2024 Lake Tahoe Clarity Report

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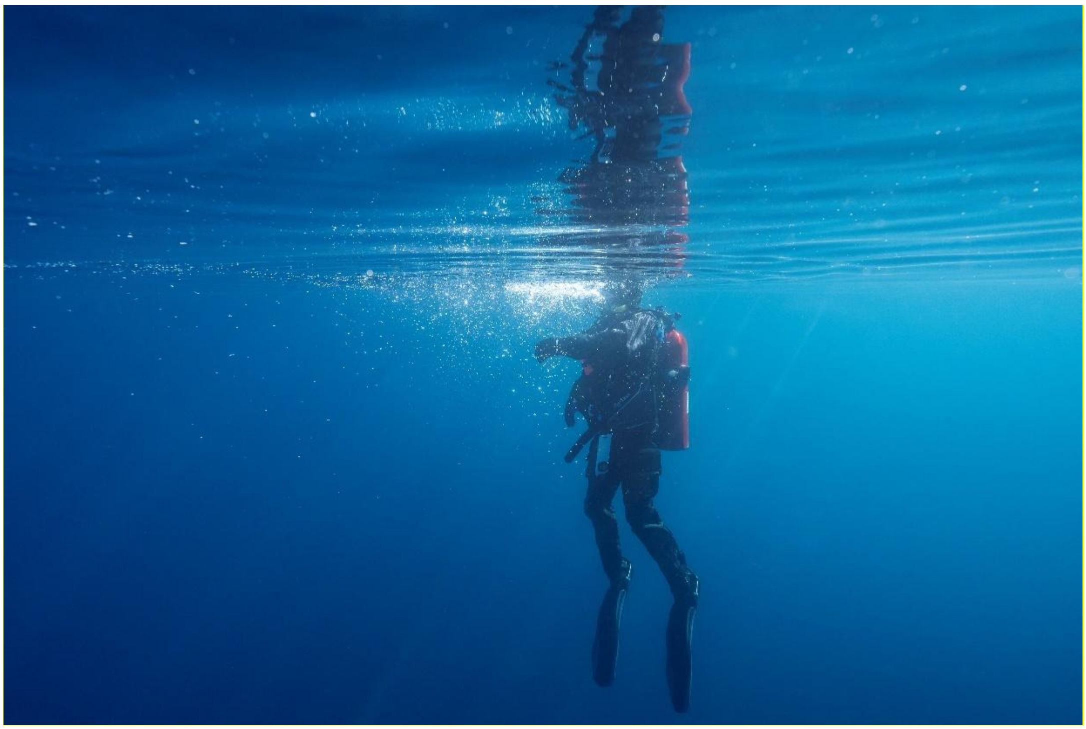
Prepared for the Tahoe Regional Planning Agency



TERC Research Diver seen in the clear waters of Lake Tahoe. Photo Credit: Brandon Berry

13 June 2025

Executive Summary

After steep declines in water clarity through the 1990s, annual average clarity appears to have plateaued, although with high variation. Winter trends have stabilized or improved, but summer trends remain concerning. To understand why Lake Tahoe's clarity is not improving, we suggest that targeted research is needed into the nature of the clarity-reducing particles and their potential aggregates.

In 2024, the annual average clarity remained comparable to previous years. The long-term trend shows annual average Secchi depth decreasing through the late 1990s and leveling off to the present day, with continuing high variation. The annual average for 2024 was 19.0 m with a 95% confidence interval (CI) of 17.0 – 20.2 m, which makes it statistically similar to last year.

Somewhat different patterns are observed in winter and summer. Observations of lake clarity for 2024 show relatively poor winter (December 2023 through March 2024) clarity in an otherwise stable or improving winter trend and relatively poor clarity during the summer (June 2024 through September 2024), which seems to be part of a trend of degrading summer clarity.

In 2023, the high winter clarity (28.0 m) was partly the result of complete lake mixing (turnover) observed in early March 2023. Deepwater mixing brings very clear water from the bottom of the lake to the top, greatly increasing clarity for a limited period. As deepwater mixing did not occur in 2024, the water did not get the increase in clarity that has been associated with past full mixing events.

The seasonal decline in summer clarity in 2024 was consistent with the number of particles observed in the water. Particles that scatter light can include both inorganic (e.g., sediment) and organic materials, such as dead terrestrial matter washing in from the watershed, as well as phytoplankton that may grow in response to favorable growing conditions (e.g., nutrients and higher temperatures). However, summer water clarity remained low after concentrations of observed particles dropped, suggesting unobserved factors or more complex dynamics affecting summer clarity.

With trends now appearing somewhat stable overall on an annual average – highly variable and generally not improving – future research should focus on examining the nature of the particles that affect water clarity. The relative importance of sediment and detritus entering from the watershed and airshed, and phytoplankton growth in response to changing environmental conditions can imply different processes at play in water clarity.

1. History of Clarity Measurements

Clarity is measured as the depth to which a 10-inch white disk, called a Secchi disk, remains visible when lowered into the water. In 2024, UC Davis scientists took 27 readings at Lake Tahoe's long-term index station (LTP station) and 12 readings from the mid-lake index station (MLTP) that were deemed acceptable (Table 1). View the historic clarity readings from 1968-2024 at https://portal.edirepository.org/nis/mapbrowse?scope=edi&identifier=1340.

More than 80 organizations, including government agencies, nonprofits, and research institutions, are collaborating with scientists to improve Lake Tahoe's water clarity and ecological health under the Lake Tahoe Environmental Improvement Program (EIP), one of the most comprehensive landscape-scale restoration programs in the nation. EIP partners are helping to meet Total Maximum Daily Load (TMDL) targets by reducing pollution through improved roadway maintenance, erosion control, as well as river and wetland protection and restoration. Measures taken to reduce sediment loading are typically also useful in reducing nutrient and other pollutants that can enter lakes.

Past research has established that the primary factor controlling lake clarity is the concentration of fine particles in the upper waters of the lake, in the approximate size range of 1-6 µm. These particles can be comprised of inorganic particles (e.g., fine silt or clay), organic material of terrestrial origin (e.g., decaying plant debris), particles associated with atmospheric deposition (e.g., wildfire ash), or small phytoplankton naturally found in lakes (e.g., *Cyclotella*). An additional category of particles currently remains unmonitored – picoplankton (phytoplankton cells < 2 µm) or other particles that may be smaller than 1 µm.

2. Annual and Seasonal Average Water Clarity Trends

In summary, the 2024 Secchi depth measurements from index station LTP reflect the trends observed in recent years (**Figures 1-3**). Although the annual average decreased slightly as compared to 2023 (**Figure 1**), the value is not significantly different from last year, and the trend has remained level since the late 1990s (**Figure 4**). Winter clarity appears relatively stable or improving (**Figure 2**). Summer clarity demonstrates variation and oscillations that complicate trend detection but, overall, it is not improving (**Figure 3**). Similar annual average results were observed at MLTP (**Table 1**). Unlike LTP, however, the annual average trend at MLTP has not leveled off but clarity continues to decline (**Figure 5**).

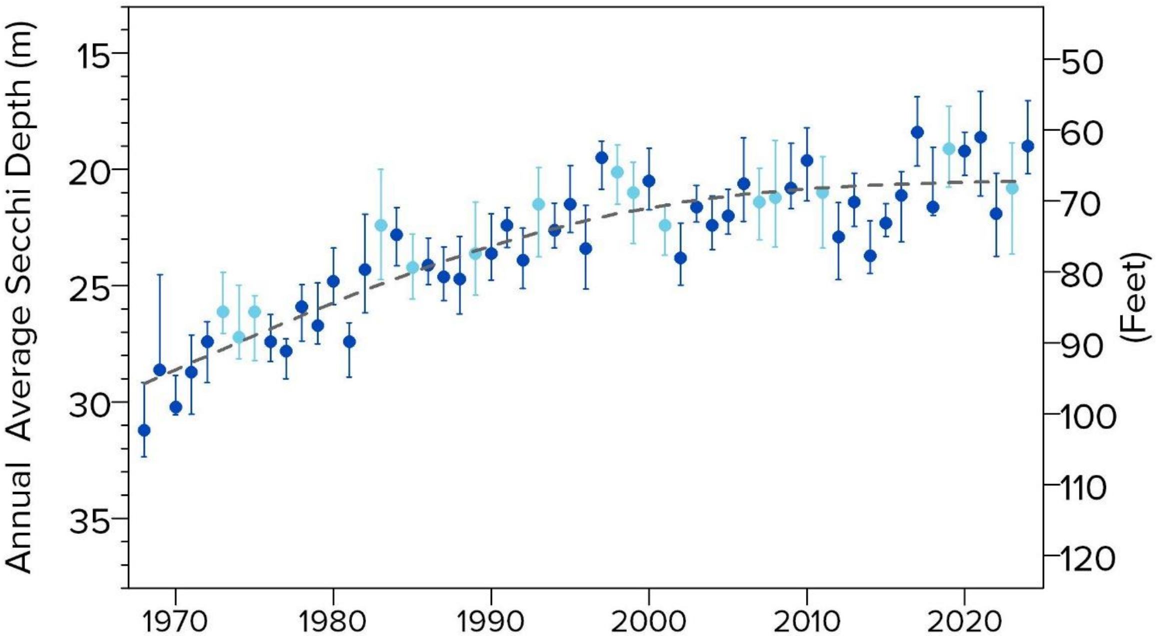


Figure 1: Annual average (January - December) Secchi disk measurements at the LTP Station 1968-2024. The whiskers on each point represent 95% bootstrapped confidence intervals. Trend line is derived from a Generalized Additive Model (GAM). The value for 2024 was 19.0 m with CI of 17.0 – 20.2 m. Light blue circles are years in which the lake fully mixed during winter, a process that typically enhances winter water clarity for a short time.

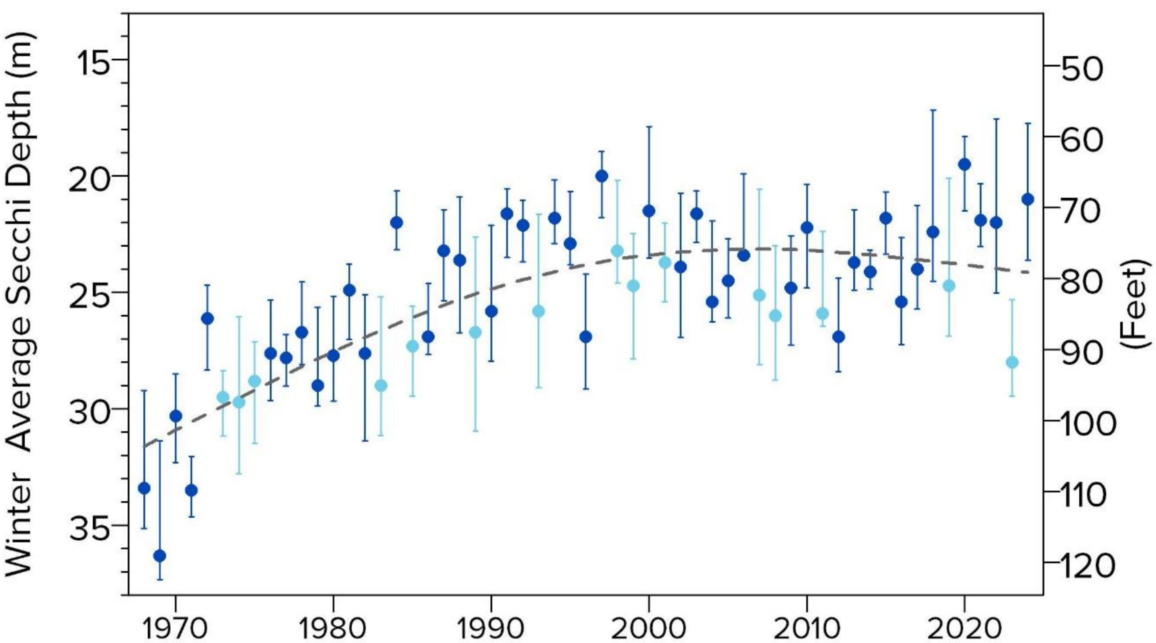


Figure 2: Winter average (December - March) Secchi disk measurements collected at LTP Station 1968-2024. The whiskers on each point represent 95% bootstrapped confidence intervals. Trend line is derived from a Generalized Additive Model (GAM). The value for 2024 was 21.0 m with CI of 17.7 – 23.6 m (69 ft, CI 58 – 77 ft). Light blue circles are years in which the lake fully mixed during winter, a process that typically enhances winter water clarity for a short time.

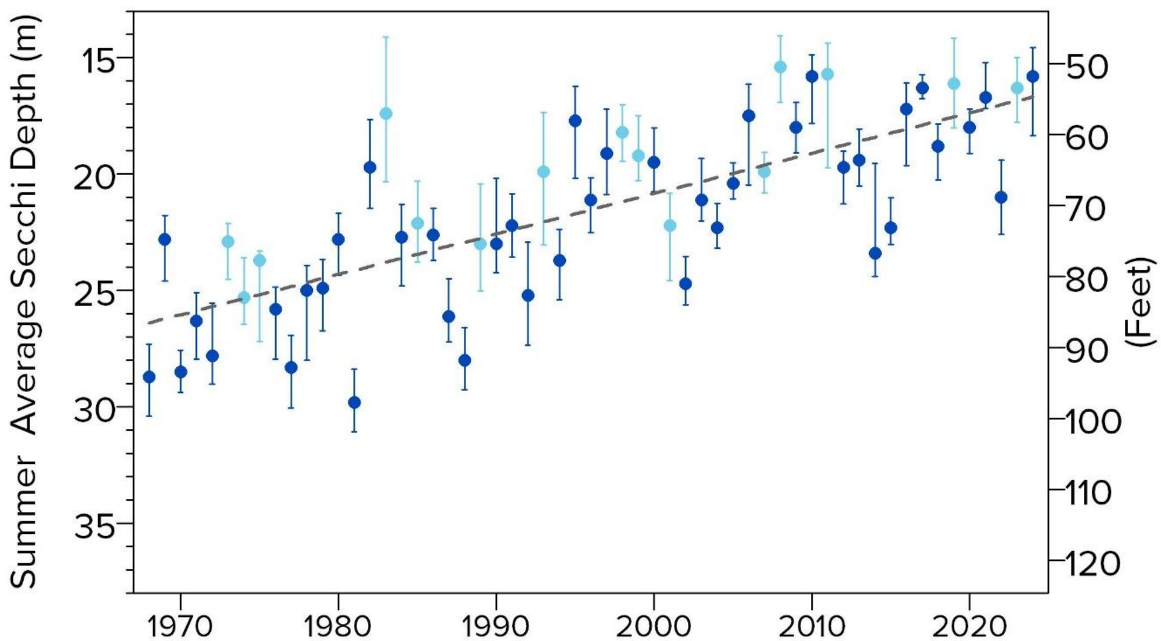


Figure 3: Summer average (June – September) Secchi disk measurements collected at LTP Station 1968-2024. The whiskers on each point represent 95% bootstrapped confidence intervals. Trend line is derived from a Generalized Additive Model (GAM). The value for 2024 was 15.8 m with CI of 14.6 – 18.3 m (52 ft, CI 48 – 60 ft). Light blue circles are years in which the lake fully mixed during winter, a process that typically enhances winter water clarity for a short time and also brings nutrients into upper layers that can boost phytoplankton growth.

Table 1: Summary of 2024 Secchi disk mean, minimum, maximum, and 95% bootstrapped confidence intervals (in meters), and number of samples at the index station (LTP) and the mid-lake station (MLTP).

Station ID	Ave Type	Ave	Min	Max	CI	N
Index (LTP)	Annual	19.0	13.5	31.4	17.0 - 20.2	27
Index (LTP)	Winter	21.0	17.3	31.4	17.7 – 23.6	10
Index (LTP)	Summer	15.8	13.5	24.8	14.6 – 18.3	12
Mid-lake (MLTP)	Annual	18.6	12.5	24.5	16.6 – 20.8	12

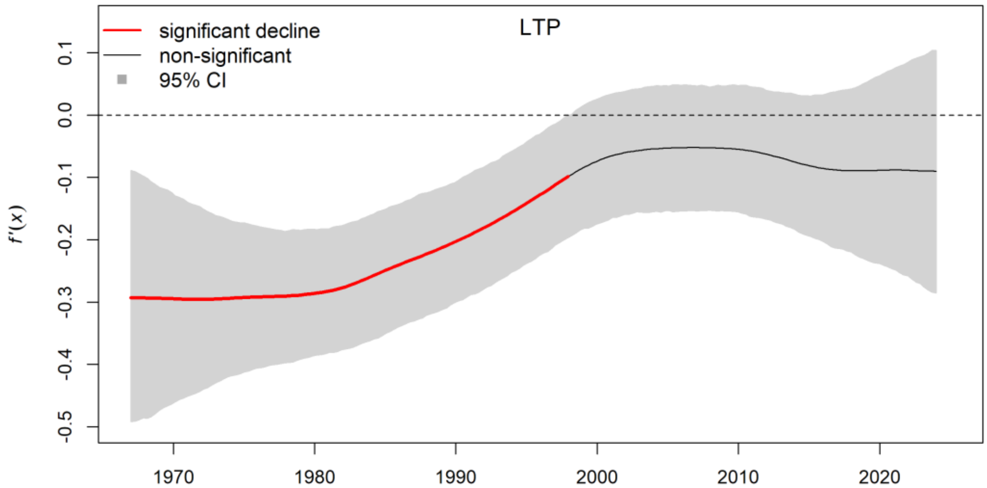


Figure 4. Derivatives (*f'(x)*) of the long-term trend in Secchi depth at the LTP station (1968-2024) show periods of significant change. Negative *f'(x)* values correspond to declines in Secchi depth; positive values correspond to increases in Secchi depth. Periods of significant decline in Secchi depth are shown in red. Non-significant periods, when the 95% confidence intervals overlap with zero, are shown as a thin black line. The 95% confidence intervals (gray polygon) around the derivatives were generated from 10,000 draws from the posterior distribution of the GAM model parameters.

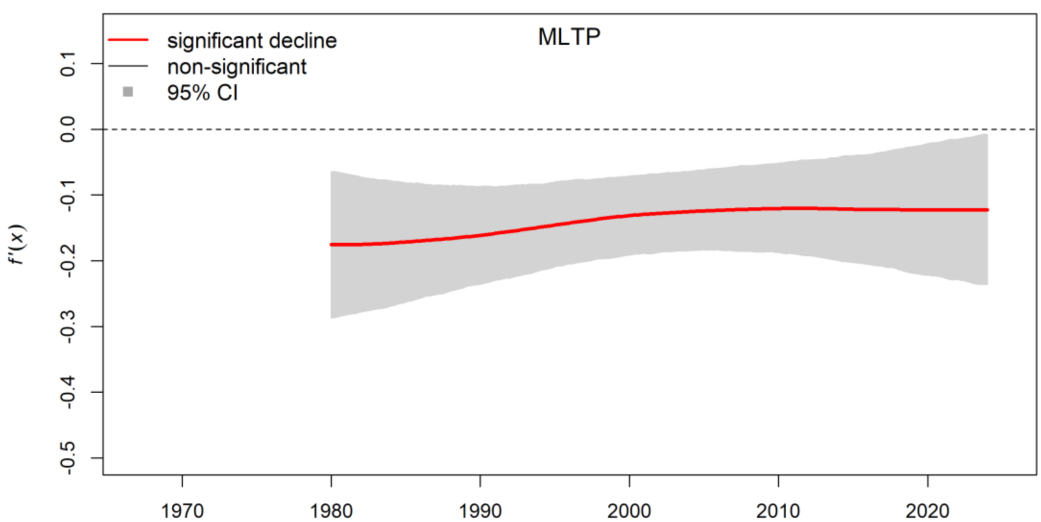


Figure 5. Derivatives (*f'(x)*) of the long-term trend in Secchi depth at the MLTP station (1980-2024) show periods of significant change. Negative *f'(x)* values correspond to declines in Secchi depth; positive values correspond to increases in Secchi depth. A period of significant decline in Secchi depth is shown in red, without the 95% confidence intervals (gray polygon) crossing zero. The 95% confidence intervals around the derivatives were generated from 10,000 draws from the posterior distribution of the GAM model parameters.

3. Individual Measurements of Water Clarity

Secchi values are shown for the observation year (**Figure 6** – blue solid circles), with values from the last 10 years shown for context (**Figure 6** – gray solid circles).

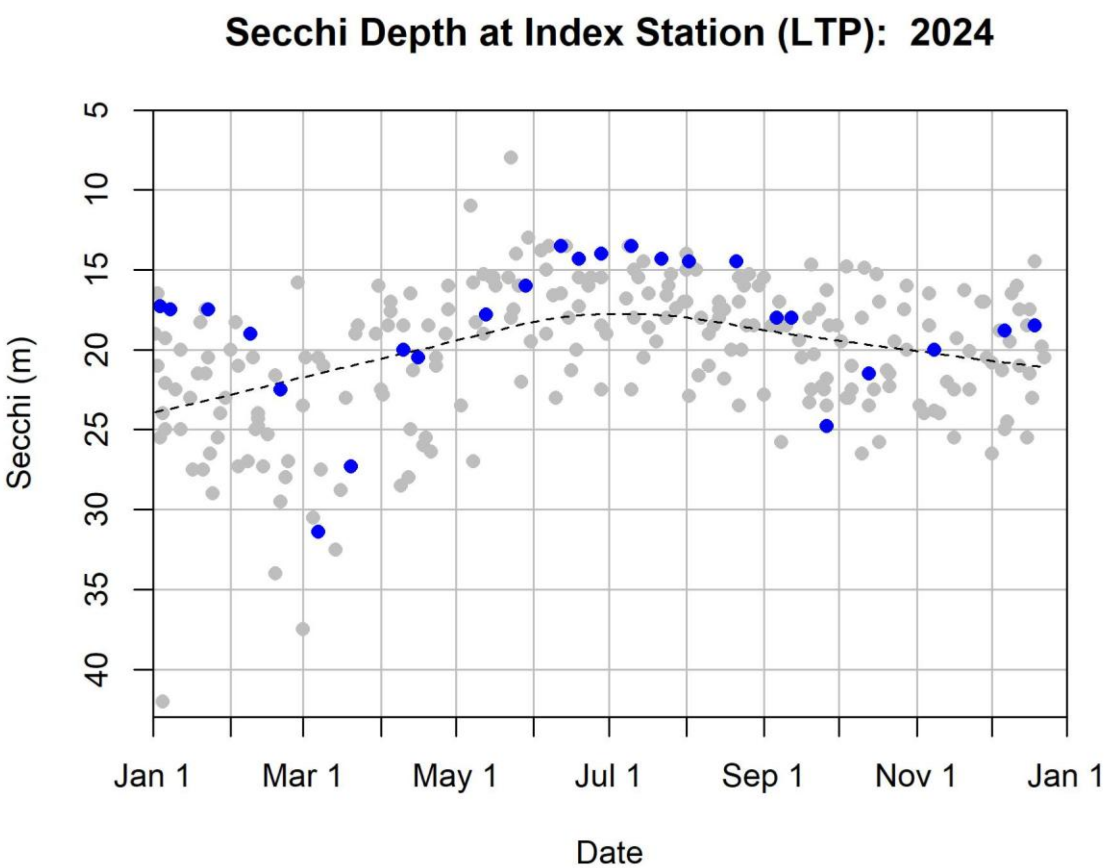


Figure 6: Blue solid circles represent individual Secchi measurements at Index station (LTP) in 2024. Gray circles are those in the last 10 years. The dashed line shows the averaged seasonal transition of Secchi in the last 10 years (LOWESS fit).

A key observation from **Figure 6** is that values from June to August 2024 had a long period of being consistently at the shallower end of normal summer observations before getting deeper in September. Summer clarity averages shown in **Figure 3** include June to September, and the higher clarity observed this September (Figure 6) contributed high variation to this summer averaged measurement.

Last year (2023) showed one of the highest winter averages for clarity following a full deepwater mixing event. Around February 26, 2023, full mixing of the lake brought clearer water from depth. Deepwater mixing does not occur every year but characteristically contributes to high winter clarity averages when it does. Deepwater mixing was not observed in 2024, and winter averages remained within a range statistically similar to most other non-turnover years.

4. Factors Affecting Water Clarity

4.1 Particles at the index lake monitoring station (LTP) and entering by stream flow

Particle data from two different instruments are shown here – the Liquilaz, and the LISST-100X instrument – which provide complementary data that help create a more comprehensive understanding of particles across a range of sizes and locations in the lake. Since many of the particles are known to enter from streams and runoff, we show representative data from one stream site as well as precipitation data that affect the influx of particles into the lake.

The greatest concentrations of fine particles (1-6.73 µm size range) in the top 20 m of the water column (**Figure 7**) occur following the spring run-off and then taper to a minimum at the end of each year. Associated with this influx of particles is a rapid decrease in clarity (**Figure 8**). In lower run-off years (e.g., 2022; **Figure 7**), there is a smaller decrease in Secchi depth (**Figure 8**). The observed clarity decrease in 2024 (indicative period highlighted in red; **Figure 7**) is aligned well with this trend, given an average to slightly below average run-off period. However, in 2024, Secchi depth (**Figure 8**) remained low after the particle concentration dropped in the summer, suggesting a relationship of clarity with other factors.

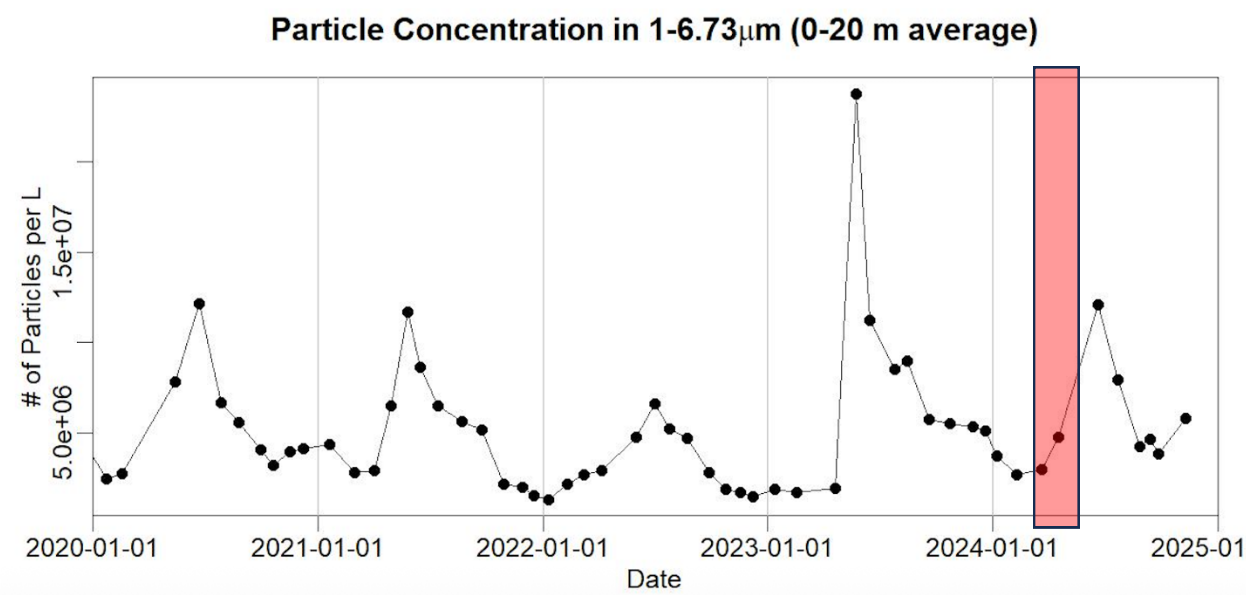


Figure 7: Particle concentrations measured with the Liquilaz instrument at the Index station (LTP) from 2020 through the end of 2024. The annual period of decrease in water clarity is highlighted in red for reference.

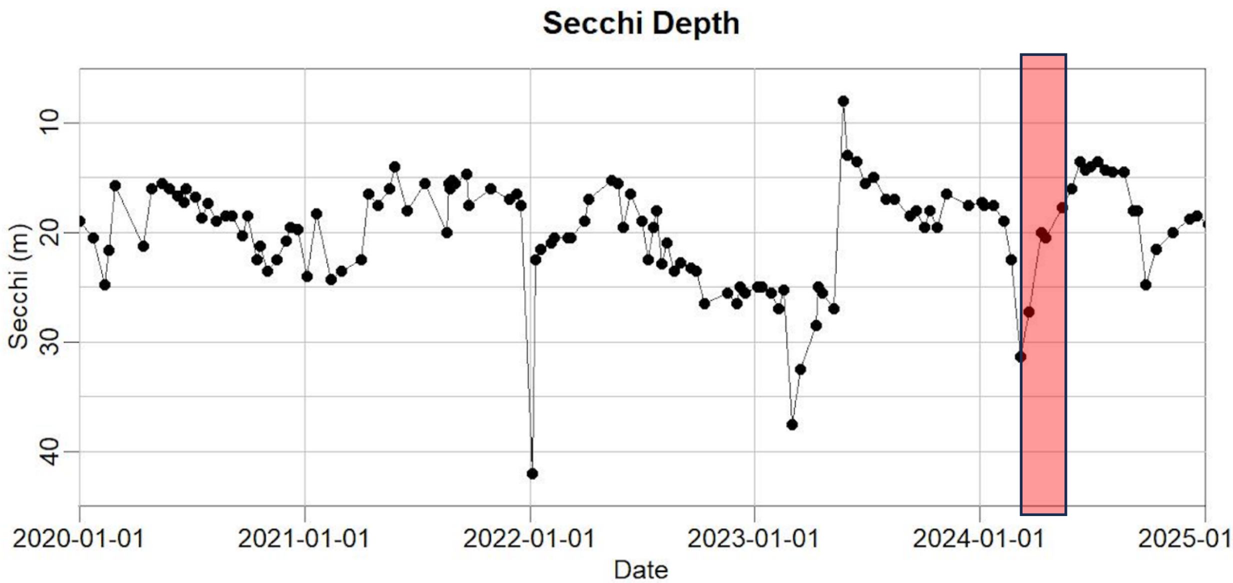


Figure 8: Secchi measurements (meters) at Index station (LTP) from 2020 through 2024. The annual period of decreasing clarity is highlighted in red for reference with Figure 7.

Similar results for particles were obtained using a complementary method, the LISST-100X, an instrument using a scattering transmissometer measuring particles from 1-250 µm **(Figure 9).** As reported last year, using the LISST-100X, a step change in the number of particles in the water column is apparent in 2015. Since then, conditions have been relatively constant, with intermittent spikes in the integrated total volume concentration that could be correlated with episodic events (e.g., run-off) in the catchment (McInerney, 2024). Similar trends are observed in the results from the Liquilaz for the same period.

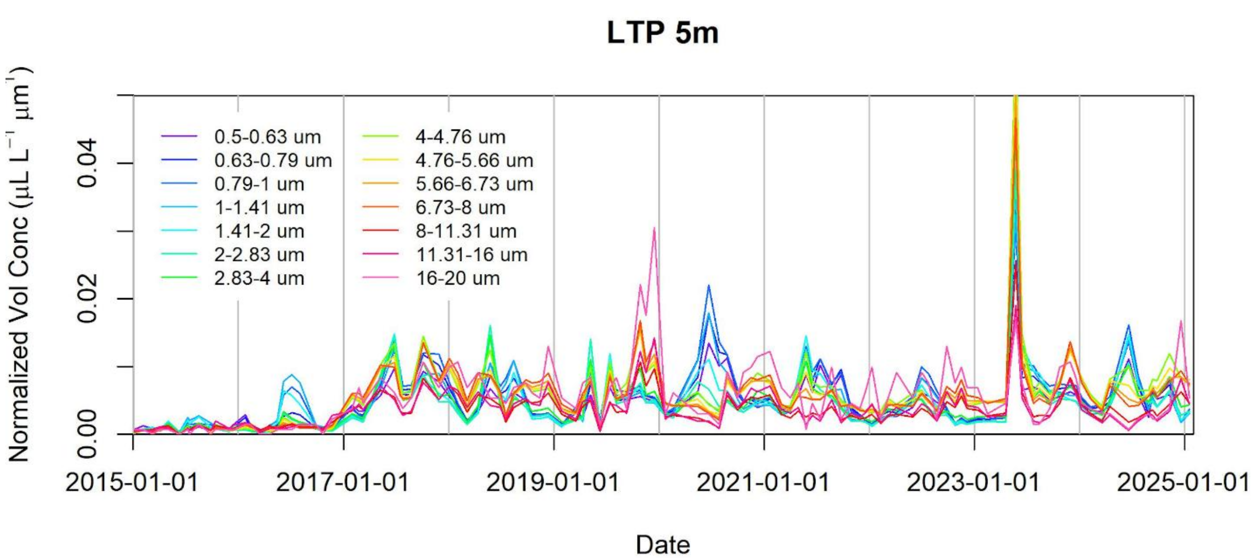


Figure 9: Estimate of particle concentration normalized by bin width for small particles at the 5m depth at the LTP station, using the LISST-100X instrument as a complement to Liquilaz (Figure 7). While results are available at 0, 2, 5, 10, 15, and 20m depths, the 5m depth at the LTP site is an example of similar trends at all depths.

Runoff measurements show dynamics of particle inflow suggestive of the spring influx observed in **Figures 7** and **9**. Using Blackwood Creek as indicative of other streams around the watershed, **Figure 10** shows the stream flow into the lake (**Figure 10a**), the turbidity (**Figure 10b**), the particle concentration (1.0-6.73 µm size range) in the creek, (**Figure 10c**), and daily particle load from the creek (**Figure 10d**). Measurements of inflow (**Fig. 10a**) show stream discharge at or slightly below average values, consistent with a precipitation year that was slightly below average (**Figure 11**).

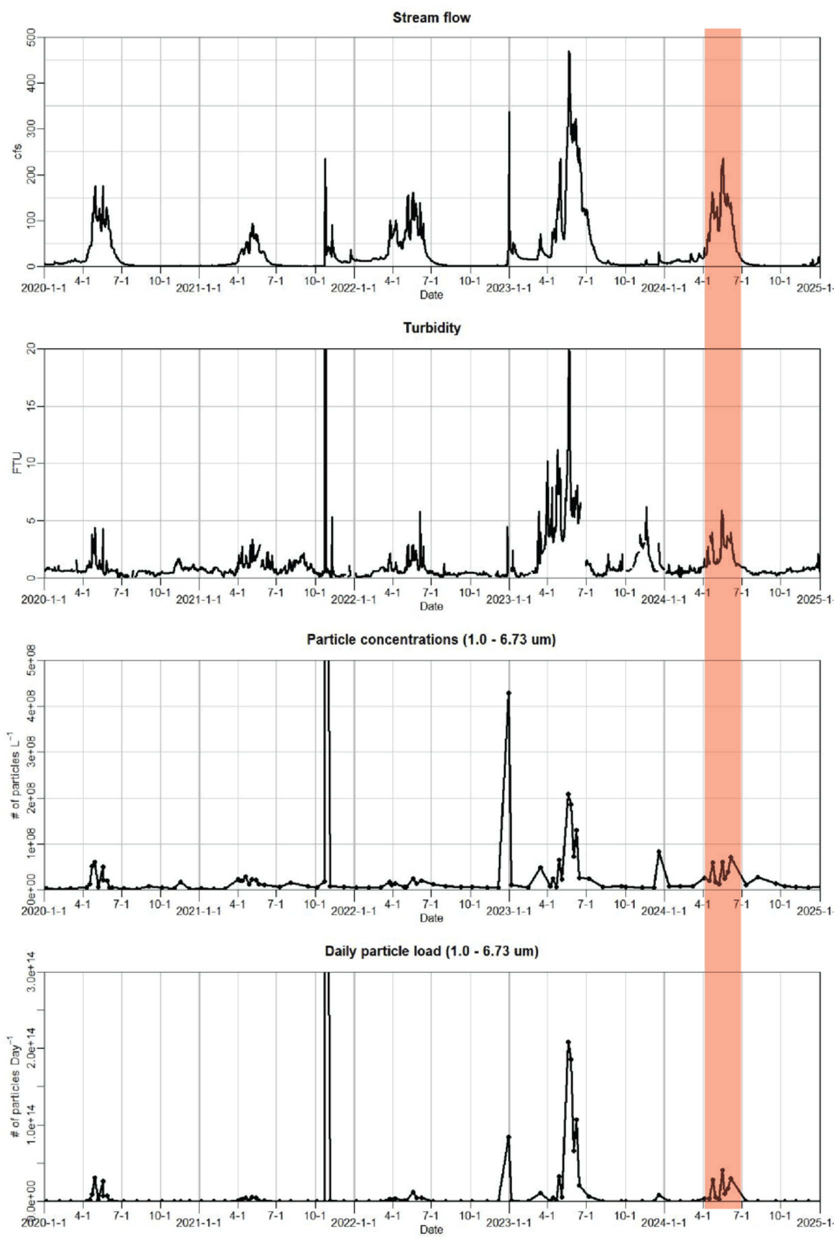


Figure 10: Flow conditions in Blackwood Creek from 2020 – 2025: (a) flow rates (cfs), (b) turbidity (FTU), (c) particle concentrations in the 1.0-6.73 µm size range, (d) total particle daily loading from the creek. The annual spring run-off period is highlighted in red for reference.

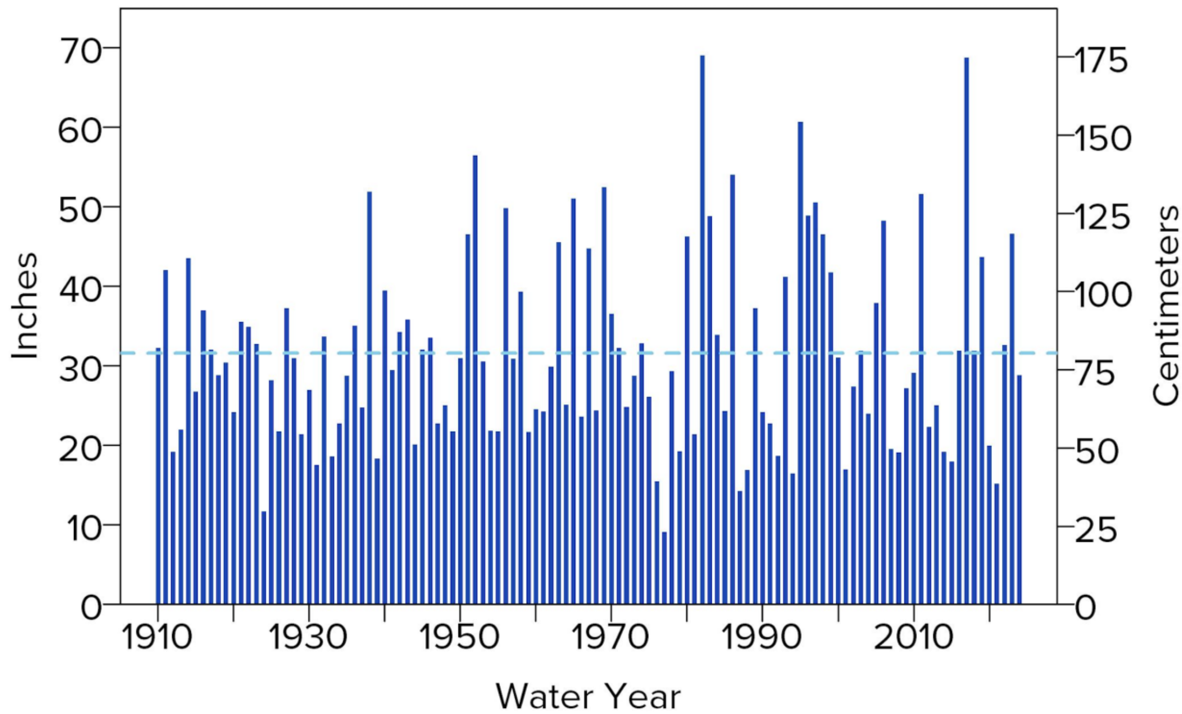


Figure 11: Average annual precipitation from 1910-2024.

4.2 Phytoplankton at the index monitoring station (LTP)

Currently, the relative contribution of phytoplankton to water clarity dynamics is unknown. The particle data in Section 4.1 includes inorganic and organic particles. Organic particles may include living and dead phytoplankton, small-sized zooplankton, and organic debris washed into the lake from the watershed. Detailed investigations of Lake Tahoe particles in the past have implicated inorganic fine sediment as the primary driver of water clarity in Lake Tahoe (Jassby et al. 1999, Swift et al. 2006), with approximately 58% of light attenuation associated with inorganic particles, and 25% of attenuation associated with organic particles.

While the specific contribution of small-sized phytoplankton to light attenuation is not known for 2024, water clarity tends to be at the lowest when phytoplankton are at their maximum densities in the uppermost warmer layer (**Figure 12**) during the thermal stratification period. Lake Tahoe typically stratifies in late May or early June. During thermal stratification, three distinct density layers form, and this layering can lead to differences in nutrient and oxygen availability, affecting not only the distribution of phytoplankton but also the overall lake ecosystem.

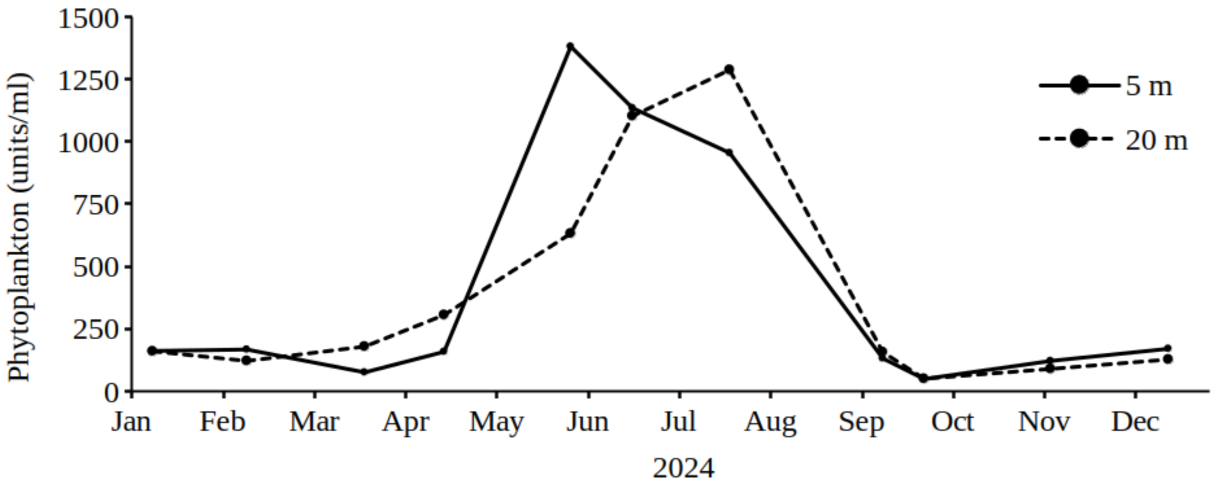


Figure 12: Shifts in the abundance (numbers of cells or filaments per ml) of phytoplankton community at 5 m and 20 m depth at the index station (LTP) during 2024.

Water clarity tends to be at its highest when phytoplankton are at their minimum densities during the winter season. In 2024, phytoplankton abundance was relatively low during the winter, and we observed a prominent feature in the lake water samples: a high level of large-sized suspended particles, mostly identified as organic matter from plant debris, likely washed out from the vegetated watershed. This debris was widely dispersed across all sampled depths (5, 20, 40, 60, 75, 90 m) in January and February, persisted through March, and decreased by mid-April. During this period, motile phytoplankton were prevalent throughout the water column. From wintertime lows of phytoplankton abundance, a steep spring increase occurred from April to May, and levels remained relatively high throughout the summer while water clarity was relatively low. The phytoplankton community was dominated numerically by diatoms, which were also the major contributors to biomass, followed by green algae and cryptophytes. The initial phytoplankton abundance peak in May was associated with the smallest size classes (**Figure 13**) of phytoplankton (e.g., *Cyclotella*), known to have strong effects on light scattering. These nano-phytoplankton gradually decreased to minimal levels by September. The deep chlorophyll maximum (DCM) was typically found between 50 and 60 m, identified below the Secchi depth. Although routine analysis by light microscopy excludes robust picoplankton enumeration, they are sometimes detectable at their larger sizes (~ 2 µm). Early November sampling revealed a noticeable presence of picoplankton, particularly in the upper 40 m, as well as increased abundance of ciliates and small rotifers. It is possible that the presence of picoplankton might have partially contributed to the decrease in water clarity, while the presence of ciliates and rotifers might have had the opposite effect, increasing clarity by consuming picoplankton and suspended particles.

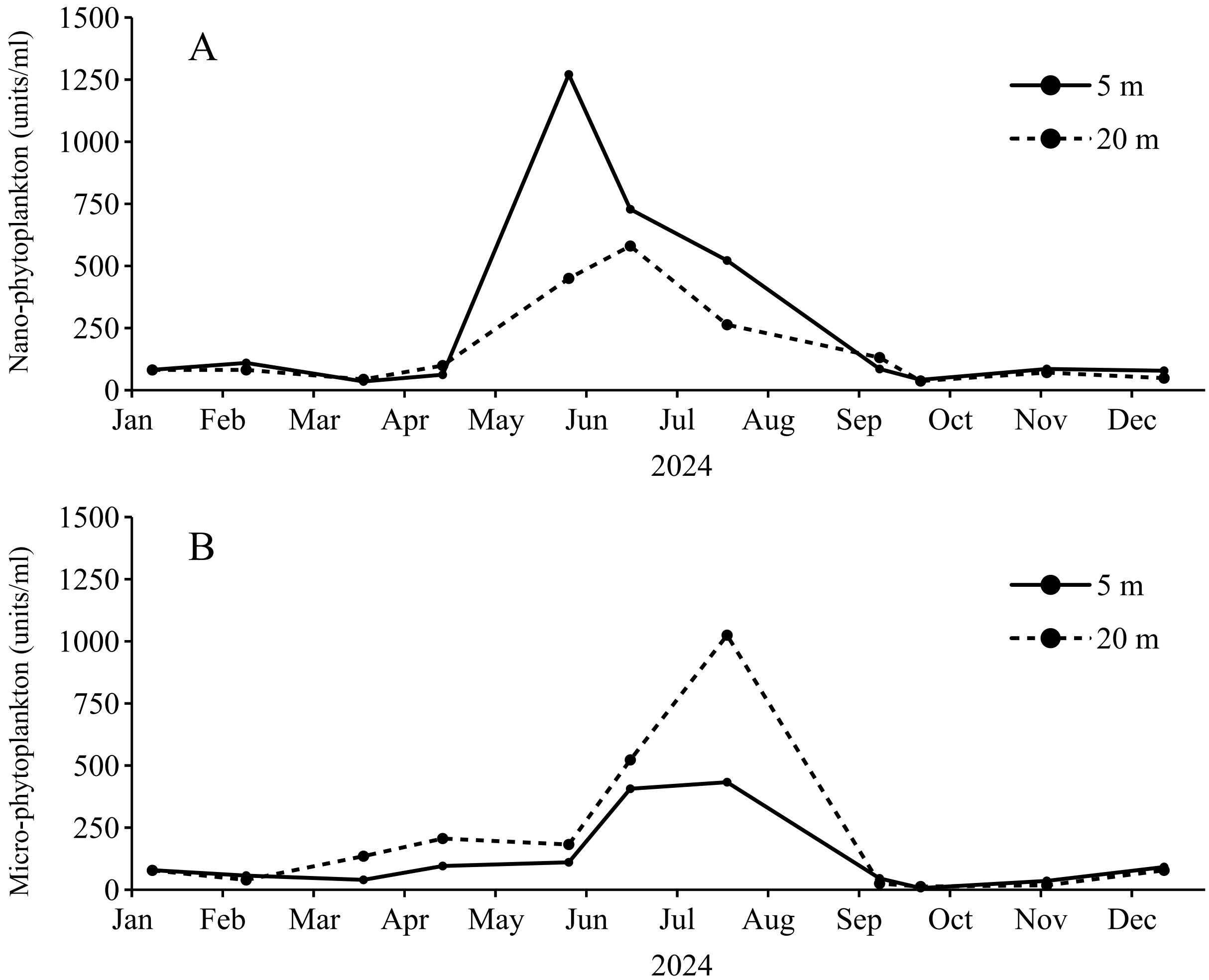


Figure 13. Seasonal shifts in two size classes of the phytoplankton community at two different depths (5 and 20 m) at Index station (LTP) during 2024. (A) Nano-phytoplankton are composed of a range of small-sized, mostly single-celled phytoplankton with an equivalent spherical diameter (ESD) between 2 and 20 µm. (B) Micro-phytoplankton refers to phytoplankton that are between 20 and 200 µm in size. Abundance is cells or filaments per ml.

Whether the relative contributions of inorganic and organic particles such as phytoplankton have changed over time is currently not known. Data do exist to match total particulate data to phytoplankton size classes, which will help to calculate these proportions in the future. However, this question is complicated by a lack of quantitative picoplankton data (cells < 2 µm). In a 2007-2008 study with methods optimized for picoplankton, these small phytoplankton were estimated to account for 36-56% of primary productivity in Lake Tahoe (Winder et al., 2009), and their small size makes them particularly effective in light scattering. Standard microscopy excludes picoplankton because it is only effective for cells larger than 2 µm. Special techniques are needed to provide picoplankton data that would complement the particulate data, and help to determine the relative contributions of phytoplankton, inorganic sediment, and organic debris to water clarity.

5. Conclusions

In recent years, analyses have increasingly concluded that water clarity rapidly declined through the late 1990s and then leveled off to modern measurements. The 2024 data are concordant with this pattern, with an annual average of 19.0 m (CI: 17.0 – 20.2m).

In 2024, as in previous years, the seasonal decrease in water clarity appears to be well correlated with the seasonal influx of particles, although this year, low summer water clarity persisted after the observed particles declined. This observation serves as the motivation for further research to understand the relative contributions of different particles, such as inorganic sediments, terrestrial organic debris, and phytoplankton, to the overall clarity of the lake. The behavior of each of these categories should vary substantially; for example, inorganic particles may sink to greater depths over time while phytoplankton continue to multiply in shallow layers. Given that water clarity has not shown an overall trend toward improvement in several decades, we suggest that understanding the nature of the particles is a priority area for research to identify the current drivers of water clarity.

In addition to ongoing monitoring, the Citizen Science Tahoe project app, started by UC Davis TERC scientists in collaboration with the League to Save Lake Tahoe and the Desert Research Institute, is an effective tool for tracking changes and alerting new issues as they arise. This app can be accessed here: https://tahoe.ucdavis.edu/citizen-science.

6. Acknowledgements

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Physical data analysis – Alicia Cortes, Sergio Valbuena, and Adrianne Smits
Particle size analysis – Aaron Vanderpool
Zooplankton enumeration and identification – Katie Senft

7. References

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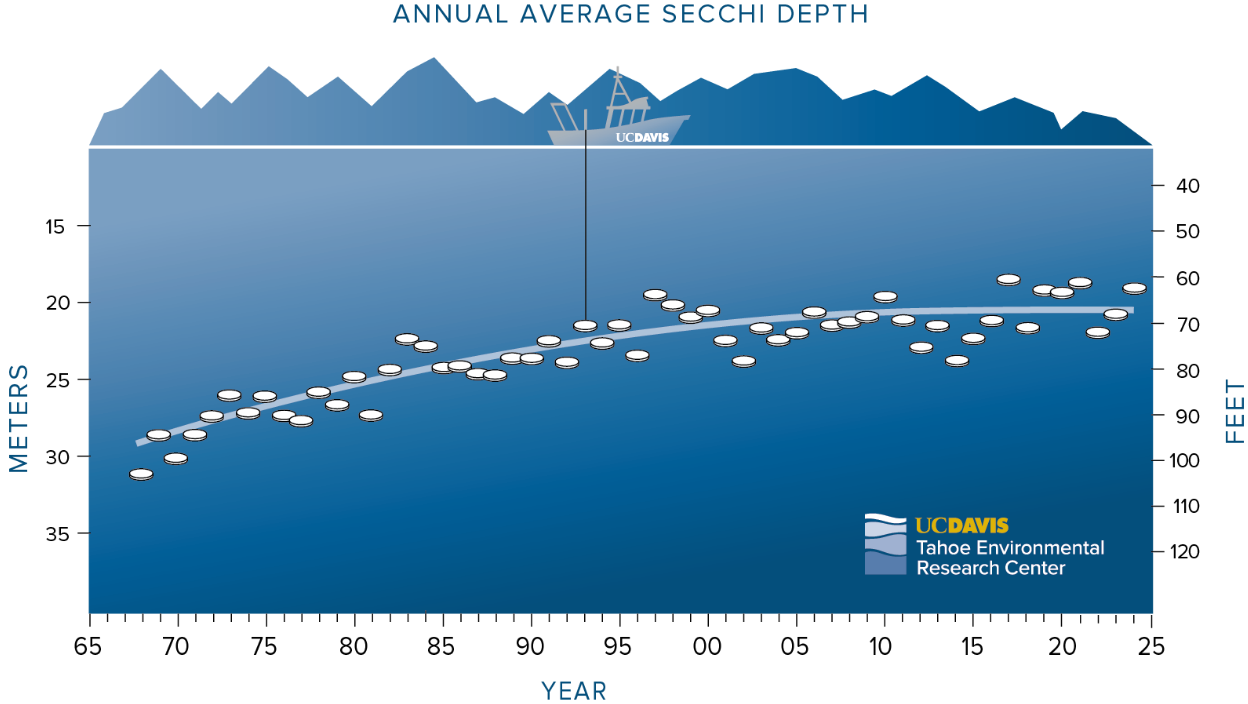
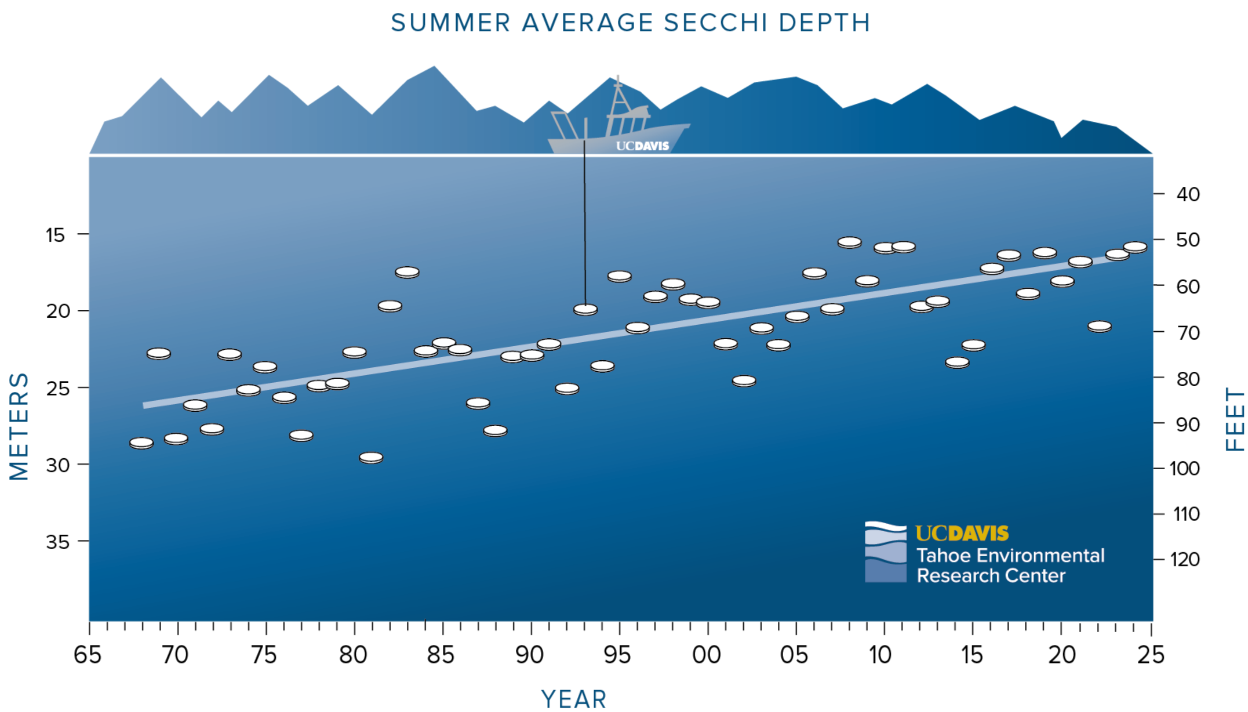
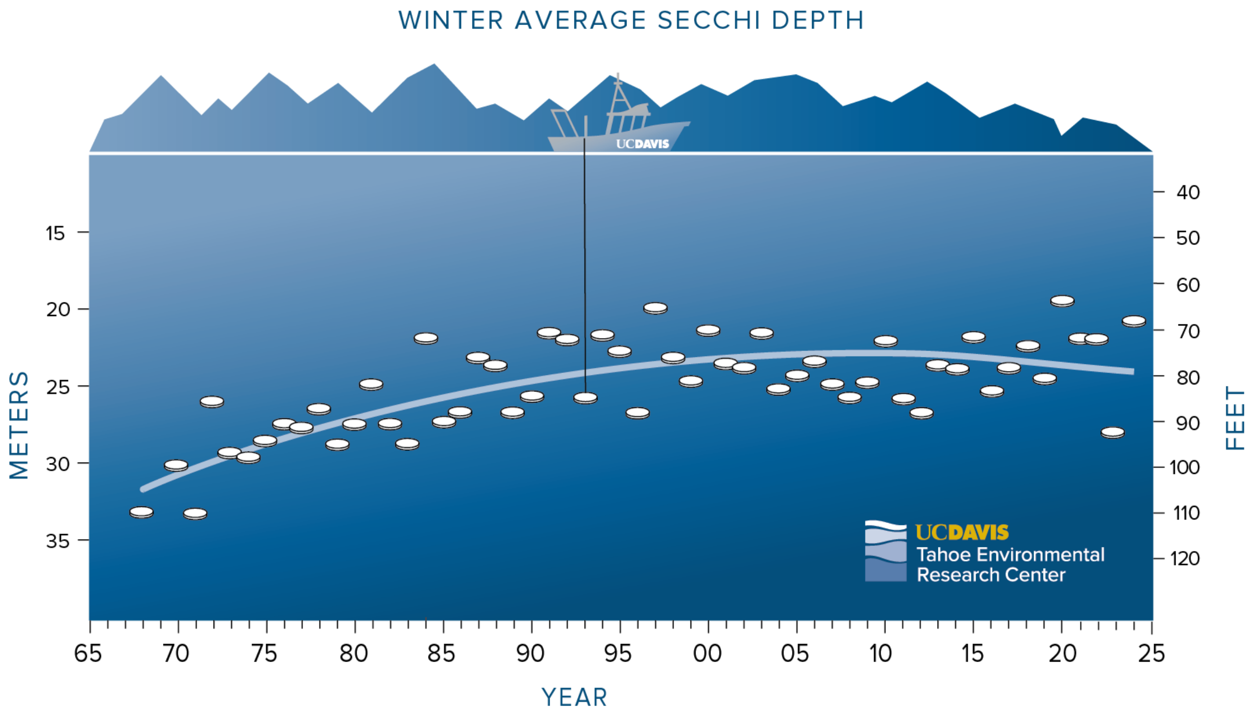
Appendix A – Public Release Secchi Charts



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