TAHOE:
STATE OF THE LAKE
REPORT
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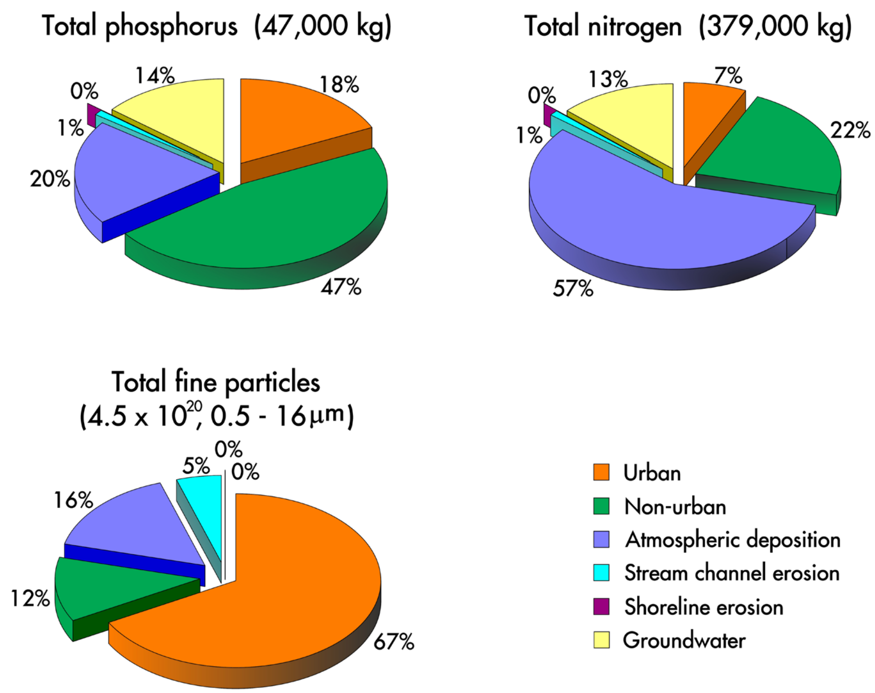
NUTRIENTS AND PARTICLES

UC DAVIS
Tahoe Environmental Research Center

Sources of clarity-reducing and blueness-reducing pollutants

Research has quantified the primary sources of nutrients (nitrogen and phosphorus) and fine particulate material that are causing Lake Tahoe to lose clarity and blueness in its upper waters. One of the primary contributors to clarity decline is extremely fine particles (in the size range of approximately 1–6 microns) in stormwater that originate from the urbanized watersheds, the streams that drain the majority of the basin's land area, and atmospheric deposition. For nitrogen, atmospheric deposition is the major source (57 percent). Phosphorus is primarily introduced by the urban (18 percent) and non-urban (47 percent) watersheds. These categories of pollutant sources form the basis of a strategy to restore Lake Tahoe's open-water clarity by management agencies, known as the Lake Tahoe Total Maximum Daily Load (TMDL) Program.



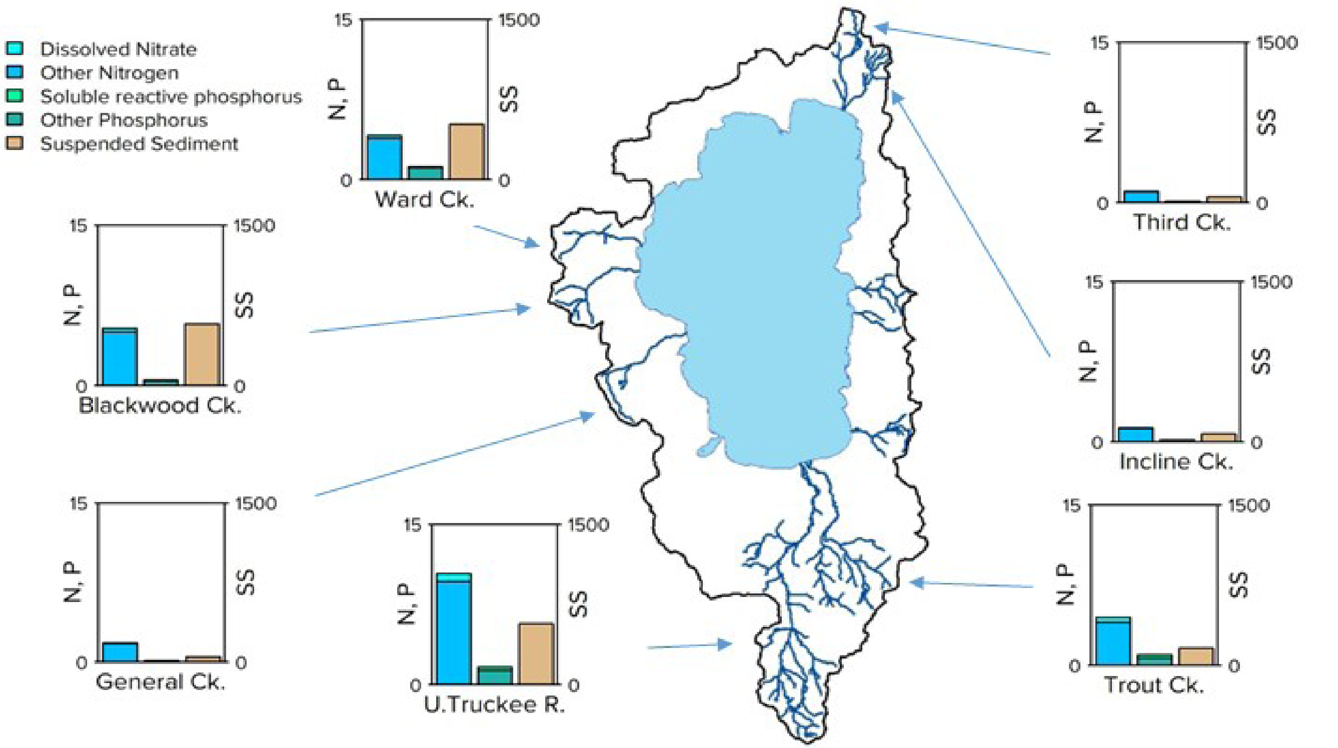
Pollutant loads from seven watersheds

In 2022

The Lake Tahoe Interagency Monitoring Program (LTIMP) measures nutrient and sediment input from seven of the 63 watershed streams. The streams are the Upper Truckee River, Trout Creek, Incline Creek, Third Creek, Ward Creek, Blackwood Creek, and General Creek. In 2022, the majority of stream phosphorus and nitrogen, as well as suspended sediments, came from the Upper Truckee River. This is often the case, but in some years, smaller streams, such as Ward Creek and Blackwood Creek, can also be significant contributors.

It should be noted that suspended sediments as represented in these data include all sediment sizes and is measured by weight. For clarity, it is the number of fine particles (in the range of 1–6 microns) that is important. These particles make up a very small fraction of the suspended sediment, but largely control lake clarity.

The LTIMP stream water quality program is supported by the Lahontan Regional Water Quality Control Board, the Tahoe Regional Planning Agency, the U.S. Geological Survey, and UC Davis TERC. TERC and the U.S. Geological Survey jointly collect and analyze the stream data.



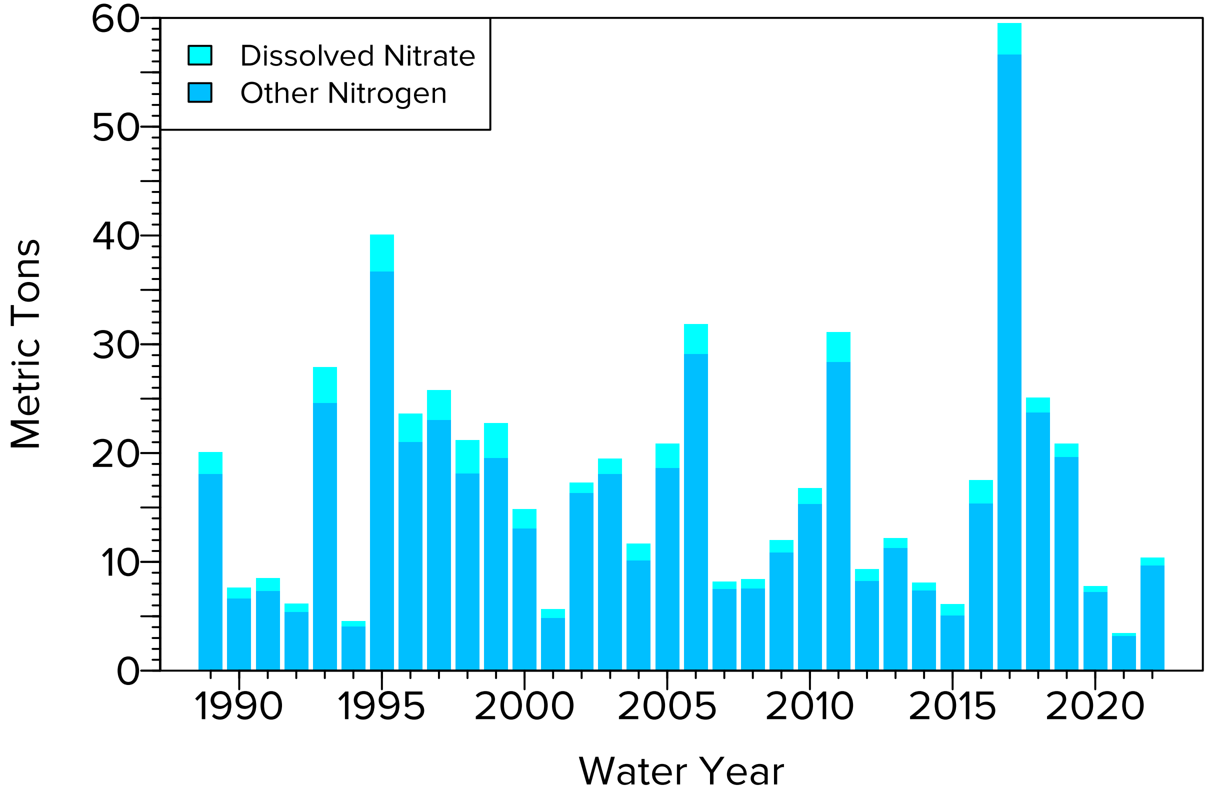
Nitrogen contribution by Upper Truckee River

Yearly since 1989

Nitrogen (N) is important because it, along with phosphorus (P), stimulates algal growth. The Upper Truckee River is the largest of 63 streams that flow into Lake Tahoe, contributing about 25 percent of the inflowing water. The river's estimated contribution of dissolved nitrate and the remainder of the total nitrogen load are shown here. Over the 34 years of record, the percentage of nitrate to total nitrogen has been in the range of 5–14 percent. The year-to-year variations primarily reflect changes in precipitation. For example, 1994 had 16.6 inches of precipitation and a low total nitrogen load of 4.6 MT, while 2017 had 68.9 inches of precipitation and a record high total nitrogen load of 59.5 MT.

In 2022, there were 32.7 inches of precipitation and the total nitrogen load from the Upper Truckee River of 11.1 MT. Nitrate load was 0.71 MT. The long-term mean annual total nitrogen load is 17.3 MT/yr while for nitrate it is 1.6 MT. (One metric ton (MT) = 2,205 pounds.)

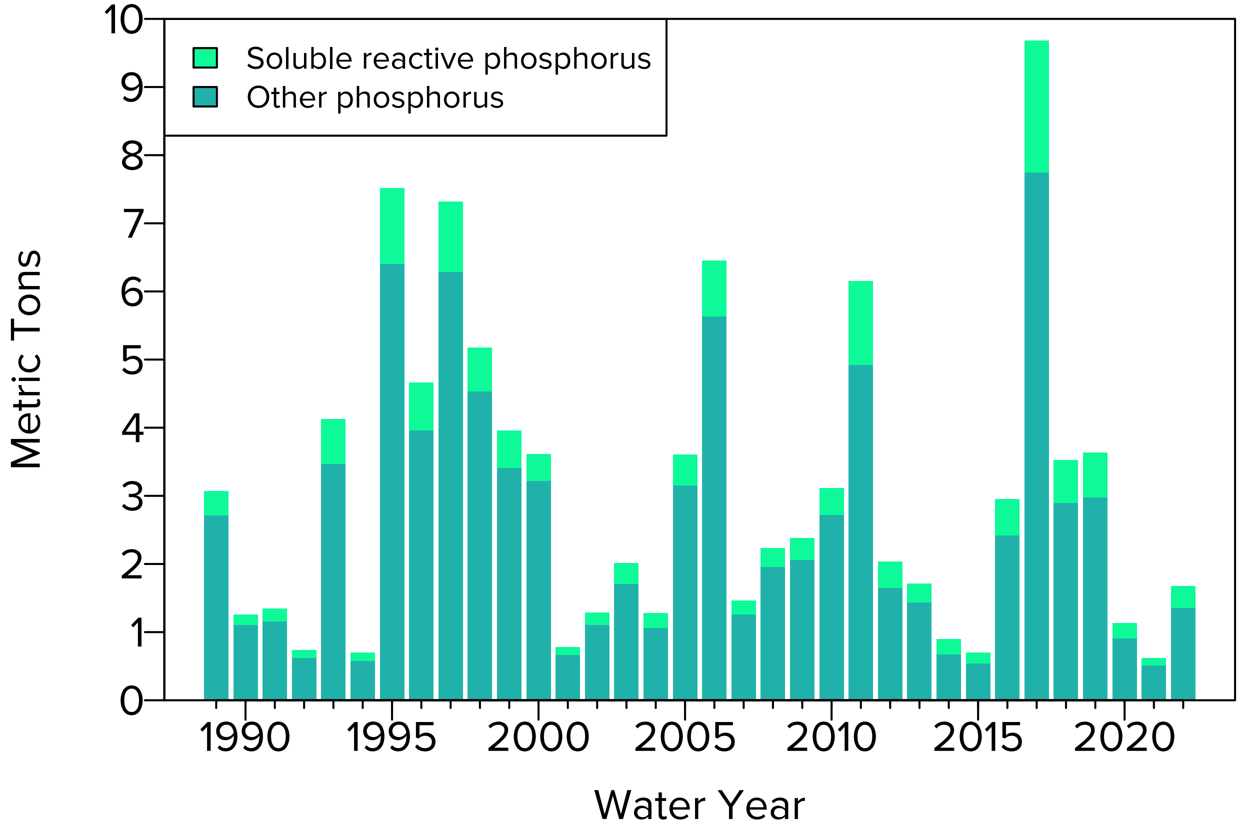
Data source: TERC and U.S. Geological Survey stream monitoring.



Phosphorus contribution by Upper Truckee River

Yearly since 1989

Soluble reactive phosphorus (SRP) is the fraction of total phosphorus immediately available for algal growth. As with nitrogen (Fig. 9.3), the year-to-year variation in estimated loads largely reflects the changes in precipitation. Near-average precipitation in 2022 resulted in a total phosphorus load of 1.68 MT and SRP load of 0.32 MT, the lowest values on record, likely due to the record low stream flows. These compare with the long-term averages of 3.02 and 0.47 MT respectively. Over the 34 years of record, the percentage of SRP to total phosphorus load has been in the range of 11–25 percent. Decreasing nutrient inputs are fundamental to restoring Lake Tahoe's iconic blueness. Total phosphorus is the sum of SRP and other phosphorus, which includes organic phosphorus and phosphorus associated with particles. (One metric ton (MT) = 2,205 pounds.) Data source: TERC and U.S. Geological Survey stream monitoring.

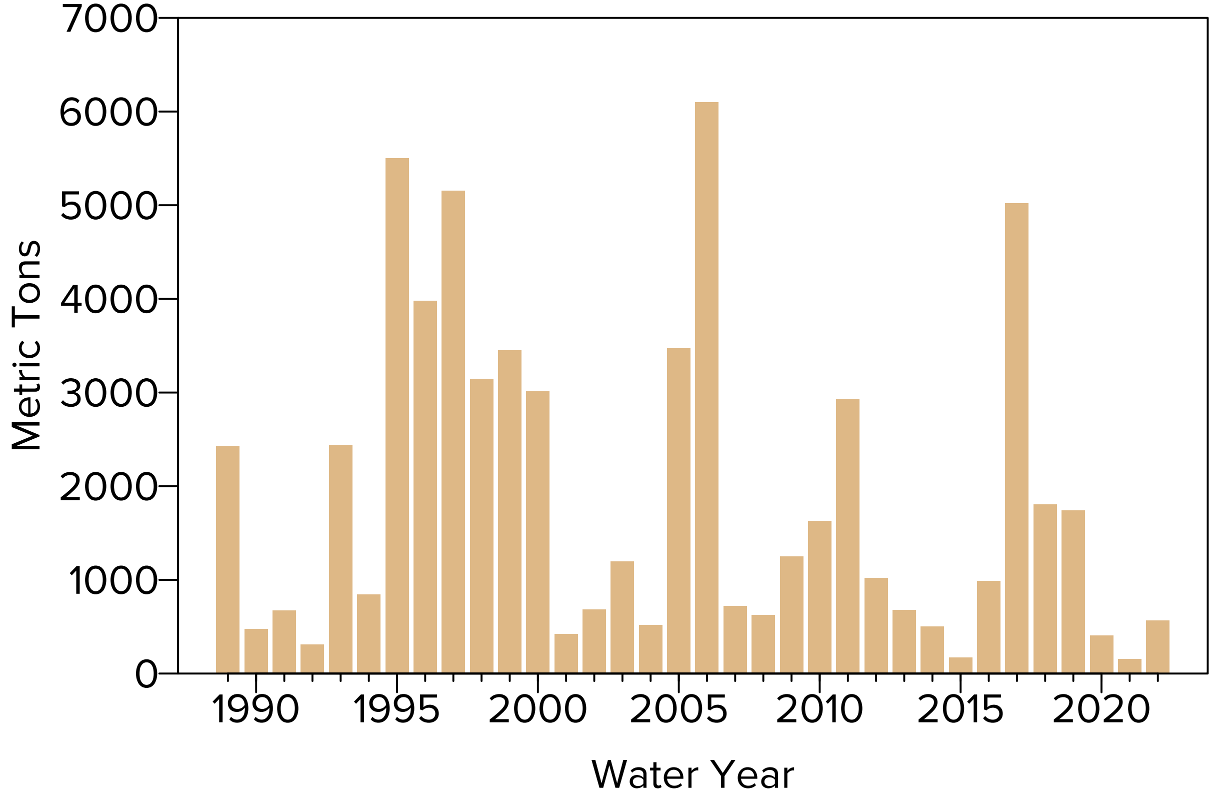


Suspended sediment contribution by Upper Truckee River

Yearly since 1989

The load of total suspended sediment delivered to the lake by the Upper Truckee River is related to landscape condition and erosion as well as to precipitation and stream flow. Inter-annual variation in sediment load over shorter time scales is more related to the latter. Plans to restore lake clarity emphasize reducing loads of very fine suspended sediment (in the size range of 1–6 microns in diameter) from urbanized areas. By contrast, efforts to restore natural stream function, watershed condition, and restoration of habitat for plants and wildlife, focus on reducing loads of total sediment regardless of size. In 2022, the estimated suspended sediment load from the Upper Truckee River was 569 MT. The highest load ever recorded was 6,100 MT in 2006. The average annual load is 1,882 MT. (One metric ton (MT) = 2,205 pounds.)

Data source: TERC and U.S. Geological survey stream monitoring.

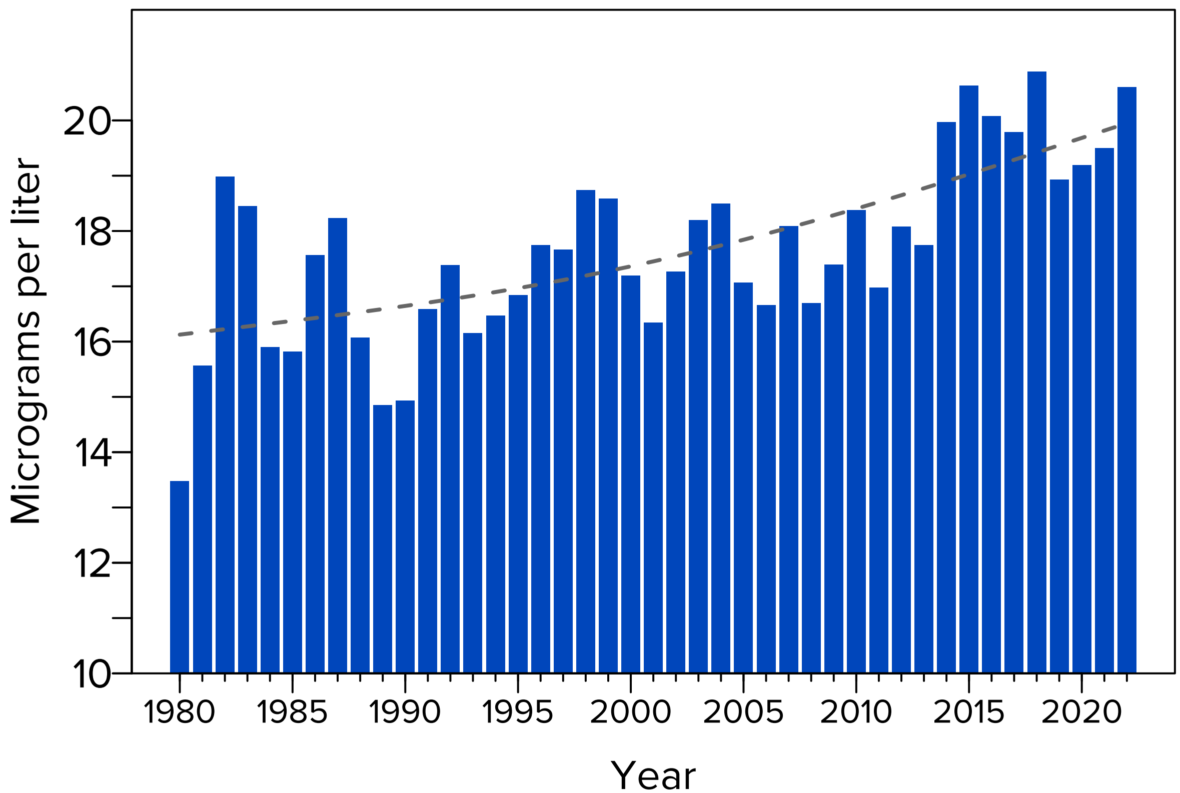


Lake nitrate concentration

Yearly since 1980

Until 2012, the volume-weighted annual average concentration of nitrate-nitrogen had remained relatively constant year-to-year, ranging between 13–19 micrograms per liter. Since that time, however, the lake's nitrate concentration has been increasing, as evident in the trend line produced with a Generalized Additive Model. In 2022, the volume-weighted annual average concentration of nitrate-nitrogen was 20.6 micrograms per liter. In 2019, lake nitrate concentration declined due to the deep mixing that redistributed the nitrate built up at the bottom of lake for the previous eight years and made it available for algal uptake. In 2021 and 2022, with only shallow mixing, nitrate has recommenced accumulating, resulting in the increasing in-lake nitrate concentration. Another factor in the last several years is the additional atmospheric nutrient loading due to wildfire smoke engulfing the region. The impact of the 2021 wildfires is the subject of a continuing analysis.

Data source: TERC lake monitoring.



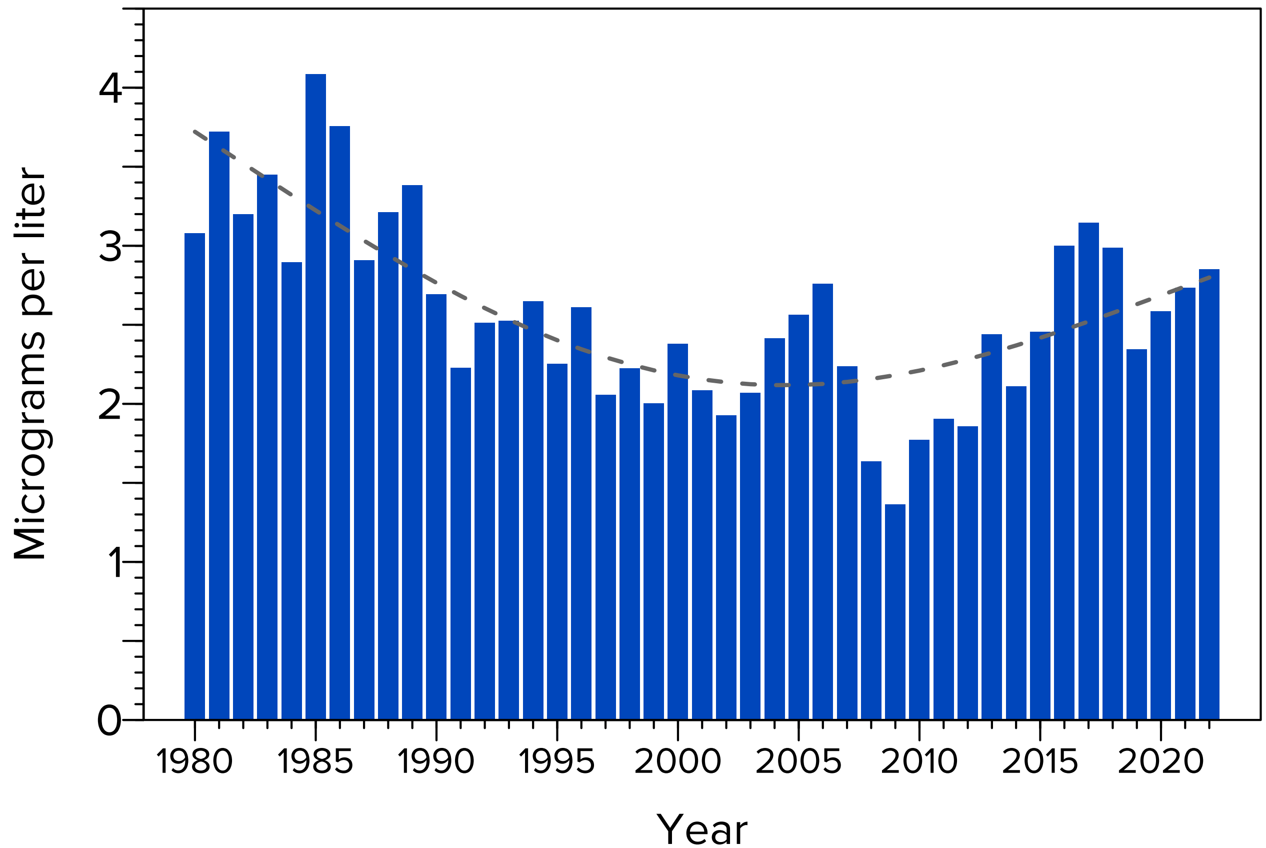
Lake total hydrolyzable phosphorus concentration

Yearly since 1980

Phosphorus naturally occurs in Tahoe Basin soils and enters the lake from soil disturbance and erosion. Total hydrolysable phosphorus (THP) is a measure of the fraction of phosphorus that algae can use to grow. It is similar to the SRP that is measured in the streams. Since 1980, THP has declined, although in the last 17 years the values have been increasing.

In 2022, the volume-weighted annual average concentration of THP was 2.85 micrograms per liter. Another factor in the last several years is the additional atmospheric nutrient loading due to wildfire smoke engulfing the region. The impact of the 2021 wildfires is the subject of a continuing analysis.

Data source: TERC lake monitoring.



Lake fine particle concentration

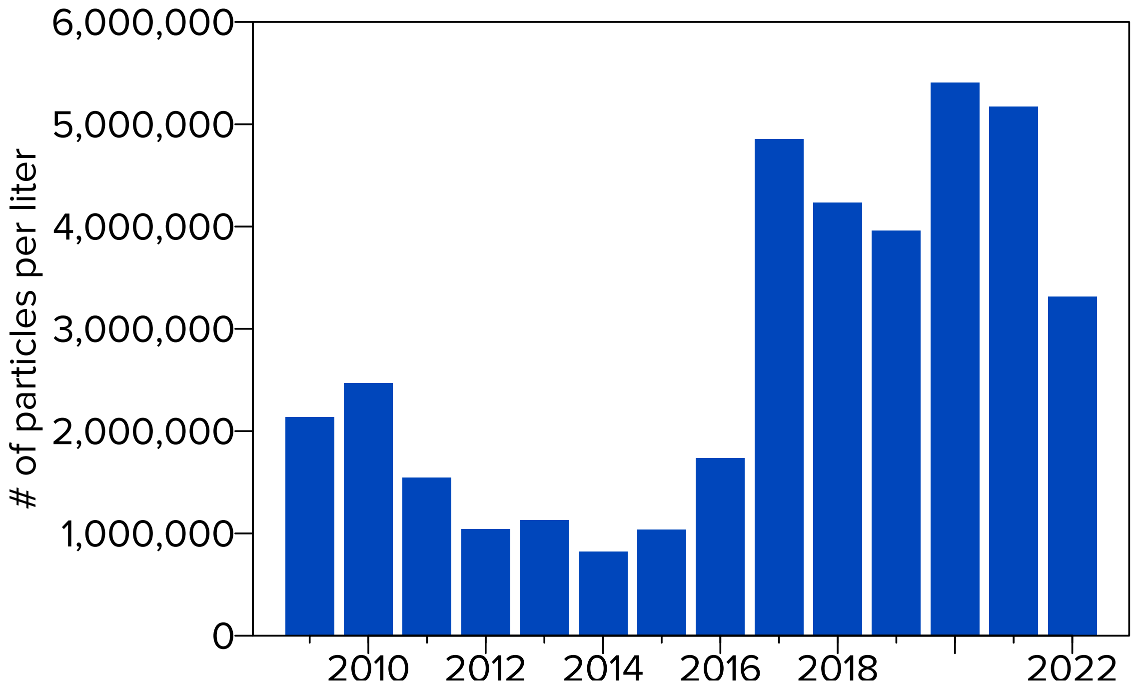
Yearly since 2009

Fine particles in the size range of approximately 1–6 microns in the upper 50 meters are principally responsible for the attenuation of visible light and the consequent loss of lake clarity. These particles can be inorganic (clay and silt) or organic (phytoplankton). As particles in this size range settle slowly, their removal from the lake depends, in large part, on their aggregation into larger particles. The settling rate of a particle depends on the square of its diameter. Larger, aggregated particles will settle disproportionately faster.

2017 was an extremely wet year and there was a large increase in fine particles delivered to Lake Tahoe from the streams in the watershed. This would account for the step change in concentration evident between 2016 and 2017. The continued high average concentration since that time is difficult to explain. In 2020 and 2021, both of which were low precipitation years, displayed an increase in particle concentration beyond the 2017 level.

In 2022, the annual fine particle concentration fell to their lowest concentration since 2017 but are still higher than earlier years. Loading of particles from wildfires and streams were lower in 2022. A preliminary analysis comparing rates of aggregation of lake particles, suggests that aggregation rates have not changed significantly over the period of the record. Water samples are taken monthly at the MLTP (mid-lake) station at 13 depths from the surface to 1,480 feet.

Data source: TERC lake monitoring.



Lake fine particle concentration

Monthly since 2015

Fine particles in the size range of approximately 1–6 microns in the upper 50 meters are principally responsible for the attenuation of visible light and the consequent loss of lake clarity. These particles can be inorganic (clay and silt) or organic (phytoplankton).

The data indicate the annual increase of fine particles at mid-year were due to a combination of particle influx from to spring snowmelt and a consequent algal bloom. In 2017, a historically wet year, there was a large increase in fine particles delivered to Lake Tahoe from the streams in the watershed. This would account for the step change in concentration evident between 2016 and 2017. The continued high average concentration since that time is difficult to explain. 2020 and 2021, both of which were low precipitation years, displayed an increase in particle concentration beyond the 2017 level.

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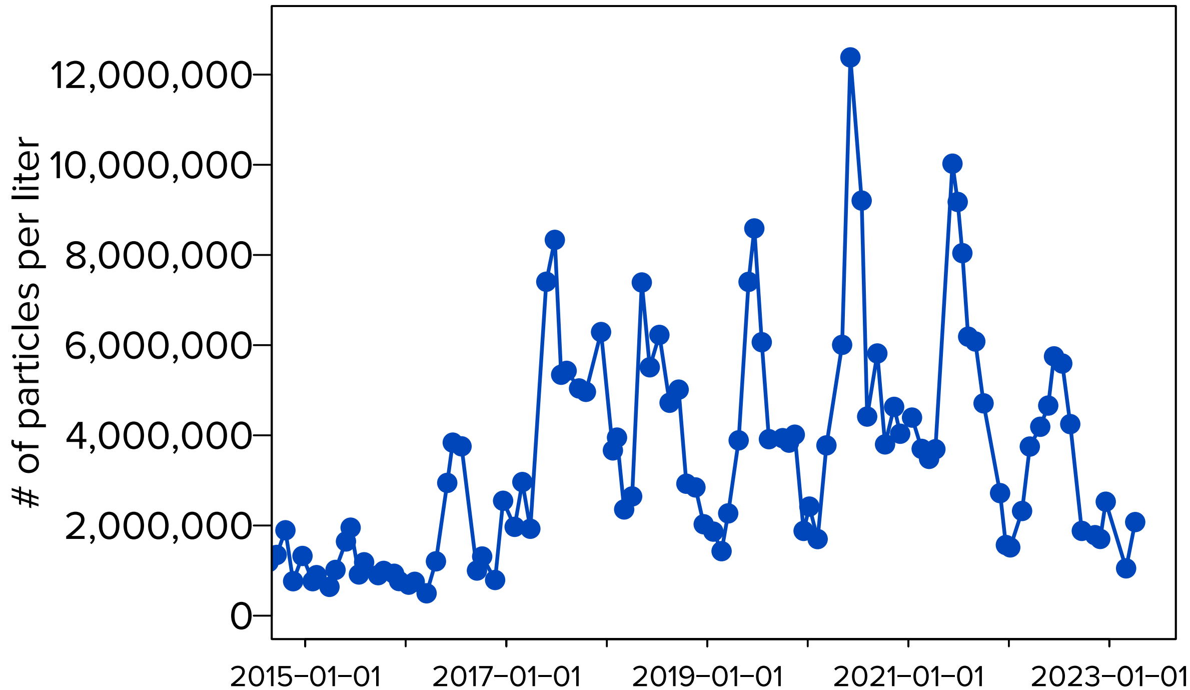
Water samples are taken monthly at the MLTP (mid-lake) station at 13 depths from the surface to 1,480 feet. Here, data from 0 m, 10 m, and 50 m were utilized.

Data source: TERC lake monitoring.



Nitrate distribution

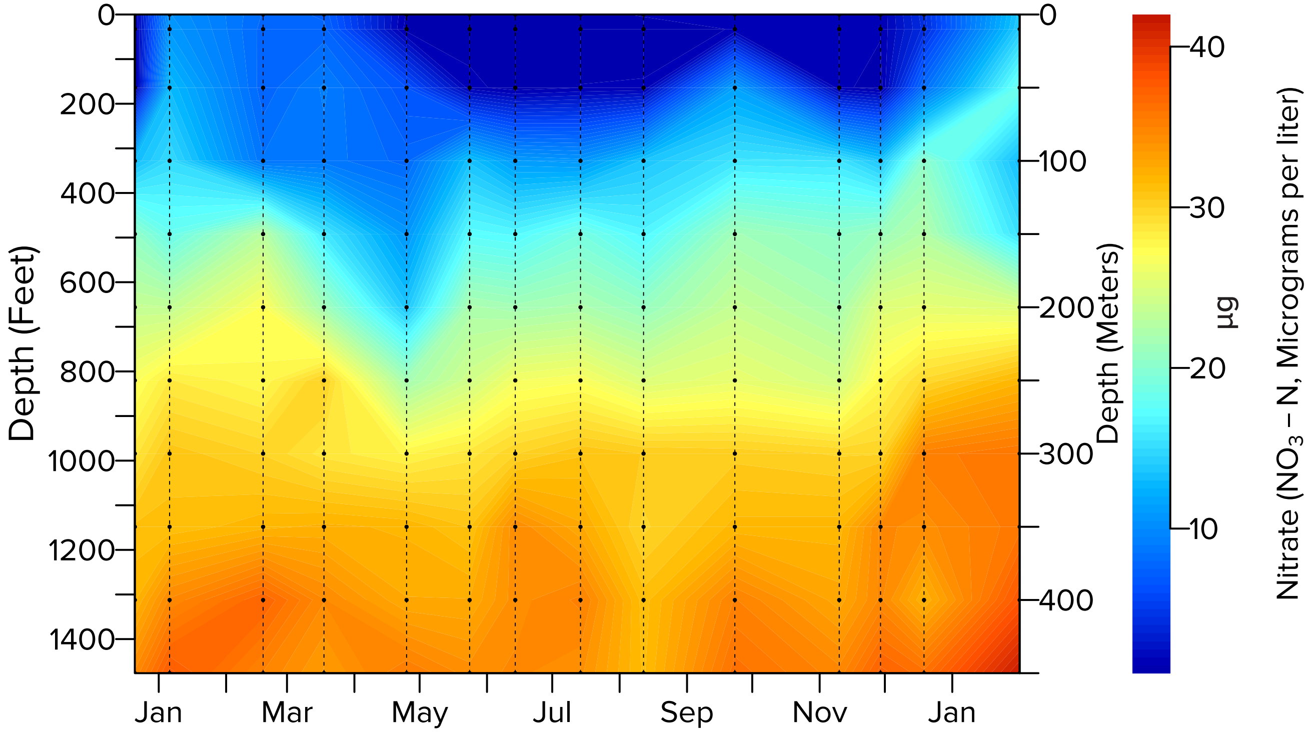
In 2022

Water samples are collected approximately every month (on dates indicated by the dashed lines) at 13 depths (indicated by the dots) at the MLTP station in the middle of the lake. These samples are the processed and analyzed in the TERC laboratory for nutrient concentrations. Here the nitrate concentration is shown in the form of color contours.

Most evident is the persistence of the high nitrate region in the lower part of the lake. It is evident that the limited extent of deep mixing in 2022 did not homogenize the nitrate distribution. Instead, a "nitricline" is evident between depths of 400 and 800 feet through much of the year.

Although most of the introduced nitrate enters at the surface through atmospheric deposition, it is rapidly taken up by the algae and surface concentrations remain generally low. As algae sink and decompose, the nitrate they consumed reappears deep in the lake. At these depths, however, there is insufficient light for algae to grow and to use these nutrients.

Data source: TERC lake monitoring.



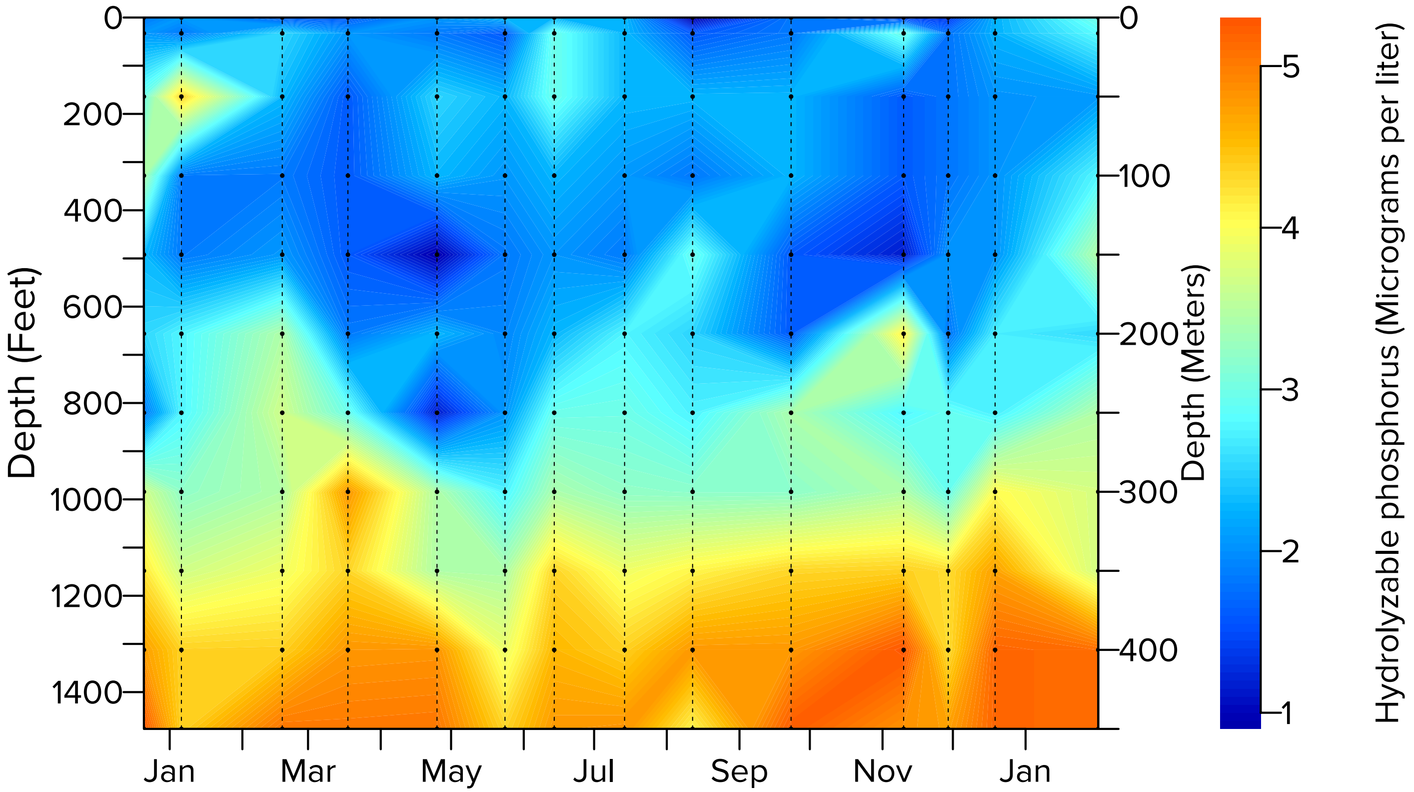
Total hydrolyzable phosphorus distribution

In 2022

Water samples are collected approximately every month (on dates indicated by the dashed lines) at 13 depths (indicated by the dots) at the MLTP station in the middle of the lake and analyzed in the TERC laboratory for nutrient concentrations. Here the total hydrolysable phosphorus (THP) concentration, the fraction of phosphorus that can be readily used by algae, is shown in the form of color contours.

Phosphorus mainly entered the lake in association with fine particles during runoff events in May through June. The relatively elevated values near the surface in June suggest that in 2022, nitrogen was the nutrient that limited algal growth, rather than phosphorus early in the summer. The elevated concentrations of phosphorus deep in the lake throughout the year were the result of the absence of deep mixing in 2022.

Data source: TERC lake monitoring.



Fine particle distribution

In 2022

Water samples are collected approximately monthly (on dates indicated by the dashed lines) at 13 depths (indicated by the dots) at the MLTP station. These samples are analyzed in the TERC laboratory for concentrations of fine particles in 15 different bin sizes. The distributions of fine particles (in the size range of 1–6 microns) are shown in the form of color contours. Particles can be inorganic particles such as clay or silt or organic particles such as very small algal diatom particles.

Unlike the nutrients in Figures 9.9 and 9.10, fine particles are in low concentrations deep in the lake throughout the year. The entry of particles in the upper part of the lake (above 300 ft) associated with spring snowmelt is evident in May through August. Remarkably in 2022, there was a large decline in the particle concentration in the upper 300 feet of the lake to levels below which have been observed in the recent years. This is consistent with the very high Secchi depths that were recorded in the last part of 2022 (See Fig. 11.4). The particles do not decrease in the upper layer in the same way as nitrogen or phosphorus, as they are not taken up by algal growth. Instead, fine inorganic particles gradually clump together (aggregate) which allows them to settle to the lake bottom more rapidly. Additionally, they can be removed by zooplankton grazing.

Data source: TERC lake monitoring.