LAKE SHOECRAFT

REPORT DESCRIPTION

This report is an update on the health of Lake Serene based on water quality data collected from 1992 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 Shoecraft, please call SWM at 425-388-3464 or visit www.lakes.surfacewater.info.

LAKE DESCRIPTION

Lake Shoecraft is located in the Seven Lakes area north of the Tulalip Reservation. The lake is fed by Lake Loma, Lake Crabapple, and Lake Goodwin and drains to Weallup Lake and eventually into Tulalip Bay. Lake Shoecraft covers 133 surface acres. The lake is relatively shallow, with a maximum depth of 10.7 meters (35 feet), and has an average depth of 5.5 meters (18 feet). The total watershed, which is the land area that drains to the lake, including the drainage from Loma, Crabapple, and Goodwin is large, but the immediate watershed is much smaller—only 4.4 times the size of the lake. Nearly all of the lake shore is densely developed with residential uses, and more development is occurring throughout the watershed. As development continues, there is the potential for adverse water quality impacts.

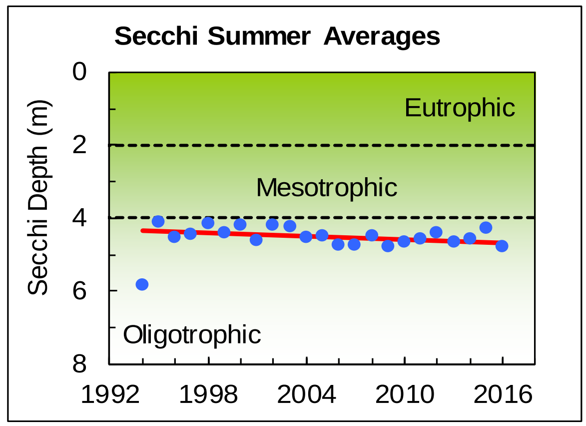
LAKE CONDITIONS

The following graphs illustrate the summer averages and trend lines (shown in red) for water clarity, total phosphorus, and chlorophyll *a* for Lake Shoecraft. 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 Shoecraft is moderate to high, with a 1990 – 2016 long-term summer average of 4.6 meters (15.1 feet). With the exception of the very good water clarity in 1993 and 1994, the values have been within a narrow range during most years. Between 1990 and 2016, there was a statistically significant trend toward improved water clarity.



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 Shoecraft averaged 10 pcu (platinum-cobalt color units) in 2010 – 2011, which indicates a slight amount of color in the lake water. This is a slight decrease in color from the 1994 – 1995 average of 11 pcu. The summer average for just 2011 decreased substantially to 3.8 pcu. The reduction in the darkness of Lake Shoecraft's true water color could be one factor in the apparent increases in water clarity.

LAKE SHOECRAFT

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 October 2014 (the most recent data), temperature data were collected at each meter throughout the Lake Shoecraft water column (see graph). Temperature profiles for 2014 show that throughout the summer season the lake was thermally stratified. This means that there was a large temperature difference between the warm upper waters and the cooler bottom waters, and mixing did not occur between these layers. In April the upper waters were about 6°F (3°C) warmer than the bottom waters. The surface waters got a little warmer in May. Then, the lake warmed considerably in June, and by July the upper waters reached their peak at 76°F (24.4°C). During the same months, bottom water temperatures changed only a little and remained around 50-57°F (10-14°C). In September, the surface waters began to cool, and by October they were almost the same from top to bottom. Because the lake is relatively shallow, the stratification weakened earlier than most lakes, and the entire lake turned over (or mixed) by mid-October. The lake will stay mixed during the winter until springtime, when the upper waters begin to warm again.

Dissolved Oxygen

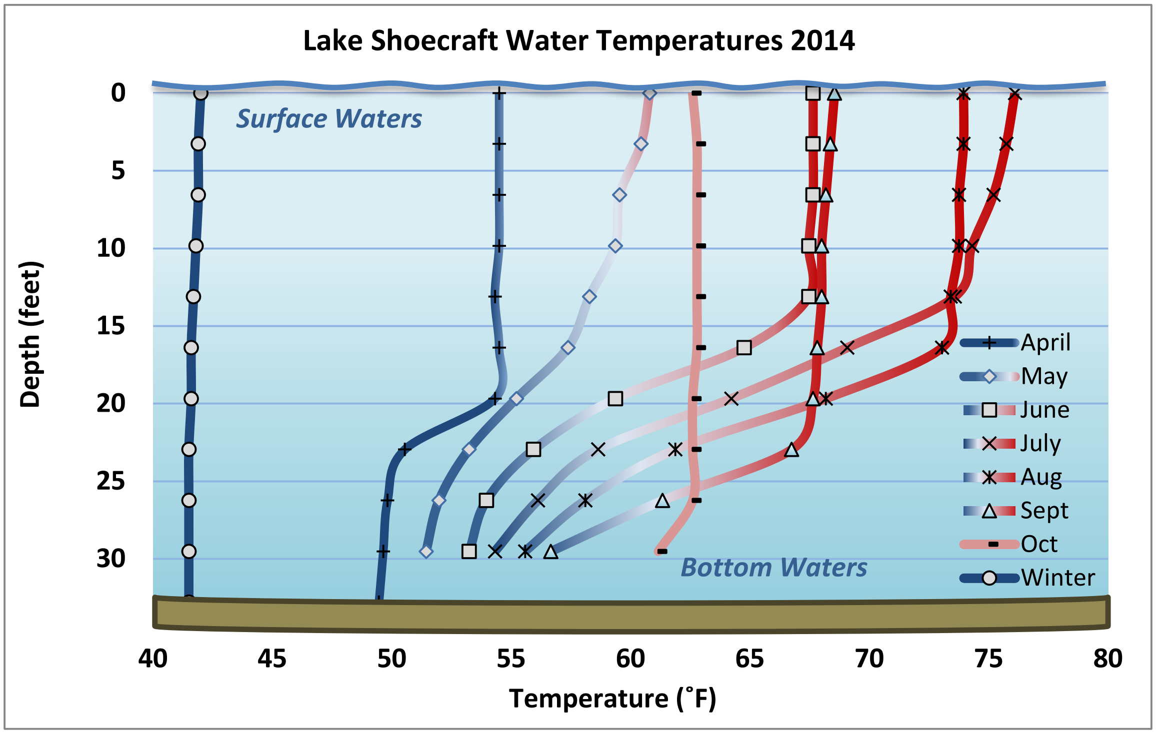
Oxygen dissolved in the water is essential for life in a lake. Most of the dissolved oxygen comes from the atmosphere. Like temperature, dissolved oxygen levels vary over time and with depth. During the warm months, the upper waters receive oxygen from the atmosphere, but the lower waters cannot be replenished 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.

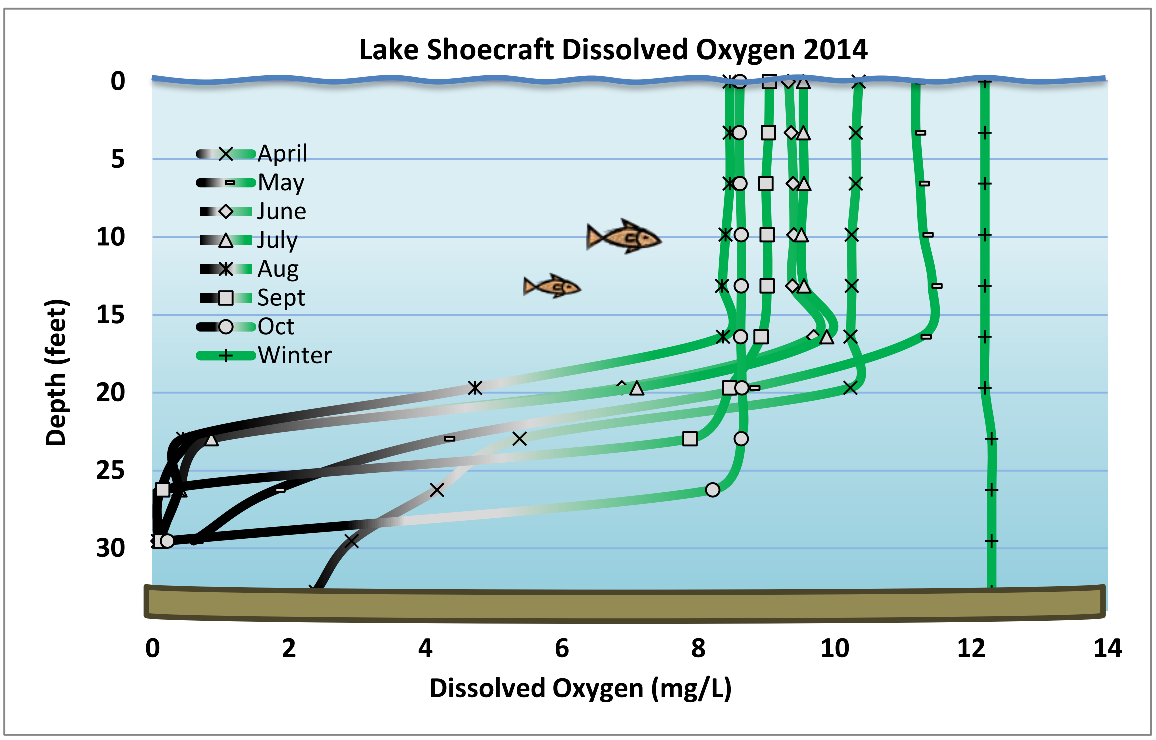
Dissolved oxygen was also measured at every meter throughout the Lake Shoecraft water column from April through October 2014 (see graph). Oxygen levels were relatively high in the upper waters in April and May. Later in the summer, the upper waters held slightly less dissolved oxygen because warmer water cannot hold as much oxygen as colder water. In June and July, there was also a small increase in dissolved oxygen levels about 15 feet deep. This indicates vigorous algae growth at that depth which added oxygen to the water.

Beginning in April, the dissolved oxygen in the bottom waters gradually declined. Through most of the summer, the bottom waters contained virtually no dissolved oxygen below about 23 feet deep. During the summer period, oxygen in the lower waters is consumed by the decomposition of organic material within the lake. When the lake is stratified, the oxygen is not replenished by the overlying oxygen-rich upper waters or the atmosphere. Very low dissolved oxygen levels in the bottom waters can lead to a release of phosphorus from the lake sediments that can result in increased algae growth in late summer and fall or the next spring.

In October, when temperatures became uniform from top to bottom and the lake mixed, dissolved oxygen again became available throughout the entire water column. The lake will remain mixed through the winter until springtime.

LAKE SHOECRAFT



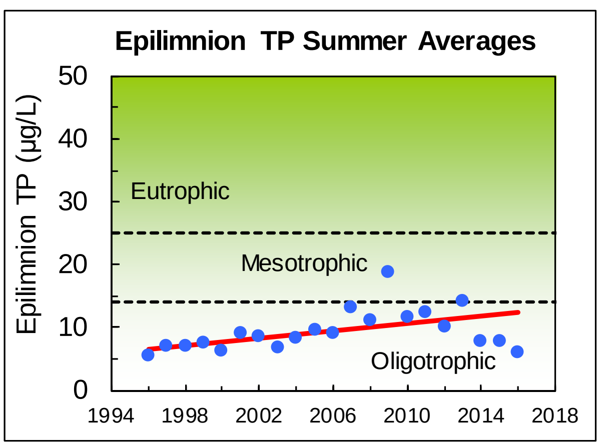


LAKE SHOECRAFT

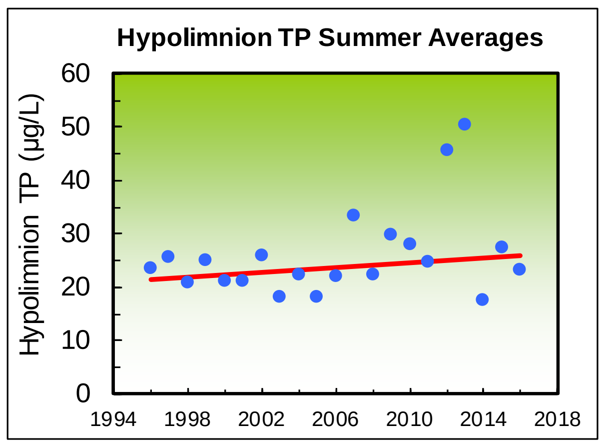
Phosphorus (key nutrient for algae)

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 (TP) concentrations in the epilimnion (upper waters) are low, with a 1996 – 2016 long-term summer average of 9 µg/L (micrograms per liter which is equivalent to parts per billion). Although the phosphorus concentrations are low, there has been a statistically significant trend toward increasing levels in the epilimnion ($p=0.03$). The phosphorus levels in 2009 and 2013 were particularly high with summer averages of 19 µg/L and 14 µg/L, respectively. Fortunately, the 2014 through 2016 summer average for the upper waters is much lower at 7.33 µg/L. Overall, phosphorus concentrations are now approaching the mesotrophic range. Increasing phosphorus levels can lead to nuisance algae growth in the lake (as reflected by the increasing trend in chlorophyll *a* values) and may be a sign of accelerating eutrophication.



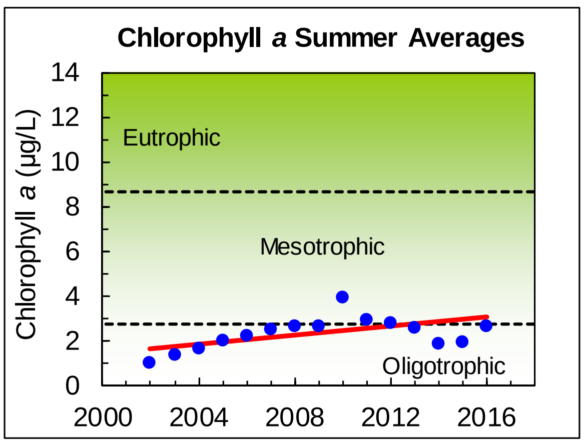
Phosphorus values in the hypolimnion (bottom waters) are higher than in the epilimnion, but still relatively low compared to many lakes. The long-term 1996 to 2016 summer average is 26 µg/L, and the phosphorus levels have been quite high in some years. In 2012 and 2013, the summer averages were the highest on record at 46 µg/L and 51 µg/L, respectively. Again, the 2014 through 2016 summer averages for the bottom waters were lower. Because of this variability, there has been no statistically significant increase in phosphorus levels between 1996 and 2016. More phosphorus in the hypolimnion indicates that phosphorus is being released from bottom sediments during periods of low dissolved oxygen and may be a precursor to future water quality concerns.



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.

Chlorophyll *a* values are low to moderate in Lake Shoecraft. The 2002 – 2016 long-term summer average is 2.3 µg/l. Although the 2014 and 2015 summer averages dropped to only 1.9 µg/L and 2.0 µg/L respectively (a decline that parallels the drops in phosphorus), between 2002 and 2015, there was a statistically significant increase in chlorophyll *a* summer averages (p=0.04). The summer average in 2016 rose to 2.7 µg/L. In addition, there have been occasional episodes of nuisance algae blooms in the lake in recent years. The increasing chlorophyll *a* levels correspond with the increasing amount of phosphorus in the epilimnion of the lake, as discussed above, and may indicate accelerating eutrophication.



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. From 2014 to 2016, Lake Shoecraft had moderate levels of total nitrogen (summer average of 368 µg/L). This is consistent with the low to moderate 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.

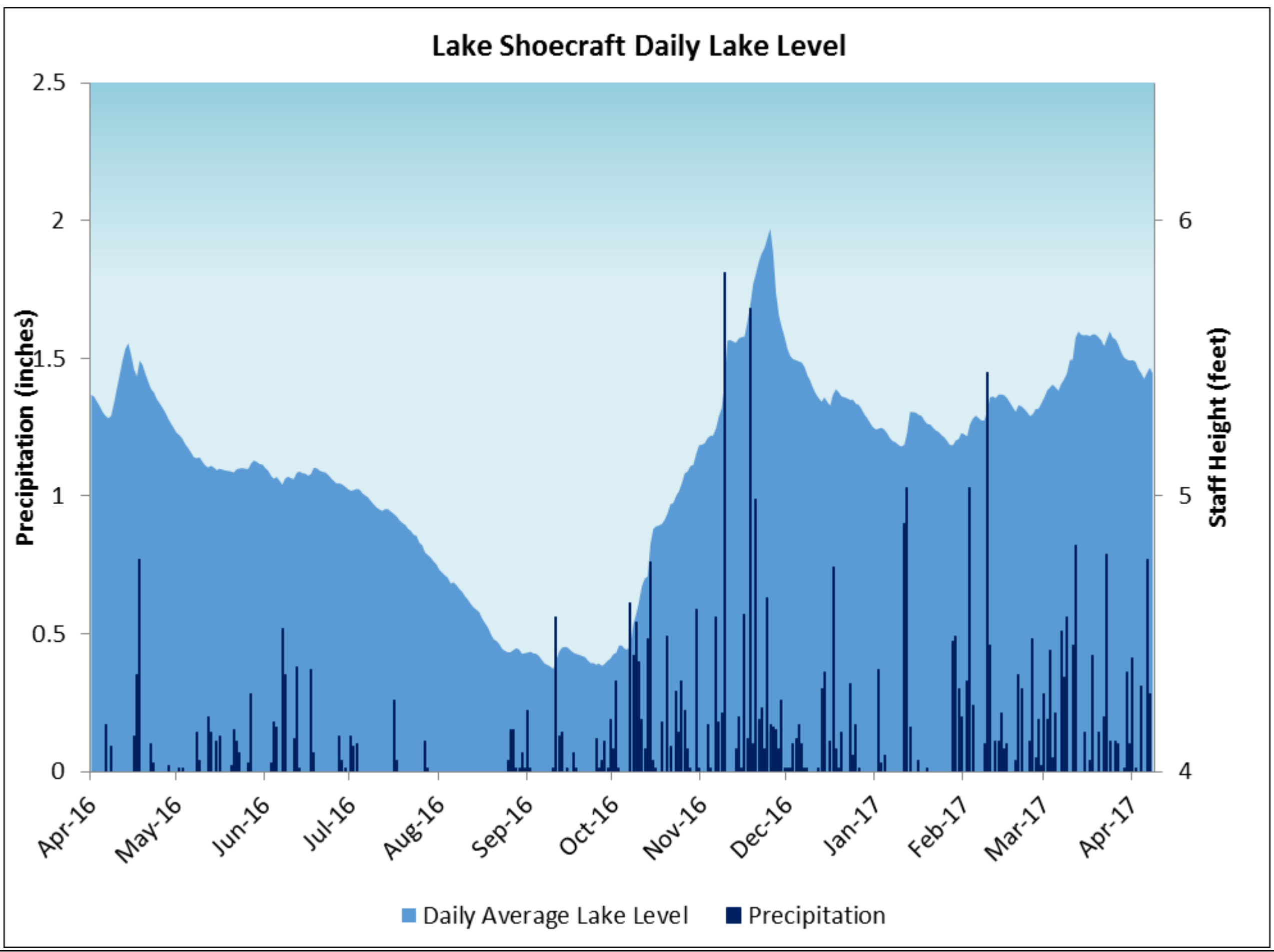
In contrast, when lakes have higher N:P ratios (greater than 20), algae growth will be limited by the amount of phosphorus available, and blue-green algae are usually less of a problem. Lake Shoecraft had a high average N:P ratio of 50, and blue green algae blooms were not a problem in 2016.

LAKE SHOECRAFT

Lake Level

Lake level data tracks the amount of water in the lake and the balance between water coming in by streams, precipitation, groundwater and water leaving by evaporation or outflow. Lake levels in our region are highest in early spring and lowest in late summer and fall. The importance of lake level is to indicate the seasonal effects of the water balance in the lake. In addition to rainfall, lake levels can be affected by sedimentation, surrounding topography, beaver activity, plugged outlets, and the ratio of developed to undeveloped land in the watershed. Paved or impervious surfaces will create faster runoff and quickly rising lake levels during large rain events, while forests, wetlands, and pastures will slow down runoff and limit large rises in lake level

Lake Levels for Lake Goodwin and Lake Shoecraft are managed by the Tulalip Tribes and lake residents with a weir and removable boards at the outlet of Lake Shoecraft. Boards are removed in the winter months to alleviate rising lake levels and are re-installed in the summer months to retain water. SWM installed a continuous gage at the north-west end of the lake in April 2016 to monitor lake levels year round. Lake data is recorded hourly as elevation in feet. The graph below shows the daily average lake level and daily total rainfall for Lake Shoecraft from the time of installation through mid-April 2017. The precipitation data used for graph was recorded at the Lake Goodwin Community Park. The lake levels fluctuated 1.6 feet in 2016. The summer of 2016 was fairly dry and the lake level dropped quite low. Heavy rains in in the fall resulted in large rises in the lake level.



LAKE SHOECRAFT

Aquatic Plants

Aquatic plants are also important in a lake ecosystem. Plants provide food and shelter for fish and other aquatic animals, stabilize the shoreline and bottom sediments, and in some cases increase water clarity by out-competing algae for nutrients. Some plants grow entirely submersed under the water (like elodea), some have leaves that float on the surface (like lilies), and others have roots under the water with most of the plant standing above the water (like cattails).

Although aquatic plants are essential for lake health, excess growth of aquatic plants can interfere with swimming, boating, fishing, and wildlife habitat. In addition, invasion by non-native plant species can seriously damage a lake ecosystem. Non-native aquatic plants choke out native plants and form dense stands that are a nuisance to humans and wildlife.

During the 1990s, Lake Shoecraft was heavily infested with Eurasian watermilfoil, an invasive aquatic plant. Snohomish County SWM and lake residents worked together to control the plants, implementing an herbicide treatment and regular diving surveys. The project was very successful—no plants were found from 2001 through 2007, and native plants slowly returned to the lake.

However, in 2008 one new milfoil plant was found in Lake Shoecraft. This new invasion followed the rapid expansion of a milfoil patch in Lake Goodwin located near the channel that feeds into Lake Shoecraft. In 2009, several dozen additional milfoil plants were found in Lake Shoecraft and removed along the northeast shoreline, and four plants were removed in the south end. Then, in 2010 through 2012, many dozens of large milfoil plants were identified at the north end of the lake and along the northeast shoreline. Divers removed as many of these plants as possible. Diving surveys and aggressive hand removal were still not enough to prevent this re-infestation of milfoil from again impairing the use of Lake Shoecraft.

In response, SWM hired a contractor to treat 12 acres of milfoil in Lake Shoecraft with herbicides in 2013. The herbicide used was a selective herbicide that has no or minimal environmental impacts, according to studies by the State Department of Ecology. Surveys in 2014 confirmed that the herbicide treatment was a success, with only a few scattered milfoil plants removed by the divers. Unfortunately, in 2015 and 2016 diving surveys found dozens of milfoil plants around the lake and a large patch at the north end of the lake. In 2016, aquatic herbicide was used to treat the large milfoil infestation at the north end of the lake, and a few patches along the east and southwest shore. A total of 6 acres were treated in 2016.

Follow-up hand removal will be conducted in 2017. Snohomish County and lake residents will continue to work on controlling and eliminating Eurasian watermilfoil plants using funds collected from the property owners around the lake. Diving costs have dramatically increased in recent years, and the current level of effort may not be enough to prevent milfoil from spreading around the lake again.

LAKE SHOECRAFT

SHORELINE CONDITION

The lake shoreline condition is important in understanding 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 Shoecraft has one of the most densely developed shorelines in the county. There were 100 homes or cabins around the lake shore in 1973. By the mid-90s, there were 114 homes bordering the lake. There are also 124 docks covering 1.5 acres of the lake. Fifty-three percent of the 2.5 mile shoreline has been structurally modified. Bulkheads comprised the majority of the modifications (30% of the entire shoreline), with rock or log revetments also widespread (22%). The zone of vegetation immediately adjacent to the shoreline has also been significantly altered, with only 29% being classified as intact native vegetation. In addition, there is only a small amount of large wood (about 24 pieces) still remaining in the lake. These old logs and branches are valuable for fish and wildlife habitat.

The high level of shoreline modification at Lake Shoecraft leaves the lake susceptible to pollution from the watershed, eliminates the buffer of native vegetation that can filter out pollution, and limits the amount of habitat available for fish and wildlife. The loss of native vegetation along the shoreline could also lead to shoreline erosion.

LAKE SHOECRAFT

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 Shoecraft may be classified as oligo-mesotrophic, with high water clarity, low to moderate phosphorus and algae concentrations, low to moderate levels of aquatic plants, and limited production of algae and plants.

Condition and Trends

Lake Shoecraft is meeting its water quality target of maintaining good water clarity. The long-term average has increased to 4.6 meters, and there has been a statistically significant trend toward improving water clarity.

Although Lake Shoecraft still has relatively low phosphorus levels, it is not meeting the target of maintaining stable phosphorus concentrations. Between 1996 and 2016, there has been a statistically significant increasing trend in phosphorus concentrations in the upper waters. This trend, together with a statistically significant increase in chlorophyll *a* summer averages, indicates that more nutrients are feeding the lake and more algae are being produced.

Overall, Lake Shoecraft is in good condition, but the lake is at risk of future water quality declines because of the increases in phosphorus and chlorophyll *a*. The primary threat to lake water quality is any increase of phosphorus entering the lake through new development and from human activities in the watershed. Measures to control phosphorus in the watershed should be taken now to prevent any future negative impacts to the lake. To find tips to protect lake water quality and more information on the impacts of elevated lake nutrient levels visit www.lakes.surfacewater.info.

DATA SUMMARY FOR LAKE SHOECRAFT						
		Water Clarity (Secchi depth	Total Phosphorus (µg/L)		Total Nitrogen (µg/L)	Chlorophyll *a* (µg/L)
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Surface**	**Surface**
McConnell, et al, 1976	**1973**	3.0 - 4.0 (3.5) *n = 3*	14 - 41 (24) *n = 3*	34 - 57 (43) *n = 3*	-	1.7 - 3.8 (2.5) *n = 3*
Entranco, 1986	**1983**	4.2 - 5.2 (4.6) *n = 5*	<5 - 9 (6) *n = 5*	<5 - 29 (14) *n = 5*	-	0.8 - 3.6 (1.8) *n = 5*
DOE	**1990**	3.4 - 5.2 (4.1) *n = 7*	-	-	-	-
Volunteer	**1992**	3.9 - 4.2 (4.0) *n = 2*	-	-	-	-
Volunteer	**1993**	4.8 - 6.8 (5.6) *n = 12*	-	-	-	-
SWM Staff or Volunteer	**1994**	4.0 - 7.1 (5.9) *n = 12*	-	-	-	0.5 - 4.3 (2.4) *n = 2*
SWM Staff or Volunteer	**1995**	3.7 - 4.9 (4.1) *n = 12*	-	-	-	1.3
SWM Staff or Volunteer	**1996**	4.1 - 4.9 (4.6) *n = 12*	4 - 7 (6) *n = 2*	13 - 34 (24) *n = 2*	-	-
SWM Staff or Volunteer	**1997**	4.1 - 5.1 (4.5) *n = 13*	5 - 9 (7) *n = 2*	25 - 26 (26) *n = 2*	-	-
SWM Staff or Volunteer	**1998**	3.7 - 5.1 (4.2) *n = 15*	6 - 8 (7) *n = 4*	13 - 30 (21) *n = 4*	-	-
SWM Staff or Volunteer	**1999**	3.8 - 5.2 (4.4) *n = 13*	5 - 13 (8) *n = 4*	22 - 27 (25) *n = 4*	-	-
SWM Staff or Volunteer	**2000**	2.6 - 5.2 (4.2) *n = 12*	5 - 9 (6) *n = 4*	8 - 36 (21) *n = 4*	-	-
SWM Staff or Volunteer	**2001**	4.4 - 5.0 (4.6) *n = 8*	6 - 11 (9) *n = 4*	17 - 29 (21) *n = 4*	-	
Volunteer	**2002**	3.7 - 4.8 (4.2) *n = 7*	7 - 13 (9) *n = 4*	21 - 30 (26) *n = 4*	-	0.1 - 2.1 (1.1) *n = 4*
Volunteer	**2003**	3.9 - 5.0 (4.3) *n = 5*	6 - 8 (7) *n = 4*	14 - 21 (18) *n = 4*	-	1.3 - 1.6 (1.4) *n = 4*
Volunteer	**2004**	4.2 - 5.3 (4.5) *n = 7*	6 - 11 (8) *n = 4*	15 - 31 (22) *n = 4*	-	1.3 - 2.1 (1.7) *n = 4*

LAKE SHOECRAFT

DATA SUMMARY FOR LAKE SHOECRAFT						
		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	**2005**	3.9 - 5.0 (4.5) *n = 4*	4 - 19 (10) *n = 4*	6 - 33 (18) *n = 4*	-	1.6 - 2.4 (2.0) *n = 4*
Volunteer	**2006**	4.5 - 5.3 (4.8) *n = 5*	8 - 12 (9) *n = 4*	13 - 38 (22) *n = 4*	-	1.6 - 3.2 (2.3) *n = 4*
SWM Staff	**2007**	4.2 - 5.1 (4.8) *n = 4*	9 - 18 (13) *n = 4*	23 - 46 (34) *n = 4*	-	1.6 - 3.7 (2.5) *n = 4*
Volunteer	**2008**	3.9 - 5.0 (4.5) *n = 12*	8 - 19 (11) *n = 4*	11 - 34 (22) *n = 4*	-	2.1 - 3.3 (2.7) *n = 4*
Volunteer	**2009**	3.7 - 5.4 (4.8) *n = 9*	9 - 46 (19) *n = 4*	21 - 41 (30) *n = 4*	-	1.6 - 3.2 (2.6) *n = 4*
Volunteer	**2010**	4.2 - 6.0 (4.7) *n = 10*	11 - 13 (12) *n = 4*	18 - 33 (28) *n = 4*	-	2.7 - 5.3 (3.9) *n = 4*
Volunteer	**2011**	3.4 - 5.4 (4.6) *n = 8*	10 - 15 (13) *n = 4*	18 - 39 (25) *n = 4*	-	1.9 - 4.7 (3.0) *n = 4*
Volunteer	**2012**	3.6 - 5.6 (4.4) *n = 10*	8 - 13 (10) *n = 4*	22 - 62 (46) *n = 4*	-	2.1 - 4.3 (2.8) *n = 4*
Volunteer	**2013**	3.7 - 5.4 (4.7) *n = 10*	9 - 19 (14) *n = 4*	26 - 72 (51) *n = 4*	-	2.1 - 3.2 (2.6) *n = 4*
Volunteer	**2014**	3.5 - 5.6 (4.6) *n = 10*	6 - 12 (8) *n = 4*	6 - 25 (18) *n = 4*	373 - 447 (406) *n = 4*	1.1 - 3.2 (1.9) *n = 4*
Volunteer	**2015**	*3.4 - 4.9 (4.3) n = 10*	*7 - 8 (8) n = 4*	*17 - 39 (28) n = 4*	*299 - 361 (323) n = 4*	*1.1 - 2.7 (2.0) n = 4*
Volunteer	**2016**	4.1 - 5.4 (4.8) *n = 12*	4 - 8 (6) *n = 4*	12 - 31 (23) *n = 4*	318 - 396 (374) *n = 4*	1.6 - 4.5 (2.7) *n = 4*
Long Term Avg		**4.6 (1990-2016)**	**9 (1996-2016)**	**26 (1996-2016)**	**368 (2014-2016)**	**2.3 (2002-2016)**
TRENDS		**Increasing**	**Increasing**	**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.
- DOE = Washington Department of Ecology
- "Surface" samples are from 1 meter depth and "bottom" samples are from 1-2 meters above the bottom.