The Lakes of Maple Valley and Covington

Monitoring Results for the 2014 Water Year at Lake Lucerne, Pipe Lake, and Lake Wilderness

Lake Wilderness, July 2007 *photo by Sally Abella, King County Lakes Program*

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King County

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Prepared for:

The Cities of Maple Valley and Covington.

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Department of Natural Resources and Parks

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1.0. PROGRAM OVERVIEW

The King County Lakes and Streams Monitoring Group and its predecessor the Lake Stewardship Program have worked with volunteers to monitor water quality for three lakes that are currently within the Cities of Maple Valley and Covington. Lake Lucerne data has been collected since the 1980s, while Pipe and Wilderness Lakes have been monitored since the 1970s. The water quality data indicate that the three lakes currently range from low to moderate in primary productivity, with generally good water quality.

Level I monitoring was conducted at Lake Wilderness during the 2014 water year. Level I volunteers collected data for precipitation, lake level, water temperature and Secchi depth (water clarity) on a weekly basis year round. The main emphasis of this effort was to observe the hydrological balance between the lake and its watershed. Lake level was noted from a staff plate fixed to a dock on the south side of Lake Wilderness. There was no level I monitoring on Pipe or Lucerne Lakes.

Level II monitoring occurred on Wilderness, Pipe and Lucerne lakes twice monthly from May- October. In addition to measuring water temperature and Secchi depth, Level II monitors collected water samples to be analyzed at the King County Environmental Lab (KCEL) for various chemical parameters. The main emphases in this effort were nutrient balances and algal concentrations in the lake. Level II data were collected at a mid-lake sampling station, located at the deepest point in the lake. All volunteers routinely made observations regarding recreational lake use, algal blooms, and special weather conditions that may have had an effect on measurements.

Lake monitors were provided with training, equipment, and technical assistance on an ongoing basis. They were also offered the option of attending the annual Lake Stewardship Program training workshop held in late April. Level I data was reported to King County on a quarterly basis for quality control assessment and upload to the Small Lakes Data and Information webpage (http://green2.kingcounty.gov/SmallLakes). Level II samples collected by volunteers were routinely picked up by Lake Stewardship staff for delivery to KCEL, and data was analyzed and uploaded to the web upon receipt from the lab.

Specific objectives of the monitoring program include: (1) gathering baseline data with the intent of assessing long-term trends; (2) defining seasonal and water column variability; (3) identifying potential concerns, and proposing possible management solutions when feasible; (4) educating lake residents, lake users, and policy makers regarding lake water quality; and (5) providing a foundation of understanding the nature and character of the smaller lakes in King County.

The discussion in this report focuses on the 2014 water year. Specific data used to generate the charts in this report can be downloaded from the King County Lake small lakes data website at:
http://your.kingcounty.gov/dnrp/wlr/water-resources/small-lakes/data/default.aspx

Data can also be provided in the form of excel files upon request.

Further introduction and a discussion of the philosophy of the volunteer lake monitoring program and the parameters measured can be found on-line at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/waterres/smlakes/2006_Intro.pdf

2.0. WHAT WE MEASURE AND WHY

Secchi depth/transparency is a common method used to assess and compare water clarity over time. It is a measure of the water depth at which a black and white disk disappears from view when lowered from the water surface. Readings can be affected by suspended particles in the water, such as from sediment or algae. Secchi depth measurements were collected at the mid-lake sampling station bi-weekly from May through October (Level II volunteers), and from a dock on the south side of the lake on a weekly basis throughout the year (Level I volunteers).

Precipitation is measured using a plastic volumetric rain gauge mounted in an open area. This data is collected daily by Level I volunteers daily and is used to relate precipitation to lake level.

Lake level is tracked by Level I volunteers using a staff plate mounted to a fixed dock or other structure. This information is used to track lake level changes both seasonally and over time and can be related to precipitation levels in the basin.

Water temperature, as with Secchi depth, is measured by Level I volunteers year-round, and by Level II volunteers from May through October at a depth of 1 meter. On two occasions during the Level II sample season, temperature is measured at additional depths (water column profile). Temperature is important in many biological processes in a lake, can affect rates of plant and algal growth, and can create or inhibit ideal habitat for fish and other aquatic life.

Phosphorus and **nitrogen** are naturally occurring elements necessary for growth and reproduction in both plants and animals. However, many activities associated with residential development can increase these nutrients in water beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is often the nutrient in least supply, meaning that biological productivity is most often limited by the amount of available phosphorus in the water. Increases in phosphorus can lead to more frequent and dense algae blooms – a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by cyanobacteria (bluegreen algae) that can produce toxins.

Samples to be analyzed for total phosphorus (TP) and total nitrogen (TN) were collected by Level II volunteers at a depth of one meter during the months of May through October. Samples from additional depths were collected in May and August (water column profiles).

The **ratio of total nitrogen to total phosphorus (N:P)** can be used to determine if nutrient conditions are favorable for the growth of cyanobacteria. When N:P ratios are near or below 25, nitrogen is as likely to be the limiting nutrient as phosphorus. Certain cyanobacteria species may then be able to dominate the algal community due to their ability to “fix” nitrogen (convert it to a form more easily utilized for nutrition).

Chlorophyll-*a* concentration serves as an indicator of the abundance of phytoplankton (algae) in a lake. Chlorophyll-*a* is a pigment that is necessary for algae to photosynthesize and store energy. While all algal cells contain some chlorophyll-*a*, the amount varies depending on the species. For example, some cyanobacteria have other light-catching pigments, and little chlorophyll-*a* compared to other planktonic species, so chlorophyll-*a* levels may not always correlate with the abundance of cyanobacteria.

Pheophytin is a product of chlorophyll decomposition and is generally measured along with chlorophyll-*a* as an indicator of how fresh or viable the phytoplankton in the sample are. Bottom sediments will contain a large amounts of pheophytin compared to chlorophyll-*a*, while actively-growing algae from the water column will have very little pheophytin present. Chlorophyll-*a*/pheophytin samples were collected at a depth of 1 meter from May through October, and at additional depths in May and August (water column profiles).

A common method of tracking water quality trends in lakes is by calculating the **Trophic State Index (TSI)**, developed and first presented by Robert Carlson (1977). TSI values predict the biological productivity of the lake based on three parameters: water clarity (Secchi), total phosphorus, and chlorophyll-*a.* The values are scaled from 0 to 100, which allow them to be used for comparisons of water quality over time and between lakes. If all of the assumptions about a lake ecosystem are met, the three TSI values should be very close together for a particular lake. When they are far apart in value, lake conditions and measurements should be examined to understand what special conditions exist at the lake that are different from Carlson's assumptions, or if data should be evaluated for errors. The index assumes that higher nutrient availability equates to more phytoplankton production, and more phytoplankton particles in the water lead to decreased clarity, and vice versa.

The Index relates to three commonly used categories of productivity:

- *oligotrophic* (low productivity, below 40 on the TSI scale - low in nutrient concentrations, small amount of algae growth);
- *mesotrophic* (moderate productivity, between 40 and 50 on TSI scale – moderate nutrient concentrations, moderate growth of algae growth); and
- *eutrophic* (high productivity, above 50 – high nutrient concentrations, high level of algae growth).

A lake may fall into any of these categories naturally, depending on the conditions in the watershed, climate characteristics, vegetation, rock and soil types, as well as the shape and volume characteristics of the lake basin. Activities of people, such as land development, sanitary waste systems, and agricultural practices can also increase productivity, which is known as "cultural eutrophication."

Water column profiles are collected on two occasions during the summer sampling season, water is collected from three depths at the mid-lake sampling station: 1 meter, the

middle depth of the water column, and 1 meter from the lake bottom. These **water column profiles** provide information about how temperature, nutrients, and other variables change at different depths. Additional parameters are also measured during these profile events. These include ammonia (NH_3), nitrate/nitrite (NO_2/NO_3), orthophosphate (OPO_4), alkalinity, and water color (UV254). Ammonia, a form of nitrogen, is often found in deep water at higher levels when oxygen is low, as are nitrate/nitrite and orthophosphate. Total alkalinity illustrates the buffering capacity of a lake, or the ability to resist changes in pH. UV254 is the wavelength at which dissolved organic molecules absorb light and is used to measure the amount of color in the water related to organic compounds.

3.0. RESULTS LAKE LUCERNE

While a small number of samples were taken in the 1970s, consistent volunteer monitoring began at Lake Lucerne in the 1980s and continued through 2014, with only one gap in the early 1990s. The data indicate that this 16-acre lake is relatively low in primary productivity (oligotrophic - mesotrophic) with good water quality.

Lake Lucerne has no public access boat launch, but does have a history of both milfoil and hydrilla infestations for which eradication efforts have been underway since 1995. Milfoil has been eradicated, and the last hydrilla plant was found eight years ago. Lake Lucerne has not been treated with the herbicide fluridone (Sonar PR ™) since 2008. The year 2014 was the sixth year since the last treatment in adjoining Pipe Lake. Recently, a healthy mixture of native *Potamogeton* species has recolonized the bottom of both lakes. Lake users and residents should keep a close eye on aquatic plants growing nearshore to catch new or expanding patches of noxious weeds, but encourage native species that provide good habitat for fish and other aquatic animals.

3.1 Physical Parameters

No precipitation or lake level data were collected for Lake Lucerne in 2014.

Volunteers collected Secchi depth transparency and 1m temperature data from early May through late October during the Level II monitoring season when volunteers collect water samples for laboratory analysis. Secchi transparency ranged between 4.0 and 7 meters (m) from May through October (Figure 1), averaging 5.4 m, which is fairly typical clarity for Lake Lucerne (although slightly clearer than 2013).

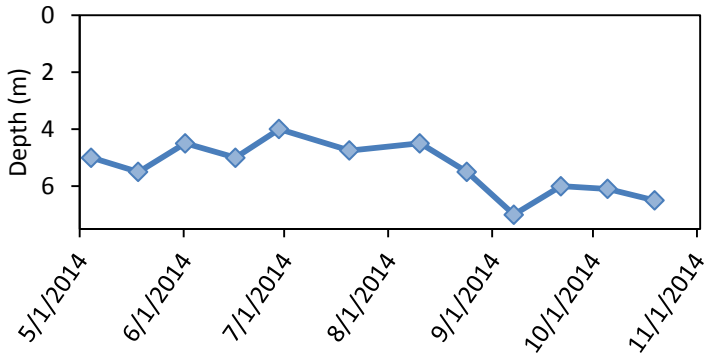

Figure 1. 2014 Lake Lucerne Secchi depth[1].

[1] Note inverted Y axis

Surface water temperatures reached a maximum of 26 degrees Celsius, with an average of 21.4 degrees (Figure 2) over the period, which was slightly cooler than in 2013. The temperature increased gradually over the summer with a slight decrease in late July before beginning to cool in mid-August.

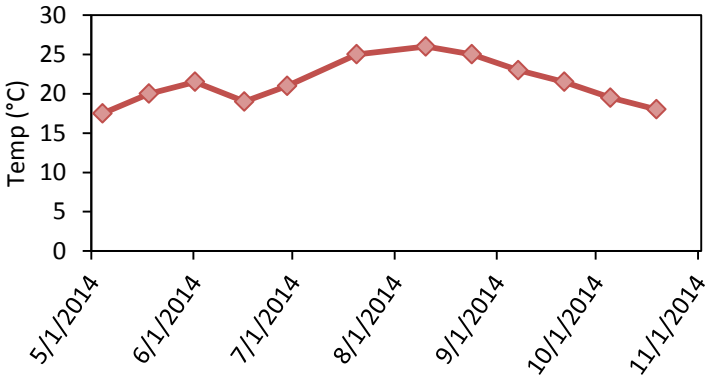

Figure 2. 2014 Lake Lucerne temperature

Mean summer water temperatures over the years that Lake Lucerne has been monitored have varied (Figure 3), but to-date there is no trend toward a directional change over time. Year to year variability was particularly evident by the warm years of 2009, 2012, 2013 and 2014when seasonal averages were higher than in other years in the series.

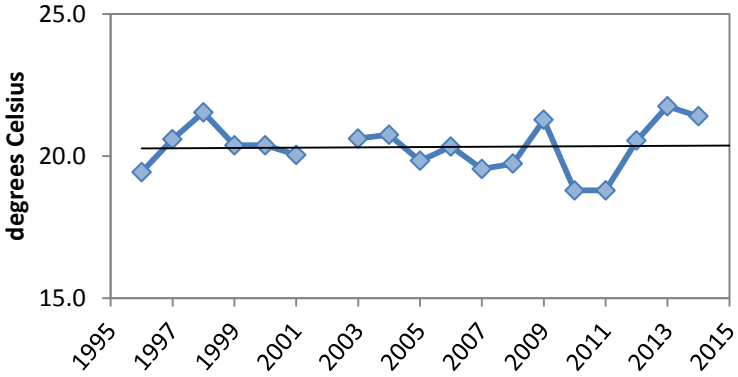

Figure 3. Mean May – October 1m water temperatures for Lake Lucerne, 1996-2014

3.2 Nutrient and Chlorophyll Analysis

Total nitrogen (TN) concentrations began slightly higher in spring and tapered throughout the summer with a slight increase in late September. Total phosphorus (TP) was generally stable at low levels throughout the season with little variability (Figure 4).

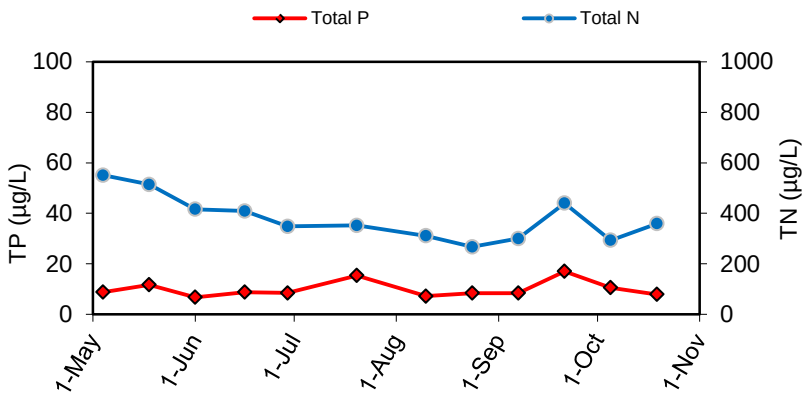

Figure 4. 2014 Lake Lucerne total phosphorus and total nitrogen concentrations

Total phosphorus and total nitrogen concentrations were quite variable throughout the sampling season. N:P ratios ranged from 62.6 to 22.9. The ratio remained above 24 for 11 of the 12 sampling events during the summer which suggests generally poor conditions for the growth of nuisance bluegreen algae at Lake Lucerne (Figure 5). The lowest N:P value was found in late July when an uptick in phosphorus was not matched by an equivalent increase in nitrogen.

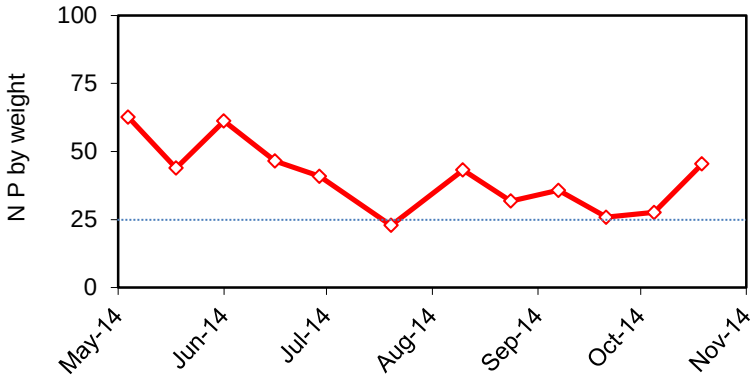

Figure 5. 2014 Lake Lucerne N:P ratio. Values below the blue line indicate a potential nutrient advantage for cyanobacteria

Since 1995 total phosphorus concentrations at Lake Lucerne appear to be on the decline (figure 6). A regression line shows and R^2 of 0.4186 which indicates that 41% of the data show a downward trend in total phosphorus concentrations since sampling began.

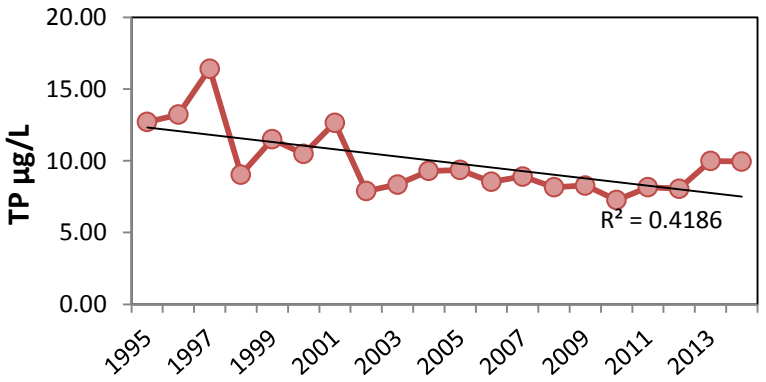

Figure 6. Mean total phosphorus concentrations (µg/L) in Lake Lucerne, 1995-2014

Chlorophyll *a* concentrations remained low throughout the season (Figure 7), with little change. Pheophytin, which is a degradation product of chlorophyll, was at levels below detection throughout the entire period.

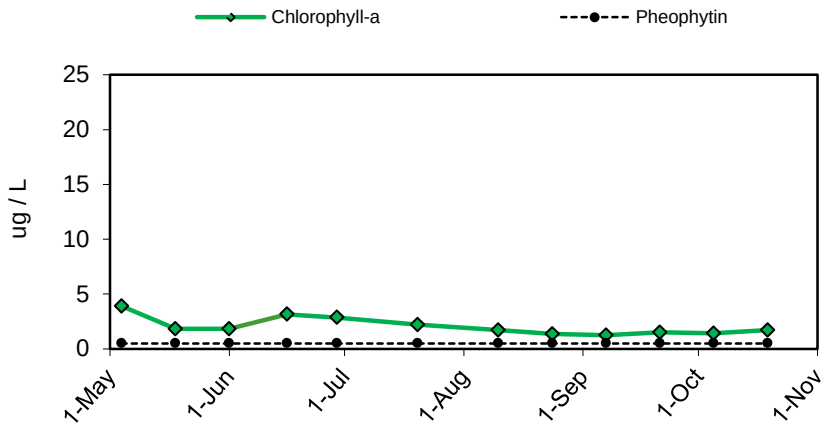

Figure 7. 2014 Lake Lucerne chlorophyll-*a* and pheophytin concentrations

3.3 Water Column Profiles

Profile temperature data indicate that thermal stratification was present by mid-May and persisted through the summer (Table 1).

Table 1. 2014 Lake Lucerne profile sample results. Secchi and depth in meters. Temperature in degrees Celsius. Chlorophyll and pheophytin in µg/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 in absorption units. Sample values below minimum detection level (MDL) are marked in bold, red with the MDL value

Lake	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NO2-3	NH4	Total P	OPO4	UV254	Total Alk
Lucerne	05/18/14	5.5	1	20	1.83	<MDL	0.514	0.200	0.023	0.0117	0.001	0.085	29
Lucerne	05/18/14		5	10.5	4.21	<MDL	0.510			0.0113			
Lucerne	05/18/14		9	8			0.482	0.232	0.005	0.0137	0.002		
Lucerne	8/24/14	5.5	1	25	1.36	<MDL	0.267	<MDL	0.004	0.0084	0.001	0.077	31.6
Lucerne	8/24/14		5	20	3.57	<MDL	0.264			0.0083			
Lucerne	8/24/14		9	10			0.442	<MDL	<MDL	0.0334	0.001		

Concentrations of total phosphorus (Total P) were fairly consistent across depths for the May profile event while the August profile showed phosphorus concentrations nearly 40 times higher than in surface waters. The amount of orthophosphate (OPO4) did not follow the same pattern, indicating little release of phosphorus from the sediments back into the lake water, which is an indicator of internal loading. Ammonia (NH4) values were lower in the deep water than in the epilimnion (surface water) once again indicating little sediment release of phosphorus during stratification.

Chlorophyll *a* data (Chlor-a) indicate that algae were more abundant in the mid-water column on both dates, but with degraded chlorophyll (pheophytin) present in measurable amounts only in August at the mid depth. The lower the particulate (algae primarily), the greater the water clarity so the Secchi transparency throughout this period directly relates to the low chlorophyll values in the surface water.

Alkalinity, also known as acid neutralizing capacity or buffering capacity, was moderately low, meaning the lake remains somewhat sensitive to acidification. The water color (UV254) was very low, indicating that dissolved organic carbon was not abundant in the lake water.

3.4 TSI Ratings

The 2014 TSI value for Secchi was on the threshold between oligotrophy and mesotrophy, while the TSI values for chlorophyll and total phosphorus were significantly lower (Figure 8). The relationship between Secchi and total phosphorus indicators have held relatively steady for the past 10 years, with phosphorus predicting less productivity than the Secchi values. The chlorophyll TSI has been more variable between years, but has

generally been between the other two values. However, all are in the same general level of algal productivity at or below the mesotrophic threshold.

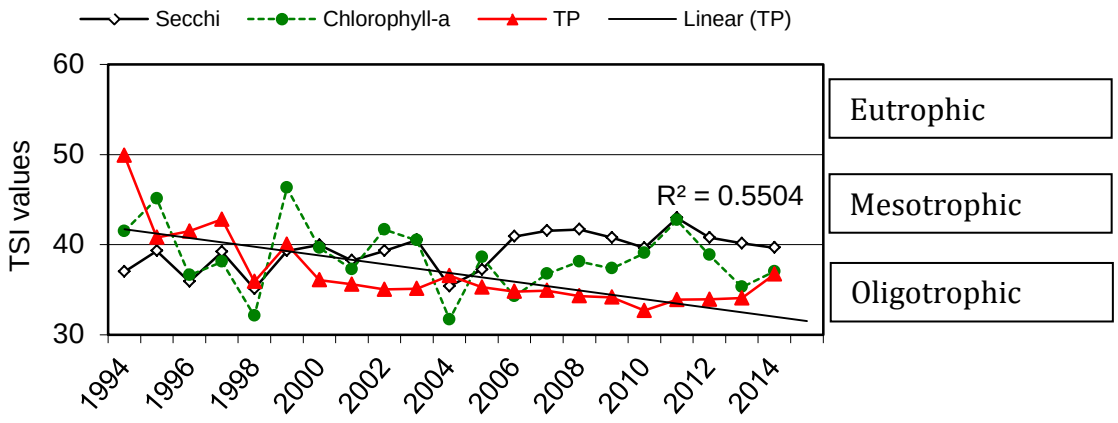

Figure 8. Lake Lucerne Trophic State Indicators, 1994-2014

A trend line run through the TSI-TP indicator values since 1994 shows a significant decreasing trend over time. The correlation coefficient of 0.55 indicates that 55% of the variability in the data can be explained by a downward trend over time.

3.5 Conclusions

Based on monitoring data, overall water quality in Lake Lucerne appears to have been stable over the period measured. Generally high N: P ratios indicate conditions are not favorable for nuisance bluegreen algae blooms most of the time.

Residential development continues in the Lake Lucerne watershed, and continuing to monitor the lake will ensure that impacts from stormwater will be noticed if they begin to have negative effects on the water quality of the lake.

With the completion of herbicide treatments as part of the hydrilla eradication project in Lake Lucerne, the city and the residents around the lake should be vigilant in looking for invasive aquatic plants colonizing the lake, such as Eurasian watermilfoil, in addition to the return of native aquatic plants.

4.0. PIPE LAKE

Volunteer monitoring began at Pipe Lake in the 1970s and has been continuous since the early 1990s. The data indicate this 52-acre lake is low in primary productivity (high oligotrophic) with very good water quality. Approximately 55% of the shoreline of Pipe Lake is in the City of Maple Valley. The remainder is in the City of Covington.

Pipe Lake has no public access boat launch, but there is a community boat launch at Cherokee Bay. The lake is connected to Lake Lucerne by a short, shallow channel and has a history of both milfoil and hydrilla infestations for which eradication efforts have been funded by government agencies since 1995. Eurasian watermilfoil has been eradicated, and the last plant of hydrilla was found in 2006. The year 2014 is the fifth in which no herbicide was applied to the lake. Residents should watch aquatic plants growing nearshore to catch growing patches of milfoil, hydrilla or other noxious weeds. Since 2006 no hydrilla has been found and no other submerged noxious aquatic weeds have been identified, although native plants are returning and providing good habitat for fish and other wildlife.

4.1 Physical Parameters

No level I precipitation or lake level data was collected for Pipe Lake in 2014.

Volunteers collected Secchi transparency and temperature data from early May through late October during the Level II monitoring season during which volunteers collect water samples for laboratory analysis. Secchi transparency from late May through October ranged from 5.0 to 7.5 m, averaging 6.4 m, which placed it as the clearest lake monitored during the 2014 water year (Figure 9). This was an increase from 2013 when the average was 5.8 m.

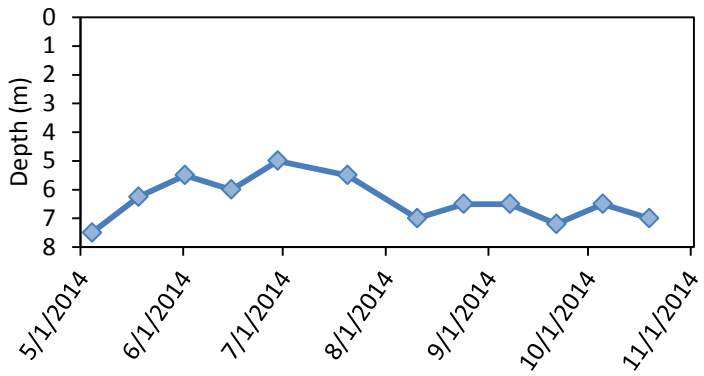

Figure 9. 2014 Pipe Lake Secchi depth[2].

[2] Note inverted Y-axis

Water temperatures during the same period ranged from 18.0 degrees Celsius to a peak of 26.0 degrees Celsius (Figure 10) with an average of 21.6, which was the warmest average of all lakes monitored in 2014, as well as warmer than the previous year (21.0 °C). The temperature at 1 meter rose gradually from May until August and then gradually decreased as air temperatures cooled until the last sample event in October.

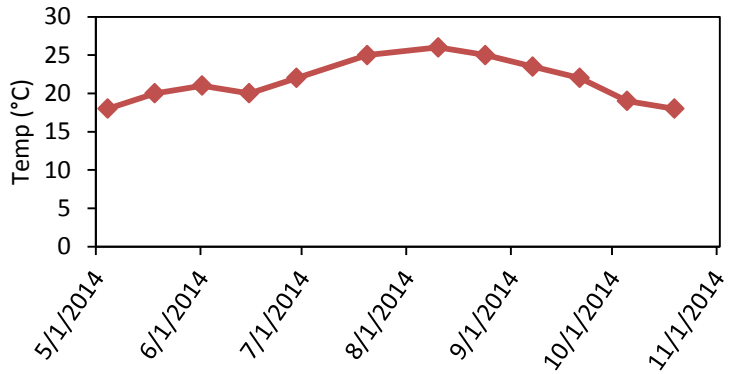

Figure 10. 2014 Pipe Lake temperature at 1 m

Mean summer 1 m water temperatures over the years of monitoring in Pipe Lake have varied between years, particularly during the early years of measurement (Figure 11), and after a period of relative stability between 2006 and 2012, the average increased sharply in 2013 and 2014, due to the long period of warm surface temperatures shown in Figure 10. However, to-date, the summer average temperature shows no statistically strong trend of change through time. A regression line run through all of the yearly averages show a slight increase in temperature over time with a weak correlation coefficient of 0.22.

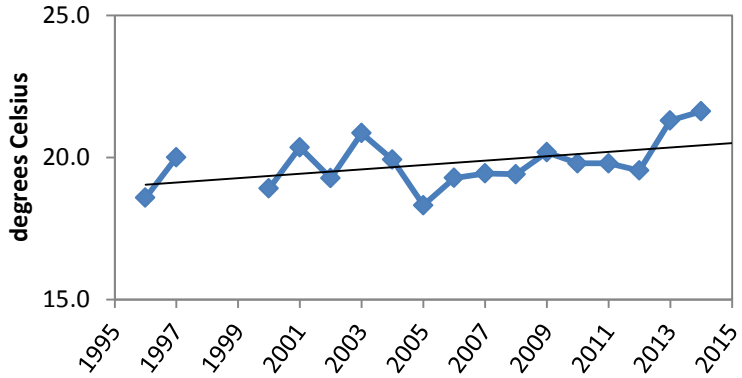

Figure 11. Mean May – October 1m water temperatures for Pipe Lake over time

4.2 Nutrient and Chlorophyll Analysis

Total nitrogen decreased throughout the summer from May until October (Figure 12) with very slight upticks during the second May sampling day and the first October sample. Total phosphorus remained low through the entire season, with a similar pattern and only small variations between dates. Note that on the chart, the TN scale is 10 times the value of the TP scale.

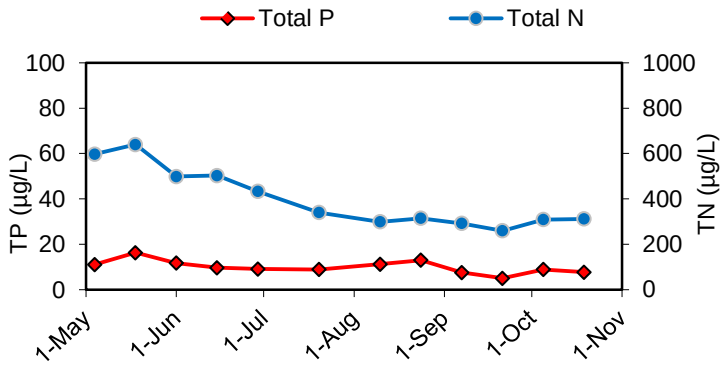

Figure 12. 2014 Pipe Lake total phosphorus and total nitrogen concentrations

The N:P ratio ranged from 24.2 to 53.8, averaging 40.8, which is higher than the 2013 average, and indicates no general advantage for nuisance cyanobacterial growth in terms of nutrient ratios (Figure 13). Note that the ratio was at its lowest during the second August sample and was above 25 for all of the other sampling dates. Lakes in the Puget lowlands often support large amounts of cyanobacteria in the fall. However, the overall low values of phosphorus in Pipe Lake would be likely to keep abundance low even if cyanobacteria were present.

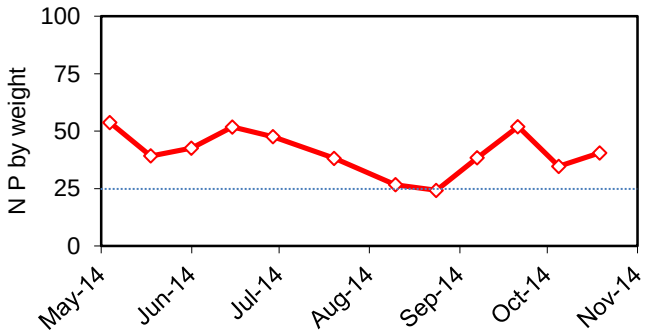

Figure 13. 2014 Pipe Lake N:P ratio. Values below the blue line indicate a potential nutrient advantage for cyanobacteria

Since 1995 Pipe Lake has seen a downward trend in total phosphorus concentrations (figure 14). A regression line run through the data has an R^2 value of 0.3544 indicating that 34% of the variability can be explained by a downward trend. Since 1998 the phosphorus concentrations have seen little year to year variability with slight increases seen in 2003 and 2008.

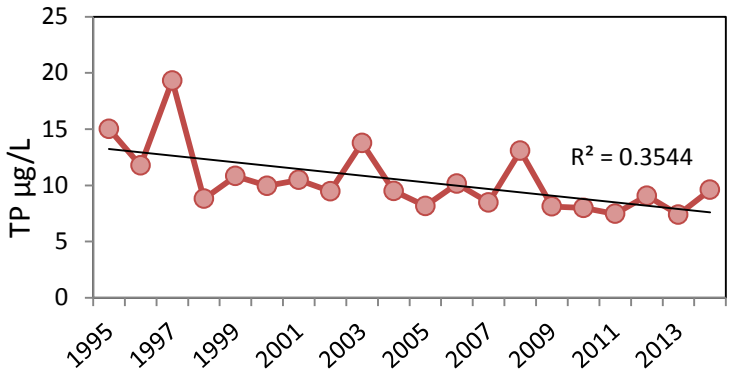

Figure 14. Total phosphorus concentrations in Pipe Lake, 1995-2014

The chlorophyll-*a* level rose a little in mid-June, but remained very low through the season with the highest value being collected in late October (Figure 15). Pheophytin, which is a degradation product of chlorophyll, stayed below the minimum detection level until September, when it rose slightly. This indicates that phytoplankton concentrations remained generally low in Pipe Lake throughout the summer, climbing slightly in fall with thermal mixing, which is consistent with phosphorus limitation. This is very similar to what was observed in Lake Lucerne in 2013.

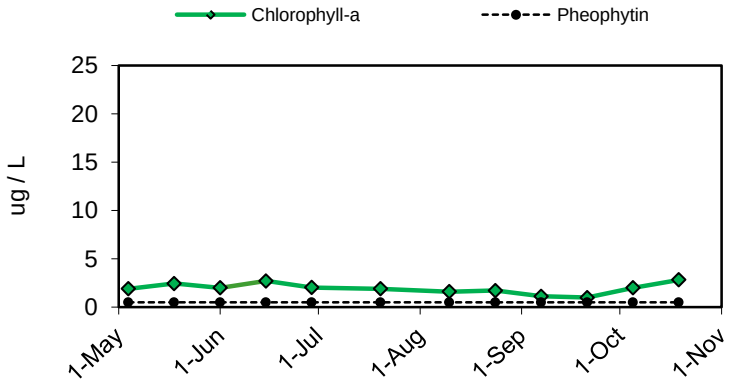

Figure 15. 2014 Pipe Lake chlorophyll-*a* and pheophytin concentrations

Profile water temperatures collected in May indicated stratification was present at that time, and it was the same in late August (Table 2).

The May profile showed a small increase in total phosphorus, orthophosphate (OPO4), in the bottom water, but all had risen considerably by August. This indicates that low oxygen conditions were established in the bottom water of Pipe Lake by late summer, resulting in some phosphorus release from the sediments that can contribute to internal loading.

Chlorophyll-*a* data indicated that shallow water algae were slightly higher in May than August, with more present in the middle depth than at the surface on both occasions. The small amounts of chlorophyll correlated with the high Secchi readings that indicate very clear water.

Table 2. 2014 Pipe Lake profile sample results. Secchi and depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in µg/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 in absorption units. Sample values below minimum detection level (MDL) are marked in bold, red with the MDL value

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NO2-3	NH4	Total P	OPO4	UV254	Total Alk
Pipe	05/18/14	6.25	1	20	2.45	<MDL	0.640	0.225	0.020	0.0163	0.001	0.088	27.8
Pipe	05/18/14		10	8.5	3.11	<MDL	0.569			0.0108			
Pipe	05/18/14		19	6			0.571	0.318	0.015	0.0287	0.006		
Pipe	8/24/14	6.5	1	25	1.72	<MDL	0.315	<MDL	0.008	0.0130	0.001	0.0722	29.4
Pipe	8/25/14		10	18	7.66	<MDL	0.485			0.0115			
Pipe	8/26/14		19	5			2.070	<MDL	1.740	0.2450	0.092		

Alkalinity, was relatively low and very similar to adjoining Lake Lucerne, indicating that the lake is somewhat sensitive to pH changes. Water color measurements (UV254) also were very low, contributing to water clarity and indicating that dissolved organic carbon was not an important component of the lake water.

4.3 TSI Ratings

The 2014 TSI indicators for chlorophyll *a* and total phosphorus were very close to each other in the oligotrophic range. The TSI–Secchi indicator was just below the mesotrophic threshold (Figure 16). Pipe Lake has been solidly in the range for oligotrophy for some time, and it appears to have been stable since 2001, with minor variations from year to year.

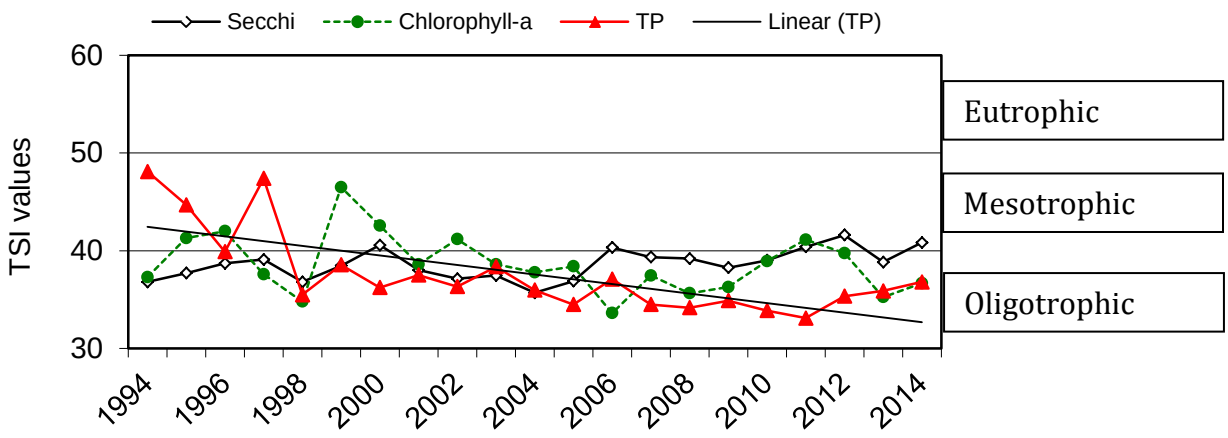

Figure 16. Pipe Lake Trophic State Indicators, 1994-2014

A trend line run through the TSI-TP indicator values since 1998 shows a decreasing trend over time (Figure 15). A correlation coefficient (R^2) of 0.22 indicates that 22% of the variability over time can be explained by the trend. This is similar to the decreasing trend observed in Lake Lucerne, although it is not as strong of a correlation. However, it does support the idea that stormwater controls connected to residential development in the area have been successful to-date in preventing an increase in nutrient delivery to these two lakes.

4.4 Conclusions

Based on monitoring data, water quality in Pipe Lake appears to have been stable over the last decade or even longer, although measurements were more variable in the early years of monitoring. The N:P ratios indicate conditions in the lake are not generally favorable for nuisance bluegreen algae blooms. To-date, the data suggest that recent residential construction in the watershed has not increased nutrient inputs that could impair water quality.

With the sunset of the hydrilla eradication project in the lakes, the city and the residents around the lake should be vigilant in looking for invasive aquatic plants, such as Eurasian watermilfoil and Hydrilla, as the aquatic vegetation returns to the lake.

5.0. LAKE WILDERNESS

Volunteer monitoring began at Lake Wilderness in the mid-1970s and has continued through 2014, with few gaps in the record. The data indicate this 67-acre lake is moderate in primary productivity (mesotrophic) with generally good water quality.

Of the three lakes in Maple Valley, Wilderness is the only one that has an active "Level I" volunteer, whose monitoring consists of daily precipitation and water level readings, as well as weekly measurements of water temperature and clarity throughout the entire water year.

Lake Wilderness has a public access boat launch and a large city park with a bathing beach, as well as a regional public trail that occupies much of the east shoreline. There is a history of Eurasian watermilfoil infestation, with monitoring and control activities funded by the City of Maple Valley and additional monitoring provided by the Lake Wilderness Preservation Association, a local non-profit. Residents have been active stewards of the lake through the years and should continue to watch for new patches of Eurasian milfoil, as well as other noxious weeds that might invade the lake, such as Brazilian elodea.

5.1 Physical Parameters

Excellent records of precipitation and water level were kept over the year (Figure 17). The lake level, which generally follows a regional pattern of winter high – summer low stands, increased in early winter and then began to decrease by late April. While there was a steady decrease in the lake level through the summer, overall it was fairly steady throughout the year (similar to 2013). There was a difference of only 33 cm between the highest and lowest daily stands during the year, distinctly less than the difference recorded for many previous years.

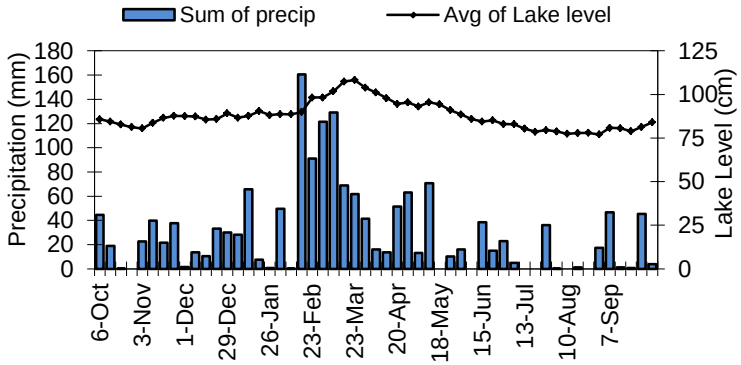

Figure 17. Lake Wilderness Water Year 2014 weekly water levels and precipitation

Secchi transparency ranged from 2.3 to 8.0 m through the year (Figure 18). The summer average of 5.0 m placed it as the fifth clearest lake of the 33 small lakes monitored in 2014.

Water clarity fluctuated periodically throughout the season. The low spring readings were the result of an algae bloom that was similar in timing to the *Aphanizomenon* bloom in January of 2013. Summer conditions appeared to be slightly less clear than in 2013.

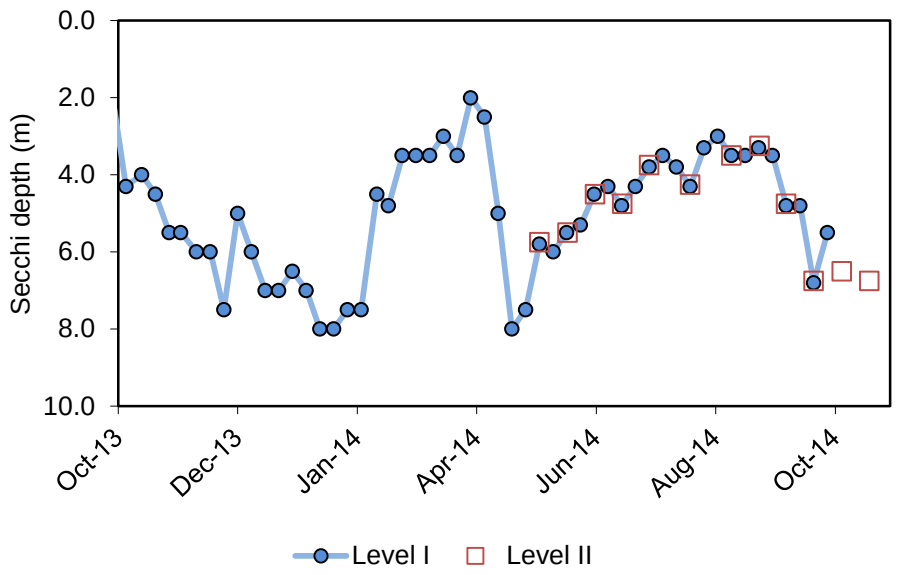

Figure 18. Lake Wilderness water year 2014 Secchi transparency[3].

Annual water temperatures ranged from 3.0 to 25.5 degrees Celsius (Figure 19), with a summer average of 20.0 degrees Celsius, placing Lake Wilderness water clarity in the middle third of the 33 lakes monitored in 2014. These temperatures were very similar to the temperatures recorded in 2013.

[3] Note inverted Y-axis

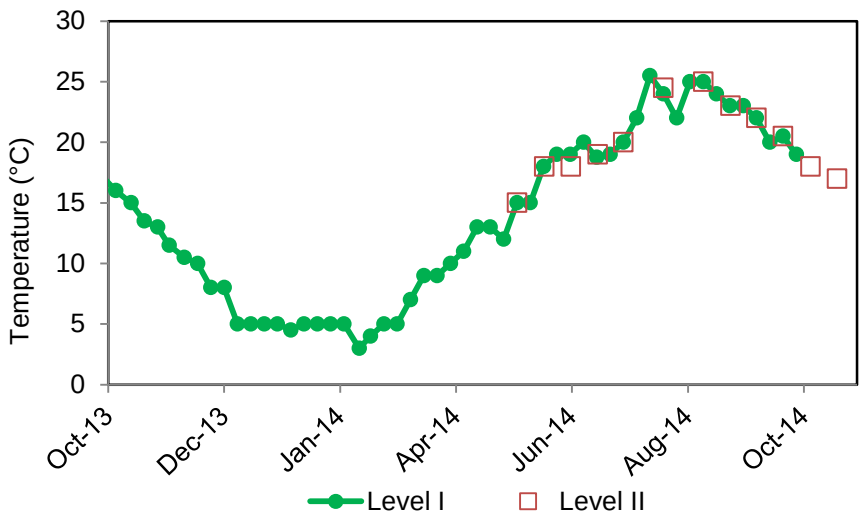

Figure 19. Lake Wilderness water year 2014 1m Temperature

Mean summer water temperatures in Lake Wilderness have varied between years (Figure 20), but to-date show no statistically strong trend toward change through time. A trend line run through the data is flat with a very low correlation coefficient (R^2 of 0.01), suggesting variation without a directional change through time.

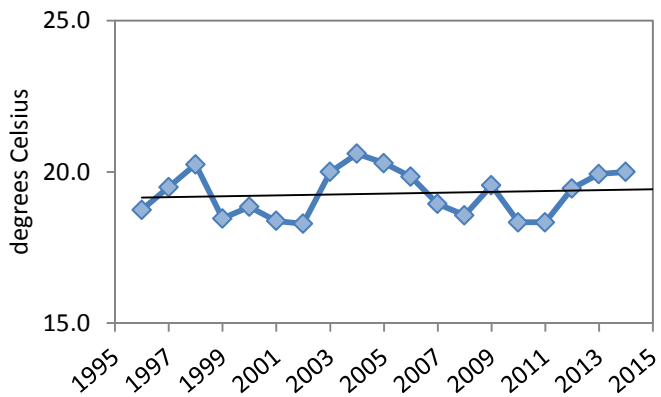

Figure 20. Mean May – October 1m water temperatures in Lake Wilderness, 1996-2014

5.2 Nutrients and Chlorophyll

Total nitrogen started high and decreased from May through August, after which it began increasing slowly through mid-September before slowly decreasing and then slightly rising during the final samples in October (Figure 21). Total phosphorus dropped after the first sample date and remained low until October when it began to increase concurrently with nitrogen. Note that nitrogen scale is 10 times higher than for phosphorus.

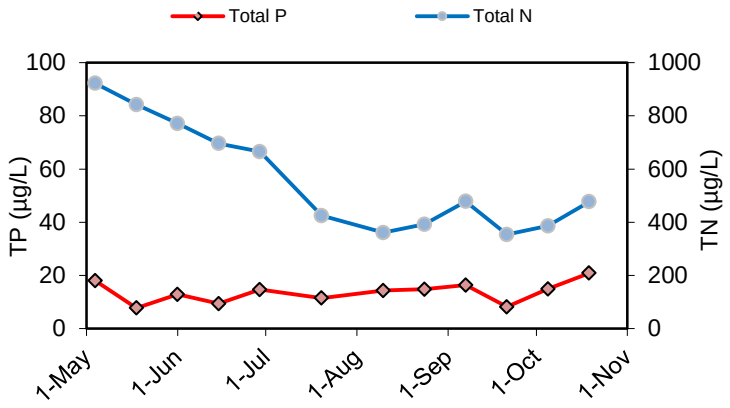

Figure 21. 2014 Lake Wilderness total phosphorus and total nitrogen concentrations

The N:P ratio ranged from 22.8 to 107.9, averaging 45.7 over the whole season (Figure 22), but the steady decrease from a maximum in late May to values below 25 in September show that nutrient conditions became hospitable for cyanobacteria in the fall, similar to previous years.

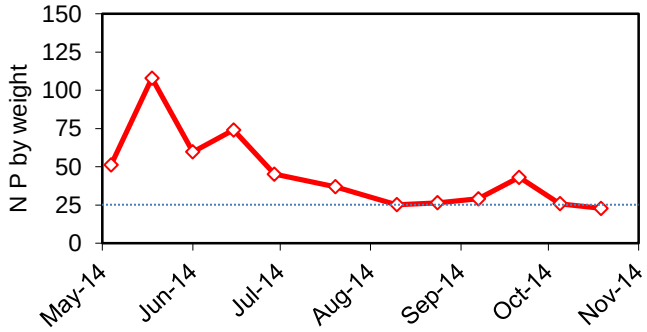

Figure 22. 2014 Lake Wilderness N:P ratio. Values below the blue line indicate a potential nutrient advantage for cyanobacteria

Since 1994 Lake Wilderness has seen a decrease in annual mean total phosphorus concentrations (Figure 23). A regression line run through the data gives an R^2 of 0.6124 indicating that 61% of the variability can be explained as a downward trend. Phosphorus concentrations have steadily deceased since 1994 with slight increases seen in 2001 and 2006.

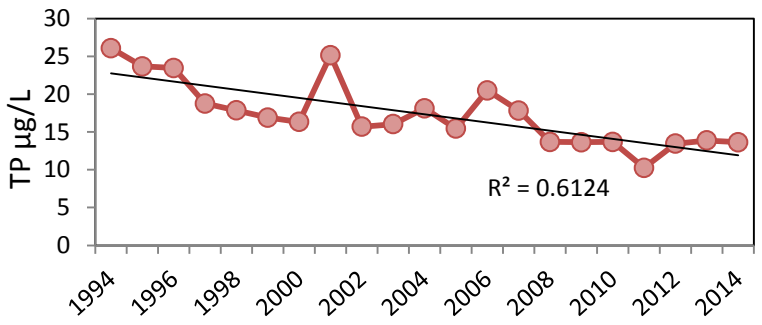

Figure 23. Lake Wilderness annual mean total phosphorus concentrations from 1994-2014

Chlorophyll-*a* was low throughout most of the sampling timeframe with an increase from late May until July before it decreased through the rest of the season(Figure 24). Pheophytin, which is a by-product of decomposing chlorophyll, was below the method detection limit for every sample.

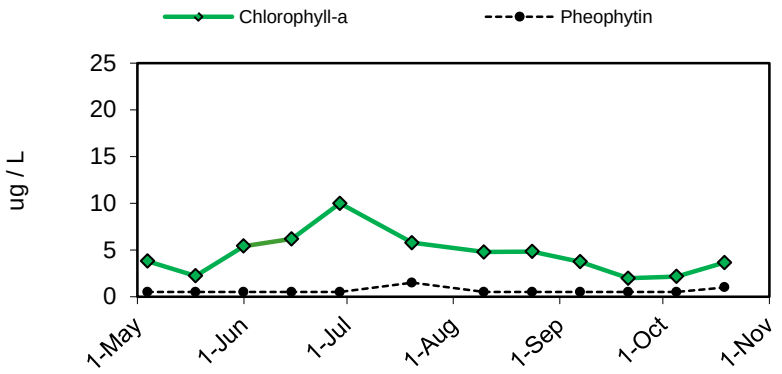

Figure 24. 2014 Lake Wilderness chlorophyll *a* and pheophytin concentrations

5.3 Cyanobacteria Toxins

Because of Lake Wilderness has a history of occasional toxin-producing bluegreen (cyanobacteria) blooms, regular surveillance of the lake is carried out by residents, City of Maple Valley staff, and the King County field crew who sample the beach for bacteria during the summer. In 2014 only a single algae bloom sample was submitted under the Washington State Department of Ecology's harmful algal bloom program. The sample was submitted on November 20th and had anatoxin (cyanobacteria produced nerve toxin) values below the method detection limit and a microcystin (cyanobacteria produced liver toxin) concentration of 0.4µg/l which is well below the state provisional guideline of 6µg/L.

5.4 Water Column Profiles

Profile temperature data indicate that thermal stratification was present early in the season and persisted through the summer (Table 3).

Table 3. 2014 Lake Wilderness profile sample results. Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in µg/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 in absorption units. Sample values below minimum detection level (MDL) are marked in bold, red with the MDL value

Lake	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NO2-3	NH4	Total P	OPO4	UV254	Total Alk
Wilderness	05/18/14	5.5	1	18	2.23	<MDL	0.842	0.547	0.022	0.0078		0.039	41.3
Wilderness	05/18/14		4	15	4.23	<MDL	1.040			0.0134			
Wilderness	05/18/14		8	10	7.27	3.500	0.755	0.230	0.219	0.0736	0.014		
Wilderness	8/24/14	3.25	1	23	4.84	<MDL	0.392	<MDL	0.006	0.0148	0.001	0.0429	44.3
Wilderness	8/24/14		4	22	5.61	<MDL	0.352			0.0149			
Wilderness	8/24/14		8	11	67	TA	0.821	0.142	0.012	0.0893	0.004		

In the May profile event, ammonia and total phosphorus were considerably higher in the deep water sample, which suggests that low oxygen conditions may have started to form. However, the very high total phosphorus and nitrogen values in the deep water in August were not accompanied by a high orthophosphate value at depth, suggesting that the high phosphorus may not have been due to internal loading of phosphorus from the sediments into the lake water. While chlorophyll was fairly evenly distributed through the water column in May, it was very high in the deeper water in August. This also supports the notion that benthic material may have been included in the deep water sample, and the material from the bottom may also have been the source of the high phosphorus values.

Alkalinity, also known as acid neutralizing capacity, was higher than in nearby Pipe and Lucerne Lakes, suggesting that water coming into the lake in the Wilderness basin contains more dissolved salts that increase the buffering capacity of the lake water.

Water color (UV254) was lower than Pipe and Lucerne, contributing to the good water clarity of Lake Wilderness and indicating that little dissolved organic carbon was coming in from the surrounding watershed. Wilderness had the third lowest UV254 measurements of all the lakes monitored in 2014.

5.5 TSI Ratings

In 2014, the TSI for all three indicators were close together with total phosphorus and Secchi each being lower than chlorophyll (Figure 25). All three indicators place the water quality at the low end of mesotrophic. Since 2001 there appears to be an overall downward trend in the phosphorus TSI (towards less phosphorus in the water), accompanied by an upward trend in the TSI Secchi (towards less clarity).

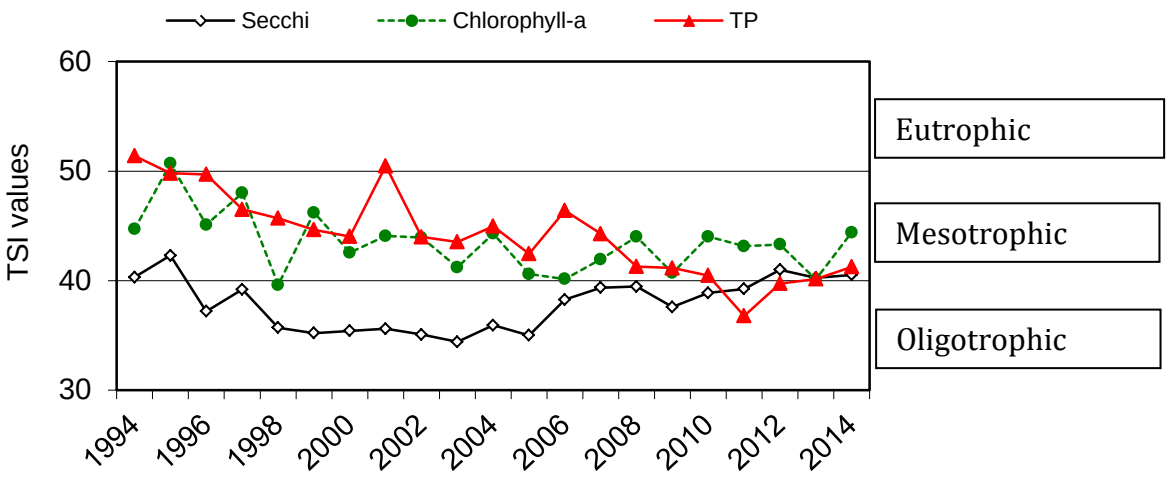

Figure 25. Lake Wilderness Trophic State Indicators, 1994-2014

5.6 Conclusions

Based on the monitoring data, although overall water quality in Lake Wilderness may be fairly stable over the period measured, there is a downward trend in TSI phosphorus and an upward trend in TSI-Secchi transparency. This makes it difficult to project into the future, and continued monitoring may be needed to track where the lake may be heading over time. While N: P ratios are very high in spring, they decrease steadily to low values in the late summer and fall that indicates conditions can be favorable for nuisance cyanobacteria.

One cyanobacterial bloom was sampled in November of 2014. This bloom had very low concentrations of both anatoxin and microcystin. Close monitoring of algae blooms at the lake, particularly during recreational seasons, should continue to determine how frequently the blooms at the lake produce toxins and how often the concentrations are above the draft state guidelines for recreational activities.