California Regional Water Quality Control Board

San Francisco Bay Region

Lake Merritt Low Dissolved Oxygen Advance Restoration Plan

2024-2025 Nutrient Data Analysis

Final Staff Report

January 2026

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

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1 Executive Summary

This report presents findings from the summer 2024 and 2025 nutrient monitoring study conducted at Lake Merritt, Oakland, California. The study assessed nutrient dynamics in this tidally influenced urban estuary, where water quality is influenced by both San Francisco Bay inflows through the Lake Merritt Channel and local tributary inputs such as Glen Echo Creek. The study objective was to evaluate spatial and temporal variability in nutrient concentrations that may influence algae levels, which can affect dissolved oxygen conditions and ecological health. Lake Merritt is on the 303(d) List for impaired waters for low dissolved oxygen/organic enrichment and this study is part of a series of analyses to ultimately resolve the impairment.

From June through October 2024, Water Board staff conducted monthly sampling at nine locations across Lake Merritt, the Channel, and tributary sites. Measured parameters included ammonia, nitrate + nitrite, total Kjeldahl nitrogen, total nitrogen, orthophosphate, total phosphorus, and dissolved organic carbon (DOC). Redfield ratio's (N:P) were calculated to identify limiting nutrients; nutrient mass loads were estimated; and nutrient concentrations were compared with nutrient data collected by United States Geological Survey (USGS) in San Francisco Bay. Nutrient loads from major creeks draining into Lake Merritt and from the Bay were estimated with samples from 2024 and 2025.

Key Findings:

1) For spatial patterns, dissolved inorganic nitrogen (the sum of total ammonia and nitrate + nitrite) was lower in the lake compared to the Bay water or creek sources suggesting that available nitrogen is being used by algae in the lake. In addition, overall lake nutrient concentrations were more similar to Bay water than creek samples indicating the dominance of Bay water in affecting lake water quality conditions.
2) For temporal patterns, dissolved inorganic nitrogen increased through the summer in alignment with overall nutrient trends in San Francisco Bay.
3) Nitrogen consistently limited productivity in the lake, while phosphorus was the limiting nutrient in Glen Echo Creek. Thus, phosphorous control efforts like Phoslock will not affect primary production in the lake.
4) Mass load estimates indicate that more than 99% of nutrient inputs derive from Bay inflows. These findings confirm that Lake Merrit's nutrient dynamics are strongly influenced by tidal exchange with San Francisco Bay.
5) Future monitoring priorities to support the Water Board's Lake Merritt Low Dissolved Oxygen Advance Restoration Plan include:
   - Collect continuous dissolved inorganic nitrogen data with a SUNA (Submersible Ultraviolet Nitrate Analyzer) during the summer to see how much nutrient concentrations could be affected by and perhaps limit algae blooms.
   - Analyze SUNA nitrate data with continuous chlorophyll-a and dissolved oxygen data to refine understanding of nutrient-oxygen interactions.

Overall, this study provides a current baseline of nutrient conditions in Lake Merritt and highlights the need for continued targeted monitoring. In summer 2026, deployment of a SUNA sensor will build on this work by providing continuous nitrate data to improve understanding of nutrient uptake dynamics and tidal influences in the lake.

2 Introduction

2.1 Study Area/Sampling Locations

Lake Merritt is a tidally influenced estuarine lake located in Oakland, California. Tidal waters enter from San Francisco Bay through the Oakland Inner Harbor and flow into the lake via the Lake Merritt Channel (Figure 1), which is regulated by tide gates operated by the Alameda County Flood Control and Water Conservation District at the Lake Merritt Pump Station (18 E. 8th Street, Oakland). The tide gates control the extent of exchange with San Francisco Bay, meaning the lake is not always directly connected to the Bay or continuously following its tidal cycle. Lake Merritt provides important habitat for fish and wildlife, serves as a popular site for recreation, and is situated within a highly urbanized watershed.

Earthstar Geographics, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community, Maxar

Figure 1. Map of Lake Merritt within the San Francisco Bay area.

Sampling locations for the 2024 monitoring effort were selected to capture spatial variability across the lake, including inner-lake sites, channel area, and sites near inflows and potential nutrient sources. Figure 2 shows the locations of all sampling sites across Lake Merritt and the Lake Merritt Channel. The nine monitoring stations are described in detail in Table 1, including station names and CEDEN codes, location types, site selection considerations, coordinates, and the parameters measured with their associated sampling frequency.

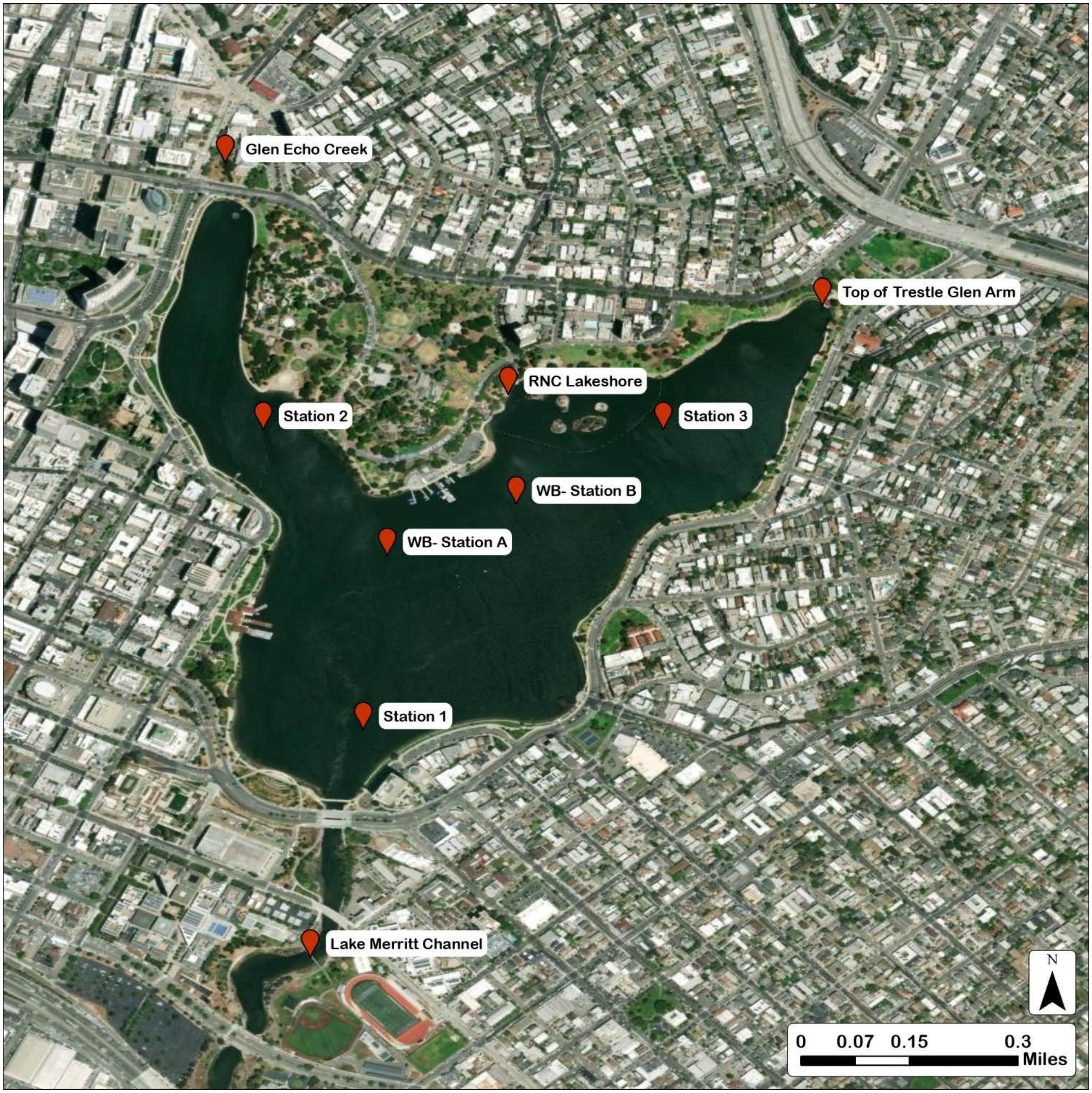

Figure 2. Map of sampling stations for the 2024 Lake Merritt nutrient monitoring study

Table 1. Detailed list of sampling locations and monitoring parameters measured in 2024

Station Name/CEDEN Code	Location Type	Site Selection Consideration	Coordinates	Parameters Measured & Sampling Frequency
Station 1 (204LME450)	Mid-lake	Long-term continuous monitoring site, representative of central lake conditions and incoming tidal flows from channel	37.800, -122.259	*Continuous Monitoring:* Dissolved oxygen, temperature, salinity, turbidity, chlorophyll-a, and depth *Monthly (June through October):* Nutrients[1] and dissolved organic carbon (DOC) *June only:* Biochemical oxygen demand (BOD) and total organic carbon (TOC)
Station 2 (204LME600)	Mid-lake	Long-term continuous monitoring site, representative of Glen Echo Arm conditions near lake center	37.806, -122.261	Same as Station 1
Station 3 (204LME575)	Mid-lake	Long-term continuous monitoring site, representative of Trestle Glen Arm conditions near lake center	37.806, -122.253	Same as Station 1
Water Board Station A (204LME500)	Mid-lake	Short-term continuous monitoring site (June-October 2024), representative of central lake conditions	37.804, -122.259	*Continuous Monitoring:* Dissolved oxygen, temperature, salinity *June only:* Nutrients, DOC, BOD, and TOC *October only:* Nutrients and DOC

Water Board Station B (204LME550)	Mid-lake	Short-term continuous monitoring site (June-October 2024), representative of central lake conditions	37.805, -122.256	Same as Water Board Station A
Glen Echo Creek (204GLE005)	Tributary	In the creek immediately above the lake – location is subject to lake water intrusion depending on tidal cycle	37.811, -122.262	*Monthly (June through October):* Nutrients and dissolved organic carbon (DOC) *June only:* Biochemical oxygen demand (BOD) and total organic carbon (TOC)
Top of Trestle Glen Arm (204LME055)	Mixture of tributary input and lake water	Right at the concrete opening inside the lake (there is no daylighting area on the tributary above the lake)	37.809, -122.249	Same as Glen Echo Creek
Lake Merritt Channel, near 10th Street (204LMC800)	Bay water inflow	Representative of bay water when sampled during incoming tides	37.796, -122.260	Same as Glen Echo Creek
Rocky shore near Rotary Nature Center (RNC), by a storm drain (204LME200)	Lake perimeter	Shallow area with low water circulation near a storm drain	37.807, -122.256	Same as Glen Echo Creek
Cove near East 18th Street runoff (204LME300) – *not shown on map*	Lake perimeter	Near Park Blvd. runoff	37.801, -122.255	*June only:* Nutrients, BOD and TOC

[1] "Nutrients" refers to total ammonia, low-level nitrate + nitrite as nitrogen, total Kjeldahl nitrogen, orthophosphate, and total phosphorus.

In October 2025, four additional upstream watershed sites were sampled to supplement the Lake Merritt and Lake Merritt Channel stations. These supplemental sites, located in the upper portions of the Glen Echo Creek, Indian Gulch, and Pleasant Valley Creek watersheds, were added to characterize upstream nutrients and streamflow to improve our understanding of watershed contributions to the lake. The locations of the upstream sites are shown in Figure 3 and Figure 4, and site descriptions are provided in Table 2. Only stations sampled in both 2024 and 2025 were used for year-to-year comparisons.

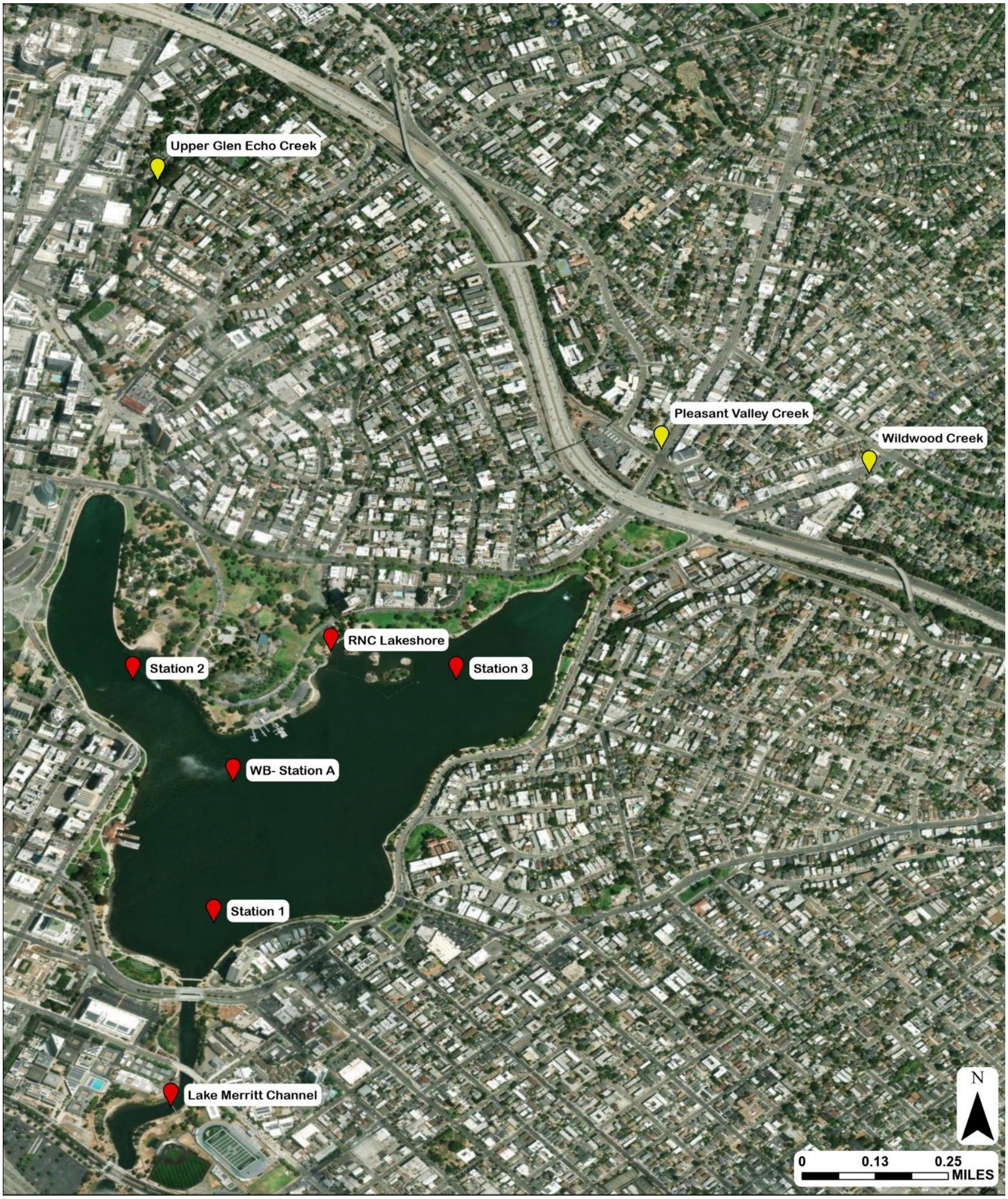

Figure 3. Map of 2025 sampling stations for comparison with the 2024 Lake Merritt nutrient monitoring study

Note: Red icons indicate sites sampled in both 2024 and 2025, while yellow icons indicate sites sampled only in 2025.

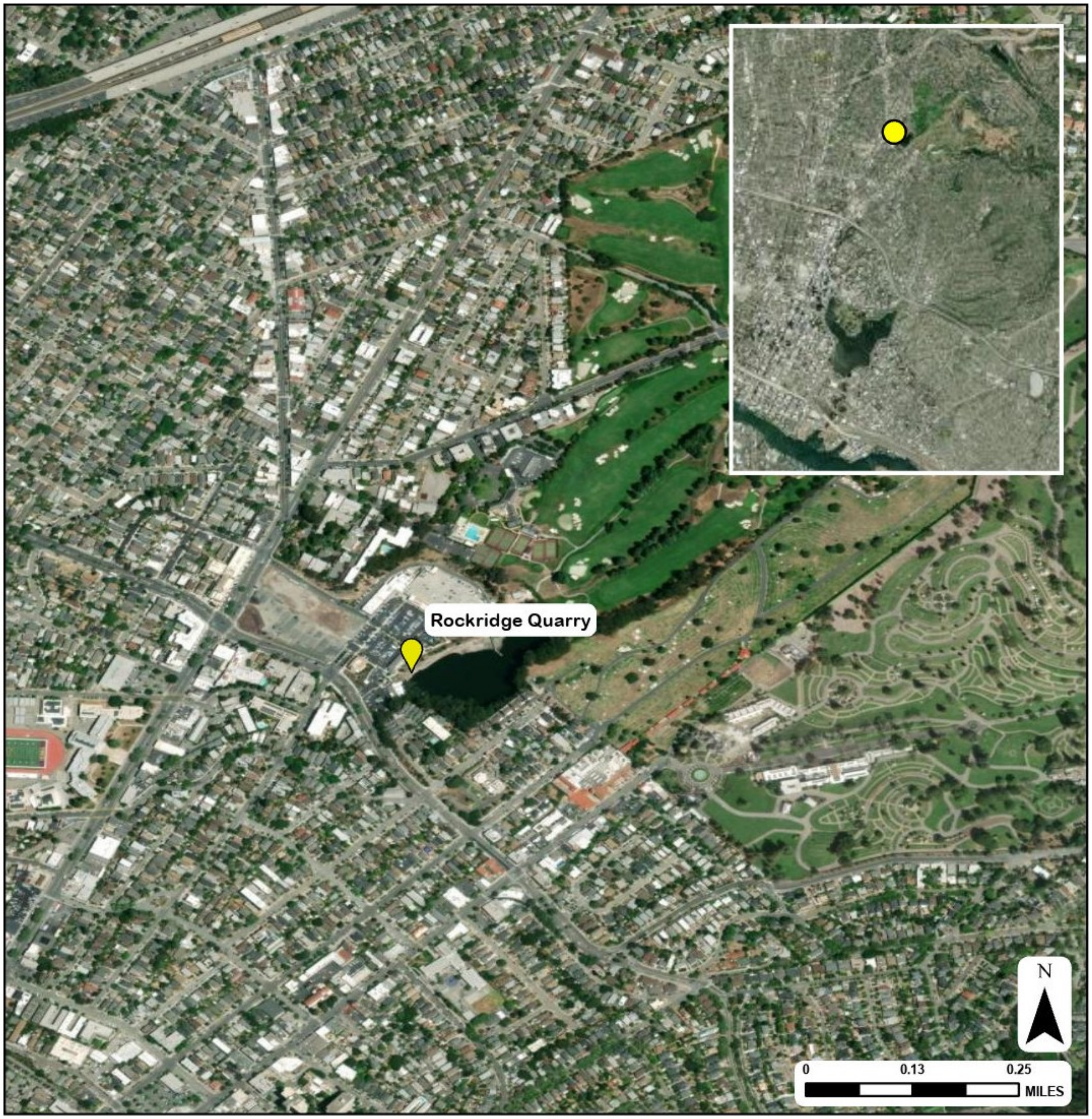

Figure 4. Zoomed-in map of the Rockridge Quarry downstream of the Claremont Country Club

Table 2. Supplemental upstream watershed sampling locations and monitoring parameters measured in October 2025

Station Name	Location Type	Site Selection Consideration	Coordinates	Parameters Measured
Upper Glen Echo Creek	Mid-channel	Representative of Glen Echo Creek watershed inflows to Lake Merritt	37.818, -122.260	*In-situ:* Dissolved oxygen, temperature, salinity; *Laboratory:* Nutrients[1]
Rockridge Quarry	Upper watershed drainage	Representative of upper Glen Echo Creek watershed conditions	37.834, -122.249	Same as Upper Glen Echo Creek
Pleasant Valley Creek Manhole	Manhole	Representative of Pleasant Valley Creek inflows to the Trestle Glen arm of Lake Merritt	37.811, -122.248	Same as Upper Glen Echo Creek
Wildwood Creek Storm Drain	Storm drain	Representative of Wildwood Creek inflows to the Trestle Glen arm of Lake Merritt	37.811, -122.243	Same as Upper Glen Echo Creek

[1] "Nutrients" refers to total ammonia, low-level nitrate + nitrite as nitrogen, total Kjeldahl nitrogen, orthophosphate, and total phosphorus.

2.2 Methods

Monthly grab sampling was conducted on June 5, July 17, August 14, September 11, and October 9, 2024, led by the Water Board staff. At the inner-lake sites, grab samples were collected from a boat, while the Lake Merritt Channel and Glen Echo Creek samples were collected using a bucket and rope. All field collection and quality assurance procedures followed the State Surface Water Ambient Monitoring Program (SWAMP) protocols. At each site, water quality parameters (i.e., dissolved oxygen, temperature, pH, and specific conductivity) were measured using a YSI ProDSS meter. All probes were checked for quality assurance and passed all calibration checks. Streamflow at Glen Echo Creek was measured using a SonTek FlowTracker 2.

Field sampling methods were designed to capture representative nutrient conditions across Lake Merritt and the Lake Merritt Channel, with particular attention to tidal influence and sampling logistics. Only surface water samples (approximately 0.1 m below the surface) were collected at each site. Sampling at the Lake Merritt Channel was prioritized during incoming tides to ensure samples represented Bay water entering the lake. Other lake and Glen Echo Creek stations were sampled at varying points in the tidal cycle, since completing the full sampling circuit required approximately six hours, roughly the length of a typical tidal cycle. In general, Lake Merritt Channel samples were collected when current velocities were small, either near the end of a weak flood tide

(June and October) or during slack tide (July, August, and September) (Figure 5). Based on a post-analysis, the Lake Merritt Channel nutrient sample collected in 2024 occurred when the tide gates were open.

One of the intended tributary input sites, Top of Trestle Glen Arm (204LME055), was collected inside the lake rather than upstream in the tributary due to the lack of accessible open water in the watershed. However, because the sample represented a mixture of tributary and lake water and results were not useful, data from this site were removed from this report.

In October 2025, Water Board staff collected samples in Lake Merritt and at the Lake Merritt Channel to support a year-to-year comparison and get a better understanding of nutrient sources. In addition to the inner-lake and channel sites, four supplemental upstream watershed locations were sampled to characterize nutrient loads entering Lake Merritt from the upper portions of the Glen Echo Creek, Indian Gulch, and Pleasant Valley Creek watersheds. Grab samples at the upper Glen Echo Creek site were collected from the middle of the creek channel, while samples at the Rockridge Quarry, Pleasant Valley Creek manhole, and Wildwood Creek storm drain were collected using a bucket and rope. Analytical methods were consistent with those used in 2024. Streamflow was measured at Glen Echo Creek; however, flow measurements could not be obtained at the manhole or storm drain. At the Pleasant Valley Creek manhole, the water surface was located well below street grade, making safe and accurate flow measurement impractical. At the Wildwood Creek storm drain, water levels were insufficient for reliable flow measurement. Despite these limitations, upper and lower bound flow estimates were developed by Water Board staff through inspection of short videos taken during sampling to calculate nutrient loads. Locations and details of these supplemental sites are provided in Table 2, Figure 3, and Figure 4. Based on a post-analysis, the Lake Merritt Channel nutrient sample collected in 2025 occurred when the tide gates were closed.

All data are accessible through CEDEN using the station codes in Table 1 and are also provided in the accompanying Excel file on the Lake Merritt project webpage. Additionally, Water Board Stations A and B were combined as a single station (Water Board Station B) because Station A only had data available for two months—June and October. These two sites are located very close to one another and exhibit similar water quality characteristics.

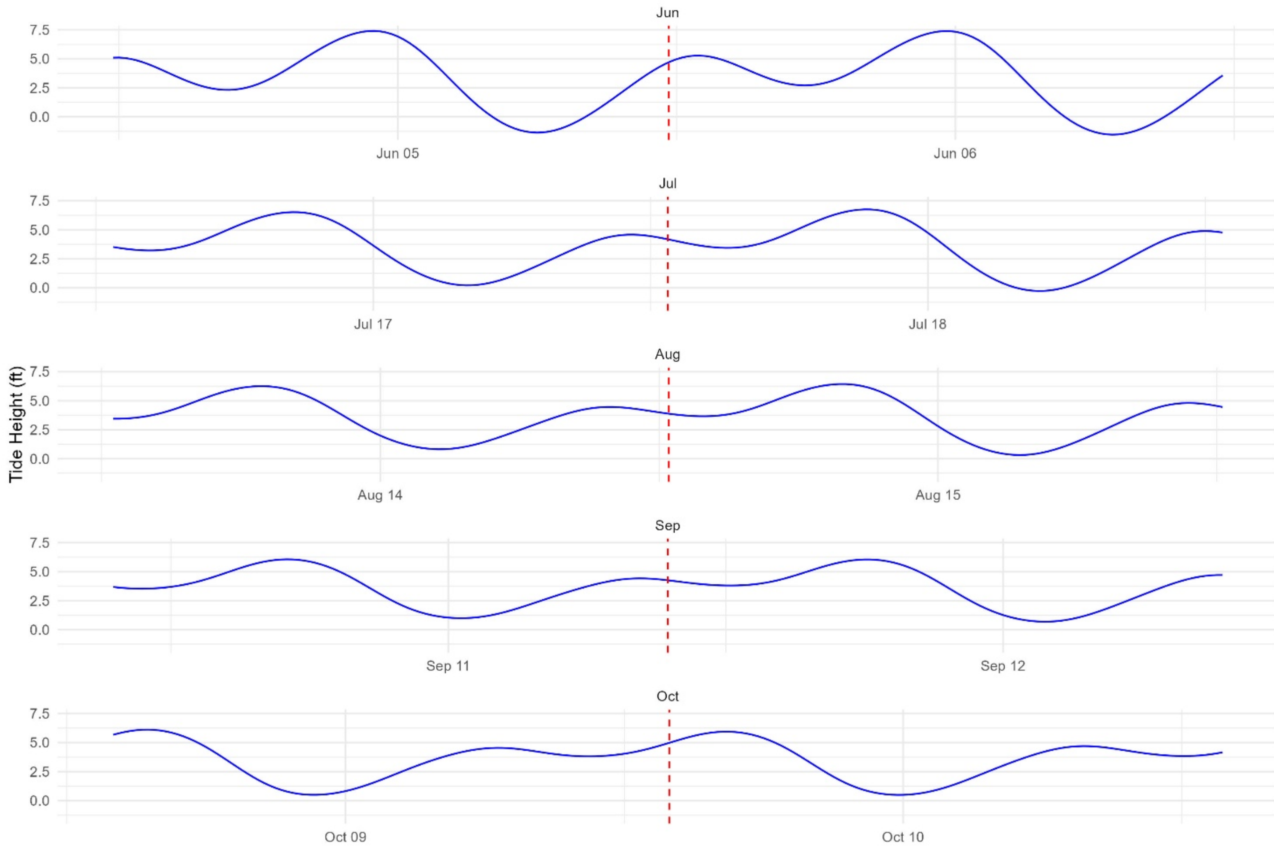

Figure 5. Tide heights in Alameda, San Francisco Bay on the dates of Lake Merritt sampling
Note: Red dashed lines indicate the approximate time of sample collection at the Lake Merritt Channel during each event.

2.3 Monitoring Parameters

Water grab samples were analyzed for the parameters listed in Table 3, with laboratory analyses performed by Babcock Laboratories, Inc. Total nitrogen was calculated by the lab as the sum of total Kjeldahl nitrogen (TKN) and nitrate + nitrite. Dissolved inorganic nitrogen (DIN) was subsequently calculated by the Water Board as the sum of nitrate + nitrite and total ammonia.

Due to a lack of informative results, after the first round of sampling, biochemical oxygen demand (BOD) and total organic carbon (TOC) were dropped and not analyzed for July through October. All BOD results from the first sampling event (June 5, 2024) were non-detects, indicating that BOD was not a significant factor affecting dissolved oxygen conditions. TOC was also discontinued after the first round of sampling, as it did not provide additional information beyond that obtained from dissolved organic carbon (DOC) and other nutrient parameters. In addition, because the study focused on the dissolved nutrient fractions, DOC was retained as the carbon metric to remain consistent with dissolved nitrogen and phosphorus measurements.

All non-detect (ND) values were substituted with one-half of the method detection limit (MDL), following standard practice to retain the full dataset for analysis. MDLs for each parameter are provided in Table 2.

Table 3. Summary of monitoring parameters, preservatives, holding times, reporting levels, and method detection limits.

Analyte	Preservative	Holding Time	Reporting Level	Method Detection Limit
Total Ammonia	H_2SO^4	28 d	0.01 mg/L	0.0049 mg/L
Low Level Nitrate + Nitrite as Nitrogen (NO_3N+NO_2N) 353.2*	H_2SO^4	28 d	0.01 mg/L	0.0038 mg/L
Total Kjeldahl Nitrogen (TKN)	H_2SO^4	28 d	0.1 mg/L	0.093 mg/L
Orthophosphate	None	48 hrs	0.05 mg/L	0.016 mg/L
Total Phosphorus	H_2SO^4	28 d	0.01 mg/L	0.01 mg/L
Biochemical Oxygen Demand (BOD)	None	48 hrs	1 mg/L	1 mg/L
Total Organic Carbon (TOC)	H_2SO^4	28 d	0.7 mg/L	0.13 mg/L
Dissolved Organic Carbon (DOC)	H_2SO^4, field filter	28 d	0.3 mg/L	0.19 mg/L

3 Results and Discussion

3.1 Salinity

Lake Merritt is tidally influenced by waters coming from San Francisco Bay through Oakland Inner Harbor, and then into the Lake Merritt channel. Measuring salinity in water samples, particularly from tributaries, helps distinguish whether the samples represent freshwater inputs from the upstream watershed or a mixture of creek and lake water, as lake water can be pushed upstream into low lying stream segments during incoming tides.

At Station 1, Station 2, Station 3, Rotary Nature Center Shore, and Water Board Station B stations (hereafter collectively referred to as “Lake Merritt stations”), salinity ranged from 25.0 to 34.3 ppt, with a mean of 30.8 ± 2.5 ppt (standard deviation, SD) and a median of 31.3 ppt (Figure 6). Salinity values at the Lake Merritt Channel were similar, ranging from 29.1 to 34.4 ppt, with a mean of 32.2 ± 2.0 ppt (standard deviation, SD) and a median of 32.6 ppt, consistent with brackish conditions. The boxplots indicate that salinity levels and variability at the Lake Merritt stations were comparable to those observed in the Lake Merritt Channel, which represents bay water entering the lake. This similarity indicates strong hydrologic connectivity between the lake and the channel.

In contrast, salinity in the Glen Echo Creek was more variable, ranging from 0.4 to 32 ppt, with a mean of 11.1 ± 14.5 ppt and a median of 1.67 ppt. These results highlight that although the samples were collected upstream in the Glen Echo Creek, tidal influence can push saline water back into this section of the creek and mix with incoming freshwater. The boxplot for Glen Echo Creek shows that three of the samples collected were freshwater (< 1.4 ppt, indicated by diamonds at bottom of the box), while the other two samples reflected marine water mixed with freshwater (> 20 ppt, indicated by circles).

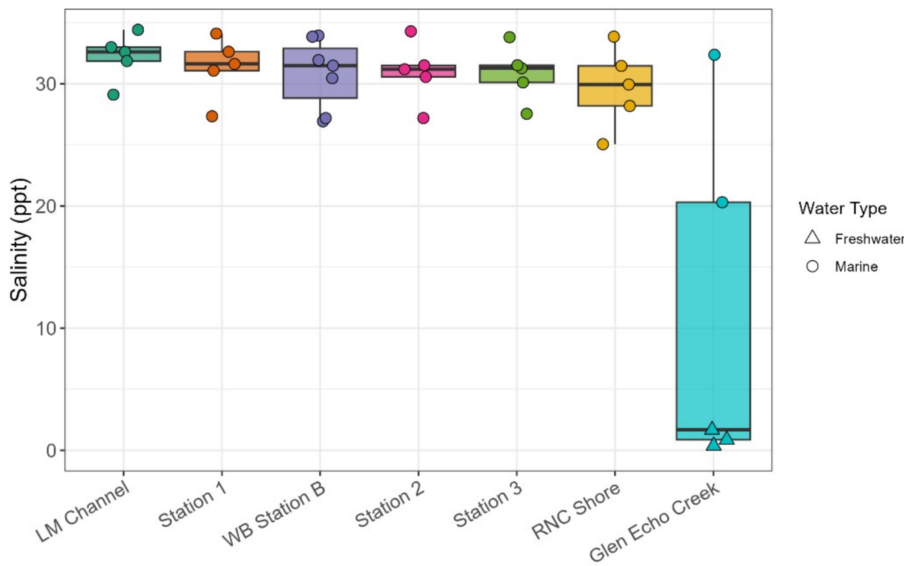

Figure 6. Boxplots of Salinity (ppt) from June to October 2024

Salinity was further examined using a time-series plot to assess temporal variation (Figure 7). At the Lake Merritt stations and the Lake Merritt Channel, trends were similar: salinity was lowest in June and highest in October. From June through September, values remained relatively stable with only minor variation. In contrast, at Glen Echo Creek the lowest salinity occurred in July, while the highest was again observed in October. This plot also highlights that the June-August samples from Glen Echo Creek were freshwater, whereas the September and October samples reflected a mixture of marine and freshwater.

For June through August, low salinity values at Glen Echo Creek suggest that collected samples represent the chemical characteristics of freshwater outflow from the creek. In contrast, the elevated salinity observed in September and October indicates a strong influence of lake water, suggesting that samples during those months represented a mixture of creek outflow and lake water pushed into Glen Echo Creek, presumably due to tidal action, rather than purely freshwater inflows. Because the September and October data are confounded by the mixing of Glen Echo Creek and lake water, they are shown as individual points but not connected by a line. These samples are included for completeness but should not be considered when evaluating potential temporal trends at Glen Echo Creek, as they do not reflect typical freshwater conditions. For future sampling, consideration of tidal cycles, along with concurrent conductivity measurements, will be important to ensure sampling captures freshwater conditions in Glen Echo Creek. Additionally, sampling farther upstream of the tidal influence could help avoid this issue.

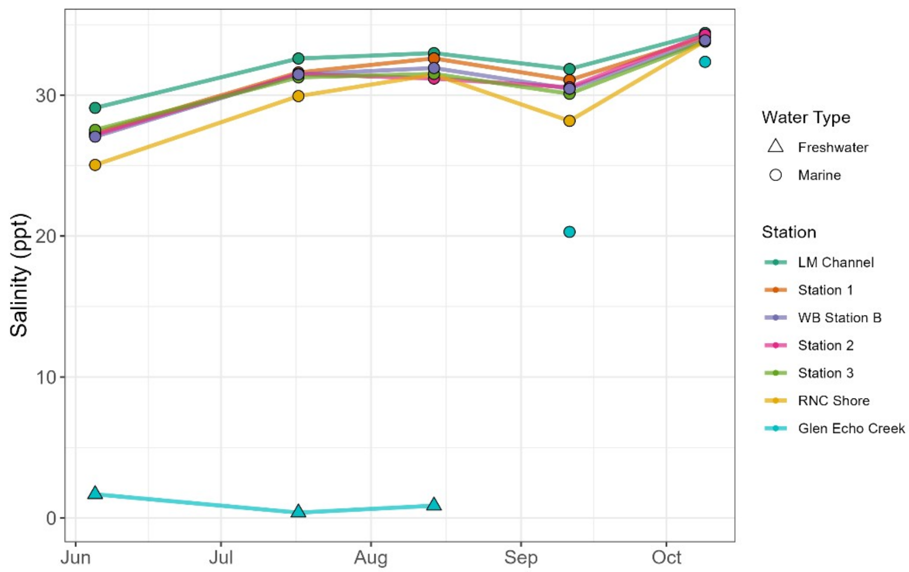

Figure 7. Time series of Salinity (ppt) from June to October 2024
Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

3.2 Dissolved Organic Carbon

Bay water entering Lake Merritt through the Lake Merritt Channel had the lowest dissolved organic carbon (DOC) concentrations and smallest variation (Figure 8), ranging from 1.9 to 2.4 mg/L (mean = 2.1 ± 0.2 mg/L; median = 2.2 mg/L). DOC concentrations at the Lake Merritt stations were slightly higher and more variable, ranging from 2.2 to 4.6 mg/L (mean = 2.9 ± 0.6 mg/L; median = 2.7 mg/L), and increased gradually from Station 1 toward the center of the lake (WB Station B) and into the arms (Station 2, Station 3, and RNC shore). The highest concentrations were observed at the Glen Echo Creek, reflecting stronger freshwater influence from creek inputs (DOC range = 2.9-5.2 mg/L; mean = 3.7 mg/L ± 0.9 mg/L; median = 3.5 mg/L). Overall, DOC concentrations in Lake Merritt and the Lake Merritt Channel were within the typical range reported for San Francisco Bay and other estuarine systems, with slightly higher values observed farther inland toward freshwater inputs.

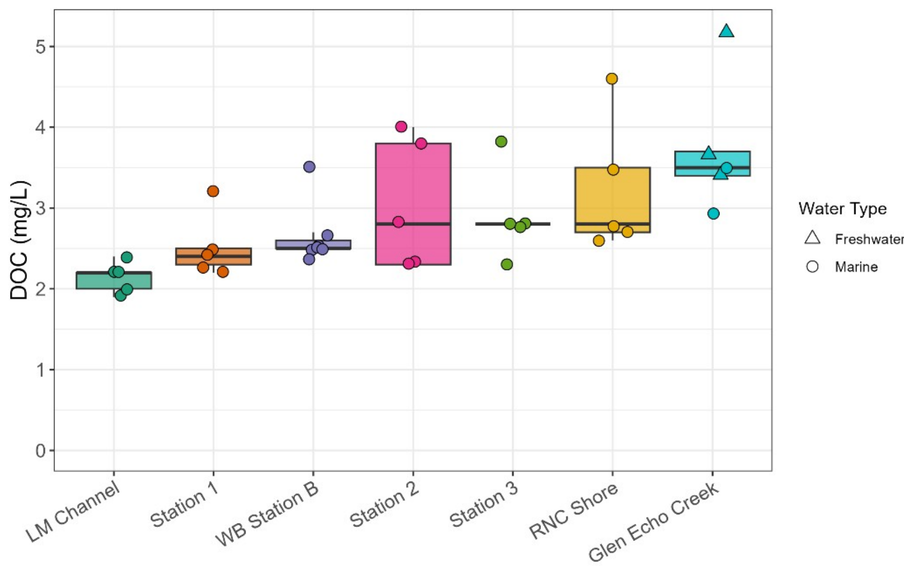

Figure 8. Boxplots of Dissolved Organic Carbon (DOC, in mg/L) from June to October 2024

For most Lake Merritt stations and the Lake Merritt Channel, DOC concentrations peaked in September (Figure 9), showing a sharp increase from August to September, followed by a decline in October to levels comparable to those measured in June and July. In June, Station 2 exhibited higher DOC relative to the other Lake Merritt stations, likely due to inputs from Glen Echo Creek during early summer when spring runoff may have delivered DOC-rich freshwater. At Glen Echo Creek, DOC was highest in June and lowest in August. The September and October sampling events (shown as circles) at Glen Echo Creek were likely influenced by lake water backing into the channel, indicated by the elevated salinity measured during these events. Under freshwater inflow conditions (low salinity) in June and July, DOC at Glen Echo Creek was higher than at the Lake Merritt stations, reflecting terrestrially derived organic matter inputs.

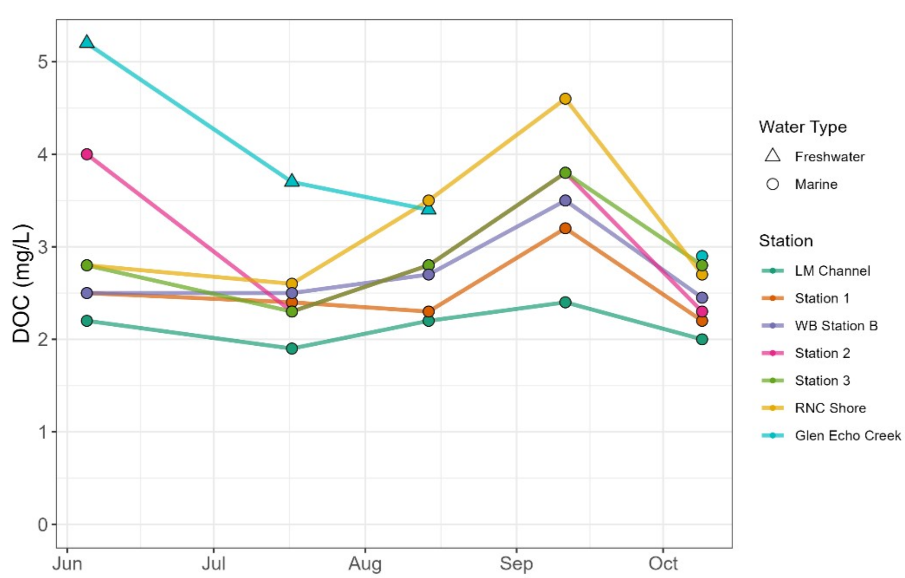

Figure 9. Time series of Dissolved Organic Carbon (DOC, in mg/L) from June to October 2024

Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

3.3 Nitrogen Species

3.3.1 Total Ammonia

At the Lake Merritt stations, total ammonia (as N, mg/L) concentrations ranged from non-detect (0.005 mg/L) to 0.34 mg/L (mean = 0.07 ± 0.08 mg/L; median = 0.07 mg/L). At the Lake Merritt Channel, concentrations ranged from 0.04 to 0.16 mg/L (mean = 0.10 ± 0.05 mg/L; median = 0.10 mg/L). At the Glen Echo Creek, concentrations were more consistent, ranging narrowly from 0.09 to 0.15 mg/L (mean = 0.12 ± 0.03 mg/L; median = 0.11 mg/L). Overall, there were no clear differences in the distribution of total ammonia concentrations among sites, although the Glen Echo Creek showed the least variation (Figure 10).

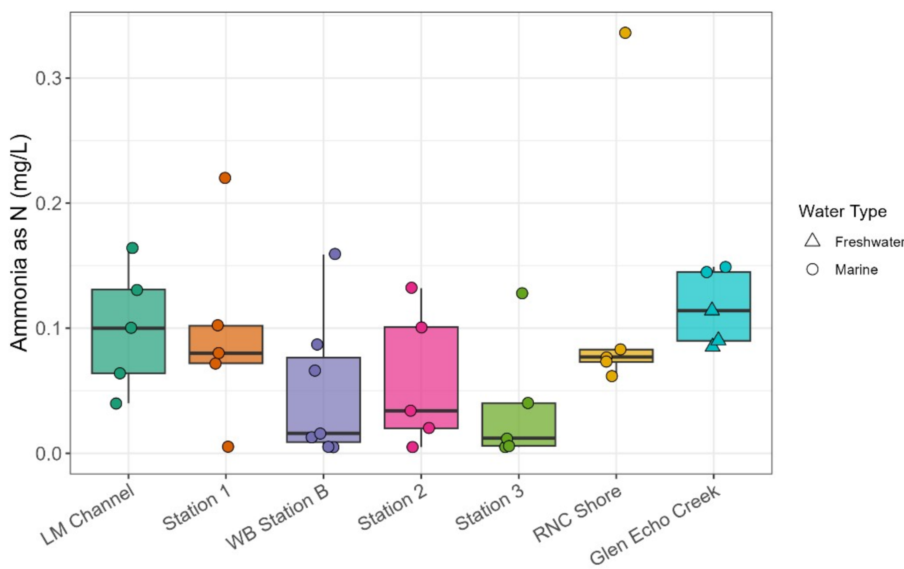

Figure 10. Boxplots of Total Ammonia as Nitrogen (mg/L) from June to October 2024

For the Lake Merritt stations and the Lake Merritt Channel, total ammonia concentrations peaked in September (Figure 11), with a sharp increase from August to September, followed by a decline in October. In contrast, ammonia concentrations at the Glen Echo Creek showed moderate variability across the freshwater samples.

Total ammonia concentrations were compared to the site-specific chronic freshwater ammonia criteria calculated using measured pH and temperature, following the U.S. EPA 2013 freshwater ammonia criteria. Out of all 43 samples collected in Lake Merritt and the Lake Merritt Channel, none exceeded the calculated acute and chronic ammonia threshold for their respective pH and temperature conditions, indicating that ammonia levels were consistently below concentrations expected to cause toxicity to freshwater organisms.

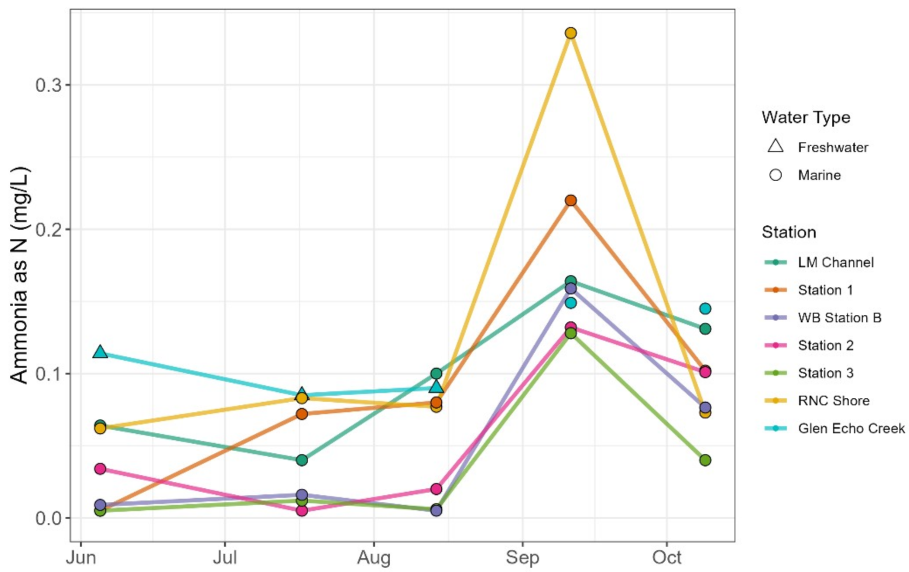

Figure 11. Time series of Total Ammonia as Nitrogen (mg/L) from June to October 2024
Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

3.3.2 Nitrate + Nitrite

The highest nitrate + nitrite (as N, mg/L) concentrations were observed at the Glen Echo Creek (Figure 12); ranging from 1.1 to 1.6 mg/L (mean = 1.3 ± 0.2 mg/L; median = 1.3 mg/L). Concentrations at the Lake Merritt Channel were substantially lower, ranging from 0.056 to 0.16 mg/L (mean = 0.10 ± 0.04 mg/L; median = 0.1 mg/L). The lowest concentrations were measured at the Lake Merritt stations, where values ranged from non-detect (0.004 mg/L) to 0.078 mg/L (mean = 0.02 ± 0.02 mg/L; median = 0.013 mg/L). These patterns suggest that inputs from Glen Echo Creek and the Lake Merritt Channel deliver water with relatively high nitrate + nitrite, while concentrations in the lake are reduced through dilution and biological uptake. Although nitrate + nitrite concentrations from Glen Echo Creek were much higher compared to the incoming Lake Merritt channel, they are within the typical range of other Bay Area urban creeks.

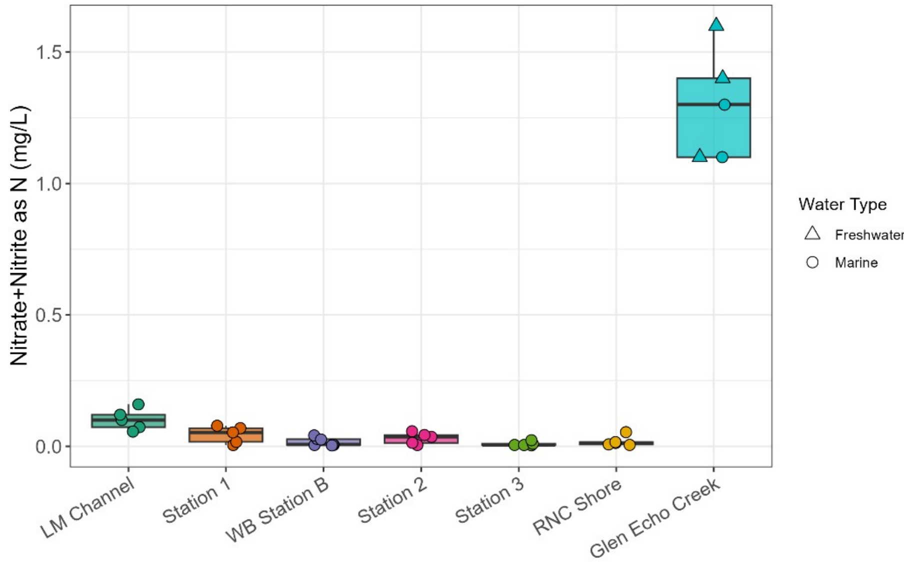

Figure 12. Boxplots of Nitrate + Nitrite as Nitrogen (mg/L) from June to October 2024

To better highlight trends at the Lake Merritt Channel and Lake Merritt stations, a second figure was generated focusing on those sites (Figure 13). This comparison further highlights that nitrate + nitrite concentrations at the Lake Merritt Channel were slightly, but consistently, higher than those at the Lake Merritt stations. Station 1 (mean = 0.04 ± 0.03 mg/L; median = 0.053 mg/L) may reflect some influence from the Channel, as concentrations there were marginally higher than at other Lake Merritt stations.

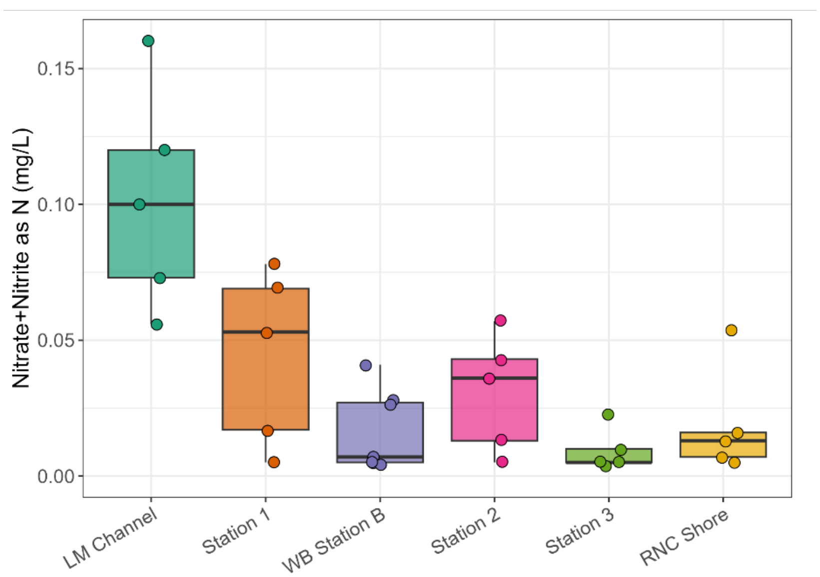

Figure 13. Boxplots of Nitrate + Nitrite as Nitrogen (mg/L) from June to October 2024 for Lake Merritt Channel and Lake Merritt stations

To further assess temporal patterns, nitrate + nitrite concentrations were examined from June through October (Figure 14). At the Glen Echo Creek, nitrate + nitrite concentrations showed moderate variability across the freshwater samples. To better visualize patterns at the Lake Merritt Channel and Lake Merritt stations, a second time-series plot was generated excluding Glen Echo

Creek data ([Figure 15](#)). In this plot, the Lake Merritt Channel showed the lowest concentrations in July, rising to the highest values in October, whereas the Lake Merritt stations exhibited no consistent temporal trends.

Nitrate + nitrite concentrations at Station 1 appeared to be influenced by the Lake Merritt Channel in August and October, resulting in slightly higher values compared to the other Lake Merritt stations. In September, this channel influence was less evident, which may reflect sampling under conditions when lake water, rather than incoming channel water, was the dominant influence, possibly due to tide gate closures.

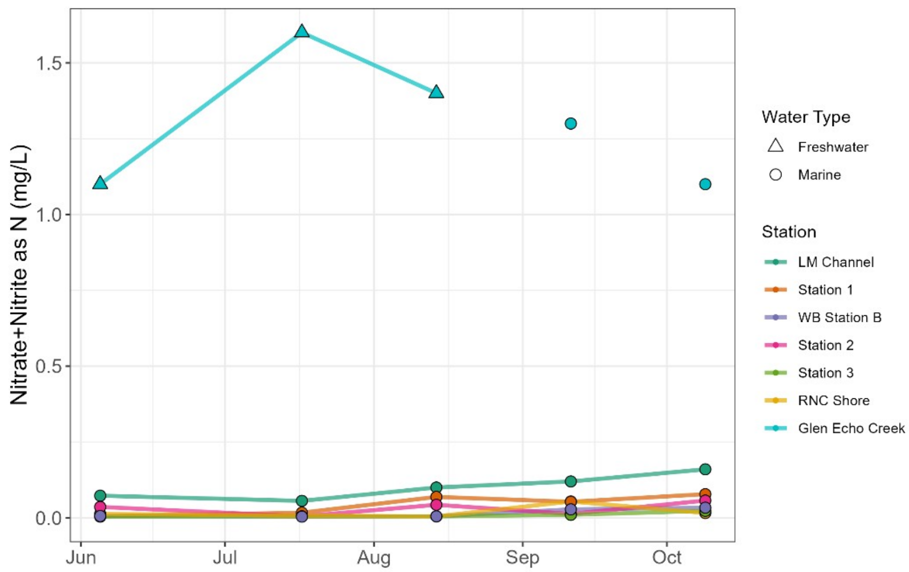

Figure 14. Time series of Nitrate + Nitrite as Nitrogen (mg/L) from June to October 2024
Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

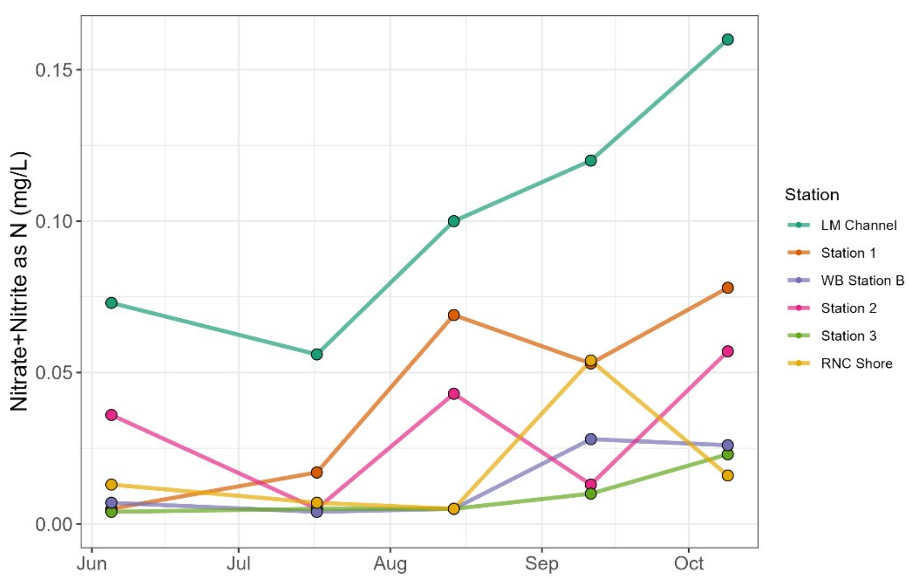

Figure 15. Time series of Nitrate + Nitrite as Nitrogen (mg/L) from June to October 2024 for Lake Merritt Channel and Lake Merritt stations

3.3.3 Dissolved Inorganic Nitrogen

Dissolved inorganic nitrogen (DIN) is the sum of total ammonia and nitrate + nitrite, representing the forms of nitrogen that are bioavailable for algal uptake. The highest DIN concentrations and greatest variation were observed at the Glen Echo Creek (Figure 16); ranging from 1.2 to 1.7 mg/L (mean = 1.4 ± 0.2 mg/L; median = 1.4 mg/L). Concentrations at the Lake Merritt Channel were substantially lower, ranging from 0.096 to 0.30 mg/L (mean = 0.20 ± 0.09 mg/L; median = 0.2 mg/L). The lowest concentrations were measured at the Lake Merritt stations, with values ranging from 0.009 mg/L to 0.39 mg/L (mean = 0.10 ± 0.09 mg/L; median = 0.08 mg/L).

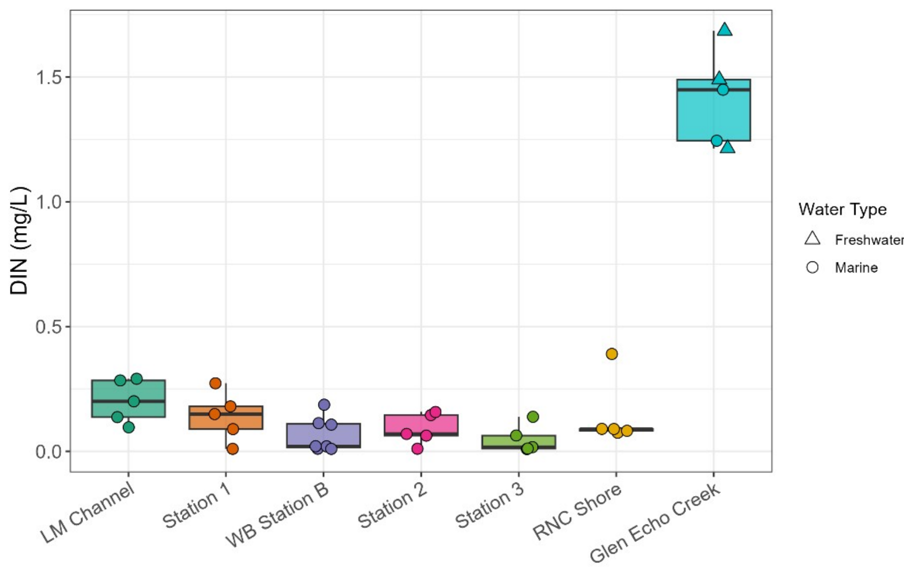

Figure 16. Boxplots of Dissolved Inorganic Nitrogen (DIN, in mg/L) from June to October 2024

To better visualize patterns at the Lake Merritt Channel and Lake Merritt stations, Figure 17 was generated excluding the Glen Echo Creek data. DIN concentrations at the Lake Merritt Channel were slightly higher than at the Lake Merritt stations and generally decreased from Station 1 toward the center of the lake (WB Station B) and into the arms (Station 2 and Station 3). The RNC Shore did not follow this decreasing trend, as four samples showed low variability while one sample had a relatively high DIN concentration of 0.39 mg/L.

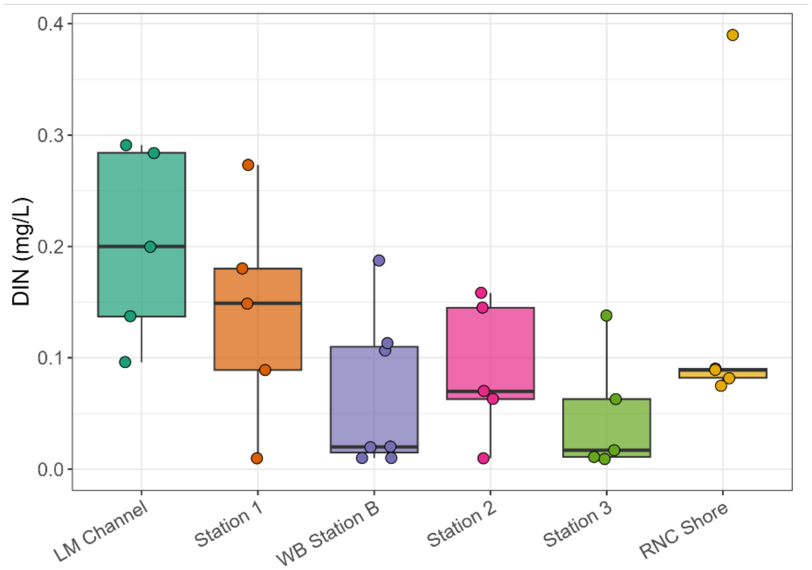

Figure 17. Boxplots of Dissolved Inorganic Nitrogen (DIN, in mg/L) from June to October 2024 for Lake Merritt Channel and Lake Merritt stations

In addition to spatial patterns, DIN concentrations were examined over time to assess temporal changes from June through October (Figure 18). At the Glen Echo Creek, the highest DIN concentration was observed in July (1.7 mg/L), while the lowest concentrations (1.2 mg/L) were observed in both June and October. Despite one sample reflecting freshwater influence (June) and one sample reflecting marine influence (October), both concentrations were the same highlighting the limited influence of salinity on DIN at this site during these periods. To better understand trends at the Lake Merritt stations and Channel, a second time-series plot was generated excluding Glen Echo Creek data (Figure 19). For Station 1, WB Station B, Station 3, and RNC Shore, DIN concentrations peaked in September, showing a clear increase from August to September, followed by a decline in October. In contrast, at the Lake Merritt Channel and Station 2, DIN concentrations decreased from June to July and then gradually increased, reaching their highest levels in October.

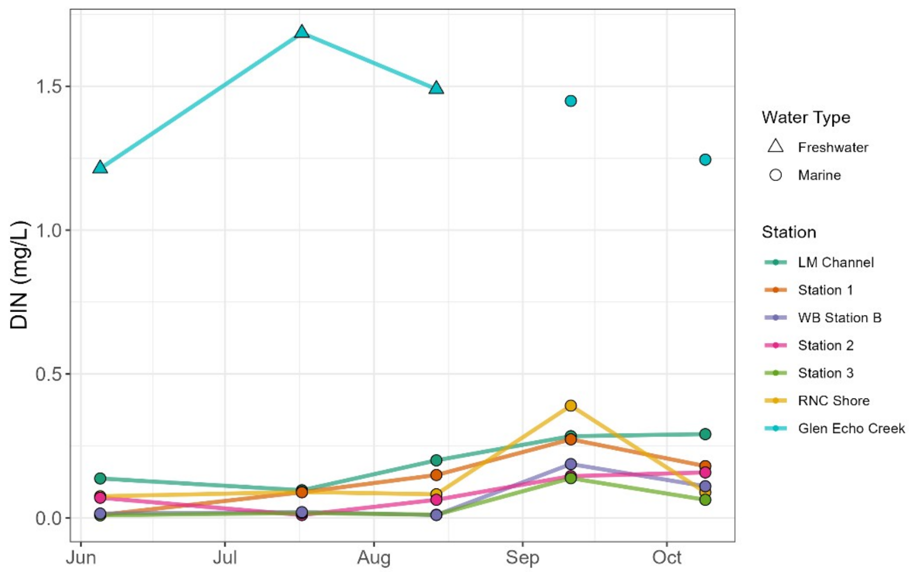

Figure 18. Time series of Dissolved Inorganic Nitrogen (DIN, in mg/L) from June to October 2024

Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

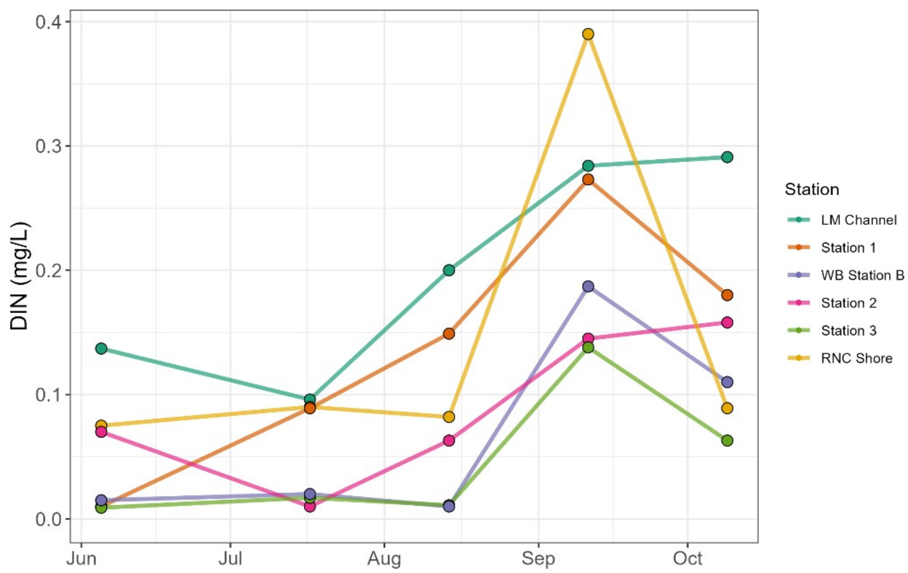

Figure 19. Time series of Dissolved Inorganic Nitrogen (DIN, in mg/L) from June to October 2024 for Lake Merritt Channel and Lake Merritt stations

3.3.4 Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) represents the sum of organic nitrogen and ammonia, providing an estimate of the nitrogen pool available for microbial and algal processing, excluding nitrate and nitrite. The lowest and least variable TKN concentrations were measured at the Glen Echo Creek (Figure 20), ranging from 0.40 to 0.60 mg/L (mean = 0.50 ± 0.07 mg/L; median = 0.50 mg/L). Concentrations at the Lake Merritt Channel were slightly higher, ranging from 0.60 to 0.80 mg/L (mean = 0.74 ± 0.09 mg/L; median = 0.80 mg/L). The highest TKN concentrations and greatest variability were observed at the Lake Merritt stations, with values ranging from 0.40 to 1.3 mg/L (mean = 0.77 ± 0.22 mg/L; median = 0.80 mg/L).

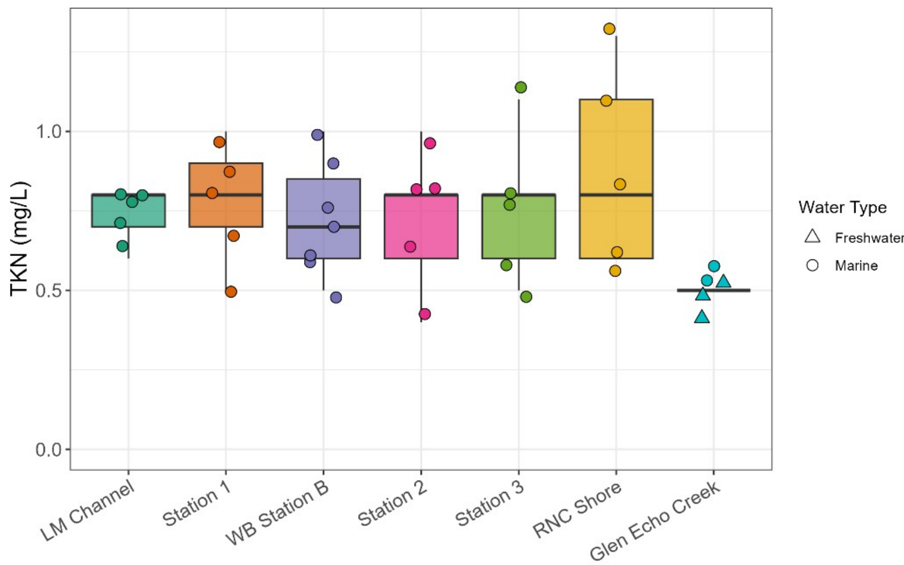

Figure 20. Boxplots of Total Kjeldahl Nitrogen (TKN, in mg/L) from June to October 2024

To evaluate temporal changes, TKN concentrations were examined from June through October (Figure 21). At the Glen Echo Creek, the lowest concentration was observed in July, with little variability around the mean. Despite three samples reflecting freshwater conditions and two reflecting marine influence, TKN concentrations at Glen Echo Creek were generally lower than at the other sites. At the Lake Merritt Channel the lowest concentration was also observed in July and there was minimal variation. At Station 1, WB Station B, Station 2, and Station 3, concentrations increased steadily from June, peaked in September, and declined in October. In contrast, at the RNC Shore, concentrations increased steadily from June and reached their peak in October.

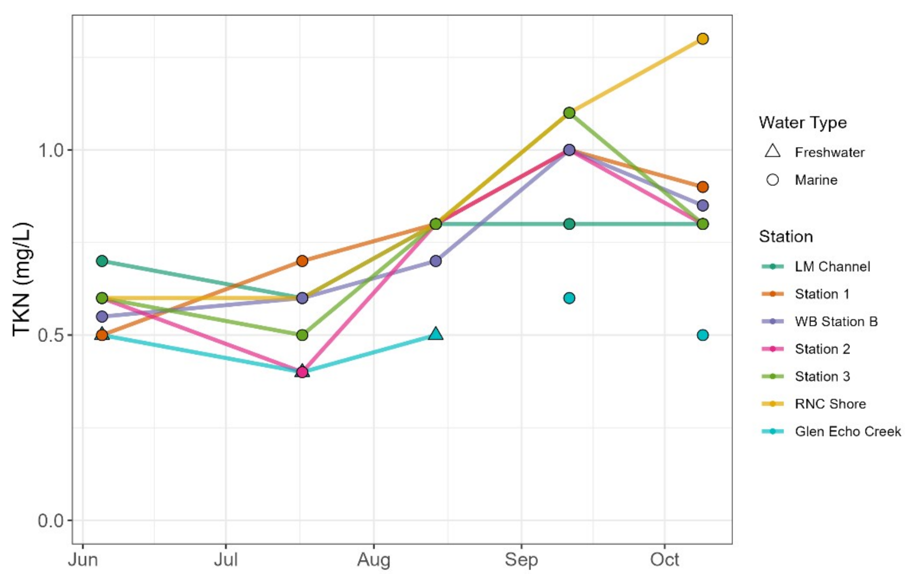

Figure 21. Time series of Total Kjeldahl Nitrogen (TKN, in mg/L) from June to October 2024

Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

3.3.5 Total Nitrogen

Total nitrogen (TN) was calculated by Babcock Laboratories, Inc. as the sum of total Kjeldahl nitrogen (TKN) and nitrate + nitrite. The highest Total Nitrogen (TN) concentrations were measured at the Glen Echo Creek (Figure 22), ranging from 1.6 to 2.0 mg/L (mean = 1.8 ± 0.19 mg/L; median = 1.9 mg/L). At the Lake Merritt stations, concentrations spanned a wider range (0.40 to 1.3 mg/L) but had similar central values (mean = 0.80 ± 0.24 mg/L; median = 0.80 mg/L). Concentrations at the Lake Merritt Channel were comparable, ranging from 0.64 to 0.98 mg/L (mean = 0.83 ± 0.13 mg/L; median = 0.86 mg/L).

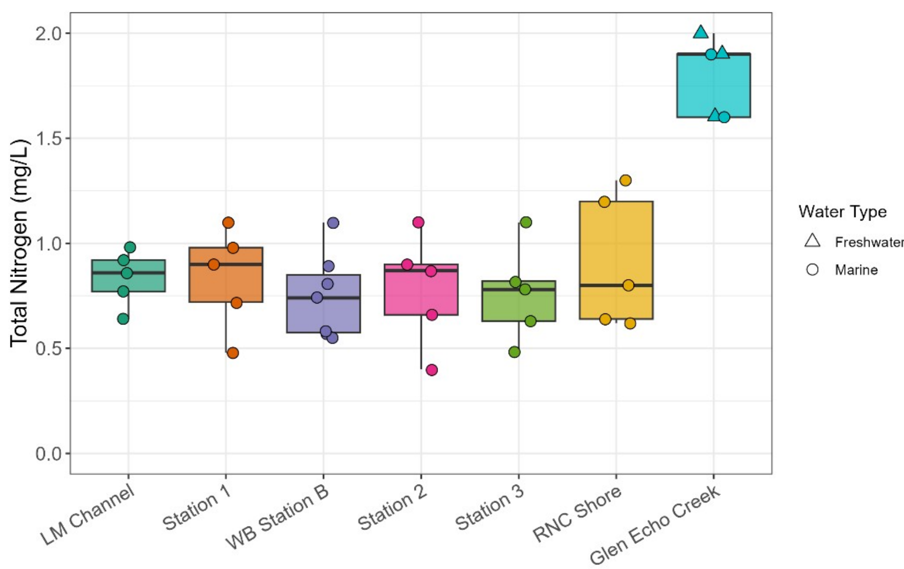

Figure 22. Boxplots of Total Nitrogen (TN, in mg/L) from June to October 2024

To evaluate temporal patterns, TN concentrations were analyzed from June through October (Figure 23). At the Glen Echo Creek, concentrations peaked in July and were lowest in both June and October, though overall variability remained small despite three samples being mostly freshwater while two samples were a mixture of freshwater and marine. At the Lake Merritt Channel, concentrations declined slightly from June to July, then increased steadily through the fall, reaching the highest values in October. At the Lake Merritt stations, most sites showed a consistent rise from June to September followed by a small decline in October. The exception was the RNC Shore, where concentrations continued to rise past September and peaked in October.

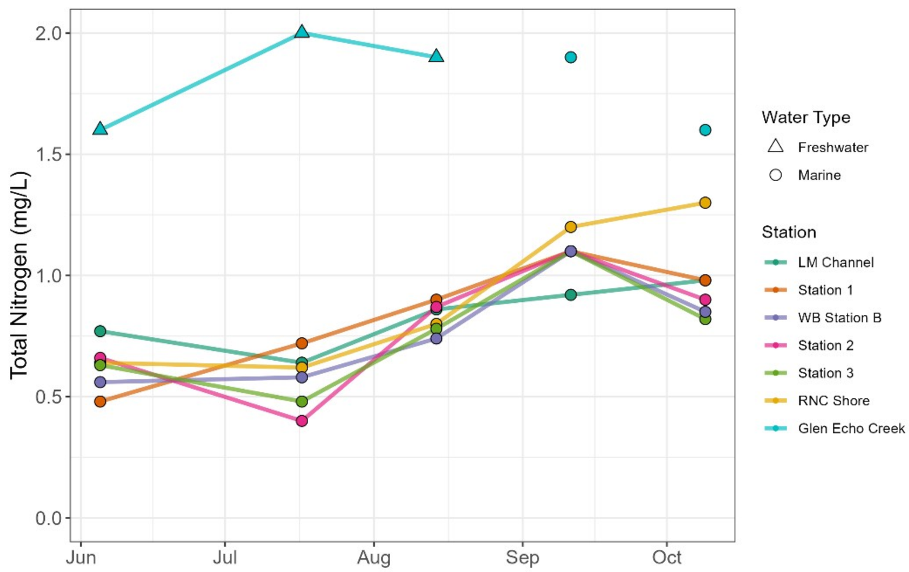

Figure 23. Time series of Total Nitrogen (TN, in mg/L) from June to October 2024
Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

3.4 Phosphorus Species

3.4.1 Orthophosphate

Orthophosphate, the dissolved inorganic fraction of phosphorus readily available for biological uptake, was analyzed to assess spatial and temporal variability among sites. The lowest orthophosphate concentrations were observed at the Lake Merritt Channel (Figure 24), ranging from non-detect (0.025 mg/L) to 0.20 mg/L (mean = 0.14 ± 0.07 mg/L, median = 0.17 mg/L). At Glen Echo Creek, concentrations spanned a narrower range (0.13-0.16 mg/L) but had similar central values (mean = 0.15 ± 0.014 mg/L; median = 0.16). Concentrations at the Lake Merritt stations were also comparable, although they exhibited higher maximum values, ranging from 0.08 to 0.27 mg/L (mean = 0.16 ± 0.05 mg/L; median = 0.16 mg/L).

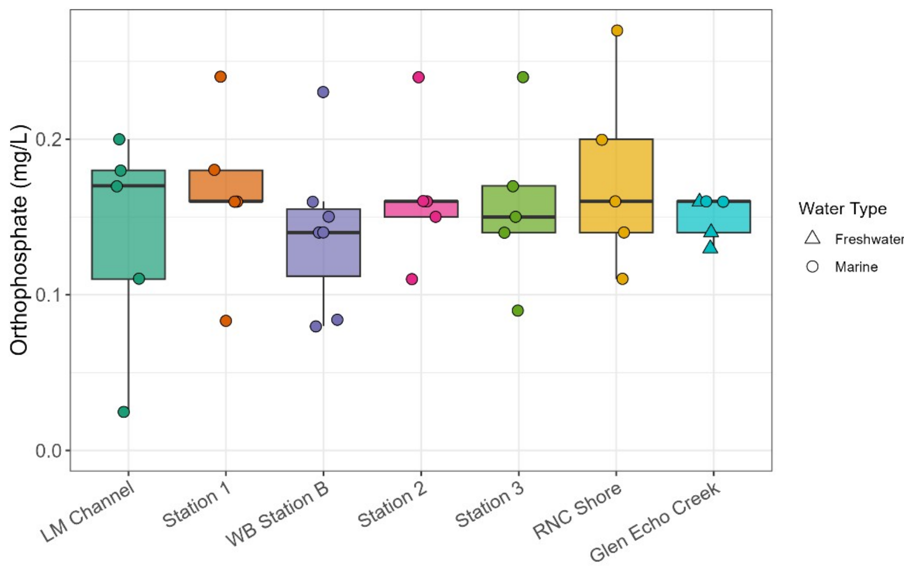

Figure 24. Boxplots of Orthophosphate (mg/L) from June to October 2024

To assess temporal variability, orthophosphate concentrations were examined from June through October across all sites (Figure 25). At the Lake Merritt Channel, orthophosphate concentrations were lowest in June, increased steadily to a peak in September, and then declined slightly in October to values similar to those observed in August. The Lake Merritt stations followed the same temporal trend, although orthophosphate concentrations were generally higher than those observed at the Channel in all months except October, when Lake Merritt Channel concentrations were slightly higher than at the other sites. The highest overall concentration occurred at the RNC Shore in September, but by October levels had declined to values comparable to other stations.

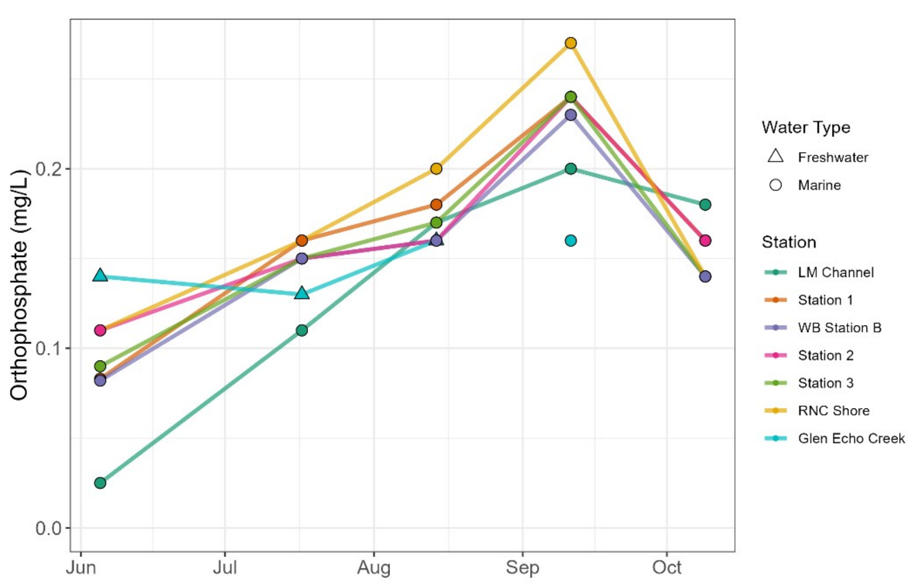

Figure 25. Time series of Orthophosphate (mg/L) from June to October 2024

Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

3.4.2 Total Phosphorus

Total phosphorus, which represents both dissolved and particulate forms of phosphorus, was measured to provide a broader assessment of nutrient availability across sites. The lowest total phosphorus concentrations were observed at the Lake Merritt Channel (Figure 26), ranging from 0.03 to 0.21 mg/L (mean = 0.15 ± 0.07 mg/L, median = 0.18 mg/L). At Glen Echo Creek concentrations spanned a narrower range (0.15-0.20 mg/L) but had similar central values (mean = 0.17 ± 0.02 mg/L; median = 0.17). Concentrations at the Lake Merritt stations were also comparable, although they exhibited higher maximum values, ranging from 0.04 to 0.44 mg/L (mean = 0.18 ± 0.09 mg/L; median = 0.17). Among the Lake Merritt stations, WB Station B and the RNC Shore showed slightly higher total phosphorus concentrations.

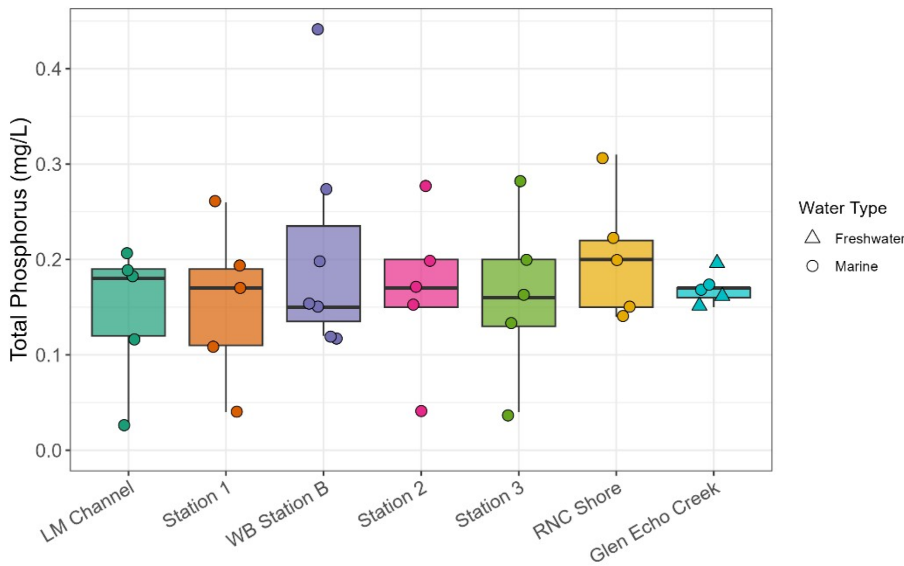

Figure 26. Boxplots of Total Phosphorus (mg/L) from June to October 2024

To assess temporal variability, total phosphorus concentrations were examined from June through October across all sites (Figure 27). At the Lake Merritt Channel, concentrations declined from June to July to the lowest levels observed, then increased to a peak in September before declining slightly in October. A similar trend was observed at Stations 1, 2, and 3. At WB Station B, concentrations peaked earlier, in July, and were higher than at the other Lake Merritt stations. At the RNC Shore, concentrations increased steadily each month until reaching a peak in September, followed by a slight decline in October.

At Stations 1, 2, 3, and the Lake Merritt Channel, total phosphorus values measured in July were lower than expected, with some results falling below corresponding dissolved fractions described in the previous section. Although the laboratory confirmed the reported results, these measurements may underestimate true total phosphorus concentrations and should be interpreted with caution.

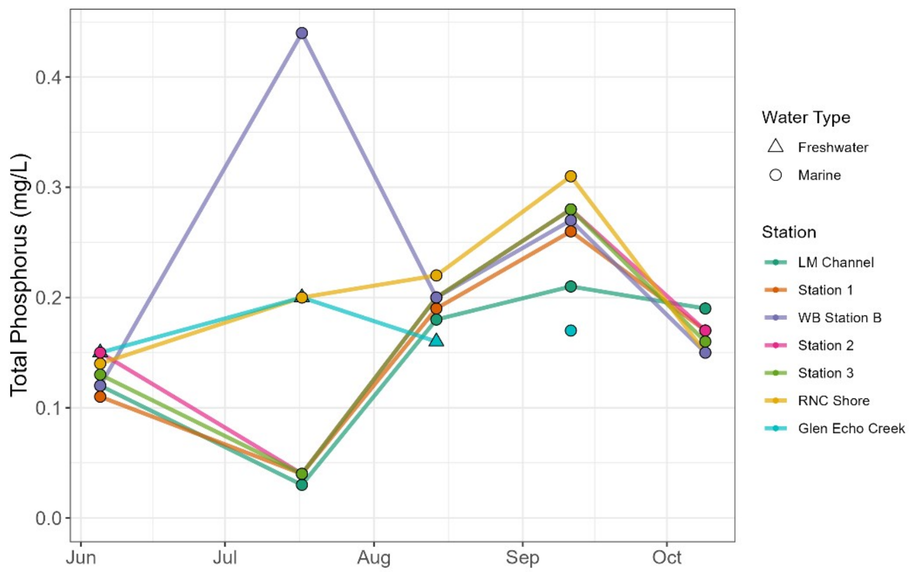

Figure 27. Time series of Total Phosphorus (mg/L) from June to October 2024
Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

3.5 Redfield Ratios

The Redfield ratio describes the standard atomic ratio of carbon, nitrogen, and phosphorus (106:16:1) originally observed in marine phytoplankton and seawater, and is commonly used as a benchmark to assess nutrient limitation in aquatic ecosystems (Redfield, 1934; Redfield et al., 1963). Redfield ratios were calculated to provide insight into nutrient dynamics and the potential for nitrogen or phosphorus to limit algal growth Lake Merritt. This assessment helps determine whether nutrient reduction activities could be effective for nutrient management in the system. Redfield ratios were calculated using the dissolved fractions of nitrogen and phosphorus (i.e., DIN and orthophosphate), which are most relevant for evaluating nutrient limitation in an estuarine environment like Lake Merritt. An N:P ratio below 16:1 indicates nitrogen limitation; a condition commonly observed in marine and estuarine systems such as San Francisco Bay. Conversely, an N:P ratio above 16:1 indicates phosphorus limitation, which is more typical of freshwater systems.

To illustrate spatial differences in nutrient limitation potential, box plots of Redfield ratios were generated for Lake Merritt and comparison sites (Figure 28). At the Lake Merritt Channel and interior Lake Merritt stations, Redfield ratios were consistently well below the red dashed line representing the 16:1 threshold, confirming that nitrogen is the limiting nutrient in this system. In contrast, at Glen Echo Creek, all monthly Redfield ratios were above the 16:1 red dashed line, indicating that phosphorus is the controlling nutrient for algal growth within the creek ecosystem.

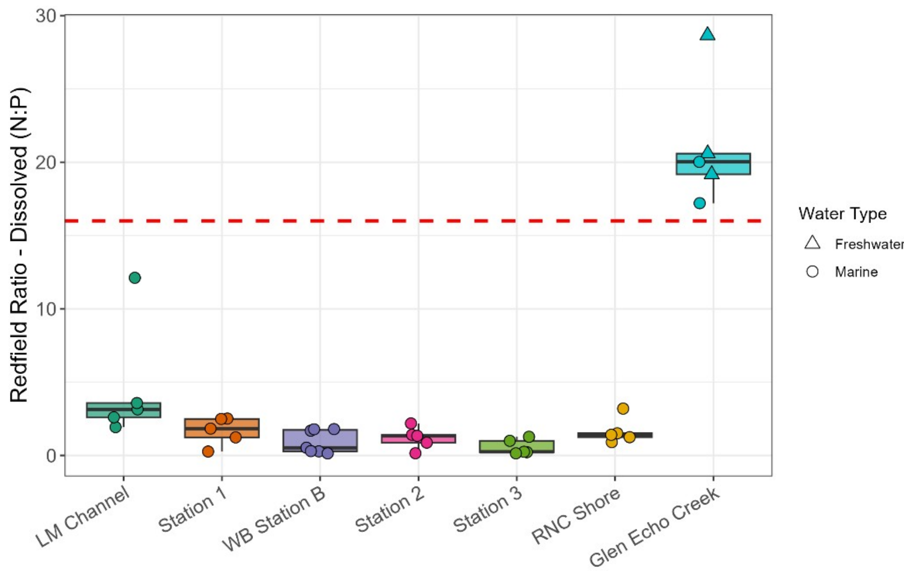

Figure 28. Boxplots of Redfield Ratios (N:P) from June to October 2024

To assess temporal trends, Redfield ratios were evaluated from June through October across all sites (Figure 29). At Glen Echo Creek, the ratio consistently exceeded the 16:1 threshold, approaching the threshold in October. In contrast, the Lake Merritt stations remained well below the 16:1 threshold throughout the monitoring period. At the Lake Merritt Channel, the Redfield ratio was slightly below the 16:1 threshold in June, then declined in July and remained far below the threshold through October. Overall, these patterns indicate that the Lake Merritt Channel and lake stations were nitrogen limited, whereas the Glen Echo Creek was phosphorus limited.

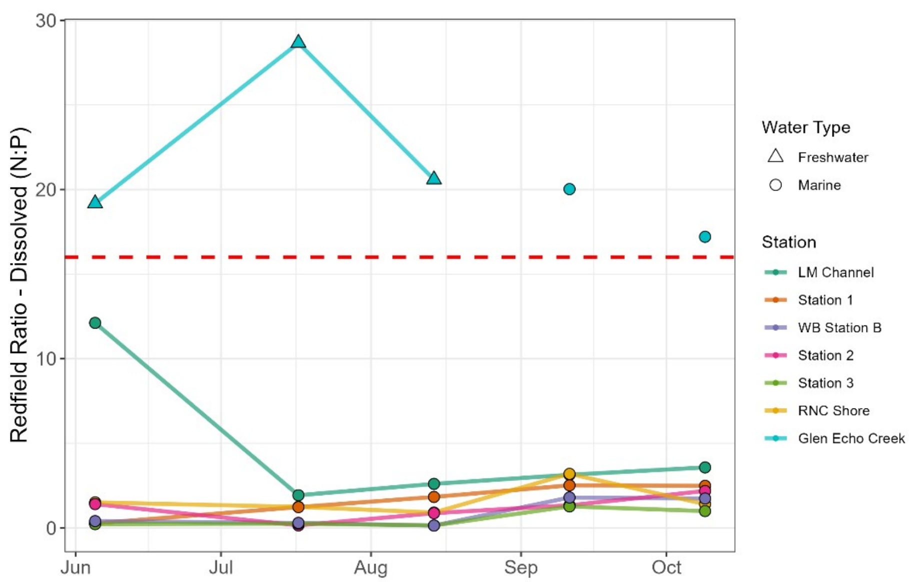

Figure 29. Time series of Redfield Ratio (N:P) from June to October 2024
Note: The time trend line for Glen Echo Creek only spans June through August, as the September and October samples reflect tidal influence and do not represent typical freshwater conditions.

3.6 Nutrient Mass Loads

Screening level load estimates were calculated to quantify nutrient inputs to Lake Merritt from the major creeks and from the San Francisco Bay via the Lake Merritt Channel. These estimates provide a preliminary assessment of nutrient contributions to the lake and help guide further investigation into potential nutrient sources.

3.6.1 Nutrient Load Calculations

Screening level nutrient load estimates for the creeks were calculated using available flow and nutrient concentration data. Streamflow measurements were not collected at Glen Echo Creek during the 2024 nutrient sampling events. However, streamflow was measured on January 21, 2025, at a location upstream of the nutrient sampling site. Although this measurement was collected during the winter season, when base flows are typically higher, the measured flow is considered representative of average summer conditions because it was very similar to the October 2025 flow.

The original Glen Echo Creek nutrient sampling location (Figure 2) could not be safely accessed for flow measurements, and the site does not have stable unidirectional flow due to the influence of lake water at high tide. As a result, streamflow was measured at the farthest downstream location that would represent average summer flows and could be safely accessed, approximately 1.15 km upstream of the nutrient sampling site. The measured flow rate at this location was 0.0063 m^3/sec (0.22 cubic feet per second) or 541 m^3/day.

To estimate the summer load from Glen Echo Creek in 2024, concentrations of dissolved inorganic nitrogen, total nitrogen, orthophosphate, and total phosphorus for June, July, and August were averaged and then multiplied by the flow rate. The resulting load is presented in the first row of Table 4. September and October samples collected in 2024 were excluded from the load calculations because, as described in Section 3.1, these samples may not represent nutrient concentrations in the flowing creek as the salinity indicated that the sampled water was a mixture of marine and freshwater, whereas the June, July, and August samples were representative of freshwater conditions. Loads derived from mixed marine and freshwater samples would not be representative of creek-derived nutrient inputs.

Accordingly, the Glen Echo Creek contribution to the October load estimates shown in the second row of Table 4 were calculated using nutrient concentration and flowrate data collected on October 8, 2025.[1] For the Pleasant Valley Creek contribution to the October 2025 load, nutrient concentrations were measured in a sample collected from a manhole on October 22, 2025, and the flowrate was estimated during sample collection. For Wildwood Creek, nutrient concentrations were measured in a sample collected from a storm drain on October 22, 2025, and the flowrate at the sampling was visually estimated. For Pleasant Valley Creek and Wildwood Creek, measured concentrations were multiplied by upper-end visual flow estimates of 1.7×10^{-4} m^3/sec and 8.3×10^{-5} m^3/sec, respectively. Flow estimates were used because observed flows were low and could not be reliably measured with the flow meter during the sampling events. Measured concentrations of DIN, TN, orthophosphate, and total phosphorus were multiplied by these flow estimates to calculate dissolved and total nutrient loads.

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[1] A nutrient sample was collected and streamflow was measured at a location along Upper Glen Echo Creek different than the January 21, 2025, flow measurement site (approximately 0.35 km downstream of the January site; Figure 3). The measured flow rate at this location was 0.0064 m^3/sec.

The summer 2025 screening-level load estimates for Upper Glen Echo Creek, Pleasant Valley Creek, and Wildwood Creek were summed to represent total creek-derived nutrient inputs to Lake Merritt. These combined creek load estimates are presented in the second row of Table 4.

The nutrient load estimates into Lake Merritt from San Francisco Bay were calculated with a different approach since incoming flow varies based on tidal cycles. Water exchange between Lake Merritt and San Francisco Bay occurs through the Lake Merritt Channel and is controlled by tide gates operated by the Alameda County Flood Control District. These tide gates are used to manage lake water levels and can be closed during high tides or large storm events to reduce flood risk within Lake Merritt. When the tide gates are closed or partially closed, inflow of bay water into Lake Merritt is restricted, whereas when the gates are open, tidal exchange allows bay water to enter the lake.

Because operation of the tide gates affects both the timing and volume of water entering Lake Merritt, nutrient loads delivered through the Lake Merritt Channel are variable and depend on both tidal conditions and gate operations. Nutrient loads entering Lake Merritt from San Francisco Bay via the Lake Merritt Channel were estimated using two methods, as described below.

Nutrient concentrations were measured in samples collected from the Lake Merritt Channel during inflow tides in June through October 2024 and October 2025. In March 2025, a pressure transducer was installed at the Lake Merritt Boating Center docks to continuously measure lake water depth. Increases in lake water level were used to identify periods of bay water inflow into Lake Merritt through the Lake Merritt Channel.

Hourly changes in lake water depth (m/hour) were calculated for the period from June 1, 2025, through November 5, 2025. Hourly volumetric changes (m^3/hour) were then calculated by multiplying each hourly change in lake water depth by the surface area of Lake Merritt (607,028 m^2). Only positive volumetric changes, corresponding to inflow conditions, were used in the load calculations. For each day in the analysis period, the corresponding monthly nutrient concentrations measured in 2024 were assigned to each hour.[2] Hourly nutrient loads (kg/hour) for dissolved inorganic nitrogen, total nitrogen, orthophosphate, and total phosphorus were then calculated by multiplying the hourly volumetric change (m^3/hour) by the assigned nutrient concentration (mg/L), with appropriate unit conversions applied (1,000 L/m^3 and 1,000,000 mg/kg).

For the first method, hourly nutrient loads were summed over the entire analysis period and then divided by the total number of days in the period (155 days) to calculate an average daily load. This screening level load estimate is presented in the third row of Table 4. This estimate is strongly influenced by the number of days the tide gates were closed since very little inflow occurs during gate closures so the average daily flow over the 155-day period will be reduced because there is very little inflow on many of those days. Therefore, the daily average loads are proportional to the proportion of time the tide gates are open. Because this load estimate is influenced by the proportion of open gate conditions, these loads cannot be directly compared to similarly computed

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[2] Station 1 sonde depth data collected in 2024 were considered unreliable for that time period. Therefore, nutrient concentrations measured in August through September 2024 were paired with the more reliable Lake Merritt Boating Center docks depth data collected in 2025. However, nutrient concentrations measured in October 2025 were applied to depth data collected in October and November 2025. A brief comparison of Alameda tide heights between 2024 and 2025 indicated similar tidal amplitudes during the analysis period, supporting the assumption that tidal exchange conditions were comparable between the two years.

loads from other time periods, which may have a much different proportion of open gate conditions that would impact the results.

For the second method, an algorithm was developed to identify periods when the tide gates were open or closed based on daily changes in lake water level. For each day, the daily minimum water level was subtracted from the daily maximum to calculate the daily range. Over the full analysis period, days with a daily range less than 0.10 m were considered periods when the tides gates were closed, while days with a daily range greater than 0.10 m were classified as periods when the tide gates were open (Figure 30). Hourly nutrient loads were then summed only for hours on days when the tide gates were open and divided by the total number of open-gate days (78 days) to calculate an average daily load for the appropriate time period. This daily mean flow estimate will be much larger than the estimate generated for the entire 155-day period because the average is not reduced by the inclusion of days for which the flow is very small. This screening level load estimate is presented in the fourth row of Table 4. This estimate is not dependent on the amount of time the tide gates are open because the loads are only computed during open conditions. Therefore, this load best represents the load coming into Lake Merritt (not accounting for tidal outflow) under normal (open gate) conditions and can be directly compared to similarly computed loads for other similar time periods in other years when the tide gate is open.

In both methods, nutrient loads were calculated only during periods of rising lake water levels, with negative (outflow) values excluded. As a result, these estimates account solely for nutrient loads associated with incoming tides and do not include nutrients exported from Lake Merritt during outgoing tides. Consequently, the reported values represent only inflow loads and should not be interpreted as a complete accounting of nutrient fluxes into and out of Lake Merritt.

Although the two methods described did not account for negative (outflows) values, a screening level load estimate of nutrient export associated with outgoing tides is presented in the fifth row of Table 4 for completeness. The summer nutrient load export from Lake Merritt was calculated using the same approaches described above (i.e., Method 1 and Method 2). However, the outgoing nutrient concentrations used in these calculations were from Station 1, as these are most representative of Lake Merritt outflow to the channel. These screening level export estimates provide an approximation of the nutrients leaving Lake Merritt, which represent a combination of nutrients entering the system from both the creek inflows and tidal inputs.

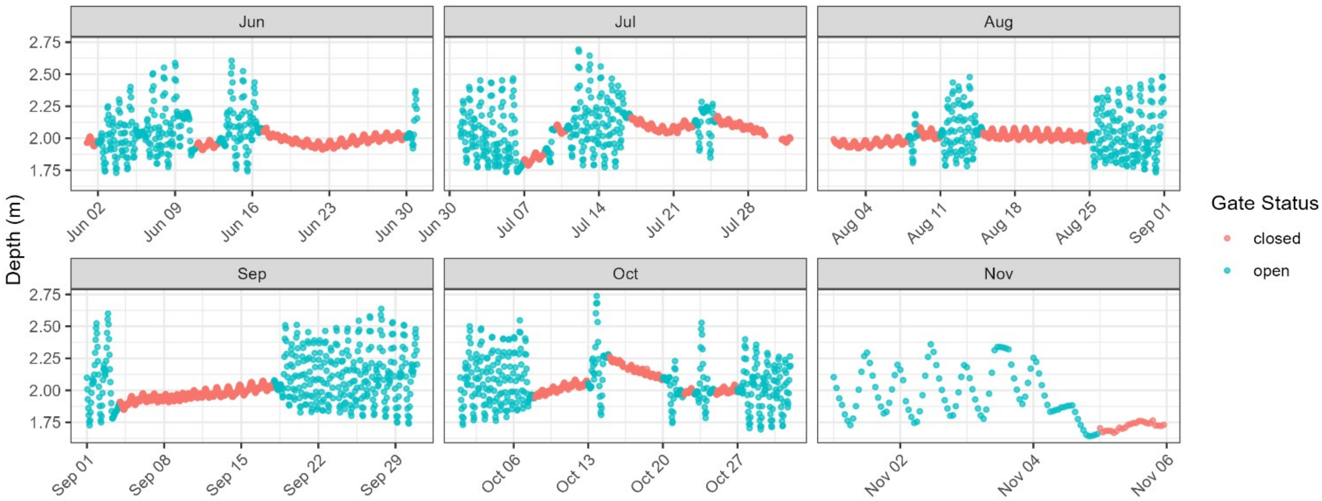

Figure 30. Continuous lake water depth (m) from June through November 2025 with inferred tide gate status
Note: Blue indicates open tide gates and red indicates closed tide gates.

Table 4. Nutrient mass load estimates (kg/day) for Lake Merritt

Dates	Source	Mass (DIN) in kg/day	Mass (TN) in kg/day	Mass (Ortho P) in kg/day	Mass (TP) in kg/day
June – August 2024	Glen Echo Creek (average)	0.79	0.99	0.08	0.09
Summer 2025	Glen Echo Creek, Pleasant Valley Creek, and Wildwood Creek (sum)	0.74	0.99	0.09	0.11
Summer 2025	SF Bay (via LM Channel) - Method 1 (includes closures)	66	241	43	45
Summer 2025	SF Bay (via LM Channel) - Method 2 (assumes open)	118	432	77	80
Summer 2025	Tidal Outflow	Range*: 39 - 71	Range*: 215 - 384	Range*: 47 - 84	Range*: 46 - 82

* The lower value in each range represents the full analysis period, including gate closures, while the upper value represents only periods when the tide gates are open.

3.6.2 Nutrient Load Results

Overall, the analyses indicate that the vast majority of screening level nutrient loads to Lake Merritt originate from San Francisco Bay inflow through the Lake Merritt Channel, while inputs from creeks represent only a very small fraction of the total load. For all nutrients evaluated (DIN, TN, orthophosphate, and TP), more than 99 % of the estimated inputs were derived from San Francisco Bay (Figure 31). Although DIN and TN concentrations in Glen Echo Creek were substantially higher than those measured in Lake Merritt (Figure 16 and Figure 22), the resulting creek loads shown in Table 4 remain small because streamflow is low relative to the flow from tidal influxes. In addition, during the monitoring period, creek-derived loads were dominated by Glen Echo Creek, as the other tributaries were characterized by extremely low flow conditions in late summer.

It is important to note that creek sampling did not capture large storm events or wet-season conditions, when creek flows and associated nutrient loads would be expected to be higher. As a result, the creek load estimates presented here likely underestimate peak creek contributions. However, even accounting for this limitation, the results suggest that tidal inputs from San Francisco Bay are the dominant source of nutrient inputs to Lake Merritt.

These results are based on screening level inflow load estimates and do not represent a complete accounting of the nutrient mass balance. This analysis does not account for the changes in nutrient concentrations due to in-lake biological uptake. However, the estimates presented are sufficient to support the conclusion that the loads delivered through the channel are substantially larger than those from the creeks.

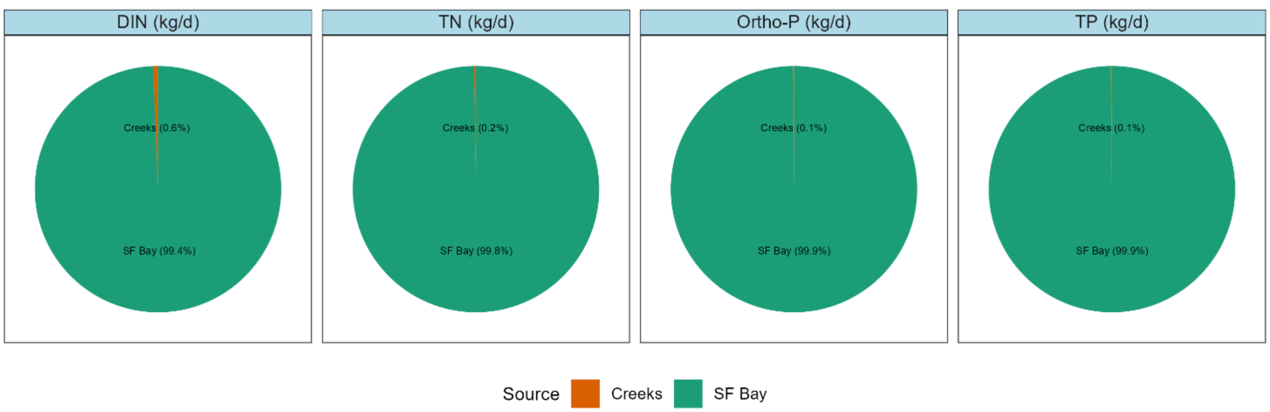

Figure 31. Nutrient load contributions from major creeks and San Francisco Bay to Lake Merritt

3.7 Comparison with United States Geological Survey Cruise Data

As part of the Water Quality of San Francisco Bay Research and Monitoring Project, the United States Geological Survey (USGS) conducts vertical water column sampling twice per month at 37 fixed stations, spaced 3-6 kilometers apart along the deep-channel longitudinal axis of the San Francisco Bay-Delta system. In 2024, sampling occurred only between January and September. To facilitate comparisons among San Francisco Bay, the Lake Merritt Channel, and Lake Merritt, the nearest available USGS stations were selected: (1) Station 18 – Point Blunt (37.846667, -122.421667); (2) Station 22 – Potrero Point (37.765, -122.35833); and (3) Station 24 – Candlestick Point (37.698333, -122.338333). For this analysis, data collected from June through September were used since USGS did not collect samples in October. The USGS did not collect any samples in September or October 2025, so it was not possible to compare the October 2025 Lake Merritt samples with the USGS data.

To visualize differences in nitrate + nitrite concentrations across sites, box plots were generated comparing the three USGS stations with the Lake Merritt Channel (Figure 32). Within San Francisco Bay, concentrations and variability were similar among the three stations: Pt Blunt (range = 0.16-0.33 mg/L; mean = 0.22 ± 0.06 mg/L; median = 0.21 mg/L); Potrero Pt (range = 0.14-0.33 mg/L; mean = 0.23 ± 0.07 mg/L; median = 0.22 mg/L); Candlestick Pt (range = 0.11-0.36 mg/L; mean = 0.25 ± 0.10 mg/L; median = 0.22 mg/L). Interestingly, concentrations at the Lake Merritt Channel were consistently lower, showing a clear difference between San Francisco Bay and the Lake Merritt Channel. The observed pattern may reflect a combination of physical, biological, and biogeochemical processes within the Lake Merritt system, including limited tidal exchange, biological uptake, as well as potential differences in analytical methods. Additional investigation is needed to better understand the relative importance of these factors and to confirm the underlying drivers of the observed trends.

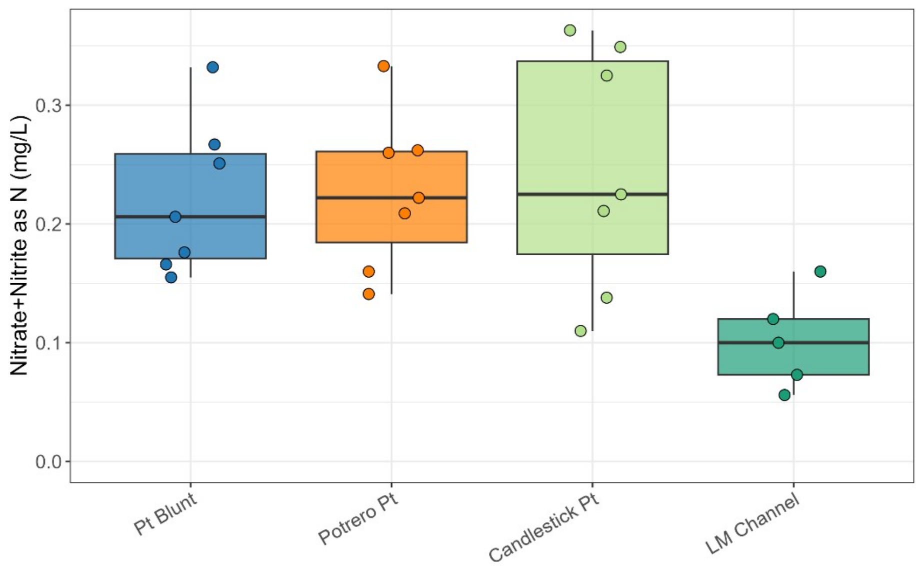

Figure 32. Boxplots of Nitrate + Nitrite as Nitrogen (mg/L) from June to October 2024 for San Francisco Bay (i.e., Pt Blunt, Potrero Pt, and Candlestick Pt) and Lake Merritt Channel

To further examine temporal patterns in nitrate +nitrite concentrations, time-series plots were generated to highlight changes over the sampling period (Figure 33). At Potrero Pt and Candlestick Pt, concentrations were lowest in early June and generally increased, reaching a peak in late August before slightly declining in early September. At Pt Blunt, concentrations declined from mid-June to late July, reaching their lowest values, then increased from mid-July to a peak in late August, similar to the other Bay stations, followed by a slight decrease in September. October samples were not collected at the Bay stations, so comparisons for that month were not possible. In the Lake Merritt Channel, concentrations decreased from June to July and then increased steadily, peaking in October. This general pattern mirrors the Bay trend, with concentrations rising from late July through September, suggesting a broadly consistent seasonal increase in nitrate + nitrite concentrations across the system.

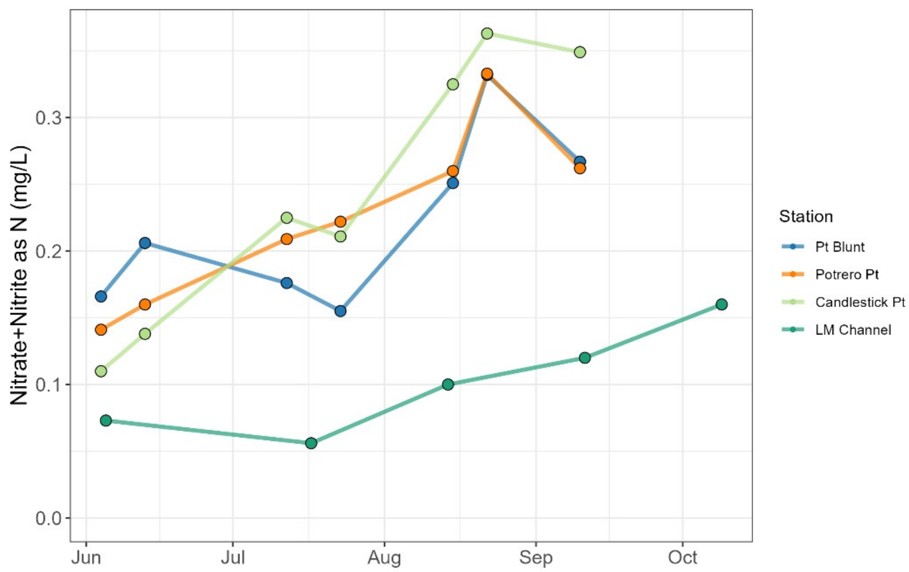

Figure 33. Time series of Nitrate + Nitrite as Nitrogen (mg/L) from June to October 2024 for San Francisco Bay (i.e., Pt Blunt, Potrero Pt, and Candlestick Pt) and Lake Merritt Channel

3.8 Annual Comparison: October 2024 and October 2025

An annual comparison was conducted to evaluate nutrient concentrations in Lake Merritt between October 2024 and October 2025. For the nitrogen species, concentrations measured at the Lake Merritt Channel in October 2025 were consistently higher than all the samples collected in October 2024 (Figure 34). In contrast, nitrogen concentrations at Glen Echo Creek in October 2025 were consistently lower than those measured in October 2024. Across the remaining Lake Merritt sites, no clear or consistent pattern emerged between the two years. Overall, the differences in nitrogen concentrations between October 2024 and October 2025 were minimal, indicating limited inter-annual variability at each site.

A similar pattern was observed for the phosphorus species. At the Lake Merritt Channel, October 2025 concentrations were consistently higher than all the samples collected in October 2024 (Figure 35). Glen Echo Creek phosphorus concentrations in October 2025 were consistently lower than those measured in October 2024, mirroring the nitrogen results. However, unlike the nitrogen species, several of the Lake Merritt sites showed higher orthophosphate and total phosphorus concentrations in October 2025 compared to October 2024. Despite these differences, the ranges of phosphorus concentrations across both years remained largely overlapping. Overall, the year-to-year differences were small and suggest minimal inter-annual variability in phosphorus species concentrations across the Lake Merritt sites.

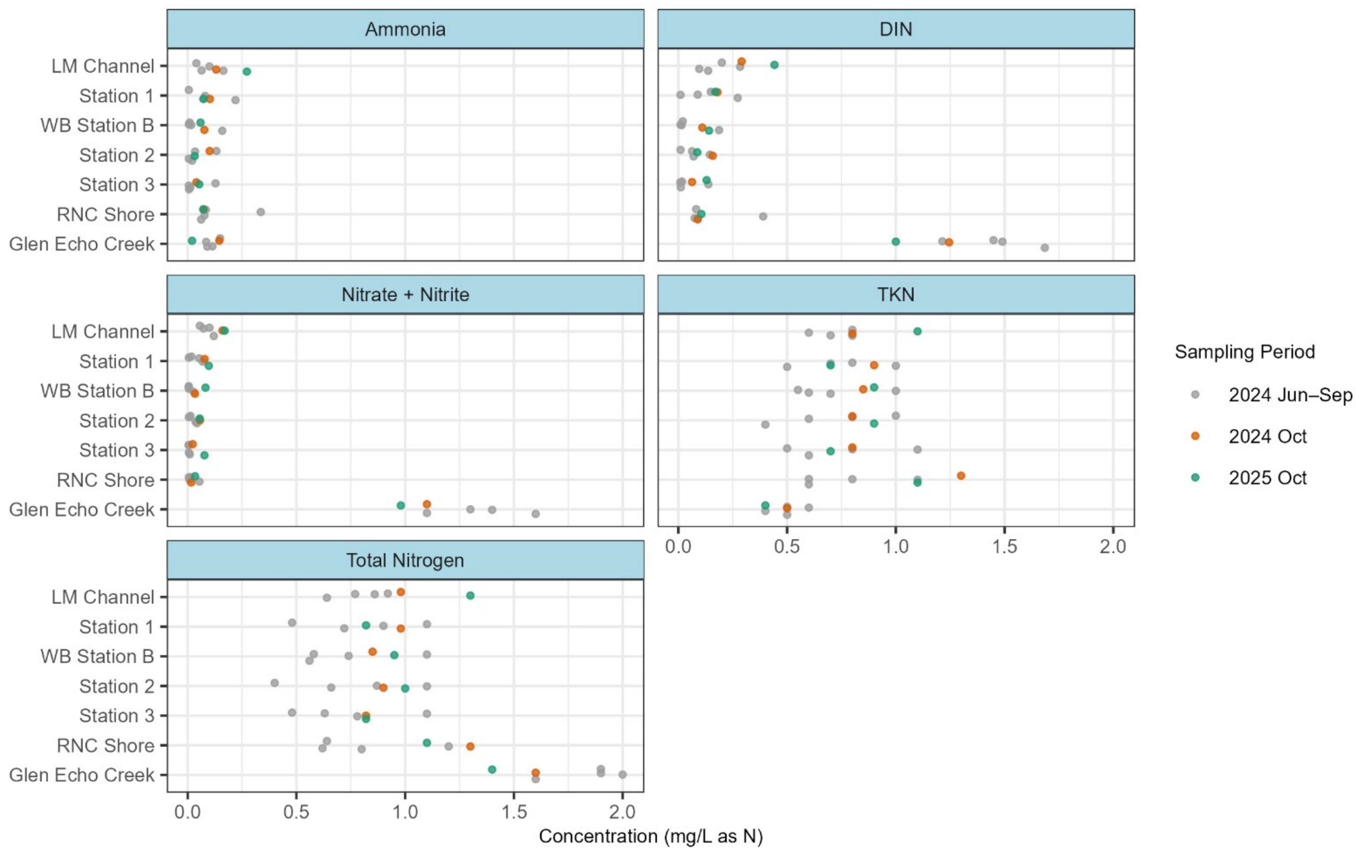

Figure 34. Comparison of nitrogen species concentrations across stations for October 2024 (orange) and October 2025 (green) samples
Note: June-September 2024 samples are shown in gray for reference.

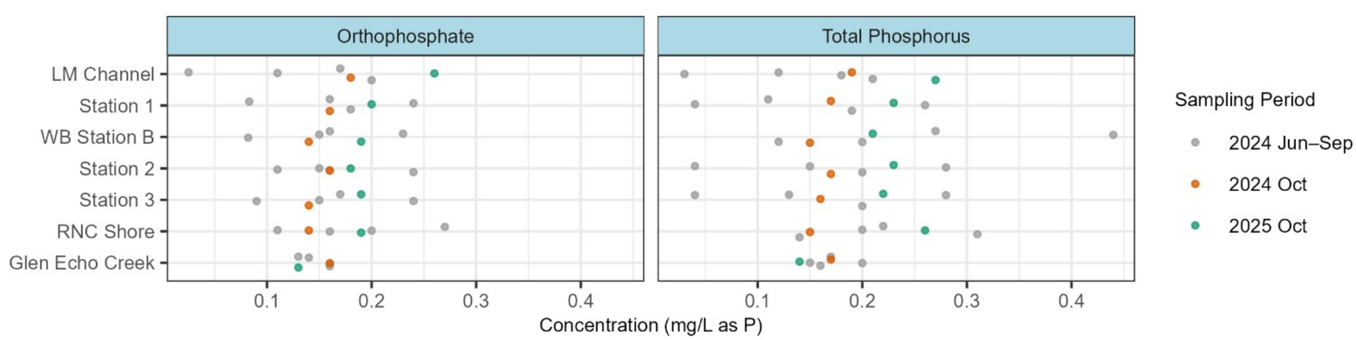

Figure 35. Comparison of phosphorus species concentrations across stations for October 2024 (orange) and October 2025 (green) samples
Note: June-September 2024 samples are shown in gray for reference.

4 Conclusions

4.1 Spatial Trends

Nitrogen species showed a clear gradient among sites. Glen Echo Creek consistently exhibited the highest concentrations of nitrate + nitrite, DIN (total ammonia + nitrate + nitrite), and total nitrogen but these levels are relatively common for a highly urban watershed. The Lake Merritt Channel generally had slightly higher concentrations than the inner-lake stations, indicating in-lake uptake of dissolved nitrogen by algae. Within the lake, Station 1 and Station 2 appeared to reflect inputs from the Lake Merritt Channel and Glen Echo Creek, respectively.

Phosphorus patterns were less variable. Orthophosphate and total phosphorus concentrations were lowest at the Lake Merritt Channel, but mean and median values across all stations were very similar, suggesting limited spatial variability in phosphorus.

4.2 Temporal Trends

Nitrogen species exhibited distinct temporal signals. Total ammonia at the Lake Merritt stations were lowest in June, increased steadily through the summer, and peaked in September before declining in October. Nitrate + nitrite did not show a clear summer peak at the Lake Merritt stations; however, concentrations at the Lake Merritt Channel were lowest in July and highest in October. DIN (total ammonia + nitrate + nitrite) reflected the temporal trends observed in its individual components, with Glen Echo Creek showing the highest overall concentrations.

Phosphorus concentrations showed mixed temporal trends. Orthophosphate concentrations at both the Lake Merritt Channel and Lake Merritt stations were lowest in June, peaked in September, and declined slightly in October. Total phosphorus patterns were less clear, with some stations showing unexpectedly lower concentrations than the dissolved fractions.

Overall, these results indicate that nutrient and carbon dynamics in Lake Merritt are seasonally driven, with late summer emerging as a critical period for elevated concentrations and potential ecological impacts. The timing of these peaks highlights the importance of monitoring during the summer as well as water exchange periods to better understand nutrient cycling and potential ecological risks.

4.3 Implications & Recommendations/Future Monitoring

This sampling effort successfully characterized nutrient inputs from three of the four major tributaries to Lake Merritt (Glen Echo Creek, Pleasant Valley Creek, and Wildwood Creek). During the sampling, the primary accessible above-ground reach of Trestle Glen Creek was dry due to upstream diversions by the City of Oakland, preventing sample collection at this location. Future monitoring should prioritize sampling at this final creek to complete tributary coverage. In addition, future efforts should include targeted wet-season base flow sampling, when nutrient loads are likely to be higher than during dry-weather conditions. Despite these data gaps, results indicate that nutrient loads from the two major watersheds were largely driven by Glen Echo Creek. To further improve source characterization, the Water Board has requested EPA funding to support a desktop nutrient load analysis for these watersheds plus other lands adjacent to Lake Merritt.

In summer 2026 (June-October), the Water Board will fund deployment of a SUNA (Submersible Ultraviolet Nitrate Analyzer) sensor at Water Board Station A in Lake Merritt to collect continuous nitrate measurements. These measurements will help characterize temporal variations in nitrate concentrations and improve understanding of nutrient uptake dynamics and tidal influences within the lake.

Expanding monitoring to include SUNA nitrate data combined with continuous chlorophyll-a and dissolved oxygen measurements, would improve understanding of nutrient-oxygen dynamics and help guide potential management actions to address low dissolved oxygen conditions in Lake Merritt. Notably, a small fish and invertebrate mortality event in 2025 was not associated with an algal bloom, indicating that dissolved oxygen conditions may also be driven by processes other than algal production and warrant further investigation.

In summer 2026, the Water Board, City of Oakland, and interested parties will work with a group of technical experts to inform any other high priority monitoring and analyses. The experts will also provide recommendations for lake management actions to improve dissolved oxygen in Lake Merritt.

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