2018 Summit Lake Water Quality Report

Prepared by Thurston County Environmental Health Division

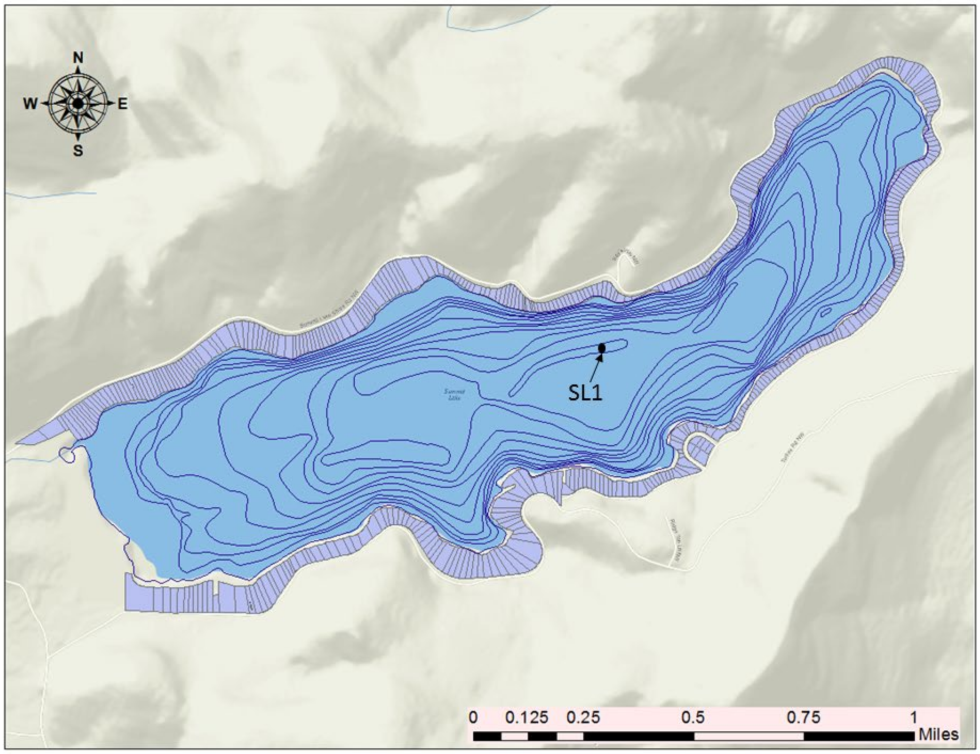

Figure 1. Summit Lake map showing location of sample site SL1 and 456 parcels along the shoreline.

PART OF TOTTEN INLET WATERSHED

- **SHORELINE LENGTH**: 5.6 miles
- **LAKE SIZE**: 0.8 square miles (530 acres)
- **BASIN SIZE**: 2.8 square miles
- **MEAN DEPTH**: 16.2 meters (53 feet)
- **MAXIMUM DEPTH**: 30 meters (100 feet)
- **VOLUME**: 34,537,440 cubic meters (28,000 acre-feet)

PRIMARY LAND USES:
Most of the basin is commercial forest with dense development upslope of the lake or along the shoreline (Figure 1).

PRIMARY LAKE USE:
Domestic water supply, fishing, boating, swimming, and other water sports.

PUBLIC ACCESS:
Washington Department of Fish and Wildlife public boat launch; three small private community accesses; 126-acre boy scout camp at the west end of the lake.

GENERAL TOPOGRAPHY:
The approximate altitude of the lake is 460 feet. The drainage is steep and rugged with ridges as high as 1200 feet and slopes up to 80 percent. There are numerous springs and intermittent streams that flow into the lake. The outlet, at the west end of the lake, is controlled by flash boards and flows into Kennedy Creek.

GENERAL WATER QUALITY:
Good to Excellent - The lake has low nutrient and chlorophyll-*a* levels and good water clarity. Good water quality is important because the lake is used as a drinking water source for most of the lake residents.

DESCRIPTION

Summit Lake is in the northwestern corner of Thurston County, about eight miles west of McCleary and nine miles west of Olympia, Washington. Summit Lake is one of the deepest lakes (30 meters) in Thurston County. It is fed by intermittent streams, seeps, and springs. The outlet is Kennedy Creek, which flows north to discharge into Totten Inlet. Many residents depend on the lake for drinking water.

The Department of Fish and Wildlife manage the lake for rainbow trout and kokanee. Summit Lake also supports naturally reproducing largemouth bass, smallmouth bass, yellow perch, brown bullhead, pumpkinseed sunfish, coastal cutthroat and northern pike minnow.

METHODS

In 2018, Thurston County Environmental Health (TCEH) conducted monthly monitoring at Summit Lake from May to October. Figure 1 shows the sample site SL1 located in the deepest part of the lake. Table 1 lists the types of data collected (TCEH, 2009) and Appendix A provides the raw data. The Custer Color Strip (Figure 2) has been used as a reference for water color since the 1990s.

Table 1. List of parameters, units, method, and sampling locations.

Parameter	Units	Method	Sampling Location
Transparency	meters	Secchi Disk	Depth where disk is no longer visible
Color	#1 to #11	Custer Color Strip	Color of water on white portion of Secchi Disk
Vertical Water Quality Profile	• Water Temperature (°C) • Dissolved Oxygen (mg/L) • pH (standard units) • Specific Conductivity (µS/cm)	YSI EXO1 Multi-parameter Sonde	~ 0.5 meter below the water surface to ~ 0.5 meter above the bottom sediments
Total Phosphorus	mg/L	Grab Samples with Kemmerer	Surface Sample: ~ 0.5 meter below the surface Bottom Sample: ~ 0.5 meter above the benthos
Total Nitrogen	mg/L	Grab Samples with Kemmerer	Surface Sample: ~ 0.5 meter below the surface Bottom Sample: ~ 0.5 meter above the benthos
Chlorophyll-a	µg/L	Composite of Multiple Grab Samples	Photic Zone
Phaeophytin-a	µg/L	Composite of Multiple Grab Samples	Photic Zone

Figure 2. TCEH compared water color to the Custer Color Strip.

Quality Assurance and Quality Control (QA/QC)

Each day TCEH collected 10% field replicates and daily trip blanks to assess total variation (3 to 4 lakes sampled each day). The calibration of the Yellow Springs Instrument (YSI) EXO1 was verified before and after each sampling day. See Appendix B for QA/QC data.

The Seasonal Kendall Test

TCEH used the Seasonal Kendall test, a highly robust, non-parametric test, to identify trends from 2008 to 2018 (Appendix C). This test compares the relationship between data points at separate time periods and determines if there is a trend (positive or negative). The Seasonal Kendall test statistic was computed by performing a Mann-Kendall calculation for each sample month (May to October) from 2008 to 2018. TCEH calculated the Z statistic to determine if the trend was statistically significant and Theil-Sen estimator, also called Sen Slope, to estimate the magnitude of the trend over time.

RESULTS

Weather Conditions

Weather conditions during the 2018 sample season are provided in Table 2.

Table 2. Weather on sample days and the average, minimum, and maximum air temperatures for each month.

Month	Weather on Sample Day	Monthly Weather Temperature (°C) Mean (Low/High)
May	Sunny (16°C); 1-6 mph N wind	16 (7/31)
June	Partly cloudy (21°C); 9-13 mph S to SW wind	17 (9/31)
July	Sunny, (21°C); 9-13 mph N wind	17 (9/31)
August	Hazy from wildfire smoke, (28°C); 5-7 mph NE wind	21 (12/34)
September	Partly cloudy (17°C); 3-6 mph NNE wind	17 (9/29)
October	Sunny with some fog (9°C); 0-3 mph SE wind	12 (6/22)

Vertical Water Quality Profiles

During the summer, lakes often stratify into layers based on temperature and density differences.

- Epilimnion: upper warm, circulating strata in contact with the atmosphere
- Metalimnion: middle layer with steep thermal gradient (thermocline)
- Hypolimnion: deepest layer of colder, relatively stagnant water

The vertical water quality profiles illustrate how the water column at Summit Lake was thermally stratified for most of the summer (Figures 3 to 5). Warmer, more oxygenated water existed on the surface in the epilimnion. Below this layer, the temperature and oxygen concentration declined with depth.

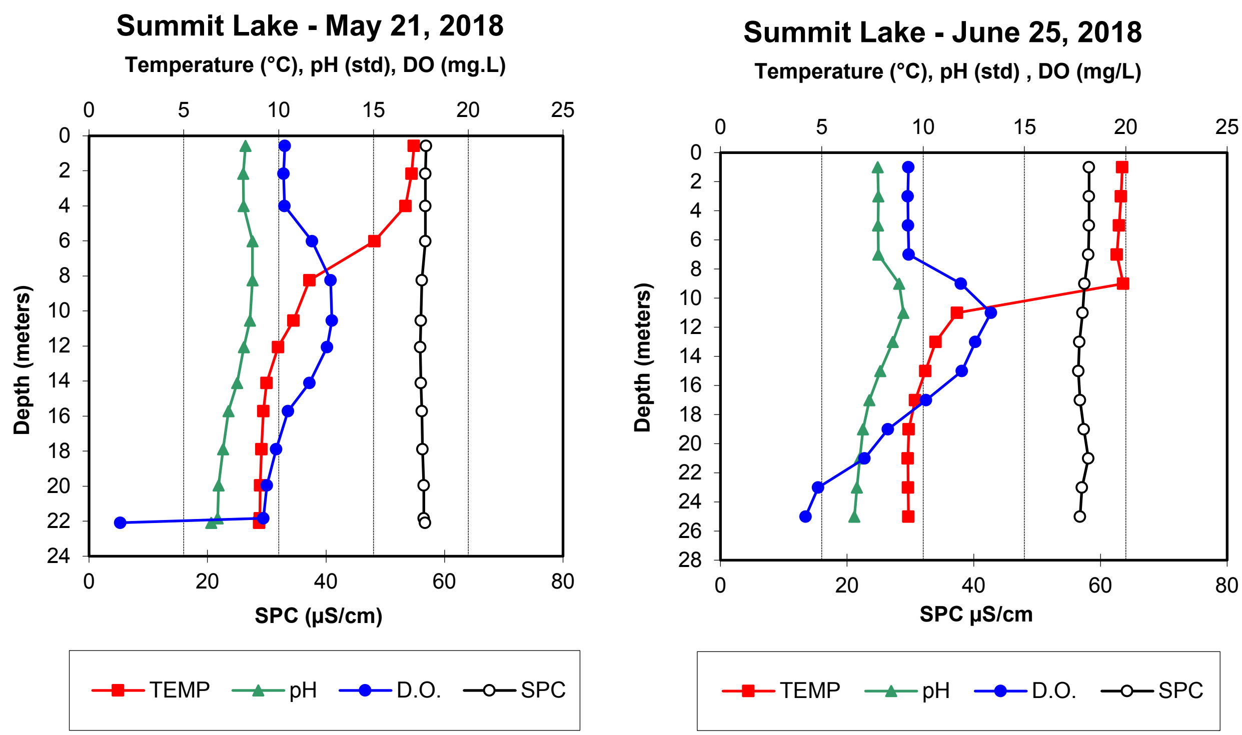

Figure 3. Vertical water quality profiles for Summit Lake collected during May and June 2018.

In May, the lake was beginning to stratify.

- May Epilimnion – Mean Temperature 16.95°C; Mean DO 10.30 mg/L
- May Hypolimnion – Mean Temperature 9.12°C; Mean DO 8.71 mg/L

Three layers became readily apparent in June. The summer sun heated the surface layer, the epilimnion. This heat was retained because air temperature remained high until September (Table 2). The epilimnion grew deeper, from 4 meters deep in May to 9 meters deep in June.

- June Epilimnion – Mean Temperature 19.74°C; Mean DO 9.79 mg/L
- June Hypolimnion – Mean Temperature 9.27°C; Mean DO 6.10 mg/L

The dissolved oxygen (DO) profile during thermal stratification had a positive heterograde curve. This type of curve is readily apparent in the June vertical water quality profile. When the water column is sufficiently transparent to permit photosynthesis in the metalimnion, excess oxygen accumulates there because thermal stratification prevents vertical mixing of the water column (Wetzel, 1983).

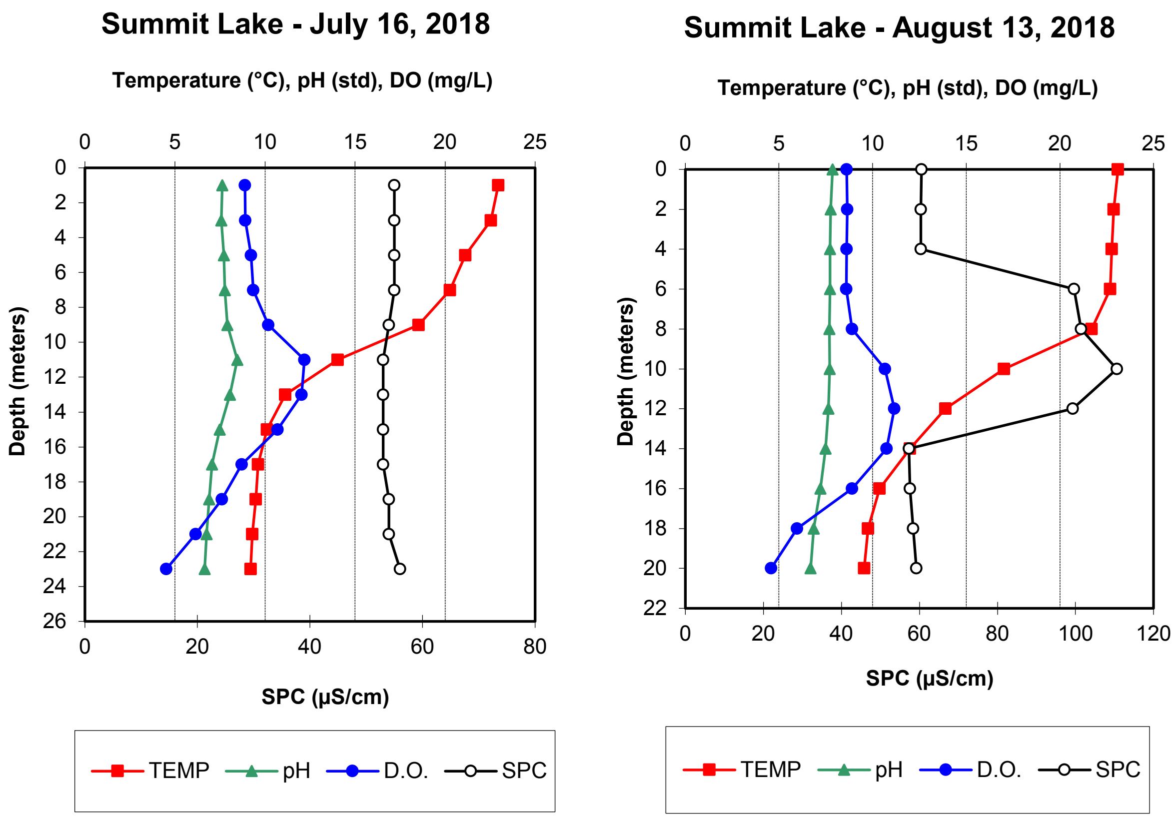

Figure 4. Vertical water quality profiles for Summit Lake collected during July and August 2018.

Higher winds in July (Table 2) mixed the surface waters, so the thermocline was less evident than it was in June.

- July Epilimnion – Mean Temperature 21.73°C; Mean DO 9.09 mg/L
- July Hypolimnion – Mean Temperature 9.33°C; Mean DO 6.09 mg/L

By August, the thermocline was discernable again.

- August Epilimnion – Mean Temperature 22.86°C; Mean DO 8.62 mg/L
- August Hypolimnion – Mean Temperature 9.66°C; Mean DO 5.28 mg/L

Transparency remained high in July and August, which allowed photosynthesis to create oxygen in the metalimnion. The DO positive heterograde curve was present both months.

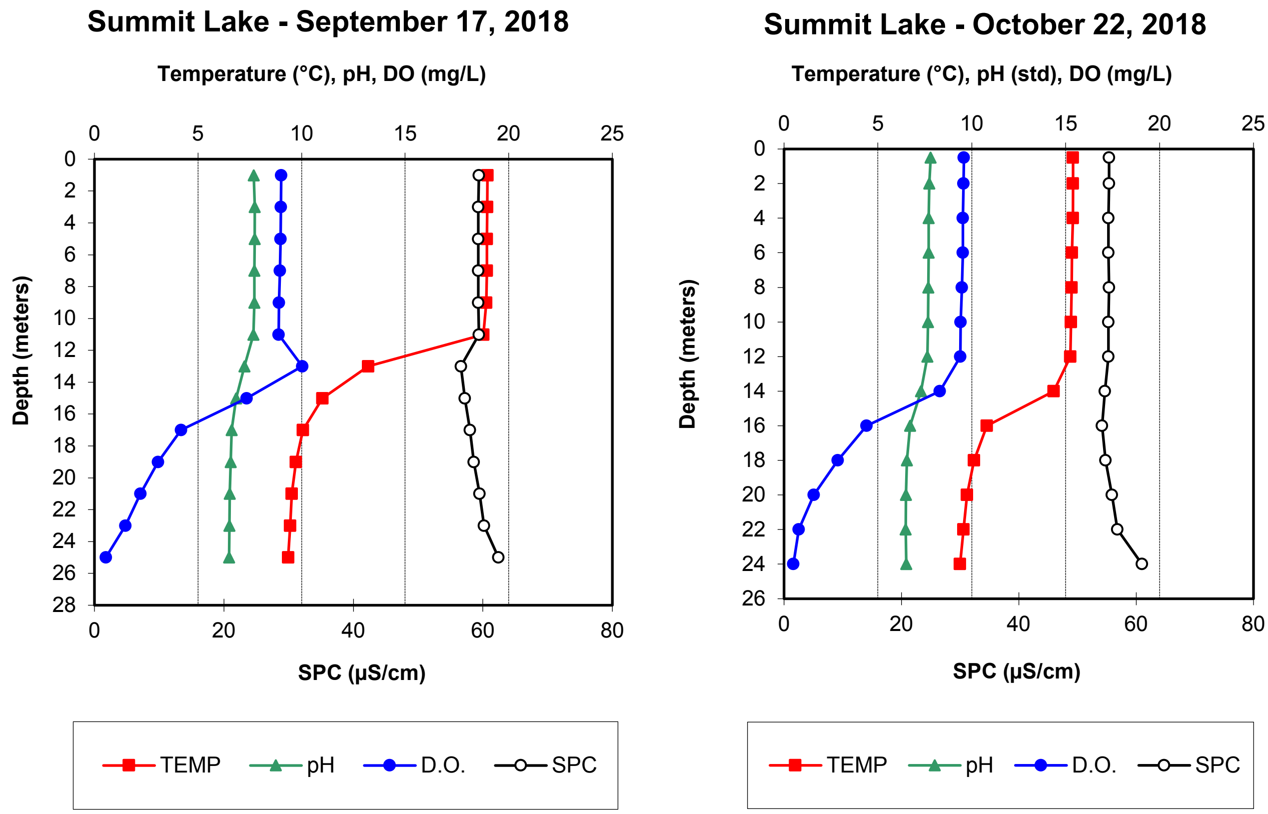

Figure 5. Vertical water quality profiles from Summit Lake collected during September and October 2018.

In September, the temperature of the epilimnion declined and this layer extended deeper to 11 meters. Also, the positive heterograde curve was less pronounced.

- September Epilimnion – Mean Temperature 18.92°C; Mean DO 8.96 mg/L
- September Hypolimnion – Mean Temperature 9.44°C; Mean DO 1.42 mg/L

The epilimnion continued to cool and sink (to 12 meters) in October, but the lake had not yet turned-over. The DO curve was clinograde. Oxygen consuming processes or advection of low oxygen groundwater produced anoxic conditions in the hypolimnion.

- October Epilimnion – Mean Temperature 15.33°C; Mean DO 9.49 mg/L
- October Hypolimnion – Mean Temperature 9.56°C; Mean DO 0.96 mg/L

Surface Water Temperature Trends

The Seasonal Kendall analysis for trends for 2008 to 2018 shows that surface temperature has significantly increased at SL1 from May to August (Figure 6). No trend was detected in September and October.

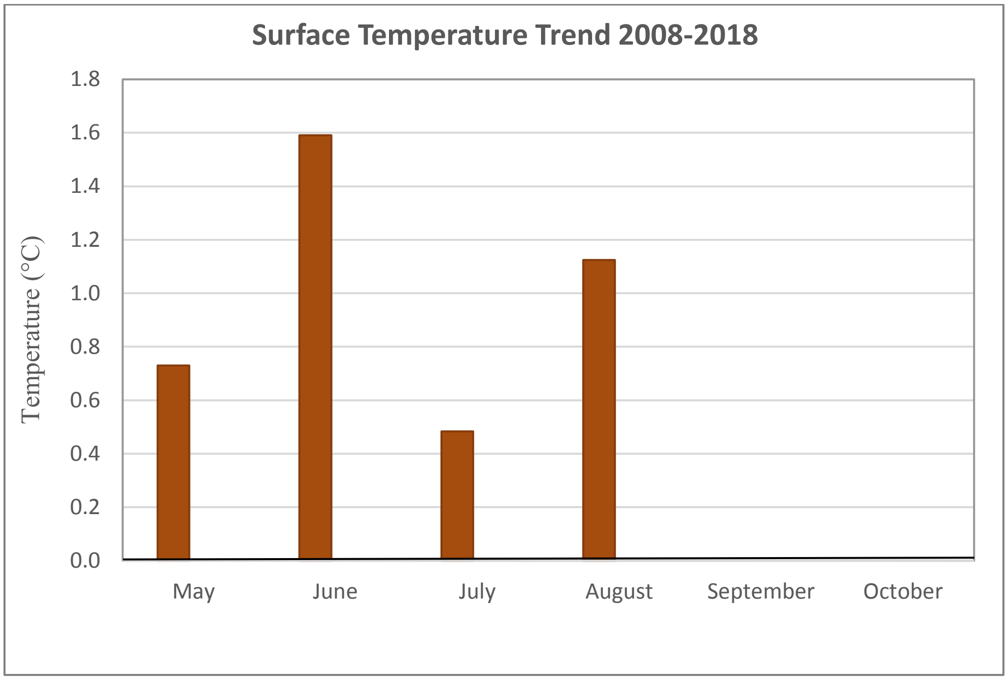

Figure 6. Surface temperature trend (+ or -) and magnitude of change (Theil-Sen estimator) for SL1 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p<0.05$) for that time period.

Water Color and Transparency

Color can reveal information about a lake's nutrient load, algal growth, water quality and surrounding landscape. High concentrations of algae cause the water color to appear green, golden, or red. Weather, rocks and soil, land use practices, and types of trees and plants influence dissolved and suspended materials in the lake. Tannins and lignins, naturally occurring organic compounds from decomposition, can color the water yellow to brown.

Transparency of water to light has been used to approximate turbidity and phytoplankton populations. Secchi depth is closely correlated with the percentage of light transmission through water. The depth at which the Secchi disk is no longer visible approximates 10% of surface light, however suspended particles in the water affect accuracy. The health department recommends visibility of at least 1.2 meters, or four feet, at public swimming beaches.

Figure 7 shows the color and transparency for SL1 for 2018.

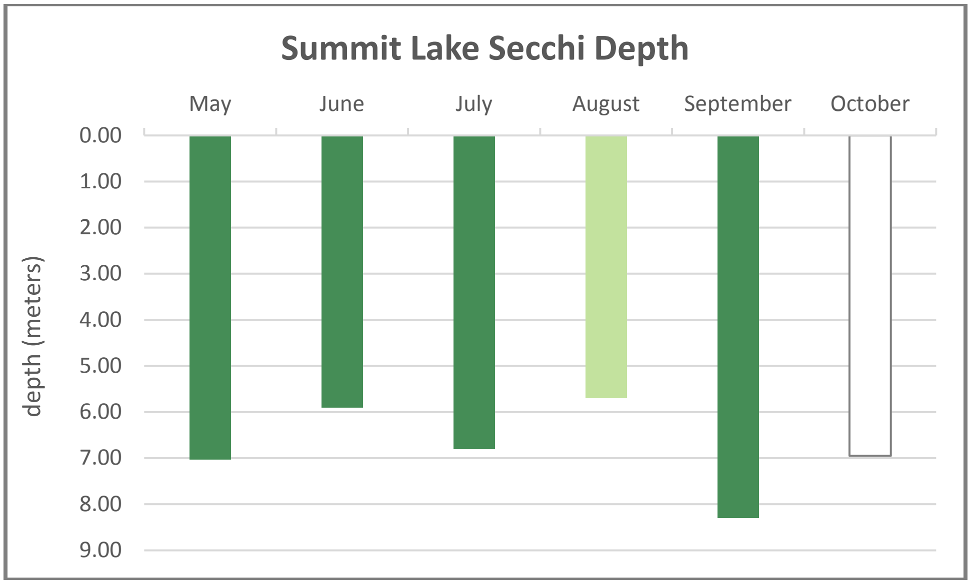

Figure 7. Water color and Secchi depths for 2018.

In 2018, transparency was lowest in August (5.7 meters) and highest in May, September, and October (7 to 8.3 meters). The color of the water, based on the reference Custer Color Strip, was #4 from May to July and in September. August was reported as #6 and October as #1.

Figure 8 shows the annual average transparency (Secchi depth) compared to the long-term average (LTA). Positive values reflect transparency better than the long-term average. In 2018, transparency at SL1 was marginally higher (0.1 meter) than the long-term average.

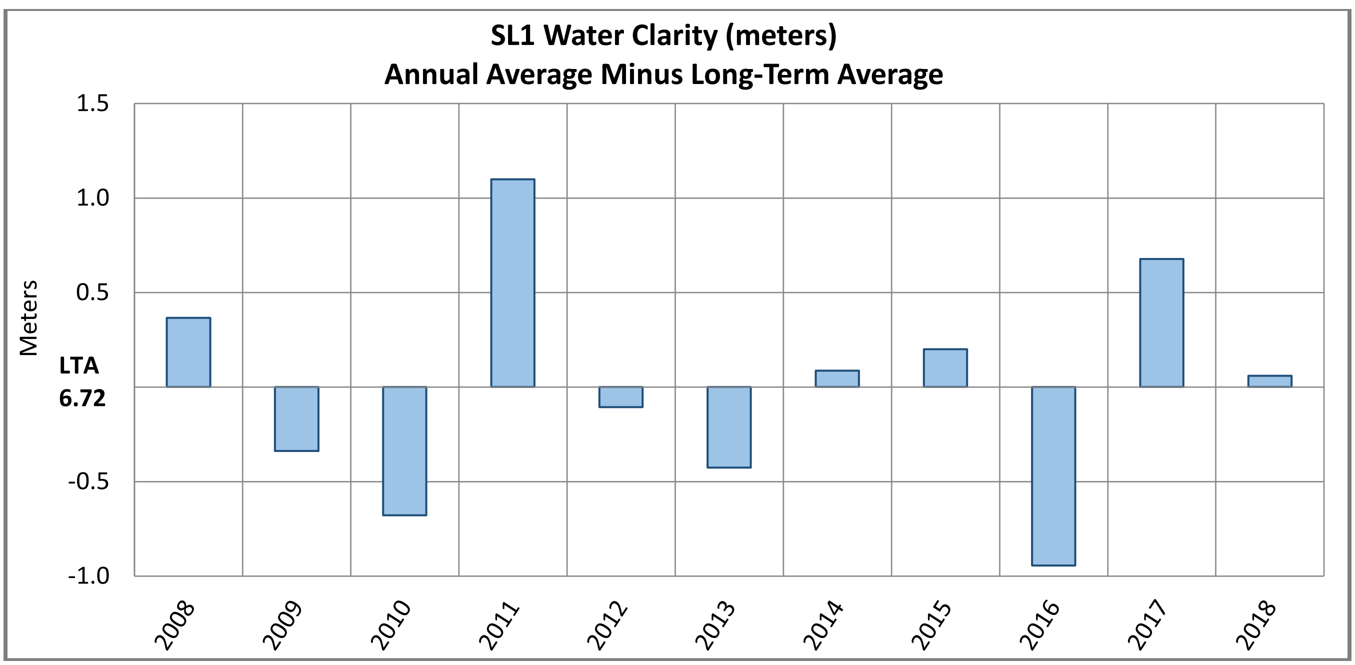

Figure 8. Transparency at SL1 compared to the long-term average (LTA).

The Seasonal Kendall test for 2008 to 2018 revealed a trend of reduced transparency (Figure 9) in June and increased water clarity in October. No significant ($p<0.05$) trends existed in May and July to September.

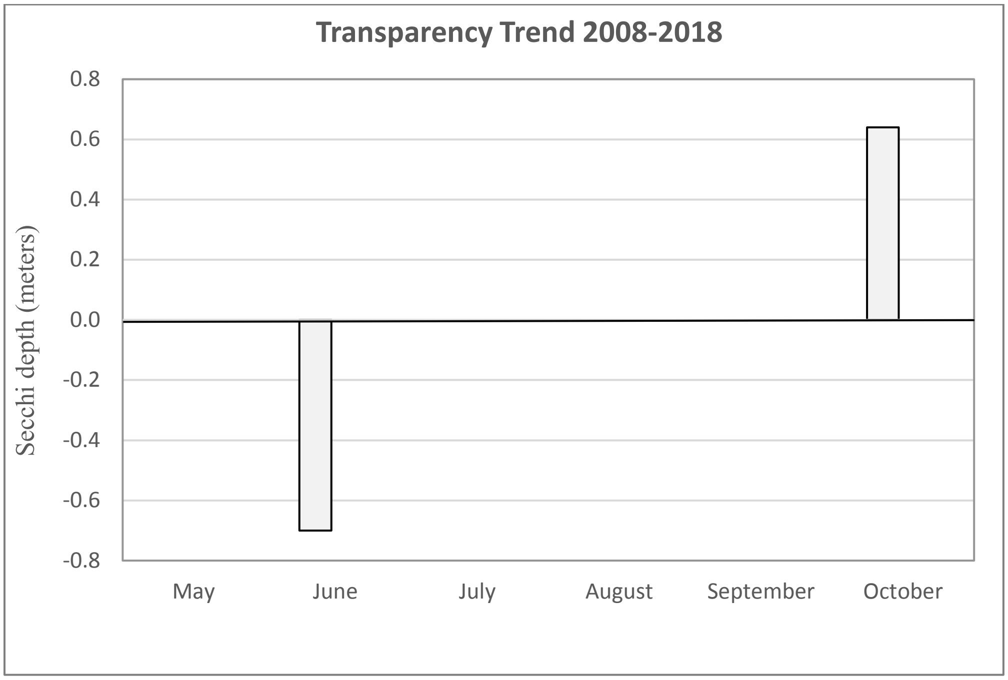

Figure 9. Transparency trend (+ or -) and magnitude of change (Theil-Sen estimator) for SL1 from 2008 to 2018. The lack of a bar means the site did not have a significant trend (p<0.05) for that time period.

Productivity

Pigments

Chlorophyll-a pigment is present in algae and cyanobacteria and is widely used to assess the abundance of phytoplankton in suspension. Phaeophytin is also a pigment, but it is not active in photosynthesis. It is a breakdown product of chlorophyll and is present in dead suspended material (Moss, 1967). Phaeophytin absorbs light in the same region of the spectrum as chlorophyll-a, and, if present can interfere with acquiring an accurate chlorophyll-a value. The ratio of chlorophyll-a to phaeophytin-a has been used as an indicator of the physiological condition of phytoplankton in the sample. Phaeopigments have been reported to contribute 16 to 60% of the measured chlorophyll-a content (Marker et al., 1980).

2018 Productivity Data

Figures 10 shows that the highest concentration of chlorophyll-a in 2018 occurred in May, September, and October. The supply of oxygen at the surface was highest in May (10.3 mg/L) and declined each month until September and October, when it increased to 9 to 9.5 mg/L. The ratio of chlorophyll-a to phaeophytin-a peaked in May and September.

Transparency was not correlated to productivity, as measured by the concentration of chlorophyll-a in the photic zone. Transparency was highest in May and September to October, when productivity was higher (Figure 7). Lake color was likely affected by changes in the algae and cyanobacteria communities; phytoplankton identification would provide more information about productivity and phytoplankton assemblages.

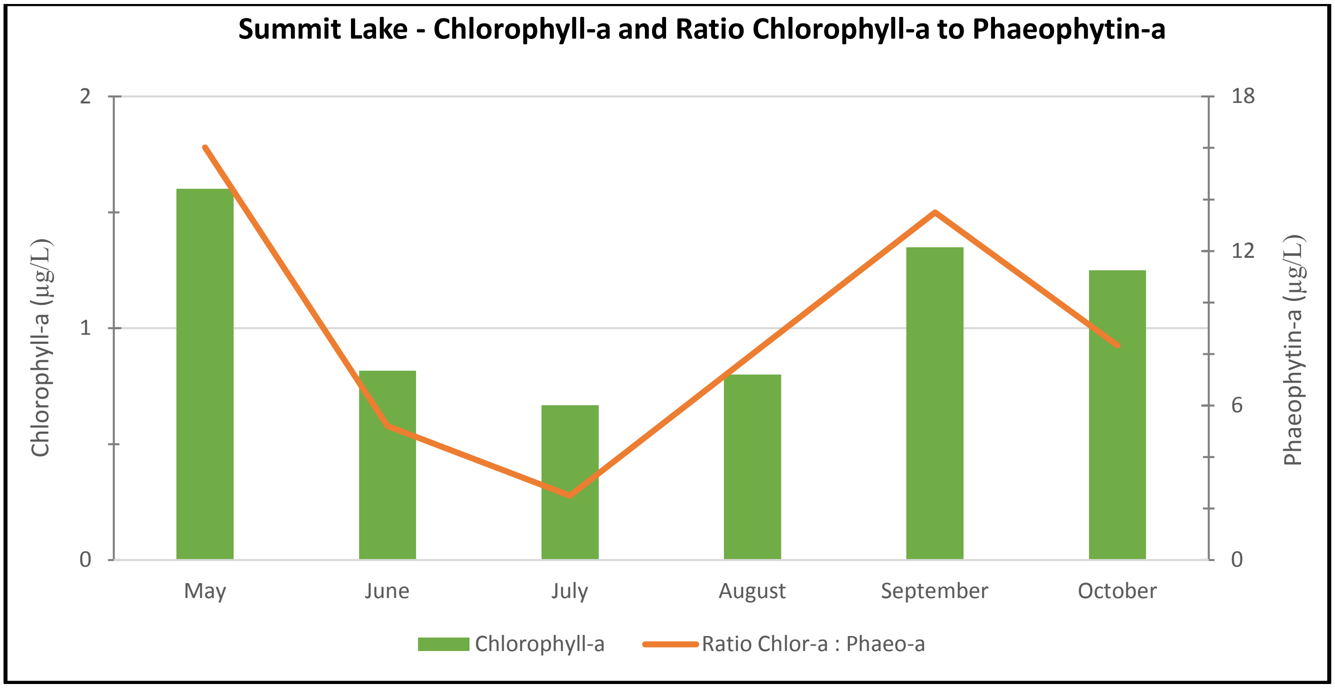

Figure 10. Chlorophyll-a concentration and ratio of chlorophyll-a to phaeophytin-a pigments in samples collected at SL1.

The Seasonal Kendall test for trends from 2008 to 2018 for chlorophyll-a concentration indicates a significant ($p<0.05$) increase in chlorophyll-a concentration in May and decrease June to October. Figure 11 shows the magnitude of change for all significant trends.

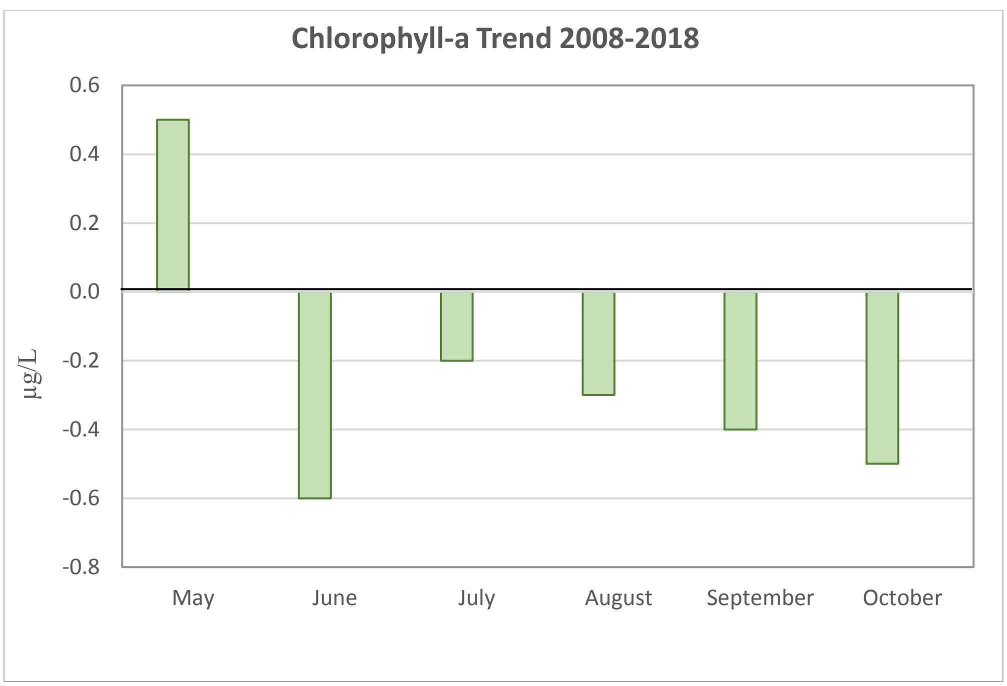

Figure 11. Chlorophyll-a trend (+ or -) and magnitude of change (Theil-Sen estimator) for SL1 from 2008 to 2018.

Nutrients

Surface Nutrients

Inorganic nutrients, particularly the elements phosphorus and nitrogen, are vital for algal nutrition and cellular constituents. Over enrichment of surface waters leads to excessive production of autotrophs, especially algae and cyanobacteria (Correll, 1998) Figure 12 shows the total phosphorus (TP) and total nitrogen (TN) present in the surface waters at SL1.

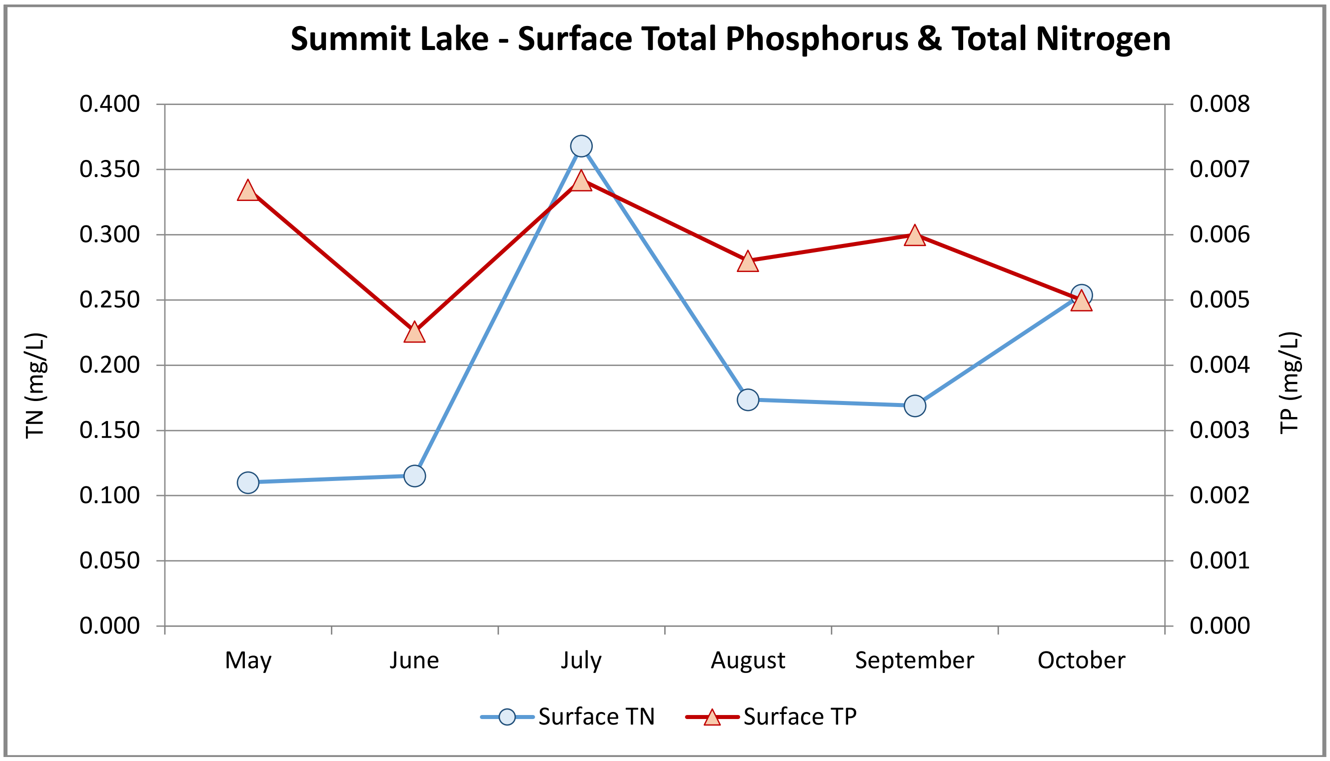

Figure 12. 2018 surface concentration of TP and TN at SL1 at Summit Lake.

The concentration of TP in surface waters was highest in May and July. TN was highest in July and October. Thermal stratification reduced internal loading to surface waters from May to October; changes in the phytoplankton community and external sources likely affect nutrient levels during stratification.

Total Phosphorus

Compared to the rich supply of other elements required for nutrition or structure, phosphorus is the least abundant and most commonly limits biological productivity. Lakes in this region experience undesirable algae growth when the annual average surface phosphorus level reaches 0.030 mg/L (Gilliom, 1983). Washington adopted numeric action values in the state water quality standards to protect lakes. The action level for the Puget Lowlands ecoregion is 0.020 mg/L (WAC, 2019). Figure 13 displays the TP concentration at SL1.

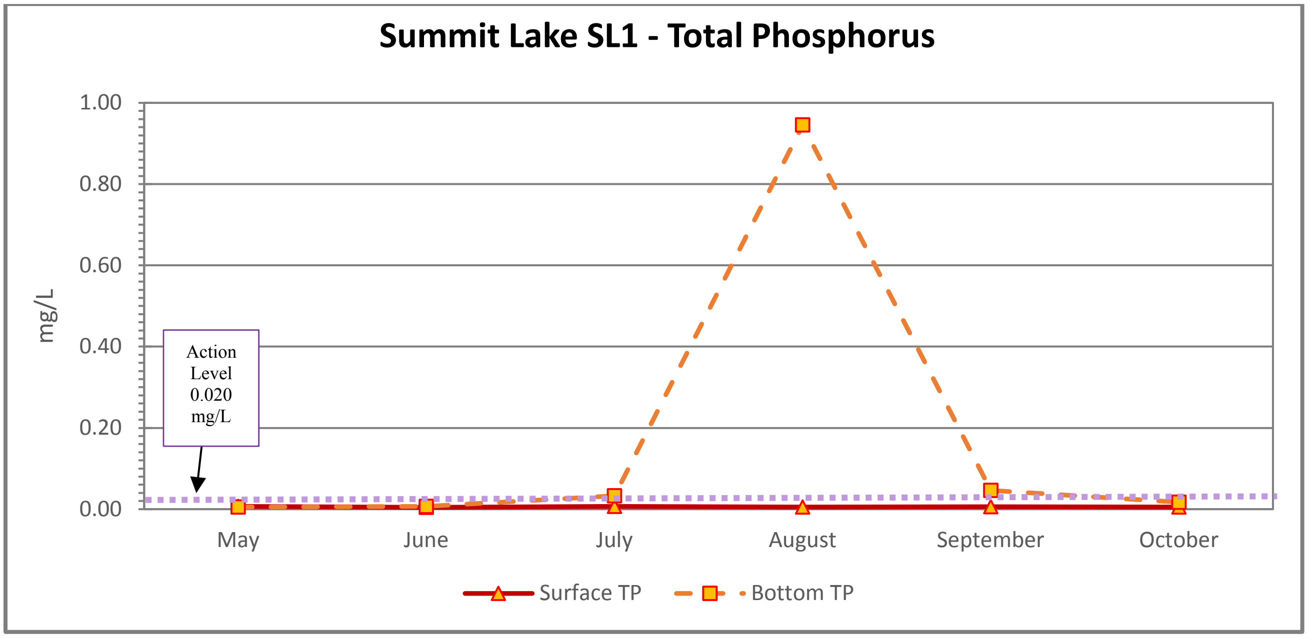

Figure 13. Concentration of Total Phosphorus at the surface and bottom of Summit Lake in 2018. Bottom samples were collected 0.6 to 0.7 meters from the bottom, except for in August, when the sample was collected 0.4 meters from the bottom.

At SL1, the 2018 average TP concentration at the surface was 0.006 mg/L and 0.125 mg/L at the bottom. The concentration was higher at the bottom because Summit Lake was thermally stratified during the summer. During stratification, the hypolimnion was mostly stagnant, not mixing with the oxygenated water above. At the same time, oxygen in the hypolimnion was consumed by redox processes like decomposition. Due to the lack of oxygen near the bottom, phosphorus stored in the sediments was released into the water column. This phosphorus accumulated in the hypolimnion, until turn-over later in the fall.

Figure 14 displays the average annual concentration of total phosphorus at SL1 from 2008 to 2018 (surface mean 0.006 mg/L; bottom mean 0.034 mg/L). The surface samples for total phosphorus have been below the state action level (purple dotted line at 0.020 mg/L) for the entire of the period of record.

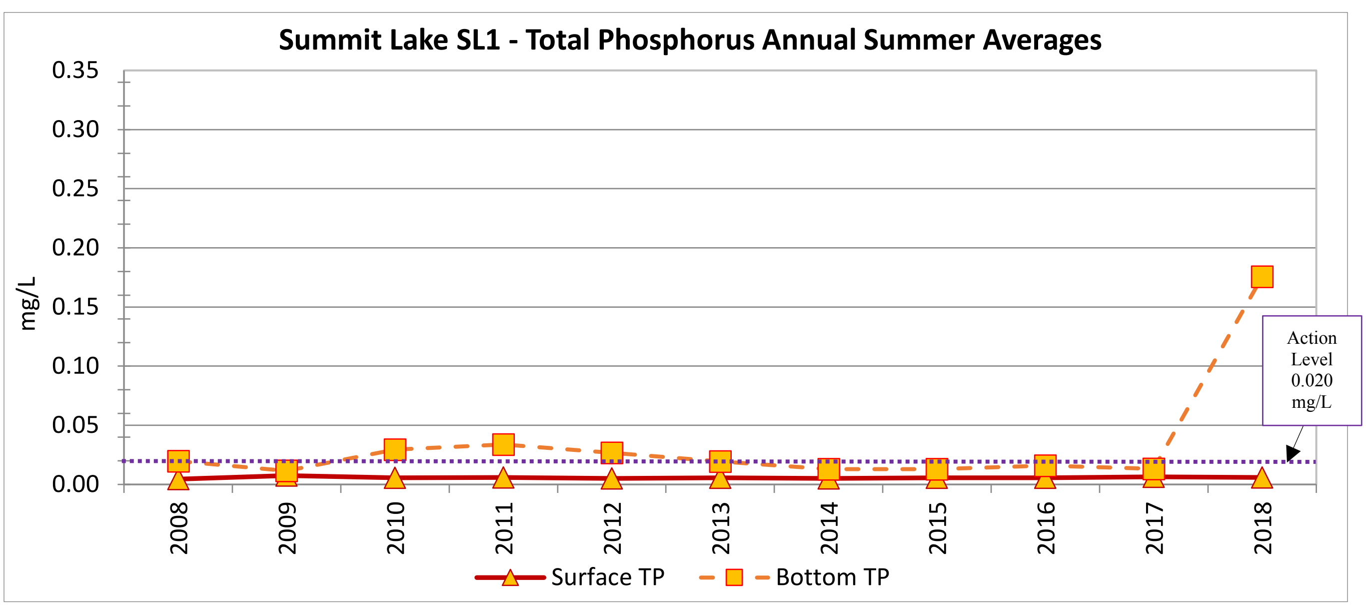

Figure 14. Average Annual Total Phosphorus at SL1 from 2008 to 2018.

The Seasonal Kendall test (2008 to 2018) revealed significant trends (Sen slope + or - 0.001 mg/L) in surface water at SL1 (Figure 15):

- Increase in July
- Decrease in September

No trends for TP concentration were detected for the remainder of the sampling season.

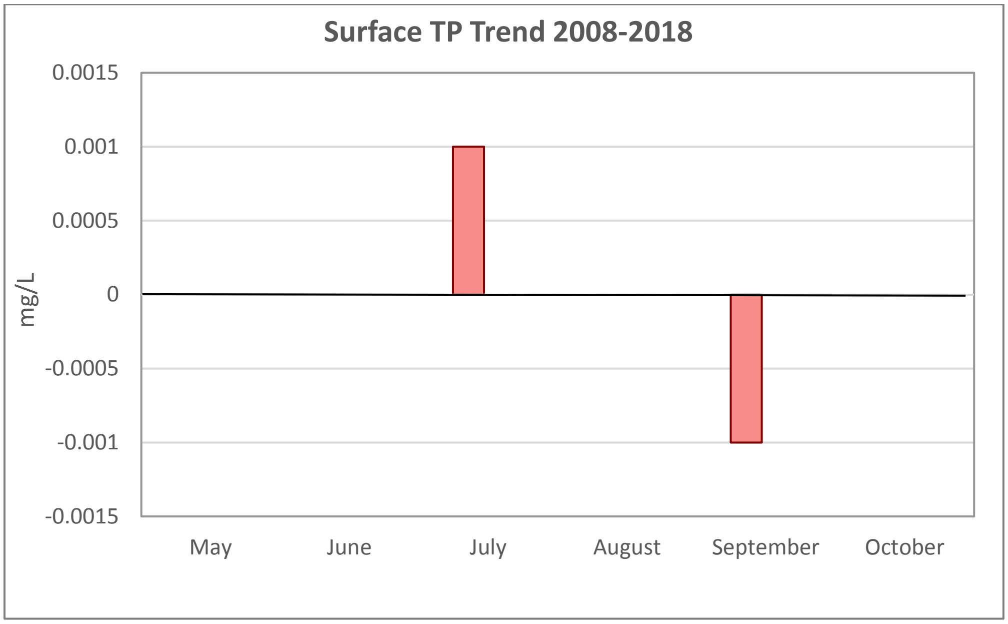

Figure 15. Surface TP trend (+ or -) and magnitude of change (Theil-Sen estimator) for SL1 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p<0.05$) for that time period.

Nitrogen

Nitrogen is also limiting to lake productivity, but supplies are more readily augmented by inputs from external sources. The State of Washington does not have established action or cleanup levels for surface total nitrogen. In 2018, the average total nitrogen concentration was 0.192 mg/L at the surface and 0.620 mg/L at the bottom. The total nitrogen concentration was higher at the bottom because the hypolimnion was hypoxic during stratification; ammonia-nitrogen was released from the bottom sediments and accumulated in the hypolimnion. Figure 16 shows the 2018 TN concentrations for the Summit Lake site.

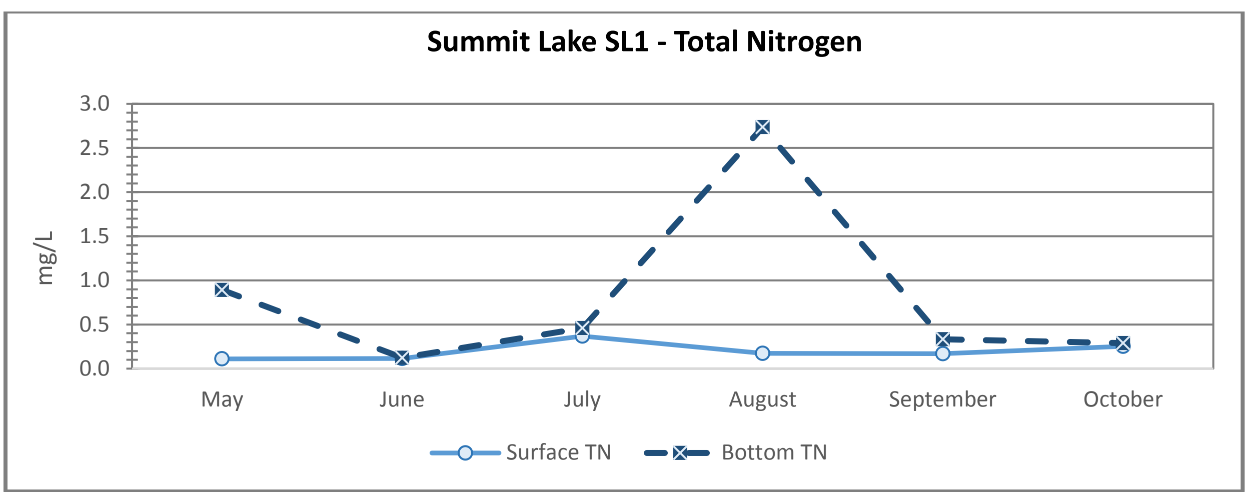

Figure 16. Concentration of Total Nitrogen at the surface and bottom at SL1 in 2018. Bottom samples were collected 0.6 to 0.7 meters from the bottom, except for in August, when the sample was collected 0.4 meters from the bottom.

Figures 17 displays the average annual concentrations for total nitrogen from 2008 to 2018. The mean/median TN concentration for the period of record was:

- 0.164/0.153 mg/L at the surface
- 0.286/0.237 mg/L at the bottom

The TN concentration was above the median: at the surface in 2013 to 2014 and 2016 to 2018 and at the bottom in 2010, 2014, and 2016 to 2018.

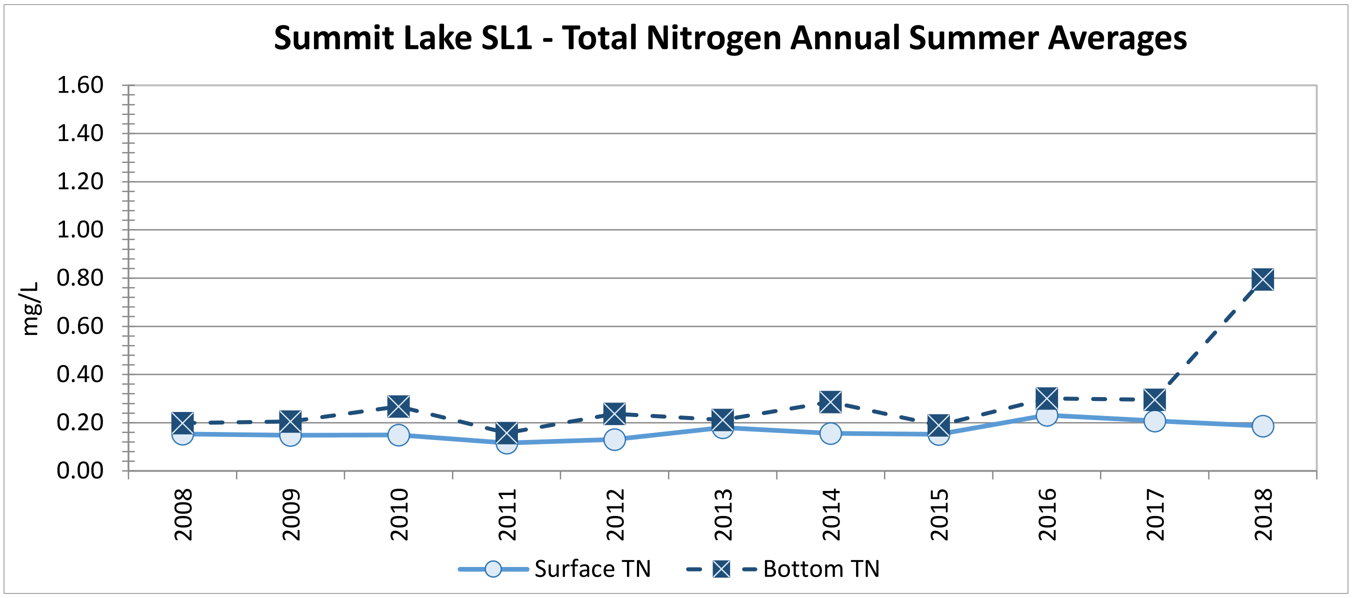

Figure 17. Average Annual Total Nitrogen at SL1 from 2008 to 2018.

The Seasonal Kendall test shows a significant ($p<0.05$) trend (Figure 18) of surface TN concentrations:

- Downward trend in May (0.017 mg/L) when productivity trended higher (Figure 11)
- Upward trend from June to August (0.036 to 0.043 mg/L)

No significant trend was detected for September and October.

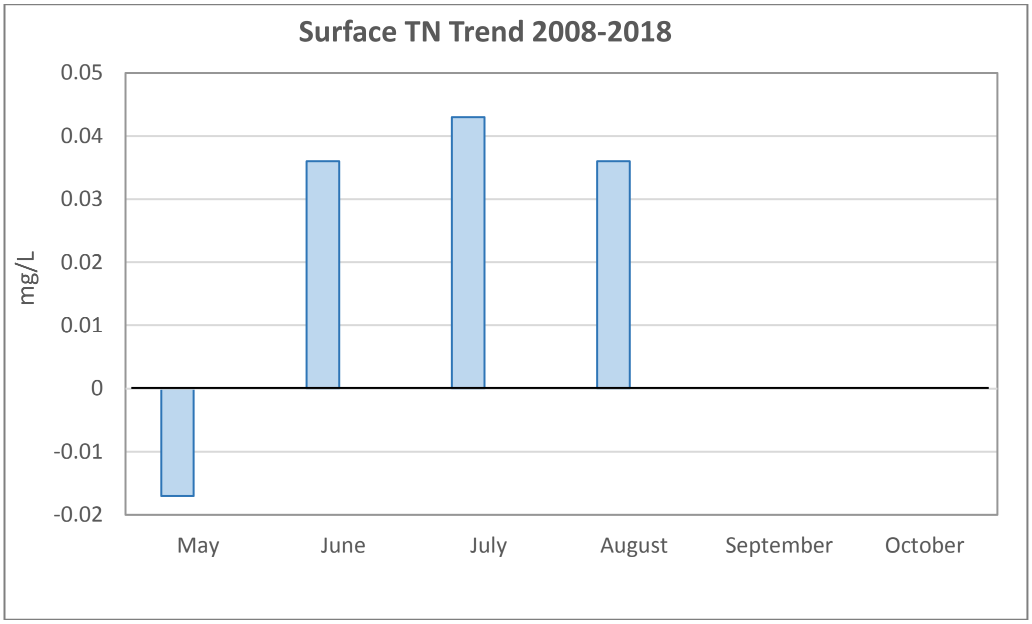

Figure 18. Surface TN trend (+ or -) and magnitude of change (Theil-Sen estimator) for SL1 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p<0.05$) for that time period.

Nitrogen to Phosphorus Ratios

To prevent dominance by cyanobacteria (blue-green algae), the TN to TP ratio (TN:TP) should be above 10:1 (Moore and Hicks, 2004). Figure 19 shows the TN to TP ratio at the Summit Lake site.

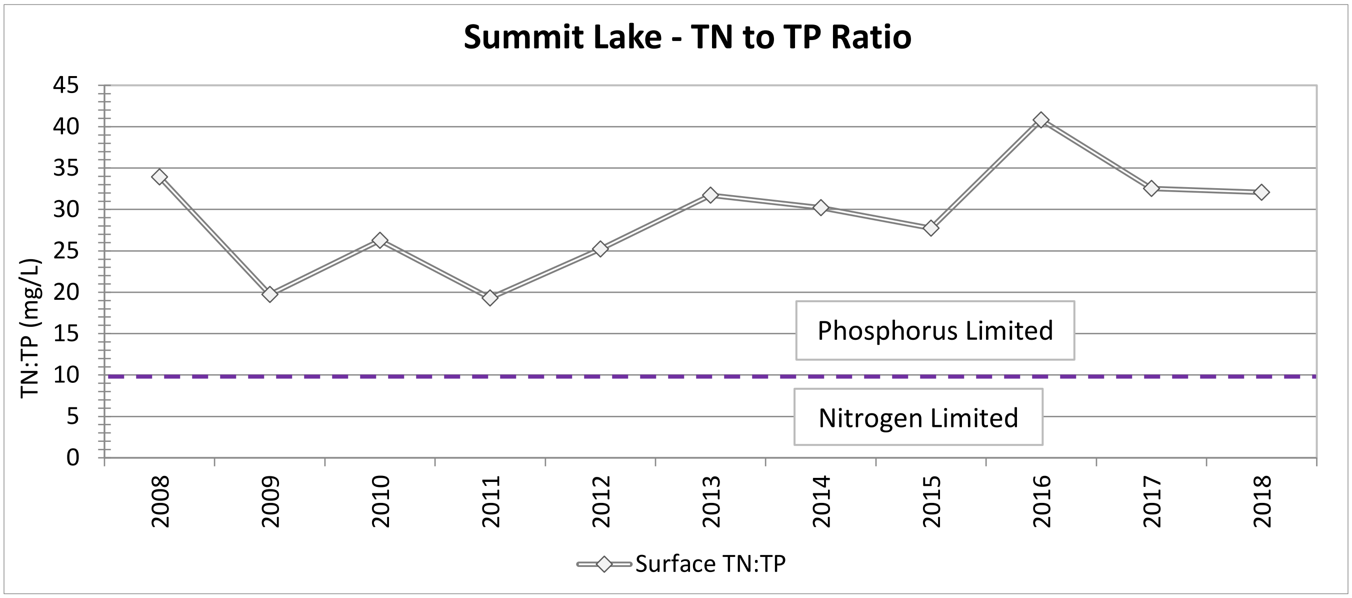

Figure 19. TN:TP at SL1 from 2008 to 2018.

Trophic State Indices (TSI)

The most commonly used method to classify lakes is called the Carlson's Trophic State Index (Carlson, 1977). Based on the productivity, this method uses three index variables: transparency (Secchi disk depth), chlorophyll-a, and phosphorus concentrations. Table 3 provides the index values for each trophic classification.

Table 3. Trophic State Index variables.

TSI Value	Trophic State	Productivity
0 to 40	oligotrophic	Low
41 to 50	mesotrophic	Medium
> 50	eutrophic	High

For SL1, the 2018 TSI results were:

- Chlorophyll-a: 31 oligotrophic
- Total Phosphorus: 29 oligotrophic
- Secchi Disk: 32 oligotrophic

The average of the three TSI variables is 31, which categorizes SL1 as oligotrophic in 2018. Based on the TP concentration and Secchi depth, SL1 has been classified as oligotrophic since 2008 (Figure 20). In 2010, the TSI score for chlorophyll-a concentration entered the mesotrophic range with a score of 42.

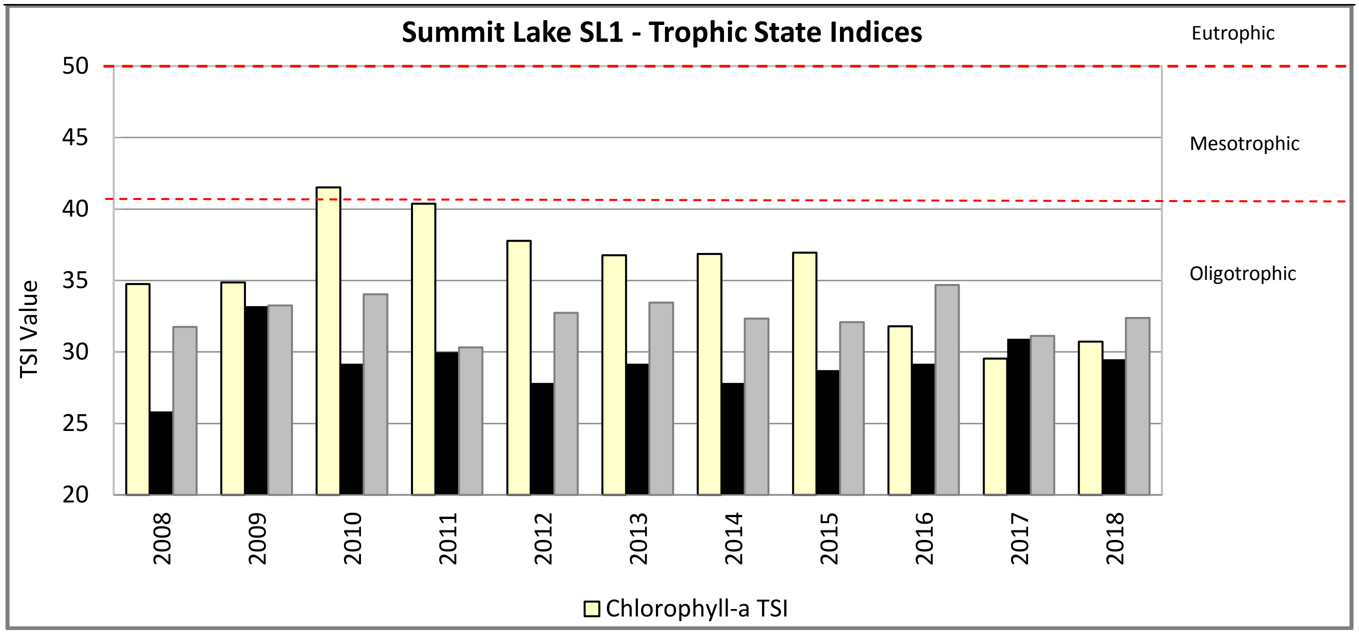

Figure 20. SL1 Trophic State Index from 2008 to 2018.

The Mann Kendall test (2008 to 2018) reveals significant trends ($p<0.05$) for TSI values:

- declining chlorophyll-a concentration (3.5)
- increasing TP concencentration (0.3)

No trend was found for Secchi depth TSI scores (Appendix C).

SUMMARY

Thermal Stratification and Increased Temperature Trends

In 2018, the water column at Summit Lake was thermally stratified from May to October. The trend from 2008 to 2018 was increased temperature in surface water at SL1 from May to August. In September and October, no significant trends existed.

Water Clarity and Transparency Trends

In 2018, the mean transparency was 6.8 meters, slightly higher than the long-term average. Transparency ranged from 7 to 8 meters and was not correlated to the concentration of chlorophyll-a. The general transparency trend from 2008 to 2018 was a decline in June and an increase in October, with no trends detected for the remainder of the sample season. The TSI values for Secchi depth also showed no trends.

Chlorophyll-a and Lower Productivity Trends

In 2018, the mean concentration of chlorophyll-a was 1.1 µg/L (range 0.7 to 1.6 µg/L). The highest productivity was in May, September and October. The Seasonal Kendall test for trends (2008 to 2018) in chlorophyll-a concentration indicates a significant ($p<0.05$) increasing trend in May (0.5 µg/L) and decreasing trend from June to October (0.2 to 0.6 µg/L). The largest decline in productivity over the last decade was in June.

TCEH sampled Summit Lake five times for toxic algae in 2018, detecting toxins over the Thurston County and Washington State advisory levels two times for anatoxin-a in April (Appendix D).

Nutrients and Trends

The average TP concentration was 0.006 mg/L at the surface, below the action level (0.020 mg/L) for lower mesotrophic lakes in the Puget Sound Lowlands ecoregion. The Seasonal Kendall test (2008 to 2018) reveals significant trends for TP in surface water:

- Increased TP concentration in July (0.001 mg/L)
- Decreased TP concentration in September (0.001 mg/L)

No significant trends were identified for the remainder of the sample season.

The average surface TN concentration was 0.192 mg/L in 2018. The Seasonal Kendall test indicates a significant ($p<0.05$) trends of surface TN concentrations:

- Decreased TN concentration in May (0.017 mg/L)
- Increased TN concentrations from June to August (0.036 to 0.043 mg/L)

No significant trend was detected at SL1 in September and October.

Classified as Oligotrophic

In 2018, the Summit Lake site SL1 was classified as oligotrophic based on an average of the three TSI variables. The TSI trend from 2008 to 2018 was toward lower productivity and increased TP concentrations. The transparency TSI value had no significant trend.

DATA SOURCES:

Thurston County Community Planning and Economic Development
(360) 786-5549 or
https://www.thurstoncountywa.gov/planning/Pages/water-gateway.aspx

Thurston County Environmental Health
(360) 867-2626 or
https://www.co.thurston.wa.us/health/ehrp/annualreport.html

FUNDING SOURCE:

Thurston County funded monitoring in 2018.

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Appendices

Appendix A. Raw data

Table A-1 Raw data collected at the Summit Lake site SL1.

Date	Time	Bottom Depth (meters)	Secchi (meters)	Water Color	Bottom Sample Depth (meters)	Surface TP (mg/L)	Bottom TP (mg/L)	Surface TN (mg/L)	Bottom TN (mg/L)	Chl a (µg/L)	Phae a (µg/L)	Lake Notes
5/21/2018	12:35	22.14	7.03	4	21.5	0.007	0.005	0.110	0.893	1.6	<0.1	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 0, 2, 4, 6
6/25/2018	13:50	25.00	5.90	4	19.0	0.005	0.007	0.101	0.110	0.5	0.2	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 2, 7
6/25/2018	**13:50**	**-**	**-**	**-**	**-**	**0.004**	**0.007**	**0.130**	**0.136**	**1.1**	**<0.1**	**replicate samples**
7/16/2018	13:50	23.60	6.80	4	23.0	0.007	0.033	0.368	0.459	0.7	0.3	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 3, 5
8/13/2018	13:16	21.40	5.70	6	21.0	0.006	0.945	0.174	2.737	0.8	<0.1	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 3, 5
9/17/2018	13:20	25.70	8.30	4	25.0	0.006	0.046	0.177	0.300	1.3	<0.1	calm; partly cloudy
9/17/2018	**13:20**	**-**	**-**	**-**	**-**	**0.006**	**0.046**	**0.161**	**0.365**	**1.4**	**<0.1**	**QA**
10/22/2018	13:16	26.16	6.95	1	25.5	0.005	0.017	0.185	0.266	1.2	0.2	
10/22/2018	**13:16**	**-**	**-**	**-**	**-**	**0.005**	**0.017**	**0.323**	**0.311**	**1.3**	**<0.1**	**QA**
Mean Values		24.00	6.78	-	22.50	0.006	0.125	0.192	0.620	1.10	0.23	

Appendix B. Quality Assurance/Quality Control

Table B-1 provides the amount of instrument drift for specific conductivity, dissolved oxygen (collected with optical sensor), and pH. The temperature thermistor was checked against a NIST thermometer on May 31, 2018 and difference was 0.04° C.

Table B-1. Instrument drift for Summit Lake sample days in 2018.

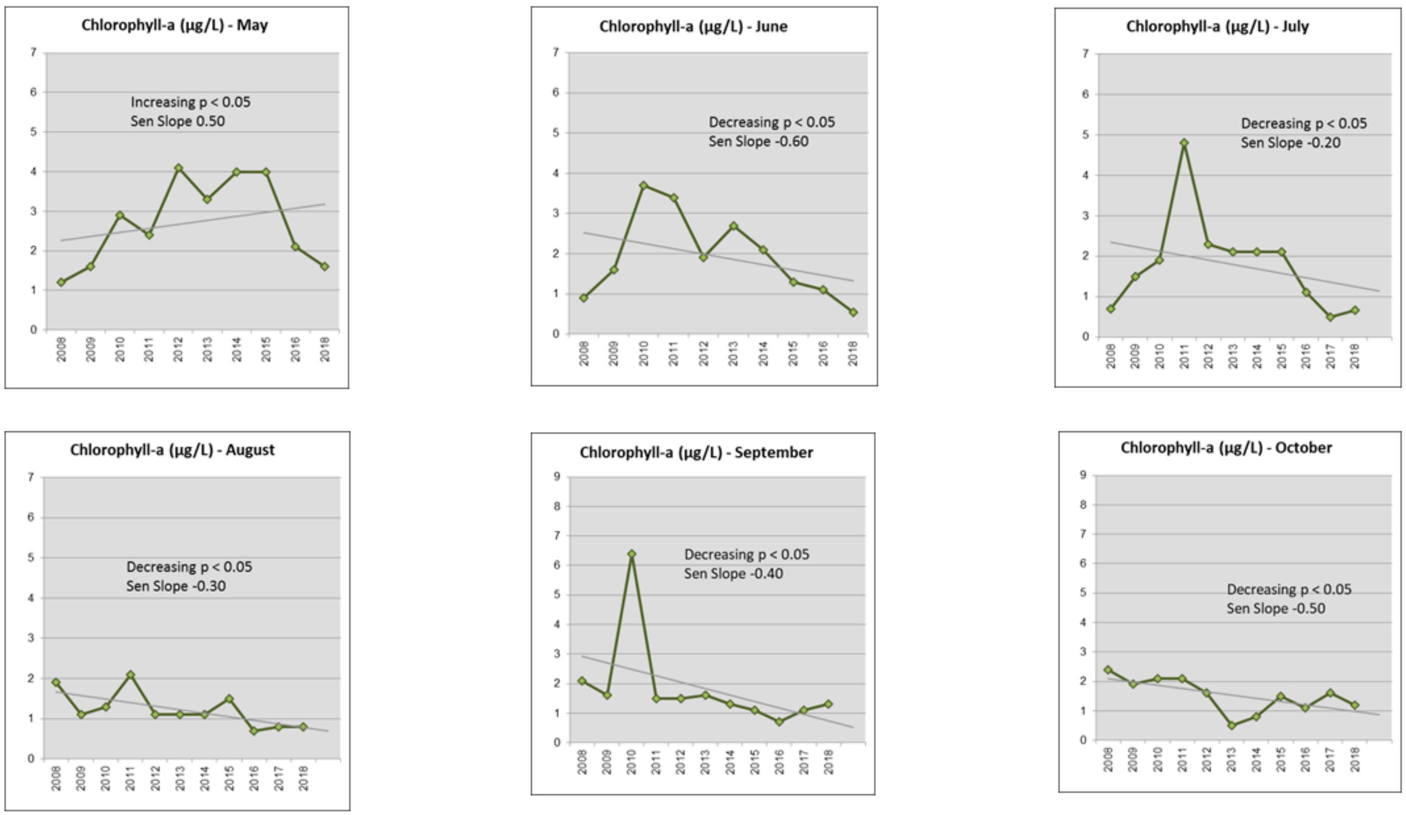
End Date	Percent Difference SPC (µS/cm)	Percent Difference ODO (% sat)	Percent Difference pH (std units)
5/22/2018	-4.98	-0.01	-0.43
6/26/2018	0.00	0.06	-0.14
7/17/2018	0.00	0.49	-2.00
8/14/2018	0.00	0.22	0.14
9/18/2018	0.00	0.16	0.14
10/23/2018	0.11	-0.06	-0.86
Mean Percent Difference	**-0.81**	**0.14**	**-0.52**

Table B-2. Precision of field replicates.

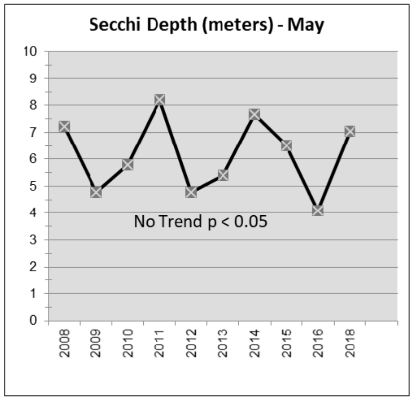
Site	Datetime	sample	field replicate	Relative Percent Difference
SL1 Surface TP	6/25/2018 12:35	0.005	0.004	4.907
SL1 Bottom TP	6/25/2018 12:35	0.007	0.007	3.150
SL1 Surface TP	9/17/2018 13:20	0.006	0.006	0.000
SL1 Bottom TP	9/17/2018 13:20	0.046	0.046	0.000
SL1 Surface TP	10/22/2018 13:16	0.005	0.005	0.000
SL1 Bottom TP	10/22/2018 13:16	0.017	0.017	0.000
			Relative Standard Deviation TP samples:	***0.256***
SL1 Surface TN	6/25/2018 12:35	0.101	0.130	24.891
SL1 Bottom TN	6/25/2018 12:35	0.110	0.136	20.777
SL1 Surface TN	9/17/2018 13:20	0.177	0.161	9.467
SL1 Bottom TN	9/17/2018 13:20	0.300	0.365	19.549
SL1 Surface TN	10/22/2018 13:16	0.185	0.323	54.331
SL1 Bottom TN	10/22/2018 13:16	0.266	0.311	15.598
			Relative Standard Deviation TN samples:	***12.409***
SL1 Chlor-a	6/25/2018 12:35	0.53	1.10	69.278
SL1 Chlor-a	9/17/2018 13:20	1.300	1.400	7.407
SL1 Chlor-a	10/22/2018 13:16	1.200	1.300	8.000
			Relative Standard Deviation Chlor-a samples:	**11.209**
SL1 Phae-a	6/25/2018 12:35	0.21	0.10	72.449
SL1 Phae-a	9/17/2018 13:20	0.100	0.100	0.000
SL1 Phae-a	10/22/2018 13:16	0.200	0.100	66.667
			Relative Standard Deviation Phae-a samples:	**26.254**

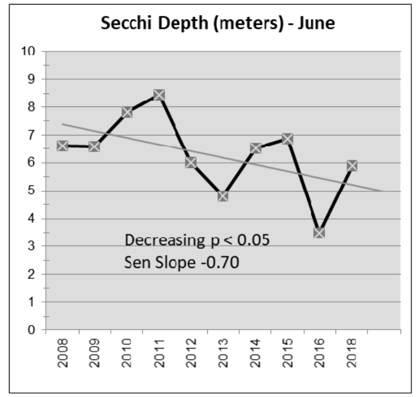
Appendix C. Trends

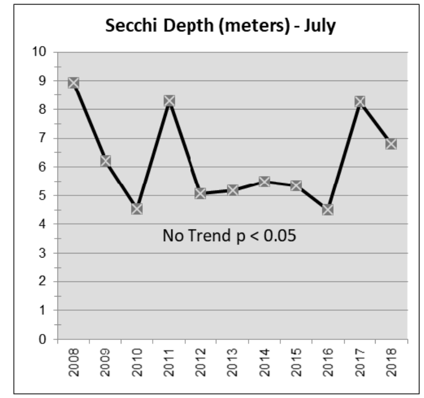
Summit Lake - Chlorophyll-a Trends

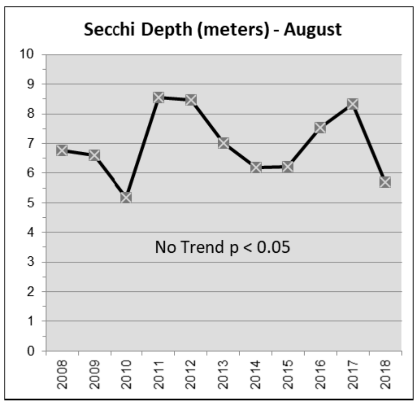


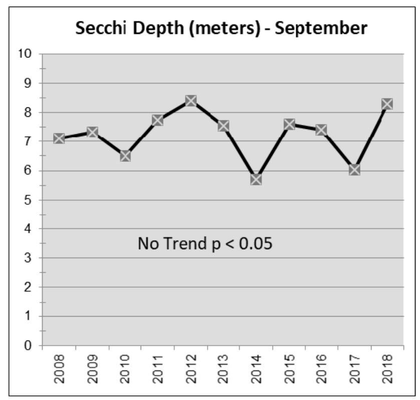
Summit Lake - Secchi Depth Trends

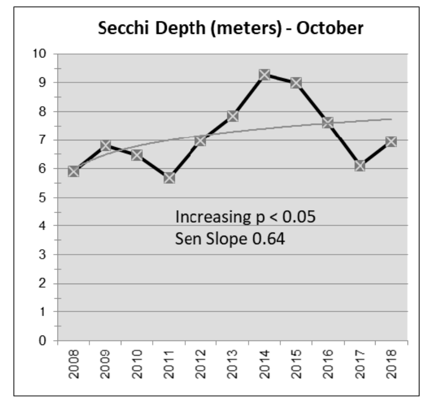




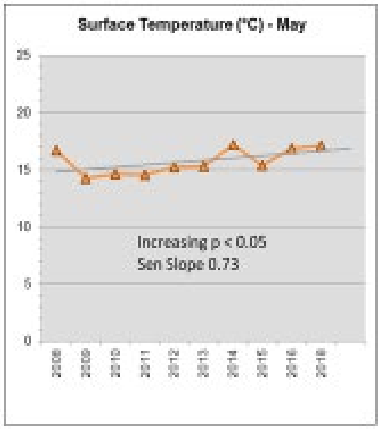


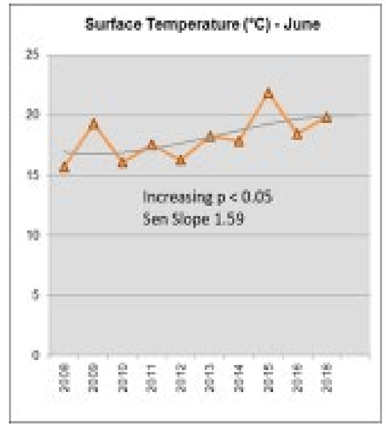


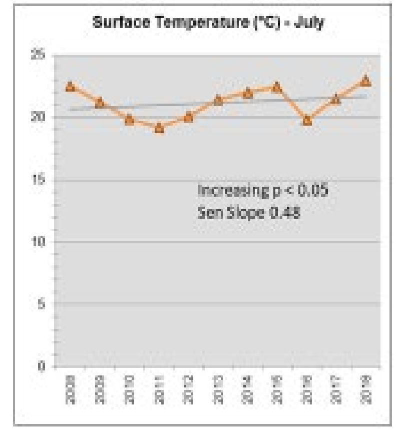


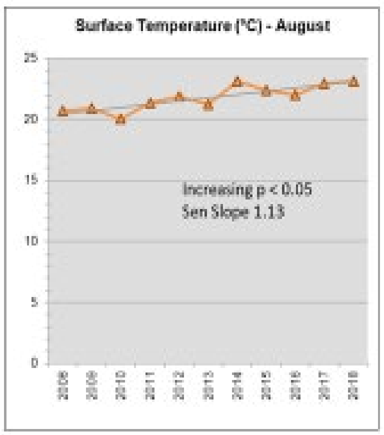


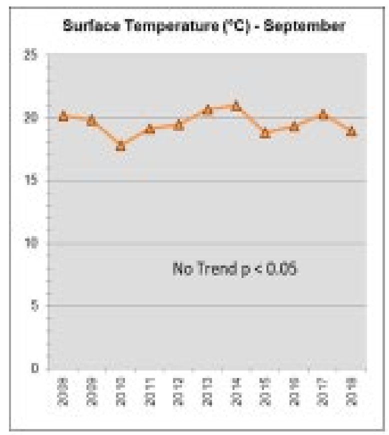
Summit Lake Surface Water - Temperature Trends

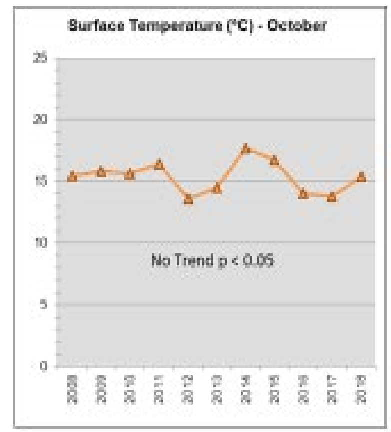




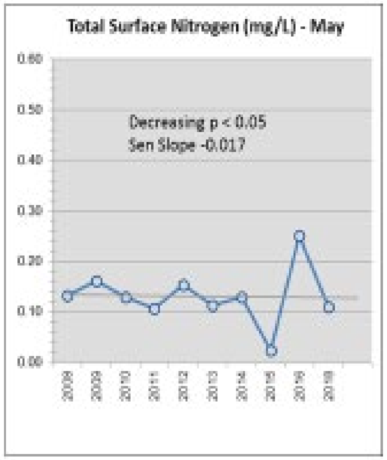


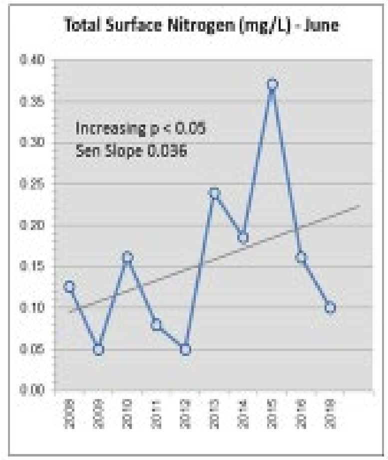


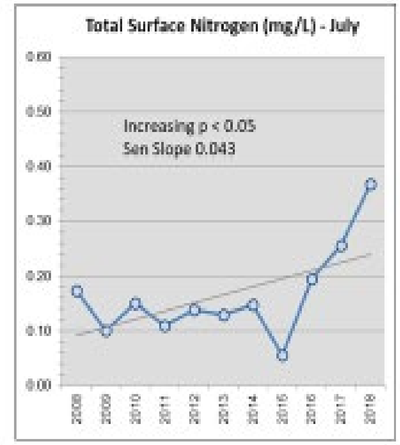


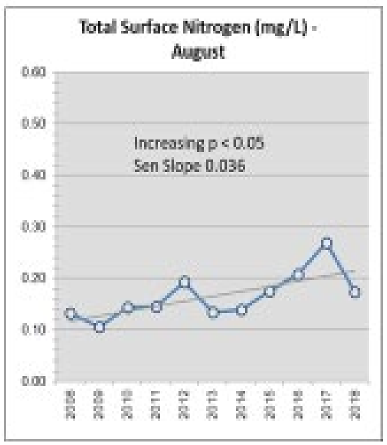


Summit Lake Surface Water - Total Nitrogen Trends

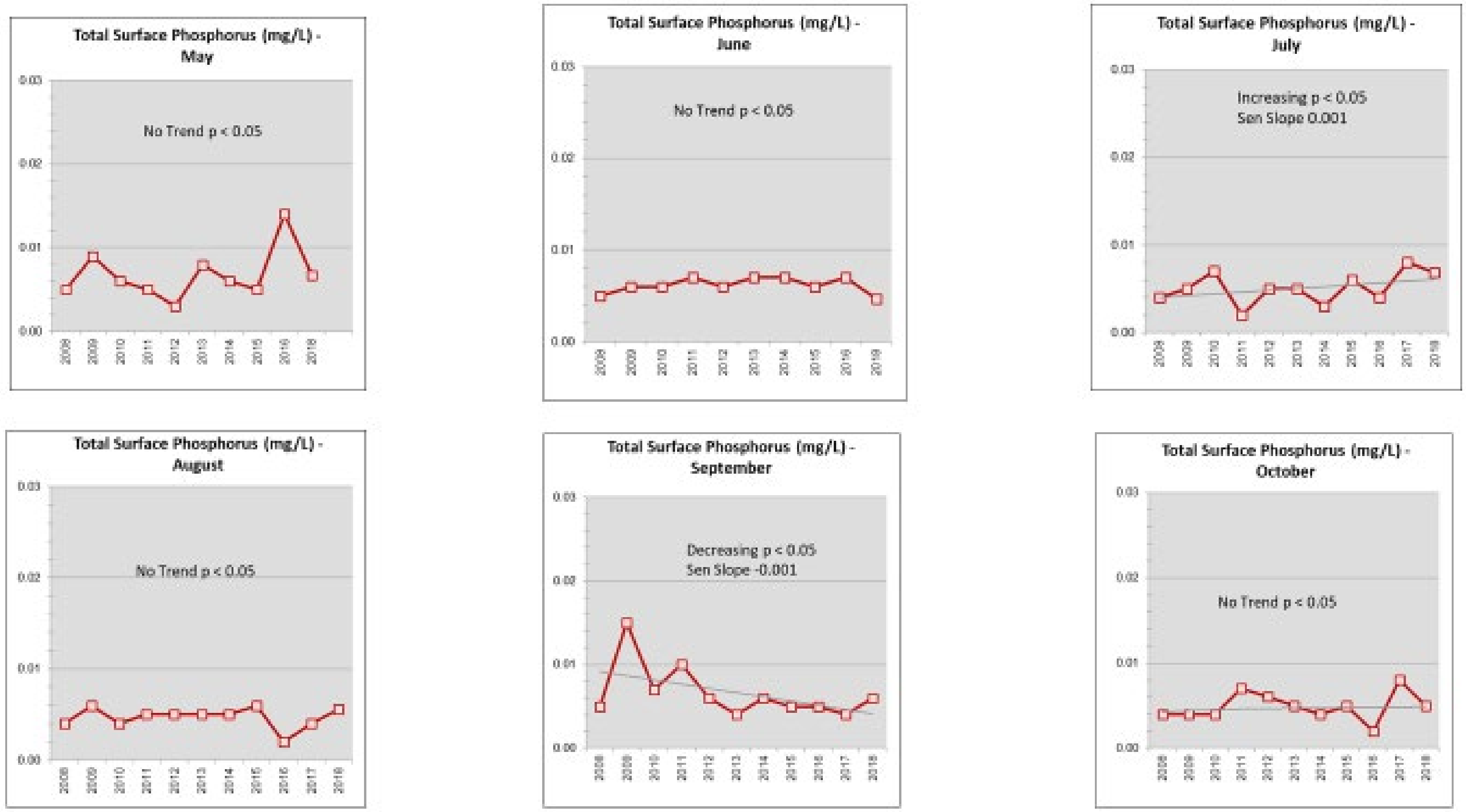




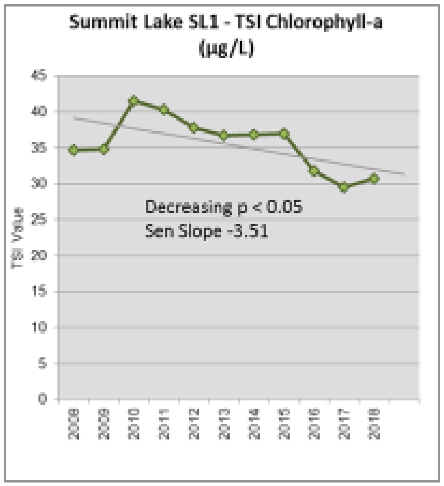


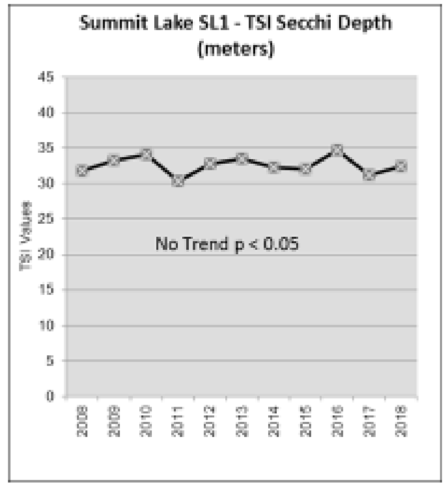


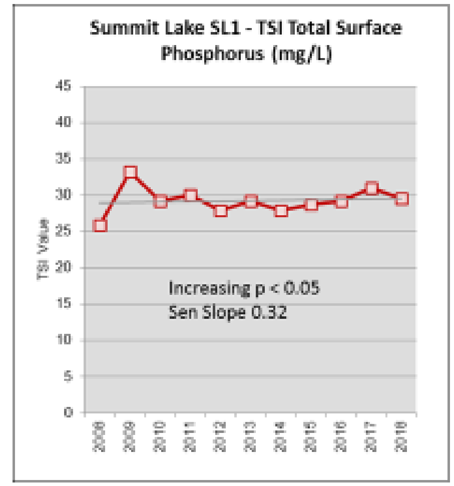
Summit Lake Surface Water - Total Phosphorus Trends



Summit Lake Surface Water - TSI Trends







Appendix C. Toxic Algae Results - 2012 to 2018

Toxin	Washington ≥ µg/L Recreational Advisory Level
Anatoxin-a	1
Cylindrospermopsin	4.5
Microcystin	6
Saxitoxin	75