LAKE ARMSTRONG

REPORT DESCRIPTION

This report is an update on the health of Lake Armstrong based on water quality data collected from 1994 through 2016 by local volunteers and Snohomish County Surface Water Management (SWM) staff. For additional background on the information provided here or to find out more about Lake Armstrong, please visit www.lakes.surfacewater.info or call SWM at 425-388-3464.

LAKE DESCRIPTION

Lake Armstrong is a 31 acre lake located north of the City of Arlington. The maximum depth is 8.7 meters (28 feet) and the average depth is over 4.6 meters (15 feet). The watershed, which is the land area that drains to the lake, is mostly undeveloped, except for about a dozen homes around the lake shore.

LAKE CONDITIONS

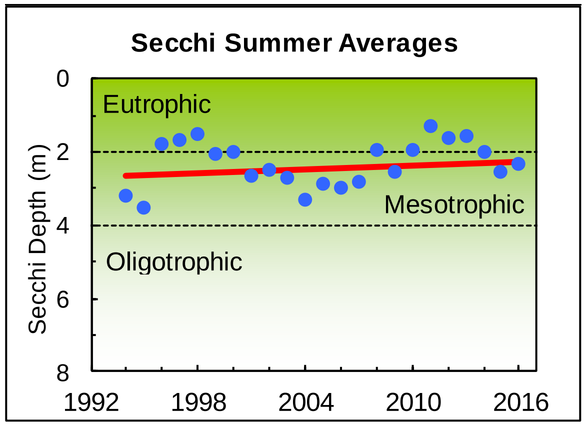
The following graphs illustrate the summer averages and trend lines (shown in red) for water clarity, total phosphorus, and chlorophyll *a* for Lake Armstrong. Please refer to the table at the end of the report for long-term averages and for averages and ranges for individual years.

Water Clarity

The water clarity of a lake, measured with a Secchi disk, is a reading of how far one can see into the water. Water clarity is affected by the amount of algae and sediment in the lake, as well as by water color. Lakes with high water clarity usually have low amounts of algae, while lakes with poor water clarity often have excessive amounts of algae.

The water clarity in Lake Armstrong is low to moderate, with a long-term summer average of 2.3 meters (7.5 feet). From 1996 through 2000, water clarity was substantially worse than the previous years. There was better water clarity from 2001 through 2004. Since 2004, clarity has again declined, with some of the lowest summer averages on record in 2011 through 2013. Water clarity has gotten slightly better since 2013, although the 2016 summer average decreased to 2.5 meters (8 feet). There is no statistically significant trend in water clarity.

It may be that watershed activities (such as land clearing or timber harvest) are washing more nutrients into the lake leading to increased algae blooms and poorer water clarity. However, darker color of the water is another factor in the poor water clarity in recent years.



Water Color

The color of lake water affects water clarity and the depths at which algae and plants can grow. In many lakes, the water is naturally brown, orange, or yellow. This darker color comes from dissolved humic compounds from surrounding wetlands and does not harm water quality. Measurements of true water color provide clues to changes in water clarity. True water color is only the color from dissolved materials and not of the color of algae or sediment suspended in the water.

The water color of Lake Armstrong averaged 71 pcu (platinum-cobalt color units) in 2010 - 2011, which is darker than most lakes in Snohomish County and significantly darker than in the 1990s. The 1994 -1995 water color average was only 23 pcu. This darker water color may be an important factor in the decrease in water clarity that has occurred over the same time span.

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Temperature

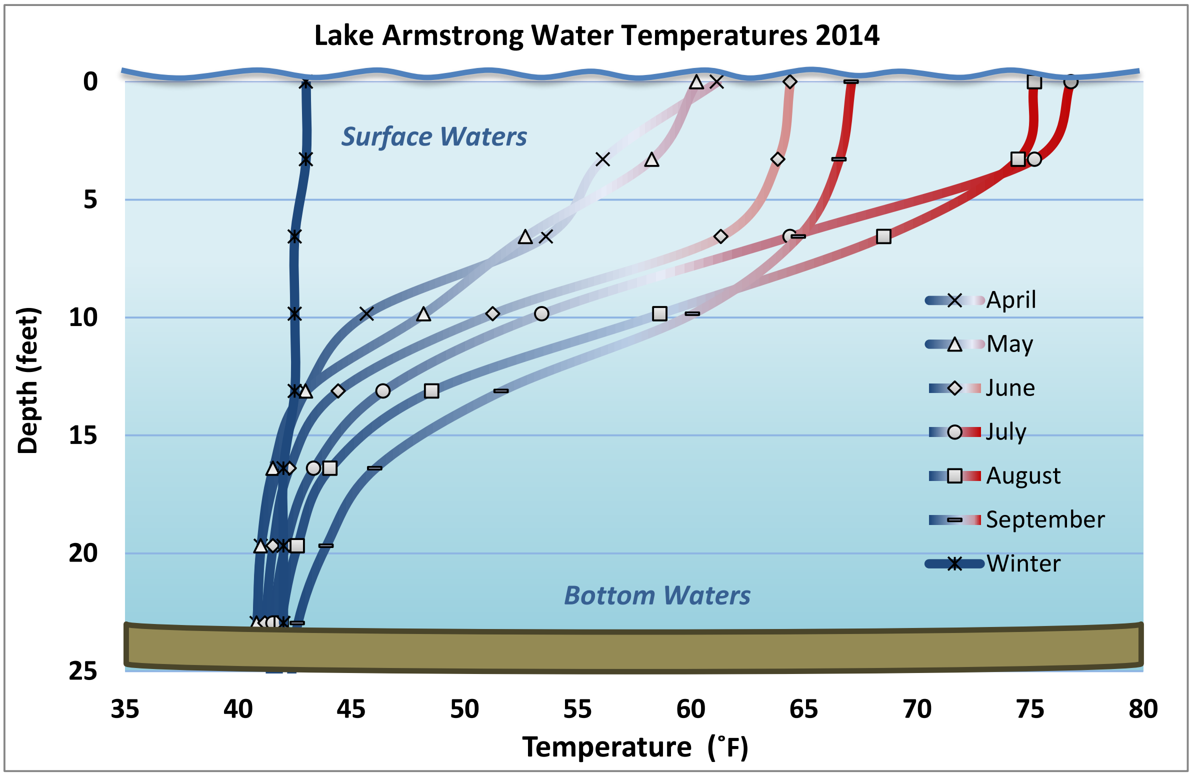
The temperature of lake water changes with the seasons and varies with depth. During spring and summer, the sun warms the upper waters. Because warmer water is less dense, it floats above the cooler, denser water below. The temperature and density differences create distinct layers of water in the lake, and these layers do not mix easily. This process is called stratification and occurs during the warm months. The warm, upper water layer is called the epilimnion. The colder, darker bottom zone is called the hypolimnion. These layers will stay separated until the fall when the upper waters cool, the temperature differences decrease, and the entire lake mixes, or turns over.

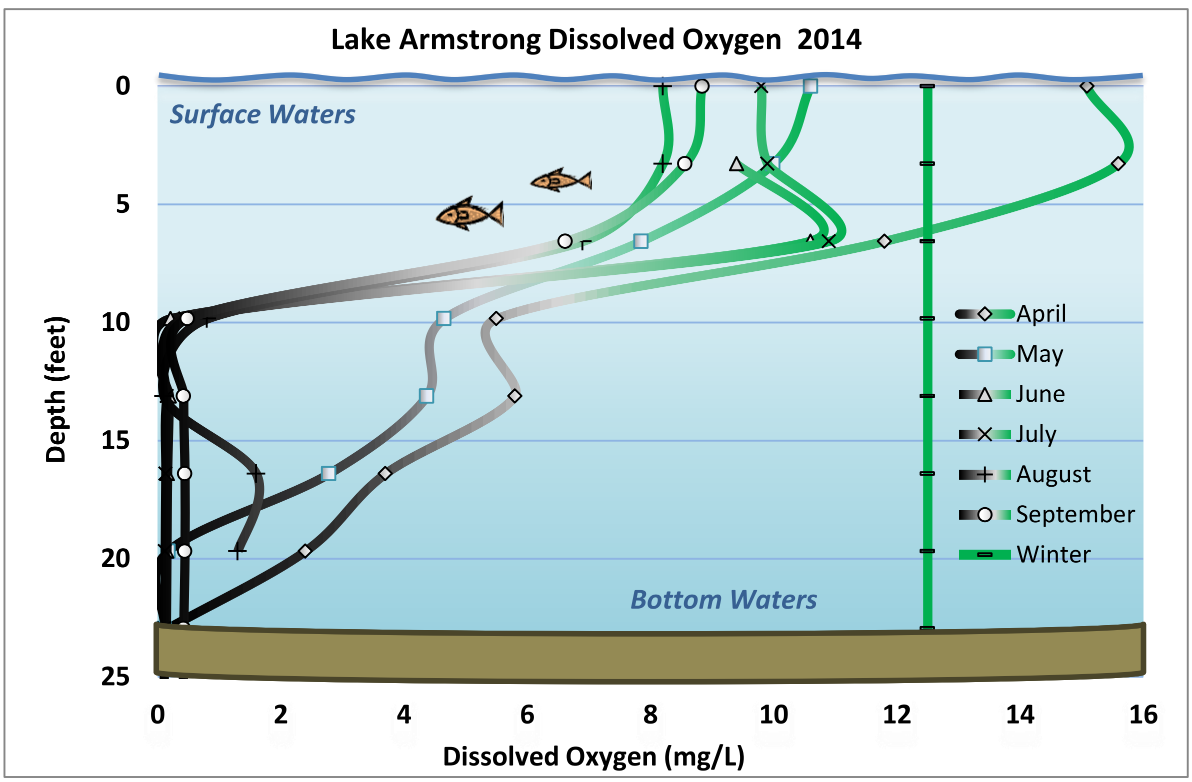
From April through September 2014 (the most recent available data), temperature measurements were taken at each meter throughout the Lake Armstrong water column. The temperature data show that the lake was beginning to stratify in April and May, and was strongly thermally stratified from June through September (see graph). This means that there was a strong temperature difference between the warm upper waters and the cool bottom waters, and mixing did not occur between these layers. By June the upper waters were significantly warmer than the lower waters with a 22°F (12°C) temperature difference. The upper waters reached their peak in temperature in July at 77°F (25°C) and began to cool down through September. At the same time, bottom water temperatures changed only a little and remained around 42°F (6°C). In October to December, the surface waters will continue to cool until the temperatures are almost equal from top to bottom. As stratification weakens the lake water will turn over (or mix). The lake will stay mixed during the winter until springtime, when the upper waters began to warm again.

Dissolved Oxygen

Oxygen dissolved in the water is essential for life in a lake. Most of the dissolved oxygen comes from the atmosphere. Like temperature, dissolved oxygen levels vary over time and with depth. During the warm months, the upper waters receive oxygen from the atmosphere, but the lower waters cannot be replenished with oxygen because of the separation between water layers. Meanwhile, bacteria in the lake bottom are consuming oxygen as they decompose organic matter. Eventually oxygen is depleted in the bottom waters. Low dissolved oxygen in the bottom waters can lead to a release of nutrients from the lake sediments.

The depth profiles of dissolved oxygen measured in 2014 largely correspond to the temperature profiles seen during that time period (see graph). There was little or no oxygen in the water around 10 feet and below by June. During the stratified summer period, oxygen in the lower waters is consumed by the decomposition of organic material within the lake. Since the lake is strongly stratified, the oxygen is not replenished by the overlying oxygen-rich upper waters or by the atmosphere. However, in June and July, there was a sharp increase in dissolved oxygen levels about 7-8 feet deep. This indicates vigorous algae growth at that depth which added oxygen to the water. During the fall and winter the lake will mix, and dissolved oxygen will be replenished throughout the lake.


Lake Armstrong Water Temperatures 2014
Surface Waters
Bottom Waters
Depth (feet)
0
5
10
15
20
25
35
40
45
50
55
60
65
70
75
80
Temperature (˚F)
April
May
June
July
August
September
Winter

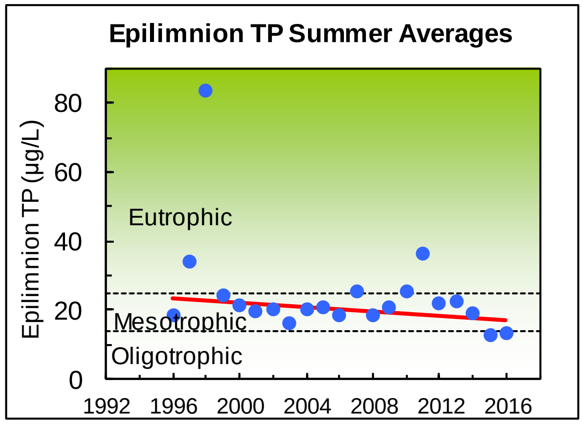

Lake Armstrong Dissolved Oxygen 2014
Surface Waters
Bottom Waters
Depth (feet)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
Dissolved Oxygen (mg/L)
April
May
June
July
August
September
Winter

Phosphorus (key nutrient for algae)

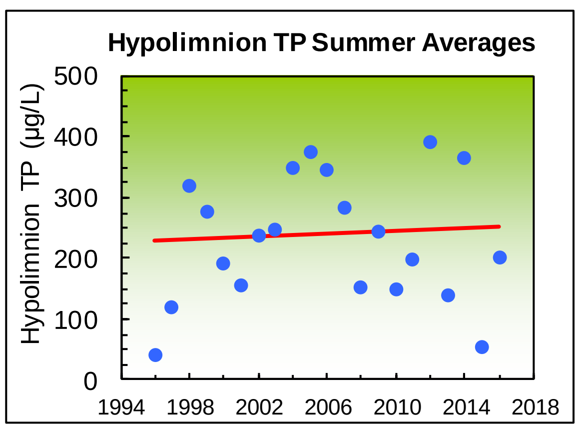
Nutrients are essential for the growth of algae, fish, and aquatic plants in a lake. However, too many nutrients, especially phosphorus, can pollute a lake and lead to unpleasant algae growth. Nutrients enter the lake through stormwater runoff or from streams flowing into the lake. Sources of nutrients include fertilizers, pet and animal wastes, poorly-maintained septic systems and erosion from land clearing and construction. Monitoring of phosphorus levels over time helps to identify changes in nutrient pollution.

Total phosphorus concentrations in the epilimnion (upper waters) are relatively high, with a long-term 1996 - 2016 summer average of 24 µg/L (micrograms per liter, which is equivalent to parts per billion). There was a very high phosphorus average in 1998. From 1999 through 2010, phosphorus values were lower and stable, ranging between 16 and 25 µg/L. In 2011, the summer average increased to 36 µg/L, which corresponds with the poor water clarity for that year. In 2012 and 2013, the summer averages declined to slightly below the long-term average, with decreases from 2014 to 2016.

Between 1996 and 2016, there has been no statistically significant trends in phosphorus levels in the epilimnion. However, long-term phosphorus levels in the upper waters remain high, which is why Lake Armstrong is listed as "impaired" in Washington State's official 2012 water quality assessment.



Phosphorus averages in the hypolimnion (bottom waters) are much higher than in the epilimnion, with a long-term 1996 - 2016 summer average of 230 µg/L. There are no trends apparent because of the wide variability from year to year. The concentrations were especially high in 1998-1999, 2004-2006, and 2012 and 2014. The 2016 summer average of 203 µg/L is considerably higher than the average in 2015 (53 µg/L), although similar to the long term average. High and/or increasing phosphorus levels point to the on-going build-up of nutrients in the bottom sediments which are released during periods of oxygen depletion in the summer months. This is a sign of accelerated eutrophication.



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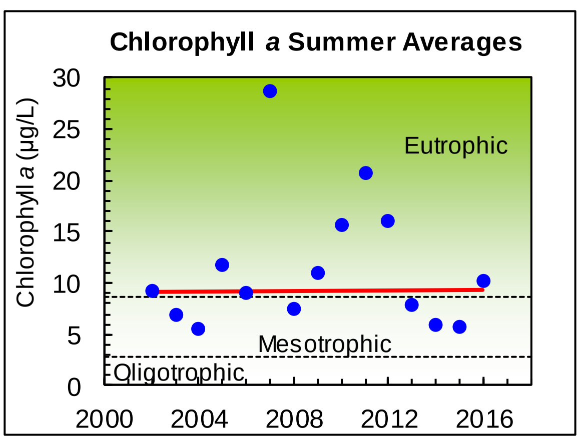
Chlorophyll a (Algae)

Algae are tiny plant-like organisms that are essential for a healthy lake. Fish and other lake life depend on algae as the basis for their food supply. However, excessive growths of algae, called algae blooms, can cloud the water, form unsightly scums, and sometimes release toxins. Excess nutrients, such as phosphorus and nitrogen, are the main cause of nuisance algae growth in a lake. Chlorophyll *a* measurements are one method for tracking the amount of algae in a lake.

Sampling between 2002 and 2016 shows that chlorophyll *a* values are moderate to high and are also quite variable. The long term summer average is 11 µg/L. In 2007, the summer average was exceptionally high at 29 µg/L. The higher average was the result of one value of 96 µg/L measured in October, which corresponded with an algae bloom. Levels were lower in 2013 through 2015, and rose again in 2016. Observations at Lake Armstrong indicate that the lake does experience regular nuisance blue-green algae blooms. Although chlorophyll *a* levels have been higher in some years, there is not a statistically significant trend toward increasing chlorophyll *a* levels.



Toxic Blue-Green Algae (Cyanobacteria)

Blue-green algae, also called cyanobacteria, are a group of algae capable of producing toxins during periods of high growth, known as blooms. The toxins can cause serious illness in people and pets that come into contact with affected water. Blooms often look like blue or green paint floating on the surface. Lake users should avoid contact with the water and keep pets away from the lake when it is experiencing a blue-green algae bloom. If a bloom has been identified as toxic, the lake will have postings at public access sites.

Since 2005, volunteers and SWM staff have screened algae at Lake Armstrong for potential toxic blooms. Beginning in 2009, routine toxin testing also began as part of a larger project coordinated by the Washington State Department of Health. The project was funded by a grant from the U.S. Centers for Disease Control (CDC) and included monitoring of thirty lakes in Snohomish, King, and Pierce Counties. The CDC project was conducted to identify algae blooms that could pose a potential health threat and to alert the public about toxic algae. Water samples were tested for two types of toxins: microcystin (a liver toxin) and anatoxin-a (a neurotoxin).

Lake Armstrong did not have noticeable surface accumulations or scums of blue-green algae from 2009-2011. Several water samples taken from 2009 through 2010 did test positive for microcystin, but were below the Washington State Department of Health recreational guideline of 6 ug/L. However, in October and November 2011, microcystin was measured at 32.8 and 21.5 µg/L, respectively, which exceeded the Washington State guideline. No toxic algae blooms were reported in 2012-2014. In September and early October 2015, Lake Armstrong experienced heavy algae and scum. Microcystin was measured as high as 162 µg/L, which is well above the State guidelines. In August and September 2016, Microcystin levels ranged from 1.42 µg/L to 16.2 µg/L. Anatoxin was detected at very low concentrations (0.015 µg/L) in September 2016, below the state guideline of 1 µg/L for anatoxin.

Limited testing will continue in 2017 as part of the regular lake monitoring program. Continued monitoring will help to alert the public to potential health risks, as well as determine the frequency and severity of the toxic algae blooms at Lake Armstrong.

Lake Armstrong Toxic Algae Testing Results

Year	# Weeks Sampled	# Weeks Toxic*	Microcystin Range (µg/L)	Anatoxin Range (µg/L)
2009	1	0	0.07	-
2010	8	0	0.05—0.17	-
2011	11	2	0.07—32.8	-
2015	5	3	4.1 - 162	-
2016	4	1	1.41-16.2	.015

**Number of weeks above the State recreational guideline of 6 µg/L for Microcystin and 1 µg/L for Anatoxin*

Nitrogen (another essential nutrient for algae)

Nitrogen is another important nutrient for plant and algae growth. Similar to phosphorus, lakes with high levels of nitrogen typically have more aquatic plants and algae. The 2014 - 2016 summer average of total nitrogen is 890 µg/L, compared to the average of 458 µg/L from 2014-2015. Values in 2016 ranged from 739-1,260 µg/L. This is consistent with the moderate to high chlorophyll *a* concentrations measured in the lake.

The relative abundance of nitrogen and phosphorus can also be a useful indicator of lake conditions. This is referred to as the nitrogen to phosphorus ratio or N:P ratio. When lakes have low N:P ratios (typically less than 20), algae growth is often high and harmful blue-green algae blooms may be a problem. Low N:P ratios may also indicate that fertilizers, septic systems, polluted runoff from developed areas, and release of phosphorus from the lake bottom sediments are contributing most of the nutrients to the lake.

In contrast, when lakes have higher N:P ratios (substantially greater than 20), algae growth will be limited by the amount of phosphorus available, and blue-green algae are usually less of a problem. Lake Armstrong has a moderately low average N:P ratio of 28. Blue-green algae blooms are sometimes present in the lake.

SHORELINE CONDITION

The condition of the lake shoreline is important to understanding the overall lake health. Frequently, lake shorelines are modified through removal of natural vegetation, the installation of bulkheads or other hardening structures, and/or removal of partially submerged logs and branches. These types of alterations can be harmful to the lake ecosystem because natural shorelines protect the lake from harmful pollution, prevent bank erosion, and provide important habitat for fish and wildlife.

Lake Armstrong has one of the least developed shorelines in the county. Less than one percent of the 1.8 km (1.1 miles) shoreline has been modified. The vegetation immediately adjacent to the shoreline is also intact, with 96% remaining in native grasses, trees, and shrubs. The amount of old logs and branches remaining in the lake is also high (about 178 pieces), which is valuable for fish and wildlife habitat. In addition, there are only six docks on the entire lake. The development around the lake appears to have changed little over the past few decades. Previous shoreline surveys showed there were only 8 homes along the shoreline in 1973 and 11 by the mid-90s. The natural state of the shoreline plays an important role in protecting the lake and providing quality aquatic habitat for fish and wildlife.

LAKE ARMSTRONG

SUMMARY

Trophic State

All lakes go through a process of enrichment by nutrients and sediment. In this process, known as eutrophication, nutrients and sediment contribute to the ever-increasing growth of algae and aquatic plants. Over thousands of years, lakes will gradually fill up with organic matter and sediments.

Lakes can be classified by their degree of eutrophication, also known as their trophic state. There are three primary trophic states for lakes—oligotrophic, mesotrophic, and eutrophic—as well as intermediate states. Oligotrophic lakes are usually deep, with clear water, low nutrient concentrations, and few aquatic plants and algae. Mesotrophic lakes are richer in nutrients and produce more algae and aquatic plants. Eutrophic lakes are often shallow and characterized by abundant algae and plants, high nutrient concentrations, limited water clarity, and low dissolved oxygen in the bottom waters.

The trophic state classification of a lake does not necessarily indicate good or bad water quality because eutrophication is a natural process. However, human activities that contribute sediment and excess nutrients to a lake can dramatically accelerate the eutrophication process and result in declining water quality.

Based on the long-term monitoring data, Lake Armstrong may be classified as meso-eutrophic, with low to moderate water clarity and moderate to high phosphorus and nitrogen concentrations, and high chlorophyll *a* concentrations.

Condition and Trends

The water quality targets for Lake Armstrong call for improvements in water clarity and reductions in phosphorus levels. However, monitoring results are mixed for Lake Armstrong. Water clarity is variable, with low 2011- 2013 summer averages and improved conditions in 2015 and 2016. Phosphorus levels in the upper waters appear to have stabilized after several years of poor readings in the mid 1990s. On the other hand, phosphorus levels in the bottom waters are quite high and variable, with the 2012 average being the highest on record, but with the 2015 summer average being one of the lowest on record. Any increases in phosphorus may lead to future problems, such as more nuisance algae blooms. This may be already occurring because chlorophyll *a* levels have been high in some recent years.

Overall, Lake Armstrong is in fair condition, but it is at risk of future water quality declines because of high phosphorus levels in the bottom waters and potentially increasing algae levels. The primary threat to the lake is future modifications to the shoreline that may come with increased development. The current natural shoreline provides protection for the lake.

The lake may also be susceptible to activities in the watershed, such as land clearing, as exhibited by the high nutrient values seen in the 1990s that were likely the results of watershed activities. Measures to control nutrients in the watershed should be taken now to prevent any future negative impacts to the lake.

To find out more about ways to protect lake water quality and information on the causes and problems of elevated lake nutrient levels visit www.lakes.surfacewater.info.

DATA SUMMARY FOR LAKE ARMSTRONG						
		Water Clarity (Secchi depth	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Surface**	**Surface**
Bortleson, et al, 1976	**8/13/73**	2.7	18	400	-	-
SWM Staff	**1994**	3.0 - 3.4 (3.2) *n = 3*	-	-	-	1.2 - 4.7 (3.0) *n = 2*
SWM Staff or Volunteer	**1995**	3.0 - 3.9 (3.5) *n = 3*	-	-	-	6.6
SWM Staff or Volunteer	**1996**	1.6 - 2.1 (1.8) *n = 6*	10 - 27 (19) *n = 2*	29 - 51 (40) *n = 2*	-	-
SWM Staff or Volunteer	**1997**	1.0 - 2.9 (1.7) *n = 4*	15 - 53 (34) *n = 2*	100 - 136 (118) *n = 2*	-	-
SWM Staff or Volunteer	**1998**	0.7 - 2.1 (1.5) *n = 6*	15 - 275 (84)[a] *n = 4*	46 - 575 (319) *n = 4*	-	-
SWM Staff or Volunteer	**1999**	1.8 - 2.2 (2.0) *n = 4*	20 - 29 (24) *n = 4*	142 - 524 (278) *n = 4*	-	-
SWM Staff or Volunteer	**2000**	1.4 - 2.6 (2.0) *n = 4*	18 - 30 (22) *n = 4*	102 - 294 (192) *n = 4*	-	-
SWM Staff or Volunteer	**2001**	2.3 - 3.1 (2.7) *n = 4*	15 - 26 (20) *n = 4*	105 - 283 (157) *n = 4*	-	-
SWM Staff or Volunteer	**2002**	2.3 - 2.7 (2.5) *n = 4*	17 - 25 (20) *n = 4*	74 - 439 (237) *n = 4*	-	2.1 - 19 (9.2) *n = 4*
SWM Staff	**2003**	1.2 - 3.5 (2.7) *n = 6*	11 - 20 (16) *n = 4*	130 - 438 (248) *n = 4*	-	3.2 - 12 (6.9) *n = 4*
SWM Staff	**2004**	3.0 - 3.9 (3.3) *n = 4*	14 - 27 (20) *n = 4*	46 - 816 (349) *n = 4*	-	2.8 - 8.3 (5.6) *n = 4*
SWM Staff	**2005**	2.5 - 3.0 (2.9) *n = 4*	18 - 24 (21) *n = 4*	120 - 776 (376) *n = 4*	-	3.7 - 22 (12) *n = 4*
SWM Staff	**2006**	1.9 - 3.9 (3.0) *n = 4*	13 - 24 (18) *n = 4*	136 - 505 (347) *n = 4*	-	2.9 - 15 (9.0) *n = 4*
SWM Staff	**2007**	2.8 - 3.1 (2.8) *n = 4*	16 - 34 (25) *n = 4*	115 - 403 (283) *n = 4*	-	4.5 - 96 (29)[a] *n = 4*
Volunteer	**2008**	1.7 - 2.6 (1.9) *n = 8*	15 - 22 (19) *n = 4*	60 - 278 (153) *n = 4*	-	5.6 - 10 (7.4) *n = 4*
Volunteer	**2009**	2.2 - 3.1 (2.6) *n = 5*	17 - 24 (21) *n = 4*	82 - 451 (245) *n = 4*	-	4.8 - 16 (11) *n = 4*

LAKE ARMSTRONG

DATA SUMMARY FOR LAKE ARMSTRONG						
		Water Clarity (Secchi depth in meters)	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**		**Surface**	**Bottom**	**Surface**	**Surface**
Volunteer	**2010**	1.5 - 2.4 (1.9) *n = 5*	19 - 33 (25) *n = 4*	89 - 195 (151) *n = 4*	-	7.2 - 25 (16) *n = 4*
Volunteer	**2011**	1 - 1.7 (1.3) *n = 5*	22 - 56 (36) *n = 4*	55 - 299 (197) *n = 4*	-	16 - 25 (21) *n = 4*
Volunteer	**2012**	1.5 - 1.7 (1.6) *n = 4*	18 - 32 (22) *n = 4*	315 - 580 (393) *n = 4*	-	7.5 - 28 (16) *n = 4*
Volunteer	**2013**	1.2 - 2.3 (1.6) *n = 12*	19 - 31 (23) *n = 4*	87 - 185 (140) *n = 4*	-	4.3 - 15 (7.9) *n = 4*
SWM Staff or Volunteer	**2014**	0.7 - 2.8 (2.0) *n = 7*	14 - 27 (19) *n = 4*	251 - 641 (364) *n = 4*	362 - 641 (503) *n = 4*	2.7 - 9.1 (6.0) *n = 4*
Volunteer	**2015**	*1.4 - 3.4* *(2.5)* *n = 12*	*11 - 15* *(13)* *n = 4*	*12 - 90* *(53)* *n = 4*	*359 - 457* *(412)* *n = 4*	*1.6 - 13* *(5.7)* *n = 4*
Volunteer	**2016**	1.7 - 3.1 (2.3) *n = 11*	5 - 18 (13) *n = 4*	21 - 728 (203) *n = 4*	353 - 518 (459) *n = 4*	6.0 - 15 (10) *n = 4*
Long Term Avg		**2.3** **(1994-2016)**	**24** **(1996-2016)**	**230** **(1996-2016)**	**458** **(2014-2016)**	**11** **(2002-2016)**
TRENDS		**None**	**None**	**None**	**NA**	**None**

NOTES

- Table includes summer (May-Oct) data only.
- Each box shows the range on top, followed by summer average in ( ) and number of samples (*n*).
- Total phosphorus data are from samples taken at discrete depths only.
- "Surface" samples are from 1 meter depth and "bottom" samples are from 1-2 meters above the bottom.

[a] Average is influenced by one high value.