to 2,180 metric tons (Charles R. Goldman, 1974). The appropriateness of this as a reference point has been questioned because the biomass estimates were 1) based on periphyton growth on artificial surfaces, and thus not representative of natural conditions, and 2) based on a limited data (Heyvaert et al., 2013a). The threshold study report suggests that values measured in 1981 off of undeveloped sites may be a close approximate for what values would have been between 1967 and 1971. The 1981 water year reported measure of periphyton biomass off undeveloped areas was generally below 10 grams per square meter (TRPA, 1982). Caution is urged against using a single measure taken in July (a time at which periphyton levels on the like are generally thought to be lower) to establish baseline conditions for periphyton biomass (personal communication Scott Hackley). Ash Free Dry Weight (the unit of measure used to assess periphyton biomass in 1981) has not always been monitoring by UC Davis, and at present only one additional July measure is available, although additional hard copy records maybe available in Davis (personal communication Scott Hackley). UCD-TERC notes "there exists no baseline for periphyton that be considered as pre-disturbance (Hackley et al., 2016b)." Consideration in standard modification should be given to observed heterogeneity in nearshore environmental conditions.

Attain or Maintain Threshold – No changes recommended.

Status



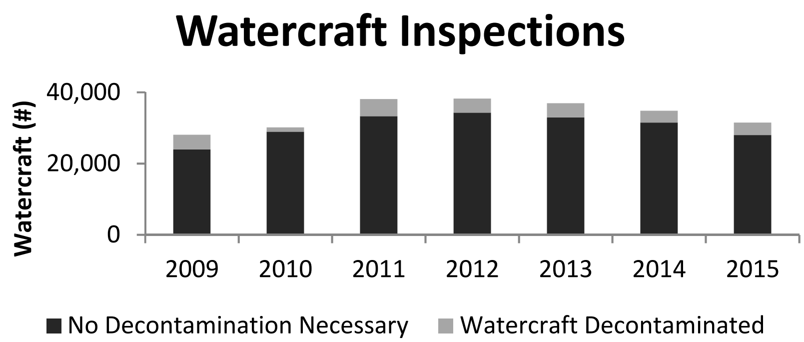
AQUATIC INVASIVE SPECIES

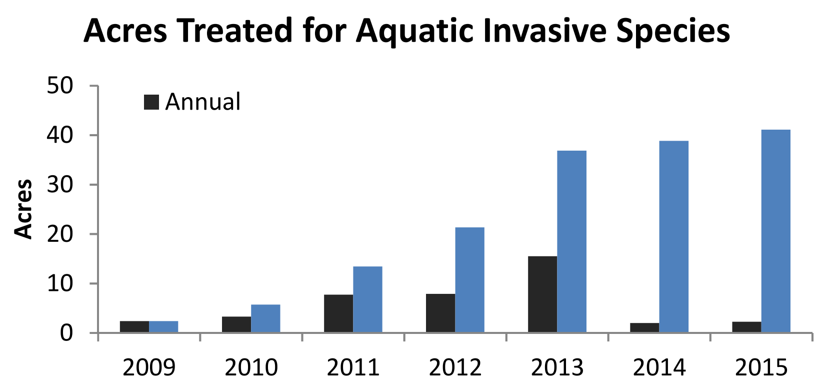
Status – **Insufficient Data to Determine Status**
Trend - **Little or No Change and Insufficient Data to Assess Trend**
Confidence – **Low**

Number of New AIS

0

Prevention and Control





The cumulative treatment of aquatic invasive species (AIS) since 2009.

Data Evaluation and Interpretation

BACKGROUND

Relevance – Aquatic Invasive Species (AIS) are non-native organisms that threaten the abundance and diversity of native organisms in Lake Tahoe. Non-native species have been intentionally and unintentionally introduced to the Lake Tahoe Region over the last 150 years. Prior to 1960, a number of species were introduced by managers to augment recreational opportunities. These include a variety of salmonid species including rainbow trout (*Oncorhynchus mykiss*), Lake trout (*Salvelinus namaycush*), Kokanee salmon (*Oncorhynchus nerka*), brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). The last intentional introduction was of a salmonid prey species, mysid shrimp (*Mysis diluviana*) in the 1960s (Wittmann and Chandra, 2015). A number of species were likely introduced non-officially by individuals and became established sometime in the mid-1980s and new introductions continued through the first decade of the 20th century. These include warm water fish species, including bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), aquatic plants Eurasian watermilfoil (*Myriophyllum spicatum*) and curlyleaf pondweed (*Potamogeton crispus*), and Asian clams (*Corbicula fluminea*). The presence of these species continues to threaten native taxa of the lake and is a nuisance to users of the lake. The presence of AIS also results in economic impacts in the Region with potential costs to tourism, property owners, boaters, and maintenance estimated at between $22 to $78 million per year (Wittmann and Chandra, 2015). In December 2012 TRPA adopted the current standard related to management of AIS in the Region (TRPA, 2012c). The presence of aquatic weeds increases nutrients in the system which may impact nearshore clarity.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category – Aquatic invasive species (nearshore/littoral)

Adopted Standard – Prevent the introduction of new aquatic invasive species into the Region's waters and reduce the abundance and distribution of known aquatic invasive species. Abate harmful ecological, economic, social and public health impacts resulting from aquatic invasive species.

Type of Standard – Management standard

Indicators (Unit of Measure) – Number of new AIS/areal extent of AIS distribution, acres treated for AIS.

Human & Environmental Drivers – Non-native species have been both intentionally and unintentionally introduced to Lake Tahoe over the last 150 years (see background for a more detailed description). Habitat modification such as channelization and modification of the Truckee Marsh for the Tahoe Keys also created micro-environments within the lake that may be more suitable for colonization by AIS. Climate change further threatens to alter the lake's physical environment, with the potential for making further AIS establishment more likely.

MONITORING AND ANALYSIS

Monitoring Partners – Lake Tahoe Aquatic Invasive Species Coordination Committee, California Tahoe Conservancy, California Department of Fish and Wildlife, California Department of Parks and Recreation, California State Lands Commission, Lahontan Regional Water Quality Control Board, Nevada Department of Wildlife, Nevada Division of State Lands, Tahoe Resource Conservation District, Tahoe Regional Planning Agency, Tahoe Science Consortium, U.S. Department of Agriculture – Agricultural Research Service, U.S. Forest Service – Lake Tahoe Basin Management Unit, U.S. Fish and Wildlife Service, University of Nevada Reno, League to Save Lake Tahoe.

Monitoring Approach – Monthly veliger surveys for mussel larvae are done during the boating season.

Analytic Approach – The seven individual subparts of the adopted standard(s) for AIS were evaluated individually. The "abundance" was evaluated as the number or density of AIS, while "distribution" was evaluated as the geographic spread of AIS.

INDICATOR STATE

Status – The seven individual subparts of the adopted standard(s) for AIS are evaluated individually below. The standards include one management standard with a numerical target, and six management standards without numerical targets.

1. *Prevent the introduction of new aquatic invasive species into the Region's waters* – Every year, there are approximately 30,000 watercraft seal inspections at boat launches around the lake, ensuring all boats entering the lake are compliant with AIS regulations. Additionally, the watercraft inspectors perform approximately 7,000 to 8,000 full watercraft inspections per year, of which roughly 50 percent of vessels undergo decontamination. Any vessel not cleaned, drained and dried is deemed to be a high risk of harbouring some form of aquatic invasive species and is decontaminated. There are an estimated 30 non-native aquatic species that are established in the Region's waters (Wittmann and Chandra, 2015). No new aquatic species have been documented in Lake Tahoe since the standard was adopted in 2012. This part of the standard is in attainment.

2. *Reduce the abundance of known aquatic invasive species* – Six acres of weeds have been removed from Emerald Bay to reduce the abundance in this area of the lake. Abundance of all AIS throughout the lake has not been fully survey and is unknown. The "Eyes on the Lake" program assists in providing data to show incidental observed occurrence of certain species. There is no established baseline against which to assess reductions in abundance. The status of

this standard is unknown due to insufficient data.

3. *Reduce the distribution of known aquatic invasive species* – Between 2009 and 2012, six acres of weeds were removed from Emerald Bay and the bay is currently free of Eurasian watermilfoil and curlyleaf pondweed. Each infestation requires multiple treatments of the same area, so the total acres of treated measure includes multiple treatment of the same location. In 2014, an Asian clam shell was found in Sand Harbor State Park, which is 20 kilometres from the nearest confirmed infestation. The status of this standard is unknown due to insufficient data.

4. *Abate harmful ecological impacts resulting from aquatic invasive species* – Actions taken to reduce the abundance and distribution of known AIS are expected to contribute to abating impacts from AIS. Select species have been studied, but the full extent of ecological impacts of AIS have not been studied or measured. Crayfish may be feeding on benthic organisms, and warm water fish can out compete native species. The status of this standard is unknown due to insufficient data.

5. *Abate harmful economic impacts resulting from aquatic invasive species* - Actions taken to reduce the abundance and distribution of known AIS are expected to contribute to abating impacts from AIS. The area of heaviest infestation of weeds is the Tahoe Keys, and weeds are regularly harvested during the summer but do not remove the species from the system. Harvesting collects plant fragments, to abate further spreading. The estimated costs of a potential dreissenid mussel infestation to tourism/property owners/boat and maintenance is between $22 to $78 million per year (Wittmann & Chandra 2015). Because the harmful impacts of all AIS have not been studied or measured, the status of this standard is unknown due to insufficient data.

6. *Abate harmful social impacts resulting from aquatic invasive species* – Actions taken to reduce the abundance and distribution of known AIS are expected to contribute to abating impacts from AIS. The area of heaviest infestation of weeds is the Tahoe Keys, and weeds are regularly harvested during the summer but do not remove the species from the system. Harvesting collects plant fragments, to abate further spreading. Because the harmful impacts have not been studied or measured, the status of this standard is unknown due to insufficient data.

7. *Abate harmful public health impacts resulting from aquatic invasive species* – Actions taken to reduce the abundance and distribution of known AIS are expected to contribute to abating impacts from AIS. To date no harmful public health impacts have been attributed to AIS in Lake Tahoe. Reported impacts in other areas include toxic algal blooms and drowning. Because the harmful impacts have not been studied or measured, the status of this standard is unknown due to insufficient data.

Trend – Little to no change and Insufficient data to assess the trend. No new aquatic invasive species have been documented in Lake Tahoe since the standard was adopted, thus the trend with respect to this standard is little to no change. Insufficient data exists to assess the trend with respect to the majority of the AIS standards.

Confidence –

Status – Low. Where insufficient data exists to determine status, the confidence in the status determination is low.
Trend – Low. Trend was not assessed due to insufficient data.
Overall Confidence – Low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Management of AIS is guided by the Lake Tahoe Region Aquatic Invasive Species Management Plan. The Plan has been accepted by the Governors of California and Nevada, adopted as a Bi-State Plan, and approved by the national Aquatic

Nuisance Species Task Force." Within the plan, management of AIS is broadly classed into prevention, monitoring and rapid response, and control (TRPA, 2014). Prevention program actions are designed to prevent the spread of existing and introduction of new AIS into the Region's waters. The monitoring and rapid response program aims to monitoring existing AIS populations and ensure early detection and rapid response to new introductions. Control program actions aim to minimize the impact of AIS and where feasible ultimately eradicate existing AIS populations. The core of the prevention program is the mandatory inspection and decontamination of watercraft prior to launch. Since the inception of motorized watercraft inspections in 2007, more than 200,000 boats have been inspected prior to launch and more than 44,000 crafts have been decontaminated. These activities have prevented hundreds of fouled boats from entering the lake. Numerous control actions have been piloted within Lake Tahoe.

"Eyes on the Lake" is a citizen science program, led by the League to Save Lake Tahoe (League), designed to report the incidence of AIS in Tahoe's waters. League staff train community members how to identify and report the location and presence of aquatic plants in the Lake.

The "Tahoe Keepers" self-inspection and decontamination training program provides paddlers and hand-launched watercraft users with the information and training to help prevent the introduction and spread of AIS from non-motorized watercraft. Since the program's inception over 3,000 people have self-certified through the online education program.

AIS control program highlights include:

- Since 2009 over 40 acres have been treated for AIS.
- Between 2009 and 2012 six acres of weeds were removed from Emerald Bay and the bay is currently free of Eurasian watermilfoil and curlyleaf pondweed.
- The Tahoe Keys Property Owners Association spends as much as $400,000 annually on harvesting weeds within the Keys. The Association is developing an integrated weed management plan to address AIS in the Keys. The plan will outline improved harvesting and fragment collection methods with increased use of bottom barrier mats, evaluate additional control methods (e.g. sterile grass carp, UV light weed rollers), and further study the potential to use herbicides that require additional review by the Lahontan Regional Water Quality Control Board.

Effectiveness of Programs and Actions – No new AIS have been detected in the lake since the inception of the prevention program. Quality control measures have been implemented, including a "secret shopper" program that evaluates the rigor of the inspection program and identifies adaptive improvements. After a comprehensive review of AIS control options, researchers classified AIS into three categories based on the feasibility and effectiveness of existing control options. Species with "feasible control actions" included Eurasian watermilfoil, curlyleaf pondweed, and warm water fish species. The integrated weed treatment in Emerald Bay was successful and the bay remains weed free. Species with "potential" control options included signal crayfish and American bullfrog, while mysid shrimp and Asian clam were categorized as species with no feasible control option at this time (Wittmann and Chandra, 2015). The review identified the importance of investigating new control techniques for species in the latter categories.

Interim Control Program Targets –

1. Prevent the spread of existing AIS to new areas in the lake.
2. Finalize and implement the Tahoe Keys Integrated Weed Management Plan.
3. Complete lakewide programmatic environmental review for all invasive species.
4. Treat 20 to 50 acres of existing AIS by the end of 2019 (includes retreatment work).
5. Implement the use of one or more new (not currently in use in the Region) techniques to treat known AIS infestations.

Interim Target Attainment Date – 2019 threshold evaluation reporting cycle.
RECOMMENDATIONS
Analytic Approach – No changes recommended. **Monitoring Approach** – The design and implementation of a routine monitoring program that quantifies the distribution and abundance of existing AIS in the Region as described in the implementation plans is needed (Wittmann and Chandra, 2015). **Modification of the Threshold Standard or Indicator** – AIS are an emerging threat to the ecosystem and the knowledge base on the distribution, abundance and impacts is continuing to evolve. The establishment of a management standard in 2012 was a critical step to indicate the importance of action to address the issue. The standard as currently written provides broad goals for the program. Control program are aspirational and contingent on securing new funding. Data collection should continue to be supported. The numerous subparts of the standard make objective evaluation of progress or attainment of the standard challenging. The standard could be clarified into individual standards that can be independently evaluated or criteria stated that should be used to arrive at an attainment determination. Objective determination of “attainment” status for standards without a specific target is recurrent challenge both in the Region and in the larger field of monitoring and evaluation (M&E). The standard should be assessed against best practice for the establishment of standards and indicators for M&E, and amended as necessary to improve the evaluability of the standard and the information it provides for management. **Attain or Maintain Threshold** – No changes recommended.

Tributaries

The Tahoe Basin contains 63 streams that flow into Lake Tahoe. These streams drain a total land area of approximately 800 square kilometers. Approximately 83 square kilometers, or 10.5 percent of the land area, is developed, and much of that development is concentrated near the shore of Lake Tahoe. Total tributary inflow to Lake Tahoe is approximately 430 million cubic meters in an average water year (October 1 to September 30) (Reuter, J.E. et al., 2009). The Lake Tahoe Interagency Monitoring Program routinely monitored seven streams through 2014 to track water quality conditions, and continuously monitored for inflow. Together, these seven streams deliver roughly half of the total tributary inflow to Lake Tahoe (Lahontan and NDEP, 2010b)(Lahontan and NDEP 2010). Two of the routinely monitored streams are in Nevada: Third and Incline; and five of the streams are in California: Trout, General, Blackwood and Ward creeks, and the Upper Truckee River. Of these seven monitored streams, approximately 90 percent of the cumulative total inflow is from the five California streams, and less than 10 percent is from the two Nevada streams.

Indicators associated with two standards are monitored to document the long-term status and trend of Tahoe Basin tributary waters: 1) attainment of applicable state water quality standards; and 2) total annual loads of nutrients (nitrogen and phosphorus) and suspended sediment (Table 4-1). Attainment of applicable state standards relies on the measured concentrations of nutrients and suspended sediments to evaluate status and trends relative to established state numerical standards (i.e., targets). Assessment of attainment status for pollutant load standards is challenging because the management standard pollutant specific desired ambient conditions in the lake, not specific loading levels. Despite this challenge, quantitative information on annual load of nutrients and suspended sediment is presented in this section. The report also includes the first assessment of trend in flow weighted pollutant load in the Region.

Inter-annual variability in local weather and the resulting amounts, timing, and type of precipitation have a strong influence on stream inflow and the resulting loads of sediments and nutrients (Coats et al., 2008; Gunter, M, 2005). The influence of natural stream inflow on annual pollutant loads is readily apparent in the data presented in this section. Flow-weighted concentrations of sediment, nitrogen, and phosphorus were examined to reveal the underlying trends in pollutant concentrations. Although there are no established standards for flow-weighted concentrations of pollutants, an examination of their trends is thought to provide more insight into the influence of TRPA policies and management actions.

Policy and management actions to attain standards for Tahoe Basin tributary waters are implemented through the TRPA Regional Plan and the Environmental Improvement Program, and generally aim to reduce pollutant loading to Lake Tahoe. These actions include:

- Restoring and enhancing stream environment zones (SEZ)
- Limiting the rate and extent of urban growth
- Implementing best management practices (BMPs) on developed properties to reduce nutrient and sediment discharge from disturbed soils
- Reducing private automobile use through improvements to public transit and alternative transportation modes with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment

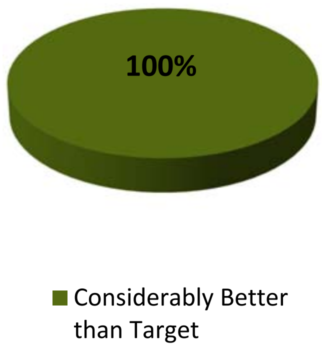
- Ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects

More specific information about these actions is provided in Chapter 12: Implementation and Effectiveness, of this report.

The status and trends of six indicators in the tributary water quality indicator reporting category were evaluated. Data for the indicators were derived from seven monitoring sites located at the mouth of seven streams. Evaluated indicators included concentrations of suspended sediment, total phosphorus and total nitrogen, and combined tributary loads of suspended sediment, total phosphorus, and total nitrogen. Fine sediment particles are thought to be the primary driver of the observed declines in lake clarity (Lahontan & NDEP, 2010a, 2010b), so an evaluation of fine sediment particle load also is presented. Inter-annual variability in local weather and the resulting amount, timing, and type of precipitation have a strong influence on stream inflow and loading of sediments and nutrients (Coats et al., 2008; Lahontan & NDEP, 2010b).

Tributaries: **Suspended Sediment Concentration**

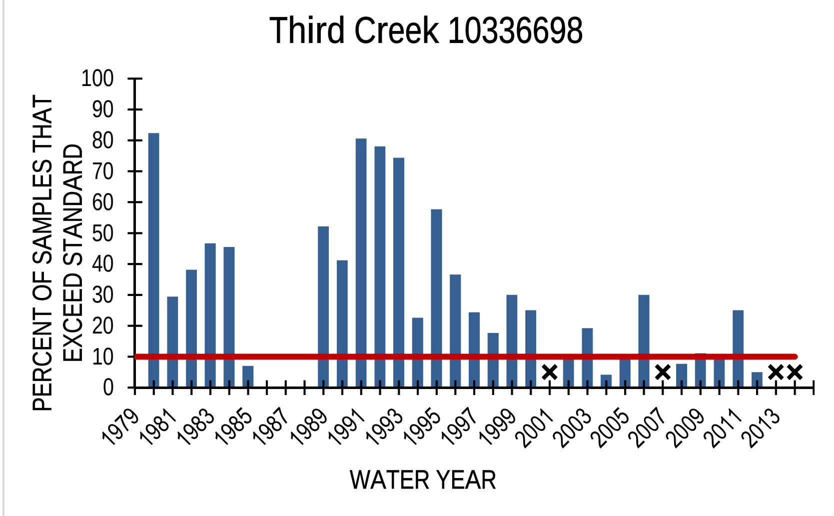
Status	Trend

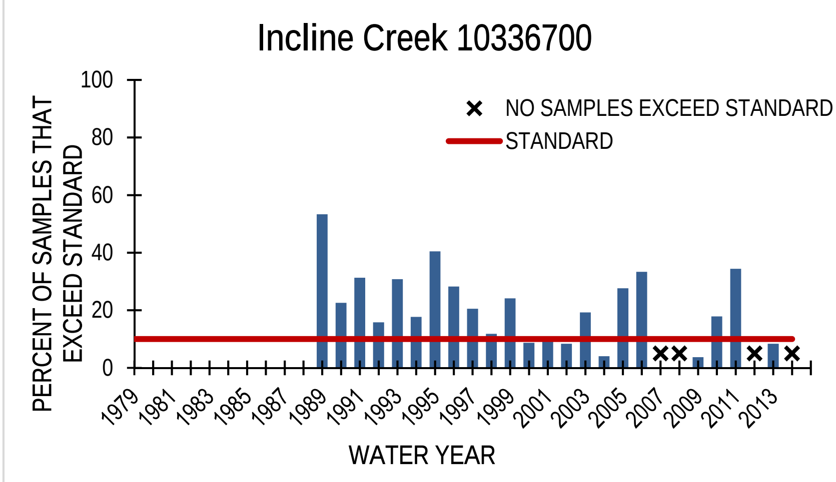


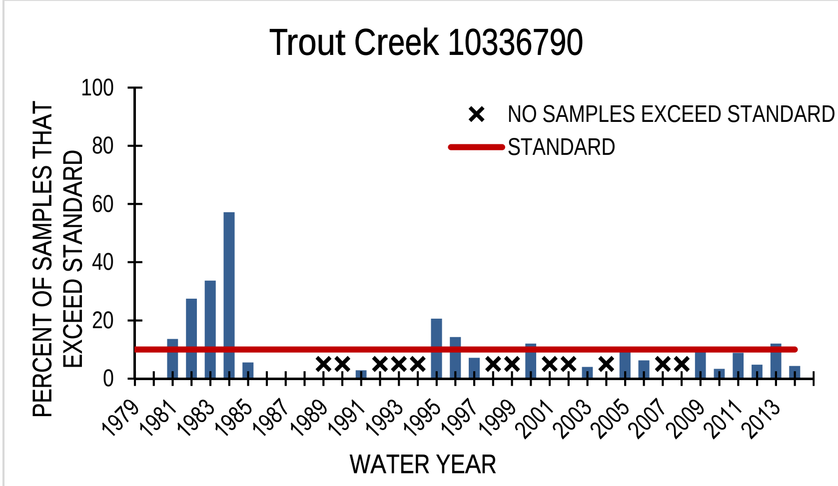
SUSPENDED SEDIMENT CONCENTRATION

Status: **Considerably Better than Target**
Trend: **Moderate Improvement or Little or No Change**
Confidence: **Moderate**

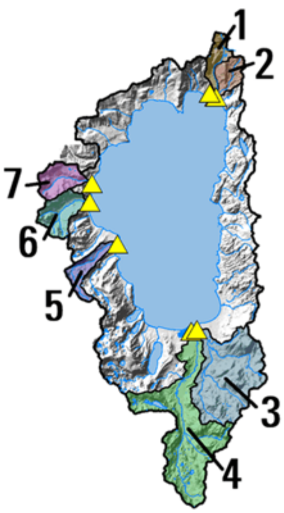
Proportion of monitored streams determined to be in each status determination category. Suspended sediment concentration in all streams was considerably better than the target during the 2014 water year.



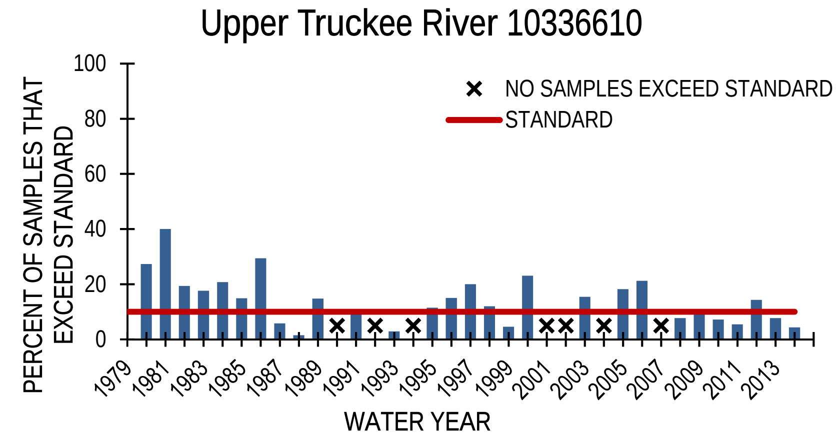


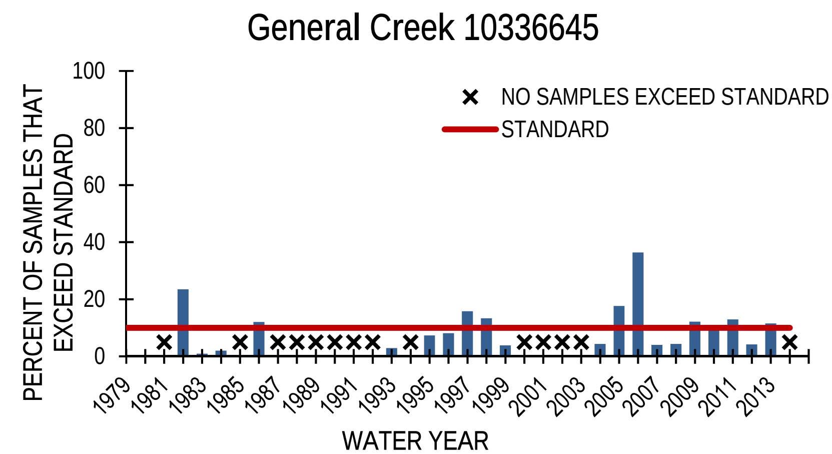


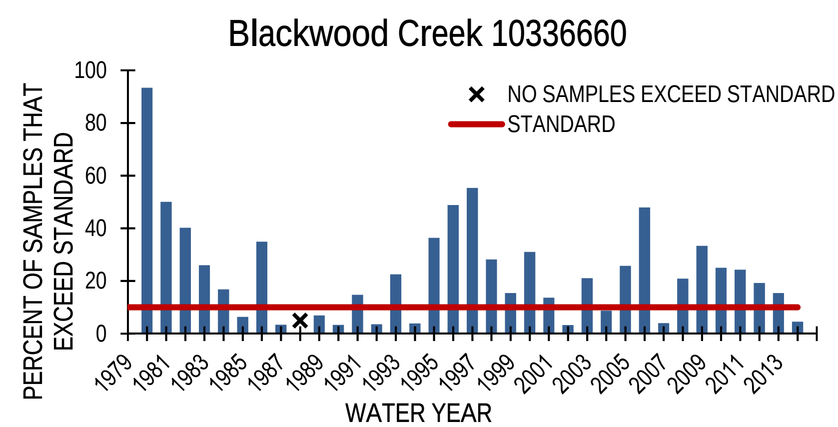
Map

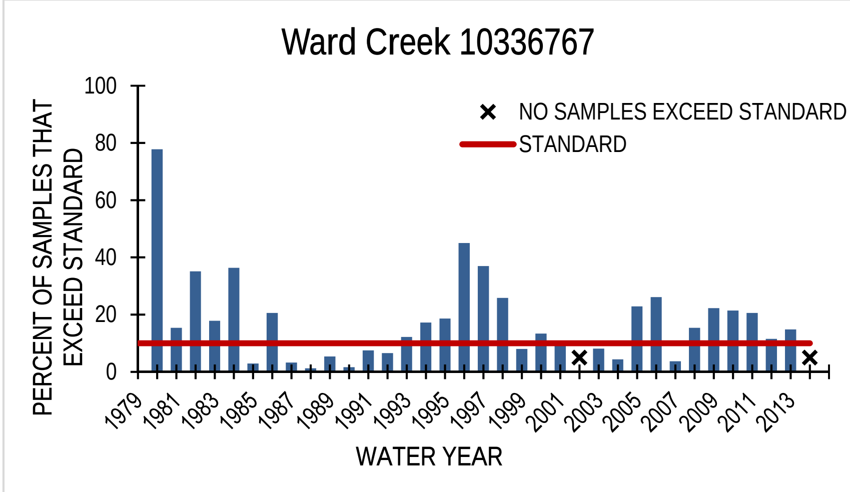


The seven streams routinely monitored for suspended sediment concentration include two streams in Nevada: (1) Third Creek, and (2) Incline Creek; and five streams in California: (3) Trout Creek, (4) Upper Truckee River, (5) General Creek, (6) Blackwood Creek, and (7) Ward Creek









The figures above show how measurements of suspended sediment concentration compared to the water quality standard in place for each of seven regularly monitored Lake Tahoe tributaries by water year. The individual bar presented for each water year (October 1 – September 30) represents the proportion of all individual samples collected in the water year that exceeded 60 milligrams per liter (mg/L). The suspended sediment concentration standard for both California and Tahoe Regional Planning Agency (TRPA) states that the stream must attain a 90th percentile value for suspended sediment concentration of 60 mg/L. This is interpreted to mean that no more than ten percent of the stream's suspended sediment concentration measurements for the water year can exceed 60 mg/L. The horizontal red line represents this standard. The symbol 'x' denotes that sufficient samples were collected and that none of the samples contained suspended sediment concentration values greater than 60 mg/L. Years without an 'x' or a plotted percentage of exceedences mean that no samples were collected, or that data is missing. Data are from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Data Evaluation and Interpretation

BACKGROUND

Relevance –Sediment (particularly fine sediment) delivered to Lake Tahoe is known to directly affect the transparency of Lake Tahoe (Lahontan & NDEP, 2010b). Suspended sediment concentration is the amount of organic and inorganic particles suspended in water in the stream. Suspended sediments occur naturally in streams and are essential to the ecological function of a stream (EPA, 2003). Deposition of suspended sediments can create micro-habitats such as pools and sand bars for biota (EPA, 2003). Excessive amounts of suspended sediment are the leading cause of impairment in streams and lakes of the United States (EPA, 2003). Too much suspended sediment in the stream can have direct impacts on stream and lake biota. Identified impacts include loss of spawning habitat for fish, reduced amounts of light available for photosynthesis by plants, and shifts to turbidity-tolerant fish communities (EPA, 2003).

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category –Tributaries

Adopted Standards – Attain a 90th percentile value for suspended sediment concentration of 60 milligrams per liter (mg/L).

Type of Standard – Numerical

Indicator (Unit of Measure) –Suspended sediment concentration expressed in milligrams per liter (mg/L). The unit of measure reported here is the proportion of suspended sediment samples that exceed 60 mg/L each water year (October 1 to September 30) for a given stream.

Human & Environmental Drivers – All the tributaries within the Tahoe Basin deliver sediment and nutrients to a single downstream water body: Lake Tahoe. The Tahoe Basin has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics resulting in high variability throughout the Region. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the Region from west to east; precipitation can be twice as high on the west shore relative to the east shore of Lake Tahoe. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. Landscape disturbances including, but not limited to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the lake or its tributaries. Weather variations and its effects on stream hydrology (particularly the extremes of droughts and floods), and long-term climate change are considered among the most important environmental drivers of tributary runoff.

MONITORING AND ANALYSIS

Monitoring Partners – U.S. Geological Survey (USGS; Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center (TERC)), Tahoe Regional Planning Agency, U.S. Forest Service – Lake Tahoe Basin Management Unit, and Nevada Division of State Lands. Water years 2015 and 2016 partners include Lahontan Regional Water Quality Control Board and California Tahoe Conservancy.

Monitoring Approach – The Lake Tahoe Interagency Monitoring Program (LTIMP) stream monitoring program was first developed in 1979 to assess sediment and nutrient input from tributaries to Lake Tahoe, and to support research that aims to understand the drivers affecting the transparency of Lake Tahoe. The tributary monitoring focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). Up to 10 streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood and Ward Creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood Creeks). Six of these streams have been monitored since water years 1980 or 1981. In water year 2012 the number of streams routinely monitored was reduced to seven (see map above), and all streams have primary monitoring stations at or near the point of discharge to Lake Tahoe. Sampling procedures generally follow national field monitoring protocols established by the USGS (Rowe et al., 2002; USGS, variously dated). The number of individual samples collected at each primary monitoring station in a given water year that were analyzed for suspended sediment concentration has varied over the period of record (data collection began in 1979) from two to 155. For the last 10 water years, the average number of samples collected per year for each of the seven streams was 28. Samples are collected under three hydrologic conditions: regular monthly runs, storm events, and snow-melt runoff. These conditions are intended to span streamflow conditions from low to high volumes and turbidity conditions from clear to extreme. Field water quality data including water and air temperature, pH, specific conductance, and dissolved oxygen are collected during sampling events. USGS gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Suspended sediment concentration is determined by measuring the dry weight of all the sediment from a known volume of a water-sediment mixture (EPA, 2003). USGS laboratory methods used for suspended sediment concentration are well established (Guy, 1969). Long-term stream monitoring is important to detect changes in tributary water quality that may occur as a result of uncontrollable drivers such as weather and climate change, as well as the cumulative impact of remedial work intended to reduce the amount of pollutants entering the streams within the watershed.

Analytic Approach – For a given water year and stream, the number of samples exceeding suspended sediment concentration values of 60 mg/L was divided by the total number of samples collected and then multiplied by 100. In addition, the annual average suspended sediment concentration value for a given stream was determined by calculating the average of suspended sediment concentration values for all the samples collected in a given water year. Data from the LTIMP tributary monitoring program were downloaded from the USGS website (http://waterdata.usgs.gov/usa/nwis/qw) and data from the early years of LTIMP were obtained from TERC.

The status determination in Table1 below was from assigned scores for individual streams in California and Nevada and the overall assessment. Assigned scores for individual streams was determined by evaluation of its 2014 value relative to the standard. Assigned scores for individual streams for California and Nevada.

The trend of annual average suspended sediment concentration and the trend of the proportion of samples that exceed 60 mg/L in a given year for each stream were tested using the nonparametric Mann-Kendall trend (Helsel and Hirsch, 2002). The Mann-Kendall trend test assesses if there is a monotonic upward or downward trend. This is a simple trend test because values associated with suspended sediment concentration were not adjusted for variables expected to affect the annual average concentration and the percent of exceedance, such as streamflow and seasonality. A more robust trend test that removes the effects of streamflow was completed in the total suspended sediment load for tributaries section of this chapter. For this evaluation, trends were tested for consecutive years where no values were missing. For example, for Third Creek the record from water years 1989 to 2014 was used, whereas the record used for Ward Creek was water years 1980 to 2014. The trend was considered statistically significant if the P-value was less than 0.0071 (used in a latter section for test of trends for suspended sediment loads). Serial correlation was tested using a method in (Dufour, 1981).

The trend determination was based on 1) the Mann-Kendall trend test, 2) the change in percent exceedance rate between different time periods.

INDICATOR STATE

Status – Considerably better than target. None of the seven monitored streams in water year 2014 exceeded the standard for suspended sediment concentration (see Table 1 and figure above in this indicator summary). Caution should be used in interpreting the results of the 2014 water year as the exceptionally low amount of precipitation and subsequent low streamflow may have influenced the percent of samples with suspended sediment concentration values exceeding 60 mg/L. Four of the streams had no samples with suspended sediment concentration values exceeding 60 mg/L. Two of these streams were in Nevada (Third and Incline Creeks), and two of the streams were in California (General and Ward Creeks). The Upper Truckee River, and Trout and Blackwood Creeks only had four to five percent of samples exceeding 60 mg/L of suspended sediment concentration and therefore met the standard. The last time all seven of the monitored streams met the standard was in water year 2007. Annual average suspended sediment concentration values were low and ranged from 4 mg/L at General Creek to 20 mg/L at Upper Truckee River during water year 2014.

Overall, the current status of tributary suspended sediment concentration was determined to be considerably better than target. In Table 1 below, scores for suspended sediment concentration status were assigned for each of the seven regularly monitored streams in the Lake Tahoe Basin, and for the overall assessment.

Table 1: Annual average suspended sediment concentrations for 2014 Water Year and status determinations relative to standard. The SSC standard is a not to exceed standard, where percent to target values below 100% indicate the standard is in attainment.

Stream	WY 2014 Annual Average SSC (mg/L)	WY 2014 Percent of Samples Exceeding 60 mg/L	Percent to target	Status
Third Creek	9	0	0%	Considerably better than target
Incline Creek	11	0	0%	Considerably better than target
Trout Creek	18	4	40%	Considerably better than target
Upper Truckee River	20	4	40%	Considerably better than target
General Creek	4	0	0%	Considerably better than target
Blackwood Creek	9	5	50%	Considerably better than target
Ward Creek	8	0	0%	Considerably better than target

Trend – Moderate improvement or little or no change. Mann-Kendall test for trend indicates a statistically significant downward trend at Third Creek and Incline Creek for both the percent of samples that exceeded 60 mg/L each water year (Third Creek p-value = 0; Incline Creek p-value = 0.002), and the annual average suspended sediment concentration (Third Creek p-value = 0, Incline Creek p-value = 0.004). No serial correlation was found with the annual values.

Table 2: Trend determination for suspended sediment concentrations for seven monitored streams in the Tahoe Basin.

Stream	Trend
Third Creek	Moderate Improvement
Incline Creek	Moderate Improvement
Trout Creek	Little or No Change
Upper Truckee River	Little or No Change
General Creek	Little or No Change
Blackwood Creek	Little or No Change
Ward Creek	Little or No Change

The seven monitored streams can be divided into four categories in terms of trend: 1) suspended sediment concentration standard infrequently exceeded, and minimally so, 2) suspended sediment concentration standard frequently exceeded but minimally so, 3) suspended sediment concentration standard frequently exceeded by a substantial amount with no trend, and 4) suspended sediment concentration standard frequently exceeded by a substantial amount with declining trend.

Streams in the first category (suspended sediment concentration standard infrequently exceeded), include General Creek and Trout Creek. Both have exceeded the suspended sediment concentration standard during 29 percent of the monitored water years. During the early 1980s, Trout Creek exceeded the standard by large amounts, but since water year 1989 Trout Creek has exceeded the standard infrequently and by small amounts, although no statistically significant trend was found. General Creek in contrast has had more exceedances during water years 2004 to 2014 than the previous water years (see Appendix WQ-1), however the standards were exceeded minimally except during water year 2006, and no statistically significant trend was found. Thus, a trend of little or no change is assigned to these tributaries.

The Upper Truckee River is an example of a stream meeting criteria for the second category, frequently exceeded the standard, but minimally so. Upper Truckee River has exceeded the suspended sediment concentration standard 49 percent of the monitored water years. The Upper Truckee River has seen a reduction since 2007 in the percent of samples with suspended sediment concentration above 60 mg/L, although no trend based on the period of record was found to be statistically significant. Thus, a trend of little or no change is assigned to this tributary.

Streams falling into the third category (standard frequently exceeded by a large amount) include Blackwood and Ward Creeks. Blackwood and Ward Creeks have exceeded the suspended sediment concentration standard 69 and 62 percent, respectively, of the monitored water years but with no statistically significant trends. The percentage of samples from Blackwood and Ward Creeks that are greater than 60 mg/L each water year track each other fairly well, and these watersheds are located next to each other on the west shore of Lake Tahoe. These watersheds are relatively undeveloped (although Blackwood has historically been highly disturbed), are dominated by more erosive volcanic soils, and receive relatively higher amounts of precipitation compared to other watersheds of the Region. It is hypothesized that the higher suspended sediment concentration values measured in these streams are driven by local meteorology and runoff characteristics. No significant trend was detected for either, thus a trend of little or no change is assigned to both tributaries.

Finally, two streams fall into the fourth category (standard frequently exceeded by a large amount but with declining trend) include Third and Incline Creeks. Although Third and Incline Creeks have exceeded the suspended sediment concentration standard in 75 and 62 percent of water years monitored, respectively, both Third and Incline Creeks differ from the others in that the proportion of samples exceeding the standard each water year shows a statistically significant decline since 1989. Over the course of the period monitored, this change represents an annual decrease in the percentage of samples exceeding the standard of 1.6 percent and one percent for Third and Incline Creeks respectively. A trend of moderate improvement is assigned to Incline and Third Creeks.

Confidence –

Status – High. There is high confidence in the reliability of the suspended sediment concentration data. The sample and data collection follow USGS field monitoring protocols (USGS, variously dated) and field and laboratory data are subject to extensive quality assurance requirements (Guy, 1969; USGS, 2014). Although sampling frequency has decreased since the start of LTIMP, the sampling frequency is considered sufficient to characterize different inflow conditions observed during the water year. The laboratory analytical method for measuring suspended sediment concentration is well established.

Trend – Low. Confidence in the trend determination is determined to be low. Assessments and interpretation of trend are based on both statistical trend test (quantitative) and visual inspection (qualitative).

Overall – Moderate. Overall confidence takes the middle of the two determinations between high and low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen, and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects.

Effectiveness of Programs and Actions – Quantitative evaluation of the effectiveness of any individual policy, program or action implemented to improve the tributary water quality is challenging because of the diversity of contributing factors. Although each of the programs and actions are thought to aid in improving (or preserving) tributary water quality, the signal from any of these individual actions cannot be discerned from the year-to-year variability in suspended sediment concentration monitored as part of the LTIMP Tributary Monitoring Program. Although there is high inter-annual variability associated with annual average suspended sediment concentration and the 90th percentile value for suspended sediment concentration of 60 milligrams per liter (mg/L) for some of the streams (for example, Blackwood and Ward Creeks), based on the reduction in exceedances of adopted suspended sediment concentration threshold standards, it appears that, overall, the TRPA Regional Plan has contributed to the improving trend of fewer exceedances of adopted threshold standards for suspended sediment concentration.

Interim Target – Standard is currently in attainment.

Target Attainment Date – Standard is currently in attainment.

RECOMMENDATIONS

Analytic Approach – The percent of samples collected in a given water year that exceed 60 mg/L of suspended sediment concentration is highly dependent on the number of samples collected and the timing of when samples are collected. Generally, suspended sediment concentration is higher during storm or snowmelt runoff events where erosion has occurred and sediment has entered the stream. If only these types of events are sampled, then the calculation of annual average suspended sediment concentration and the number of samples exceeding 60 mg/L will be high, and when these events are missed then they will be low. The LTIMP tributary sampling schedule tries to sample all different parts of the hydrograph and at different turbidities, and this aids in estimating a fairly representative average concentration during the water year. However, a time-of-sampling bias may be introduced due to lack of sampling for some streams once it is dark outside (see Modification of the Threshold Standard or Indicator section below for possible ways to rectify this). Another issue is the effect of streamflow and seasonality on suspended sediment concentration. The effects of streamflow and seasonality can be removed from concentration data using different statistical techniques and then the adjusted concentration data can be tested for time trends. A simple way to calculate a potentially more representative annual average concentration includes using a flow-weighted concentration, calculated by dividing the annual suspended sediment load by the annual total streamflow (Buck, 2014; Heimann et al., 2011). Another method involves converting the daily suspended sediment load into daily mean suspended sediment concentration, and then taking the average of all the concentrations for a given water year. The different methods of estimating a more representative annual average concentration, or for suspended sediment concentration, the percent of samples above 60 mg/L in a water year, would need to be further explored and compared.

Monitoring Approach – Major changes were implemented in water year 2015, to include the measurement of continuous turbidity which is used to improve load calculations for total phosphorus, suspended sediment, and possibly fine sediment. Only five of the seven streams monitored have continuous turbidity, and a priority should be made to add continuous turbidity in Third and Incline Creeks. The addition of continuous turbidity monitoring allowed sampling frequency to be decreased. Suspended sediment concentrations should continue to be monitored to track long-term trends, however, coordinated additional work such as focused studies and effectiveness monitoring, are needed to assess the causes of changes in suspended sediment concentration in the monitoring data. This includes assessing the effectiveness of watershed restoration projects and understanding the impacts of uncontrollable drivers such as weather and climate change.

Modification of the Threshold Standard or Indicator – Consideration should be given to the large natural variation in stream flow both within and among watersheds, as well as the seasonal variation of concentrations. Another factor to consider is the time of day when the sampling is done. Sampling only during daylight hours can introduce a time-of-sampling bias. This may be important for streams in Lake

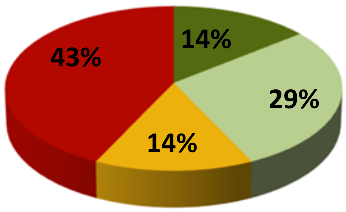
Tahoe because the daily spring snowmelt runoff peak occurs in the middle of the night for the larger streams. The suspended sediment concentrations will be higher during the rise near the peak, and during the peak, then during the recession of streamflow. Therefore, only sampling during daylight hours can bias the concentrations low. In contrast, for streams where the daily snowmelt runoff peak occurs during day-light hours, the overall concentrations can be biased high. Also storm events often occur at night, and due to the flashy nature of the streams, the rise, peak and recession of streamflow can occur in the matter of a few hours in the middle of the night. One way to alleviate this problem for suspended sediment concentration, total phosphorus and possibly fine sediment, is to correlate known samples concentrations of these constituents with the continuous turbidity measurements when the sample was taken, and then use regression equations to estimate concentrations during unsampled time periods (Coats and Lewis, 2014a). The estimated daily concentrations using this method could be used to calculate annual average concentration and the percent of days that have estimated concentrations above 60 mg/L. Using continuous turbidity will not help with total Kjeldahl nitrogen, and dissolved constituents such as nitrate and soluble reactive phosphorus (Coats and Lewis, 2014a). The way to alleviate this potential time-of–sampling bias for these constituents is to install auto-sampler equipment that are triggered to collect water samples based on changes in streamflow or turbidity, which would occur regardless of whether it is day or night. In a later section on suspended sediment loads, the time-of-sampling bias is addressed by using only samples collected between 8 am and 7 pm from Third, Incline, and Trout Creeks, and the Upper Truckee River, and 6 am to 12 am for General, Blackwood and Ward Creek when calculating loads (see Total Suspended Sediment Load for Tributaries section). This same methodology of only using samples from specific time periods in a day could be used when calculating the annual average concentration and the percent of samples exceeding the suspended sediment standard.

Standard review should consider consistency with the TMDL program and include input from federal, state and local agencies, and the science community.

Attain or Maintain Threshold – Continue to pursue the strategies and actions identified in the Lake Tahoe TMDL and Regional Plan with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2031.

Tributaries **Phosphorus Concentration**

Status	Trend

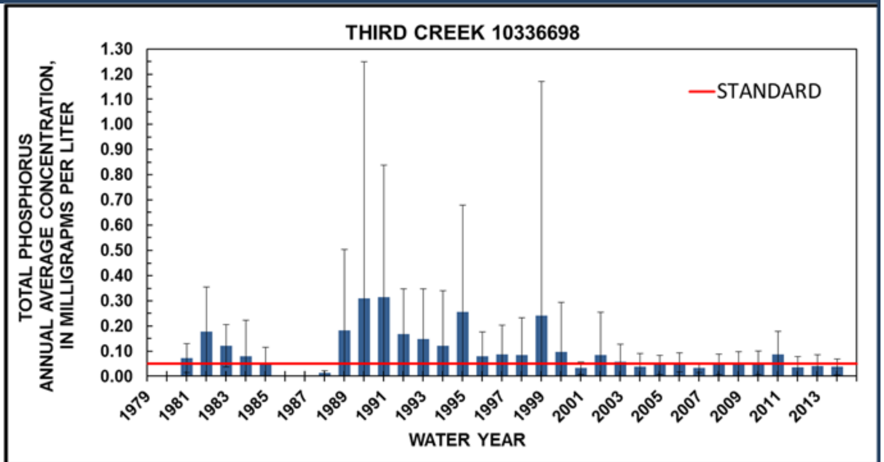


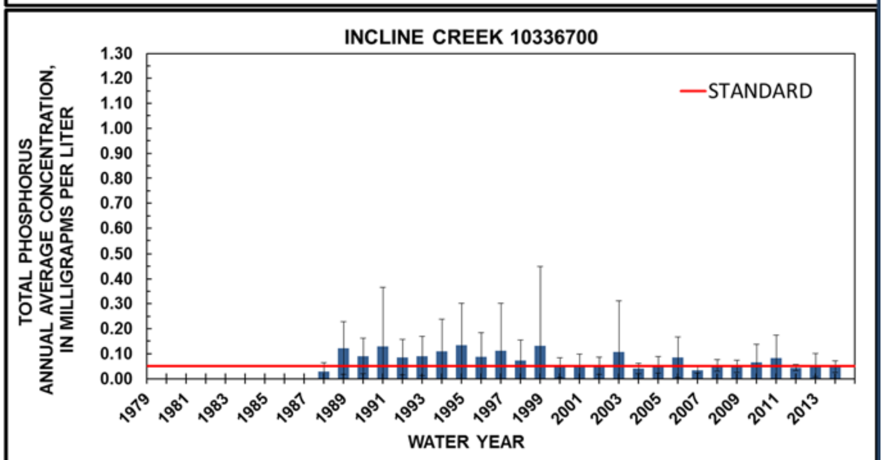
- Considerably better than target
- At or somewhat better than target
- Somewhat worse than target
- Considerably worse than target

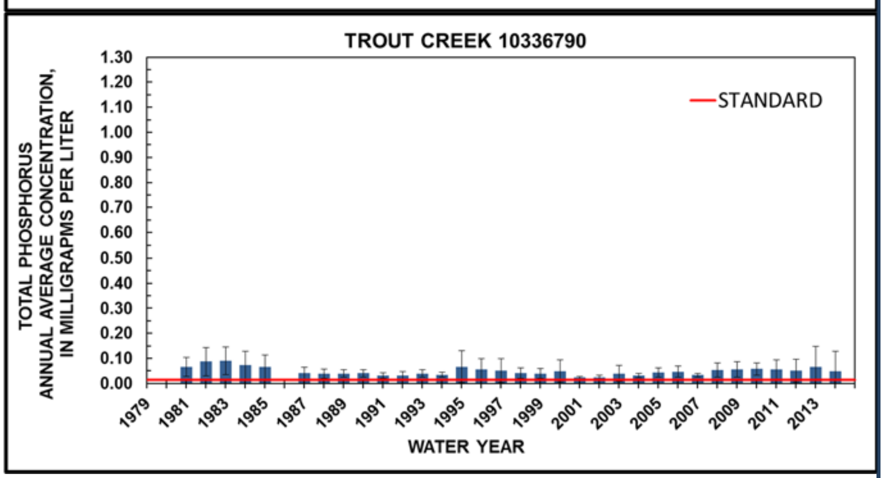
PHOSPHORUS CONCENTRATION

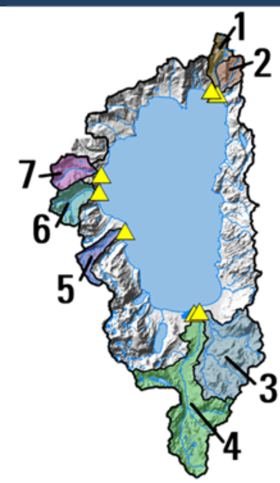
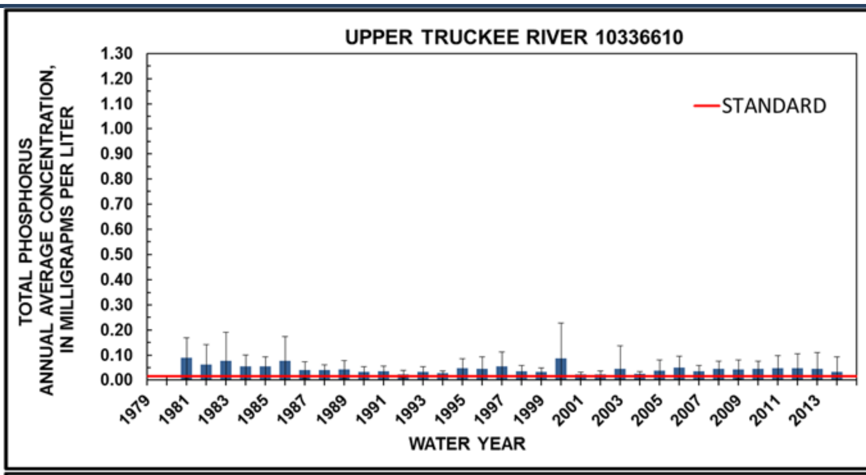
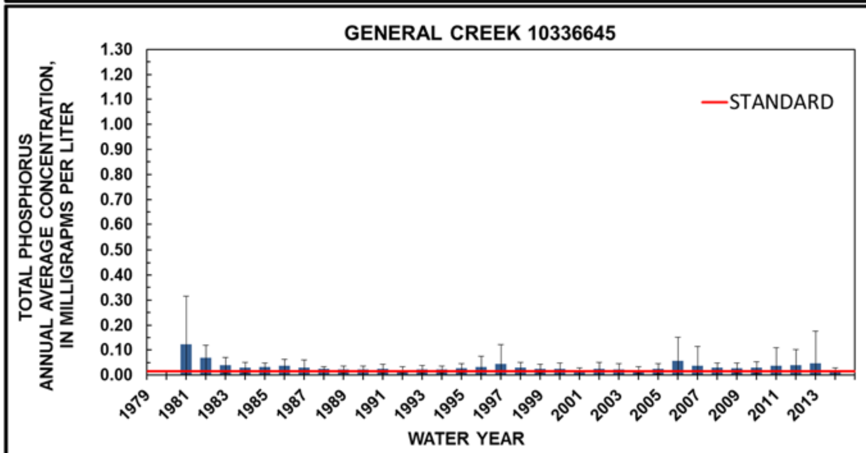
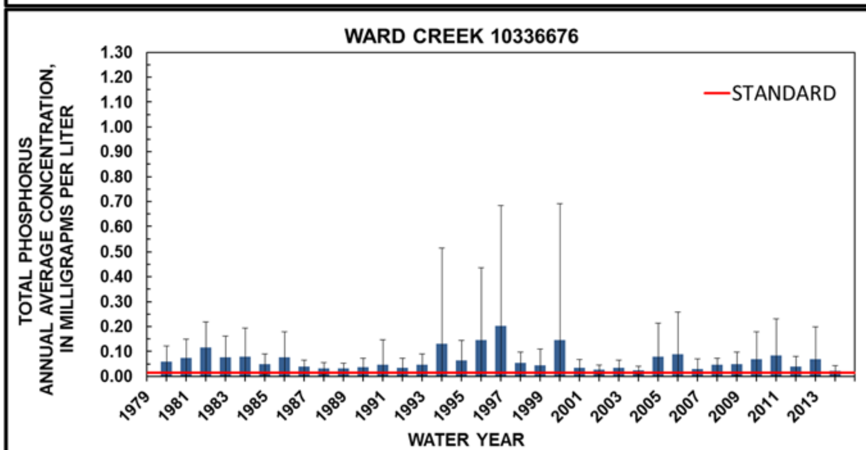
Status: **See Pie Chart Above**
Trend: **Little to No Change and Rapid Improvement**
Confidence: **Moderate**

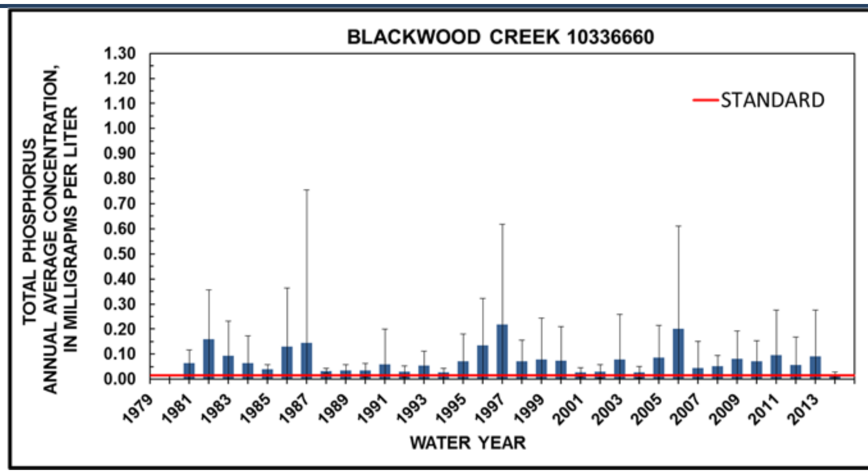
Proportion of monitored streams determined to be in each status determination category.







Map	
 The seven streams routinely monitored for total phosphorus concentration includes two streams in Nevada: (1) Third Creek, and (2) Incline Creek; and five streams in California: (3) Trout Creek, (4) Upper Truckee River, (5) General Creek, (6) Blackwood Creek, and (7) Ward Creek.	  



Annual average total phosphorus concentration, determined from samples collected during a water year (October 1 to September 30), compared to the water-quality standard in place for each of seven regularly monitored streams in the Lake Tahoe Basin. The individual bars represent the annual average total phosphorus concentration. Black lines indicate standard deviation of observed conserventations. The horizontal red line represents the numeric standard of 0.05 milligrams per liter (mg/L) for streams in Nevada, and the numeric standard of 0.015 mg/L for streams in California. Data is from the Lake Tahoe Interagency Monitoring Program (LTIMP). Total phoshorus includes dissolved and particulate forms of phosphorus.

Data Evaluation and Interpretation

BACKGROUND

Relevance –Phosphorus is a nutrient important to the growth and reproduction of plants, and is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan & NDEP, 2010a). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (Hackley et al., 2013). Free-floating algae (phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis and by scattering light. Attached algae (periphyton) coat rocks in the nearshore, adversely affecting nearshore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). Lake Tahoe is an ultraoligotrophic lake and management goals include maintaining this status due to its historic, cultural, economic, and aesthetic valuePhosphorus occurs naturally in the soils of Lake Tahoe, and is delivered to surface waters and Lake Tahoe through soil erosion, and subsequent transport in streams and stormwater. This indicator measures the average concentration of total phosphorus for each water year in the seven routinely monitored streams. Phosphorus is also found in atmospheric deposition, groundwater discharge to Lake Tahoe and streams (Lahontan & NDEP, 2010b)

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category –Tributaries

Adopted Standards – TRPA: attain applicable state standards for concentrations of dissolved phosphorus; Nevada: the annual average concentration of total phosphates cannot exceed 0.05 mg/L as phosphorus in Incline Creek (NAC 445A.1636) and Third Creek (NAC 445A.1642); California: The annual average value and the 90th percentile value of total phosphorus cannot exceed 0.015 mg/L in the Upper Truckee River, and Trout, General, Blackwood, and Ward Creeks (LRWQCB, 1995).

Type of Standard – Numerical

Indicator (Unit of Measure) –The indicator is annual average total phosphorus concentration measured over a water year (October 1 to September 30). Annual average total phosphorus concentration is based on samples collected during each water year from each of the seven monitored streams. The number of individual samples collected at each monitoring station in a given water year varied during the period of record from three to 138. Annual average total phosphorus concentrations are reported in milligrams per liter (mg/L). Although the TRPA standard is for state standards for dissolved phosphorus (i.e., the fraction of total phosphorus that will pass through a 0.45-micron filter), the states do not have standards for dissolved phosphorus. Both California and Nevada have standards for total phosphorus, which is what was used for this evaluation.

Human & Environmental Drivers – All the tributaries within the Tahoe Basin deliver sediment and nutrients to a single downstream water body: Lake Tahoe. The Tahoe Basin has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics resulting in high variability throughout the Region. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the basin from west to east; precipitation can be twice as high on the west shore relative to the east shore of Lake Tahoe. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. Landscape disturbances including, but not limited to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries. Weather variations and its effects on stream hydrology (particularly the extremes of droughts and floods), and long-term climate change are considered among the most important environmental drivers of tributary runoff.

MONITORING AND ANALYSIS

Monitoring Partners – U.S. Geological Survey (USGS; Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center (TERC)), Tahoe Regional Planning Agency, U.S. Forest Service – Lake Tahoe Basin Management Unit, and Nevada Division of State Lands. Water years 2015 and 2016 partners include Lahontan Regional Water Quality Control Board and California Tahoe Conservancy.

Monitoring Approach – The Lake Tahoe Interagency Monitoring Program (LTIMP) stream monitoring program was first developed in 1979 to assess sediment and nutrient input from tributaries to Lake Tahoe, and to support research that aim to understand the drivers affecting the transparency of Lake Tahoe. Tributary monitoring focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). Up to 10 streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood and Ward Creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood Creeks). Six of these streams have been monitored since water years 1980 or 1981. In water year 2012 the number of streams routinely monitored was reduced to seven (see map above), and all streams have primary monitoring stations at or near the point of discharge to Lake Tahoe. The seven monitored streams collectively drain 350 square kilometers, roughly 43 percent of the Tahoe Basin. Sampling procedures generally follow national field monitoring protocols established by the USGS (Rowe et al., 2002; USGS, variously dated). The number of individual samples collected at each monitoring station in a given water year that were analysed for total phosphorus has varied over the period of record from three to 138. For the last 10 water years, the average number of samples collected per year for each of the seven streams was 28. Samples are collected under three hydrologic conditions: regular monthly runs, storm events, and snow-melt runoff. These conditions are intended to span streamflow conditions from low to high volumes and turbidity conditions from clear to extreme. Field blank and replicate samples, and field water-quality data including water and air temperature, pH, specific conductance, and dissolve oxygen, are collected during sampling events. USGS gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Analytical methods in the laboratory for measuring nutrients have been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al., 2009a). Long-term stream monitoring is important to detect changes in tributary water quality that may occur as a result of uncontrollable drivers such as weather and climate change, as well as the cumulative impact of remedial work within a watershed meant to improve tributary water quality.

Analytic Approach – The annual average total phosphorus concentration for a given stream is determined by calculating the average of total phosphorus concentrations for all the samples collected in a given water year. Data from the LTIMP tributary monitoring program were downloaded from the USGS website (http://waterdata.usgs.gov/usa/nwis/qw) and data from the early years of LTIMP were obtained from TERC. Early in the LTIMP tributary monitoring program samples were analyzed for total hydrolyzable phosphorus (hydrolyzable phosphorus plus orthophosphate). TERC personnel developed regression equations that they used to convert total hydrolyzable phosphorus to total phosphorus concentration based on samples where both analytical methods were performed.

The status determinations for individual streams (Table 1) were based on the percent of water year 2014 total phosphorus annual average concentration greater than the standard or the percent of the standard when below the standard.

The trend of annual average total phosphorus concentrations for each stream was tested using the nonparametric Mann-Kendall test (Helsel and Hirsch, 2002). The Mann-Kendall test assesses if there is a monotonic upward or downward trend. This is a simple trend test because the annual average total phosphorus concentrations were not adjusted for variables expected to affect the annual average concentration, such as streamflow and seasonality. A more robust trend test that removes the effects of streamflow was completed for total phosphorus loads in the section on Total Phosphorous Load. For this evaluation, trends were tested for consecutive years where no values were missing. For example, for Third Creek the record from water years 1988 to 2014 was used, whereas the record used for Ward Creek was water years 1980 to 2014. The trend was considered statistically significant if the P-value was less than 0.0071 (used in a later section for Total Phosphorus Loads). Serial correlation was tested using a method in (Dufour, 1981).

The trend determination was based on 1) the Mann-Kendal trend test, 2) the change in standard exceedance rate between different time periods (see also Appendix WQ-1), 3) visual inspection of graphed data record. Patterns and visual trends were noted based on the graphs at the beginning of this indicator sheet.

INDICATOR STATE

Status – The annual average total phosphorus concentrations for water year 2014 for the two Nevada streams ranged from 0.037 mg/L at Third Creek (74 percent of standard) to 0.047 mg/L at Incline Creek (94 percent of standard); and ranged from 0.015 mg/L at General Creek (at the standard) to 0.049 mg/L at Trout Creek (227 percent greater than the standard) for the five California streams. Between water years 1981 and 2014, the annual average total phosphorus concentrations for the two Nevada streams ranged from 0.013 mg/L (26 percent of the standard at Third Creek in 1988) to 0.315 mg/L (530 percent greater than the standard at Third Creek in 1991). The annual average total phosphorus concentrations for the five California streams ranged from 0.015 mg/L (at the standard at General Creek in 2014) to 0.218 mg/L (1353 percent greater than the standard at Blackwood Creek in 1997) over the same period.

Table 1: Annual average phosphorous concentrations for 2014 Water Year and status determinations relative to standard. The phosphorous standard is a not to exceed standard, where percent to target values below 100% indicate the standard is in attainment.

Stream	Water Year 2014 Annual Average Total Phosphorus Concentration (mg/L)	Percent to Target	Status
Nevada Streams			
Third Creek	0.037	74%	Considerably Better than Target
Incline Creek	0.047	94%	At or Somewhat Better than Target
California Streams			
Trout Creek	0.049	327%	Considerably Worse than Target
Upper Truckee River	0.034	227%	Considerably Worse than Target
General Creek	0.015	100%	At or Somewhat Better than Target
Blackwood Creek	0.017	113%	Somewhat Worse than Target
Ward Creek	0.022	147%	Considerably Worse than Target

Trend – Little to no change and rapid improvement. The only stream that had a statistically significant trend based was Third Creek, which had a decreasing trend (p-value = 0.0005, Mann-Kendall) with a slope of -0.005 mg/L per year. No serial correlation was found with the annual average total phosphorus concentrations.

Patterns of total phosphorus annual average concentration in the streams from each state are evaluated separately, since the numeric standard in Nevada (0.05 mg/L) is 3.3 times larger than the California standard (0.015 mg/L). In Nevada, annual average total phosphorus concentrations in Incline Creek and Third Creek frequently exceeded the standard by more than 25 percent during the period 1989 to1999. However, the number of exceedances has declined since 2001. Since 2001, the annual average total phosphorus concentrations have either been below the standard or have not exceeded the standard by more than 25 percent, except for values measured in Incline Creek in 2003, 2006, and 2011, and Third Creek in 2002 and 2011. Third Creek shows an improving trend, and was below the standard during the last three water years. Based on visual inspection of the graphs at the beginning of this indicator sheet, Incline Creek shows an improving trend, although not statistically significant. In California, Trout Creek, Upper Truckee River, and General Creek show relatively stable annual average total phosphorus concentrations that exceeded the 0.015 mg/L standard by more than 25 percent in all water years except in water year 2014 at General Creek, which was at the standard. Blackwood and Ward Creeks had the most variability in annual average total phosphorus concentration, and exceeded the standard by the greatest amounts. Blackwood and Ward Creeks exceeded the standard by more than 25 percent in all years, except for water year 2014 when Blackwood Creek only exceed the standard by 13 percent. The magnitude of exceedances from the standard was higher in wetter years. There is no discernable trend for the five California streams based on the graphs at the beginning of this report and the Mann-Kendall trend test, although in water year 2014, annual average total phosphorus concentrations were the lowest during the period of record for General, Blackwood and Ward Creeks.

Table 2: Trends for Total Phosphorous concentrations at monitored streams in the Tahoe Basin

Stream	Trend
Third Creek	Rapid Improvement
Incline Creek	Little or No Change
Trout Creek	Little or No Change
Upper Truckee River	Little or No Change
General Creek	Little or No Change
Blackwood Creek	Little or No Change
Ward Creek	Little or No Change

Confidence

Status – High. There is high confidence in the reliability of the total phosphorus concentration data. The sample and data collection follow USGS field monitoring protocols (USGS, variously dated). Field and laboratory data are subject to extensive quality assurance requirements (Goldman et al., 2009a). Although sampling frequency has decreased since the start of LTIMP, the sampling frequency is considered sufficient to characterize different inflow conditions observed during the water year. The analytical methods for measuring nutrients have been developed for waters with extremely low nutrient concentrations.

Trend- Moderate. Assessments and interpretation of trend are based on both statistical trend test (quantitative) and visual inspection (i.e., qualitative).

Overall - Moderate. Overall confidence takes the lower of the two confidence determinations.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen, and fine sediment that may contribute to total phosphorus loads), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects.

Effectiveness of Programs and Actions – Quantitative evaluation of the effectiveness of any individual policy, program or action implemented to improve the tributary water quality is challenging because of the diversity of contributing factors. Although each of the programs and actions are thought to aid in improving (or preserving) tributary water quality, the signal from any of these individual actions cannot be discerned from the year-to-year variability in total phosphorus concentrations monitored as part of the LTIMP Tributary monitoring program. Although there is high inter-annual variability associated with annual average total phosphorus concentration for some of the streams (for example, Blackwood and Ward Creeks), based on the reduction in exceedances of adopted total phosphorus concentration threshold standards, it appears that, overall, the TRPA Regional Plan has contributed to the improving trend of fewer exceedances of adopted threshold standards for total phosphorus.

Interim Target – Based on visual inspection of the data record, it is difficult to discern when the tributaries will be in compliance with the applicable total phosphorus annual average concentration standards. Only Third Creek had a statistically significant trend, whereas the other streams did not have statistically significant trends, so their trend slopes were not different from zero.

Target Attainment Date – Based on inspection of the data record, it is difficult to determine a date in the future that the adopted standards will be achieved for the monitored tributaries. The five monitored California tributaries have met the standard only once for one stream, hence it appears unlikely that the California monitored tributaries will ever achieve the California standard. For Nevada tributaries, challenges still exist for Third and Incline Creek, especially during bigger streamflow years such as 2011, although additional actions to reduce phosphorus may help improve Third and Incline Creeks to eventually attain the standards.

RECOMMENDATIONS

Analytic Approach – Annual average total phosphorus concentrations are highly dependent on the number of samples collected and the timing of when samples are collected. Generally, total phosphorus concentrations are higher during storm or snowmelt runoff events where erosion has occurred and sediment has entered the stream. If only these types of events are sampled, then the calculation of annual average total phosphorus concentrations will be high, or when these events are missed the average concentration will be low. The LTIMP tributary sampling schedule tries to sample all different parts of the hydrograph and at different turbidities. This aids in estimating a fairly representative average concentration during the water year. There are a few possible ways to calculate a more representative annual average concentration; the first is to use a flow-weighted concentration, calculated by dividing the annual total phosphorus load by the annual total streamflow (Buck, 2014; Heimann et al., 2011). Another method involves converting the daily total phosphorus load into daily mean total phosphorus concentration, and then taking the average of all the concentrations for a given water year.

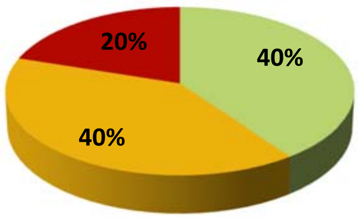
Monitoring Approach – Major changes were implemented in water year 2015, to include the measurement of continuous turbidity which is used to improve load calculations for total phosphorus, suspended sediment, and possibly fine sediment. Only five of the seven streams have continuous turbidity, and a priority should be made to add continuous turbidity in Third and Incline Creeks. The addition of continuous turbidity monitoring allowed sampling frequency to be decreased. Total phosphorus concentrations should continue to be monitored to track long-term trends, however, coordinated additional work such as focused studies and effectiveness monitoring, are needed to assess the causes of changes in total phosphorus concentrations in the monitoring data. This includes assessing the effectiveness of watershed restoration projects and understanding the impacts of uncontrollable drivers such as weather and climate change.

Modification of the Threshold Standard or Indicators– The standards evaluated here were established by the California and Nevada. Standard review for pollutant concentrations should consider the large natural variation in yearly stream inflow within and among watersheds, seasonal variation of concentrations, and the time of day when the samples are collected (as discussed above). Standard review should also consider consistency with the TMDL program and include input from federal, state and local agencies, and the science community.

Attain or Maintain Threshold –Pursue strategies and actions identified in the Lake Tahoe TMDL and Regional with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2031.

Tributaries: **Nitrogen Concentration**

Status	Trend

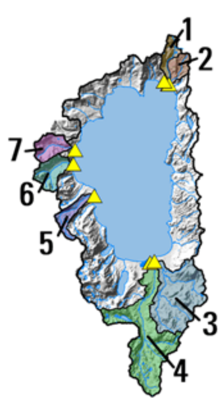


- At or Somewhat Better than Target
- Somewhat worse than target
- Considerably worse than target

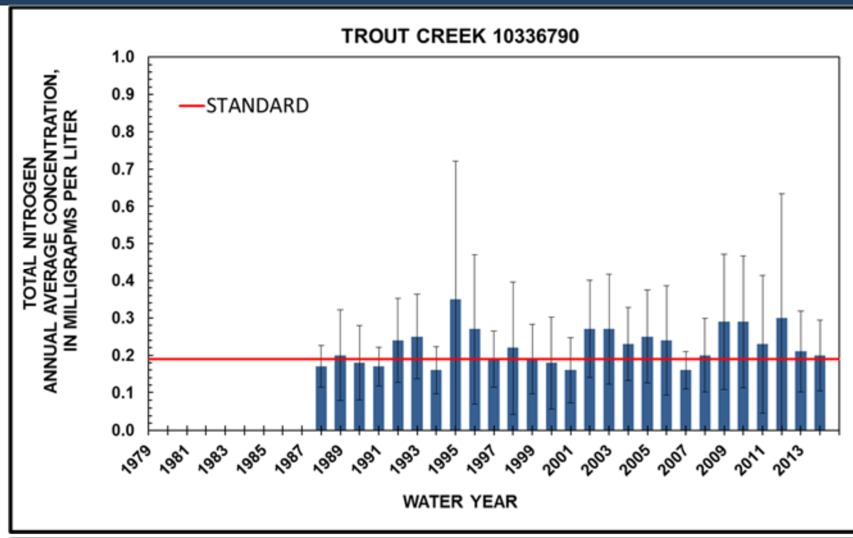
NITROGEN CONCENTRATION

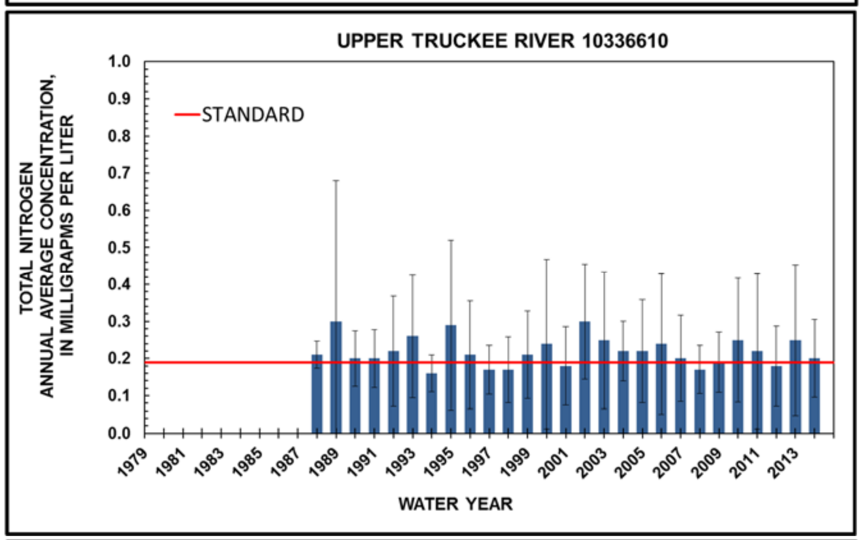
Status: **See Pie Chart Above**
Trend: **Little to No Change**
Confidence: **Moderate**

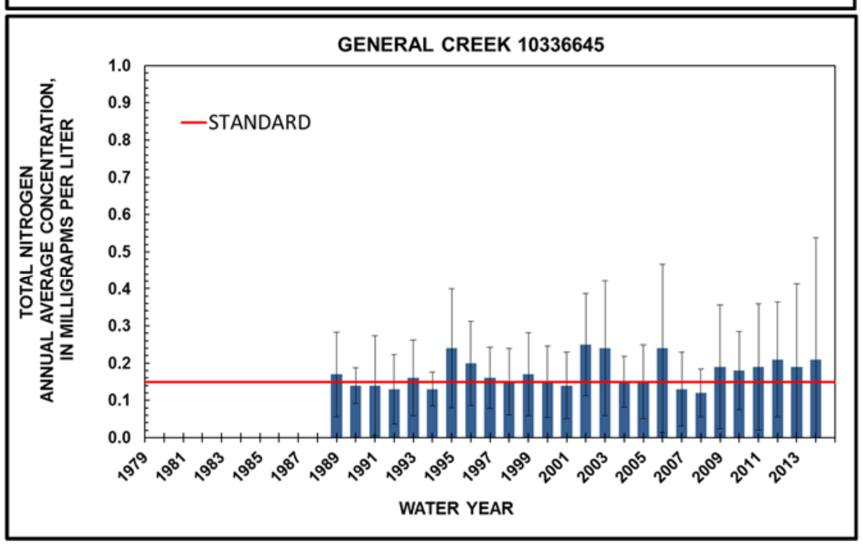
Map

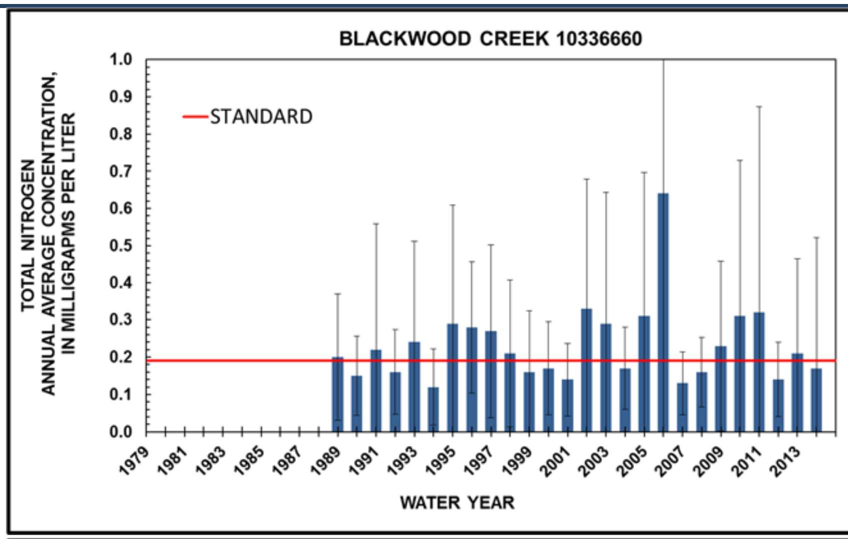


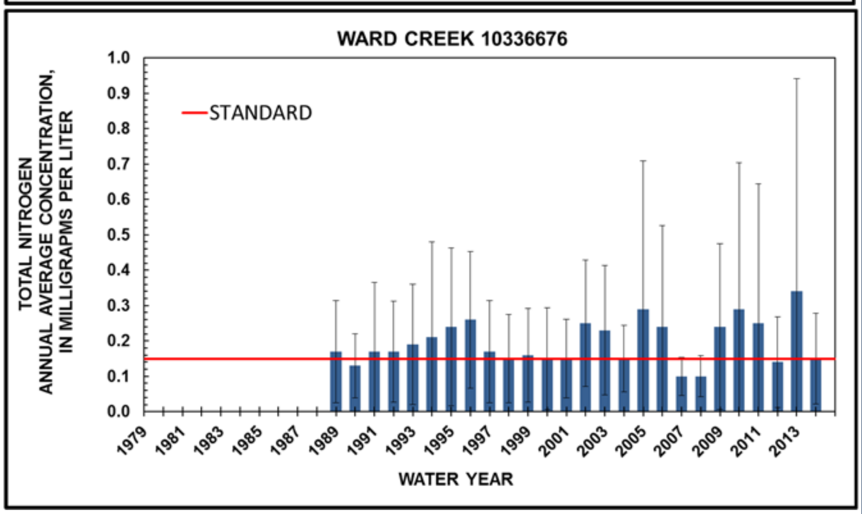
The seven streams routinely monitored for total nitrogen concentration includes two streams in Nevada: (1) Third Creek, and (2) Incline Creek; and five streams in California: (3) Trout Creek, (4) Upper Truckee River, (5) General Creek, (6) Blackwood Creek, and (7) Ward Creek.











Annual average total nitrogen concentration, determined from samples collected during a water year (October 1 to September 30), for each of five regularly monitored California streams in the Lake Tahoe Basin. The individual bars represent the annual average total nitrogen concentration. Black lines indicate standard deviation of observed conserventations. The horizontal red line represents the California numeric standard for annual average total nitrogen concentration: 0.15 milligrams per liter (mg/L) for General and Ward Creeks, and 0.19 mg/L for Blackwood and Trout Creeks, and the Upper Truckee River. Nevada does not have a numeric total nitrogen standard for tributaries to Lake Tahoe. Total nitrogen concentration is determined by adding the measured concentrations of total Kjeldahl nitrogen and dissolved nitrate plus nitrite (as nitrogen). Data are from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Data Evaluation and Interpretation

BACKGROUND

Relevance – This indicator measures the average concentration of total nitrogen for each water year in the five routinely monitored California streams. Nitrogen is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin(Lahontan & NDEP, 2010a). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (Hackley et al., 2016b). Free-floating algae (phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis. Attached algae (periphyton) coat rocks in the nearshore, adversely affecting nearshore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). However, persistently high levels of algae in Lake Tahoe would be considered undesirable. Nitrate and nitrite are inorganic forms of nitrogen that are directly available for use by plants, whereas total nitrogen includes all organic and inorganic forms of nitrogen that are directly and indirectly available to plants. Sources of nitrate in stream water include atmospheric deposition, urban runoff, and decomposition of organic matter, especially from alder, which is an important nitrogen-fixer.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category –Tributaries

Adopted Standards – TRPA: attain applicable state standards for concentrations of dissolved inorganic nitrogen. California does not have a standard for dissolved inorganic nitrogen, but does for total nitrogen: 0.15 milligram per liter (mg/L) for General and Ward Creeks, and 0.19 mg/L for Blackwood and Trout Creeks, and the Upper Truckee River. Nevada has water quality standards for nitrate for Incline Creek and Third Creek: a single value must be less than or equal to 10 mg/L. There are no exceedances of this standard. Nevada does not have a water quality standard for beneficial uses for total nitrogen for Incline Creek and Third Creek.

Type of Standard – Numerical

Indicator (Unit of Measure) – The indicator is annual average total nitrogen concentration measured over a water year (October 1 to September 30). Annual average total nitrogen concentration is based on samples collected during each water year from each of the five monitored California streams. The number of individual samples collected at each monitoring station in a given water year varied over the period of record from three to 91. Total nitrogen concentration is determined by adding the measured concentrations of total Kjeldahl nitrogen and dissolved nitrate plus nitrate (as nitrogen). All annual average total nitrogen concentrations are reported in milligrams per liter (mg/L).

Human & Environmental Drivers – All the tributaries within the Tahoe Basin deliver sediment and nutrients to a single downstream water body: Lake Tahoe. The Tahoe Basin has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics resulting in high variability throughout the Region. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the basin from west to east; precipitation can be twice as high on the west shore relative to the east shore of Lake Tahoe. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. Landscape disturbances including, but not limited to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries. Weather variations and its effects on stream hydrology (particularly the extremes of droughts and floods), and long-term climate change are considered among the most important environmental drivers of tributary runoff.

MONITORING AND ANALYSIS

Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center (TERC)), Tahoe Regional Planning Agency, U.S. Forest Service – Lake Tahoe Basin Management Unit, and Nevada Division of State Lands. For water years 2015 and 2016 partners include Lahontan Regional Water Quality Control Board and California Tahoe Conservancy.

Monitoring Approach – The Lake Tahoe Interagency Monitoring Program (LTIMP) stream monitoring program was first developed in 1979 to assess sediment and nutrient input from tributaries to Lake Tahoe, and to support research that aims to understand the drivers affecting the transparency of Lake Tahoe. The tributary monitoring focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). Up to 10 streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood and Ward Creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood Creeks). Six of these streams have been monitored since water years 1980 or 1981. In water year 2012 the number of streams routinely monitored was reduced to seven (see map above), and all streams have primary monitoring stations at or near the point of discharge to Lake Tahoe. Sampling procedures generally follow national field monitoring protocols established by the (Rowe et al., 2002; USGS, variously dated). The number of individual samples collected at each monitoring station in a given water year that were analysed for total nitrogen has varied from three to 91 for the five California streams. For the last 10 water years, the average number of samples collected per year for each of the five California streams was 33. Samples are collected under three hydrologic conditions: regular monthly runs, storm events, and snow-melt runoff. These conditions are intended to span streamflow conditions from low to high volumes and turbidity conditions from clear to extreme. Field blank and replicate samples, and field water-quality data including water and air temperature, pH, specific conductance, and dissolved oxygen are collected during sampling events. USGS gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Analytical methods in the laboratory for measuring nutrients have been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al., 2009a). Long-term stream monitoring is important to detect changes in tributary water quality that may occur as a result of uncontrollable drivers such as weather and climate change, as well as the cumulative impact of remedial work meant to reduce the amount of pollutants entering the streams within the watershed. Although the dissolved nitrate plus nitrite concentration data dates back to the early 1980s for some of the streams, the total nitrogen data starts in either water year 1988 or 1989 because that is when stream water samples were first analyzed for total Kjeldahl nitrogen.

Analytic Approach – The annual average total nitrogen concentration for a given stream was determined by calculating the average of total nitrogen concentrations for all the samples collected in a given water year. Data from the LTIMP tributary monitoring program were obtained from USGS and TERC. The laboratory analytical method for dissolved nitrate plus nitrite was updated in 2003; a window of about 5.5 years exists where samples were analyzed using both the old method and the new method. Regression equations were used to convert nitrate concentrations from the old method to the new method(Coats and Lewis, 2014a). Dissolved nitrate plus nitrite concentrations prior to April 22, 2003 were converted for the five California streams.

The status determination scores for individual streams were determined by evaluation of its 2014 value relative to the standard. Assigned scores for individual streams are based on the percent to target, as described in the methodology chapter of this report.

The trend of annual average total nitrogen concentrations was tested using the nonparametric Mann-Kendall trend test (p. 326) (Helsel and Hirsch, 2002). The Mann-Kendall trend test assesses if there is a monotonic upward or downward trend. This is a simple trend test because values associated with total nitrogen concentration were not adjusted for variables expected to affect the annual average concentration, such as streamflow and seasonality. A more robust trend test that removes the effects of streamflow was completed for total nitrogen loads. For this evaluation, trends were tested for water years 1989 to 2014 for all the streams. The trend was considered statistically significant if the P-value was less than 0.01 (calculated as 0.05 divided by five, see later section on Total Nitrogen Load for discussion of Bonferroni Adjustment). Serial correlation was tested using a method in (Dufour, 1981).

The trend determination was based on 1) the Mann-Kendall trend test, 2) the change in percent exceedance rate between different time periods (see also Appendix WQ-1).

INDICATOR STATE

Status – The annual average total nitrogen concentrations for water year 2014 for the five California streams ranged from 0.15 mg/L at Ward Creek (at the standard) to 0.21 mg/L at General Creek (40 percent greater than the standard). The 2011 Threshold Evaluation Report set an interim target of one stream in attainment. This interim target was achieved for the 2015 water year, during which two streams were in attainment.

***Table 1:** Annual average* total nitrogen *concentrations for 2014 Water Year and status determinations relative to standard for each of the five regularly monitored California streams. The* total nitrogen *standard is a not to exceed standard, where percent to target values below 100% indicate the standard is in attainment.*

Stream	Water Year 2014 Annual Average (mg/L)	Percent to Target	Status
Trout Creek	0.2	105%	Somewhat worse than target
Upper Truckee River	0.2	105%	Somewhat worse than target
General Creek	0.21	140%	Considerably worse than target
Blackwood Creek	0.17	89%	At or Somewhat Better than Target
Ward Creek	0.15	100%	At or Somewhat Better than Target

Trend – Little or no change. None of the five California streams had a statistically significant trend based on the Mann-Kendall trend test. Between water years 1988 and 2014, the annual average total nitrogen concentrations for the five California streams ranged from 0.10 mg/L (67 percent of the standard at Ward Creek in water years 2007 and 2008) to 0.64 mg/L (237 percent greater than the standard at Blackwood Creek in 2006).

Annual average total nitrogen concentrations relative to the numerical standard differed from that observed for total phosphorus. Total phosphorus in the California streams exceeded the numerical standard in all years, except for General Creek in water year 2014. However, annual average total nitrogen concentration varied both above and below the standard during these years. The patterns for total nitrogen and total phosphorus concentrations are not expected to be the same, since total nitrogen is comprised primarily of dissolved organic nitrogen (Coats and Goldman, 2001), which is not directly associated with soil erosion, but is associated largely with microbial processing of vegetation biomass. For General Creek, annual average total nitrogen concentration was near (within 25 percent of the standard), at, or below the 0.15 mg/L value in about 62 percent of the water years for which data is available. Ward Creek, with the same total nitrogen standard of 0.15 mg/L, was near, at, or below the standard in 54 percent of the water years. Trout Creek, Blackwood Creek, and the Upper Truckee River, all with a total nitrogen standard of 0.19 mg/L, were near, at, or below the standard in about 59, 62, and 67 percent of the years, respectively. There is no discernable long-term trend in annual average total nitrogen concentrations.

Table 2: Trends in Total Nitrogen Concentrations for monitored streams in the Tahoe Basin

Stream	Trend
Trout Creek	Little or No Change
Upper Truckee River	Little or No Change
General Creek	Little or No Change
Blackwood Creek	Little or No Change
Ward Creek	Little or No Change

Confidence –

Status - High. There is high confidence in the reliability of the total nitrogen concentration data. The sample and data collection follow USGS field monitoring protocols (USGS, variously dated). Field and laboratory data are subject to extensive quality assurance requirements (Goldman et al., 2009a). Although sampling frequency has decreased since the start of LTIMP, the sampling frequency is considered sufficient to characterize different inflow conditions observed during the water year. The laboratory analytical method for measuring nutrients have been developed for waters with extremely low nutrient concentrations.

Trend - Moderate. Assessments and interpretation of trend are based on both statistical trend test (quantitative) and visual inspection (qualitative).

Overall - Moderate. Overall confidence takes the lower of the two confidence determinations.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen, and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road
- Restored or enhanced 120 acres of disturbed forested uplands
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles
- Issued 18,076 BMP certificates to commercial, multifamily and single family residential properties

Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do maintain a healthy environment. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

Effectiveness of Programs and Actions – Quantitative evaluation of the effectiveness of any individual policy, program or action implemented to improve the tributary water quality is challenging because of the diversity of contributing factors. Although each of the programs and actions are thought to aid in improving (or preserving) tributary water quality, the signal from any of these individual actions cannot be discerned from the year-to-year variability in annual average total nitrogen concentration monitored as part of the LTIMP Tributary monitoring program.

Interim Target – Based on visual inspection of the data record, it is difficult to discern when the tributaries will be in compliance with the applicable total nitrogen concentration standards. None of the tributaries had a statistically significant downward trend in annual average total nitrogen concentrations.

Target Attainment Date – Based on inspection of the data record, it is difficult to determine a date in the future that the adopted standards will be achieved for the monitored tributaries.

RECOMMENDATIONS

Analytic Approach – Annual average total nitrogen concentrations are highly dependent on the number of samples collected and the timing of when samples are collected. The LTIMP tributary sampling schedule tries to sample all different parts of the hydrograph and at different turbidities, and this aids in estimating a fairly representative average concentration during the water year. However, a time-of-sampling bias may be introduced due to lack of sampling for some streams once it is dark. A simple way to calculate a potentially more representative annual average concentration includes using a flow-weighted concentration, calculated by dividing the annual total nitrogen load by the annual total streamflow (Buck, 2014; Heimann et al., 2011). Another method involves converting the daily total nitrogen load into daily mean total nitrogen concentration, and then taking the average of all the concentrations for a given water year. Another issue is the effect of streamflow and seasonality on total nitrogen concentration. The effects of streamflow and seasonality can be removed from concentration data using different statistical techniques (Helsel and Hirsch, 2002) and then the adjusted concentration data can be tested for time trends. The different methods for estimating a more representative annual average concentration, and testing adjusted concentration data for trends, would need to be further explored and compared.

Another factor to consider is the time of day when the sampling is done. Sampling only during daylight hours can introduce a time-of-sampling bias. This may be important for streams in Lake Tahoe because the daily spring snowmelt runoff peak occurs in the middle of the night for the larger streams. Also storm events often occur at night, and due to the flashy nature of the streams, the rise, peak and recession of streamflow can occur in the matter of a few hours in the middle of the night. Time-of-sampling bias for these constituents could be alleviated through the use of auto-sampler equipment that are triggered to collect water samples based on changes in streamflow or turbidity, which would occur regardless of whether it's day or night. In the indicator sheet for Total Suspended Sediment Load, the time-of-sampling bias is addressed by using only samples collected between 8 am and 7 pm from Third, Incline, and Trout Creeks, and the Upper Truckee River, and 6 am to 12 am for General, Blackwood and Ward Creek when calculating loads (see later section). This same methodology of only using samples from specific time periods in a day could be used when calculating the annual average concentration.

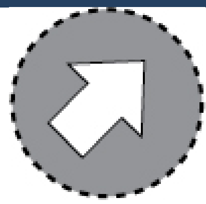
Monitoring Approach – Major changes were implemented in water year 2015, to include the measurement of continuous turbidity which is used to improve load calculations for total nitrogen, suspended sediment, and possibly fine sediment. Only five of the seven streams have continuous turbidity, and a priority should be made to add continuous turbidity in Third and Incline Creeks. The addition of continuous turbidity monitoring allowed sampling frequency to be decreased. Total nitrogen concentrations should continue to be monitored to track long-term trends, however, coordinated additional such as focused studies and effectiveness monitoring, are needed to assess the causes of changes in total nitrogen concentrations in the monitoring data. This includes assessing the effectiveness of watershed restoration projects and understanding the impacts of uncontrollable drivers such as weather and climate change.

Modification of the Threshold Standard or Indicator – The standards evaluated here were established by the State of California. The standards evaluated here were established by the California and Nevada. Standard review for pollutant concentrations should consider the large natural variation in yearly stream inflow within and among watersheds, seasonal variation of concentrations, and the time of day when the samples are collected (as discussed above). Standard review should also consider consistency with the TMDL program and include input from federal, state and local agencies, and the science community. Standard revision should also reflect.

Attain or Maintain Threshold – Continue to pursue the strategies and actions identified in the Lake Tahoe TMDL and Regional Plan with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2031.

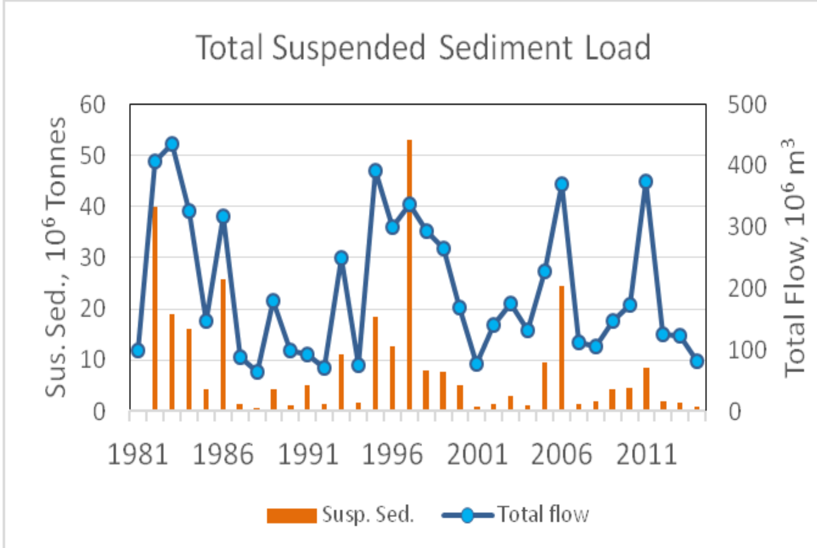
Tributaries: **Suspended Sediment Load**

Status	Trend



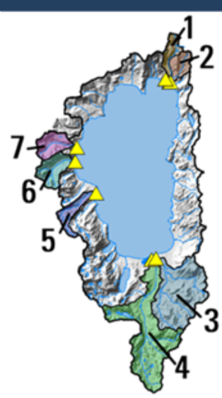
SUSPENDED SEDIMENT LOAD

Status: **Insufficient Data to Determine Status**
Trend: **Moderate Improvement**
Confidence: **Low**



Combined yearly load (million metric tonnes/year) of suspended sediment with total yearly inflow (million cubic meters) for the seven streams currently monitored in the Lake Tahoe Basin. Data are displayed for each water year (October 1 to September 30) from 1982 through 2014. The combined yearly load represents an estimate of the total mass of suspended sediment is transported by seven streams to Lake Tahoe during a single water year. The solid line is the combined total yearly inflow volume from the same streams, having a combined contributing watershed area of 350.51 square kilometers. Data is from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Map



The seven streams routinely monitored for suspended sediment load include two streams in Nevada: (1) Third Creek, and (2) Incline Creek; and five streams in California: (3) Trout Creek, (4) Upper Truckee River, (5) General Creek, (6) Blackwood Creek, and (7) Ward Creek.

Data Evaluation and Interpretation

BACKGROUND

Relevance – This indicator measures how much suspended sediment is delivered to Lake Tahoe via seven regularly monitored streams (reported as suspended sediment load). Suspended sediment, especially fine suspended sediment, delivered to Lake Tahoe is known to directly affect the transparency of Lake Tahoe(Swift et al., 2006). The protection and restoration of the Lake's transparency is a central environmental goal, and Lake transparency is considered a key socioeconomic value. The tributaries to Lake Tahoe have been identified as one of four source categories of pollutant (i.e., sediment and nutrient) loading to the Lake (Lahontan and NDEP, 2010a).

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category –Tahoe Basin Tributaries

Adopted Standards – 1) Tributaries: reduce total yearly nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe; 2) Littoral Lake Tahoe: decrease sediment load as required to attain turbidity values not to exceed three NTU (Nephelometric Turbidity Units). In addition, turbidity shall not exceed one NTU in shallow waters of the lake not directly influenced by stream discharges. 3) Pelagic Lake Tahoe - Reduce the loading of dissolved phosphorus, iron, and other algal nutrients from all sources as required to achieve ambient standards for primary productivity and transparency.

Type of Standard – Management (for tributaries); one numerical standard (related to sediment in the littoral zone).

Indicator (Unit of Measure) – Indicators measured include total yearly suspended sediment load (expressed in million metric tonnes/year) and total annual stream flow (expressed in million cubic meters of water). The load for each day at each stream was estimated from multiple regression of measured values. The daily values were summed over each water year, to generate an estimate of yearly load for each stream. The combined yearly load represents an estimate of the total mass of suspended sediment that is transported by seven streams to Lake Tahoe during a single water year.

Human & Environmental Drivers – All the tributaries within the Tahoe Basin deliver sediment and nutrients to a single downstream water body: Lake Tahoe. The Tahoe Basin has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics resulting in high variability throughout the Region. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the basin from west to east: precipitation can be twice as high on the west shore relative to the east shore of Lake Tahoe. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. Landscape disturbances including, but not limited to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the lake or its tributaries. Weather variations and its effects on stream hydrology (particularly the extremes of droughts and floods), and long-term climate change are considered among the most important environmental drivers of tributary runoff.

MONITORING AND ANALYSIS

Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, U.S. Forest Service – Lake Tahoe Basin Management Unit, Nevada Division of State Lands, Lahontan Regional Water Quality Control Board and California Tahoe Conservancy.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to assess sediment and nutrient input from tributaries to Lake Tahoe, and to support research that aims to understand the drivers affecting the transparency of Lake Tahoe. Up to ten streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood and Ward creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. In water year 2012 the number of streams routinely monitored was reduced to seven (see map above), and all streams have primary monitoring stations at or near the point of discharge to Lake Tahoe. The seven monitored streams collectively drain 350 square kilometers, roughly 43 percent of the Tahoe Basin. Sampling procedures generally follow national field monitoring protocols established by the USGS (USGS, variously dated); (Rowe et al., 2002). The number of samples collected per water year at each primary monitoring station has varied over the period of record from three to 138. Over the last ten water years, an average of 28 samples have been collected each year from each of the seven streams. Samples are collected under three hydrologic conditions: regular monthly runs, storm events, and snow-melt runoff. These conditions are intended to span streamflow conditions from low to high volumes and turbidity conditions from clear to extreme. Field blank and replicate samples, and field data including water and air temperature, pH, specific conductance, and dissolved oxygen, are collected during sampling events. U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Analytical methods in the laboratory for measuring nutrients have been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al., 2009b), and methods for suspended sediment concentration are well established (Guy, 1969). Long-term stream monitoring is important to detect changes in tributary water quality that may occur as a result of watershed development or restoration, or as a result of uncontrollable drivers such as weather and climate change.

Analytic Approach – In order to assess tributary water quality, it was necessary to develop and test new methods for estimating total annual constituent loads and apply the new methods to the historic LTIMP water quality data for the seven streams. This involved the following steps:

- Identifying and correcting, where possible, for sources of bias in the water-quality database. The sources of bias include changes in chemical analytic methods, and reduction in the frequency of nighttime sampling in some watersheds.
- Filling in some missing mean daily discharge values for Incline Creek (6 days) and Blackwood Creek (58 days) that were missing due to ice effects on the stream stage measurements. This was done by adjusting values from the nearby streams of Third and Ward creeks (respectively) for watershed area.
- Removing the sampling bias due to a reduction in nighttime sampling over the period of record. For this analysis, load estimates are based only on samples collected between 8 AM and 7 PM from the eastside and southern stream (Third, Incline, Trout creeks, and Upper Truckee River), and 6 AM to midnight from the westside streams (Blackwood, General and Ward creeks).
- Calculating total flow volume by summing daily volumes over each water year.
- Generating synthetic data sets for sediments and nutrients, and resampling them to compare the accuracy and precision of different load calculation models according to the mean square error, and Akaike information criterion.
- Determining relationships between sample size and confidence limits for estimated loads for different load calculation models.
- Estimating the load for each day at each stream from multiple regression using the measured values, and then summing the daily values over each water year. Annual loads for 26 missing station-years were estimated by regression with same-year loads at other near-by stations. Missing station years included General Creek 2001; Incline Creek 1982 to 1988 and 2012; Trout Creek 1984 and 1986 to 1988; Third Creek 1984, 1986 to 1988, 2007 and 2014; Upper Truckee River 1994; and Ward Creek 1994.
- Regressing total annual loads against annual maximum daily discharge and total annual discharge, and then testing for time trends in the residuals using the Mann-Kendall trend test.
- The Mann-Kendall test determines whether or not a variable tends to increase or decrease over time. In order to limit the probability of a false positive to 0.05 in a group of seven

tests, a threshold level of significance for the P value at each station was set to 0.0071 (0.05/7). This is known as the Bonferroni adjustment (Miller, 1981).

The methods summarized above are described in detail in Coats and Lewis (Coats and Lewis, 2014b, 2014c).

INDICATOR STATE

Status –Insufficient data to determine status. There is no clearly established numerical target for total suspended sediment load for any of the standards identified above; thus, no determination of status can be determined. Annual suspended sediment load is strongly influenced by the volume of total annual runoff. Over the period of complete record (1989 to 2014) the total annual suspended sediment load for the seven monitoring stations averaged 7,520 metric tonnes/year, with a median value of 4,320 tonnes/year, and a range of 0.790 tonnes/year (in 2001) to 53,200 tonnes/year (in 1997). Although water year 1997 had the highest total annual suspended sediment load in the record, it was only the sixth highest year for total annual runoff. A flood in January 1997 had an estimated return period of more than 100 years (Rowe et al., 1988), and contributed to the high sediment loads in that year. In the analysis of time trends, it was found that the annual maximum daily discharge as well at the total annual discharge explains a significant fraction of the variance in total annual suspended sediment load.

Table 1: *Annual average suspended sediment yield and load summary for seven streams in the Lake Tahoe Basin, 1982 to 2014. The seven monitored tributaries vary considerably in their suspended sediment load and yield per unit area.*

Stream	Area (square kilometers)	Average Yield (Tonnes/km^2/yr)	Average Total Load (Tonnes x 10^3/yr)
Blackwood	28.8	99.8	2.87
Third	15.6	67.6	1.05
Ward	25.2	41.1	1.04
Upper Truckee	139.9	19.9	2.79
Incline	17.3	18.7	0.32
General	19.1	14.8	0.28
Trout	104.6	7.7	0.8
Total	**350.5**	**26.1**	**9.15**

Blackwood Creek continues to be the largest source of suspended sediment entering the lake in terms of both yield and load, due most likely to the predominance of highly erodible volcanic tuff in its headwaters, and a history of land disturbance (logging, overgrazing and gravel mining) in the 19th and early 20th centuries. The Upper Truckee River has a relatively low suspended sediment yield per square kilometers of contributing watershed area, but its large size makes it the second-greatest contributor of suspended sediment load. The steep and highly-developed watershed of Third Creek contributes disproportionately to the total load, while Trout Creek is a relatively small contributor despite its large area, due perhaps to the relatively gentle slope of the extensive flood plain in the lower part of the watershed.

Trend – Because the inter-annual variability in suspended sediment load is driven largely by the variability in annual runoff, it is virtually impossible to recognize long-term trends in load without first removing the effect of hydrology. After regressing total annual suspended sediment load at each station with total annual discharge and maximum annual daily discharge, the residuals for each station were plotted against water year, and the trends tested using the Mann-Kendall trend test. The results showed highly significant downward trends in suspended sediment load for Incline Creek ($P< 0.0008$), Third Creek ($P< 0.0001$), and the Upper Truckee River ($P< 0.0049$). When the combined suspended sediment loads, total annual discharge, and maximum annual daily discharge for all seven watersheds are considered together, the downward trend is highly significant ($P< 2.1 \times 10^{-5}$). The smoothed trend line is shown below.

Table 2 shows the percent changes in regression-estimated suspended sediment loads for given annual hydrologic conditions. For example, at a given total annual and maximum annual discharge in Third Creek, the estimated total annual suspended sediment load in 2014 was (on average) 68.1 percent less than it would have been for the same hydrologic conditions (had they occurred) in 1983.

Table 2: *Change in SS residuals after regression of total load vs. total annual and maximum annual discharge. Trends are based on day-time samples only. Streams without significant trends are not shown.*

Stream	LTIMP Code	Percent Change	Annual % Change	Time Period (years)
Upper Truckee River	UT-1	-45.3	-1.42	32
Incline Creek	IN-1	-77.4	-3.09	25
Third Creek	TH-1	-68.1	-2.19	31
Total		**-54.1**	**-1.69**	**32**

Third Creek suspended sediment load showed the strongest downward trend. Simon et al. (2003) also found this trend based on a downward shift in the sediment rating curve following the flood in January 1997. They attributed the downward trend to the flood-induced flushing of sediment stored in the channel, and to recovery of the watershed following heavy development. Glancy (1987) showed that development during the early 1970's in the watersheds of First, Second, Third, Wood and Incline creeks resulted in an average 10-fold increase in sediment load (Glancy, 1987). hose impacts are apparently now declining as the watersheds heal.

Several analytical steps were taken to examine the basin-wide significance of the identified downward trends in suspended sediment load, after exclude the possible leveraging effect of Third Creek: (1) the sediment loads, total annual discharge, and maximum annual daily discharge for the other six stations were pooled; (2) the effect of hydrology was removed; and (3) a trend in the residuals was tested. The results showed that even without Third Creek, the downward trend in suspended sediment load (1982-2014) is still highly significant. The trend can most likely be attributed to long-term watershed recovery from disturbance of land development. There also may be an effect from the flushing of stored channel sediment by the flood of January 1997(Simon et al., 2003). Such an effect could persist for several years, and would not have been removed from the annual residuals by regression.

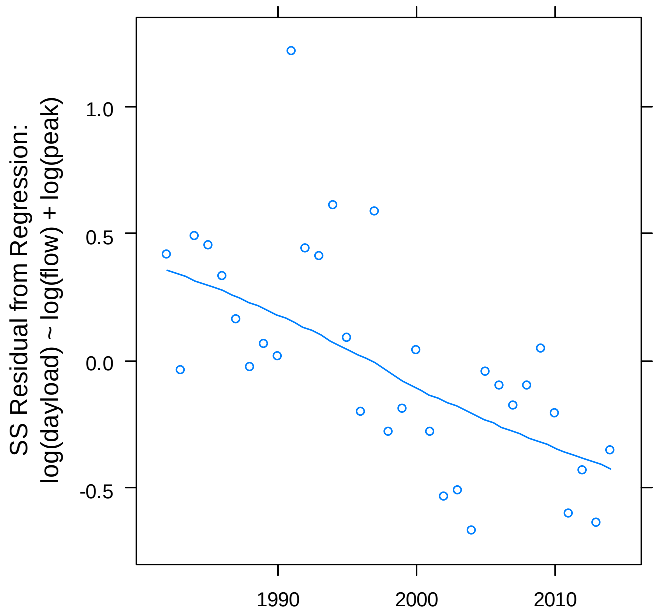


***Figure 1:** Trend in total suspended sediment load for seven watersheds, 1982-2014. The downward trend is significant at $P < 2.1 \times 10^{-5}$.*

Confidence –

Status – Low. Where insufficient data exists to determine status, confidence in the status determination is low. The confidence in an estimate of total annual suspended sediment load depends on the number of samples, and on the variance of the daily loads that are sampled to derive the annual load. (Coats and Lewis, 2014b, 2014a) presented tables that can be used to estimate the confidence intervals for average conditions in Tahoe Basin streams, for suspended sediment, and for several forms of nitrogen and phosphorous nutrients. In the past, LTIMP stream sampling collected about 20 to 35 discrete water samples per year at each station. With the method used here to estimate total suspended sediment suspended sediment loads based on 27 samples per year, we can be 90 percent sure that the true load is within +/- 30 percent of the estimated load. For the early 1980s, when more than 100 samples per year were collected at each station, the 95 percent confidence limits are +/- 10 percent of the estimated load.

Trend – High. When the combined suspended sediment loads, total annual discharge, and maximum annual daily discharge for all seven watersheds are considered together, the downward trend is highly significant ($P < 2.1 \times 10^{-5}$).

Overall – Moderate. Overall confidence takes the middle of the two confidence determinations when high and low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road

- Restored or enhanced 120 acres of disturbed forested uplands
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles
- Issued 18,076 BMP certificates to commercial, multifamily and single family residential properties

Effectiveness of Programs and Actions – Quantitative evaluation of the effectiveness of any individual policy, program or action implemented to improve the tributary water quality is challenging because of the diversity of contributing factors. Each of the programs and actions are thought to aid in improving (or preserving) tributary water quality; however, the signal from any of these individual actions cannot be discerned from the year-to-year variability in suspended sediment loads monitored as part of the LTIMP Tributary Monitoring Program. Although there is high inter-annual variability associated with suspended sediment yield and load, and both are strongly related to stream flow, the trend analysis finds a significant long-term decline in suspended sediment load overall. This suggests the adverse effects of legacy development and watershed disturbance have subsided, while urban growth limits, implementation of water quality BMPs, more protective forest management practices, and watershed restoration are having a positive influence.

Interim Target – Because this is a management standard with no defined numerical target, one cannot reasonably establish an interim target.

Target Attainment Date – Because this is a management standard with no defined numerical target, one cannot reasonably predict when this threshold standard will be attained.

RECOMMENDATIONS

Analytic Approach – The load calculations used in these indicator sheets were derived from procedures developed in an applied science project for the USDA Forest Service, with funding from the Sierra Nevada Public Land Management Act (Coats and Lewis, 2014b, 2014a)(Coats and Lewis, 2014 a,b). Software compatible with the updated water quality data base also were provided. It is recommended that the revised methods for calculating total loads continue in use for now, but that they be revised and updated as improvements (such as use of turbidity as a covariate, and development of new statistical models for total load) become available. With each updating, annual loads should be recalculated for the entire period of record using the improved method.

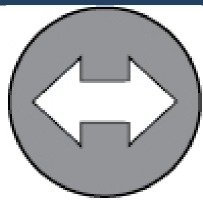
Monitoring Approach – Suspended sediment loads and yields should continue to be monitored to track long-term trends; however, coordinated additional work such as focused studies and effectiveness monitoring, are needed to assess the causes of those changes. This includes assessing the effectiveness of watershed restoration projects, and understanding the effects of uncontrollable drivers such as weather and climate change. Only five of the seven streams have continuous turbidity monitoring, and a priority should be made to add continuous turbidity in Third and Incline creeks. In addition to increasing the confidence of annual suspended sediment load estimates, this monitoring will be useful as an explanatory variable in future estimates of suspended sediment, total phosphorous, and possibly fine sediment particle numbers. Continuous turbidity monitoring, which the USGS initiated in water year 2015, will provide confidence limits at the 90 percent level of +/- 20 percent of the estimated load with only 20 discrete water samples per year (27 samples are currently required provide that level of confidence).

Modification of the Threshold Standard or Indicator –The load reduction needed to attain any of the three standards is not provided, which precludes objective evaluation of standard attainment. Consideration should be given to the establishment of specific standards that enable objective determination of status. Standard review should consider consistency with the TMDL program and include input from federal, state and local agencies, and the science community.

Attain or Maintain Threshold – No changes recommended. Continue to pursue the strategies and actions identified in the Lake Tahoe TMDL and Regional Plan with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2031.

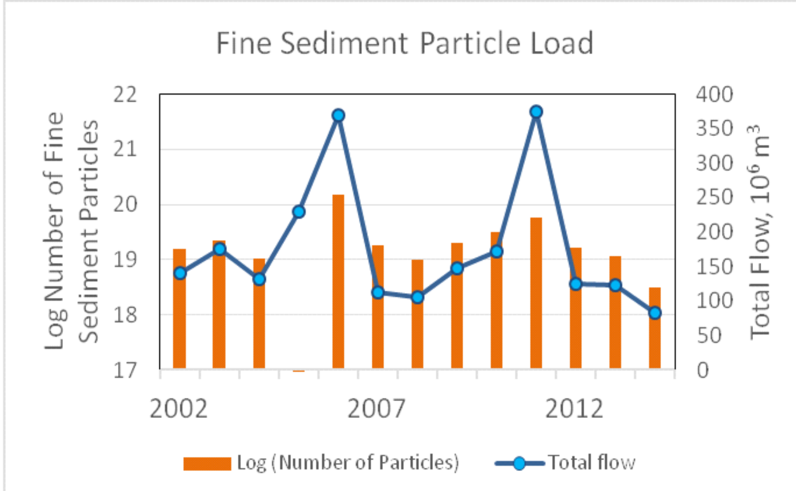
Tribitaries: **Fine Sediment Load**

Status	Trend



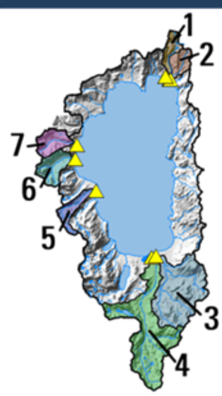
FINE SEDIMENT LOAD

Status: **Insufficient Data to Determine Status**
Trend: **Little or No Change**
Confidence: **Moderate**



Combined yearly fine sediment load (log particle numbers/year) of sediment particles less than or equal to 20 micrometers (μm) with total yearly inflow for the seven streams currently monitored in the Lake Tahoe Basin. Data is displayed for each water year (October 1 - September 30) from 2002 through 2014. The combined yearly load represents an estimate of the total number of fine sediment particles that are transported by seven streams to Lake Tahoe during a single water year. The solid line is the combined total yearly inflow from the same streams, having a total combined watershed area of 350.51 square kilometers. Data are from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Map



The seven streams routinely monitored for fine sediment particles includes two streams in Nevada: (1) Third Creek, and (2) Incline Creek; and five streams in California: (3) Trout Creek, (4) Upper Truckee River, (5) General Creek, (6) Blackwood Creek, and (7) Ward Creek.

Data Evaluation and Interpretation

BACKGROUND

Relevance – This indicator measures how much fine sediment particles (FSP) is delivered to Lake Tahoe via seven regularly monitored streams. Fine sediment particles delivered to Lake Tahoe from all sources is believed to account for over half of the loss in lake transparency (Swift et al., 2006). The protection and restoration of the lake's transparency is a central environmental goal, and lake transparency is considered a key socioeconomic value. The tributaries to Lake Tahoe have been identified as one of four source categories of pollutant (i.e., sediment and nutrient) loading to the lake (Lahontan and NDEP, 2010a) Fine sediment particle ($\leq$ 16μm) numbers are used directly in the Lake Clarity Model as technical underpinning for the Lake Tahoe Total Maximum Daily Load analyses, so accurate and precise measurement is important.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category –Tahoe Basin Tributaries

Adopted Standards – None

Type of Standard – Not applicable

Indicator (Unit of Measure) – The total number of FSP less than 20 µm that are transported by seven streams to Lake Tahoe during a single water year. The particle number for each day at each stream was estimated from multiple regression of measured values, using the Composite Method of Aulenbach (Aulenbach, 2013). The daily values were summed over each water year, to generate an estimate of yearly load for each stream.

Human & Environmental Drivers – All the tributaries within the Tahoe Basin deliver sediment and nutrients to a single downstream water body: Lake Tahoe. The Tahoe Basin has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics resulting in high variability throughout the Region. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the basin from west to east: precipitation can be twice as high on the west shore relative to the east shore of Lake Tahoe. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain sediment. Landscape disturbances including, but not limited to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the lake or its tributaries. Weather variations and its effects on stream hydrology (particularly the extremes of droughts and floods), and long-term climate change are considered among the most important environmental drivers of tributary runoff.

MONITORING AND ANALYSIS

Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, U.S. Forest Service – Lake Tahoe Basin Management Unit, Nevada Division of State Lands, Lahontan Regional Water Quality Control Board, and California Tahoe Conservancy.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to assess sediment and nutrient input from tributaries to Lake Tahoe, and to support research to understand the drivers affecting the transparency of Lake Tahoe. Up to ten streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood and Ward creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. In water year 2012 the number of streams routinely monitored was reduced to seven (see map above), and all streams have primary monitoring stations at or near the point of discharge to Lake Tahoe. The seven monitored streams collectively drain 350 square kilometers, roughly 43 percent of the Tahoe Basin. Sampling procedures generally follow national field monitoring protocols established by the USGS (Rowe et al., 2002; USGS, variously dated). The number of samples collected per water year at each primary monitoring station has varied over the period of record from three to 138. Over the last ten water years, an average of 28 samples has been collected each year from each of the seven streams. Samples are collected under three hydrologic conditions: regular monthly runs, storm events, and snow-melt runoff. These conditions are intended to span streamflow conditions from low to high volumes and turbidity conditions from clear to extreme. Field blank and replicate samples, and field data including water and air temperature, pH, specific conductance, and dissolved oxygen, are collected during sampling events. U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Fine sediment particle numbers are measured in the UC Davis, Tahoe Environmental Research Center laboratory, using a Liquiaz particle counter. These measurements have only regularly been made since 2002. Long-term stream monitoring also is important to detect changes in water quality that may occur as a result of watershed development or restoration, or as a result of uncontrollable drivers such as weather and climate change.

Analytic Approach – In order to assess tributary water quality, it was necessary to develop and test new methods for estimating total annual constituent loads and apply the new methods to the historic LTIMP water quality data for the seven streams. This involved the following steps:

- Identifying and correcting, where possible, for sources of bias in the water-quality data base. The sources of bias include changes in chemical analytic methods, and reduction in the frequency of nighttime sampling in some watersheds.
- Filling in some missing mean daily discharge values for Incline Creek (six days) and Blackwood Creek (58 days) that were missing due to ice effects on the stream stage measurements. This was done by adjusting values from the nearby streams of Third and Ward creeks (respectively) for watershed area.
- Removing the sampling bias due to a reduction in nighttime sampling over the period of record. For this analysis, load estimates are based only on samples collected between 8 AM and 7 PM in the eastside and southern stream (Third, Incline, Trout and Upper Truckee River), and 6 AM to midnight in the west-side streams (Blackwood, General and Ward Creeks).
- Calculating total flow volume by summing daily volumes over each water year.
- Generating synthetic data sets for sediments and nutrients, and resampling them to compare the accuracy and precision of different load calculation models according to the mean squared error, and Akaike Information Criterion.
- Determining relationships between sample size and confidence limits for estimated loads for different load calculation models.
- Estimating the load for each day at each stream from multiple regression using the measured values, and then summing the daily values over each water year. Annual loads for three missing station-years were estimated by regression with same-year loads at other near-by stations. Missing station years included Incline Creek 2012, and Third Creek 2007 and 2014.
- Regressing total annual loads against maximum annual daily discharge and total annual discharge, and testing for time trends in the residuals using the Mann-Kendall Trend Test.

The methods summarized above are described in detail in Coats and Lewis, 2014a and 2014b.

INDICATOR STATE

Status – Insufficient date to determine status. There is no clearly established numerical target for FSP load for any of the standards identified above; thus, no determination of status can be determined. The annual load of FSP is strongly influenced by the volume of total annual runoff. The log average total annual FSP load for the seven monitoring stations (2002 to 2004 and 2006 to 2014) was 16.94/year (8.77 x 10^{16})/year), with a log median value of 16.72 (year (1.84 x10^{19}/year), and a range of 15.96/year in 2014 to 17.64 in 2006. The seven monitored tributaries vary considerably in their FSP yield per unit area (Table 1). Blackwood Creek was found to be the largest source of fine sediment particle yield on a unit area basis, due most likely to the highly erodible volcanic tuff in its headwaters, and a history of land disturbance (logging, over-grazing and gravel mining) in the 19th and early 20th centuries. The Upper Truckee River was found to be the largest total source of fine sediment particle load and second largest source on a unit area basis. The steep and highly-developed watershed of Third Creek surprisingly contributed the lowest fine sediment particle load to Lake Tahoe.

Table 1: *Annual average FSP yield and load for seven streams in the Lake Tahoe Basin, 2002-04 and 2006-14.*

Stream	Area (square kilometers)	Average Yield Log (Fine Sediment Particles) (# of particles/km2/yr)	Average Total Load (Total # of particles)	Percent of Annual Fine Sediment Particle Load
Blackwood	28.75	17.27	18.73	18%
Upper Truckee	139.9	17.05	19.19	51%
Ward	25.3	17.0	18.41	8%
Incline	17.33	16.84	18.08	4%
General	19.14	16.74	18.03	3%
Third	15.59	16.64	17.83	2%
Trout	104.6	16.61	18.63	14%
Total	**350.61**	**16.94**	**19.48**	**100%**

Trend – Little or no change. To test for a trend in fine sediment particle, the annual load was regressed against total annual discharge and the residuals were plotted (see Figure 1). Unlike the case of suspended sediment, the maximum annual daily discharge did not contribute to explaining the total variance in fine sediment particle, and so it was not included in the regression from which the residuals were extracted. The P-value was 0.74, indicating that a time trend in the residuals was not detected. A longer period of record, and more frequent sampling would improve the ability to detect trends in fine sediment particle.

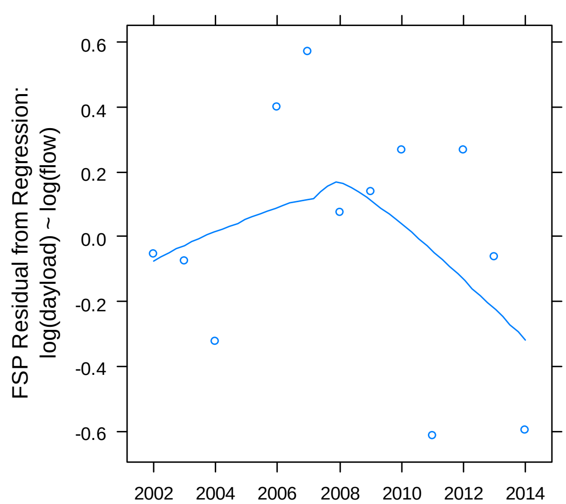


Figure 1: *Trend in FSP load for seven watersheds, 2002-04 and 2006-14, The downward trend is not significant at P = 0.74.*

Confidence –

Status – Low. Where insufficient data exists to determine status, confidence in the status determination is low. The most recent recalculation of total fine sediment particle loads used 20 to 40 samples per station per year. Based on the LTIMP realignment study (Coats and Lewis, 2014a), 26 samples provide 90 percent confidence that the true value is within +/-20 percent of the estimated number.

Trend – Low. The P-value was 0.74, indicating that a time trend in the residuals was not detected.
Overall – Low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles
- Restored or enhanced 120 acres of disturbed forested uplands
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles
- A total of 18,076 BMP certificates were issued to commercial, multi-family and single family residential properties

Effectiveness of Programs and Actions – Quantitative evaluation of the effectiveness of any individual policy, program or action implemented to improve the tributary water quality is challenging because of the diversity of contributing factors. Although each of the programs and actions are thought to aid in improving (or preserving) tributary water quality, the signal from any of these individual actions cannot be discerned from the year-to-year variability in fine sediment particle loads monitored as part of the LTIMP Tributary Monitoring Program. Although there is high inter-annual variability associated with fine sediment particle loads, and loads are strongly related to streamflow, a longer data record will help to determine if there is a long-term trend.

Interim Target – The Tahoe TMDL adopted in 2010 sets a 10-year fine sediment particle load reduction milestone of 19 percent. Reducing total fine sediment particle load from 4.8E+20 to 3.89E+20. The overall milestone established individual targets for the forested upland nine percent reduction (from 4.1E+19 to 3.73E+19) and a 26 percent reduction from stream channels (from 1.7E+19 to 1.26E+19) (Lahontan and NDEP, 2010a).

Target Attainment Date – 2020, ten years after the Tahoe TMDL was adopted (Lahontan and NDEP, 2010a).

RECOMMENDATIONS

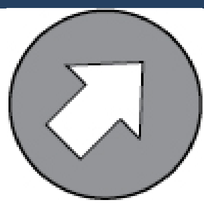
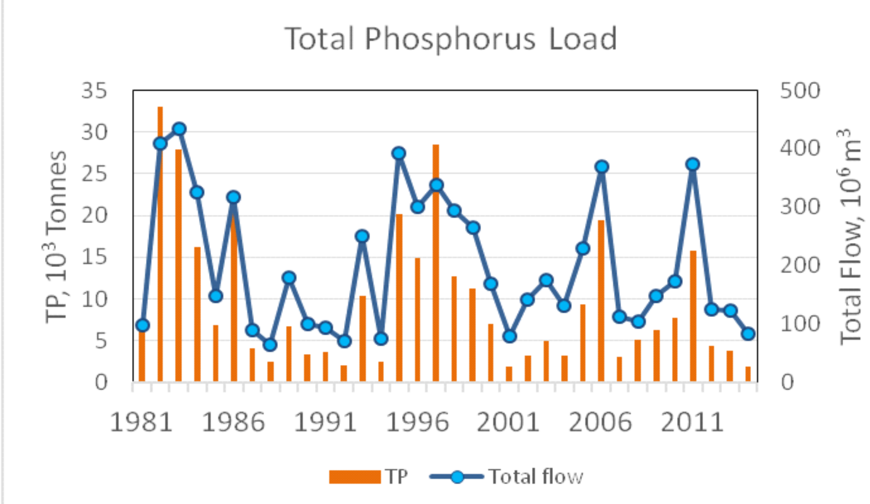
Analytic Approach – The load calculations used in these indicator sheets were derived from procedures developed in an applied science project for the USDA Forest Service, with funding from the Southern Nevada Public Land Management Act(Coats and Lewis, 2014b, 2014a). Software compatible with the updated water quality database also were provided. It is recommended that the revised methods for calculating total loads continue in use for now, but that they be revised and updated as improvements become available. With each update, annual loads should be recalculated for the entire period of record using the improved method.

Monitoring Approach – Monitoring of fine sediment particle loads and yields should continue to detect changes in water quality, and to assess the causes of those changes. This is particularly important given the identification of fine sediment particles as a priority pollutant in the Tahoe Total Maximum Daily Load program. Only five of the seven streams have continuous turbidity monitoring, and a priority should be made to add continuous turbidity in Third and Incline creeks. In addition to increasing the confidence of annual suspended sediment load estimates, this monitoring will be useful as an explanatory variable in future regression estimates of suspended sediment, total phosphorous, and possibly fine sediment particle numbers. The analysis presented here looks at FSP(< 20 μm) while the TMDL defines FSP using a slightly different size class (< 16 μm). Further work should consider looking at change in FSP using the TMDL definition.

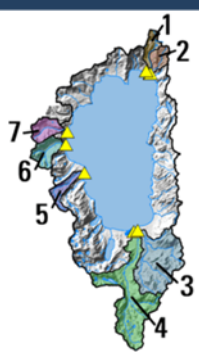
Modification of the Threshold Standard or Indicator – No standard has been adopted for FSP. Consideration should be given to the establishment of specific standards that enable objective determination of status. Standard review should consider consistency with the TMDL program and include input from federal, state and local agencies, and the science community.

Attain or Maintain Threshold – Continue to pursue the strategies and actions identified in the Lake Tahoe TMDL and Regional Plan with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2031.

Tributaries: **Phosphorus Load**

Status	Trend
 **PHOSPHORUS LOAD** Status: **Insufficient Data to Determine Status** Trend: **Moderate Improvement** Confidence: **Moderate**	

Map



The seven streams routinely monitored for total phosphorous load includes two streams in Nevada: (1) Third Creek, and (2) Incline Creek; and five streams in California: (3) Trout Creek, (4) Upper Truckee River, (5) General Creek, (6) Blackwood Creek, and (7) Ward Creek.

Combined yearly total phosphorus load (Tonnes/yr), and total yearly inflow for seven streams currently monitoring in the Lake Tahoe Basin. Data are displayed for each water year (October 1 to September 30) from 1981 through 2014. The yearly load for each stream is calculated as the sum of daily loads for a given water year. The combined total phosphorus load represents an estimate of the total mass of phosphorus transported by seven streams to Lake Tahoe during a single water year. The solid line is the combined total yearly inflow from the same streams, having a total combined watershed area of 350.51 square kilometers. Data are from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Total phosphorus includes soluble reactive phosphorus, particulate phosphorus and phosphorus incorporated into dissolved organic matter. particulate phosphorus comprises a heterogeneous mixture of unweathered mineral grains, phosphorus incorporated into organic matter, and phosphorus adsorbed onto iron and aluminum silicate minerals. The concentration of soluble reactive phosphorus is strongly controlled by physicochemical equilibrium reactions, which tend to buffer the stream-water concentrations. During summer months, soluble reactive phosphorus is taken up by periphyton in the stream channel, and then later released as the algae decompose. The load of particulate phosphorus far outweighs the load of soluble reactive phosphorus, and is strongly controlled by discharge.

Data Evaluation and Interpretation

BACKGROUND

Relevance –Phosphorus is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan and NDEP, 2010a). Soluble reactive phosphorus approximates the amount of orthophosphate that is directly available for use by plants, whereas total phosphorus includes all forms of phosphorus that are directly and indirectly available to plants. Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (Lahontan and NDEP, 2010a). Free-floating algae (i.e., phytoplankton) occur naturally throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis and by scattering light. Attached algae (periphyton) coat rocks in the nearshore, adversely affecting nearshore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). However, persistently high levels of algae in Lake Tahoe would be considered undesirable. Phosphorus occurs naturally in the soils of the Lake Tahoe Basin, and is delivered to surface waters and Lake Tahoe through soil erosion and subsequent transport in streams and storm water, atmospheric deposition, and fertilizer runoff (Lahontan and NDEP, 2010a). This indicator measures how much phosphorus is delivered to Lake Tahoe via seven routinely monitored streams (measured as total phosphorus load).

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category –Tahoe Basin Tributaries

Adopted Standards – 1) Tributaries: reduce total yearly nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe; 2) littoral and pelagic Lake Tahoe related standards for nutrient and sediment: reduce the loading of dissolved phosphorus, iron, and other algal nutrients from all sources, as required, to achieve ambient standards for primary productivity and transparency. (The load reduction needed to attain these standards is not provided.)

Type of Standard – Management for tributaries, and for littoral and pelagic Lake Tahoe.

Indicator (Unit of Measure) – The total phosphorus load for each day at each stream was estimated from multiple regression of measured values. The daily values were summed over each water year, to generate an estimate of yearly total phosphorus load for each stream. The combined yearly load represents an estimate of the total mass of total phosphorus that is transported by seven streams into Lake Tahoe during a single water year.

Human & Environmental Drivers – All the tributaries within the Tahoe Basin deliver sediment and nutrients to a single downstream water body: Lake Tahoe. The Tahoe Basin has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics resulting in high variability throughout the Region. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the basin from west to east: precipitation can be twice as high on the west shore relative to the east shore of Lake Tahoe. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain sediment. Landscape disturbances including, but not limited to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the lake or its tributaries. Weather variations and its effects on stream hydrology (particularly the extremes of droughts and floods), and long-term climate change are considered among the most important environmental drivers of tributary runoff.

MONITORING AND ANALYSIS

Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, U.S. Forest Service – Lake Tahoe Basin Management Unit, Nevada Division of State Lands, Lahontan Regional Water Quality Control Board, and California Tahoe Conservancy.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to assess sediment and nutrient input from tributaries to Lake Tahoe, and to support research to understand the drivers affecting the transparency of Lake Tahoe. Up to ten streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood and Ward creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. In water year 2012 the number of streams routinely monitored was reduced to seven (see map above), and all streams have primary monitoring stations at or near the point of discharge to Lake Tahoe. The seven monitored streams collectively drain 350 square kilometers, roughly 43 percent of the Tahoe Basin. Sampling procedures generally follow national field monitoring protocols established by the USGS (Rowe et al., 2002; USGS, variously dated). The number of samples collected per water year at each primary monitoring station has varied over the period of record from three to 138. Over the last ten water years, an average of 28 samples has been collected each year from each of the seven streams. Samples are collected under three hydrologic conditions: regular monthly runs, storm events, and snow-melt runoff. These conditions are intended to span streamflow conditions from low to high volumes and turbidity conditions from clear to extreme. Field blank and replicate samples, and field data including water and air temperature, pH, specific conductance, and dissolved oxygen, are collected during sampling events. U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Analytical methods in the laboratory for measuring nutrients have been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al., 2009a). Long-term stream monitoring is important to detect changes in tributary water quality that may occur as a result of watershed development or restoration, or as a result of uncontrollable drivers such as weather and climate change.

Analytic Approach – In order to assess tributary water quality, it was necessary to develop and test new methods for estimating total annual constituent loads and apply the new methods to the historic LTIMP water quality data for the seven streams. These new methods were then used to analyze the historical LTIMP water quality data for the seven streams. This involved the following steps:

- Identifying and correcting, where possible, for sources of bias in the water-quality data base. The sources of bias include changes in chemical analytic methods, and reduction in the frequency of nighttime sampling in some watersheds.
- Filling in some missing mean daily discharge values for Incline Creek (six days) and Blackwood Creek (58 days) that were missing due to ice effects on the stream stage measurements. This was done by adjusting values from the nearby streams of Third and Ward creeks (respectively) for watershed area.
- Removing the sampling bias due to a reduction in nighttime sampling over the period of record. For this analysis, load estimates are based only on samples collected between 8 AM and 7 PM from the eastside and southern stream (Third, Incline, Trout creeks, and Upper Truckee River), and 6 AM to midnight from the west-side streams (Blackwood, General and Ward creeks).
- Calculating total flow volume by summing daily volumes over each water year.
- Generating synthetic data sets for sediments and nutrients, and resampling them to compare the accuracy and precision of different load calculation models according to the mean squared error, and Akaike information criterion.
- Determining relationships between sample size and confidence limits for estimated loads for different load calculation models.
- Estimating the load for each day at each stream from multiple regression using the measured values, and then summing the daily values over each water year. Annual loads for 26 missing station-years were estimated by regression with same-year loads at other near-by stations. Missing station years included General Creek, 2001; Incline Creek, 1982 to 1988 and 2012; Trout Creek, 1984 and 1986 to 1988; Third Creek, 1984, 1986 to 1988, 2007 and 2014; Upper Truckee River, 1994; and Ward Creek, 1994.
- Regressing total annual loads against maximum annual daily discharge and total annual discharge, and testing for time trends in the residuals using the Mann-Kendall trend test.
- The Mann-Kendall test determines whether or not a variable tends to increase or decrease over time. In order to limit the probability of a false positive to 0.05 in a group of seven tests, a threshold level of significance for the P value at each station was set to 0.0071 (0.05/7). This is known as the Bonferroni adjustment (Miller, 1981).

The methods summarized above are described in detail in Coats and Lewis, 2014a and 2014b.

INDICATOR STATE

Status – Insufficient date to determine status. There is no clearly established numerical target for total phosphorus load for any of the standards identified above; thus, no determination of status can be determined. The combined average total phosphorus load (1981 to 2014) for the seven monitored streams was 9,709 kilograms per year, ranging from 1,823 (2001) to 32,983 (1982) kilograms per year, with a median value of 6,660 kilograms per year. Individually, the seven monitored tributaries (1981 to 2014) varied considerably in their total phosphorus yield per unit area and loads (see Table 1). Blackwood Creek had the highest yield per unit area, although the Upper Truckee River, with the largest watershed area, contributed a greater total phosphorus load to Lake Tahoe. The steep and highly-developed watershed of Third Creek had a disproportionately high total phosphorus yield, but the small size of its contributing area resulted in a low average total phosphorus load. The Trout Creek basin was the smallest contributor of total phosphorus yield per unit area, but its large watershed area made it the third largest contributor of total phosphorus load to Lake Tahoe.

***Table 1** Total phosphorus yield and load summary for seven streams in the Lake Tahoe Basin, 1981-2014*

Stream	Area (square kilometers)	Average Yield Per Unit Area ($kg/km^2/year$)	Average Total Load, Tonnes
Blackwood	28.75	72.40	2.08
Ward	25.20	50.10	1.26
Third	15.59	32.10	0.50
Upper Truckee	139.90	25.30	3.54
Incline	17.33	24.50	0.42
General	19.14	19.90	0.38
Trout	104.60	14.70	1.53
Total	**350.51**	**27.70**	**9.71**

Trend – Because the inter-annual variability in total phosphorus load is driven largely by the variability in annual runoff, it is virtually impossible to recognize long-term trends in load without first removing the effect of hydrology. The annual total phosphorus load for each of the seven streams was regressed against the associated total and maximum annual daily discharge, and tested for trends in the residuals. The downward trends were significant ($P< 0.0035$) for Blackwood, General, Third, and Ward creeks, and the Upper Truckee River. However, all of the streams except Blackwood Creek showed a leveling off or even an upturn in total phosphorus load beginning about water year 2000.

The basin-wide trend in total phosphorus load was analyzed by regressing the total annual total phosphorus load (summed over the seven stations) against the sum of the annual total and annual maximum daily discharge. The downward trend shown in Figure 1 is significant at $P< 0.00025$. As with the trends for four of the streams, the total trend shows a leveling off after about water year 2000, due to some high positive residual values after 2005, and low values between 2001 and 2004.

***Table 2:** Change in total phosphorus residuals after regression of total annual load vs. total annual and maximum annual discharge.*

Stream	LTIMP Code	Percent Change	Percent Change per Year	Time Period (Years)
Ward Creek	WC-8	-42.4	-1.01	34
Blackwood Creek	BC-1	-46.0	-1.39	33
General Creek	GC-1	-46.5	-1.45	32
Upper Truckee River	UT-1	-34.1	-1.03	33
Third Creek	TH-1	-50.3	-1.57	32
Total		**-38.6**	**-1.17**	**33**

Percent changes in regression-estimated total phosphorus loads for given annual hydrologic conditions are presented in table 2. For example, at a given total annual and maximum annual discharge in Ward Creek, the estimated total annual total phosphorus load in 2014 was (on average) 42.4 percent less than it would have been for the same hydrologic conditions (had they occurred) in 1973. Trends are based on day-time samples only. Streams without a significant trend are not shown.

The reason for the 20-year downward trend and subsequent leveling off is unclear. It is hypothesized that the 20-year downward trend is due to long-term recovery from the 19th century clear-cut logging and mid-20th century land development. The record-low residuals of 2001 to 2004 may be an effect of the flushing of channel sediment (Simon et al., 2003). The cause of the high positive residual values after 2005 is unknown.

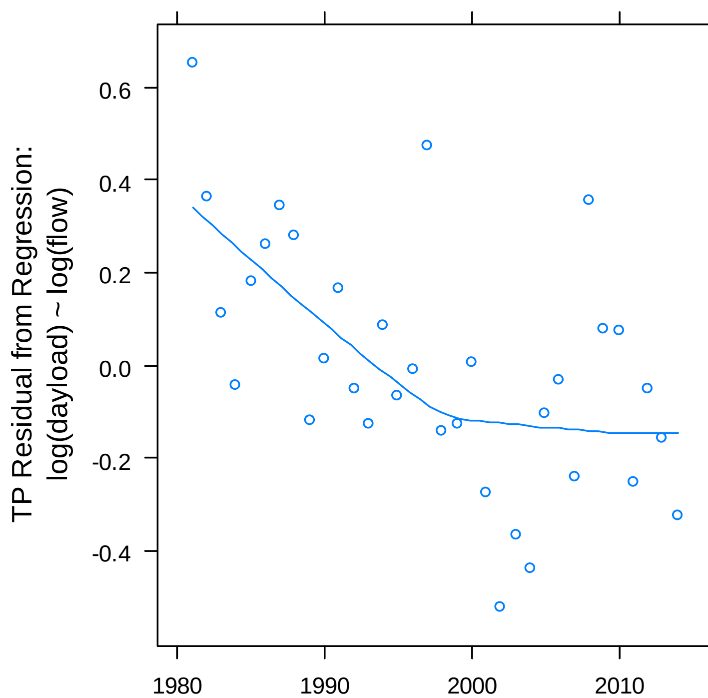


***Figure 1:** Trend in total phosphorous load residuals for seven watersheds, 1981 to 2014. The downward trend shown is significant at P< 0.00025*

Confidence –

Status – Low. Where insufficient data exists to determine status, confidence in the status determination is low. The confidence in an estimate of total annual total phosphorus load depends on the number of samples and the variance of the daily loads that are sampled to derive the annual load. Coats and Lewis (Coats and Lewis, 2014b, 2014a) presented tables that can be used to estimate the confidence intervals for average conditions in Tahoe Basin streams, for total phosphorus. Currently the LTIMP collects about 20 to 30 discrete water samples per year at each station. With the method used here to estimate total phosphorus loads based on 25 samples per year, we can be 90 percent sure that the true load is within +/- 20 percent of the estimated load.
Trend - Moderate. The downward trend shown in Figure 1 is significant at P< 0.00025. However, the total trend shows a leveling off after about water year 2000, due to some high positive residual values after 2005, and low values between 2001 and 2004.
Overall – Low. Overall confidence takes the lower of the two confidence determinations.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 to 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road
- Restored or enhanced 120 acres of disturbed forested uplands
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles
- Issued 18,076 BMP certificates to commercial, multifamily and single family residential properties

Effectiveness of Programs and Actions – Quantitative evaluation of the effectiveness of any individual policy, program or action implemented to improve the tributary water quality is challenging because of the diversity of contributing factors. High inter-annual variability in loads, which is thought to be primarily driven by variability in annual precipitation, complicates the determination of overall effectiveness of the TRPA Regional Plan and actions taken by Regional partners. Although there is high inter-annual variability associated with total phosphorus loads, and loads are strongly related to stream flow, the trend analysis finds a significant long-term decline in total phosphorus loads. This suggests the adverse effects of legacy development and watershed disturbance have subsided, while urban growth limits, implementation of water quality BMPs, more protective forest management practices, and watershed restoration are having a positive influence.

Interim Target – Because this is a management standard with no defined numerical targets, one cannot reasonably establish an interim target.

Target Attainment Date – Because this is a management standard with no defined numerical targets, one cannot reasonably establish an interim target.

RECOMMENDATIONS

Analytic Approach – The load calculations used in these indicator sheets were derived from procedures developed in an applied science project for the USDA Forest Service, with funding from the Sierra Nevada Public Land Management Act (Coats and Lewis, 2014b, 2014a). Software compatible with the updated water quality data base also were provided. It is recommended that the revised methods for calculating total loads continue in use for now, but that they be revised and updated as improvements become available. With each updating, annual loads should be recalculated for the entire period of record using the improved method.

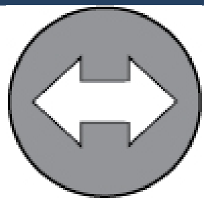
Monitoring Approach – Total phosphorous loads should continue to be monitored to track long-term trends; however, coordinated additional work such as focused studies and effectiveness monitoring, are needed to assess the causes of those changes. This includes assessing the effectiveness of watershed restoration projects and understanding the effects of uncontrollable drivers such as weather and climate change. Only five of the seven streams have continuous turbidity monitoring, and a priority should be made to add continuous turbidity in Third and Incline creeks. In addition to increasing the confidence of annual total phosphorus load estimates, this monitoring will be useful as an explanatory variable in future regression estimates of suspended sediment, total phosphorus, and possibly fine sediment particle numbers. With the method used here to estimate total phosphorus loads based on 25 samples per year, we can be 90 percent sure that the true load is within +/- 20 percent of the estimated load. The use of continuous turbidity monitoring would improve the precision of the estimates. With turbidity as an additional predictor variable, 17 samples per year would provide the same level of confidence that now requires 25 samples per year.

Modification of the Threshold Standard or Indicator –The load reduction needed to attain any of the three standards is not provided, which precludes objective evaluation of standard attainment. Objective determination of "attainment" status for standards without a specific target is a recurrent challenge both in the Region and in the larger field of monitoring and evaluation (M&E). The standard should be assessed against best practice for the establishment of standards and indicators for M&E, and amended as necessary to improve the evaluability of the standard and the information it provides for management. Standard review should consider natural variation in yearly stream flow, consistency with the TMDL program, and include input from federal, state and local agencies, and the science community.

Attain or Maintain Threshold – Continue to pursue the strategies and actions identified in the Lake Tahoe TMDL, Regional Plan and Regional Transportation Plan with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2031.

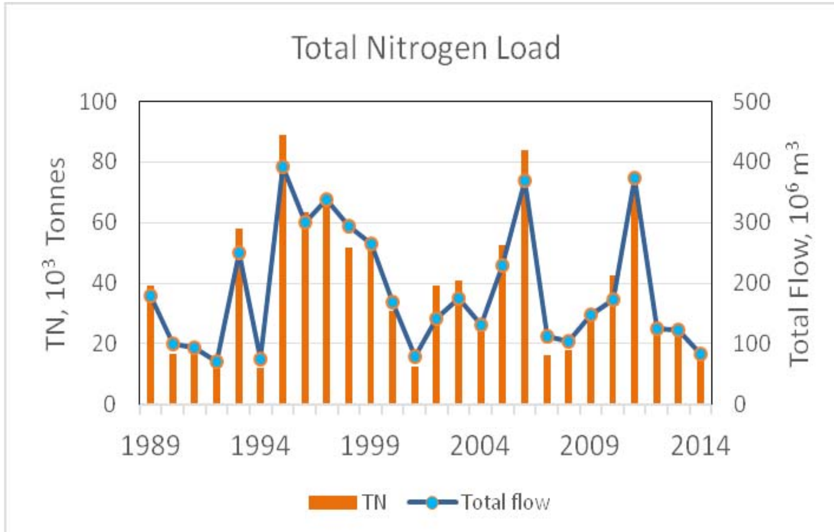
Tributaries: **Nitrogen Load**

Status	Trend



NITROGEN LOAD

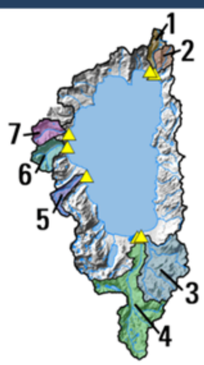
Status: **Insufficient Data to Determine Status**
Trend: **Little or No Change**
Confidence: **Moderate**



Combined yearly total nitrogen load and total yearly inflow for seven streams currently monitoring in the Lake Tahoe Basin. Data are displayed for each water year (October 1 to September 30) from 1989 through 2014. The yearly load for each stream is calculated as the sum of daily loads s for a given water year. The combined total nitrogen load represents an estimate of the total mass of nitrogen that is transported by seven streams to Lake Tahoe during a single water year. The solid line is the combined total yearly inflow from the same streams, having a total combined watershed area of 350.51 square kilometers. Data is from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Total nitrogen includes nitrate, nitrite and total Kjeldahl nitrogen. Total Kjeldahl nitrogen comprises dissolved organic nitrogen, particulate organic nitrogen, and ammonium (NH_4-N). The latter is present in basin stream water at very low concentrations, with about half of the samples below the level of detection, so for all practical purposes it can be ignored in total load calculations. Nitrate-N accounts for 10 to 15 percent of the total nitrogen load in basin streams, but its direct availability for algal growth enhances its importance. Sources of nitrate-N in stream water include atmospheric deposition, urban runoff, and decomposition of organic matter, especially from alder, which is an important nitrogen-fixer.

Map



The seven streams routinely monitored for total nitrogen load includes two streams in Nevada: (1) Third Creek, and (2) Incline Creek; and five streams in California: (3) Trout Creek, (4) Upper Truckee River, (5) General Creek, (6) Blackwood Creek, and (7) Ward Creek.

Data Evaluation and Interpretation

BACKGROUND

Relevance – This indicator measures the total nitrogen delivered to Lake Tahoe via seven monitored streams (reported as total nitrogen load). Nitrogen is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan and NDEP, 2010a). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (Lahontan & NDEP, 2010a) . Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis. Attached algae (i.e., periphyton) coat rocks in the near-shore, adversely affecting nearshore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). However, persistently high levels of algae in Lake Tahoe are considered undesirable. Nitrate and nitrite are inorganic forms of nitrogen that are directly available for use by plants, whereas total nitrogen includes all organic and inorganic forms of nitrogen that are directly and indirectly available to plants. Nitrogen occurs naturally in the soils of the Lake Tahoe Region, but organic nitrogen primarily comes from the decomposition of plant material. Atmospheric deposition of automobile exhaust is considered a primary source of inorganic nitrogen to Lake Tahoe (Lahontan & NDEP, 2010a).

Between 40 and 80 percent of the total organic nitrogen load is dissolved organic nitrogen (Coats and Goldman, 2001). If only a fraction of the dissolved organic nitrogen is biologically available, its importance as a nitrogen source for algal growth would outweigh that of dissolved inorganic nitrogen (equals nitrate plus nitrite plus ammonium). In a study of the bioavailability of dissolved organic nitrogen to bacteria and phytoplankton, Seitzinger et al. (2002) found that 30 to 45 percent of the dissolved organic nitrogen in stream water from a pine forest was biologically available (Seitzinger et al., 2002). The availability of dissolved organic nitrogen from urban runoff varied from 48 to 70 percent. The bioavailability of humic-associated nitrogen in a river draining coniferous forest (generally thought to be refractory) may be as high as 37 percent (Carlsson et al., 1999).

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category –Tahoe Basin Tributaries

Adopted Standards –

1. Tributaries: reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe;
2. Pelagic and Littoral Zones:
    a) Reduce dissolved inorganic nitrogen loading from all sources by 25 percent of the 1973 to 1981 yearly average; and
    b) Reduce dissolved inorganic nitrogen loads from surface runoff by approximately 50 percent, from groundwater approximately 30 percent, and from atmospheric sources, approximately 20 percent of the 1973 to 1981 annual.

Type of Standard – Management (tributaries); for littoral and pelagic Lake Tahoe: numerical standards and management standards with numeric targets.

Indicator (Unit of Measure) – The total nitrogen load for each day at each stream was estimated by the period-weight sample method (described below) as the sum of total Kjeldahl nitrogen and nitrate-N loads. The daily values were summed over each water year, to generate an estimate of yearly total nitrogen load for each stream. The combined yearly load represents an estimate of the mass of total nitrogen that is transported by seven streams into Lake Tahoe during a single water year.

Human & Environmental Drivers – All the tributaries within the Tahoe Basin deliver sediment and nutrients to a single downstream water body: Lake Tahoe. The Tahoe Basin has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics resulting in high variability throughout the Region. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the basin from west to east: precipitation can be twice as high on the west shore relative to the east shore of Lake Tahoe. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain sediment. Landscape disturbances including, but not limited to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the lake or its tributaries. Weather variations and its effects on stream hydrology (particularly the extremes of droughts and floods), and long-term climate change are considered among the most important environmental drivers of tributary runoff.

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Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to assess sediment and nutrient input from tributaries to Lake Tahoe, and to support research to understand the drivers affecting the transparency of Lake Tahoe. Up to ten streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood and Ward creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. The seven monitored streams collectively drain 350 square kilometers, roughly 43 percent of the Tahoe Basin. In water year 2012 the number of streams routinely monitored was reduced to seven, and all streams have primary monitoring stations at or near the point of discharge to Lake Tahoe. Sampling procedures generally follow national field monitoring protocols established by the USGS (Rowe et al., 2002; USGS, variously dated). The number of samples collected per water year at each primary monitoring station has varied over the period of record from three to 138. Over the last ten water years, an average of 28 samples has been collected each year from each of the seven streams. Samples are collected under three hydrologic conditions: regular monthly runs, storm events, and snow-melt runoff. These conditions are intended to span streamflow conditions from low to high volumes and turbidity conditions from clear to extreme. Field blank and replicate samples, and field data including water and air temperature, pH, specific conductance, and dissolved oxygen, are collected during sampling events. U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Analytical methods in the laboratory for measuring nutrients have been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al., 2009)(Goldman et al. 2009).

Analytic Approach – In order to assess tributary water quality, it was necessary to develop and test new methods for estimating total annual constituent loads and apply the new methods to the historic LTIMP water quality data for the seven streams. This involved the following steps:

- Identifying and correcting, where possible, for sources of bias in the water-quality data base. The sources of bias include changes in chemical analytic methods, and reduction in the frequency of nighttime sampling in some watersheds.
- Filling in some missing mean daily discharge values for Incline Creek (six days) and Blackwood Creek (58 days) that were missing due to ice effects on the stream stage measurements. This was done by adjusting values from the nearby streams of Third and Ward creeks (respectively) for watershed area.
- Removing the sampling bias due to a reduction in nighttime sampling over the period of record. For this analysis, load estimates are based only on samples collected between 8 AM and 7 PM in the eastside and southern stream (Third, Incline, Trout and Upper Truckee River), and 6 AM to midnight in the westside streams (Blackwood, General and Ward Creeks).
- Calculating total flow volume by summing daily volumes over each water year.
- Generating synthetic data sets for sediments and nutrients, and resampling them to compare the accuracy and precision of different load calculation models according to the mean square error, and Akaike information criterion.
- Determining relationships between sample size and confidence limits for estimated loads for different load calculation models.
- Estimating the load of total Kjeldahl nitrogen and nitrate-N for each day at each stream by the period-weighted sample method using the measured concentrations, and then summing the daily values over each water year. In this method, daily concentration is interpolated from the data and multiplied by the mean daily discharge to derive the daily load.
- Annual loads for 26 missing station-years were estimated by regression with same-year loads at

other near-by stations. Missing station years included General Creek (GC-1), 2001; Incline Creek, 1982 to 1988 and 2012; Trout Creek, 1984 and 1986 to 1988; Third Creek, 1984, 1986 to 1988, 2007 and 2014; Upper Truckee River, 1994; Ward Creek, 1994.

- Regressing total annual loads against maximum annual daily discharge and total annual discharge, and testing for time trends in the residuals using the Mann-Kendall trend test.
- In order to limit the probability of a false positive to 0.05 in a group of seven tests, a threshold level of significance for the P value at each station was set to 0.0071 (0.05/7). This is referred to as the Bonferroni adjustment (Miller, 1981).

The methods summarized above are described in detail in Coats and Lewis, 2014a and 2014b.

INDICATOR STATE

Status – No target established. Established numerical standards (targets) for dissolved and total nitrogen load have been identified for the pelagic and littoral zones of Lake Tahoe. However, the comparative basis for these standards (i.e., average loads from the 1973 to 1981 period) from the various sources identified above are not available; thus, no determination of status can be rendered, and status is unknown. The annual total nitrogen load is strongly influenced by the volume of total annual runoff, perhaps more than the other constituents (i.e., suspended sediment and total phosphorus). The combined total annual total nitrogen load for the seven monitored streams averaged (1989 to 2014) 38,556 kilograms/year, with a median value of 35,051 kilograms/year, and a range from 12,268 kilograms/year in 1994 to 89,030 kilograms/year in 1995. Note that 1995 had both the highest total annual total nitrogen load, and the highest total annual runoff in the data record (1989 to 2014).

Table 1: *Total Nitrogen yield and load summary for seven streams in the Lake Tahoe Basin, 1989-2014. The seven monitored tributaries vary considerably in their total nitrogen yield per unit area and resulting load.*

Stream	Area, km^2	Average Yield Per Unit Area ($kg/km^2/yr$)	Average Total Load (Tonnes)
Blackwood	28.75	229.70	6.60
Ward	25.2	148.84	3.75
Upper Truckee	139.9	119.95	16.78
General	19.14	115.74	2.22
Third	15.59	104.15	1.62
Incline	17.33	103.02	1.79
Trout	104.6	58.66	6.14
Total	**350.51**	**110.97**	**38.90**

Blackwood Creek and the Upper Truckee River continue to be the most important source of total nitrogen entering the lake. Blackwood Creek has the greatest yield per unit area. The Upper Truckee River had a lower total nitrogen yield per unit area, but its large size makes it the greatest contributor of total nitrogen load. Trout Creek basin has a much lower yield than the other monitored watersheds, due perhaps to the relatively gentle slope of the extensive flood plain in the lower part of its basin.

Trends—Little or no change. No significant trend for change in total nitrogen load over time was detected. Highly significant downward trends ($P < 0.003$) in nitrate (NO_3-N) loads were found for all seven streams with Alley's Adjusted Variable Kendall Test (Alley, 1988; Helsel and Hirsch, 2002).

In order to test for trends in total nitrogen, we added the nitrate (NO_3-N) loads and total Kjeldahl nitrogen loads for each of the seven streams by year for 1989 to 2014. With total Kjeldahl nitrogen included, only Third Creek showed a significant downward trend (a 51.1 percent reduction in load over 24 years; less than

0.002). And with total nitrogen loads and flows aggregated across watersheds, no time trend was detected (see Figure 1). The apparent lack of a trend in total Kjeldahl nitrogen masks the basin-wide downward trend in nitrate-N.

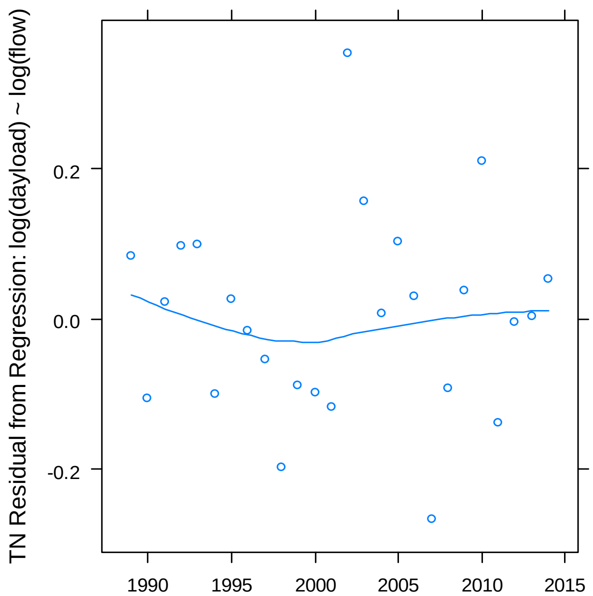


Figure 1: *Trend in total nitrogen loads for seven watersheds, 1989-2014. No significant trend over time was detected (p-value = 0.86, tau = 0.028).*

Highly significant downward trends ($P < 0.003$) in nitrate (NO_3-N) loads were found for all seven streams with Alley's Adjusted Variable Kendall Test (Alley, 1988; Helsel and Hirsch, 2002). Table 2 shows the percent changes in regression-estimated nitrate (NO_3-N) loads for given annual hydrologic conditions. For example, at a given total annual and maximum annual discharge in Blackwood Creek, the estimated total annual nitrate (NO_3-N) load in 2014 was (on average) 55.8 percent less than it would have been for the same hydrologic conditions (had they occurred) in 1975. Note that the annual nitrate (NO_3-N) loads were estimated with the period-weighted sample method, and the residuals for trend analysis were taken from the regression of total annual load versus total annual and maximum annual daily discharge.

Table 2: *Change in nitrate (NO_3-N) residuals after regression of total load vs. total annual and maximum annual discharge. Trends are based on day-time samples only.*

Stream Name	LTIMP Code	Percent Change	Percent Change per Year	Time Period (years)
Ward Creek	WC-8	-39.7	-0.95	42
Blackwood Creek	BC-1	-55.8	-1.43	39
General Creek	GC-1	-56.6	-1.72	33
Upper Truckee River	UT-1	-48.6	-1.47	33
Trout Creek	TC-1	-61.5	-1.71	36
Incline Creek	IN-1	-35.6	-1.42	25
Third Creek	TH-1	-54.9	-1.66	33
Total		**-52.1**	**-1.58**	**33**

Confidence –

Status – Low. Where insufficient data exists to determine status, confidence in the status determination is low. The confidence in an estimate of total nitrogen annual load depends on the number of samples, and on the variance of the daily loads that are sampled to derive the annual load. (Coats and Lewis, 2014b, 2014a) presented tables that can be used to estimate the confidence intervals for average conditions in Tahoe Basin streams, for total nitrogen. Currently the LTIMP stream sampling program collects about 25 to 30 samples per year at each station. With the method used here to estimate total nitrogen loads based on 28 samples per year, we can be 95 percent sure that the true load is within +/- 20 percent of the estimated load. Since much of the total nitrogen load is dissolved, continuous turbidity monitoring may not provide much additional confidence in the estimates, but this has yet to be determined.

Trend – Low. The Kendall test reports the P value for the slope of a trend, that is, the probability that the slope is not different from zero. The trend test for total nitrogen had a p-value = 0.86, tau = -0.028.

Overall – Low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road
- Restored or enhanced 120 acres of disturbed forested uplands
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles
- Issued 18,076 BMP certificates to commercial, multifamily and single family residential properties

Effectiveness of Programs and Actions – Quantitative evaluation of the effectiveness of any individual policy, program or action implemented to improve the tributary water quality is challenging because of the diversity of contributing factors. High inter-annual variability in loads, which is thought to be primarily driven by variability in annual precipitation, complicates the determination of overall effectiveness of the TRPA Regional Plan and actions taken by Regional partners. Further, there is no significant long-term trend in total nitrogen load coincident with TRPA Regional Plan implementation.

Interim Target – Because this is a management standard with no defined numerical targets, one cannot reasonably establish an interim target.

Target Attainment Date – Because this is a management standard with no defined numerical targets, one cannot reasonably establish an interim target.

RECOMMENDATIONS

Analytic Approach – The load calculations used in this indicator sheet was derived from procedures developed in an applied science project for the USDA Forest Service, with funding from the Sierra Nevada Public Land Management Act (Coats and Lewis, 2014b, 2014a). Software compatible with the updated water quality data base also were provided. It is recommended that the revised methods for calculating total loads continue in use for now, but that they be revised and updated as improvements become available. With each updating, annual loads should be recalculated for the entire period of record using the improved method.

Although primary productivity in Lake Tahoe is now P-limited at times, the warming of the lake may (by the end of this century) increase the internal supply of phosphorus, and thus shift the lake back to a condition of nitrogen limitation (N-limitation). Further investigation of the bioavailabity of different nitrogen forms could improve our understanding of the conditions under which N-limitation occurs.

Monitoring Approach – Total nitrogen loads should continue to be monitored to track long-term trends; however, coordinated additional work such as focused studies and effectiveness monitoring, are needed to assess the causes of those changes, or lack of changes. This includes assessing the effectiveness of watershed restoration projects and understanding the effects of uncontrollable drivers such as weather and climate change. As turbidity data become available, its efficacy in estimating total Kjeldahl nitrogen loads should be evaluated.

Modification of the Threshold Standard or Indicator –The load reduction needed to attain any of the three standards is not provided, which precludes objective evaluation of standard attainment. Objective determination of "attainment" status for standards without a specific target is a recurrent challenge both in the Region and in the larger field of monitoring and evaluation (M&E). The standard should be assessed against best practice for the establishment of standards and indicators for M&E, and amended as necessary to improve the evaluability of the standard and the information it provides for management. Any quantitative standards for pollutant loads would need to take into account the large natural variation in yearly stream inflow within and among watersheds. Development of any new standards should be consistent with the standards and management strategies implemented through the Lake Tahoe Total Maximum Daily Load (TMDL) program.

Attain or Maintain Threshold – Continue to pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2031.

Surface Runoff

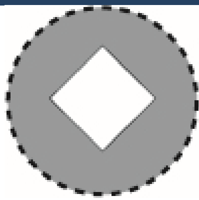
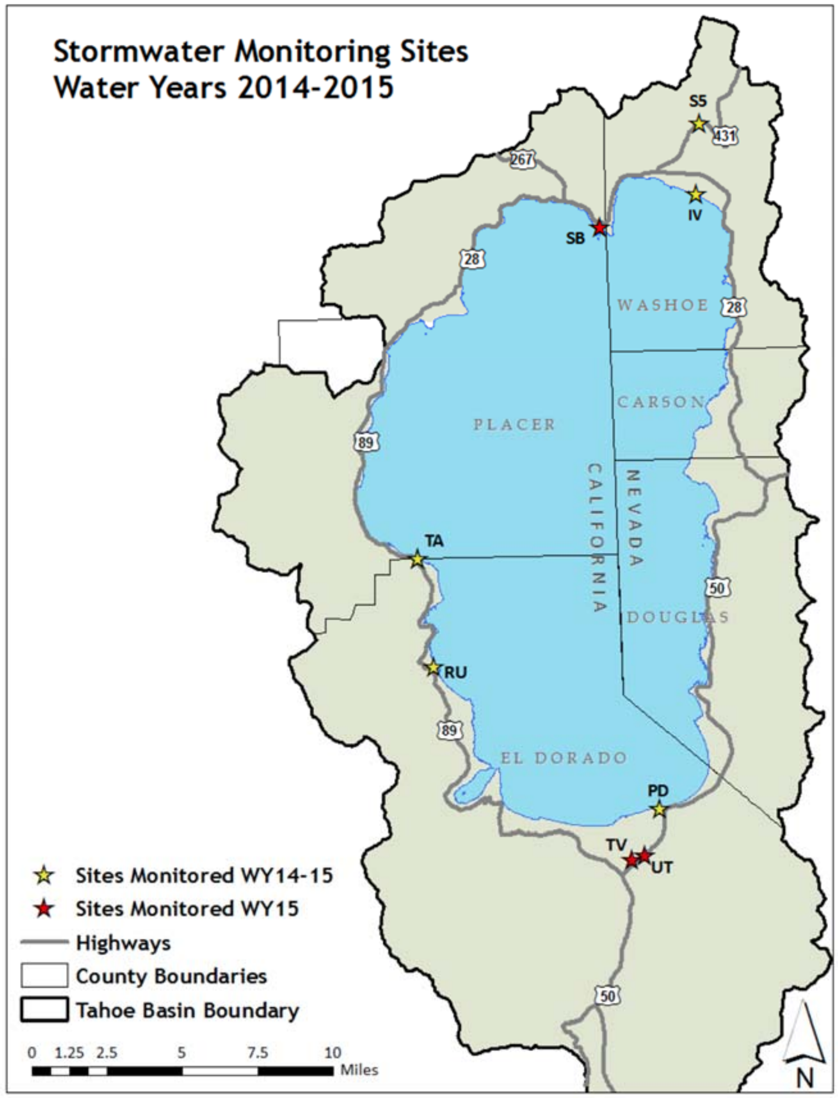
In an undisturbed watershed, the majority of stormwater is captured by vegetation, and absorbed and filtered through the soil. Development, such as roads, driveways and rooftops, alter the watershed by creating impervious surfaces that prevent stormwater from infiltrating. Instead, stormwater runs over impervious surfaces, collecting pollutants such as sediment, nutrients and oil and grease as it travels, enters the nearest stormdrain or stream and ultimately ends up in Lake Tahoe. Many people mistakenly think that storm drains lead to a sanitary sewer system, where the stormwater runoff is treated. While this is true in some communities, it is not true at Lake Tahoe. All storm drains eventually lead to Lake Tahoe. Runoff containing fine sediment and nutrients cloud the water and feed algal growth, which have led to over 30 feet of clarity loss since the 1960's.

The Lake Tahoe TMDL identified runoff from the urban areas as the primary source of pollutants contributing to the decline of lake clarity. As much as 72 percent of fine particles that are entering Lake Tahoe every year are coming from urban upland areas, such as neighborhoods, town centers and roadways (Lahontan & NDEP, 2010a, 2010b). Untreated stormwater can be significantly more turbid than water flowing into the lake through tributaries. Data collected by Tahoe Resource Conservation District and the League to Save Lake Tahoe's Pipe Keeper Program suggest that the turbidity of untreated runoff from urban areas can exceed 500 NTU (nephelometric turbidity units) while the highest recorded turbidity level in USGS monitored streams in 2014 was 315 NTU.

The Lake Tahoe TMDL is a science-based plan to reduce pollutant loads and restore deepwater transparency to historic levels. The TMDL establishes an ambitious goal of reducing pollutant load from urban stormwater by 34 percent by 2026 to meet the Clarity Challenge. To achieve this ambitious goal, the TMDL establishes load reductions milestones for each of the seven urban jurisdictions within the Tahoe Region: El Dorado, Placer, Washoe and Douglas counties; the city of South Lake Tahoe; California Department of Transportation (Caltrans); and Nevada Department of Transportation (NDOT). Each jurisdiction then has discretion to identify and implement load reduction opportunities to achieve the milestones.

Science shows that implementing Best Management Practices (BMPs) on new or existing development can improve Lake Tahoe's water quality and clarity. BMPs are measures taken to minimize soil erosion and capture polluted water before it enters Lake Tahoe and are required on all new development in the Region. The BMP Retrofit Program represents the private contribution to the environmental improvement program. TRPA's Stormwater Management Program staff provide free assistance to property owners, private businesses, and government agencies to advance effective BMP design and implementation on developed properties. Additional information is available on the Tahoe BMP website: www.tahoebmp.org

Surface Runoff: **Suspended Sediment Concentration**

Status	Map
 SUSPENDED SEDIMENT CONCENTRATION Status: **Insufficient Data to Determine Status** Trend: **Insufficient Data to Determine Trend** Confidence: **Moderate**	

Photo

Photo: a stormwater monitoring device in use at the Rubicon BMP site. Credit: Tahoe Resource Conservation District

Data Evaluation and Interpretation

BACKGROUND

Relevance – Fine suspended sediment (fine sediment particles) are the primary driver of the decline in lake clarity (responsible for 55 to 60 percent of the decline) and urban upland areas are the dominate source of fine sediment particles in the Region (Lahontan and NDEP, 2010a).

TRPA Threshold Category – Water quality

TRPA Threshold Indicator Reporting Category – Surface runoff

Adopted Standards – Achieve a 90 percentile concentration value for suspended sediment of 250 milligrams/liter.

Type of Standard – Numerical

Indicator (Unit of Measure) –The proportion of individual samples that exceed 250 milligrams/liter.

Human & Environmental Drivers – Landscape modification (e.g. impervious cover such as roads or residential and commercial development or logging) influences the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. The concentration of sediment and nutrients in stormwater runoff is influenced by the type, magnitude, and location of landscape modifications. Concentration is further mediated by the extent to which practices to mitigate potential impacts are in place. A variety of natural factors also influence the concentration of sediment and nutrients in stormwater concentrations including climate, weather, landscape topography, and vegetation. The Lake Tahoe TMDL estimated that urban upland areas contributed 348 metric tons of fine sediment particles to the lake annually, 72 percent of the annual total (Lahontan and NDEP, 2010a).

MONITORING AND ANALYSIS

Monitoring Partners – Stormwater monitoring is done under the Implementers' Monitoring Program (IMP) led by the Tahoe Resource Conservation District in cooperation with El Dorado County, Placer County, City of South Lake Tahoe, California Department of Transportation, Douglas County, Washoe County, Nevada Tahoe Conservation District, and Nevada Department of Transportation. Funding is provided by the USDA Forest Service Lake Tahoe Basin Management Unit and the California State Water Resources Control Board.

Monitoring Approach –Monitoring is guided by the Regional Stormwater Monitoring Program (RSWMP) framework and implementation plan (Tahoe RCD, 2015a). During water year 2014 five catchments were monitored for continuous flow and sampled for water quality at eleven monitoring stations: the outfalls of the five selected catchments, and the inflows to and outflows from selected BMPs located within three of those catchments. Three additional catchment outfalls were monitored in water year 2015. The catchments were chosen because of their direct hydrologic connectivity to Lake Tahoe, diversity of urban land uses, range of sizes, and a reasonably equitable distribution among the participating jurisdictions. BMP effectiveness sites were selected because of their potential efficacy in treating storm water runoff characteristic of the Lake Tahoe Basin, the broad interest in, and lack of conclusive data regarding the efficiency of the selected BMPs in reducing runoff volumes and pollutant loads, especially fine sediment particles, and the importance of determining the maintenance required to retain effectiveness. The monitoring protocol is described in detail in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe Resource Conservation District, 2015).

Analytic Approach – The number samples in exceedance of the total suspended solids and fine sediment particles standard was calculated and then divided by the total number of samples to calculate the proportion in exceedance. All calculations are based on station outflow samples. While the TRPA standard is for "suspended sediment concentrations", the Lake Tahoe TMDL which directs the data gathered in the Implementers' Monitoring Program focuses on total suspended solids and fine sediment particles, which are slightly different than suspended sediment concentrations. This report summarizes total suspended solids and fine sediment particles data, which acknowledging that both are not exactly the same as suspended sediment concentrations (Gray et al., 2000). While some monitoring stations sampled both the inflow and outflow of BMP's, only the outflows were analyzed in this report.

INDICATOR STATE

Status – Insufficient data to determine status. The sampling design and the small fraction of the outflows points and storm events sampled preclude a status determination on the concentration of stormwater inflow points. Further discussion is included in the recommendations sections. Of the small fraction of outflow points samples in water years 2014 and 2015, 64 percent of sampled outflows were better than the standard of 250 milligrams/liter for total suspended solids, while 74 percent of sampled outflows were better than the standard of 250 milligrams/liter for fine sediment particles (Tahoe Resource Conservation District, 2015).

Trend – Insufficient data to determine trend. Stormwater monitoring under the IMP component of RSWMP began in 2014. The IMP of RSWMP is currently funded through 2019 by SNPLMA, and trend assessments are expected to be included in future evaluations.

Confidence –

Status – Moderate. There is moderate confidence in the data because it is collected using widely recognized, standardized national protocols (see monitoring approach) with quality assurance/quality control procedures. Only a small proportion of outflows are sampled and not all runoff events are sampled. Regional concentration estimates are not available at this time. Current sampling tests for total suspended solids and fine sediment particles, limiting the ability to report on suspended sediment standards therefore reducing the confidence to moderate.
Trend – Low. No trend assessment was performed because both the nature and limited duration of the data preclude trend assessment.
Overall – Low. Overall confidence takes the lower of the two determinations.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, BMP retrofit regulations for developed properties, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

The Regional Plan requires the use of best management practices (BMPs) for new residential and commercial development, and BMP retrofit regulations for developed properties. For example, section 60.4.6.A.1 of TRPA Code requires properties be able to infiltrate the 20-year, one-hour storm into groundwater. The Regional Plan is also designed to limit growth and shift development from sensitive to less sensitive lands. All of these requirements contribute to reducing fine sediment and nutrient runoff from developed areas. The Regional Transportation Plan complements these by encouraging use of public transit and alternative transportation modes, and reducing reliance on private automobile. Water quality mitigation fees, collected on projects that create new cover, support erosion and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road.
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles.
- Issued 18,076 BMP certificates to developed commercial, multifamily and single family residential properties.
- TRPA's grant funded Stormwater Management Program (SMP) focuses compliance and maintenance verification activities on priority commercial and large multi-family residential properties in coordination with local jurisdictions. In 2015, the SMP notified 2,441 parcel owners with BMP Certificates issued more than five years ago that maintenance was due and re-issued 186 BMP Certificates following maintenance verification.
- Completed street sweeping on 24,644 miles of roads.

The TRPA Stormwater Management Program leads broad professional and public education including annual BMP trainings for contractors, local jurisdictions and real estate professionals, articles in "Tahoe In-Depth" mailed to all property owners, and public workshops and events to increase BMP awareness and promote proper design, installation and maintenance. Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do to maintain a healthy environment including BMP completion. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

The Lake-Friendly Business Program highlights and encourages patrons to visit businesses that are doing their part to help protect Lake Tahoe by installing and maintaining their water quality BMPs. There are currently over fifty Lake-Friendly businesses in the Region.

The TMDL Management System Handbook guides the actions of agencies in the Region to reduce inputs of nutrients and sediments into Lake Tahoe (Lahontan and NDEP, 2014). As part of the TMDL implementation, each jurisdiction in the Region prepares a load reduction plan (pollutant load reduction plans in California and stormwater load reduction plans in Nevada) that detail the steps to achieve the specified load reductions. The Lake Tahoe TMDL estimated that a 50 percent reduction in nitrogen load from urban sources (8 percent of the total nitrogen load) would be required to achieve lake clarity standards (Lahontan and NDEP, 2010b).

The 2015 TMDL Findings and Recommendations memo identified wintertime traction abrasives as a primary source of ultra-fine sediment particles (less than 16 microns in stormwater runoff) (Larsen and Kuchnicki 2015a). Managers and heavy equipment operators in the Tahoe Region continue to adaptively manage wintertime traction application practices to reduce adverse environmental impacts while ensuring safe roads. In the 2015/2016 winter season this included treating roadways with brine solution prior to storm events, which prevents ice from developing on roads and can reduce prior dry salt applications by as much as 86 percent (Wigart and Ferry 2015b). El Dorado County, the California Department of Transportation and the City of South Lake Tahoe are utilizing new wintertime traction abrasives that contain 90 percent less ultra-fine particles compared to previously used materials and also break down less into fine fractions from vehicle traffic. This new abrasive is sourced from a native granite material rather than the previously imported non-native volcanic cinders (Wigart and Ferry 2015a).

Effectiveness of Programs and Actions – Each year the actions of the TMDL implementation partners are summarized and evaluated in the TMDL Performance Report. The pollutant tracking system for urban stormwater was being refined during the reporting period. Future evaluations will use the estimated reductions in urban source pollutants to assess the effectiveness of programs and actions implemented to reduce pollutant load from urban sources (Larsen and Kuchnicki, 2015a).

TRPA infiltration requirements were designed to strike a balance between environmental benefit and cost. A 2011 synthesis of existing knowledge found diminishing returns from increasing storm retention capacity beyond the 20-year, one-hour storm. The synthesis found that doubling retention capacity required to handle the 20-year, one-hour storm would only increase annual retention by seven percent (2ndNature and NHC, 2011). TRPA Code Section 60.4.6.A.1 further requires a one-foot separation between seasonal high groundwater and the bottom of an infiltration system to protect groundwater resources.

The 2014-2015 Stormwater Monitoring Report analyzed the effectiveness of BMPs in the Region (Tahoe Resource Conservation District, 2015). At BMP's where both inflow and outflow were monitored, reported results included:

- The Central Incline Village Phase II Project, which included three upstream infiltration basins, two small roadside infiltration pools, 450 linear feet of roadside infiltration channel and a Jellyfish treatment vault, effectively eliminated flows and pollutant loads reaching Lake Tahoe (Tahoe Resource Conservation District, 2015).

- 66 percent of inflow samples (42 of 64) and 83 percent (53 of 64) of outflow samples met the TRPA suspended sediment concentration threshold of 250 milligrams/liter. However, 18 of the 53 outflow samples that met the standard were dry samples (dry samples indicate that the BMP was effective in infiltrating the storm event).

- Average suspended sediment concentration was reduced by 46 percent between inflow and outflow. Average outflow concentrations includes values of zero milligrams/liter where there was no measured flow leaving the BMP.

Interim Target –An interim target cannot be set at this time, due to the duration of the data.

Target Attainment Date – A target attainment date cannot be set at this time, due to the duration of the data.

RECOMMENDATIONS

Analytic Approach – Explore methods to extrapolate from limited field survey data to ambient concentrations at unmonitored locations. The PLRM, which is used for load estimation, uses an event mean concentration - i.e. a single value for a runoff event, and is thus not suitable for evaluation of the concentration based standards.

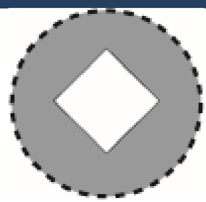
Monitoring Approach –No changes recommended.

Modification of the Threshold Standard or Indicator – Standard revision should consider consistency with the pollutant load-based standards and management strategies implemented through the Lake Tahoe Total Maximum Daily Load (TMDL) program per water quality policy 1.5 of the TRPA Regional Plan.

Attain or Maintain Threshold – The 2015 Findings & Program Recommendation Memo for the TMDL reported that no new findings relative to urban stormwater were reported in previous calendar year (Larsen and Kuchnicki, 2015b). Continue to implement the programs of the TMDL.

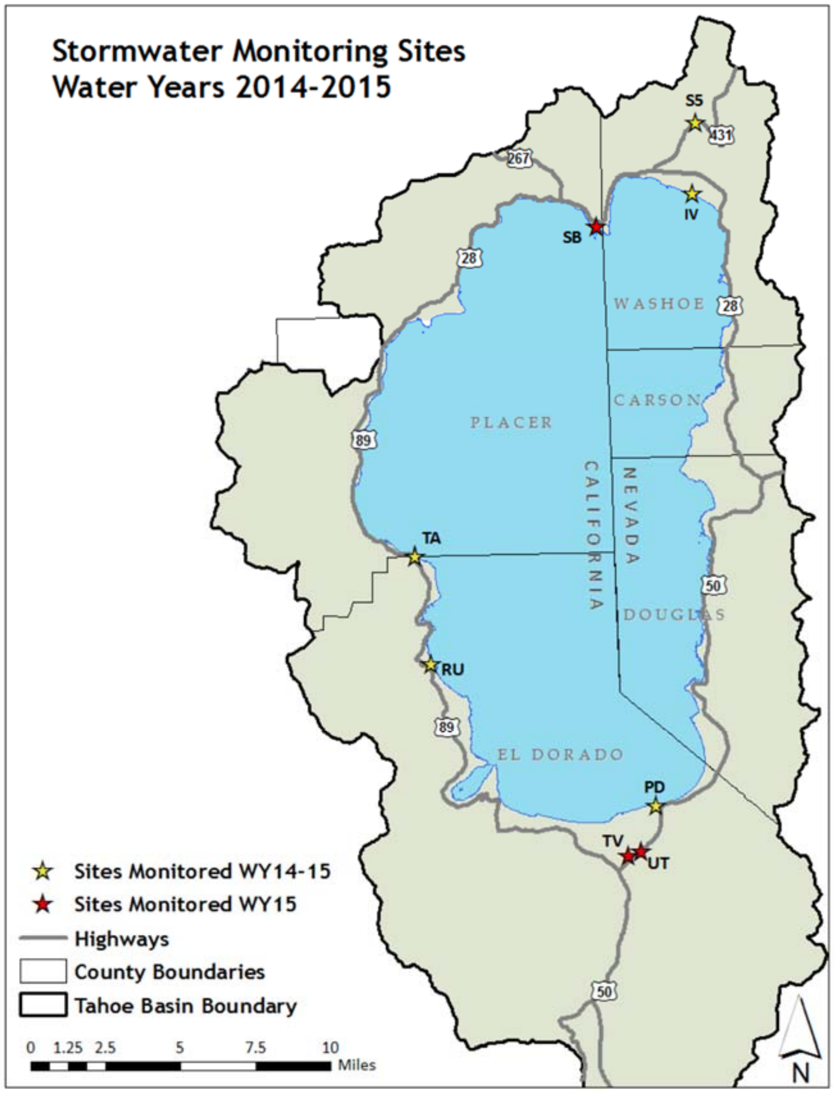
Surface Runoff: **Phosphorus Concentration**

Status	Map



PHOSPHOROUS CONCENTRATION

Status: **Insufficient Data to Determine Status**
Trend: **Insufficient Data to Determine Trend**
Confidence: **Low**



Photo

Photo: a stormwater monitoring device in use at the Tahoe Valley site. Credit: Tahoe Resource Conservation District

Data Evaluation and Interpretation

BACKGROUND

Relevance – Increased nutrient input is primarily responsible for the cultural eutrophication of Lake Tahoe. Increased organic particles in the lake are also estimated to be responsible for approximately 25 percent of the loss of clarity (Lahontan and NDEP, 2010b). The challenge is not unique to Lake Tahoe, as increasing input of nutrients (nitrogen and phosphorus) are considered a main cause of increasing primary productivity in temperate lakes (Conley et al., 2009). Lake Tahoe is an ultraoligotrophic lake and management goals include maintaining this status due to its historic, cultural, economic, and aesthetic value.

TRPA Threshold Category – Water quality

TRPA Threshold Indicator Reporting Category – Surface runoff

Adopted Standards – Achieve a 90 percentile concentration value for dissolved phosphorus of 0.1 milligrams/liter.

Type of Standard – Numerical

Indicator (Unit of Measure) – Milligrams of phosphorus in each liter of stormwater. The proportion of individual measurements that exceed 0.1 milligrams/liter is measured.

Human & Environmental Drivers – Landscape modification (e.g. impervious cover such as roads or residential and commercial development or logging) influences the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. The concentration of sediment and nutrients in stormwater runoff is influenced by the type, magnitude, and location of landscape modifications. Concentration is further mediated by the extent to which practices to mitigate potential impacts are in place. A variety of natural factors also influence the concentration of sediment and nutrients in stormwater concentrations including climate, weather, landscape topography, and vegetation. The Lake Tahoe TMDL estimated that urban upland areas contributed 18 metric tons of total phosphorus a year to the lake, 38 percent of the annual total (Lahontan and NDEP, 2010b).

MONITORING AND ANALYSIS

Monitoring Partners – Stormwater monitoring is done under the Implementers' Monitoring Program (IMP) led by the Tahoe Resource Conservation District in cooperation with El Dorado County, Placer County, City of South Lake Tahoe, California Department of Transportation, Douglas County, Washoe County, Nevada Tahoe Conservation District, and Nevada Department of Transportation. Funding is provided by the USDA Forest Service Lake Tahoe Basin Management Unit and the California State Water Resources Control Board.

Monitoring Approach –Monitoring is guided by the Regional Stormwater Monitoring Program (RSWMP) framework and implementation plan (Tahoe RCD, 2015a). During water year 2014 five catchments were monitored for continuous flow and sampled for water quality at eleven monitoring stations: the outfalls of the five selected catchments, and the inflows to and outflows from selected BMPs located within three of those catchments. Three additional catchment outfalls were monitored in water year 2015. The catchments were chosen because of their direct hydrologic connectivity to Lake Tahoe, diversity of urban land uses, range of sizes, and a reasonably equitable distribution among the participating jurisdictions. BMP effectiveness sites were selected because of their potential efficacy in treating storm water runoff characteristic of the Lake Tahoe Basin, the broad interest in, and lack of conclusive data regarding the efficiency of the selected BMPs in reducing runoff volumes and pollutant loads, especially fine sediment particles, and the importance of determining the maintenance required to retain effectiveness. The monitoring protocol is described in detail in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe Resource Conservation District, 2015).

Analytic Approach –The number samples in exceedance of the total phosphorous standard was calculated and then divided by the total number of samples to calculate the proportion in exceedance. All calculations are based on station outflow samples.

INDICATOR STATE

Status – Insufficient data to determine status. The sampling design and the small fraction of the outflows points and storm events sampled preclude a status determination on the concentration of stormwater inflow points. Further discussion is included in the recommendations sections. Of the small fraction of outflow points samples in water years 2014 and 2015, only 6.1 percent of outflow samples were below the threshold standard of 0.1 milligrams/liter for total phosphorous (Tahoe Resource Conservation District, 2015).

Trend – Insufficient data to determine trend. Stormwater monitoring under the IMP component of RSWMP began in 2014. The IMP of RSWMP is currently funded through 2019 by SNPLMA, and trend assessments are expected to be included in future evaluations.

Confidence –

Status – Low. Where insufficient data exists to determine status, confidence in the status determination is low. There is moderate confidence in the data because it is collected using widely recognized, standardized national protocols (see monitoring approach) with quality assurance/quality control procedures. Only a small proportion of outflows are sampled and not all runoff events are sampled. Regional estimates of concentration are not available at this time.

Trend – Low. No trend assessment was performed because both the nature and limited duration of the data preclude trend assessment.

Overall – Low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, BMP retrofit regulations for developed properties, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

The Regional Plan requires the use of best management practices (BMPs) for new residential and commercial development, and BMP retrofit regulations for developed properties. For example, section 60.4.6.A.1 of TRPA Code requires properties be able to infiltrate the 20-year, one-hour storm into groundwater. The Regional Plan is also designed to limit growth and shift development from sensitive to less sensitive lands. All of these requirements contribute to reducing fine sediment and nutrient runoff from developed areas. The Regional Transportation Plan complements these by encouraging use of public transit and alternative transportation modes, and reducing reliance on private automobile. Water quality mitigation fees, collected on projects that create new cover, support erosion and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road.
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles.
- Issued 18,076 BMP certificates to developed commercial, multifamily and single family residential properties.
- TRPA's grant funded Stormwater Management Program (SMP) focuses compliance and maintenance verification activities on priority commercial and large multi-family residential properties in coordination with local jurisdictions. In 2015, the SMP notified 2,441 parcel owners with BMP Certificates issued more than five years ago that maintenance was due and re-issued 186 BMP Certificates following maintenance verification.
- Completed street sweeping on 24,644 miles of roads.

The TRPA Stormwater Management Program leads broad professional and public education including annual BMP trainings for contractors, local jurisdictions and real estate professionals, articles in "Tahoe In-Depth" mailed to all property owners, and public workshops and events to increase BMP awareness and promote proper design, installation and maintenance. Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do to maintain a healthy environment including BMP completion. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

The Lake-Friendly Business Program highlights and encourages patrons to visit businesses that are doing their part to help protect Lake Tahoe by installing and maintaining their water quality BMPs. There are currently over fifty Lake-Friendly businesses in the Region.

The TMDL Management System Handbook guides the actions of agencies in the Region to reduce inputs of nutrients and sediments into Lake Tahoe (Lahontan and NDEP, 2014). As part of the TMDL implementation, each jurisdiction in the Region prepares a load reduction plan (pollutant load reduction plans in California and stormwater load reduction plans in Nevada) that detail the steps to achieve the specified load reductions. The Lake Tahoe TMDL estimated that a 50 percent reduction in nitrogen load from urban sources (8 percent of the total nitrogen load) would be required to achieve lake clarity standards (Lahontan and NDEP, 2010b).

The 2015 TMDL Findings and Recommendations memo identified wintertime traction abrasives as a primary source of ultra-fine sediment particles (less than 16 microns in stormwater runoff) (Larsen and Kuchnicki, 2015a). Managers and heavy equipment operators in the Tahoe Region continue to adaptively manage wintertime traction application practices to reduce adverse environmental impacts while ensuring safe roads. In the 2015/2016 winter season this included treating roadways with brine solution prior to storm events, which prevents ice from developing on roads and can reduce prior dry salt applications by as much as 86 percent (Wigart and Ferry, 2015b). El Dorado County, the California Department of Transportation and the City of South Lake Tahoe are utilizing new wintertime traction abrasives that contain 90 percent less ultra-fine particles compared to previously used materials and also break down less into fine fractions from vehicle traffic. This new abrasive is sourced from a native granite material rather than the previously imported non-native volcanic cinders (Wigart and Ferry, 2015a).

Effectiveness of Programs and Actions – Each year the actions of the TMDL implementation partners are summarized and evaluated in the TMDL Performance Report. The pollutant tracking system for urban stormwater was being refined during the reporting period. Future evaluations will use the estimated reductions in urban source pollutants to assess the effectiveness of programs and actions implemented to reduce pollutant load from urban sources (Larsen and Kuchnicki, 2015b).

TRPA infiltration requirements were designed to strike a balance between environmental benefit and cost. A 2011 synthesis of existing knowledge found diminishing returns from increasing storm retention capacity beyond the 20-year, one-hour storm. The synthesize found that doubling retention capacity required to handle the 20-year, one-hour storm would only increase annual retention by seven percent (2ndNature and NHC, 2011). TRPA Code Section 60.4.6.A.1 further requires a one-foot separation between seasonal high groundwater and the bottom of an infiltration system to protect groundwater resources.

The 2014-2015 Stormwater Monitoring Report analyzed the effectiveness of BMPs in the Region (Tahoe Resource Conservation District, 2015). At BMP's where both inflow and outflow were monitored, reported results included:

- The Central Incline Village Phase II Project, which included three upstream infiltration basins, two small roadside infiltration pools, 450 linear feet of roadside infiltration channel and a Jellyfish treatment vault, effectively eliminated flows and pollutant loads reaching Lake Tahoe (Tahoe Resource Conservation District, 2015).

- Six percent of inflow samples (four of 64) and 31 percent (20 of 64) of outflow samples met the TRPA phosphorus concentration threshold of 0.1 milligrams/liter. However, 19 of the 20 outflow samples that met the standard were dry samples (dry samples indicate that BMP was effective in infiltrating the storm event).

- Average concentration of phosphorus was reduced by 54 percent between inflow and outflow. Average phosphorus concentrations was 1.00 milligrams/liter at inflows, and 0.54 milligrams/liter, at outflow. Average outflow concentrations includes values of 0 milligrams/liter where there was no measured flow leaving the BMP.

Interim Target –An interim target cannot be set at this time, due to the duration of the data.

Target Attainment Date – A target attainment date cannot be set at this time, due to the duration of the data.

RECOMMENDATIONS

Analytic Approach – No changes recommended.

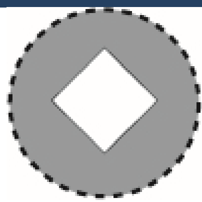
Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – Standard revision should consider consistency with the pollutant load-based standards and management strategies implemented through the Lake Tahoe Total Maximum Daily Load (TMDL) program per water quality policy 1.5 of the TRPA Regional Plan.

Attain or Maintain Threshold – The 2015 Findings & Program Recommendation Memo for the TMDL reported that no new findings relative to urban stormwater were reported in previous calendar year (Larsen and Kuchnicki, 201b). Continue to implement the programs of the TMDL.

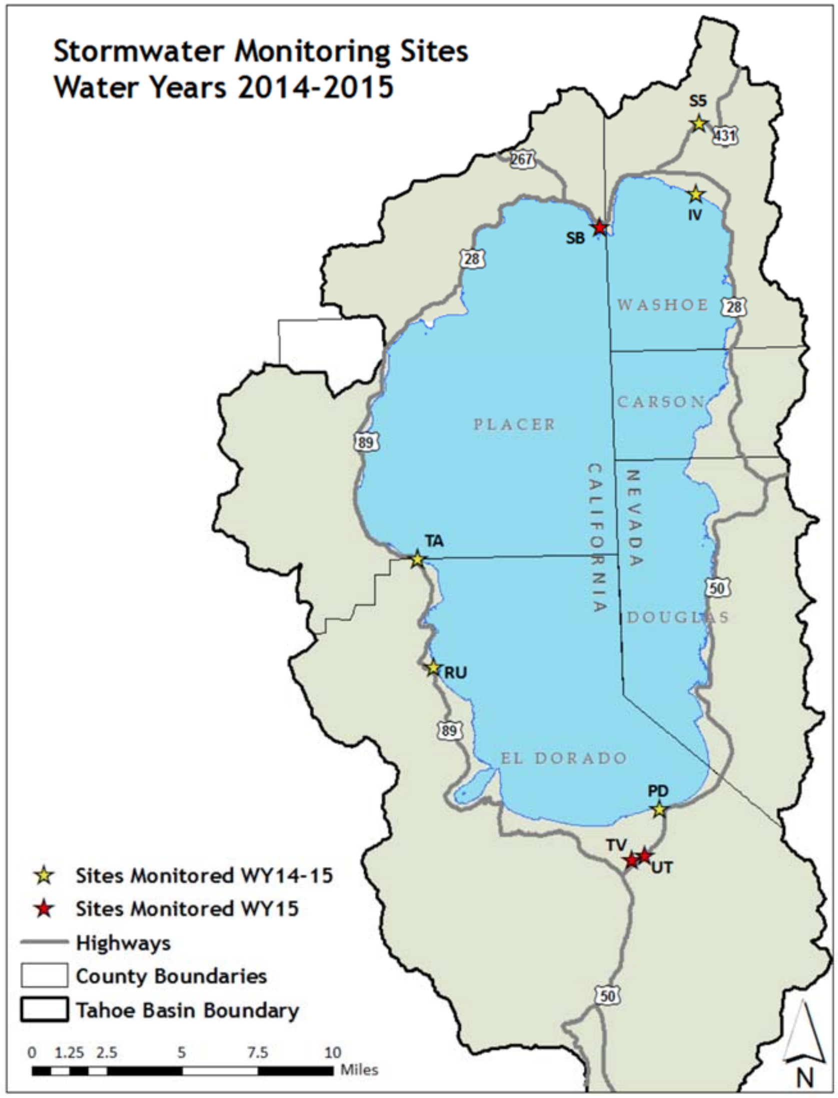
Surface Runoff: **Nitrogen Concentration**

Status	Map



NITROGEN CONCENTRATION

Status: **Insufficient Data to Determine Status**
Trend: **Insufficient Data to Determine Trend**
Confidence: **Moderate**



Photo

Photo: Stormwater monitoring device in use at the Tahoma site. Credit: Tahoe Resource Conservation District

Data Evaluation and Interpretation

BACKGROUND

Relevance – Increased nutrient input is primarily responsible for cultural eutrophication of Lake Tahoe. The challenge is not unique to Lake Tahoe, increasing nutrient (nitrogen and phosphorus) inputs are considered a main cause of increasing primary productivity in temperate lakes globally (Conley et al., 2009). Lake Tahoe is an ultraoligotrophic lake and management goals include maintaining this status due to its historic, cultural, economic, and aesthetic value. Increased organic particles in the lake are also estimated to be responsible for approximately 25 percent of the loss of clarity (Lahontan and NDEP, 2010a).

TRPA Threshold Category – Water quality

TRPA Threshold Indicator Reporting Category – Surface runoff

Adopted Standards – Achieve a 90 percentile concentration value for dissolved inorganic nitrogen of 0.5 milligrams/liter.

Type of Standard – Numerical

Indicator (Unit of Measure) – Milligrams of nitrogen in each liter of stormwater. The proportion of individual measurements that exceed 0.5 milligrams/liter is measured.

Human & Environmental Drivers – Landscape modification (e.g. impervious cover such as roads or residential and commercial development or logging) influences the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. The concentration of sediment and nutrients in stormwater runoff is influenced by the type, magnitude, and location of landscape modifications. Concentration is further mediated by the extent to which practices to mitigate potential impacts are in place. A variety of natural factors also influence the concentration of sediment and nutrients in stormwater concentrations including climate, weather, landscape topography, and vegetation. The Lake Tahoe TMDL estimated that urban upland areas contributed 63 metric tons of total nitrogen a year to the lake, 16 percent of the annual total (Lahontan and NDEP, 2010a).

MONITORING AND ANALYSIS

Monitoring Partners – Stormwater monitoring is done under the Implementers' Monitoring Program (IMP) led by the Tahoe Resource Conservation District in cooperation with El Dorado County, Placer County, City of South Lake Tahoe, California Department of Transportation, Douglas County, Washoe County, Nevada Tahoe Conservation District, and Nevada Department of Transportation. Funding is provided by the USDA Forest Service Lake Tahoe Basin Management Unit and the California State Water Resources Control Board.

Monitoring Approach –Monitoring is guided by the Regional Stormwater Monitoring Program (RSWMP) framework and implementation plan (Tahoe RCD, 2015a). During water year 2014 five catchments were monitored for continuous flow and sampled for water quality at eleven monitoring stations: the outfalls of the five selected catchments, and the inflows to and outflows from selected BMPs located within three of those catchments. Three additional catchment outfalls were monitored in water year 2015. The catchments were chosen because of their direct hydrologic connectivity to Lake Tahoe, diversity of urban land uses, range of sizes, and a reasonably equitable distribution among the participating jurisdictions. BMP effectiveness sites were selected because of their potential efficacy in treating storm water runoff characteristic of the Lake Tahoe Basin, the broad interest in, and lack of conclusive data regarding the efficiency of the selected BMPs in reducing runoff volumes and pollutant loads, especially fine sediment particles, and the importance of determining the maintenance required to retain effectiveness. The monitoring protocol is described in detail in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe Resource Conservation District, 2015).

Analytic Approach –The number samples in exceedance of the total nitrogen standard was calculated and then divided by the total number of samples to calculate the proportion in exceedance. All calculations are based on station outflow samples.

INDICATOR STATE

Status – Insufficient data exists to determine status. The sampling design and the small fraction of the outflows points and storm events sampled preclude a status determination on the concentration of stormwater inflow points. Further discussion is included in the recommendations sections. Of the small fraction of outflow points samples in water years 2014 and 2015, 8.3 percent of outflow samples met or were below the threshold standard of 0.5 milligrams/liter for total nitrogen and 91.7 percent of samples exceeded the 0.5 milligrams/liter concentration(Tahoe Resource Conservation District, 2015).

Trend – Insufficient data to determine trend. Stormwater monitoring under the IMP component of

RSWMP began in 2014. The IMP of RSWMP is currently funded through 2019 by SNPLMA, and trend assessments are expected to be included in future evaluations.

Confidence –

Status – Low. Where insufficient data exists to determine status, confidence in the status determination is low. There is moderate confidence in the data because it is collected using widely recognized, standardized national protocols (see monitoring approach) with quality assurance/quality control procedures. Only a small proportion of outflows are sampled and not all runoff events are sampled. Regional estimates of concentration are not available at this time.

Trend – Low. No trend assessment was performed because both the nature and limited duration of the data preclude trend assessment.

Overall – Low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, BMP retrofit regulations for developed properties, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

The Regional Plan requires the use of best management practices (BMPs) for new residential and commercial development, and BMP retrofit regulations for developed properties. For example, section 60.4.6.A.1 of TRPA Code requires properties be able to infiltrate the 20-year, one-hour storm into groundwater. The Regional Plan is also designed to limit growth and shift development from sensitive to less sensitive lands. All of these requirements contribute to reducing fine sediment and nutrient runoff from developed areas. The Regional Transportation Plan complements these by encouraging use of public transit and alternative transportation modes, and reducing reliance on private automobile. Water quality mitigation fees, collected on projects that create new cover, support erosion and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road.
- Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles.
- Issued 18,076 BMP certificates to developed commercial, multifamily and single family residential properties.
- TRPA's grant funded Stormwater Management Program (SMP) focuses compliance and maintenance verification activities on priority commercial and large multi-family residential properties in coordination with local jurisdictions. In 2015, the SMP notified 2,441 parcel owners with BMP Certificates issued more than five years ago that maintenance was due and re-issued 186 BMP Certificates following maintenance verification.
- Completed street sweeping on 24,644 miles of roads.

The TRPA Stormwater Management Program leads broad professional and public education including annual BMP trainings for contractors, local jurisdictions and real estate professionals, articles in "Tahoe In-Depth" mailed to all property owners, and public workshops and events to increase BMP awareness and promote proper design, installation and maintenance. Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do to maintain a healthy environment including BMP completion. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

The Lake-Friendly Business Program highlights and encourages patrons to visit businesses that are doing their part to help protect Lake Tahoe by installing and maintaining their water quality BMPs. There are currently over fifty Lake-Friendly businesses in the Region.

The TMDL Management System Handbook guides the actions of agencies in the Region to reduce inputs of nutrients and sediments into Lake Tahoe (Lahontan and NDEP, 2014). As part of the TMDL implementation, each jurisdiction in the Region prepares a load reduction plan (pollutant load reduction plans in California and stormwater load reduction plans in Nevada) that detail the steps to achieve the specified load reductions. The Lake Tahoe TMDL estimated that a 50 percent reduction in nitrogen load from urban sources (8 percent of the total nitrogen load) would be required to achieve lake clarity standards (Lahontan and NDEP, 2010b).

The 2015 TMDL Findings and Recommendations memo identified wintertime traction abrasives as a primary source of ultra-fine sediment particles (less than 16 microns in stormwater runoff) (Larsen and Kuchnicki, 2015a). Managers and heavy equipment operators in the Tahoe Region continue to adaptively manage wintertime traction application practices to reduce adverse environmental impacts while ensuring safe roads. In the 2015/2016 winter season this included treating roadways with brine solution prior to storm events, which prevents ice from developing on roads and can reduce prior dry salt applications by as much as 86 percent (Wigart and Ferry, 2015b). El Dorado County, the California Department of Transportation and the City of South Lake Tahoe are utilizing new wintertime traction abrasives that contain 90 percent less ultra-fine particles compared to previously used materials and also break down less into fine fractions from vehicle traffic. This new abrasive is sourced from a native granite material rather than the previously imported non-native volcanic cinders (Wigart and Ferry, 2015a).

Effectiveness of Programs and Actions – Each year the actions of the TMDL implementation partners are summarized and evaluated in the TMDL Performance Report. The pollutant tracking system for urban stormwater was being refined during the reporting period. Future evaluations will use the estimated reductions in urban source pollutants to assess the effectiveness of programs and actions implemented to reduce pollutant load from urban sources (Larsen and Kuchnicki, 2015b).

TRPA infiltration requirements were designed to strike a balance between environmental benefit and cost. A 2011 synthesis of existing knowledge found diminishing returns from increasing storm retention capacity beyond the 20-year, one-hour storm. The synthesis found that doubling retention capacity required to handle the 20-year, one-hour storm would only increase annual retention by seven percent (2ndNature and NHC, 2011). TRPA Code Section 60.4.6.A.1 further requires a one-foot separation between seasonal high groundwater and the bottom of an infiltration system to protect groundwater resources.

The 2014-2015 Stormwater Monitoring Report analyzed the effectiveness of BMPs in the Region (Tahoe Resource Conservation District, 2015). At BMP's where both inflow and outflow were monitored, reported results included:

- The Central Incline Village Phase II Project, which included three upstream infiltration basins, two small roadside infiltration pools, 450 linear feet of roadside infiltration channel and a Jellyfish treatment vault, effectively eliminated flows and pollutant loads reaching Lake Tahoe (Tahoe Resource Conservation District, 2015).
- 11 percent of inflow samples (seven of 64) and 31 percent (20 of 64) of outflow samples met the TRPA nitrogen concentration threshold of 0.5 milligrams/liter. However, 19 of the 20 outflow samples that met the standard were dry samples (dry samples indicate that BMP was effective in infiltrating the storm event).
- Average nitrogen concentrations at measured inflows was 2.39 milligrams/liter while average nitrogen concentrations at outflows was 1.20 milligrams/liter, a reduction of 50 percent. Average outflow concentrations includes values of 0 mg/L where there was no measured flow leaving the BMP.

Interim Target –An interim target cannot be set at this time, due to the duration of the data.

Target Attainment Date – A target attainment date cannot be set at this time, due to the duration of the data.

RECOMMENDATIONS

Analytic Approach – No changes recommended.

Monitoring Approach – IMP was designed primarily to meet jurisdiction's reporting requirements under California National Pollutant Discharge Elimination System (NPDES) permits and Nevada Interlocal Agreement commitments. The focus of both is on load reaching the lake, not concentration. The primary objectives of the RSMWP design are (a) the status and trend of catchments with respect to load estimates, and (b) the evaluation of BMP effectiveness (Tahoe RCD, 2015a). The sampling design of RSWMP reflects these objectives and poses a challenge to evaluation of TRPA concentration based standards. For example, the success of the Central Incline Village Phase II project has resulted in the site being removed from the 2016 monitoring plan, and replaced by a site where load is likely to be higher. The result of this change as described in the monitoring plan, "will skew long-term status and trends data and may encourage a false perception that erosion control projects do not have a measureable benefit" (Tahoe Resource Conservation District, 2015).

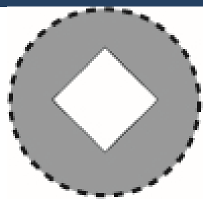
Recommendations below are summarized from the IMP (Tahoe Resource Conservation District, 2015). The Tahoe Resource Conservation District suggested the IMP discontinue monitoring of the two Rubicon monitoring stations (RI and RO) and the catchment outfall station at State Route 431 (S5) due to extremely low flow volumes. The very small pollutant loads from these catchments and the relative difficulty of monitoring sites with low flow did not warrant the effort and cost required to continue monitoring these stations. The IMP agreed with this assessment and the request was brought to Lahontan and Nevada Division of Environmental Protection who approved the change for water year 2016. In addition, the Tahoe Resource Conservation District suggested removing the first flush sample requirement for the next permit term (beginning water year 2017) for three reasons; 1) the first flush sample does not represent a consistent percentage of the total runoff volume for an event and is difficult to compare the results across events or sites, 2) first flush samples generally represents a very small portion of the total runoff volume and therefore its contribution to the calculation of the flow-weighted event mean concentration is often negligible, and, 3) Continuous turbidimeters are installed at all monitoring sites allowing questions most pertinent to jurisdictions to be answered more effectively.

Modification of the Threshold Standard or Indicator – Standard revision should consider consistency with the pollutant load-based standards and management strategies implemented through the Lake Tahoe Total Maximum Daily Load (TMDL) program per water quality policy 1.5 of the TRPA Regional Plan.

Attain or Maintain Threshold – The 2015 Findings & Program Recommendation Memo for the TMDL reported that no new findings relative to urban stormwater were reported in previous calendar year (Larsen and Kuchnicki, 2015a). Continue to implement the programs of the TMDL.

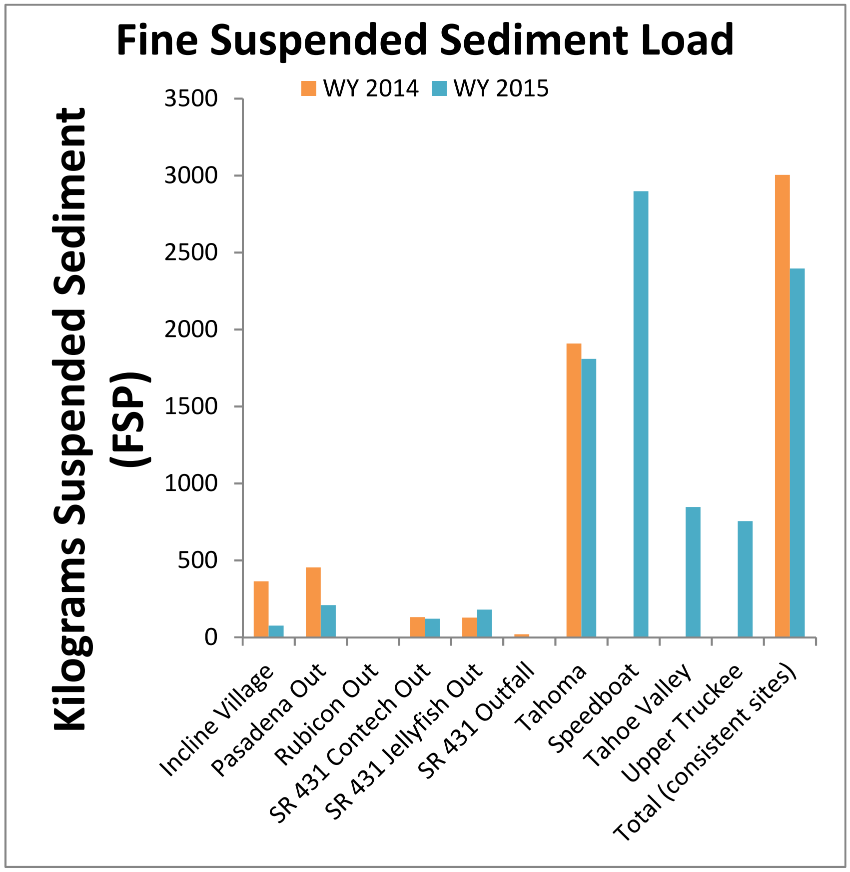
Surface Runoff: **Suspended Sediment Load**

Status	Chart



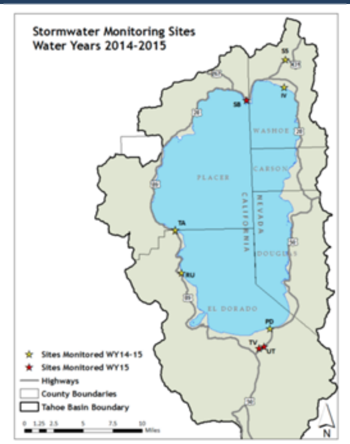
SUSPENDED SEDIMENT LOAD

Status: **Insufficient Data to Determine Status**
Trend: **Insufficient Data to Determine Trend**
Confidence: **Low**



Fine Sediment Particle load measured at outfalls around the Tahoe Basin. Total for “consistent sites” refers to sites that were monitored in both 2014 and 2015. Sites that have no data for 2014 were only installed for water year 2015. Source: Tahoe Resource Conservation District

Map



A map shows all stormwater monitoring locations during water years 2014 and 2015. Source: Tahoe Resource Conservation District

Data Evaluation and Interpretation

BACKGROUND

Relevance – This indicator measures the total suspended sediment load (measured as fine sediment particle load) delivered to Lake Tahoe via direct surface runoff. Fine suspended sediment (fine sediment particles) are the primary driver of the decline in lake clarity (responsible for 55 to 60 percent of the decline) and urban upland areas are the dominate source of fine sediment particle in the basin (Lahontan and NDEP, 2010a). The TMDL estimated that 72 percent of the fine sediment particle load originates from urban sources. The TMDL estimated that a 71 percent reduction (from 2004 loading estimate) in fine sediment particle load from urban upland sources over 65 years would be required to achieve the pelagic clarity standard.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category – Surface Runoff

Adopted Standards –

1. Reduce total annual nutrient and suspended sediment loads as necessary to achieve loading thresholds for tributaries and littoral and pelagic Lake Tahoe.
2. Tributaries - Reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe.
3. Littoral - Decrease sediment load as required to attain turbidity values not to exceed three nephelometric turbidity units (NTU). In addition, turbidity shall not exceed one NTU in shallow waters of the lake not directly influenced by stream discharges.
4. Deep Water (Pelagic) Lake Tahoe – Reduce fine sediment particles (inorganic particle size less than 16 micrometers in diameter), total phosphorus, and total nitrogen in order to achieve the following long-term water quality standards for deep water (pelagic zone) Lake Tahoe:
    a) The annual average deep water transparency as measured by Secchi disk shall not be decreased below 29.7 meters (97.4 feet), the average levels recorded between 1967 and 1971 by the University of California, Davis.
    b) Maintain annual mean phytoplankton primary productivity at or below 52gmC/m2/yr.

Type of Standard – Management and numerical

Indicator (Unit of Measure) – Kilograms/year of fine sediment particles.

Human & Environmental Drivers – Landscape modification (e.g. impervious cover such as roads or residential and commercial development or logging) influences the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. Sediment and nutrient load in stormwater runoff is influenced by the type, magnitude, and location of landscape modifications and the extent to which practices to mitigate potential impacts are in place. A variety of natural factors also influence the load of sediment and nutrients in stormwater including climate, weather, landscape topography, and vegetation. The TMDL estimated that 72 percent of total fine sediment particle load basin wide originates from urban upland sources.

MONITORING AND ANALYSIS

Monitoring Partners – Stormwater monitoring is done under the Implementers' Monitoring Program (IMP) led by the Tahoe Resource Conservation District in cooperation with El Dorado County, Placer County, City of South Lake Tahoe, California Department of Transportation, Douglas County, Washoe County, Nevada Tahoe Conservation District, and Nevada Department of Transportation. Funding is provided by the USDA Forest Service Lake Tahoe Basin Management Unit and the California State Water Resources Control Board.

Monitoring Approach – Monitoring under the IMP is guided by the Regional Stormwater Monitoring Program (RSWMP) framework and implementation plan (Tahoe RCD, 2015a). During water year 2014 five catchments were monitored for continuous flow and sampled for water quality at eleven monitoring stations: the outfalls of the five selected catchments, and the inflows to and outflows from selected BMPs located within three of those catchments. Three additional catchment outfalls were monitored in water year 2015.The catchments were chosen because of their direct hydrologic connectivity to Lake Tahoe, diversity of urban land uses, range of sizes, and a reasonably equitable distribution among the participating jurisdictions. BMP effectiveness sites were selected because of their potential efficacy in treating storm water runoff characteristic of the Lake Tahoe Basin, the broad interest in, and lack of conclusive data regarding the efficiency of the selected BMPs in reducing runoff volumes and pollutant loads, especially fine sediment particles, and the importance of determining the maintenance required to retain effectiveness. The monitoring protocol is described in detail in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe Resource Conservation District, 2015).

Analytic Approach – Load is based on estimated load at station outflow as reported in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe RCD, 2015b). Details on the analytic protocols used to estimate load are included available in the Regional Stormwater Monitoring Program (RSWMP) Framework and Implementation Guidance Document (Tahoe RCD, 2015a).
INDICATOR STATE
Status – Insufficient data to determine status. Data reported in this assessment is load as measured at specific catchments and no overall estimate of load was available at this time. Load reduction estimates and condition assessment commitments are documented in the credit accounting platform of the TMDL. A more robust picture of load in stormwater will be available in March 2017 after credit declaration and associated verification associated with the first TMDL milestone is complete. Fine sediment particle load at all monitoring location outfalls was 3,004 kilograms for water year 2014 and 6,894 kilograms for water year 2015. The two years are not comparable because three additional sites were added in 2015 and total surface volume was much greater in 2014. **Trend** – Insufficient data to determine trend. Stormwater monitoring under the IMP component of RSWMP began in 2014. The IMP of RSWMP is currently funded through 2019 by SNPLMA, and trend assessments are expected to be included in future evaluations. **Confidence –** **Status –** Low. Where insufficient data exists to determine status, confidence in the status determination is low. There is moderate confidence in the data because it is collected using widely recognized, standardized national protocols (see monitoring approach) with quality assurance/quality control procedures. Only a small proportion of outflows are sampled and not all runoff events are sampled. Regional estimates of overall load and load reduction are not available at this time. **Trend –** Low. No trend assessment was performed because both the nature and limited duration of the data preclude trend assessment. **Overall –** Low.
IMPLEMENTATION AND EFFECTIVENESS
Programs and Actions Implemented to Improve Conditions – Urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, BMP retrofit regulations for developed properties, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have: The Regional Plan requires the use of best management practices (BMPs) for new residential and commercial development, and BMP retrofit regulations for developed properties. For example, section 60.4.6.A.1 of TRPA Code requires properties be able to infiltrate the 20-year, one-hour storm into groundwater. The Regional Plan is also designed to limit growth and shift development from sensitive to less sensitive lands. All of these requirements contribute to reducing fine sediment and nutrient runoff from developed areas. The Regional Transportation Plan complements these by encouraging use of public transit and alternative transportation modes, and reducing reliance on private automobile. Water quality mitigation fees, collected on projects that create new cover, support erosion and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have: • Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road. • Inspected 108.72 miles of unpaved non-urban roads and maintained 98.2 miles. • Issued 18,076 BMP certificates to developed commercial, multifamily and single family residential properties. • TRPA's grant funded Stormwater Management Program (SMP) focuses compliance and maintenance verification activities on priority commercial and large multi-family residential properties in coordination with local jurisdictions. In 2015, the SMP notified 2,441 parcel

owners with BMP Certificates issued more than five years ago that maintenance was due and re-issued 186 BMP Certificates following maintenance verification.

- Completed street sweeping on 24,644 miles of roads.

The TRPA Stormwater Management Program leads broad professional and public education including annual BMP trainings for contractors, local jurisdictions and real estate professionals, articles in "Tahoe In-Depth" mailed to all property owners, and public workshops and events to increase BMP awareness and promote proper design, installation and maintenance. Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do to maintain a healthy environment including BMP completion. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

The Lake-Friendly Business Program highlights and encourages patrons to visit businesses that are doing their part to help protect Lake Tahoe by installing and maintaining their water quality BMPs. There are currently over fifty Lake-Friendly businesses in the Region.

The TMDL Management System Handbook guides the actions of agencies in the Region to reduce inputs of nutrients and sediments into Lake Tahoe (Lahontan and NDEP, 2014). As part of the TMDL implementation, each jurisdiction in the Region prepares a load reduction plan (pollutant load reduction plans in California and stormwater load reduction plans in Nevada) that detail the steps to achieve the specified load reductions. The Lake Tahoe TMDL estimated that a 50 percent reduction in nitrogen load from urban sources (8 percent of the total nitrogen load) would be required to achieve lake clarity standards (Lahontan and NDEP, 2010a).

The 2015 TMDL Findings and Recommendations memo identified wintertime traction abrasives as a primary source of ultra-fine sediment particles (less than 16 microns in stormwater runoff) (Larsen and Kuchnicki, 2015a). Managers and heavy equipment operators in the Tahoe Region continue to adaptively manage wintertime traction application practices to reduce adverse environmental impacts while ensuring safe roads. In the 2015/2016 winter season this included treating roadways with brine solution prior to storm events, which prevents ice from developing on roads and can reduce prior dry salt applications by as much as 86 percent (Wigart and Ferry, 2015b). El Dorado County, the California Department of Transportation and the City of South Lake Tahoe are utilizing new wintertime traction abrasives that contain 90 percent less ultra-fine particles compared to previously used materials and also break down less into fine fractions from vehicle traffic. This new abrasive is sourced from a native granite material rather than the previously imported non-native volcanic cinders (Wigart and Ferry, 2015a).

Effectiveness of Programs and Actions – Each year the actions of the TMDL implementation partners are summarized and evaluated in the TMDL Performance Report. The pollutant tracking system for urban stormwater was being refined during the reporting period. Future evaluations will use the estimated reductions in urban source pollutants to assess the effectiveness of programs and actions implemented to reduce pollutant load from urban sources (Larsen and Kuchnicki, 2015b).

TRPA infiltration requirements were designed to strike a balance between environmental benefit and cost. A 2011 synthesis of existing knowledge found diminishing returns from increasing storm retention capacity beyond the 20-year, one-hour storm. The synthesis found that doubling retention capacity required to handle the 20-year, one-hour storm would only increase annual retention by seven percent (2ndNature and NHC, 2011). TRPA Code Section 60.4.6.A.1 further requires a one-foot separation between seasonal high groundwater and the bottom of an infiltration system to protect groundwater resources.

In the long term, partners will be able to measure overall load reductions from surface runoff. However, with currently available data, the primary way to measure the effectiveness of programs and actions is to assess the effectiveness of BMP's at reducing sediment and nutrient loads. Suspended sediments in tributaries and overall lake clarity are secondary indictors of the effectives of reducing suspended sediments in runoff and can be viewed in their respective indicator sheets.

The following results on the effectiveness of BMP's were reported in the 2014-2015 Stormwater Monitoring Report (Tahoe Resource Conservation District, 2015):

- Selected BMP catchment basins (Pasadena, Rubicon, SR 431 Contech, SR 431 Jellyfish) decreased annual fine sediment particle load by 43 percent in water year 2014 and 20 percent in water year 2015

Interim Target – Due to limited data duration, an interim target cannot be set.

Target Attainment Date – Due to limited data duration, a target attainment date cannot be set.

RECOMMENDATIONS

Analytic Approach – The Lake Tahoe TMDL requires urban jurisdictions to report pollutant load estimates using the Lake Clarity Crediting Program and associated tools. The Pollutant Load Reduction Model (PLRM) provides a consistent method for evaluating both baseline and expected conditions associated with pollutant load reduction actions. The model provides estimates for the expected benefits of actions and on-the-ground field verification methods confirm treatment facility and roadway conditions are consistent with modelled parameters. Load reduction estimates and condition assessment commitments are documented in the credit accounting platform. Credit declaration and associated verification to document the first TMDL milestone is expected in March 2017. The raw RSWMP data detailed in this assessment will be used to help calibrate stormwater treatment BMP performance assumptions in PLRM. RSWMP sites will also provide data to aid in verifying the PLRM estimated changes in load are consistent with observed changes.

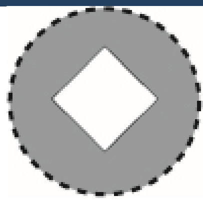
Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – Objective determination of "attainment" status for standards without a specific target is a recurrent challenge both in the Region and in the larger field of monitoring and evaluation (M&E). The standard should be assessed against best practice for the establishment of standards and indicators for M&E, and amended as necessary to improve the evaluability of the standard and the information it provides for management. Development of any new standards should also consider the benefits of alignment with the standards and management strategies implemented through the Lake Tahoe TMDL program. The Lake Tahoe TMDL estimated that a 72 percent reduction in fine sediment particle load (from 3.5E+20 particles/year to 1.015E+20 particles/year) from urban sources would be required to achieve lake clarity standards (Lahontan and NDEP, 2010a). Standard revision should also consider simplification of the text of the existing standards to ensure that the desired outcomes are readily apparent to most readers. The construction of the current standard, which references load reduction "as necessary to achieve loading thresholds for tributaries and littoral and pelagic lake Tahoe" as the target for the standard is confusing and requires readers to look up other standards to understand the standard's objective.

Attain or Maintain Threshold – No changes recommended. The 2015 Findings & Program Recommendation Memo for the TMDL reported that no new findings relative to urban stormwater were reported in previous calendar year (Larsen and Kuchnicki, 2015b).

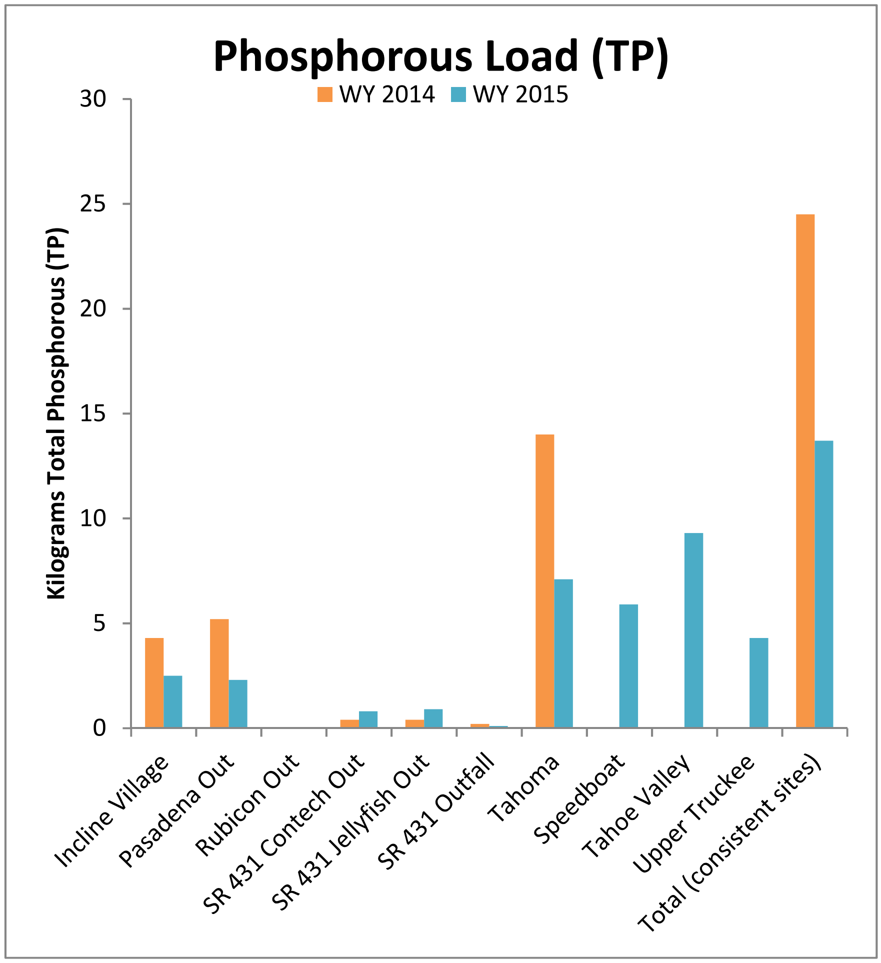
Surface Runoff: **Phosphorous Load**

Status	Chart



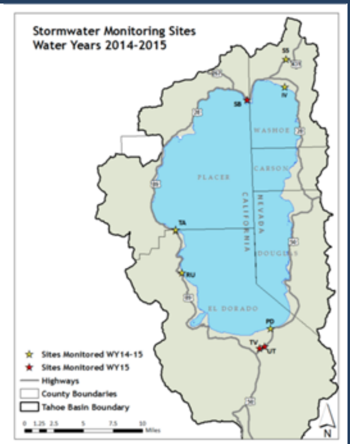
PHOSPHORUS LOAD

Status: **Insufficient Data to Determine Status**
Trend: **Insufficient Data to Determine Trend**
Confidence: **Low**



Total phosphorous load measured at outfalls around the Tahoe Basin. Total for "consistent sites" refers to sites that were monitored in both 2014 and 2015. Sites that have no data for 2014 were only installed for water year 2015. Source: Tahoe Resource Conservation District

Map



Map shows all stormwater monitoring locations during water years 2014 and 2015. Source: Tahoe Resource Conservation District

Data Evaluation and Interpretation

BACKGROUND

Relevance – This indicator measures the total phosphorous load delivered to Lake Tahoe and its' tributaries via direct surface runoff. Nitrogen and phosphorous nutrients are important to the growth and reproduction of plants, and they are considered a pollutant of concern in the Lake Tahoe Basin (Lahontan & NDEP, 2010a). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (Lahontan & NDEP, 2010a). Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis. Attached algae (i.e., periphyton) coat rocks in the nearshore, adversely affecting nearshore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). However, persistently high levels of algae in Lake Tahoe are considered undesirable. Phosphorus occurs naturally in the soils of the Lake Tahoe Basin, and is delivered to surface waters and Lake Tahoe through soil erosion and subsequent transport in streams and storm water, atmospheric deposition, and fertilizer runoff (Lahontan & NDEP, 2010a). The Lake Tahoe Total Maximum Daily Load (TMDL) estimated that a 46 percent reduction (from 2004 loading estimate) in total phosphorus load from urban upland sources over 65 years would be required to achieve the pelagic clarity standard.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category – Surface Runoff

Adopted Standards –

1. Reduce total annual nutrient and suspended sediment loads as necessary to achieve loading thresholds for tributaries and littoral and pelagic Lake Tahoe.

2. Tributaries - Reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe.

3. Littoral - Reduce the loading of dissolved inorganic nitrogen, dissolved phosphorus, iron, and other algal nutrients from all sources to meet the 1967 to 1971 mean values for phytoplankton primary productivity and periphyton biomass in the littoral zone.

4. Deep Water (Pelagic) Lake Tahoe - Reduce the loading of dissolved phosphorus, iron, and other algal nutrients from all sources as required to achieve ambient standards for primary productivity and transparency.

Type of Standard – Management and Numerical

Indicator (Unit of Measure) – Kilograms/year of total phosphorous

Human & Environmental Drivers – Landscape modification (e.g. impervious cover such as roads or residential and commercial development or logging) influences the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. Sediment and nutrient load in stormwater runoff is influenced by the type, magnitude, and location of landscape modifications and the extent to which practices to mitigate potential impacts (e.g. water quality BMPs) are in place. A variety of natural factors also influence the load of sediment and nutrients in stormwater including climate, weather, landscape topography, and vegetation. The TMDL estimated that 26 percent of total phosphorus load originates from urban upland sources.

MONITORING AND ANALYSIS

Monitoring Partners – Stormwater monitoring is done under the Implementers Monitoring Program (IMP) led by the Tahoe Resource Conservation District in cooperation with El Dorado County, Placer County, City of South Lake Tahoe, California Department of Transportation, Douglas County, Washoe County, Nevada Tahoe Conservation District, and Nevada Department of Transportation. Funding is provided by the USDA Forest Service Lake Tahoe Basin Management Unit and the California State Water Resources Control Board.

Monitoring Approach – Monitoring under the IMP is guided by the Regional Stormwater Monitoring Program (RSWMP) framework and implementation plan (Tahoe RCD, 2015a). During water year 2014 five catchments were monitored for continuous flow and sampled for water quality at eleven monitoring stations: the outfalls of the five selected catchments, and the inflows to and outflows from selected BMPs located within three of those catchments. Three additional catchment outfalls were monitored in water year 2015. The catchments were chosen because of their direct hydrologic connectivity to Lake Tahoe, diversity of urban land uses, range of sizes, and a reasonably equitable distribution among the participating jurisdictions. BMP effectiveness sites were selected because of their potential efficacy in treating storm water runoff characteristic of the Lake Tahoe Basin, the broad interest in, and lack of conclusive data regarding the efficiency of the selected BMPs in reducing runoff volumes and pollutant loads, especially fine sediment particles, and the importance of determining the maintenance required to retain effectiveness. The monitoring protocol is described in detail in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe Resource Conservation District, 2015).

Analytic Approach – Load is based on estimated load at station outflow as reported in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe RCD, 2015b). Details on the analytic protocols used to estimate load are included available in the Regional Stormwater Monitoring Program (RSWMP) Framework and Implementation Guidance Document (Tahoe RCD, 2015a).

INDICATOR STATE

Status – Insufficient data to determine status. Data reported in this assessment is load as measured at specific catchments and no overall estimate of load was available at this time. Load reduction estimates and condition assessment commitments are documented in the credit accounting platform of the TMDL. A more robust picture of load in stormwater will be available in March 2017 after credit declaration and associated verification associated with the first TMDL milestone is complete. In sites that monitored in both the 2014 and 2015 water years total phosphorous load was 24.5 kilograms in 2014 and 13.7 kilograms in 2015. Three additional sites were added in water year 2015 and total monitored load was 33.2 kilograms in water year 2015. The two years are not comparable because three additional sites were added in 2015 and total surface volume was much greater in 2014.

Trend – Insufficient data to determine trend. The first Region wide load reduction estimates are expected in March 2017. These estimates will serve as the basis for evaluating trend in future evaluations.

Confidence –

> **Status** – Low. Where insufficient data exists to determine status, confidence in the status determination is low. There is moderate confidence in the data because it is collected using widely recognized, standardized national protocols (see monitoring approach) with quality assurance/quality control procedures. Only a small proportion of the outflows are sampled and not all runoff events are sampled. Regional estimates of overall load and load reduction are not available at this time.
> **Trend** – Low. No trend assessment was performed because both the nature and limited duration of the data preclude trend assessment.
> **Overall** – Low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – The TRPA Regional Plan requires the use of best management practices (BMPs) for new residential and commercial development, and BMP retrofit regulations for developed properties. For example, section 60.4.6.A.1 of TRPA Code of Ordinances requires properties be able to infiltrate the 20-year, one-hour storm into groundwater. The Regional Plan is also designed to limit growth and shift development from sensitive to less sensitive lands. All of these requirements contribute to reducing fine sediment and nutrient runoff from developed areas. The Regional Transportation Plan complements these by encouraging use of public transit and alternative transportation modes, and reducing reliance on private automobile. Water quality mitigation fees, collected on projects that create new cover, support erosion and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Issued 18,076 BMP certificates to developed commercial, multifamily and single family residential properties.
- TRPA's grant funded Stormwater Management Program focuses compliance and maintenance verification activities on priority commercial and large multi-family residential properties in

coordination with local jurisdictions. In 2015, Stormwater Management Program staff notified 2,441 parcel owners with BMP Certificates issued more than five years ago that maintenance was due and re-issued 186 BMP Certificates following maintenance verification.

- Completed street sweeping on 24,644 miles of roads.
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road.

The Stormwater Management Program leads annual BMP trainings for contractors, local jurisdictions and real estate professionals. The Stormwater Management Program also authors articles in "Tahoe In-Depth", and participates in a variety of public workshops and events to increase BMP awareness and promote proper design, installation and maintenance. Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do maintain a healthy environment. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals.

TMDL Management System Handbook guides the actions of agencies in the Region to reduce inputs of nutrients and sediments into Lake Tahoe (Lahontan and NDEP, 2014). As part of the TMDL each jurisdiction in the Region prepares a load reduction plan (pollutant load reduction plans in California and stormwater load reduction plans in Nevada) that detail the steps to achieve the specified load reductions. The Lake Tahoe TMDL estimated that a 10 percent reduction in total phosphorous load from urban sources would be required to achieve lake clarity standards (Lahontan and NDEP, 2010b).

Effectiveness of Programs and Actions – Each year the actions of the TMDL implementation partners are summarized and evaluated in the TMDL Performance Report. The pollutant tracking system for urban stormwater was being refined during the reporting period. Future evaluations will use the estimated reductions in urban source pollutants to assess the effectiveness of programs and actions implemented to reduce pollutant load from urban sources (Larsen and Kuchnicki, 2015a).

TRPA infiltration requirements were designed to strike a balance between environmental benefit and cost. A 2011 synthesis of existing knowledge found diminishing returns from increasing storm retention capacity beyond the 20-year, one-hour storm. The synthesize found that doubling retention capacity required to handle the 20-year, one-hour storm would only increase annual retention by seven percent (2ndNature and NHC, 2011). TRPA Code Section 60.4.6.A.1 further requires a one-foot separation between seasonal high groundwater and the bottom of an infiltration system to protect groundwater resources.

In the long term, partners will be able to measure overall load reductions from surface runoff. However, with currently available data, the primary way to measure the effectiveness of programs and actions is to assess the effectiveness of BMP's at reducing sediment and nutrient loads. The currently available data enables the assessment of the effectiveness of individual BMP's in reducing sediment and nutrient loads. The following results on the effectiveness of BMP's were reported in the 2014-2015 Stormwater Monitoring Report (Tahoe Resource Conservation District, 2015):

- Selected BMP catchment basins (Pasadena, Rubicon, SR 431 Contech, SR 431 Jellyfish) decreased total phosphorus load by 30 percent in water year 2014 and 23 percent in water year 2015

Further analysis of program effectiveness, may be possible by looking at response of secondary indictors (e.g. suspended sediment in tributaries and lake clarity) that are the subject of the standards.

Interim Target – Insufficient data is available to set an interim target at this time.

Target Attainment Date – Insufficient data is available to set a target attainment date.

RECOMMENDATIONS

Analytic Approach – The Lake Tahoe TMDL requires urban jurisdictions to report pollutant load estimates using the Lake Clarity Crediting Program and associated tools. The pollutant load reduction model (PLRM) provides a consistent method for evaluating both baseline and expected conditions associated with pollutant load reduction actions. The model provides estimates for the expected benefits of actions and on-the-ground field verification methods confirm treatment facility and roadway conditions are consistent with modelled parameters. Load reduction estimates and condition assessment commitments are documented in the credit accounting platform. Credit declaration and associated verification to document the first TMDL milestone is expected in March 2017. The raw RSWMP data detailed in this assessment will be used to help calibrate stormwater treatment BMP performance assumptions in PLRM. RSWMP sites will also provide data to aid in verifying the PLRM estimated changes in load are consistent with observed changes.

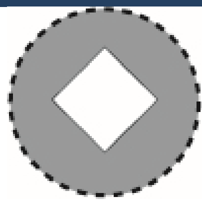
Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – Objective determination of "attainment" status for standards without a specific target is a recurrent challenge both in the Region and in the larger field of monitoring and evaluation (M&E). The standard should be assessed against best practice for the establishment of standards and indicators for M&E, and amended as necessary to improve the evaluability of the standard and the information it provides for management. Development of any new standards should also consider the benefits of alignment with the standards and management strategies implemented through the Lake Tahoe TMDL program. The Lake Tahoe TMDL estimated that a 46 percent reduction in total phosphorus load, from 18 Metric Tonnes per year (MT/yr) to 9.72 MT/yr, from urban sources would be required to achieve lake clarity standards (Lahontan and NDEP, 2010b). Standard revision should also consider simplification of the text of the existing standards to ensure that the desired outcomes are readily apparent to most readers. The construction of the current standard, which references load reduction "as necessary to achieve loading thresholds for tributaries and littoral and pelagic lake Tahoe" as the target for the standard is confusing and requires readers to look up other standards to understand the standard's objective.

Attain or Maintain Threshold – No changes recommended. The 2015 Findings & Program Recommendation Memo for the TMDL reported that no new findings relative to urban stormwater were reported in previous calendar year (Larsen and Kuchnicki, 2015b).

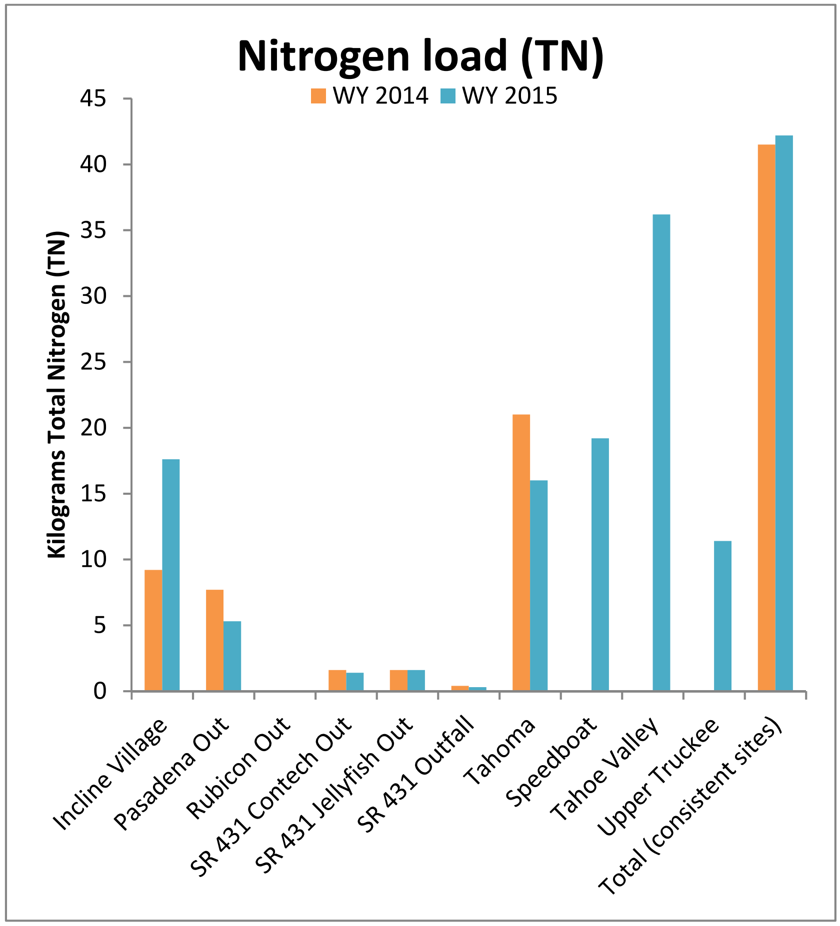
Surface Runoff: **Nitrogen Load**

Status	Chart



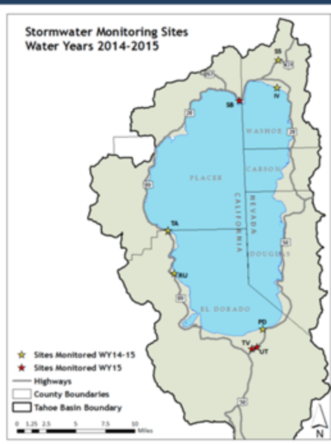
NITROGEN LOAD

Status: **Insufficient Data to Determine Status**
Trend: **Insufficient Data to Determine Trend**
Confidence: **Low**



Total Nitrogen load measured at outfalls around the Tahoe Basin. Total for "consistent sites" refers to sites that were monitored in both 2014 and 2015. Sites that have no data for 2014 were only installed for water year 2015. Source: Tahoe Resource Conservation District

Map



Map shows all stormwater monitoring locations during water years 2015 and 2015. Source: Tahoe Resource Conservation District

Data Evaluation and Interpretation

BACKGROUND

Relevance – This indicator measures the total nitrogen delivered to Lake Tahoe via seven monitored streams (reported as total nitrogen load). Nitrogen is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan and NDEP 2010). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (Lahontan and NDEP 2010). Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis. Attached algae (i.e., periphyton) coat rocks in the near-shore, adversely affecting nearshore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). However, persistently high levels of algae in Lake Tahoe are considered undesirable. Nitrate and nitrite are inorganic forms of nitrogen that are directly available for use by plants, whereas total nitrogen includes all organic and inorganic forms of nitrogen that are directly and indirectly available to plants. Nitrogen occurs naturally in the soils of the Lake Tahoe Region, but organic nitrogen primarily comes from the decomposition of plant material. Atmospheric deposition of automobile exhaust is considered a primary source of inorganic nitrogen to Lake Tahoe (Lahontan and NDEP 2010). Between 40 and 80 percent of the total organic nitrogen load is dissolved organic nitrogen (Coats and Goldman, 2001). If only a fraction of the dissolved organic nitrogen is biologically available, its importance as a nitrogen source for algal growth would outweigh that of dissolved inorganic nitrogen (equals nitrate plus nitrite plus ammonium). The availability of dissolved organic nitrogen from urban runoff varied from 48 to 70 percent. The TMDL estimated that a 50 percent reduction (from 2004 loading estimate) in total nitrogen load from urban upland sources over 65 years would be required to achieve the pelagic clarity standard.

TRPA Threshold Category – Water Quality

TRPA Threshold Indicator Reporting Category – Surface Runoff

Adopted Standards –

1. Reduce total annual nutrient and suspended sediment loads as necessary to achieve loading thresholds for tributaries and littoral and pelagic Lake Tahoe.

2. Tributaries - Reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe.

3. Littoral - Reduce the loading of dissolved inorganic nitrogen, dissolved phosphorus, iron, and other algal nutrients from all sources to meet the 1967 to 1971 mean values for phytoplankton primary productivity and periphyton biomass in the littoral zone.

4. Deep Water (Pelagic) Lake Tahoe - Reduce the loading of dissolved phosphorus, iron, and other algal nutrients from all sources as required to achieve ambient standards for primary productivity and transparency.

Type of Standard – Management and Numerical

Indicator (Unit of Measure) – Kilograms/year of total nitrogen load.

Human & Environmental Drivers – Landscape modification (e.g. impervious cover such as roads or residential and commercial development or logging) influences the volume of runoff, erosion rates, and the ability of the watershed to retain sediment and nutrients. Sediment and nutrient load in stormwater runoff is influenced by the type, magnitude, and location of landscape modifications and the extent to which practices to mitigate potential impacts are in place. A variety of natural factors also influence the load of sediment and nutrients in stormwater including climate, weather, landscape topography, and vegetation. The Lake Tahoe TMDL estimated that urban upland areas contribute 63 metric tons of total nitrogen to the lake annually, 18 percent of annual nitrogen load to the lake (Lahontan and NDEP, 2010a). Atmospheric deposition is the largest contributor (218 tons) of total nitrogen to the lake (Lahontan and NDEP, 2010a).

MONITORING AND ANALYSIS

Monitoring Partners – Stormwater monitoring is done under the Implementers' Monitoring Program (IMP) led by the Tahoe Resource Conservation District in cooperation with El Dorado County, Placer County, City of South Lake Tahoe, California Department of Transportation, Douglas County, Washoe County, Nevada Tahoe Conservation District, and Nevada Department of Transportation. Funding is provided by the USDA Forest Service Lake Tahoe Basin Management Unit and the California State Water Resources Control Board.

Monitoring Approach – Monitoring under the IMP is guided by the Regional Stormwater Monitoring Program (RSWMP) framework and implementation plan (Tahoe RCD, 2015a). During water year 2014 five catchments were monitored for continuous flow and sampled for water quality at eleven monitoring stations: the outfalls of the five selected catchments, and the inflows to and outflows from selected BMPs located within three of those catchments. Three additional catchment outfalls were monitored in water year 2015. The catchments were chosen because of their direct hydrologic connectivity to Lake Tahoe, diversity of urban land uses, range of sizes, and a reasonably equitable distribution among the participating jurisdictions. BMP effectiveness sites were selected because of their potential efficacy in treating storm water runoff characteristic of the Lake Tahoe Basin, the broad interest in, and lack of conclusive data regarding the efficiency of the selected BMPs in reducing runoff volumes and pollutant loads, especially fine sediment particles, and the importance of determining the maintenance required to retain effectiveness. The monitoring protocol is described in detail in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe Resource Conservation District, 2015).

Analytic Approach – Load is based on estimated load at station outflow as reported in the Annual Stormwater Monitoring Report Water Years 2014-2015 (Tahoe RCD, 2015b). Details on the analytic protocols used to estimate load are included available in the Regional Stormwater Monitoring Program (RSWMP) Framework and Implementation Guidance Document (Tahoe RCD, 2015a).

INDICATOR STATE

Status – Insufficient data to determine status. Data reported in this assessment is load as measured at specific catchments and no overall estimate of load was available at this time. Load reduction estimates and condition assessment commitments are documented in the credit accounting platform of the TMDL. A more robust picture of load in stormwater will be available in March 2017 after credit declaration and associated verification associated with the first TMDL milestone is complete. Total nitrogen at all monitoring location outfalls was 41.5 kilograms for water year 2014 and 109 kilograms for water year 2015. The two years are not comparable because three additional sites were added in 2015 and total surface volume was much greater in 2014.

Trend – Insufficient data to determine trend. Stormwater monitoring under the IMP component of RSWMP began in 2014. The IMP of RSWMP is currently funded through 2019 by SNPLMA, and trend assessments are expected to be included in future evaluations.

Confidence –

> **Status** – Low. Where insufficient data exists to determine status, confidence in the status determination is low. There is moderate confidence in the data because it is collected using widely recognized, standardized national protocols (see monitoring approach) with quality assurance/quality control procedures. Only a small proportion of outflows are sampled and not all runoff events are sampled. Regional estimates of overall load and load reduction are not available at this time.
> **Trend** – Low. No trend assessment was performed because both the nature and limited duration of the data preclude trend assessment.
> **Overall** – Low.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – Urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, BMP retrofit regulations for developed properties, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and storm water pollution control projects. Projects completed by EIP partners since between 2009 and 2015 have:

- Issued 18,076 BMP certificates to developed commercial, multifamily and single family residential properties.
- TRPA's grant funded Stormwater Management Program focuses compliance and maintenance verification activities on priority commercial and large multi-family residential properties in coordination with local jurisdictions. In 2015, Stormwater Management Program staff notified 2,441 parcel owners with BMP Certificates issued more than five years ago that maintenance was due and re-issued 186 BMP Certificates following maintenance verification.
- Completed street sweeping on 24,644 miles of roads.
- Retrofitted 120.55 miles of road and decommissioned an additional 7.4 miles of road.

Public outreach and educational campaigns (such as the "Take Care" campaign) highlight for residents and visitors what they can do maintain a healthy nearshore environment. Between 2012 and 2015 the South Tahoe Environmental Education Coalition delivered 36 educational programs and reached nearly 30,000 individuals. The Stormwater Management Program provides annual BMP trainings for contractors, local jurisdictions and real estate professionals, authors articles in the Tahoe In-Depth publication, and participates in a variety of public workshops and events to increase BMP awareness and promote proper design, installation and maintenance.

The TMDL Management System Handbook guides the actions of agencies in the Region to reduce inputs of nutrients and sediments into Lake Tahoe (Lahontan and NDEP, 2014). As part of the TMDL each jurisdiction in the Region prepares a load reduction plan (pollutant load reduction plans in California and stormwater load reduction plans in Nevada) that detail the steps to achieve the specified load reductions. The Lake Tahoe TMDL estimated that a 50 percent reduction in nitrogen load from urban sources would be required to achieve lake clarity standards (Lahontan and NDEP, 2010a).

Effectiveness of Programs and Actions – Each year the actions of the TMDL implementation partners are summarized and evaluated in the TMDL Performance Report. The pollutant tracking system for urban stormwater was being refined during the reporting period. Future evaluations will use the estimated reductions in urban source pollutants to assess the effectiveness of programs and actions implemented to reduce pollutant load from urban sources (Larsen and Kuchnicki, 2015a).

TRPA infiltration requirements were designed to strike a balance between environmental benefit and cost. A 2011 synthesis of existing knowledge found diminishing returns from increasing storm retention capacity beyond the 20-year, one-hour storm. The synthesize found that doubling retention capacity required to handle the 20-year, one-hour storm would only increase annual retention by seven percent (2ndNature and NHC, 2011). TRPA Code Section 60.4.6.A.1 further requires a one-foot separation between seasonal high groundwater and the bottom of an infiltration system to protect groundwater resources.

Nitrogen load in tributaries and overall lake clarity are secondary indictors of the effectives of reducing nitrogen in runoff and can be viewed in their respective indicator sheets.

In the long term, partners will be able to measure overall load reductions from surface runoff. However, with currently available data, the primary way to measure the effectiveness of programs and actions is to assess the effectiveness of BMP's at reducing sediment and nutrient loads. The following results on the effectiveness of BMP's were reported in the 2014-2015 Stormwater Monitoring Report (Tahoe Resource Conservation District, 2015):

- Selected BMP catchment basins (Pasadena, Rubicon, SR 431 Contech, SR 431 Jellyfish) decreased annual total nitrogen load by 39 percent in water year 2014 and 28 percent in water year 2015

Interim Target – Due to limited data duration, an interim target cannot be set at this time.

Target Attainment Date – Due to limited data duration, a target attainment date cannot be set at this time.

RECOMMENDATIONS

Analytic Approach – The Lake Tahoe TMDL requires urban jurisdictions to report pollutant load estimates using the Lake Clarity Crediting Program and associated tools. The Pollutant Load Reduction Model (PLRM) provides a consistent method for evaluating both baseline and expected conditions associated with pollutant load reduction actions. The model provides estimates for the expected benefits of actions and on-the-ground field verification methods confirm treatment facility and roadway conditions are consistent with modelled parameters. Load reduction estimates and condition assessment commitments are documented in the Credit Accounting Platform. Credit declaration and associated verification to document the first TMDL milestone is expected in March 2017. The raw RSWMP data detailed in this assessment will be used to help calibrate stormwater treatment BMP performance assumptions in PLRM. RSWMP sites will also provide data to aid in verifying the PLRM estimated changes in load are consistent with observed changes.

Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – Objective determination of "attainment" status for standards without a specific target is a recurrent challenge both in the Region and in the larger field of monitoring and evaluation (M&E). The standard should be assessed against best practice for the establishment of standards and indicators for M&E, and amended as necessary to improve the evaluability of the standard and the information it provides for management. Development of any new standards should also consider the benefits of alignment with the standards and management strategies implemented through the Lake Tahoe TMDL program. The Lake Tahoe TMDL estimated that a 50 percent reduction in nitrogen load (from 63 MT/yr to 31.5 MT/yr) from urban sources would be required to achieve lake clarity standards (Lahontan and NDEP, 2010a). Standard revision should also consider simplification of the text of the existing standards to ensure that the desired outcomes are readily apparent to most readers. The construction of the current standard, which references load reduction "as necessary to achieve loading thresholds for tributaries and littoral and pelagic lake Tahoe" as the target for the standard is confusing and requires readers to look up other standards to understand the standards objective.

Attain or Maintain Threshold – The 2015 Findings & Program Recommendation Memo for the TMDL reported that no new findings relative to urban stormwater were reported in previous calendar year (Larsen and Kuchnicki, 2015b). Continue to implement the programs of the TMDL.

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