# TECHNICAL MEMO

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| ***To:*** | Kitsap County<br>Long Lake Management District<br>614 Division Street<br>Port Orchard, WA 98366 |
| ***From:*** | Tetra Tech, Inc.<br>1420 5th Avenue, Suite 650<br>Seattle, WA 98101<br>Authored by: Iris Lippert, Shannon Brattebo, Harry Gibbons, Adam Baines |
| ***Date:*** | January 5, 2021 |
| ***Subject:*** | 2020 Annual Summary Technical Memo |

## 1.0 Introduction

The purpose of the Long Lake Integrated/Adaptive Lake Management Program is to achieve water quality and aquatic habitat goals established during the 2006 – 2010 lake management efforts. The current Long Lake management program is being implemented through the Kitsap County's Long Lake Management District (LLMD) from 2018 through 2022. Targeted management of the lake will lead to an ecologically sustainable and balanced ecosystem with aesthetic appeal that supports water contact recreation, sport fishery, downstream water quality needs, and salmon migration. The lake management program will limit internal phosphorus loading in order to reduce excessive phytoplankton production, will control excessive growth of rooted aquatic plants, and will eliminate, where possible, non-native plants such as Eurasian watermilfoil, Curly-leaf pondweed, fragrant waterlily (fragrant white lily) and Brazilian elodea. The integrated management program for Long Lake includes six basic elements; project management, integrated/adaptive planning, monitoring, implementation, reporting, and public education. This technical memo provides an annual assessment of in-lake activities and monitoring data collected in 2020, as well as recommended activities for 2021.

**Figure 1. Map of Long Lake and surrounding area**

Tetra Tech, Inc.
1420 5th Avenue, Suite 650, Seattle, WA 98101
Tel 206.728.9655 Fax 206.883.9301 tetratech.com

Long Lake is a shallow, lowland lake located approximately four miles south of Port Orchard in southern Kitsap County in Western Washington State (T2 3N-R2E) (**Figure 1**). Long Lake lies at an elevation of 118 feet (ft.) (36 meters [m]) above sea level. The 339-acre (137 hectare) lake has a historical volume of 2,200 acre-feet (2.69 X $10^6$ cubic meters [$m^3$]), average depth of 6.5 ft. (2 m), and center depth of 12 ft. (4 m) (Bortleson et. al., 1976). Nearly 75% of the lake is less than 10 ft. (3 m) in depth, providing a large littoral area. The drainage area is approximately 9.4 square miles (24.3 square kilometers [$km^2$]), encompassing an increasingly urbanized watershed. Salmonberry Creek is the major inlet, entering on the western shore. The single outlet, Curley Creek, drains the lake at the northeastern end, eventually flowing into the Puget Sound. Several unnamed streams enter at the southern end of the lake. Long Lake exhibits a rather high flushing rate varying from 3.6 to 8.0 $yr^{-1}$ (Jacoby et. al., 1982).

# 2.0 2020 In-Lake Activities

## 2.1 Algae Control

No specific phosphorus management activities were conducted in 2020. On July 14, 2020, Kitsap Public Health District issued a cyanobacteria (blue-green algae) warning for Long Lake. Citizens reported several surface blooms during the summer.

In 2019, a low-dose alum treatment was conducted to remove phosphorus from the water column and to inactivate the release of phosphorus from the lake sediments to reduce algal production. Despite the lower dose (5 mg Al/L compared to the 2007 dose of 17.5 mg Al/L), there was a significant increase in water clarity following the 2019 treatment due to the reduction in algal production, and Long Lake did not experience a toxic bloom, which had occurred each year for the previous four years. The 2019 treatment was anticipated to reduce HAB (Harmful Algal Blooms) event occurrences and intensity for 2 to 5 years, depending upon phosphorus cycling and loading as well as climatic impacts. To ensure prevention of HABs in the future, alum treatment will need to be repeated within 2 to 5 years (2021-2024).

## 2.2 Lake Monitoring

Citizen volunteers and Tetra Tech staff conducted in-situ monitoring on a monthly basis (May through early November) in 2020. All monitoring in 2020 included measurements of DO, conductivity, temperature, and pH at three sites in Long Lake and in the inlet of Salmonberry Creek (**Figure 2**). At the lake sites, these parameters were measured at 0.5-meter intervals within the water column. Citizens or staff recorded secchi disk depth, or transparency, at each station, and made notes on the weather and water conditions at the time of sampling.

At the mid-lake site, citizen volunteers or Tetra Tech staff also collected water samples at depths of 0.5 and 2.5 meters for laboratory analysis. These lake water samples were analyzed to determine total phosphorus (TP) concentrations and concentrations of soluble reactive phosphorus (SRP) and chlorophyll (chl). During each monitoring event, citizen volunteers or staff also collected a grab sample from Salmonberry Creek. The creek water sample was analyzed for TP. All samples were either delivered or packed with ice and sent to IEH Analytical Laboratory on the same day they were collected.

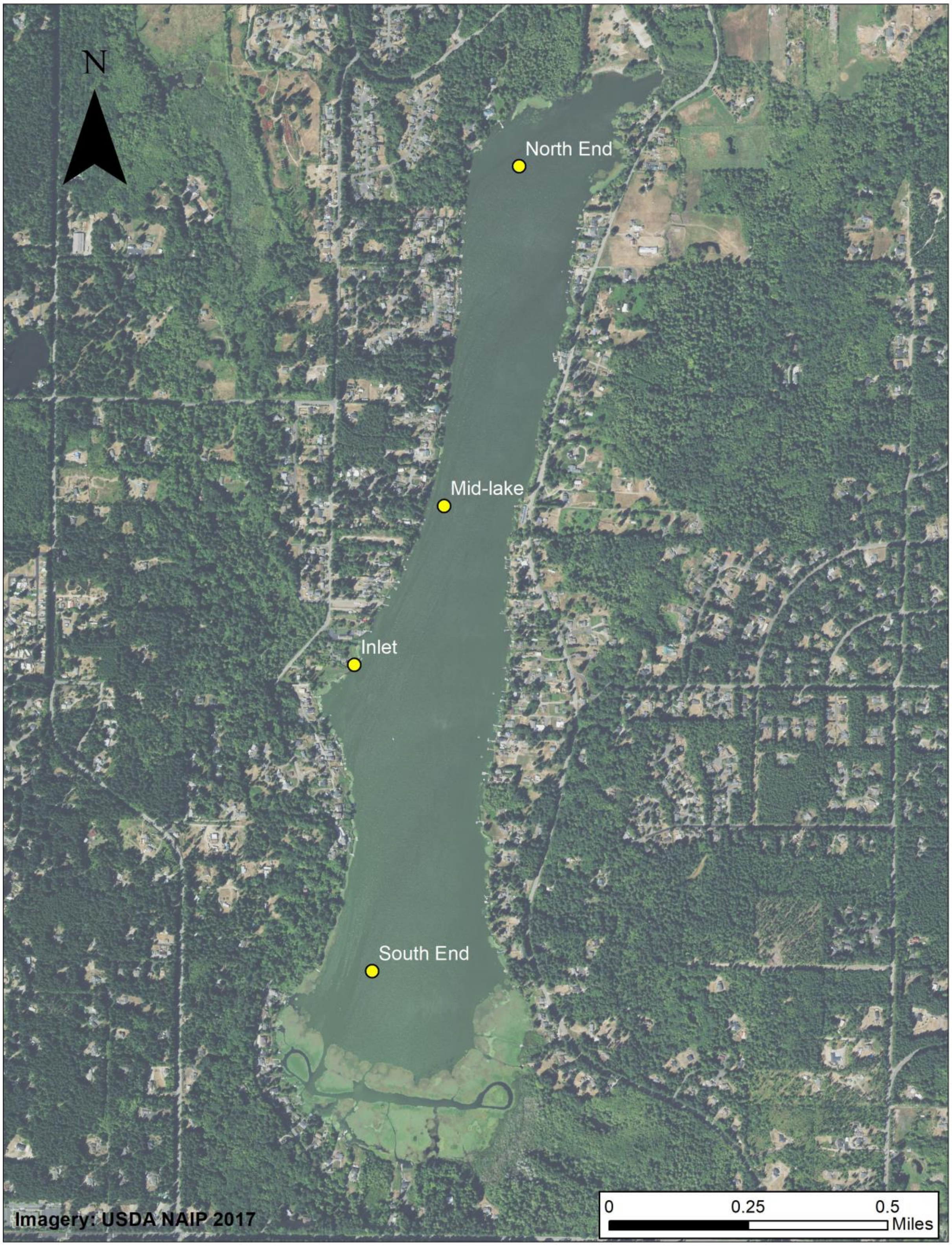

**Figure 2. Map showing sampling locations**

## 2.3 Aquatic Plant Management

### 2.3.1 Aquatic Plant Survey

Brazilian elodea (*Egeria densa*) has existed in the lake for over 40 years. It was not observed in the south end of the lake in the mid-1960s where endemic pond weeds were more abundant. The exotic elodea allegedly was introduced around 1970. During the 20-year study by University of Washington (UW), this plant composed at least 2/3 of the total plant mass (dry weight) and much of that time over ¾ of the biomass (Welch, 1996). In 1985, its abundance dropped to only 10% of total mass and summer TP and chl averaged 66 and 36 µg/L, respectively due to increased internal loading. Harvesting in the 1990s had no effect on the dominance of Brazilian elodea. Eurasian watermilfoil (*Myriophyllum spicatum*) was not present during the 20-year UW study, but it was observed during the 1996 IAVMP study (Water Environmental Services, 1996) so it is a more recent invader. Curly-leaf pondweed (*Potamogeton crispus*) is also a more recent invader and was first observed in 2006. Native pondweed species were also targeted for control in 2020 due to increasing coverage and density since 2008.

Aquatic plant management during 2006-2010 resulted in a more diverse plant community within Long Lake. The density of native macrophytes species in heavy boat use areas declined while the diversity (number of species) increased over that time period. Eurasian watermilfoil had nearly disappeared but the Brazilian elodea population in the open lake and south end had remained stable (Tetra Tech, 2010).

Aquatic plant management activities restarted in 2018 with the updated Long Lake Integrated/Adaptive Lake Management Program. The initial 2018 aquatic plant survey of Long Lake indicated that Brazilian elodea was the dominant submersed plant and was observed throughout the lake in addition to small, relatively isolated groupings of the invasive Eurasian watermilfoil and Curly-leaf pondweed. Lilies were abundant in the nearshore areas near each end of the lake with the invasive fragrant white lily (*Nymphaea odorata*) as the dominate species that was targeted in 2019 and 2020 treatments. The native yellow pond lily, *Nuphar polysepala*, covered less than 30% of the emergent plant beds. From 2008-2018 the native pondweed *P. praelongus* had increased its coverage and density to warrant control.

In 2018, several native narrow-leaf pondweed species *Potamogeton zosteriformis, P. pectinatus* and *P. filiformis* (flat stem pondweed, sago pondweed and slender-leaved pondweed) were observed throughout the lake with a relatively small percent cover. However, in 2019 an increase in pondweed production was observed due to several factors including clearer water, abundant solar energy, and nutrients within the shallow sediments. Sudden production of *P. zosteriformis* was observed within the mid-depth littoral areas especially on the east side of the lake and expanding on the west side. In addition to the expanding *P. zosteriformis* coverage, previously rare *P. pectinatus* and *P. filiformis* (sago pondweed and slender-leaved pondweed) were observed in 2019 to have displaced *P. praelongus* and taken up dominance on the east and west shorelines to a depth of 3 m, inhibiting boat passage. By the end of June 2019 these species densely covered over 24 acres along the east and west shorelines, and although four of the five species of *Potamogeton* are native, three of the four native species were observed to have grown to extreme densities that exceed a balanced habitat and have the potential to adversely impact water quality. The 2019 plant survey also indicated that the non-native invasive fragrant white lily (*Nymphaea odorata*) was a dominant species and had expanded its nearshore littoral coverage significantly on the west side of the lake and in the northeast littoral areas.

Surveys of aquatic plant growth were conducted in May and August of 2020. The May survey was conducted prior to aquatic plant treatment, and the August survey was conducted after treatment and at the end of the summer growing season. In May, a continued increase in area and density of aquatic plants was observed. At the south end of the lake, large swaths of lilies, especially white lily, have continued to expand in coverage and the formation of several small islands was observed. Brazilian elodea and native pondweed species were observed throughout the littoral area, especially in the southern portion of the lake, and a high density of *P. praelongus* was observed along the east bank and northwest corner of the lake. Proposed treatment areas for 2020 were identified in 2019 and confirmed in May 2020 to target littoral areas along the east and west shores of the lake.

A late-summer survey in August 2020 indicated that the treatments were successful in limiting pondweed growth in targeted areas, but in other areas there was continued expansion of aquatic plant growth over the summer. In the treatment areas along the west bank, no noticeable patches of pondweed species were observed in August, but the presence of the white lily had expanded since the 2018 survey. Both north and south of the treatment area on the west bank, thick patches of *P. praelongus* and other pondweed species were observed in August 2020. In the littoral area along the east bank of Long lake, some thick patches of *P. praelongus* were observed even in the treatment areas, but coverage was lower than in 2019. North of the treated area on the east bank, expanded coverage of white lily and pondweed species was observed. A map of the surveyed aquatic plants and 2020 treatment areas is shown in **Figure 3**.

The excessive growth of white lilies in Long Lake has resulted in floating masses of aquatic plant material, especially at the southern end of the lake. In 2020 one of these masses became a free-floating island. The floating island, made by root mass of mainly invasive aquatic plants, posed a significant hazard to lakefront property and directly impacted aquatic habitat both physically and chemically. In addition to the dangers of such floating plant masses, which are likely to continue to occur, removal of the floating mass was difficult and costly. In order to prevent similar hazards in the future, aggressive treatment targeting the invasive white lilies in the southern portion of the lake is highly recommended.

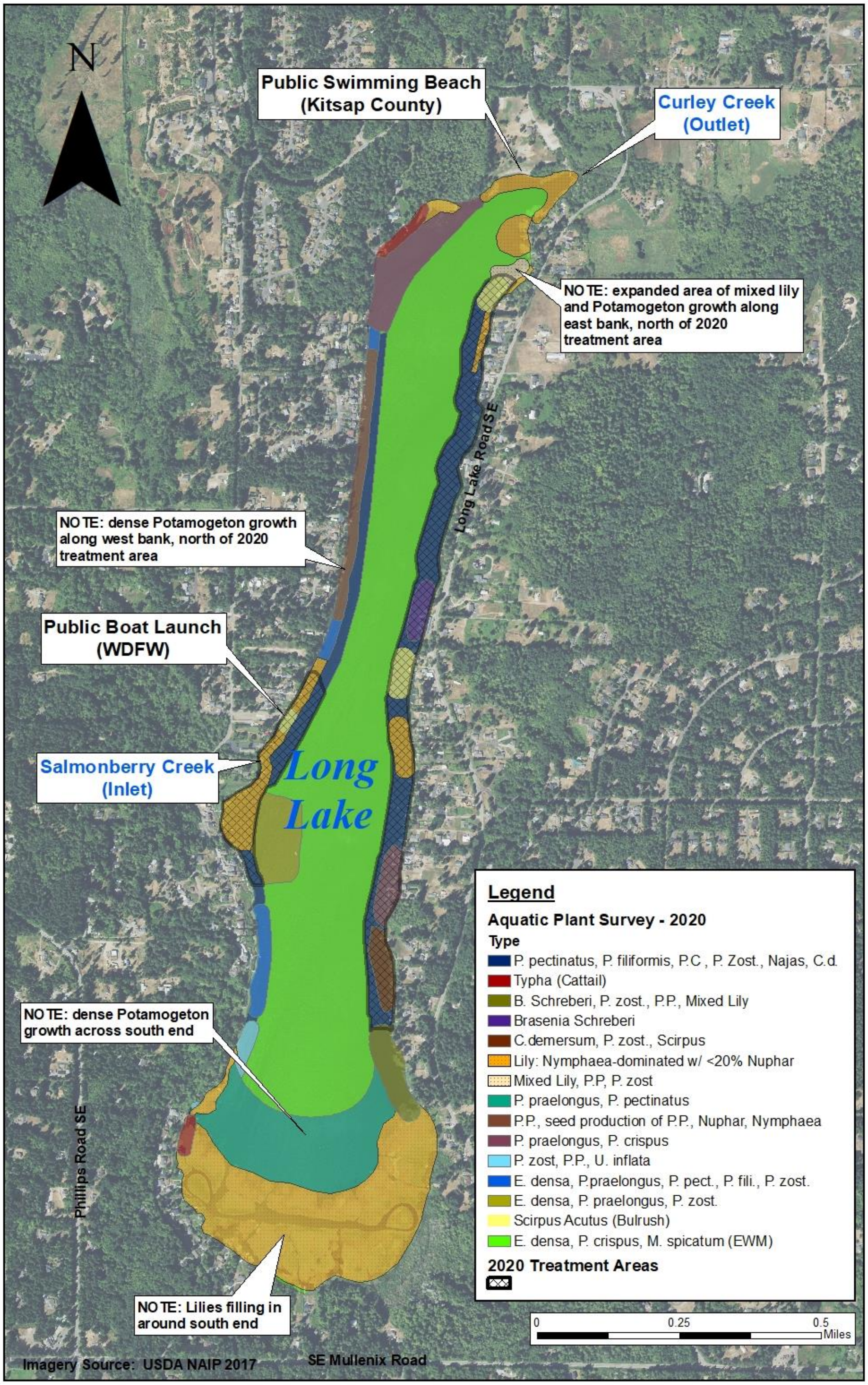

**Figure 3. Aquatic Plant Distribution – 2020 Treatment Areas and Survey**

### 2.3.2 Aquatic Plant Treatment

The goal of aquatic plant treatment at Long Lake is to target noxious invasive non-native weeds that are already present and were documented in the 2010 report and confirmed during plant surveys from 2018-2020, including the white lily, Brazilian elodea, Eurasian watermilfoil, and Curly-leaf pondweed. Native species *Potamogeton praelongus, P. zosteriformis, P. pectinatus* and *P. filiformis* (whitestem pondweed, flat stem pondweed, sago pondweed and slender-leaved pondweed) that have grown to extreme densities exceeding a balanced habitat may be targeted as well. The excess density of these plants and the dominance of non-native species within the plant community adversely impacts aquatic habitat, fisheries, and direct recreation. It also decreases water quality, leading to the release of phosphorus, which in turn leads to cyanobacteria toxic blooms. Following the pattern of rotating treatment sites used for aquatic plant treatment in 2006-2010, small areas of the littoral zone are anticipated to be treated each year in Long Lake. As in past studies, the expected result is a dramatic decrease in the density of non-native species, a dramatic increase in the presence of native species, and a reduction in the overall density of nuisance species (including non-natives), leading to an improvement in aquatic habitat. Controlling both cyanobacteria blooms and invasive plant species in 2006-2010 improved aquatic habitat, increased plant community diversity, reduced release of phosphorus that stimulated excess production, and improved conditions for recreational use.

Aquatic plant management activities restarted in 2018 with fall shallow littoral zone treatments targeting invasive, non-native white lily, Brazilian elodea, Eurasian watermilfoil, and pondweed, *P. praelongus*. In April 2019, initial carryover effectiveness of the 2018 treatment was evaluated prior to the alum treatment, and early-season sprouting of the non-native white lily indicated a limited carryover in species reduction. Based on the July 2019 survey, carryover reduction of the white lily was roughly 30%, while treatment of *P. praelongus* was more effective, with a carryover reduction of 60-70%.

Aquatic herbicides were applied on May 18, June 8, and July 9, 2020. The treatments originally planned for 2019 were delayed until spring 2020 in order to address the change in plant community and density observed in 2019 and to avoid untimely release of phosphorus that could have fueled a HAB event in the late summer of 2019. In the spring of 2020, targeted treatment areas (**Figure 3**) included the extensive native pondweed coverage in the littoral areas along the east and west banks. In total, 16.6 acres of the littoral zone were treated with the aquatic herbicide fluridone, targeting Eurasian watermilfoil, Brazilian elodea, and pondweeds. High density areas of native pondweed were targeted for treatment with the knowledge that over time bringing these species back into a balanced littoral habitat may be easier than controlling non-native species, such as the white lily.

This herbicide application was covered under an Aquatic Plant and Algae Management General Permit issued by the Washington Department of Ecology to Kitsap County on September 12th, 2018 (permit number WAG994398). The herbicide was applied by a licensed applicator, Kyle Langan of AquaTechnex. Informational notices were sent out to businesses and residences on April 28th, 2020, and prior to each treatment Kitsap County posted notices on the docks and in other areas to provide information to the public regarding the treatment.

Based on 2020 plant surveys and continued observations of expanding coverage of the white lilies, proposed treatment areas for 2021 were identified at the north and south ends of the lake (**Figure 4**).

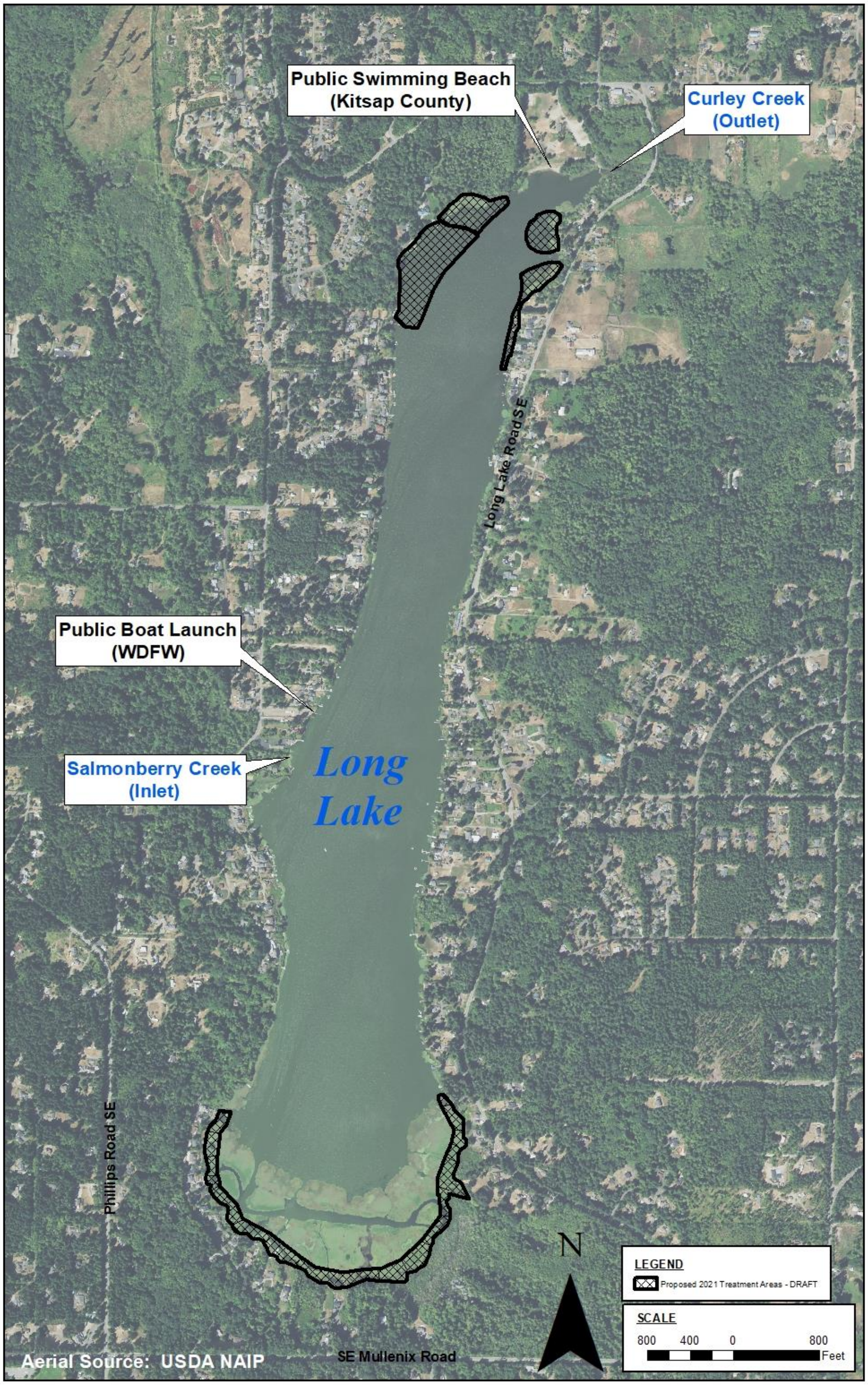

Figure 4: Proposed areas for 2021 aquatic plant treatment

## 3.0 Monitoring Results

### 3.1.1 Water Level

A data logger that records water level in Long Lake was installed in June 2018 on a homeowner's private dock and has been maintained through 2020. The logger records lake level continuously at hourly intervals. Logger data from April 2019 – May 2020 (**Figure 5)** does not have a strong correlation with precipitation records, indicating that the level in Long Lake is not responsive to local rainfall, and instead may depend more on recharge from groundwater or upstream storage.

Efforts to install a data logger in Salmonberry Creek, the main inlet to Long Lake, were unsuccessful. Kitsap County does not maintain a gage on the creek, and loggers that were previously installed on Salmonberry Creek have been subject to vandalization and theft. In 2019, citizens along the creek were contacted for potential access to a protected location near the mouth of Salmonberry Creek. However, access to private property for installation and maintenance was not granted and other options will be explored for 2021.

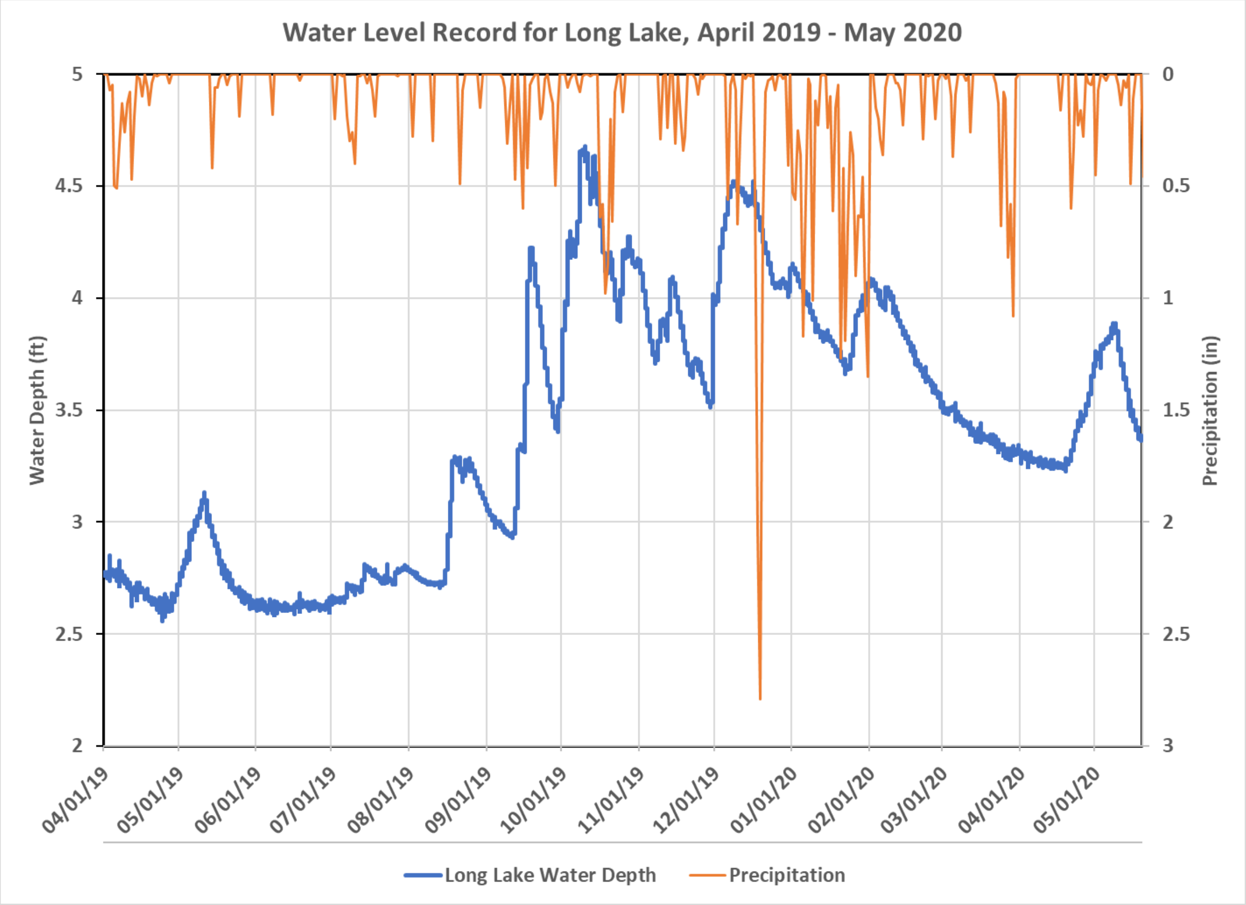

**Figure 5: Water level and precipitation records**

### 3.1.2 Total and Soluble Phosphorus

Concentrations of TP at the mid-lake station averaged 37 µg/L at 0.5 and 2.5 m depth and ranged from 25 to 62 µg/L during 2020 observations (**Table 1, Figure 6**). Maximum recorded TP (62 µg/L) was observed in July at 0.5 m, and higher concentrations of TP generally corresponded with higher chl concentrations in the lake.

Surface concentrations of TP observed in 2020 were somewhat higher than surface concentrations in 2018 and 2019 that ranged from 18-34 µg/L. However, there is a consistent trend of lower TP concentrations observed in the spring and fall. While in 2018 and 2019 the mid-lake TP concentrations were generally higher near the lake bottom, in 2020 higher surface concentrations of TP were observed during both July and September.

The concentration of TP at the inflow, Salmonberry Creek, averaged 45 µg/L in 2020. In the spring and fall, TP concentrations were higher in Salmonberry Creek than at the mid-lake station, but in July and August TP was higher in the lake. In 2020, Salmonberry Creek had higher concentrations of TP when compared to average concentrations around 30 µg/L in recent years.

Soluble Reactive Phosphorus (SRP) concentrations were low for all observations, with an average concentration of 2.6 µg/L (**Table 1**). In early November, samples were collected from the dock, and surface SRP concentration was slightly higher at 7 µg/L. Low concentrations of SRP in the summer months are consistent with higher chl concentrations, indicating phytoplankton activity in the water column that results in low concentrations of SRP while TP concentrations are high. Soluble reactive phosphorus concentrations in 2020 were generally consistent with low concentrations observed in recent years.

**Table 1. TP and SRP concentrations in Long Lake and Salmonberry Creek in 2020**

| Date | Station | Depth (m) | TP (µg/L) | SRP (µg/L) |
|---|---|---|---|---|
| 5/19/2020 | Mid-Lake | 0.5 | 25 | 3 |
| | | 2.5 | 31 | <1 |
| | Salmonberry Creek | -- | 49 | -- |
| 6/17/2020 | Mid-Lake | 0.5 | 28 | 2 |
| | | 2.5 | 30 | 2 |
| | Salmonberry Creek | -- | 46 | -- |
| 7/27/2020 | Mid-Lake | 0.5 | 62 | <1 |
| | | 2.5 | 48 | <1 |
| | Salmonberry Creek | -- | 47 | -- |
| 8/19/2020 | Mid-Lake | 0.5 | 42 | 4 |
| | | 2.5 | 49 | 2 |
| | Salmonberry Creek | -- | 38 | -- |
| 10/7/2020 | Mid-Lake | 0.5 | 32 | 4 |
| | | 2.5 | 26 | 2 |
| | Salmonberry Creek | -- | 43 | -- |
| 11/5/2020 | Dock | 0.5 | 35 | 7 |
| | Salmonberry Creek | -- | 47 | -- |

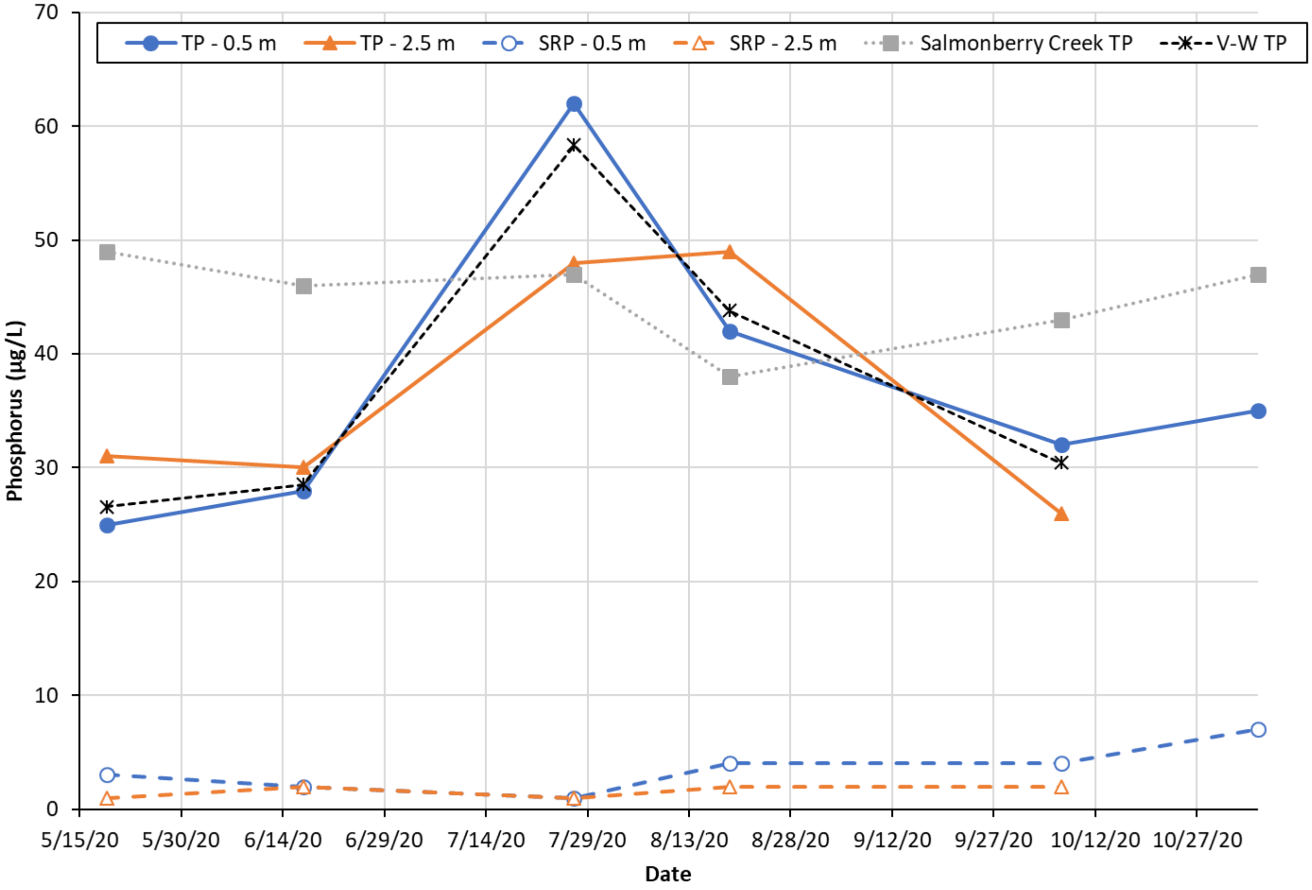

**Figure 6. Phosphorus concentrations in Long Lake and Salmonberry Creek in 2020.**

### 3.1.3 Chlorophyll-*a*

Surface concentrations of chl at the mid-lake station averaged 19.3 µg/L and ranged from 6.4 to 38 µg/L during 2020 observations (**Table 2, Figure 7**). At a depth of 2.5 m, the average mid-lake chl concentration was 22.2 µg/L, slightly higher than at the surface. Maximum recorded chl (38 µg/L) was observed in August, and higher concentrations of chl generally corresponded with higher TP concentrations in the lake. Average chl concentrations observed in 2020 were somewhat higher than observations in 2018 and 2019, when surface concentrations averaged around 12 µg/L at the surface and 9 µg/L at 2.5m. Despite the alum treatment in 2019 and no observed algae blooms that year, several blooms were observed in 2020.

**Table 2. Chlorophyll concentrations in Long Lake in 2020**

| Date | Station | Depth (m) | CHL-a (µg/L) |
|---|---|---|---|
| 5/19/2020 | Mid-Lake | 0.5 | 9.3 |
| | | 2.5 | 9.1 |
| 6/17/2020 | Mid-Lake | 0.5 | 12 |
| | | 2.5 | 22 |
| 7/27/2020 | Mid-Lake | 0.5 | 32 |
| | | 2.5 | 23 |
| 8/19/2020 | Mid-Lake | 0.5 | 38 |
| | | 2.5 | 47 |
| 10/7/2020 | Mid-Lake | 0.5 | 18 |
| | | 2.5 | 10 |
| 11/5/2020 | Mid-Lake | 0.5 | 6.4 |

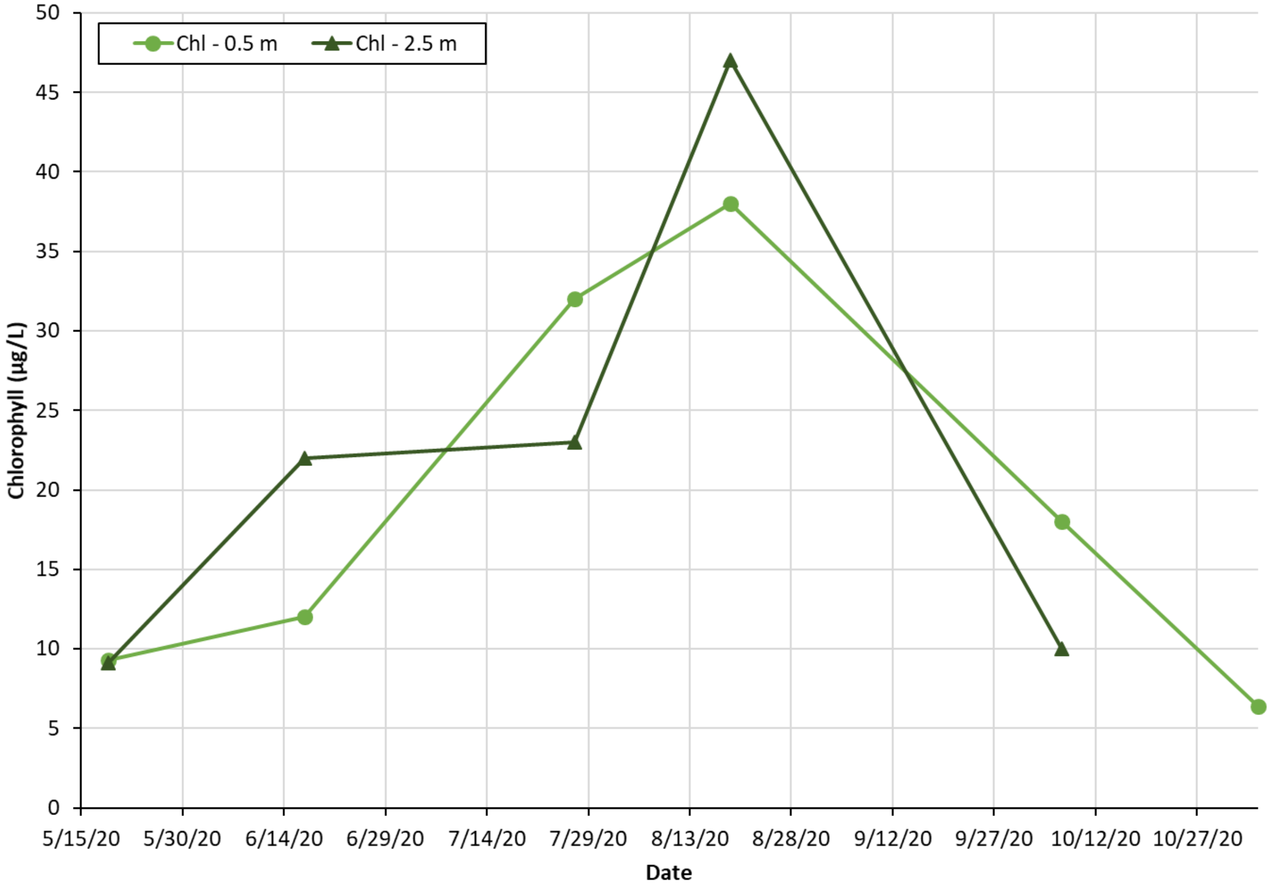

Figure 7. Chlorophyll concentrations in Long Lake in 2020.

### 3.1.4 Water Clarity

Water clarity, or transparency, as measured with a secchi disk, ranged from 0.9 to 1.7 m at the mid-lake station, 0.7 to 2.2 m at the north lake station, and 1.0 to 2.0 m at the south station (**Figure 8**). In the spring, water clarity was generally consistent across all stations, with an average secchi depth of 1.7 meters. Summer and fall measurements of water clarity varied more between dates and sites, with the minimum secchi disk depth (0.7 m) observed at the north lake station in August and maximum secchi disk depth observed in early October at the north lake station. The higher level of water clarity in the spring and fall corresponds with lower observed chl concentrations. Water clarity was significantly lower in 2020 when compared to the high clarity in 2019 due to the low-dose alum treatment and corresponding reduction in algal production. In 2020, water clarity was similar but slightly lower than in 2018, which had clarity over 2 meters in June before dropping to around 1.6 meters in July and less than 1 meter throughout August. In 2020, lower clarity was an indication of increased algae production.

Secchi disk transparency represents light availability in the water column, which translates into potential photosynthesis by algae and rooted aquatic plants. For example, the potential photosynthetic depth (photic zone) is approximately 3 times the measured transparency depth.

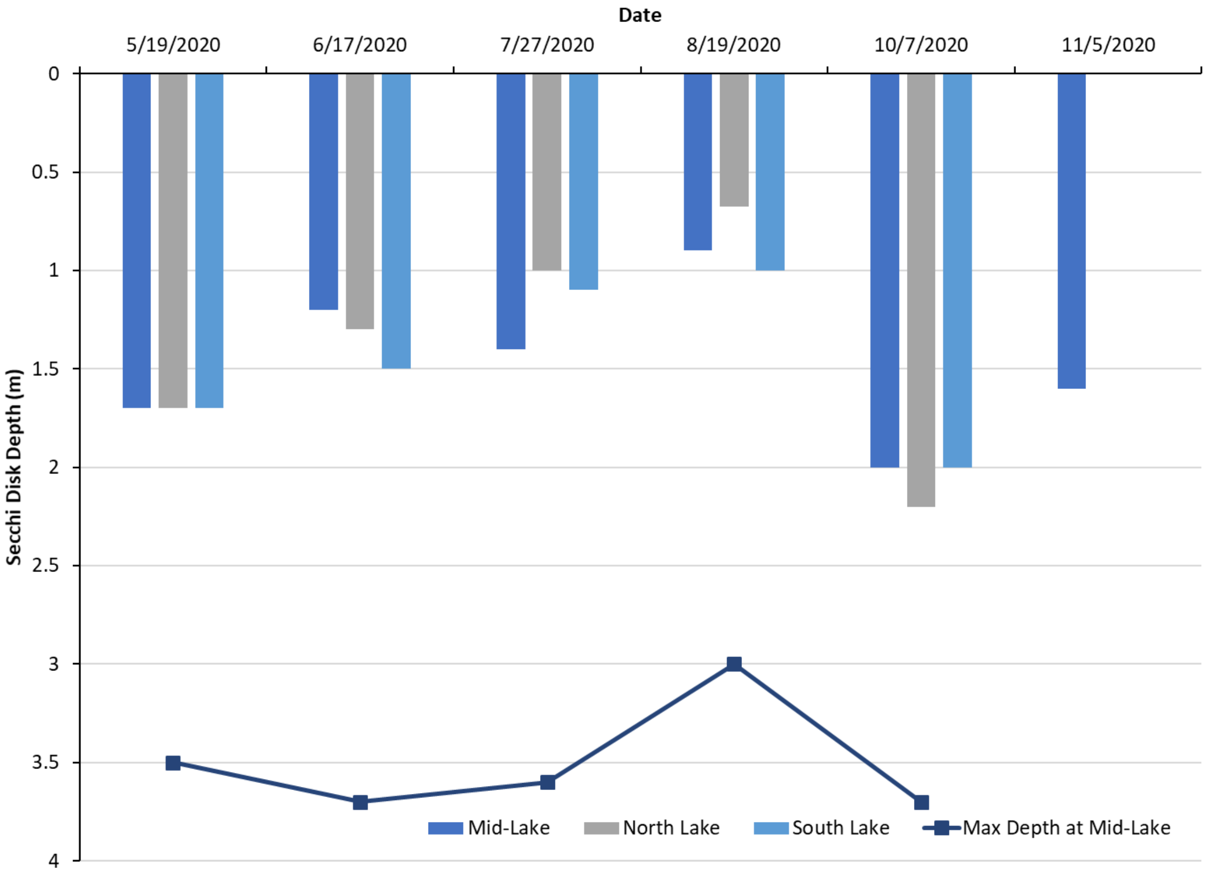

Figure 8. Secchi disk depth (water transparency) in Long Lake during 2020

### 3.1.5 Water Temperature, Dissolved Oxygen, Conductivity, and pH

Profiles of water temperature, dissolved oxygen (DO), conductivity, and pH were measured at 0.5-meter intervals at each station in 2020. At the north and south stations, profiles to the lake bottom ranged from 2 to 3 meters deep. At the mid-lake station, profiles extended 3 to 3.7 meters deep. The profiles are generally representative of 2020 conditions on Long Lake, showing seasonal and depth-related trends.

#### Water Temperature

Water temperature profiles are shown in **Figure 9**. Temperatures ranged from 11.7°C to 24.3°C at all stations. The highest temperatures were observed in August while the lowest temperatures were observed in early November. The average temperature in 2020 was 19.8°C. For most observations in 2020, temperature does not vary significantly throughout the water column, as Long Lake is a shallow lake that mixes frequently throughout the year. Weak stratification was observed in the summer months (**Figure 9**), which is consistent with prior observations of mid-late summer stratification. Water temperatures in 2020 were similar at all 3 stations, with average values differing by no more than 0.5°C.

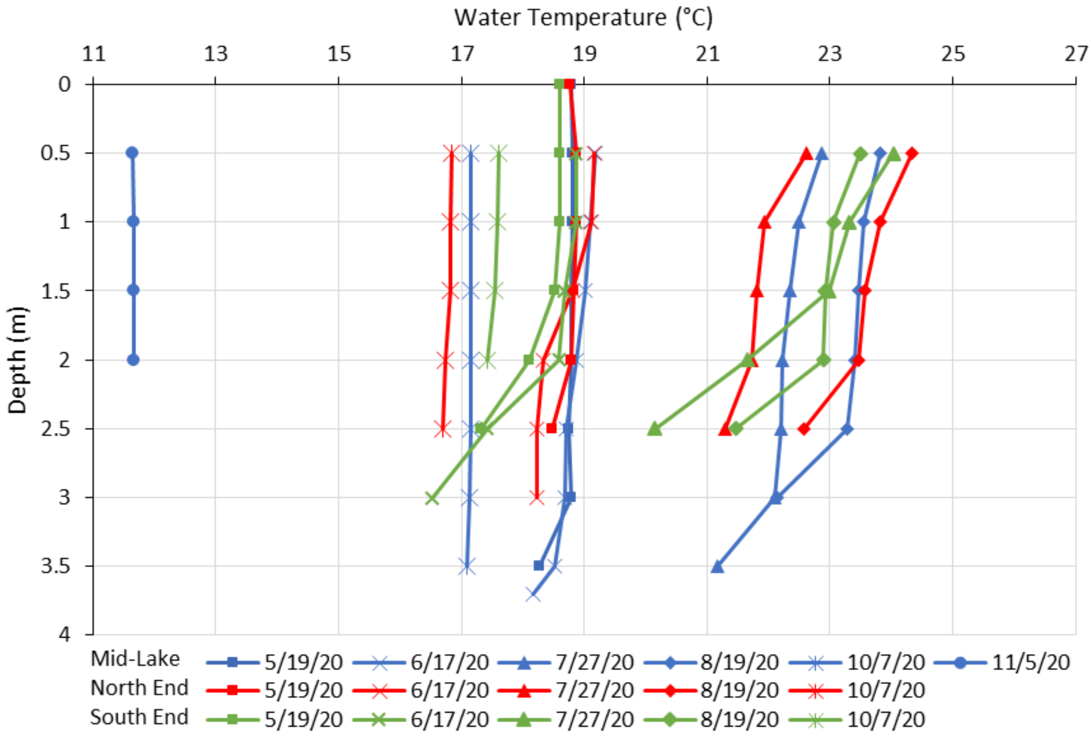

**Figure 9. Water temperatures in Long Lake, 2020**

#### Dissolved Oxygen

Dissolved oxygen concentrations ranged from 1.1 to 12.2 mg/L across all stations (**Figure 10**). Minimum DO occurred near the bottom at all stations and was lowest at the south lake station during the summer months, when the water column was stratified. At the bottom of each profile, DO concentrations are especially low due to potential interactions with bottom sediment. The maximum DO concentrations recorded in 2020 occurred in August near the surface, where there is greater photosynthetic activity.

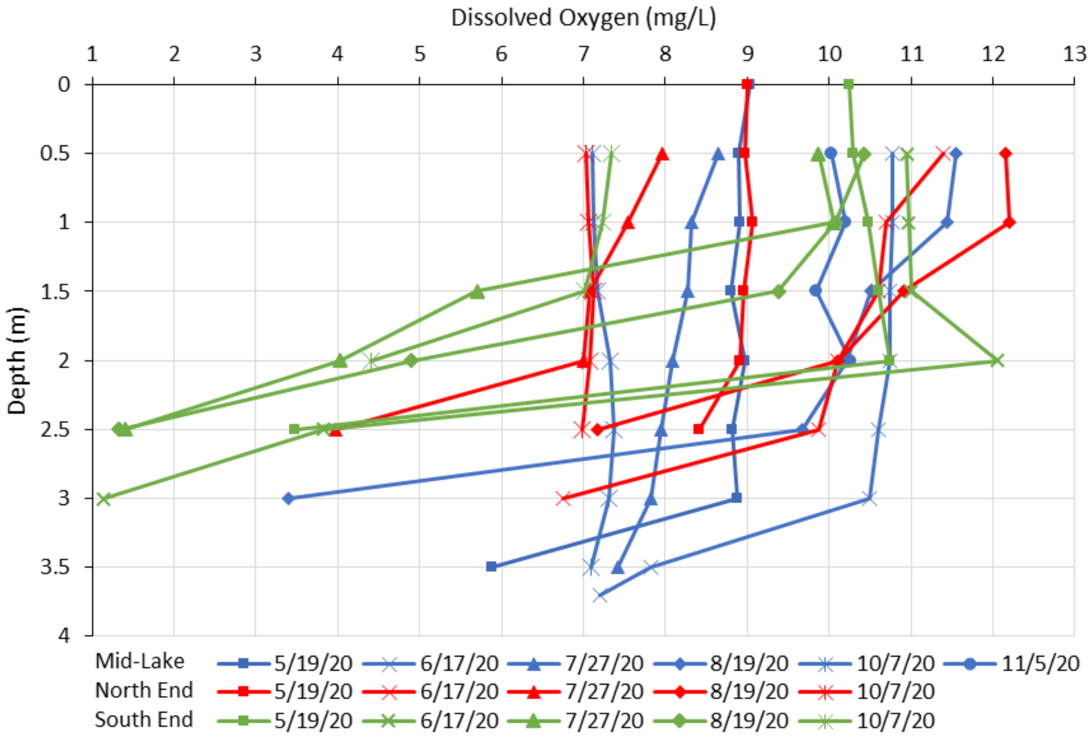

**Figure 10. Dissolved oxygen in Long Lake, 2020**

## pH

pH varied throughout the water column and ranged from 6.6 to 8.9 at all stations for 2020 monitoring dates (**Figure 11**). Observed pH was slightly lower than in 2019 but similar to 2018, when pH ranged from 6.5-8.7. The highest pH values were observed in May.

Water column pH typically followed a pattern of higher values near the surface due to photosynthetic activity, and lower values measured near the bottom due to respiration with light limited photosynthesis. At the north lake site, pH was more uniform throughout the water column than the south lake site and to some extent the mid-lake site. The pH was most likely influenced by photosynthesis both from phytoplankton in the water column as well as aquatic plants.

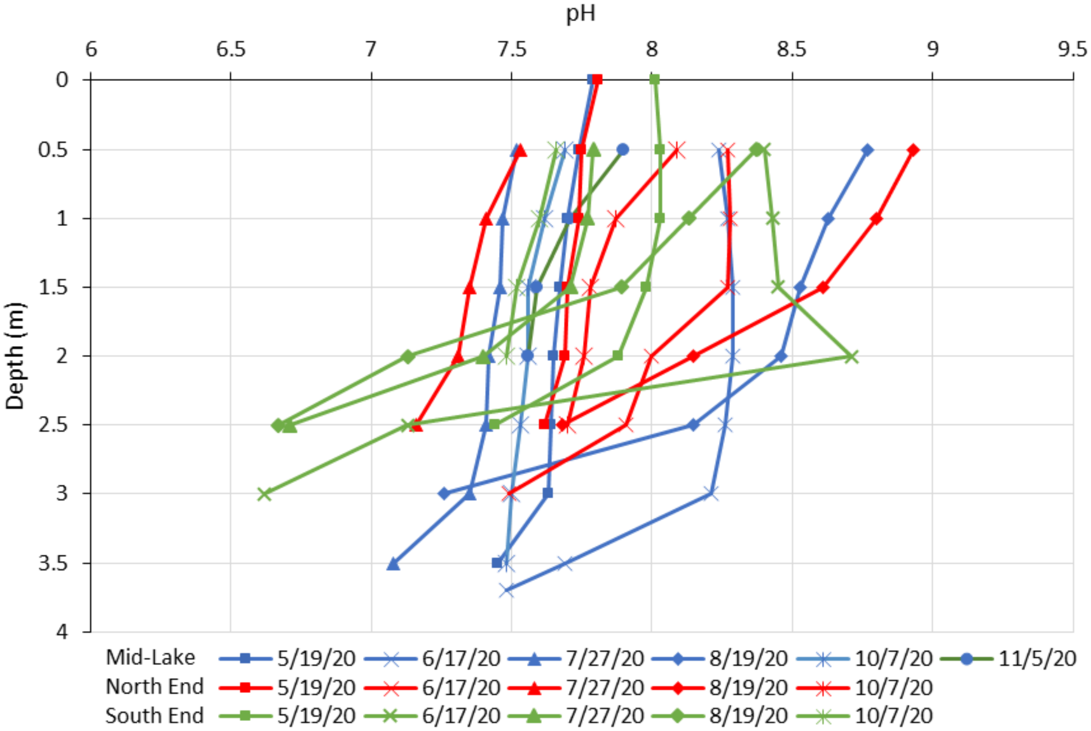

**Figure 11. pH in Long Lake, 2020**

## Conductivity

Conductivity varied over the course of the monitoring period (**Figure 12**). Conductivity ranged from maximums around 135 µS/cm in early October to a minimum of 105 µS/cm in May. Conductivity was generally uniform throughout the water column, varying only at the bottom of the profile, especially at the north end station, likely due to interaction with lake-bottom sediments. Variation in conductivity is directly correlated with phosphorus cycling at the lake bottom and in the water column. Seasonal variation in conductivity, DO, and pH is based on the processes of photosynthesis taking place in the water column and respiration near the lake bottom. In the late summer, an increase in conductivity is observed due to vertical mixing and plant senescence.

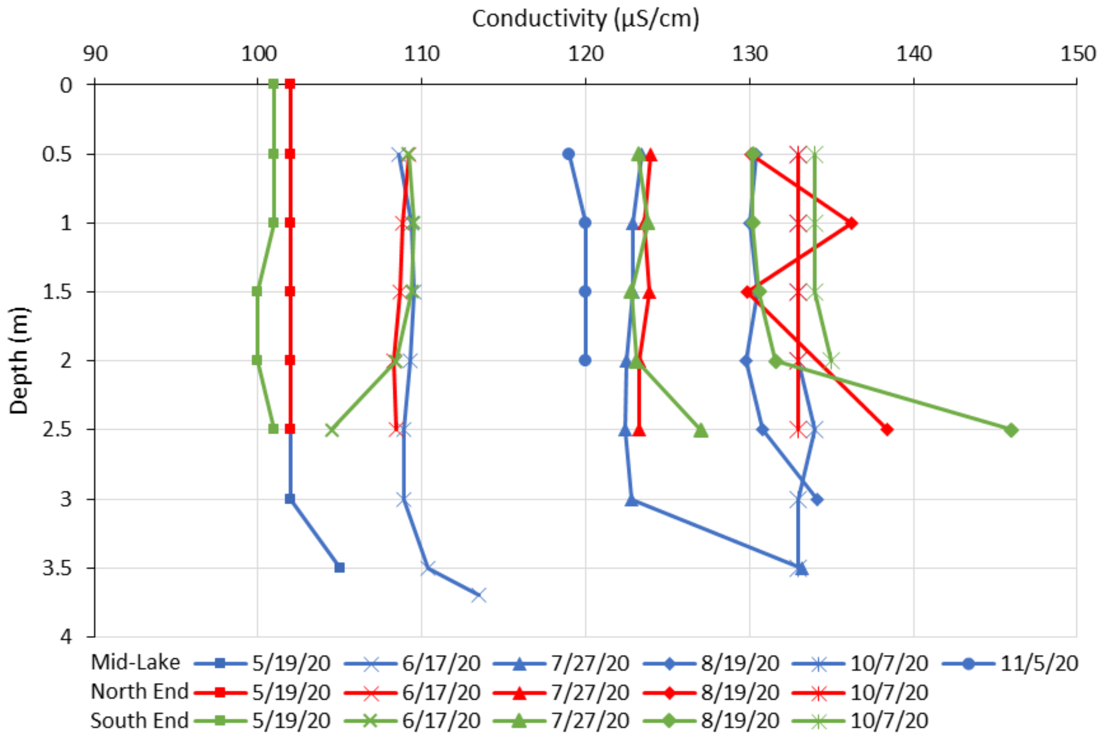

**Figure 12. Conductivity in Long Lake, 2020**

# 4.0 Water Quality Summary Discussion

This was an interesting year for lake water quality in Long Lake. The continued expansion of aquatic plants and algae growth were prominent in 2020, creating health and safety concerns for lake residents and users as well as imbalanced ecosystem conditions. In-situ monitoring was conducted monthly from May through November, with water samples collected for laboratory analysis by citizen volunteers and Tetra Tech staff. Below is a summary of noteworthy findings from the 2020 monitoring season.

- Water level in Long Lake does not appear to respond to precipitation.
    - Apparent correlation between logger data and rainfall records is weak.
- The effects of the 2019 alum treatment were not significantly persistent in 2020 most likely due to the low dose imposed upon the treatment due to budget limitations.
    - Water clarity in 2020 returned to pre-treatment levels.
    - Long Lake experienced a toxic bloom in 2020 that had been reoccurring each year for the last five years except for in 2019.
- Aquatic plant treatments in 2020 targeted 16.6 acres of the littoral zone areas along the east and west banks. These areas were treated with the aquatic herbicide fluridone, targeting Eurasian watermilfoil, Brazilian elodea, and pondweeds. Aquatic plant surveys in the spring and late summer of 2020 indicated that the treatments were successful in limiting pondweed growth in targeted areas, but in other areas there was continued expansion of aquatic plant growth over the summer.
- Floating islands made by root mass of mainly invasive aquatic plants (lilies) have formed at the southern end of the lake, and in 2020 one of these masses became a free-floating island that was a hazard to lake residents and property and directly impacted aquatic habitat.
- Compared to observations from 2006-2010 and 2018-2019, averages of temperature, pH, DO, and conductivity in 2020 are consistent with the historical data.
- Declining water quality in 2020 compared to historical averages.
    - Compared to data from 2007-2010 and 2018-2019, average concentrations of TP and chl were higher and transparency was lower in 2020. Note that in 2018 a wet winter with increased flushing resulted in lower concentrations of TP and chL and higher transparency, while the 2019 improvements are due to the low-dose alum treatment.
    - A historical record of water quality indicators and alum treatments in Long Lake is shown in **Figure 13**.

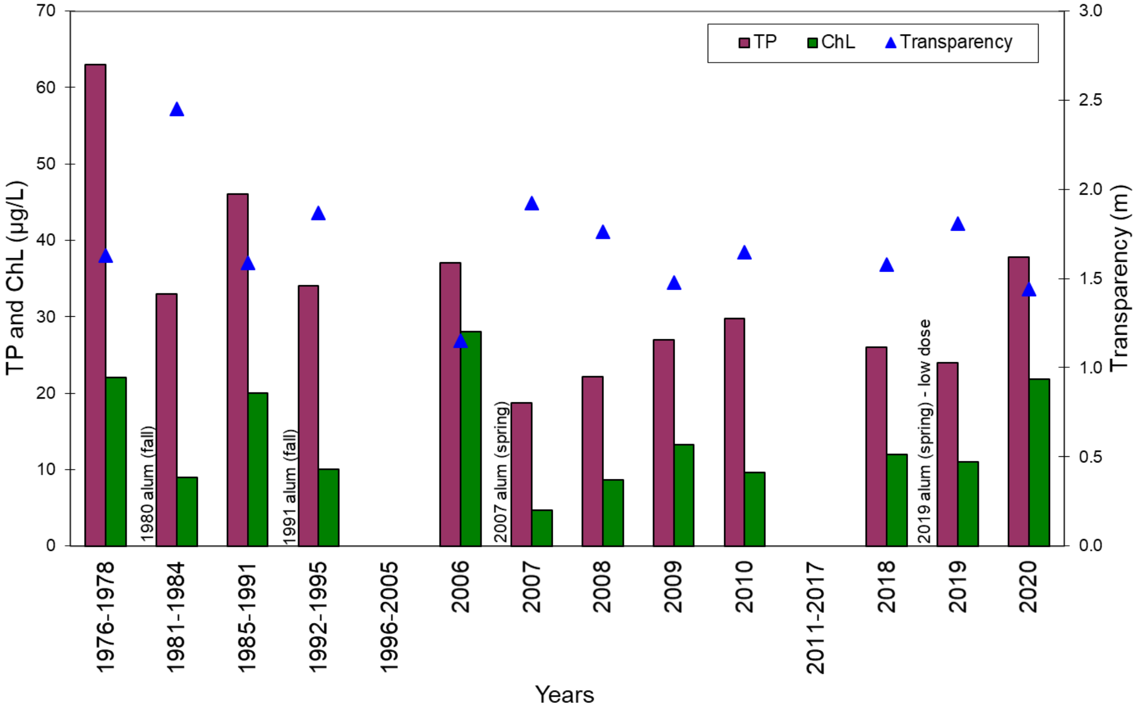

**Figure 13. Historical water quality averages**

## 5.0 Recommendations for Future Work

Based on the positive results of the aquatic plant adaptive management plan developed in 2006 to maintain a sustainable aquatic habitat that also helps to limit HAB events, a portion of the lake's littoral area (5 to 25%) should continue to be managed on a rotational 4-year adaptive program to ensure the re-establishment of native plant communities for aquatic ecosystem recovery, while maximizing the direct beneficial uses of the lake.

Aquatic plant treatments were successfully implemented in 2020 following postponement of the 2019 treatments in order to address the change in plant community and density observed following the 2019 alum treatment. Note, there was a fall treatment targeting white lilies in 2018. The treatment plan for 2021 is multiple applications of a slow release herbicide, pellet fluridone, at the end of April or beginning of May and again in mid-June. This would be followed by another in mid to late July and possibly mid-September. The result would be a significant reduction in aquatic plant production in 2021 that would carry over to 2022 as well, allowing other areas and plants to be targeted in 2022. At the same time this would not directly enhance the cycling of phosphorus to cause a spike in phosphorus availability leading to an algal bloom. This is because the slow herbicide release would not result in an immediate die-off and decay of existing plants, but a reduction in plant production and targeted plant biomass over time.

In order to enhance the adaptive aquatic plant management program, Tetra Tech assisted Kitsap County with a grant application in 2020 to update the integrated aquatic vegetation management plan (IAVMP). If funding is acquired during the current grant cycle, treatment strategies in the updated IAVMP will be expanded to include bottom barrier planning and implementation that would involve burlap barrier to be purchased and to train and citizen on how to install the bottom barriers near their shorelines. This would result in increased lake habitat diversity and shallow open water for recreation. It would also over time reduce the amount of herbicide treatment required to manage the littoral lake area. After completion of an updated IAVMP, implementation of the plan will require additional funding through future grants or other sources.

The most recent phosphorus inactivation and water column stripping alum treatment was implemented in late April of 2019. This helped limit the potential for an algal bloom and improve overall lake water quality. However, due to cost increases in materials to perform this action the dose was 3.5 times less than the successful 2007 alum treatment. To continue to limit HAB events, additional alum treatments to limit phosphorus will be needed in the near future. In 2020 Tetra Tech assisted Kitsap County with a grant application to update the algae control plan for Long Lake. The potential award of funding may be announced in early 2021. Regardless of the potential award of grant funding, additional funding through future grants and the LLMD will be required to implement future phosphorus inactivation treatments.

# 6.0 Revisions to the Adaptive Plan

Currently, the data does not dictate any significant revisions to the adaptive plan, only for enhancements through grant funding as outlined in Section 5. Unfortunately, the cost of providing an effective phosphorus inactivation program has increased significantly, beyond the estimates and costs determined in 2016, and now requires a more aggressive funding program. However, even with the increase in phosphorus inactivation management strategies, the current costs are still 300 to 500 times less than that of other restoration alternatives such as dredging, as the dredging of Long Lake for aquatic plant control and to reduce algal production would potentially cost hundreds of millions of dollars depending on depth of dredging and material disposal costs.

# 7.0 References

Bortleson, G.C., Dion, N.P., McConnell, J.B. and L.M. Nelson. 1976. Reconnaissance Data on Lakes in Washington, Water Supply Bulletin 43, Volume 3. State of Washington Department of Ecology in cooperation with the U.S. Geological Survey.

Jacoby, J.M., D.D. Lynch, E.B. Welch and M.A. Perkins. 1982. Internal phosphorus loading in a shallow eutrophic lake. Water Res. 16:911-919.

Tetra Tech, Inc. 2010. Final Report on Long Lake Water Quality: 2006-2010. Prepared for Kitsap County and CILL. 167 pp.

Tetra Tech, Inc. 2018. Long Lake Water Quality Monitoring Program: Sampling & Analysis Plan. Prepared for Kitsap County's Long Lake Management District.

Water Environmental Service, INC. 1996. Integrated Aquatic Vegetation Management Plan for Long Lake.