

LAKE STEVENS

REPORT DESCRIPTION

This report is an update to the 2003 [State of the Lakes Report](#) that includes water quality data collected from 2003 through 2009. For additional background on the information provided here or to find out more about Lake Stevens please visit www.lakes.surfacewater.info or call Snohomish County Surface Water Management (SWM) at 425-388-3464.

LAKE DESCRIPTION

Lake Stevens is the largest natural lake in Snohomish County. Approximately 80% of the lake shore lies within the limits of the City of Lake Stevens; only the southeast shore is located in unincorporated Snohomish County. The lake covers 1013 acres, has a maximum depth of 150 feet (46 meters), and has an average depth of 62 feet (19 meters).

Lake Stevens is fed by Stevens, Lundeen, Kokanee, and Stitch creeks and drains to Catherine Creek and the Pilchuck River. The watershed area draining to the lake covers 4498 acres (including the lake), which is large compared to other lake watersheds but relatively small compared to the size of Lake Stevens. The shoreline of Lake Stevens is one of the most densely developed in the county, and residential and commercial development throughout the watershed continues to increase. The large watershed size and heavy development increase the potential for water quality impacts from pollution coming from the lands surrounding the lake.

LAKE STEVENS AERATION SYSTEM

From the 1950s through the 1980s, Lake Stevens experienced declining water quality, with occasional poor water clarity and frequent and severe blooms of algae. Nutrient overloading of the lake, particularly with phosphorus, was the primary cause of the poor water quality. Historically, nutrients entered the lake through runoff from forestry and agricultural operations and later from the rapid residential development of the watershed. Over time, phosphorus built up in the lake sediments, which then also became a significant nutrient source. Detailed studies were conducted in

1982 and 1986 to determine the primary sources of nutrients. The studies concluded that restoration of the lake would require control of both external and internal nutrient sources.

Some improvements have been made in reducing watershed sources of nutrients since the 1980s. However, watershed pollution continues to be a problem for the lake, as described below under "Phosphorus in Lake Sediments".

To help control the in-lake phosphorus cycling, a hypolimnetic aeration system was installed in 1994. The aeration system is designed to provide oxygen to the bottom waters of the lake, known as the hypolimnion. During the warmer months of the year, the warm upper waters cannot mix with the colder hypolimnion, and the dissolved oxygen in the hypolimnion is consumed by on-going organic decomposition. When the dissolved oxygen in the hypolimnion is exhausted, a chemical reaction releases the phosphorus that would otherwise be bound in the lake sediments. This internal cycling of phosphorus contributes to nuisance algal growth in the lake. By oxygenating the lower waters during the warm summer and early fall months, the aeration system helps control phosphorus release and improves the water quality of Lake Stevens. However, as discussed below, the effectiveness of the aeration system appears to be declining in recent years.

LAKE CONDITIONS

Lake Quality Data

Summer averages of water clarity, total phosphorus for upper and bottom waters, and chlorophyll *a* (algae) are summarized in the table at the end of this report. Detailed data for these parameters and other measurements may be found at www.lakes.surfacewater.info by clicking on "Individual Lake Information" or by selecting "SWM's Interactive Water Quality Database".

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Temperature and Dissolved Oxygen

The great depth of Lake Stevens results in extremely strong stratification between the warm, oxygenated upper waters (epilimnion) and the cool, oxygen-poor bottom waters (hypolimnion). Prior to installation of the aeration system in 1994, dissolved oxygen levels near the lake bottom would decline throughout the summer. (See the red line in Figure 1 showing typical oxygen concentrations from the top of the lake to the lake bottom during October.) When dissolved oxygen approaches 0 mg/l at the sediment (or about 2 mg/l at 44 meters deep), phosphorus bound in the sediments can be released into the water column. Since installation of the aeration system, the levels of oxygen in the bottom waters have remained above the critical concentrations that normally lead to release of phosphorus from the sediments. (See the blue line that shows the typical October measurements after the aeration system was installed.) This means the aeration system is working to keep oxygen at acceptable levels.

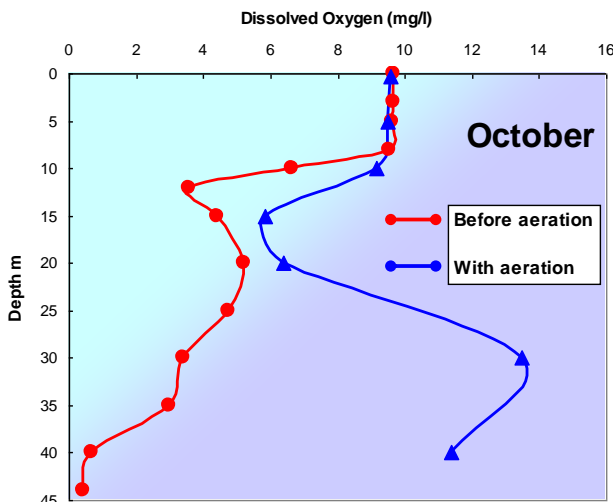


Figure 1

The four graphs on page 3 show the temperature and dissolved oxygen measurements down through the lake water column for each month in 2009. Figure 3 illustrates the temperatures in the lake and the changes from January through early summer. In

January and February, water temperatures were cold and stayed the same from the top of the lake to the bottom because the lake was completely mixed. By May the upper waters had warmed considerably, and were quite warm by July. Figure 4 shows how the oxygen levels remained high near the surface, but began to decline near the lake bottom as summer began. The aeration system was not running during the first half of the year because it was not needed—oxygen levels remained moderately high.

Figures 5 and 6 show the temperature and dissolved oxygen profiles from July through December, which includes the time when the aeration system was operating and shortly afterward. Temperatures were unaffected by the aeration—remaining constant in the bottom waters and slowly decreasing through the fall in the upper waters. Dissolved oxygen levels showed a large increase from the aerators at 30 and 40 meters depth throughout late summer and fall. Even at the very bottom, oxygen levels stayed high enough to help control the release of phosphorus from lake sediments.

Water Clarity

Water clarity in Lake Stevens is high, with a long-term summer average of 5.9 meters. There was a period from 1998 through 2001 when the water clarity was markedly worse. However, clarity has been very good since 2002. Overall, there are no statistically significant trends in water clarity from 1990 - 2009.

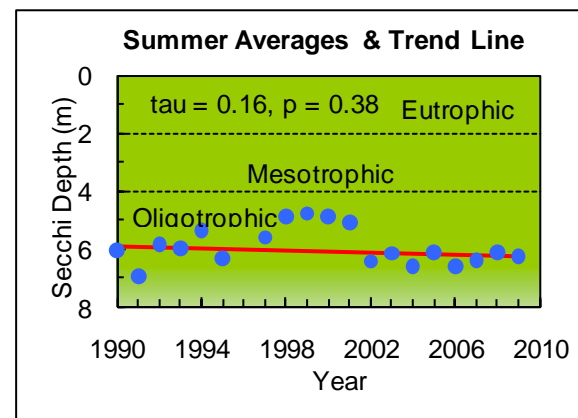
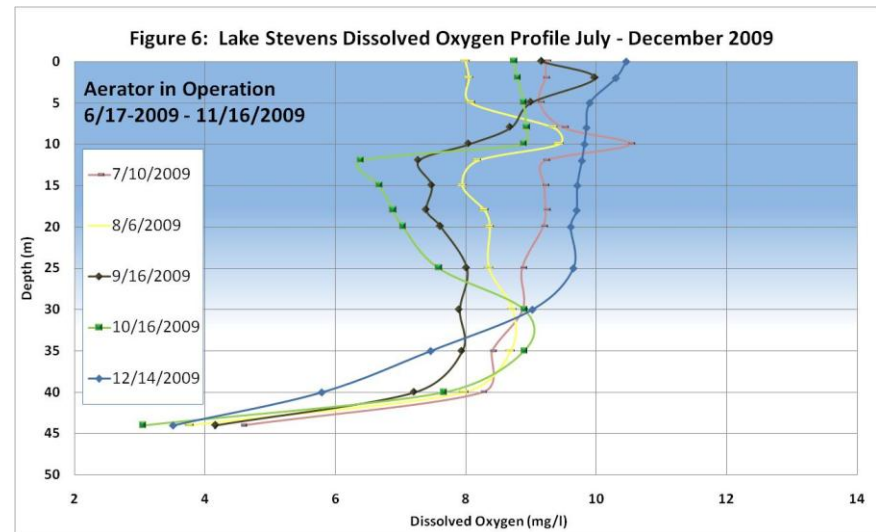
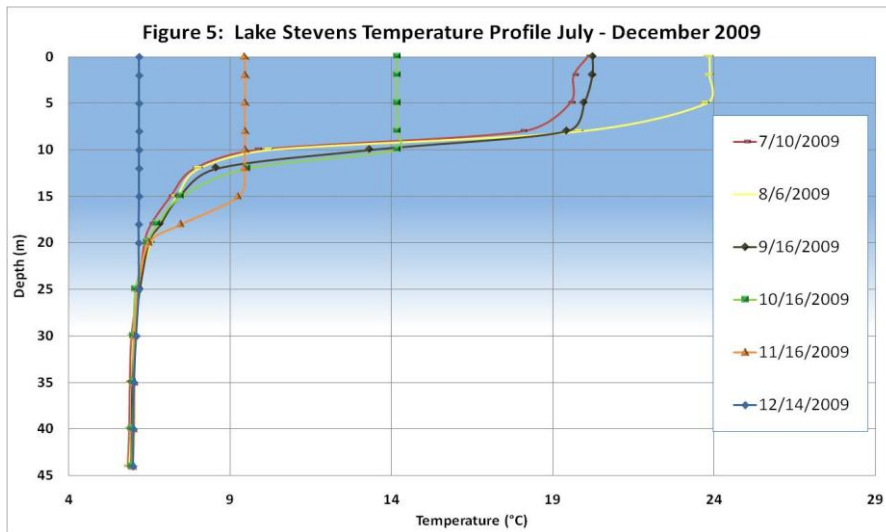
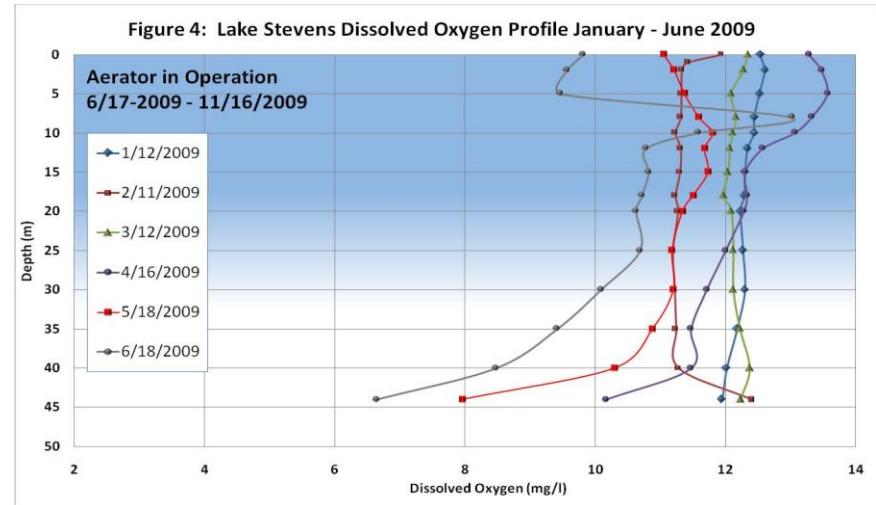
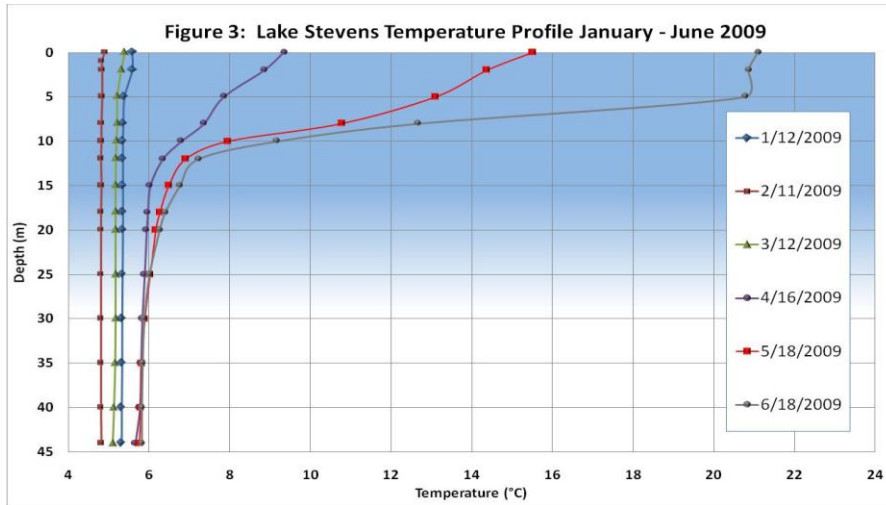


Figure 2

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Total Phosphorus (key nutrient for algae)

Total phosphorus concentrations in the epilimnion (upper waters) of Lake Stevens are low to moderate. The long-term 1997 – 2009 average is 13 µg/l. In recent years, the summer phosphorus averages in the upper waters have been slightly higher than the averages in the late 1990s, and there was an upward spike in phosphorus in 2006. This increase in phosphorus could be the result of runoff during spring and summer storms bringing more phosphorus from surrounding properties. The aeration system is not designed to address new phosphorus pollution entering the lake. Overall, there has been a small, but statistically significant, trend toward higher phosphorus concentrations in the epilimnion between 1997 and 2009.

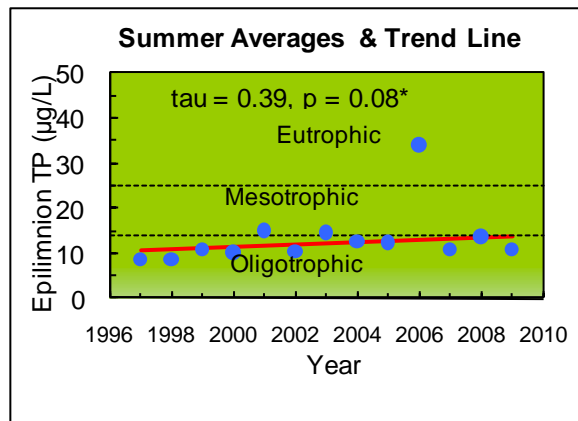


Figure 7

The phosphorus levels in the bottom waters (hypolimnion) are higher than in the upper waters (long-term average of 34 µg/l), and for many years have been increasing. Between 1999 and 2008, summertime phosphorus averages in the hypolimnion steadily increased, reaching levels not seen since 1997 and 1998—a few years after the start of the aeration system. Fortunately, the average did not continue rising in 2009. The increases in phosphorus in the bottom waters are likely signs of on-going nutrient

inputs from the lake watershed. It appears that the aeration system is not able to completely bind up this phosphorus into the sediments because of low iron availability in the lake water and in the sediments. This raises concern about the effectiveness of the aeration system to continue limiting the amount of phosphorus available for algal growth.

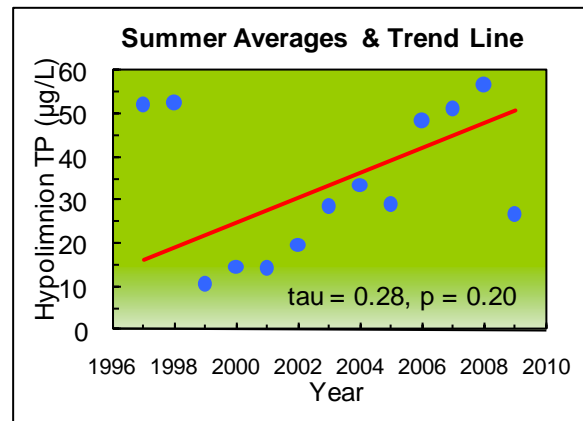


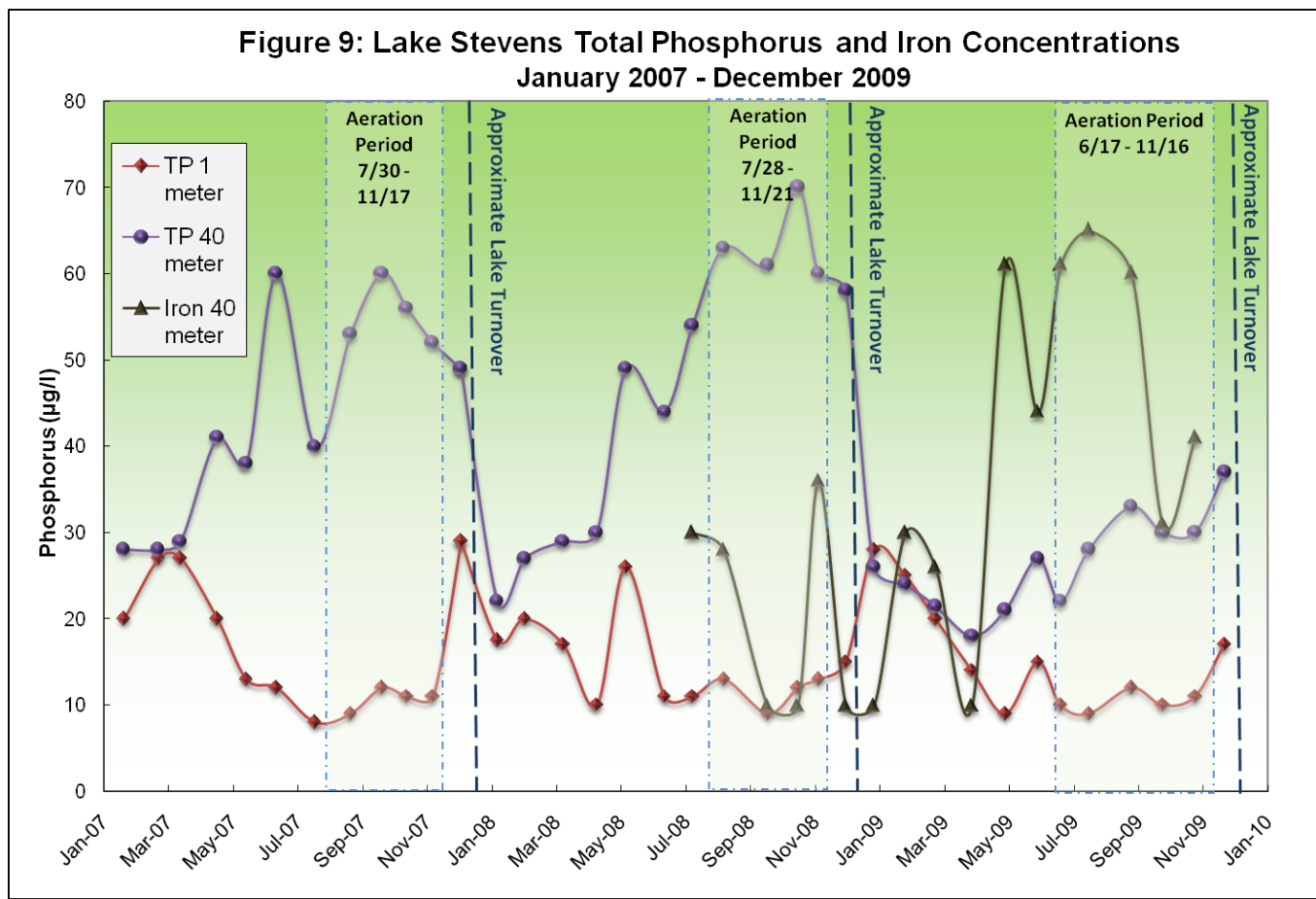
Figure 8

The year-round pattern of phosphorus concentrations in the epilimnion and hypolimnion for 2007 - 2009 is shown in Figure 9. This shows that phosphorus concentrations in the upper waters rise at the end of each year when the lake turns over and mixes. Phosphorus levels at 1 meter are elevated through the winter and spring, corresponding to the occurrences of algal blooms at that time and flushing of nutrients from the watershed during rain events. During summer and fall, less phosphorus is available for algal growth.

The pattern is different at 40 meters depth in the hypolimnion. Phosphorus concentrations steadily climb through the spring and summer into the fall, indicating a build-up of phosphorus as nutrients are released from the bottom sediments. This appears to be occurring in spite of adequate dissolved oxygen levels from the operation of the aeration system. As discussed below, this may be because of the limited amount of iron available to bind the phosphorus.

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**Figure 9: Lake Stevens Total Phosphorus and Iron Concentrations
January 2007 - December 2009**



Phosphorus in Lake Sediments

SWM and the City of Lake Stevens contracted with Tetra Tech, Inc. in 2009 to investigate the sediments in Lake Stevens. The purpose of the investigation was to measure sediment changes since the early 1980s to evaluate the effectiveness of the aeration system.

The investigation revealed that the amount of phosphorus in the sediments of Lake Stevens was significantly less than measured in 1981. However, phosphorus levels in the sediments are still higher than other lakes in the region that experience water quality problems. Figure 10 shows the phosphorus profile down through the sediments at four locations in the lake (A1 and A2 are in the lake center) compared to 1981 phosphorus concentrations. Figure 11 shows phosphorus levels compared to four other lakes.

These data indicate that there continues to be excess nutrients washing into the lake from the watershed. However, the aeration system is limiting the amount of phosphorus being recycled from the sediments back into the lake. Without the aeration system, there would be much higher phosphorus levels in the hypolimnion given the high levels of phosphorus in the sediments. The increasing summer phosphorus averages in the hypolimnion in recent years (shown above in Figure 8), however, suggest that the aeration system may be losing some of its effectiveness.

The investigation also revealed that iron levels in the lake and sediments are not sufficient to bind all the phosphorus. So, water quality may suffer within 5 to 10 years if nothing is done to supplement the aeration system. The most effective measure would be an aluminum sulfate treatment of the lake.

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Figure 10: Lake Stevens Sediment Total Phosphorus Profiles (1981 and 2009)

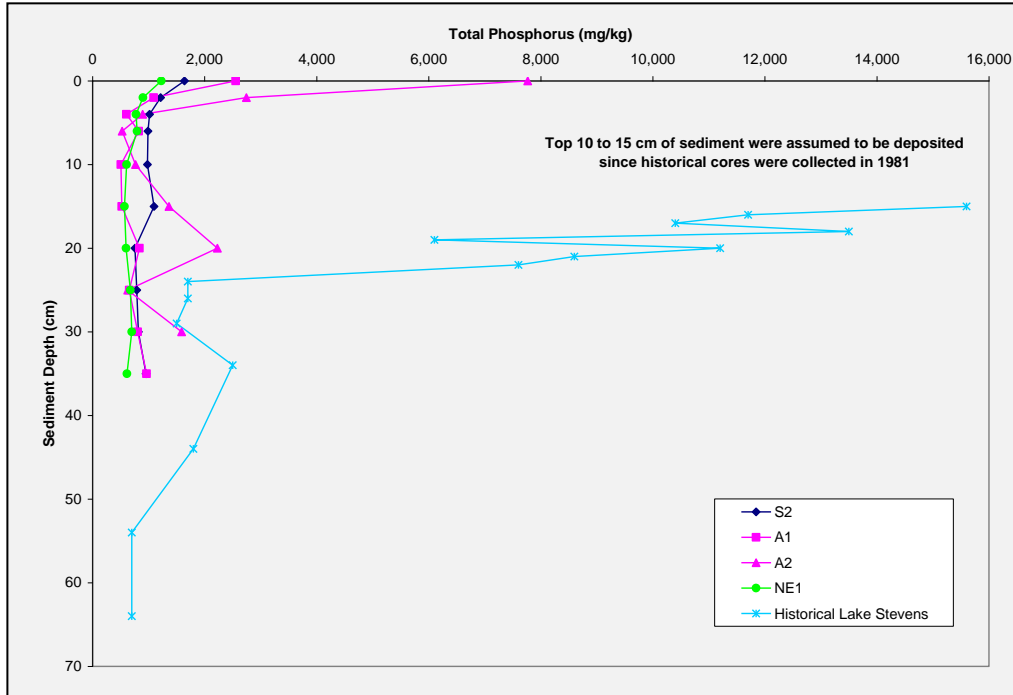
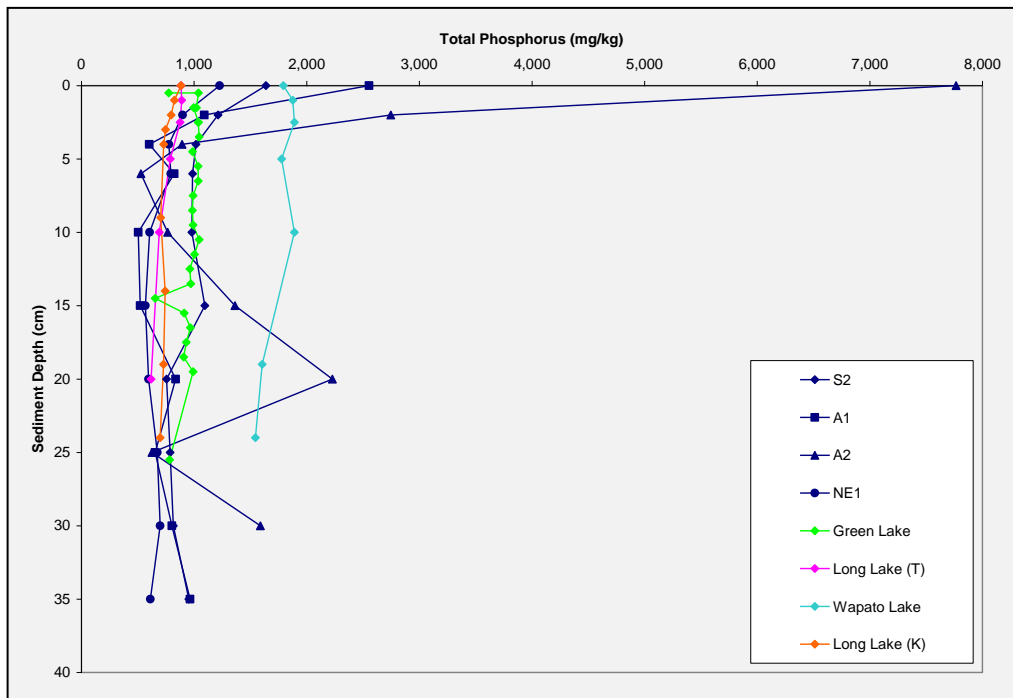


Figure 11: Lake Stevens Sediment Total Phosphorus Profiles (1981 and 2009)



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Chlorophyll a (Algae)

Chlorophyll a values in Lake Stevens from 2003 to 2009 were moderately low, with a long-term average of 1.7 µg/l. The amount of algae measured as chlorophyll a was lower in these years than it was during the 1980s. However, in the last three summers, chlorophyll a averages have been increasing and are now similar to the moderate levels of the 1990s. In fact, between 2003 and 2009, there has been a statistically significant increase in summer chlorophyll a concentrations. In addition, the lake experiences occasional nuisance blue-green algal blooms, especially in the late winter and early spring. These appear to be in response to nutrients mixed throughout the lake after turnover and nutrients flushed into the lake during rain storms.

Figure 13 shows the patterns of chlorophyll a at 1 meter and 10 meters together with lake water clarity. It

shows that water clarity is closely tied to algae levels because declines in water clarity correspond with increases in algal growth.

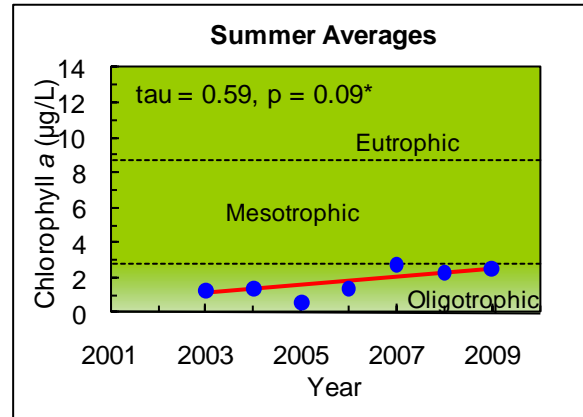
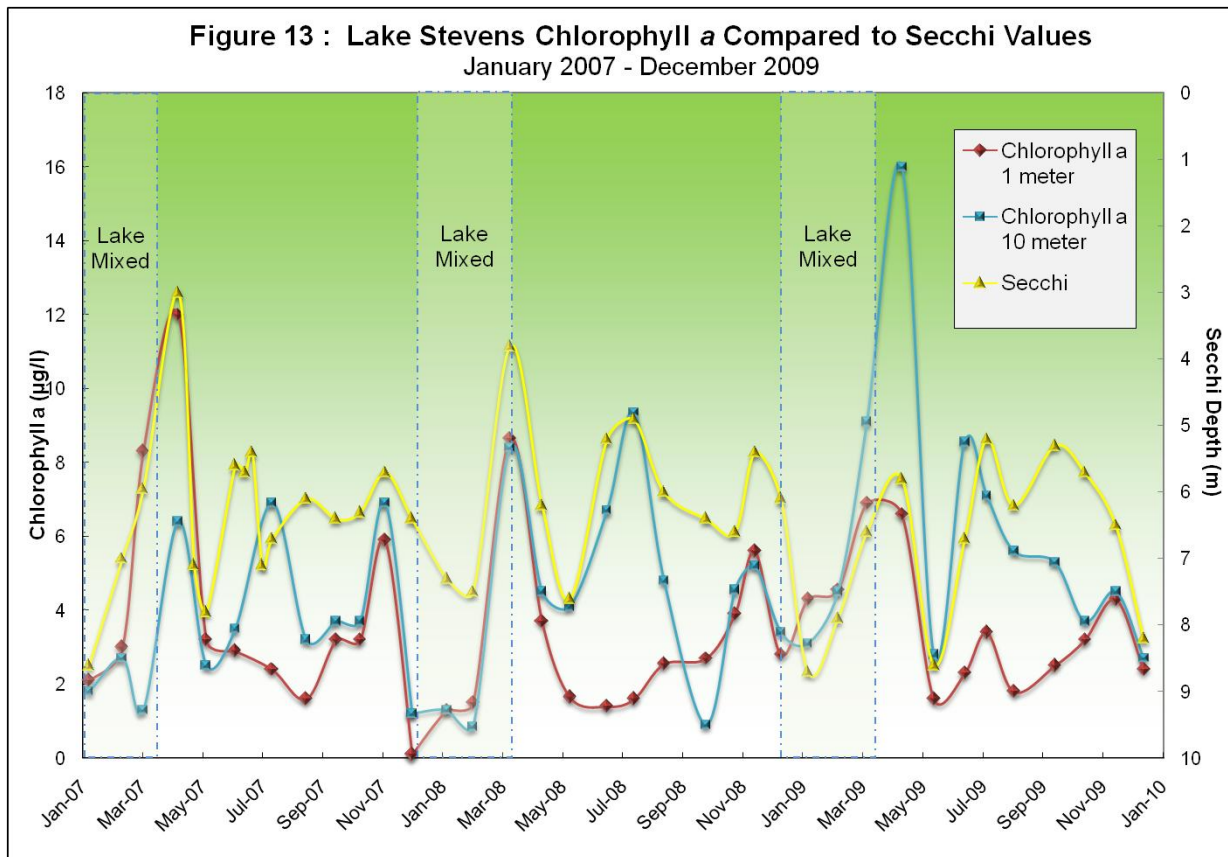


Figure 12



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Aquatic Plants

Lake Stevens supports moderate levels of aquatic plants. Although some areas with steep slopes support few plants, in most shallow areas, plants grow prolifically. Aquatic plants are important for fish and wildlife habitat. They also can help clean the water by competing with algae for nutrients.

However, Lake Stevens has a serious problem with Eurasian watermilfoil, an invasive, non-native plant. Milfoil was present in low numbers in Lake Stevens in the 1980s. Unfortunately, in recent years, Eurasian watermilfoil has grown into a major problem. The thick mats of milfoil are so dense that they interfere with swimming and boating in portions of the lake.

Dense patches of milfoil now cover 46 acres, mainly in the northwest corner and along the eastern shore. Another 90 acres have sparse to moderate concentrations of milfoil. Figure 14 illustrates the locations of milfoil in the lake as of early summer 2010. The City of Lake Stevens is working with SWM and the public in 2010 to develop a plan to identify the most effective actions to take to control the Eurasian watermilfoil infestation and prevent it from taking over the entire perimeter of the lake. In the interim, residents and recreational users of the lake should carefully check their boat and trailers and remove any Eurasian watermilfoil fragments to prevent the spread of this plant to other lakes.

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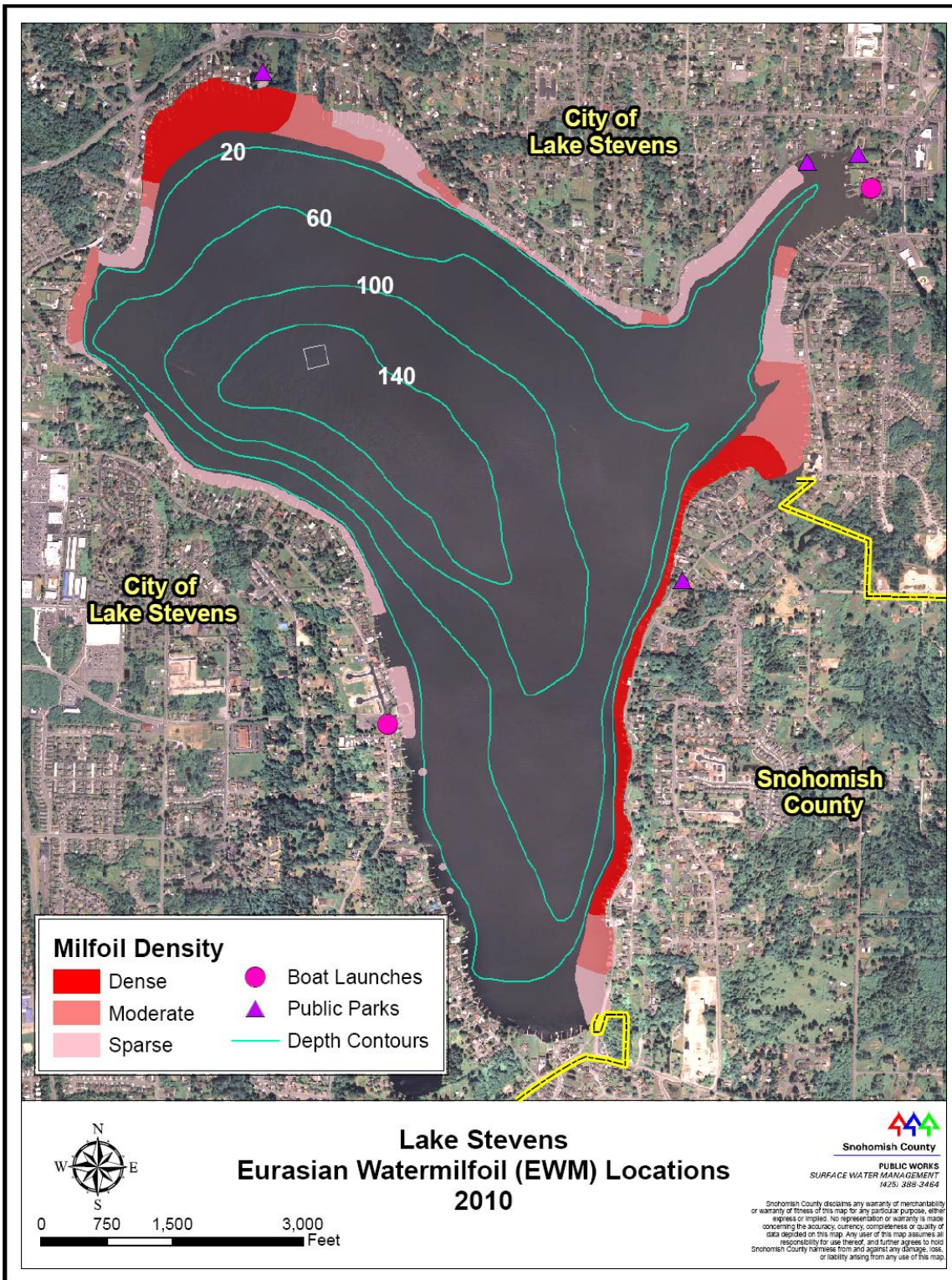


Figure 14

LAKE STEVENS

SHORELINE CONDITION

The Lake Stevens shoreline was surveyed in 2008. The condition of the lake shoreline is important to understanding overall lake health. As development near lakes increases, lake shorelines typically are modified either through removal of natural vegetation, the installation of bulkheads or other hardening structures, and/or the removal of large logs and branches. This type of alteration 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 Stevens has the most densely developed shorelines in Snohomish County (Figure 15). Surveys conducted in the mid-90s showed 349 homes bordering the lake with an average of 9.0 homes per 1000 feet of shoreline. Although homes were not surveyed in 2008, 402 docks were identified covering over 8.3 acres of the lake. Also, 78% of the 7.3-mile shoreline has now been modified. Bulkheads comprise the majority of the modifications (57%), followed by rock revetments (20%). The vegetation immediately adjacent to the shoreline has also been significantly altered, with only 16% being classified as intact in 2008. Nearly all the large wood has been removed from the lake. Only four large wood pieces were identified in 2008. These old logs and branches are valuable for fish and wildlife habitat.

The high level of shoreline modification leaves the lake susceptible to pollution from activities immediately surrounding the lake, such as the use of fertilizers and driveway/roof runoff, eliminates the buffer of native vegetation that can filter out pollution, and limits the amount of aquatic habitat available to fish and wildlife. The loss of native vegetation along the shoreline could also lead to shoreline erosion.

SUMMARY

Trophic State

Based on high water clarity, low to moderate phosphorus levels, low to moderate chlorophyll *a* values, but occasional blue-green algal blooms, Lake Stevens may currently be classified as oligo-mesotrophic. This means that the lake has low to moderate productivity of plants and algae.

Condition and Trends

Overall, Lake Stevens is still in satisfactory condition, but the lake is at risk of future water quality declines. One sign of future trouble is that phosphorus concentrations in the upper waters are increasing and phosphorus levels in the bottom waters were increasing until 2009. In addition, chlorophyll *a* (algae) concentrations show a statistically significant increase in recent years.

The aeration system maintains adequate levels of dissolved oxygen in the bottom waters. This helps bind phosphorus in the sediments and keep it from contributing to excess algal growth. However, phosphorus levels in the sediments are very high, and there is evidence that the effectiveness of the aerators may be diminishing. The reasons for this are the continuing runoff of nutrients entering the lake from human activities in the watershed and the low availability of iron necessary to bind phosphorus in the lake sediments.

Sources of nutrients entering Lake Stevens include fertilizers, pet wastes, sediment from land clearing and construction, runoff from roofs and paved areas, and poorly maintained septic systems. The aeration system cannot completely offset the impacts of these sources, especially without enough iron. If the phosphorus concentrations in the lake continue to increase, these nutrients may fuel nuisance algal growth. This could impact public use and enjoyment of the lake.

The invasion of Eurasian watermilfoil plants must also be controlled to protect public use of the lake.

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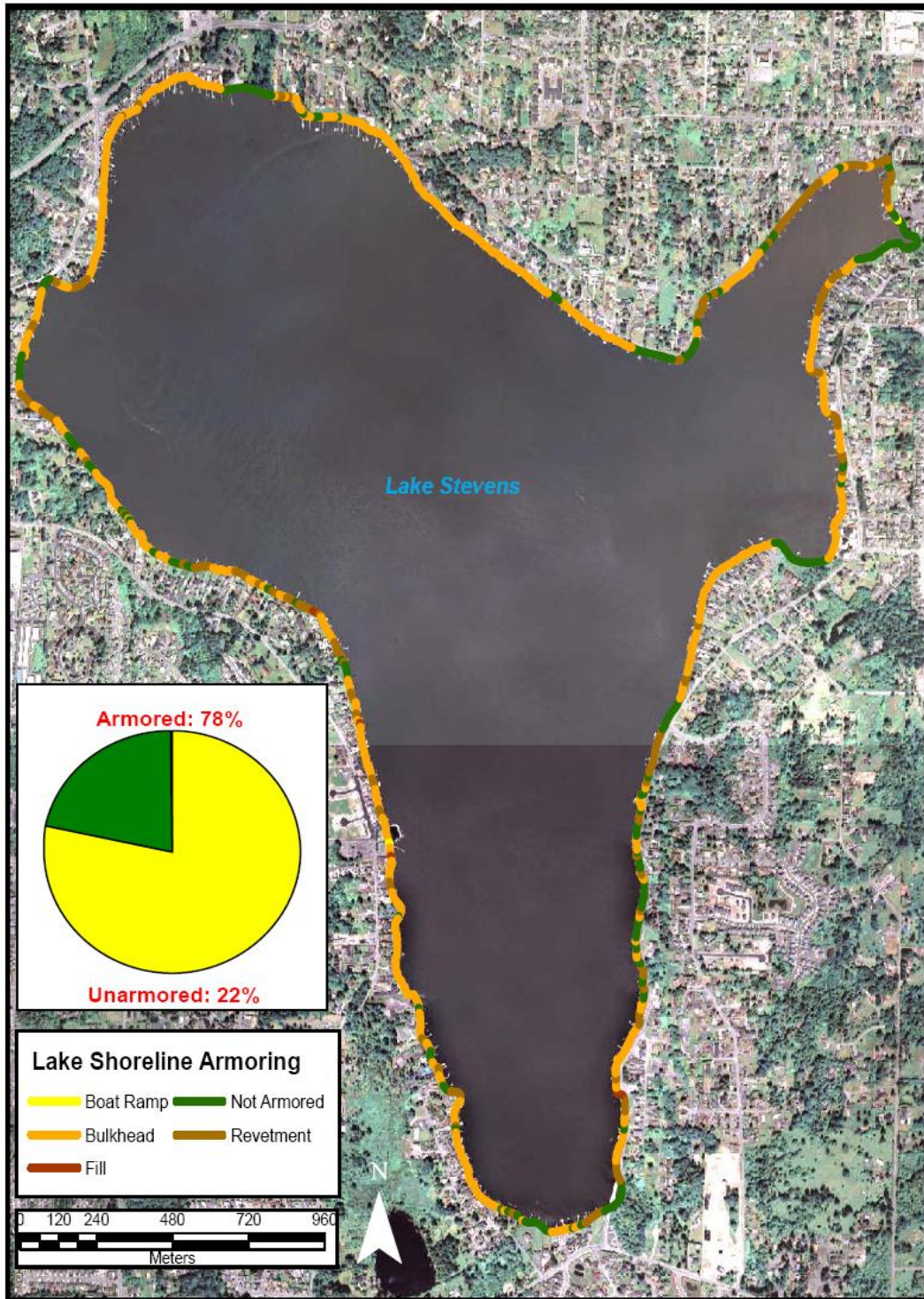


FIGURE 15

LAKE STEVENS

DATA SUMMARY FOR LAKE STEVENS					
Source	Date	Water Clarity (Secchi depth in meters)	Total Phosphorus (ug/l)		Chlorophyll a (ug/l)
			Surface	Bottom	Epilimnion
Bortleson, et al, 1976	7/27/72	5.2	5	56	-
Reid, Middleton & Associates, 1983	1982	3.6 - 9.0 (6.0) n = 5	5 - 23 (12) n = 6	20 - 35 (30) n = 6	7 - 17 (9.8) n = 6
KCM, 1987	1986	5.2 - 8.8 (6.6) n = 7	<1 - 14 (5) n = 7	56 - 109 (69) n = 7	<0.1 - 22 (4.6) n = 7
LS Volunteer or DOE	1990	4.0 - 8.8 (6.1) n = 35	-	-	3.7 - 6.0 (4.8) n = 2
LS Volunteer or DOE	1991	4.7 - 10.1 (7.0) n = 39	-	-	2.0 - 3.0 (2.5) n = 2
LS Volunteer or DOE	1992	3.8 - 7.8 (5.9) n = 34	-	-	2.2 - 5.1 (3.1) n = 4
LS Volunteer KCM or DOE	1993	3.9 - 8.2 (6.0) n = 21	4 - 12 (8) n = 6	33 - 85 (48) n = 6	1.3 - 4.0 (2.8) n = 11
DOE	1994	3.8 - 9.5 (5.4) n = 12	-	-	1.6 - 3.0 (2.3) n = 2
DOE	1995	4.6 - 9.9 (6.3) n = 13	-	-	1.0 - 4.4 (2.7) n = 2
DD#8	1997	4.0 - 7.7 (5.6) n = 6	<5 - 12 (9) n = 9	40 - 66 (52) n = 8	1.4 - 9.6 (3.5) n = 9
DD#8	1998	3.8 - 5.6 (4.9) n = 8	6 - 15 (9) n = 6	36 - 118 (53) n = 6	1.5 - 3.9 (2.6) n = 6
DD#8	1999	3.6 - 7.3 (4.8) n = 10	8 - 15 (11) n = 6	6.3 - 17 (11) n = 5	0.5 - 3.2 (1.9) n = 6
DD#8	2000	4.2 - 5.9 (4.9) n = 9	7 - 14 (10) n = 5	9.2 - 23 (15) n = 5	^a
DD#8	2001	3.6 - 6.6 (5.1) n = 11	11 - 18 (15) n = 6	11 - 21 (14) n = 6	^a
DD#8	2002	4.8 - 10 (6.4) n = 12	7 - 17 (10) n = 6	5 - 45 (20) n = 6	^a

LAKE STEVENS

DATA SUMMARY FOR LAKE STEVENS					
Source	Date	Water Clarity (Secchi depth in meters)	Total Phosphorus (ug/l)		Chlorophyll a (ug/l)
			Surface	Bottom	Epilimnion
DD#8	2003	5.1 - 7.5 (6.2) n = 10	7 - 28 (15) n = 6	8 - 46 (29) n = 6	0.1 - 3.2 (1.2) n = 6
DD#8	2004	4.0 - 8.3 (6.6) n = 10	5 - 34 (13) n = 6	21 - 53 (34) n = 6	0.2 - 2.4 (1.4) n = 6
DD#8	2005	5.2 - 7.7 (6.1) n = 11	5 - 9 (7) n = 5	19 - 39 (29) n = 6	0.2 - 1.6 (0.5) n = 6
SWM Staff or DD#8	2006	5.9 - 7.7 (6.6) n = 10	17 - 53 (35) n = 6	27 - 63 (48) n = 6	0.2 - 4.0 (1.4) n = 5
SWM Staff	2007	5.4 - 7.8 (6.4) n = 10	8 - 13 (11) n = 6	38 - 60 (51) n = 6	1.6 - 3.2 (2.8) n = 6
SWM Staff	2008	4.9 - 7.6 (6.1) n = 6	9 - 26 (14) n = 6	44 - 70 (57) n = 6	1.4 - 3.9 (2.3) n = 6
SWM Staff	2009	5.2 - 8.6 (6.3) n = 6	9 - 15 (11) n = 6	21 - 33 (27) n = 6	1.6 - 3.4 (2.5) n = 6
Long Term Avg		5.9 (1990-2009)	13 (1997-2009)	34 (1997-2009)	1.7 (2003-2009)
TRENDS		None	Increasing	None	Increasing

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
 - LS Volunteer = citizen volunteer monitors involved in the Lake Stevens Restoration Program
 - DD#8 = Lake Stevens Drainage Improvement District #8
 - "Surface" samples are from 1 meter depth and "bottom" samples are from 40 meters deep.
- ^a Chlorophyll a data for 2000-2002 not included because of quality control issues