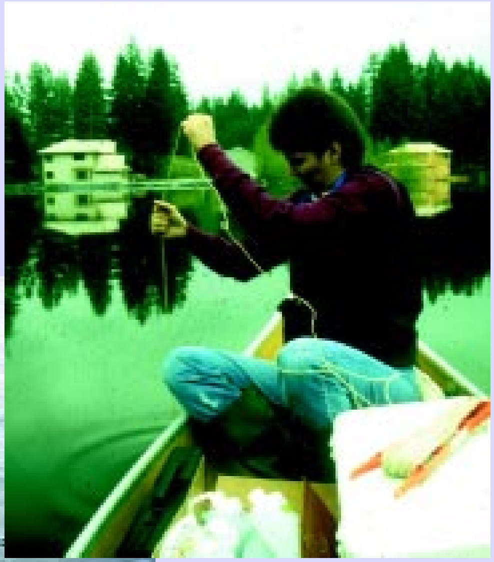
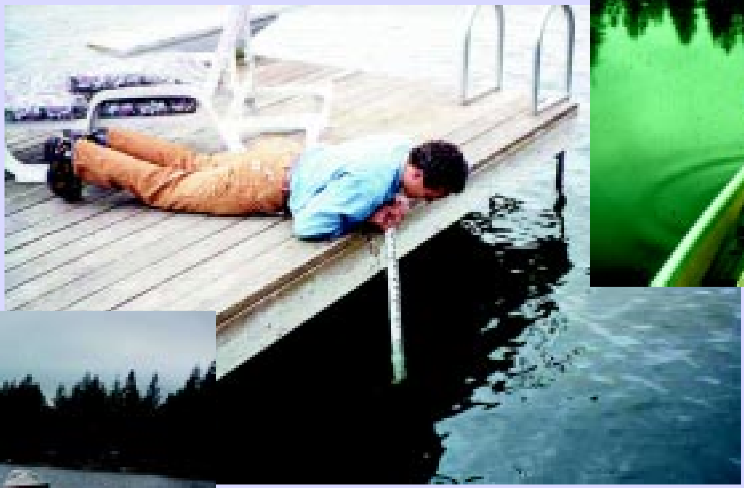
King County Lake Water Quality





A Trend Report on King County Small Lakes

November 2001

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Table of Contents

List of Figures and Tables

CHAPTER 1

Introduction

Since 1985 King County residents have monitored the health of the region's small lakes. Through the effort of these volunteers, a long-term record of water quality has been created. The results, which have been analyzed and quantified, provide the basis for the trends in lake water quality described in this report.

This chapter outlines the report's layout and methodology. Additionally, background on the volunteer monitoring program is summarized and trophic state classification discussed.

Monitoring Background

King County has over 700 lakes ranging in size from several acres to over 22,000 acres. In the western-third of the county, over 80 smaller lakes (less than 300 acres in size) can be found. Of these 80 lakes, 51 have participated in volunteer lake monitoring activities (Figure 1) associated with either the Metropolitan Municipality of Seattle (METRO) Small Lakes Program or more recently, King County's Lake Stewardship Program.

While a long data record exists for the region's large lakes like Washington, Union, and Sammamish, the data record for the "small" lakes in King County is relatively short. In 1971 and 1972, METRO completed the first surveys of small lake water quality in the Lake Washington and Green River drainage basins (METRO, 1973). The METRO survey consisted of quarterly data collection on 34 lakes. In 1973 and 1974, the United States Geological Survey (USGS) completed a separate reconnaissance of small lake water quality for King and Snohomish counties, surveying a total of 156 lakes (USGS, 1976). In this USGS report, water quality data was typically collected only for a single date. Although limited in frequency of data collection, both the METRO and USGS surveys represent the earliest reports on the quality of the region's small lakes.

Figure 1: Lake Locations

In 1984, METRO began the lake volunteer monitoring program. In this initial year, volunteers measured temperature and transparency twice each month May through October during (METRO, 1986). In 1985, volunteers began collecting water samples for phosphorus and chlorophyll *a* analysis. By choosing transparency, phosphorus, and chlorophyll *a*, the trophic state for each participating lakes could be estimated. In subsequent years, phytoplankton, dissolved oxygen, alkalinity, hardness, and nitrogen were added to the Small Lakes Volunteer Monitoring Program to broaden the data used in characterizing the region's small lakes (METRO, 1986; METRO, 1987; METRO, 1989; METRO, 1990; METRO, 1991; and METRO, 1994).

Through this initial program, data was collected at 26 lakes (Table 1) on a monthly basis in February and March and twice monthly during May to October. With this more intensive data collection, summer mean water quality was estimated for each lake and compared with other lakes in the program (METRO, 1986; METRO, 1987; METRO, 1989; METRO, 1990; METRO, 1991; and METRO, 1994).

In 1995, the METRO Small Lakes Volunteer Monitoring Program, which included both physical and chemical parameters (temperature, water clarity, nitrogen, phosphorus, and chlorophyll *a*), was merged with the King County Lake Stewardship Program which centered on the measurement of physical parameters (temperature, water clarity, lake level, and precipitation). With the merger, 18 additional King County lakes (Table 1) began participating in the water chemistry monitoring program over the next several years through the Lake Stewardship Program (King County, 1996 b; King County, 1997; King County, 1998 a; King County, 1999; and King County, 2001).

Table 1: Summary of Lake Participation by Major Year Categories

(A) Lakes with monitoring data between 1985-2000

Angle	Geneva	Sawyer
Beaver2	Killarney	Shadow
Bitter	Lucerne	Shady
Boren	Meridian	Spring
Deep	Morton	Star
Desire	North	Steel
Dolloff	Panther	Twelve
Fenwick	Pine	Wilderness
Fivemile	Pipe	

(B) Lakes with monitoring data between 1995-2000

Allen	Haller	Paradise
Beaver1	Kathleen	Ravensdale
Burien	Leota	Retreat
Cottage	McDonald	Trout
Francis	Mirror	Webster
Garrett	Neilson	Welcome

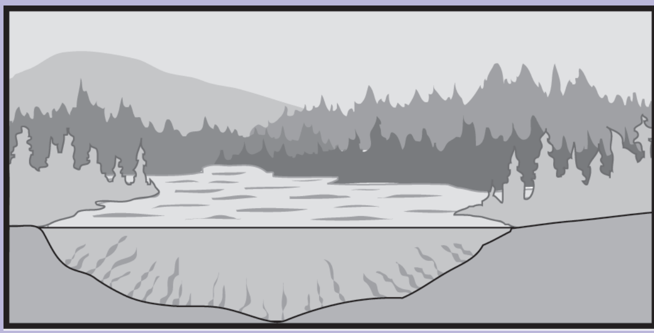
(C) Lakes added to the program in 2000

Alice	Joy	Margaret
Ames	Marcel	Walker
Horseshoe		

In 1998, the winter sampling period was eliminated from the water chemistry portion of the program and an additional sampling date was added between May and October, allowing samples to be collected on a biweekly basis rather than twice monthly. Currently, volunteers continue to collect biweekly samples from May to October.

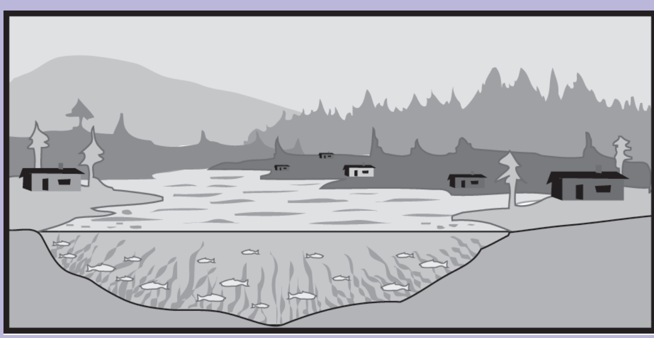
In 2000, seven new lakes (Table 1) were added to the chemistry monitoring portion of the volunteer monitoring program. The Rural Drainage Program, which was approved by the Metropolitan King County Council in 1999, provided funded for the inclusion of these seven lakes and possibly eight other lakes located in the Snoqualmie Valley, Enumclaw plateau, or Vashon Island areas.

Figure 2: Three General Trophic Categories for Lakes



Oligotrophic Lake

- Low nutrient and algal levels
- High water clarity
- Limited abundances of plants and animals
- Slow accumulation sof nutrients from natural sources



Mesotrophic Lake

- Intermediate nutrient and algal levels
- Medium water clarity
- Intermediate abundances of plants and animals
- Increased rooted aquatic plants provide habitat for fish and insects

Eutrophic Lake

- High nutrient and algal levels
- Low water clarity
- Large abundances of plants and animals
- Potential decline in some fish due to lower oxygen levels in deep water

Trophic State Classification

For all participating lakes, three common indicators of lake health have been routinely monitored. These indicators include water clarity (Secchi depth), nutrient levels (total phosphorus), and algal levels (chlorophyll *a*). In combination, these three indicators provide a good indication of lake biological activity or trophic state, a standard lake assessment tool.

This assessment of biological activity or trophic state results in the classification of lake water quality into three general categories: oligotrophic, mesotrophic, and eutrophic (Figure 2). Lakes with low concentrations of nutrients and algae and high transparencies are considered oligotrophic. A lake with high concentrations of nutrients and algae and low transparency or clarity is considered eutrophic. Lakes whose quality ranges between eutrophic and oligotrophic are considered mesotrophic.

One of the most common measures used to calculate a lake's water quality classification is the numerical trophic state index (TSI) developed by Robert Carlson (1977). This index allows the easy comparison of lake water quality by relating values for water clarity, phosphorus, and chlorophyll *a* along a trophic continuum based on a scale of 0 to 100 (Table 2). This index and its application to King County lakes is discussed further in Chapters 2, 3, and 4.

Factors Affecting Trophic State

Lake productivity (biological activity) is influenced by a variety of factors including watershed size, geology, lake depth, climate, and the quality and quantity of water entering and leaving the lake. Lakes may be naturally eutrophic, mesotrophic, or oligotrophic based on the inherent character and stability of the surrounding watershed.

Eutrophication or the increase in a lake's biological activity over time is a process that occurs naturally in some lakes and may be accelerated in others by human activities (Figure 2). Natural eutrophication processes occur on a geologic time scale of thousands of years and may not be observable in a single human lifetime. The slow infilling of lakes from sedimentation naturally occurs even in undisturbed watersheds, and as this sedimentation occurs, rooted plants generally increase in number, contributing to the accelerated filling in of the lake.

We can witness the acceleration of these natural processes through human-induced or cultural eutrophication of a lake system. Land-based activities, including home-building, commercial development, agriculture, forestry, mining, landscaping, gardening, and animal keeping all contribute nutrients and sediment to surface water and groundwater. Increases in impervious surfaces associated with land development activities also

Table 2: Summary of Summer Water Quality Parameters and Associated Values for the Trophic State Index

Trophic State/ Biological Activity	**Secchi Depth (meter)**	**Chl *a*** (µg/L)**	**TP** (µg/L)**	**TSI****
Oligotrophic/Low	>4.0	<2.6	<12	<40
Mesotrophic/Moderate	2.0-4.0	2.6-6.4	12-24	40-50
Eutrophic/High	<2.0	>6.4	>24	>50

*Data Source: Carlson, 1977
**Chl *a*-chlorophyll *a,* TP=total phosphorus, and TSI=trophic state index

result in increased quantities of surface water runoff flowing to lakes and streams. These larger surface water flows often carry loads of nutrients and sediments that stimulate plant growth and speed the infilling of lakes. This process, in turn, results in an acceleration of the overall eutrophication process.

Lake trophic status is also characterized by the frequency of algal blooms, the type of algae present, and/or the percentage of the lake surface occupied by aquatic plants. Both excess algae and aquatic plants affect the use of the lake for swimming, fishing, boating, wildlife, aesthetics, and other uses. Eutrophic lakes, for example, typically have frequent nuisance algal blooms dominated by blue-green algae (cyano-bacteria). These blooms can form surface scums affecting aesthetic and swimming uses of the lake. Excess growth of aquatic plants can also impact water quality, entangle oars, engines, and fishing lines, as well as hamper swimming.

Report Summary

This report provides an opportunity to examine long-term water quality trends in the region's small lakes. This characterization would not have occurred without the assistance of dedicated lake residents. These residents have enthusiastically volunteered their time and energy, allowing for the cost-effective collection of data on numerous lakes. In turn, the county has used this data to monitor the health of the region's small lakes and direct ongoing stewardship activities.

Water quality was analyzed for 51 lakes. Trends were analyzed for 26 lakes where long-term water quality data has been collected. Of these 26 lakes, only 23 lakes had sufficient data to complete statistical trend analysis. For 18 other lakes, water quality data has been collected for only six years. Because of the limited data record, discussion of trends at these lakes is qualitative only. In 2000, seven new lakes were added to the program through the Rural Drainage Program and have only a single year of chemical data. Trends were not discussed for these lakes, however, data for these new lakes were graphed to allow visual comparison with other lakes.

Report Layout

This report includes a brief description of sample collection and data reduction methodologies, results, and a discussion of results. Results are presented alphabetically for three groups of lakes: (1) lakes with monitoring data between 1985-2000; (2) lakes with monitoring data between 1995-2000; and (3) lakes added to the program in 2000. The discussion includes a summary of lake water quality, ongoing threats to lake water quality, and recommended actions to preserve lake health.

CHAPTER 2

Methods

This chapter details the methods used to analyze the volunteer lake monitoring data record. These methods included a series of data reduction steps and specific assumptions made in assembling the data prior to completing the data analysis.

Data Reduction

Prior to evaluating whether significant changes in water quality have occurred for the region's small lakes, a substantial amount of data reduction was performed. This reduction included:

- Initial screening of the data to remove sampling dates outside of the May through October growing season;
- Removal of data outside of the target analysis depth of one meter;
- Adjusting data for different reporting of method detection limits;
- Correcting data values as a result of method change; and
- Removal of outlier values from the individual lake data sets.

In completing this data reduction several assumptions regarding the data were made. These assumptions are included with the description of each data reduction step and are summarized below.

Data Retrieval

All laboratory records for the data collected for the volunteer lake monitoring program are located in the King County Laboratory Information Management System (LIMS) database. Historical data for all lakes were extracted from the database and downloaded to a spreadsheet. The data was sorted by date and all February and March data was removed. Additionally, the database contained data collected during profile sampling dates that included water quality information for mid and bottom depths of the respective lake. Data from these additional mid and bottom sampling depths were removed and only data from the surface depth was analyzed.

Prior to 1994, surface samples were collected at one meter. During 1994 and 1995, "surface" water samples were collected as a composite sample taken from one meter and the measured Secchi Depth. Although this brief method change was intended to provide a better estimate of chlorophyll *a* and nutrient levels in the photic zone, the ability to compare data statistically from one year to year is made more difficult when samples are not collected using the same methods. For the purpose of this report, data for this two-year period was assumed to approximate surface water conditions and was not excluded from the analysis. In 1996, water sample collection methods were returned to the discrete collection of surface samples at one meter.

Detection Limits

When analytical data are reported, qualifiers are applied to provide information on the condition of the sample received, how the laboratory handled the sample, whether a holding time was exceeded, and so on. Qualifiers are also provided on the detection limits associated with the specific parameter of interest. The term detection limit generally refers to the limiting level a parameter can be detected at or to using a specific analytical method.

For detection limits, the King County analytical laboratory reports both a method detection limit (MDL) and a reporting detection limit (RDL). The MDL is defined as the lowest concentration at which a parameter (like chlorophyll *a* or phosphorus) can be quantified and thus, represents the lowest concentration at which a sample result is reported (http://dnr.metrokc.gov/wlr/envlab/Dta_qual_Gen.htm). Thus, the MDL qualifier is reported when the resulting concentration of the measured parameter is less than the designated MDL value.

The RDL is defined as the lowest concentration at which a parameter can reliably be quantified. The RDL corresponds to the concentration at which method performance becomes quantitative and is no longer subject to the level of variation observed for values between the MDL and RDL. Thus, the RDL qualifier is applied when a parameter is detected at a value greater than or equal to the associated MDL but less than the associated RDL (http://dnr.metrokc.gov/wlr/envlab/Dta_qual_Gen.htm).

The respective MDL and RDL values for chlorophyll *a* and total phosphorus are listed in Table 3. For data where the RDL qualifier was applied, the reported value in the database was used. When the MDL qualifier was applied, a value halfway between zero and the current MDL value for the parameter was assigned. For chlorophyll *a*, this value was 0.075 µg/L while for total phosphorus, a value of 2.5 µg/L was assigned.

Over the life of the County's Laboratory Information Management System (LIMS) database, which was implemented in 1992, data reporting protocols for documenting MDL values has varied.

All data collected prior to 1992 was entered in its original format which included reporting of MDL values in several ways. For data collected between the 1970s and the early 1980s, the MDL values were entered without notation in a qualifier field. Later during the 1980s, data less than the MDL value was shown with a less than sign "<" in the value field without additional notation in the qualifier field. Since 1992, data values less than the MDL value are shown as a blank (not zero) in the value field followed by a "<MDL" entry in the qualifier field.

To address the variety of treatments of MDL values in the database, all data qualified by MDL were assigned a common value to facilitate statistical analysis. For total phosphorus data, this value was 2.5 µg/L while chlorophyll *a* data was assigned a value of 0.075 µg/L.

Chlorophyll *a* Method Change

On July 1, 1996, the King County analytical laboratory instituted a method change for chlorophyll *a* analysis that resulted in better recovery of this parameter. The details of the method change are outlined in a technical memorandum from the laboratory (Despina Strong, Conventionals Supervisor, June 3, 1996, King County Environmental Laboratory).

In brief, the new method when compared to the previous procedure resulted in a 14 percent increase in measured chlorophyll *a*. Subsequently, for this report, all chlorophyll *a* data collected prior to July 1, 1996 was increased by 14 percent before calculating seasonal averages and performing trend analyses.

Outlier Data

An outlier data point can generally be defined as a point that does not readily fit within the established pattern created by other data points. Initial screening of data can sometimes rectify outliers especially if the outlier arises from a correctable data entry error. Outliers may also result from sampling error or as an artifact of the sampling/analysis processes. For example, algae can clump and may not be randomly distributed when a subsample is taken for analysis of chlorophyll *a* or total phosphorus.

In the natural environment, outliers actually exist because the environment is variable. Water quality data can be quite variable. Distinguishing natural variability from actual outliers that might bias the analysis requires that some assumptions are made about the degree of variability that is acceptable. Thus, statistical analysis becomes an important tool for deciding which data can be selectively removed to improve estimates of the actual population that is intended for measurement.

In the case of this project, a single high value might be 10 or 100 times larger than the remaining values measured during the season. This single higher value when averaged with the other values might in turn, result in the artificial shift of the lake's trophic state from one category to the next. In order to separate potential artificial shifts from real trends, the final data reduction step taken was a lake by lake analysis for outliers and then the subsequent removal of outlier values prior to determining seasonal averages.

Several tests for outliers exist. The test for outliers used in this analysis is a non-parametric outlier test applied in SPSS software in its boxplot routine. Based on this test, outliers are defined as any data point either 1.5 times the interquartile range above the upper Tukey's Hinge (75^{th} percentile) or 1.5 times the interquartile range below the lower Tukey's Hinge (25^{th} percentile). These ranges were established for each lake. Data outside these ranges were removed prior to the calculation of seasonal averages and trophic state values. The dropped values amounted to less than 1 percent of the entire data set.

Data Analysis

After outlier data were removed for each lake, average values for Secchi depth, chlorophyll *a* and total phosphorus were calculated. This calculation was repeated for each year where data was available for a given lake. In years where fewer than six samples were collected, no average value was determined and the affected year removed from the analysis.

Trophic State

Lake water quality is classified based on trophic state or degree of biological productivity. One of the most common indices used is the numerical trophic state index (TSI) developed by Robert Carlson (1977) which incorporates lake water quality on a scale of 0 to 100. Each major division (10, 20, 30, and so on) represents a doubling of algal biomass (Carlson, 1977).

The index is based on the summer mean values of three commonly measured lake parameters: Secchi depth, total phosphorus and chlorophyll *a* (Table 4). The trophic state index value can be calculated for each parameter based on linear regression relationships established by Carlson (1977) for Secchi depth, total phosphorus and chlorophyll *a* as related to algal biomass.
The equations for each trophic parameter are listed in Table 4. For each lake and year, trophic values were determined individually for Secchi depth, chlorophyll *a*, and total phosphorus. Additionally, an average trophic value was determined by averaging the individual trophic values associated with each parameter.

Statistics Overview

Statistics can be a useful tool for analyzing data and drawing meaningful conclusions about characteristics associated with a data set. Specifically, statistics allows for hypothesis formulation before data collection occurs and actual testing of a hypothesis once the data is collected.

Many different types of statistical tests are available to scientists for evaluating questions that might be asked about a data set. In turn, each of these tests has a set of probabilities associated with different test outcomes which allow the user to determine the significance of the test outcome or how likely it is that the hypothesis being evaluated is true or false. Statistical significance, then, is defined in terms of probability and is associated specifically with the magnitude of a calculated test statistic.

Table 3: Method Detection Limit (MDL) and Reporting Detection Limit (RDL) for Chlorophyll *a* and Total Phosphorus

Parameter	Time Period	MDL	RDL
Chlorophyll *a*	1970-1991; 8/1998-present	0.15 µg/L	0.30 µg/L
Chlorophyll *a*	1992-7/1998	0.01 µg/L	0.05 µg/L
Total Phosphorus	1970-present	5 µg/L	10 µg/L

Table 4: Trophic State Index Calculation*

Parameter	Trophic State Index Equation
Secchi Depth (SD)	=10*(6-(ln(SD)/ln(2)))
Chlorophyll *a* (chl *a*)	=10*(6-((2.04)-(0.68*ln(chl a)))/ln(2))
Total Phosphorus (TP)	=10*(6-(ln(48/(TP))/ln(2)))

*Data Source: Carlson, 1977

Generally, a 95 percent confidence level is used by many scientists when evaluating a test hypothesis. This level is chosen because the likelihood of the outcome being due to chance alone is only five percent.

Analysis of Trends

For this report, the question being asked is if a significant increase or decrease trend in water quality has occurred for the County's small lakes over the past sixteen years. To answer this question, the analysis required using two statistical tests.

The first test used was the Mann-Kendall test for trend, a nonparametric test statistic (test statistic does not require the data to be drawn from a specific distribution in order for the test to be valid). For each lake, this test was used to evaluate whether a significant increase or decrease for each water quality parameter occurred. When a significant trend was found for a specific parameter, a second statistic was used to estimate the slope (unit change per time period) or magnitude of the trend. This second statistic was Sen's Nonparmetric Estimator of Slope. These two test statistics are described below.

The Mann-Kendall Trend Test is a non-parametric signed rank test and assumes no particular distribution for the data. This test is fairly robust and allows missing values to be present as well as data reported at trace levels or less than the detection limit to be used provided that a common value is assigned. This common value must be smaller than the smallest values assigned in the data set. This assignment of values can be used because the test uses only the relative magnitudes of the data rather than their measured values. (Gilbert, 1987).
Sen's nonparametric estimator of slope is used to calculate the magnitude of trend when a significant linear trend is detected. Sen's test can be used with missing data values and is generally not affected by outlier data or gross data errors (Gilbert, 1987).

To analyze volunteer monitoring data for trends, individual lake data was organized by annual summer average values for Secchi depth, chlorophyll *a*, total phosphorus, TSI Secchi depth, TSI chlorophyll *a*, TSI total phosphorus, and TSI average. The TSI valued are calculated from the original parameter values by functions (Table 5).

This data was then entered into statistical software and p scores (a measure of test significance), z scores (actual test value), and trend direction were calculated at the 95 percent confidence interval. Using Sen's nonparametric estimator of slope, the magnitude of the trend was calculated for lakes with significant p scores.

CHAPTER 3

Trend Results

Comparison of data from all lakes in a region has the potential to clarify the general patterns of water quality associated with changing land use practices, as well as pointing to specific areas where attention might be directed in the future. The results of the trend and trophic state analysis are presented first by a comparison of all the lakes and then alphabetically by individual lake. The all-lake comparison includes a summary of the trends analysis completed for the 23 lakes that had sufficient data as well as a comparison of trophic patterns for all the lakes.

Levels of Analysis

Twenty-six lakes of the 51 participating lakes have longer monitoring records with data collected between 1985-2000, of which 23 had sufficient data to complete trend analyses. These analyses included: (1) the calculation of annual summer averages for Secchi depth, chlorophyll *a*, total phosphorus, TSI Secchi depth, TSI chlorophyll a, TSI total phosphorus, and TSI average; (2) testing for trends using the Mann-Kendall's nonparametric test for trend; and (3) calculation of the slope associated with significant trends using Sen's nonparametric estimator of slope.

Twenty-five lakes had smaller data sets ranging from one to six years. For these lakes, only annual summer averages for Secchi depth, chlorophyll a, total phosphorus, TSI Secchi depth, TSI chlorophyll *a*, TSI total phosphorus, and TSI average were calculated.

Trend Analysis

Significant trends were detected in 13 of the 23 lakes analyzed for one or more water quality parameters. These lakes included Angle, Beaver 2, Bitter, Desire, Fenwick, Geneva, Killarney, Lucerne, Pine, Pipe, Sawyer, Shadow, and Spring. No significant water quality trends were detected in the remaining 10 lakes at the five percent confidence level.

Table 5: Trend Analyses Results for 23 Lakes with Eight or More Years of Monitoring Data

Lake / Sample Size	Parameter	z Score	p Score	Significant Trend	Trend Direction	Slope
Angle	Secchi	-2.57	0.01	Yes	Down	-0.14
(n=15)	Chl a	1.78	0.07			
	TP	1.78	0.07			
	mean TSI	2.77	0.006	Yes	Up	0.28
Beaver2	Secchi	-2.14	0.03	Yes	Down	-0.08
(n=14)	Chl a	2.3	0.02	Yes	Up	0.11
	TP	0	1			
	mean TSI	2.3	0.02	Yes	Up	0.25
Bitter	Secchi	0	1			
(n=11)	Chl a	2.65	0.008	Yes	Up	0.12
	TP	-0.62	0.53			
	mean TSI	1.56	0.11			
Boren	Secchi	0.62	0.53			
(n=8)	Chl a	1.63	0.17			
	TP	-1.11	0.26			
	mean TSI	-0.12	0.9			
Desire	Secchi	-1.98	0.04	Yes	Down	-0.04
(n=15)	Chl a	2.47	0.01	Yes	Up	0.5
	TP	1.48	0.13			
	mean TSI	2.38	0.017	Yes	Up	0.28
Dolloff	Secchi	1.03	0.2			
(n=12)	Chl a	0.9	0.37			
	TP	-1.16	0.14			
	mean TSI	-0.75	0.45			
Fenwick	Secchi	-1.56	0.12			
(n=9)	Chl a	0.94	0.34			
	TP	2.19	0.02	Yes	Up	1.02
	mean TSI	2.6	0.009	Yes	Up	0.52
Fivemile	Secchi	0.07	0.94			
(n=12)	Chl a	1.58	0.11			
	TP	-0.75	0.45			
	mean TSI	0.21	0.84			
Geneva	Secchi	1.99	0.05	Yes	Up	0.04
(n=12)	Chl a	-0.07	0.94			
	TP	-0.89	0.4			
	mean TSI	-0.89	0.37			

Secchi = secchi depth. Chl a = chlorophyll a. TP = total phosphorus. Mean TSI = the average of the calculated trophic state indexes of the three measured parameters. A trend is considered significant if the p value is less than or equal to 0.05.

Table 5: Trend Analyses Results for 23 Lakes with Eight or More Years of Monitoring Data

Lake / Sample Size	Parameter	z Score	p Score	Significant Trend	Trend Direction	Slope
Kilarney	Secchi	1.56	0.12			
(n=11)	Chl a	2.34	0.02	Yes	Up	0.28
	TP	-2.18	0.03	Yes	Down	-1.11
	mean TSI	0	1			
Lucerne	Secchi	-1.99	0.05	Yes	Down	-0.04
(n=12)	Chl a	1.03	0.3			
	TP	0.07	0.95			
	mean TSI	0.89	0.37			
Meridian	Secchi	-1.78	0.07			
(n=15)	Chl a	1.58	0.11			
	TP	1.58	0.11			
	mean TSI	1.78	0.07			
Morton	Secchi	-1.13	0.26			
(n=16)	Chl a	1.31	0.19			
	TP	-0.05	0.96			
	mean TSI	0.5	0.62			
Pine	Secchi	1.3	0.19			
(n=12)	Chl a	1.3	0.19			
	TP	-1.99	0.05	Yes	Down	-0.33
	mean TSI	-2.26	0.02	Yes	Down	-0.2
Pipe	Secchi	-3.1	0.002	Yes	Down	-0.09
(n=12)	Chl a	0.75	0.45			
	TP	0.89	0.37			
	mean TSI	1.71	0.09			
Sawyer	Secchi	1.67	0.095			
(n=16)	Chl a	2.12	0.034	Yes	Up	0.13
	TP	0.77	0.44			
	mean TSI	0.59	0.55			
Shadow	Secchi	-0.07	0.94			
(n=12)	Chl a	1.17	0.24			
	TP	2.13	0.034	Yes	Up	0.47
	mean TSI	1.71	0.086			
Shady	Secchi	-0.32	0.75			
(n=16)	Chl a	-0.59	0.59			
	TP	0	1			
	mean TSI	-0.41	0.68			
Spring	Secchi	-0.3	0.77			
(n=15)	Chl a	1.98	0.05	Yes	Up	0.098
	TP	-0.1	0.92			
	mean TSI	0.59	0.55			

Secchi = secchi depth. Chl a = chlorophyll a. TP = total phosphorus. Mean TSI = the average of the calculated trophic state indexes of the three measured parameters. A trend is considered significant if the p value is less than or equal to 0.05.

Table 5: Trend Analyses Results for 23 Lakes with Eight or More Years of Monitoring Data

Lake / Sample Size	Parameter	z Score	p Score	Significant Trend	Trend Direction	Slope
Star	Secchi	-1.42	0.15			
(n=14)	Chl a	0.99	0.32			
	TP	-1.42	0.15			
	mean TSI	0	1			
Steel	Secchi	1.65	0.1			
(n=13)	Chl a	1.4	0.16			
	TP	-0.92	0.36			
	mean TSI	-0.43	0.67			
Twelve	Secchi	-0.88	0.38			
(n=14)	Chl a	1.53	0.13			
	TP	1.09	0.27			
	mean TSI	1.31	0.19			
Wilderness	Secchi	1.67	0.1			
(n=16)	Chl a	0.41	0.68			
	TP	1.04	0.3			
	mean TSI	0.23	0.82			

Secchi = secchi depth. Chl a = chlorophyll a. TP = total phosphorus. Mean TSI = the average of the calculated trophic state indexes of the three measured parameters. A trend is considered significant if the p value is less than or equal to 0.05.

Trend analysis results are presented for 23 lakes (Table 5). A trend with a negative slope indicates that the summer average is declining over time. For chlorophyll, total phosphorus and TSI average, this would be interpreted as a desirable increase in water quality. For Secchi, the case is opposite—an increase would be desirable since a declining Secchi means less transparency.

For the 13 lakes where significant trends were detected, five lakes showed a decline in Secchi depth (Table 6), while Secchi depth in Lake Geneva increased. Six lakes had a significant increase in chlorophyll *a* detected. Lake Fenwick and Shadow Lake had significant increases in total phosphorus detected while Lake Killarney and Pine Lake showed a significant decrease in phosphorus. Four of 13 lakes also had a significant increase in their overall trophic state (TSI average) while Pine Lake showed a significant decrease in trophic state. Both Beaver Lake 2 and Lake Desire had a significant decrease in Secchi depth while chlorophyll *a* and trophic state values have significantly increased. Lake Geneva was notable for its increase in Secchi depth while Lake Killarney and Pine Lake were distinguished for their decrease in total phosphorous values and again Pine Lake for its decrease in average trophic state.

Trophic State

Since almost half the participating lakes have six or fewer years of water quality monitoring data, trophic state values were calculated for 42 lakes for the most recent five-year period and for the year 2000 for seven new lakes. Deep Lake and Lake

Fenwick did not have data available for the most recent five-year time period and so were not included. In Table 7 on the next page, the results of this analysis of trophic state index (TSI) values and trophic ratings are summarized. (See the section "Individual Lake Results" for details on analysis of each lake.)

Fourteen lakes were rated as oligotrophic, demonstrating high water clarity, low chlorophyll *a* values, and low total phosphorus values when compared among other lakes (Table 7). Generally, oligotrophic lakes have TSI values around 40 or less.

Twenty lakes were rated as mesotrophic in water quality having TSI values between 41 and 50 (Table 7). These lakes generally have mid-range water clarity, chlorophyll *a*, and total phosphorus values.

Thirteen of the participating lakes in King County were rated as eutrophic having TSI values between 51 and 60 (Table 7). These lakes typically have poorer summer water quality including low water clarity, high chlorophyll *a* values and high total phosphorus values.

Lakes with TSI values greater than 60 are very biologically productive and are labeled hypereutrophic. Both Allen and Panther lakes rated in this category (Table 7).

Marking the lakes on a map by average trophic status yields a regional perspective on the productivity of the small lakes in King County (Figure 3). Although there are no clearly defined relationships between the productivity of each particular lake and its location, there are clusters of lakes with higher trophic indices in the south county and east of Renton. If an additional marker could be added to this map to set apart those lakes with large attached wetlands, it might make clear why certain lakes are classified as mesotrophic instead of oligotrophic. Adjacent wetlands can affect phosphorus concentrations at certain times of the year and raise the average trophic status index. Other lakes such as Lake Marcel in the northeast, are very shallow and naturally eutrophic.

Oligotrophic lakes, as might be predicted, tend to occur on the fringes of significant land development in the county and beyond. However, there are several lakes, such as Angle Lake and Pine Lake, which are located in moderately to highly developed areas and yet still maintain low productivity. Pine Lake data showed a significant downward trend in total phosphorus over time consistent with retaining oligotrophic status, and this may be the result of a change wetland inputs to the lake. In contrast, Angle lake shows a trend towards decrease in Secchi transparency, which could signal an increase in productivity in the future.

Table 6: Significant Trend Analyses Results by Parameter

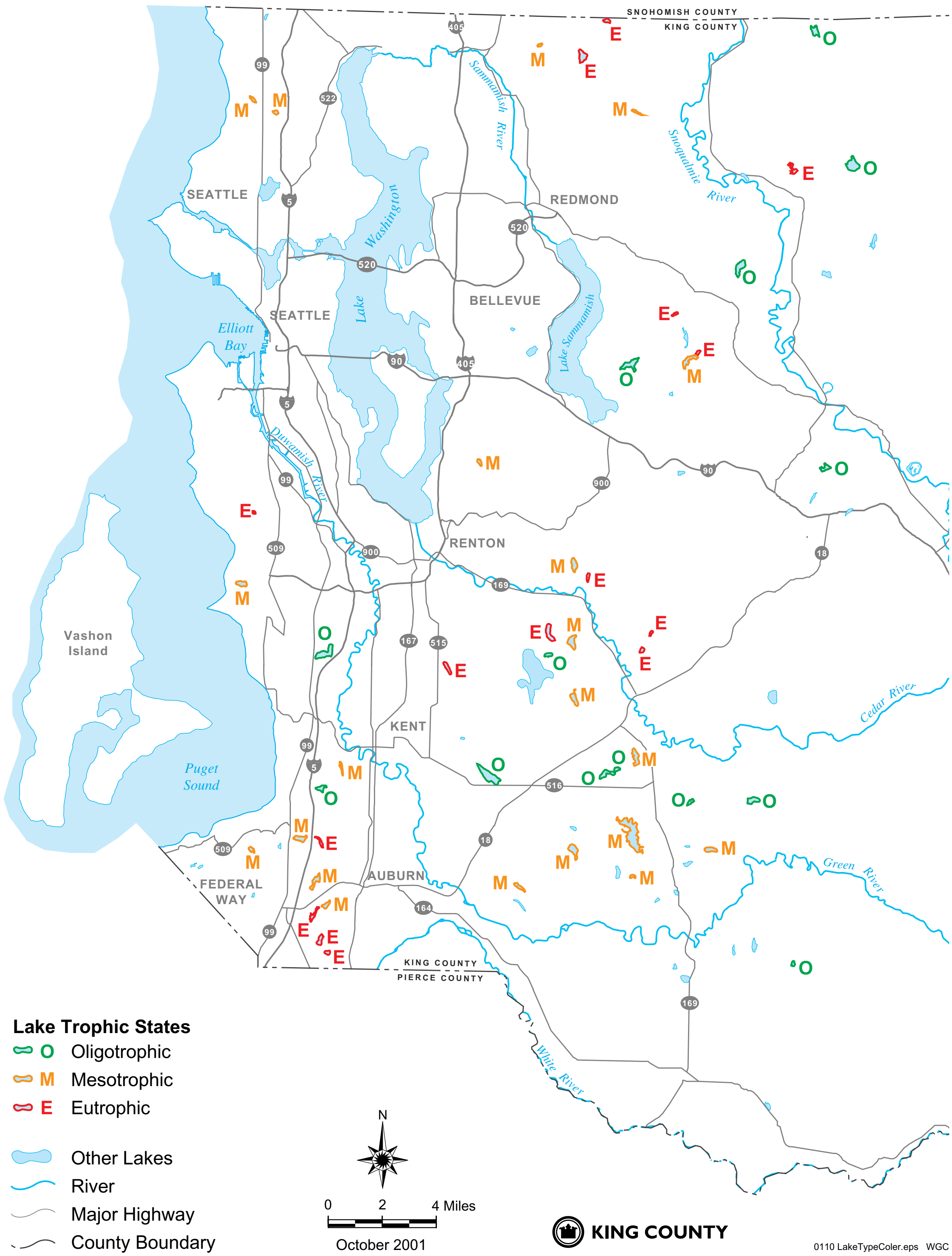
Secchi Depth/ TSI Secchi Depth		Chlorophyll a/ TSI Chlorophyll a		Total Phosphorus/ TSI Total Phosphorus		TSI Average	
Angle	↓*	Beaver 2	↑	Fenwick	↑	Angle	↑
Beaver2	↓	Bitter	↑	Killarney	↓	Beaver2	↑
Desire	↓	Desire	↑	Pine	↓	Desire	↑
Geneva	↑	Killarney	↑	Shadow	↑	Fenwick	↑
Lucerne	↓	Sawyer	↑			Pine	↓
Pipe	↓	Spring	↑				

*Arrows indicate trend direction

Table 7: 1996-2000 Carlson's Trophic State Values for 51 King County Lakes

Lake	1996	1997	1998	1999	2000	Average	Trophic Classification
Alice	--	--	--	--	39	39	Oligotrophic
Allen	63	62	63	67	60	63	Hypereutrophic
Ames	--	--	--	--	39	39	Oligotrophic
Angle	--	35	35	37	36	36	Oligotrophic
Beaver-1	--	53	51	51	51	51	Eutrophic
Beaver-2	46	45	45	45	42	45	Mesotrophic
Bitter	--	44	43	45	42	43	Mesotrophic
Boren	--	46	43	42	42	43	Mesotrophic
Burien	--	--	42	--	44	43	Mesotrophic
Cottage	52	52	47	52	53	51	Eutrophic
Deep	--	--	--	--	--	--	--
Desire	56	54	50	54	53	53	Eutrophic
Dolloff	56	56	56	53	56	55	Eutrophic
Fenwick	--	--	--	--	--	--	--
Fivemile	53	52	51	50	50	51	Eutrophic
Francis	49	49	51	50	51	50	Eutrophic
Garrett	59	58	58	--	--	58	Eutrophic
Geneva	42	41	40	40	40	40	Mesotrophic
Haller	--	46	43	43	44	44	Mesotrophic
Horseshoe	--	--	--	--	44	44	Mesotrophic
Joy	--	--	--	--	38	38	Oligotrophic
Kathleen	48	49	47	47	50	48	Mesotrophic
Killarney	51	52	51	47	48	50	Eutrophic
Leota	--	--	46	47	49	47	Mesotrophic
Lucerne	38	39	34	40	39	38	Oligotrophic
Marcel	--	--	--	--	53	53	Eutrophic
Margaret	--	--	--	--	38	38	Oligotrophic
McDonald	53	54	55	54	50	53	Eutrophic
Meridian	--	40	38	38	36	38	Oligotrophic
Mirror	--	46	45	46	44	45	Mesotrophic
Morton	42	41	40	40	39	40	Mesotrophic
Neilson	--	46	43	44	48	45	Mesotrophic
North	43	46	42	--	--	44	Mesotrophic
Panther	60	--	--	--	60	60	Hypereutrophic
Paradise	53	56	52	53	54	53	Eutrophic
Pine	41	40	39	37	39	39	Oligotrophic
Pipe	40	38	36	39	38	38	Oligotrophic
Ravensdale	39	39	39	--	--	39	Oligotrophic
Retreat	37	39	34	32	31	35	Oligotrophic
Sawyer	43	43	40	40	39	41	Mesotrophic
Shadow	--	44	44	--	44	44	Mesotrophic
Shady	41	40	36	36	37	38	Oligotrophic
Spring	44	46	43	43	43	44	Mesotrophic
Star	39	42	38	36	36	38	Oligotrophic
Steel	43	44	43	42	40	43	Mesotrophic
Trout	51	54	51	51	51	52	Eutrophic
Twelve	45	--	37	--	42	41	Mesotrophic
Walker	--	--	--	--	38	38	Oligotrophic
Webster	52	50	--	--	--	51	Eutrophic
Welcome	52	48	47	48	46	48	Mesotrophic
Wilderness	40	43	40	42	41	41	Mesotrophic

Figure 3: Trophic State of King County Lakes for Possible Geographical Trends



CHAPTER 4

Discussion

Trend analyses and trophic state results are summarized for 51 small lakes. Rates of changes in water quality are described for lakes where significant trends were detected. Ongoing threats to water quality are discussed and management actions are recommended.

State of Small Lake Quality

Based on available data, water quality remains good for many of the region's small lakes. Of the 51 lakes analyzed in this report, 23 lakes had sufficient data for trends analyses. Of these 23 lakes, 11 lakes showed a statistically significant decline in one or more water quality parameters. Only one lake (Pine) showed an overall improvement in water quality, while one lake (Killarney) showed both a decline and an improvement in separate parameters. The remaining lakes showed no detectable change in water quality for the selected trophic parameters over the time periods.

Although half of the lakes with sufficient data for trend analyses did show a statistically significant decline in water quality, the degree of decline in most cases is probably not dramatic enough to be noted by the average observer. Rates of annual change for individual parameters are summarized in Table 8.

Annual Rates of Water Quality Change

The largest changes in water quality occurred for total phosphorus (Table 8), which ranged from an annual rate of decrease of 1.11 µg/L at Lake Killarney to an annual rate of increase of 1.02 µg/L for Lake Fenwick. Lake Killarney and Pine Lake both showed minor decreasing trends for total phosphorus values while Shadow Lake and Lake Fenwick showed minor increasing trends. If the higher rates of change in phosphorus levels were to continue over time, overall water quality

Table 8: Lakes and Associated Annual Rate (Slope) of Water Quality Change by Parameter

Secchi Depth (m)/ Slope		**Chlorophyll *a* (µg/L)/ Slope**		**Total Phosphorus(µg/L)/ Slope**		**TSI Average**	
Angle	-0.14*	Desire	0.50	Fenwick	1.02	Fenwick	0.52
Pipe	-0.09	Killarney	0.28	Shadow	0.47	Angle	0.28
Beaver2	-0.08	Sawyer	0.13	Pine	-0.33	Desire	0.28
Desire	-0.04	Bitter	0.12	Killarney	-1.11	Beaver2	0.25
Lucerne	-0.04	Beaver 2	0.11			Pine	-0.20
Geneva	0.04	Spring	0.10				

*sign indicates trend direction

at Lake Killarney might improve while water quality at Lake Fenwick might decline.

Six lakes demonstrated upward trends for chlorophyll *a* (Table 8). The rates of change in chlorophyll *a* were smaller than those for total phosphorus, ranging from 0.098 µg/L per year at Spring Lake to 0.50 µg/L per year at Lake Desire. However, over time it could result in more visible water quality problems including more frequent algal blooms in an already productive lake system.

Five lakes showed small decreasing rates of change for Secchi depth (Table 8). These rates ranged from 0.04 m to 0.14 m per year. Meanwhile, Lake Geneva showed a small increase in Secchi depth over the available 16-year record. These annual rates of water clarity changes are all minor and would require several decades before a perceptible change became apparent.

Four of five lakes showed decreasing rates of change for average trophic state (Table 9). Lake Fenwick showed the largest annual rate of change at 0.52 trophic units which relates to the significant rate of change in phosphorus levels observed for the lake, since no trends were significant for chlorophyll or Secchi for that lake.

If these trends continue, observable changes in water quality may be on the horizon for several of the region's lakes if existing trends continue. The validation of these trends can only occur by collecting data over the next five to 10 years. By lengthening the data record, trends associated with the larger scale climate effects along with normal year-to-year variation can be better identified and separated from other factors.

Trophic Trends

Trophic patterns were also characterized for the lakes (Table 9). Based on this characterization, 15 lakes are classified as oligotrophic, 21 lakes are mesotrophic, 13 lakes are eutrophic, and two lakes are hypereutrophic.

The oligotrophic lakes in King County are generally characterized by their deeper lake basins with groundwater as a major water source to the lake. Groundwater is generally lower in nutrients than surface water, resulting in lower primary productivity.

The eutrophic and hypereutrophic lakes, on the other hand, typically have many wetland attributes (high organic matter, extensive aquatic plant growth, and shallow depth) resulting from nearby or adjacent shoreline wetlands or the naturally productive character of the immediate watershed. This wetland influence results in higher nutrient flows, making these lakes more biologically active.

The mesotrophic lakes are influenced by a combination of surface, groundwater, and wetland flows. Lake Sawyer is the largest of the mesotrophic lakes in the volunteer monitoring program and one of the few receiving year-round surface inflow. Most of the other lakes receive seasonal surface inflows or in some cases, only nearshore or surface runoff plus groundwater inputs.

Ongoing Threats to Water Quality

The character of land development remains the largest threat to small lake water quality. As land is converted from forested uses for residential, commercial, or industrial development, an immediate impact to lacustrine hydrologic patterns occurs.

Land development generally results in increased impervious surfaces such as rooftops, roads, parking lots, and so on. Subsequently, rainfall travels more quickly to receiving waters (lakes, streams, and wetlands) as surface water runoff, instead of percolating into the soil horizon and moving as groundwater. Surface water picks up soil particles and accumulated pollutants from impervious surfaces, thus delivering sediment and nutrients to lakes. Water clarity may decrease due to particles coming in directly from the surface flows or from increased algal populations as a result of the increase in nutrients.

All of the 12 lakes which showed a decline trend in one or more water quality parameters over the past 16 years have experienced changes in watershed land use. In most cases, the change has been the loss of forested land cover and conversion of this land to residential uses. Although the rate of these changes may be subtle, the cumulative effect of these changes to water quality has been well documented through watershed modeling analysis. While the rate of annual water quality change is small, the cumulative impact could be great if this trend continues.

In addition to large scale issues associated with land development within the watershed, shoreline alteration has a significant localized impact to lake water quality. Alterations include removal of native shoreline vegetation, armoring of the shoreline, dock construction, importing of gravel and sand to form "beaches," and removal of native aquatic plants. All of these seemingly small alterations have a cumulative effect on lake water quality resulting in additional algal growth, loss of fish habitat, and the invasion of less desirable aquatic plants.

Table 9: Trophic Classification for 51 King County Small Lakes

Oligotrophic TSI*<40	**Mesotrophic TSI 40-49**	**Eutrophic TSI 50-59**	**Hypereutrophic TSI 60+**
Alice	Beaver-2	Beaver1	Allen
Ames	Bitter	Cottage	Panther
Angle	Boren	Desire	
Deep**	Burien	Dolloff	
Joy	Fenwick**	Fivemile	
Lucerne	Geneva	Francis	
Margaret	Haller	Garrett	
Meridian	Horseshoe	Killarney	
Pine	Kathleen	Marcel	
Pipe	Leota	McDonald	
Ravensdale	Mirror	Paradise	
Retreat	Morton	Trout	
Shady	Neilson	Webster	
Star	North		
Walker	Sawyer		
	Shadow		
	Spring		
	Steel		
	Twelve		
	Welcome		
	Wilderness		

*Trophic State Index
**Trophic classification based on historical data since recent data has not been collected.

Existing Regulatory Environment

In King County, the regulatory environment protecting lakes is not straightforward. Shorelines and water quality are regulated under a variety of codes that affect the county's 700+ lakes. Lakes that are located in cities come under the set of regulations adopted by the local jurisdiction, while lakes in unincorporated areas are subject to King County's ordinances. There are even some lakes with shorelines that fall into more than one jurisdiction, and that can add a great deal of complexity

The regulations that apply to lakes in unincorporated King County can be complicated enough on their own. When the county's Sensitive Areas Ordinance (SAO) was updated in 1990, lakes were not directly identified as sensitive areas, unlike wetlands and streams. Thus, while both wetlands and streams were afforded specific buffer requirements as designated sensitive areas (and restrictions on particular activities in associated buffer zones), lakes received no defined protection from the ordinance.

Because lakes were not included specifically in the SAO, some shorelines end up being regulated through SAO requirements for wetlands that are associated with specific lakes. In addition, the regulations contained in the Shoreline Management Act (SMA) can be applied to shorelines that are owned by government. Other shorelines have received a variety of protections, depending on jurisdictions and zoning codes. This complex system has resulted in an inconsistent patchwork of shoreline development around lakes, ranging from fully developed shorelines with bulkheads and sandy beaches to shorelines with native buffer requirements from 25 to 100 feet in width, depending on which set of statutes can be applied.

Substantial losses over the last 20 years of natural shorelines of lakes and their associated functions have been partially the result of these complexities and the confusion that has resulted from this regulatory situation. An additional consideration is that the present complicated system of regulations can exasperate lakeside residents, who may be well intentioned in their land use activities, but must wade through a confusing process that is not applied uniformly across the county. It is clear that preserving functionally intact shorelines can help to maintain water quality in lakes with changes occurring in the watershed, and it generally has the added advantage of preserving important ecological habitat as well. A uniform set of ordinances throughout the entire county would make these goals easier to reach for the entire county.

Although shorelines are the most visible connection to each lake, the functionality of the entire watershed area is particularly important in preserving the water and habitat qualities for each of the county's bodies of water. In unincorporated King County, surface waters within watersheds are regulated for both water quality and quantity through the *King County Surface Water Design Manual* (1998b). Watersheds located in incorporated areas are subject to local city regulations, which may or may not be similar to the King County guidelines. Through these county and local regulations, watershed surface water functions are protected to varying degrees, depending upon the sensitivity of the resource and the set of regulations that apply. Regulations applying to lakes that are surrounded by more than one jurisdiction can be especially confusing. The resulting development may appear to be haphazard or poorly planned, although all legal requirements have been met.

A revision of the *King County, Washington-Surface Water Design Manual* (1998b) addressed the need for nutrient removal from surface water reaching six of the county's lakes, designating the lakes and their watersheds as Sensitive Lake Treatment Areas. This was a separate action from the county's Sensitive Area Ordinance and was only applied to those lakes for which a Lake

Management Plan had been completed that included predictions of water quality deterioration if protection was not applied. Protections for other lakes have not been planned as of now.

Suggestions for Action

The preservation of good water quality in King County lakes has involved the stewardship of local lake property owners, particularly the efforts of volunteer lake monitors. Much information has resulted from this work, and it would be hard to overestimate the value of what is being done currently. However, all the lakes could benefit from carefully designed cooperation and partnerships with local government. Four suggestions follow that could be implemented by lakeside and watershed residents, as well as government agencies, to protect and enhance water quality of the small lakes in King County.

Include More Lakes in Regulations

Currently, six lakes and their watersheds are listed as sensitive to eutrophication related to land use changes, thus requiring additional water quality treatment for phosphorus when land is developed within the area (King County, 1998b). These lakes and watersheds include Beaver Lake, Cottage Lake, Lake Desire, Pine Lake, Lake Sammamish, and Lake Sawyer. The designations were made only after detailed restoration and lake management plans were completed, identifying the respective lakes' vulnerability to water quality degradation. Future designation of additional sensitive lake watersheds through the completion of other lake management plans has become unlikely because of the limitations on funding available for development of similar plans.

However, expansion of the list of sensitive lake watersheds could be considered at least in part on the basis of the identification of declining trends in water quality indices, such as those lakes found in this study (Table 10). This could be coupled with evidence of changes in land use in the surrounding watersheds, leading to coherent pictures of the causal agents for trends found for the lakes and possibly suggesting some appropriate actions. Only three of the twelve lakes found to have indices in decline are currently included in King County's sensitive lake watershed designation (Table 10). However, dealing with problems while they are still small rather than waiting for a particular threshold to be crossed is often the most effective management strategy. There is little doubt that the other eight lakes would benefit from a closer look at what is happening in their watersheds, perhaps leading to some kind of further protection.

Table 10: Lakes With Declining Water Quality Trends and Current Lake Designation

Lake	Jurisdiction	Current Sensitive Lake Designation
Angle	SeaTac	No
Beaver2	Sammamish	**Yes**
Bitter	Seattle	No
Desire	King County	**Yes**
Fenwick	Kent	No
Killarney	King County/Federal Way	No
Lucerne	Maple Valley	No
Pipe	Covington/Maple Valley	No
Sawyer	Black Diamond	**Yes**
Shadow	King County	No
Spring	King County	No

Encourage Restoration of Shorelines

Historically, most lakes in King County had limited human access, with some seasonal summer use and occasionally year-round industrial or commercial usage (for example, millponds for logging and sites for private resorts). As the area's population has grown, seasonal summer use and economic uses have shifted to year-round residential use. As a result, shorelines have been modified to accommodate the variety of uses envisioned by individual property owners, varying from minor changes in shoreline access to dock construction, beach building, and bulk heading. These changes can impact the functions of the original shoreline, including water quality filtering; near-shore habitat for fish, frogs, insects, waterfowl, and other animals; and erosion control. Although property owners may reach their desired landscape and land use goals, the outcome is often at the expense of wildlife habitat and good water quality.

Development plans may include the removal and replacement of native vegetation and soils, which can often result in shorelines vulnerable to non-native weed infestations, erosion and sedimentation, increased maintenance issues, nuisance waterfowl taking up residence, and localized water quality problems. Through restoration of shorelines, common problems that plague property owners may be eliminated (like nuisance waterfowl and noxious weeds) and water quality and functional habitat values can be restored. Shoreline restoration does not have to be an all or nothing proposition. Indeed, most shorelines can be restored and still maintain easy access to the water for recreational uses, as well as provide for beautiful views (Henderson et al, 1999; King County 1998).

The King County Lake Stewardship Program staff should continue to support the development of lake-friendly landscapes, providing technical assistance and developing appropriate landscaping resources. The staff should also continue their work with related King County Department of Natural Resources restoration programs as well as staff from the King County Department of Development and Environmental Services to facilitate shoreline restoration.

Implement Stewardship Activities as a Way of Life

Because all watershed residents have direct impacts on the water quality of lakes, informed choices should be made regarding landscaping, fertilizer and pesticide use, maintenance of on-site septic systems, car washing, and pet waste management. The management and choices made for all these actions can positively or negatively influence water quality. By planting native and drought resistant vegetation, as well as reducing lawn size, residents can lower their landscape water demand and chemical usage. Poorly maintained on-site septic systems also impact water quality: signs of septic system failure include especially green grass over the drain field, overgrowth of "water-loving" plants like buttercup, and soggy areas of ground remaining during dry weather periods. Through regular inspection, residents can ensure that timely maintenance occurs and that peak operating potential of septic tanks and drain fields is maintained. Other sources of nutrients reaching lakes can come from pet or livestock waste left on the ground, vehicle washing, and erosion of soils along the shoreline of the lake or from barren upland areas. Every resident can minimize their impact by the choices that are made each day in their activities.

The King County Lake Stewardship Program staff should continue to support local implementation of personal stewardship activities near the small lakes of the region. This support should include providing technical assistance and information on the best uses and care of native plants, natural lawn care, on-site septic system maintenance, pet and livestock waste disposal, erosion control, and car-washing alternatives.

Apply Watershed Best Management Practices

Every lake and its watershed have unique features to be appreciated and understood. In preserving the functionality of any watershed, appropriate best management practices must be implemented as the land is developed. Since lakes are particularly vulnerable to additional sediment and associated nutrients from storm-water runoff, attention must be paid to how land is developed and whether appropriate mitigation can be implemented to preserve all watershed functions.

The King County Lake Stewardship Program staff should continue to support the implementation of watershed best management practices. This support includes providing technical assistance, coordinating with basin stewards and other agency staff, and working with local communities when questions arise concerning impacts on lakes as a result of projected development or changes in land use.

Final Notes

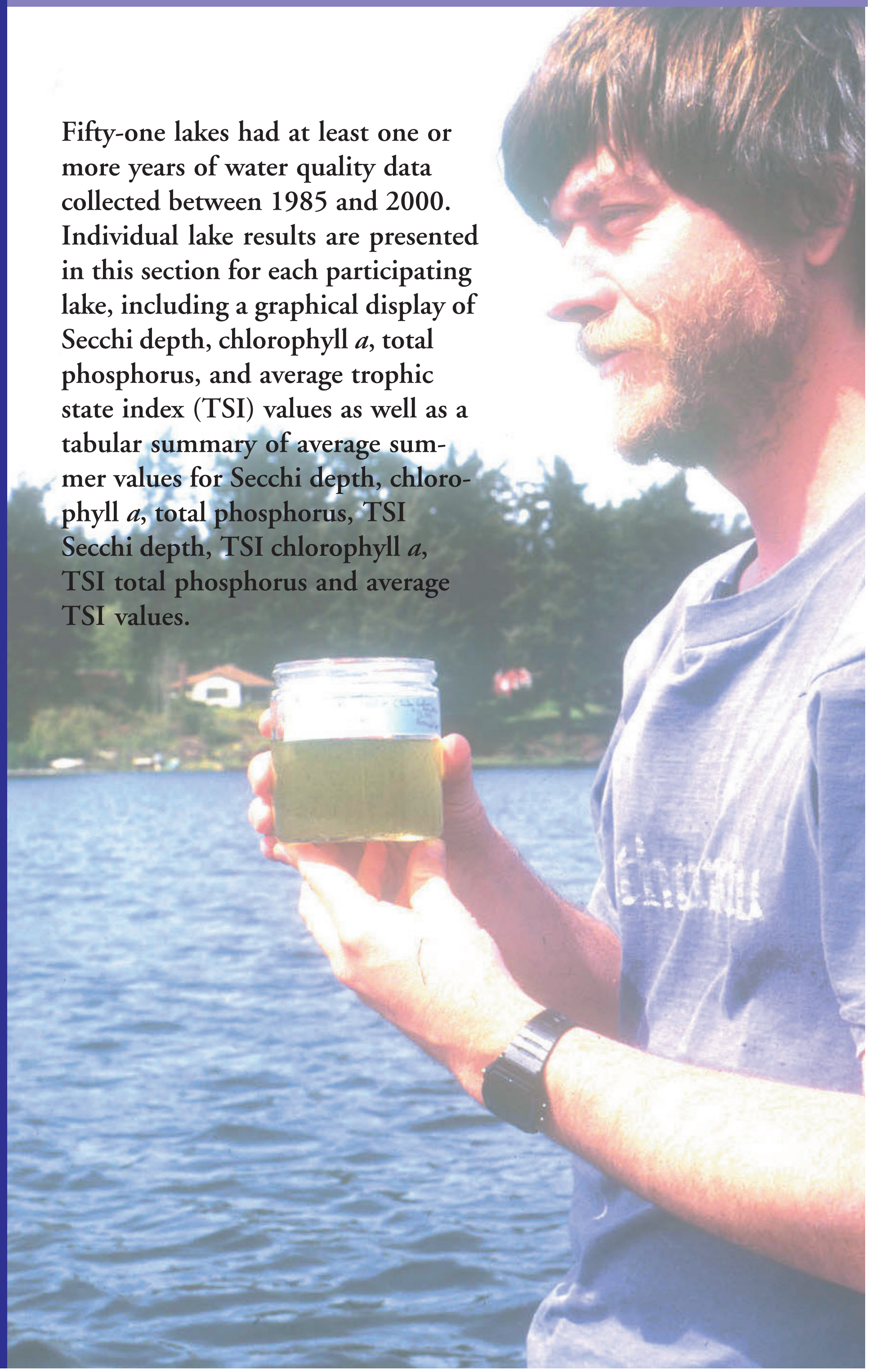
Trend identification depends on long term monitoring, in particular because there is an inherent year-to-year variability of water quality based on the complexities of processes going on in lakes and climatic impacts. This can only be taken into account by looking at longer periods of time. However, in the life span of a lake, a record of 16 years is not very long, though it is enough to document a statistically significant trend. As our monitoring records are extended, the calculated rates of degradation such as are reported here will be validated or adjusted for all the lakes that we study. Some reversals may occur with changes in management strategies, or new trends may be identified in other lakes as development of the land in King County continues.

Given the rapid growth experienced by the Puget Sound region, small lakes appear to have faired reasonably well so far. The maintenance of good water quality in most of these lakes remains largely in the hands of watershed residents who have great impacts on shoreline and water quality. Shoreline residents can be important advocates for their lake within their respective watersheds, as well as in the local jurisdictions that regulate watershed and shoreline development.

We have a lot to lose, but we have a lot to gain as well by our actions and decisions. Through partnerships among property owners, users of lakes, local governments, technical experts, and non-profit organizations, water quality in the region can continue to be appreciated and preserved. By engaging citizen volunteers and maintaining carefully designed monitoring programs, keeping track of many lakes simultaneously can continue in a cost-effective manner. The valuable information gained on the state of the county's lakes and associated watersheds will help people to make the best possible decisions for the future for our lakes.

Individual Lake Results

Fifty-one lakes had at least one or more years of water quality data collected between 1985 and 2000. Individual lake results are presented in this section for each participating lake, including a graphical display of Secchi depth, chlorophyll *a*, total phosphorus, and average trophic state index (TSI) values as well as a tabular summary of average summer values for Secchi depth, chlorophyll *a*, total phosphorus, TSI Secchi depth, TSI chlorophyll *a*, TSI total phosphorus and average TSI values.



Alice

In 2000, volunteers began collecting monitoring data on Lake Alice when the services of the Lake Stewardship Program were extended to eastern King County through the Rural Drainage Program. Because the data record consists of only a single year, no statistical trend analyses were completed for Lake Alice. In the summer of 2000, productivity was low (oligotrophic) at Lake Alice, characterized by moderate water clarity and low chlorophyll *a* and phosphorus levels (see data table below).

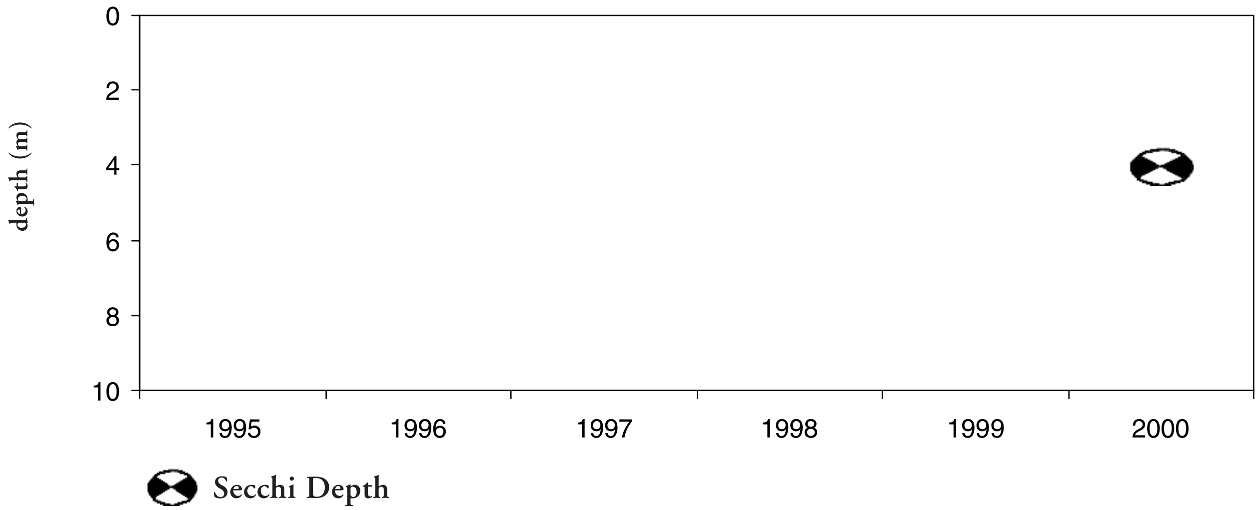
On the adjacent page, available data are shown for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state during 2000. These values are illustrated here to allow visual comparison with other lakes that have participated in the program for longer time periods.

Based on this limited data, water quality is very good at Lake Alice. The lake watershed is largely forested which contributes to high quality surface flows to the lake. However, erosion and nutrient control measures in the watershed are becoming increasingly important to preserving existing lake water quality as new land development or local shoreline alteration occurs.

Average Values for Select Trophic Parameters at Alice Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (μg/L)	TP* (μg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
2000	13	4	2.4	9.3	40	39	36	39

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index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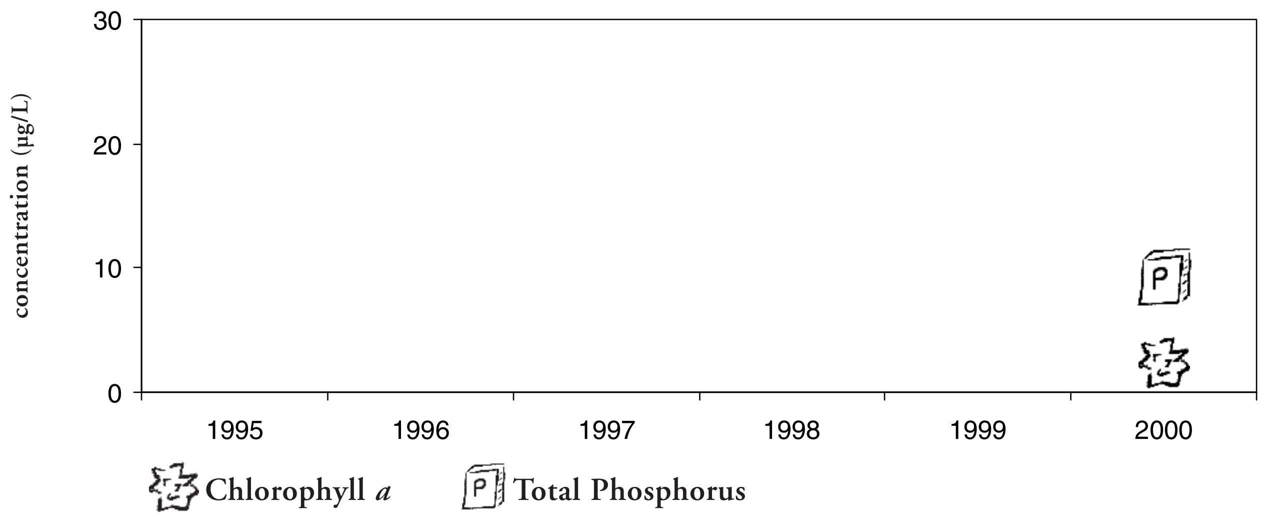
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
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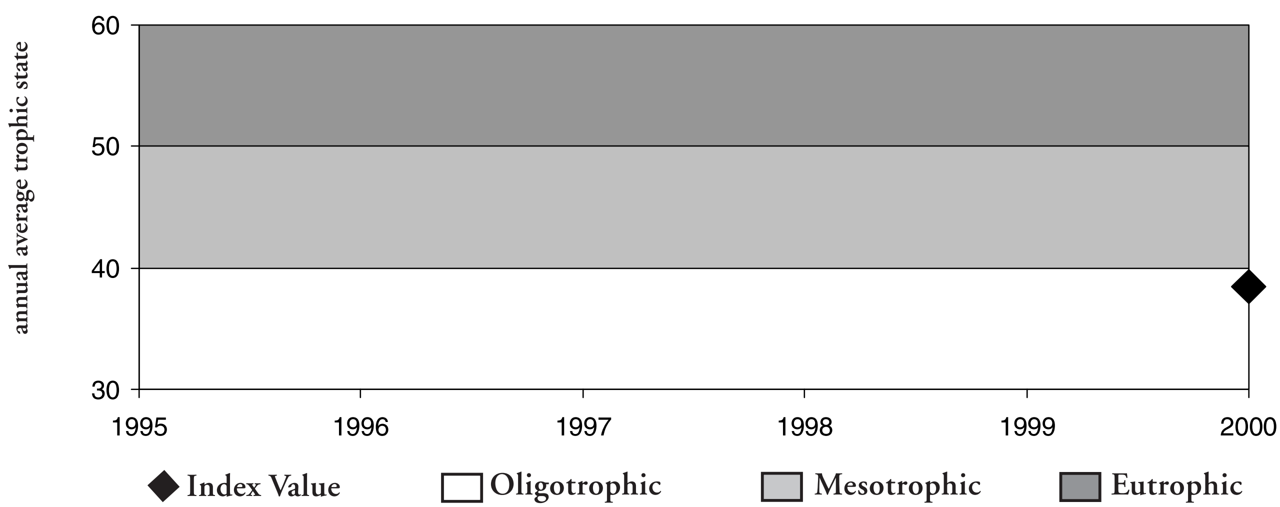
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Allen

In 1996, volunteers began collecting monitoring data on Allen Lake located in eastern King County. Because the data record is relatively short, no statistical trend analyses were completed for Allen Lake. Generally, productivity was high (eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

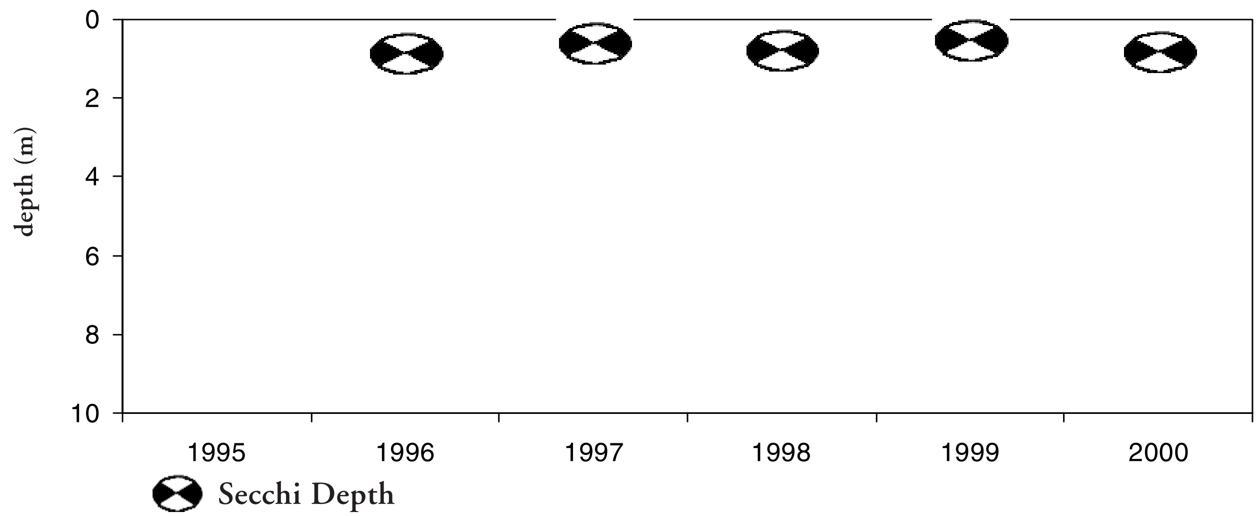
Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state values. Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels show considerable variation from year to year.

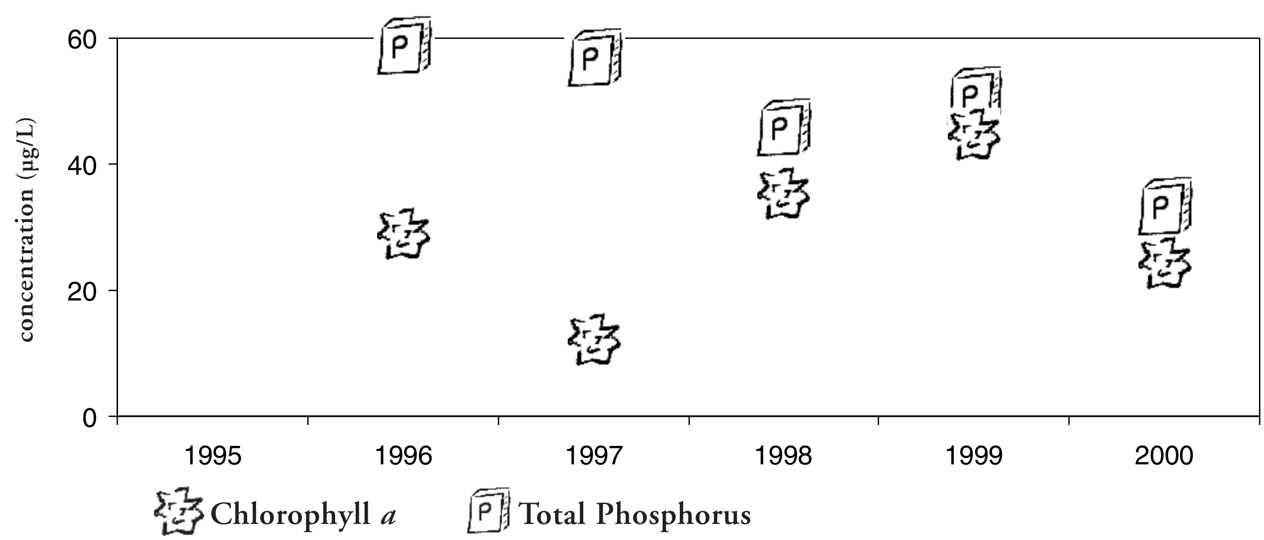
Overall, water quality is fair at Allen Lake, influenced by wetland chemistry that gives the lake its dark color and low Secchi depth. The eutrophic character of the lake is natural. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as new land development or local shoreline alteration occurs.

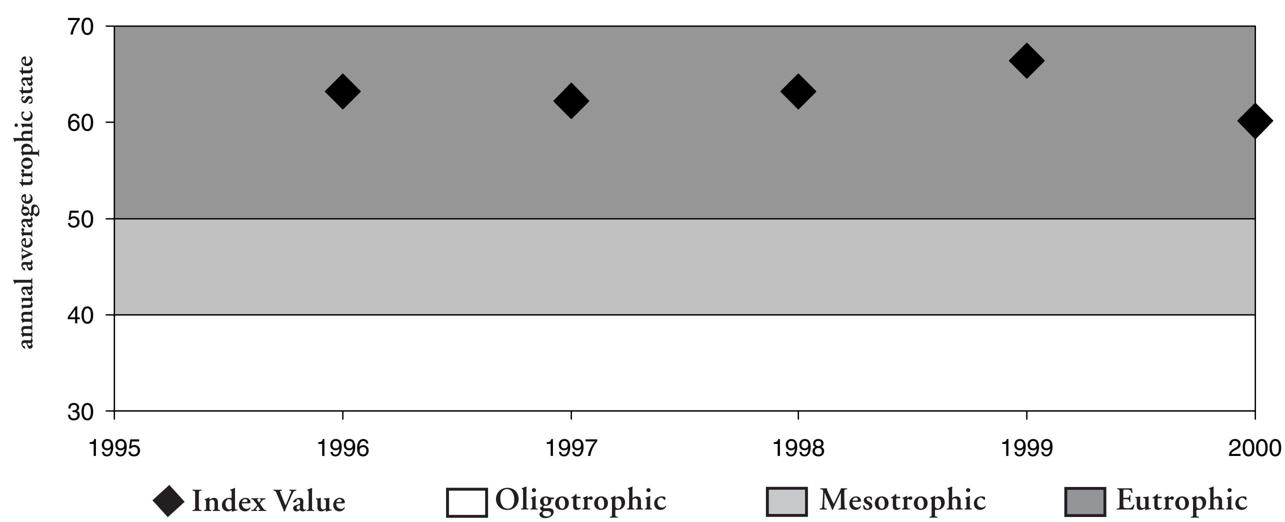
Average Values for Select Trophic Parameters at Allen Lake

Year	No. of Samples	Secchi (meter)	Chl *a* * (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	12	0.8	29.3	59	63	64	63	63
1997	12	0.5	12.3	57	69	55	62	62
1998	13	0.7	35.5	46	65	66	59	63
1999	13	0.5	44.9	51	71	68	61	66
2000	13	0.8	24.5	33	64	62	55	60

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
60
40
20
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
70
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Ames

In 2000, volunteers began collecting monitoring data on Ames Lake when the services of the Lake Stewardship Program were extended to eastern King County through the Rural Drainage Program. Because the data record consists of only a single year, no statistical trend analyses were completed for Ames Lake. In the summer of 2000, productivity was low (oligotrophic) at Ames Lake, characterized by moderate water clarity and low chlorophyll *a* and phosphorus levels (see data table below).

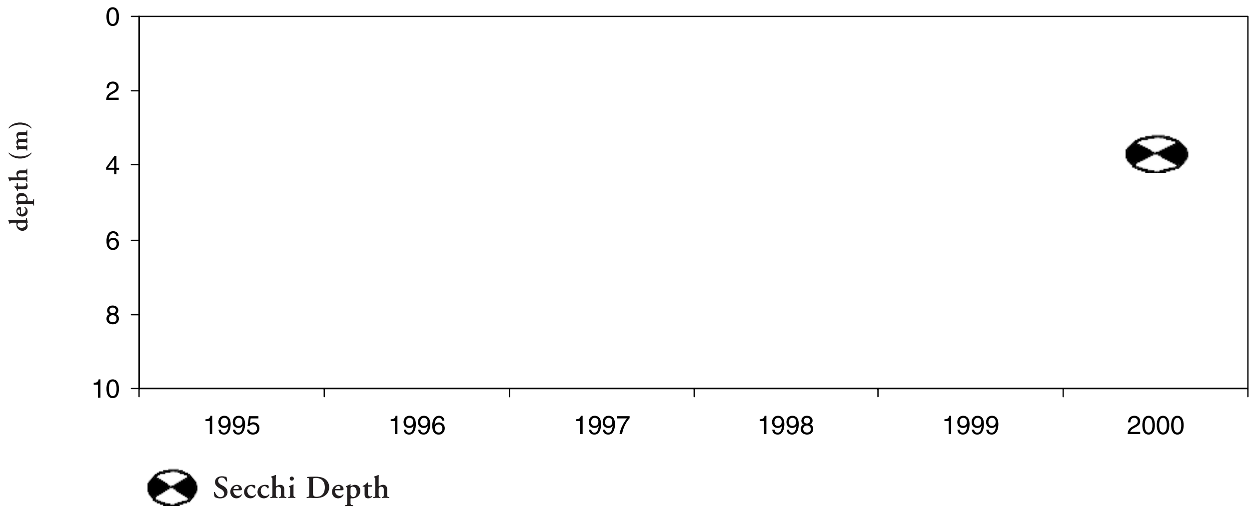
Average values for May through October are shown for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state during 2000. These values are illustrated here to allow visual comparison with other lakes that have participated in the program for longer time periods.

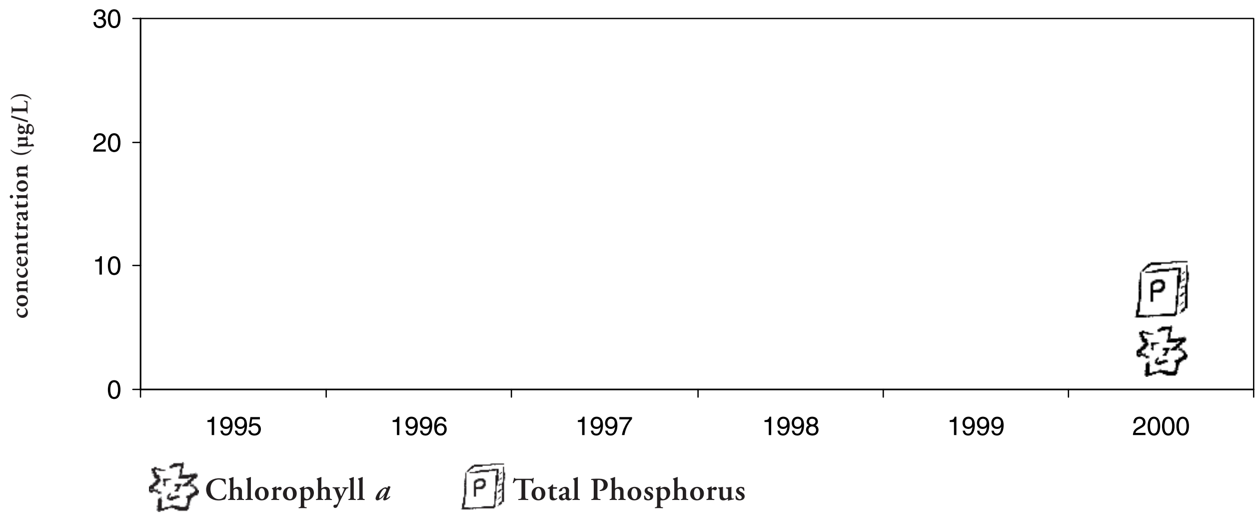
Based on this limited data, water quality is very good at Ames Lake. The lake watershed is largely forested which contributes to maintaining high quality and adequate surface flows to the lake. Increasingly, erosion and nutrient control measures in the watershed are becoming more important to preserving existing lake water quality as new land development or local shoreline alteration occurs.

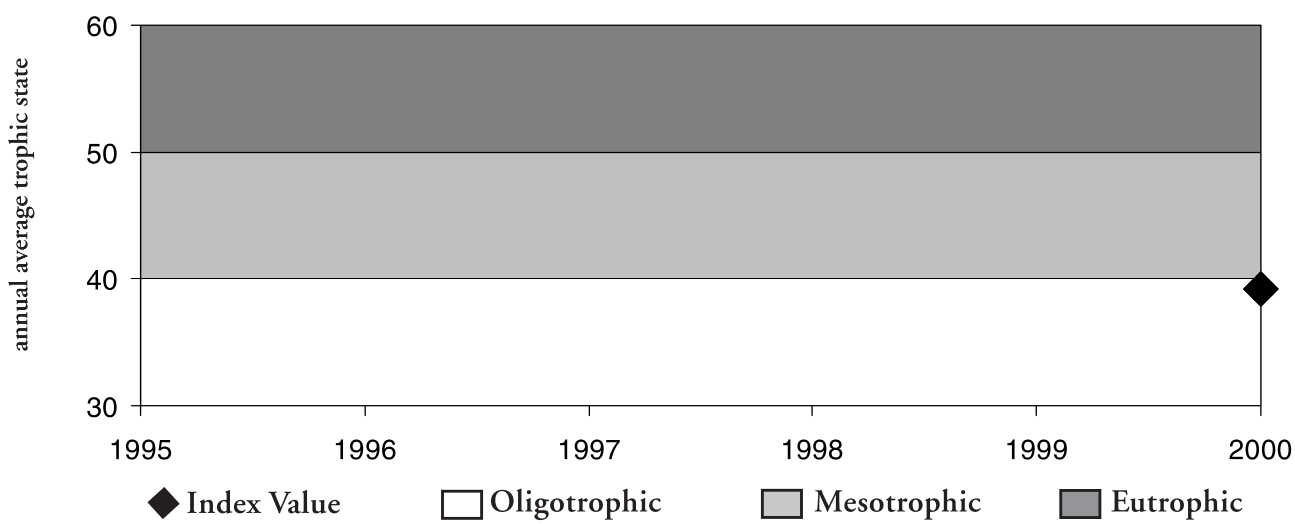
Average Values for Select Trophic Parameters at Ames Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (μg/L)	TP* (μg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
2000	13	3.6	3.2	8.1	41	42	34	39

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
P
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Angle

Volunteers have collected monitoring data since 1985 on Angle Lake located in SeaTac. The data record is nearly complete with data missing only during 1996. Generally, productivity was low (oligotrophic), characterized by excellent water clarity and low chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state values. Visual analysis reveals a gradual decrease in Secchi depth and an increase in overall trophic state during the 16-year record. Additionally, phosphorus levels have varied somewhat from year to year with peak average values occurring in 1989 and 1994.

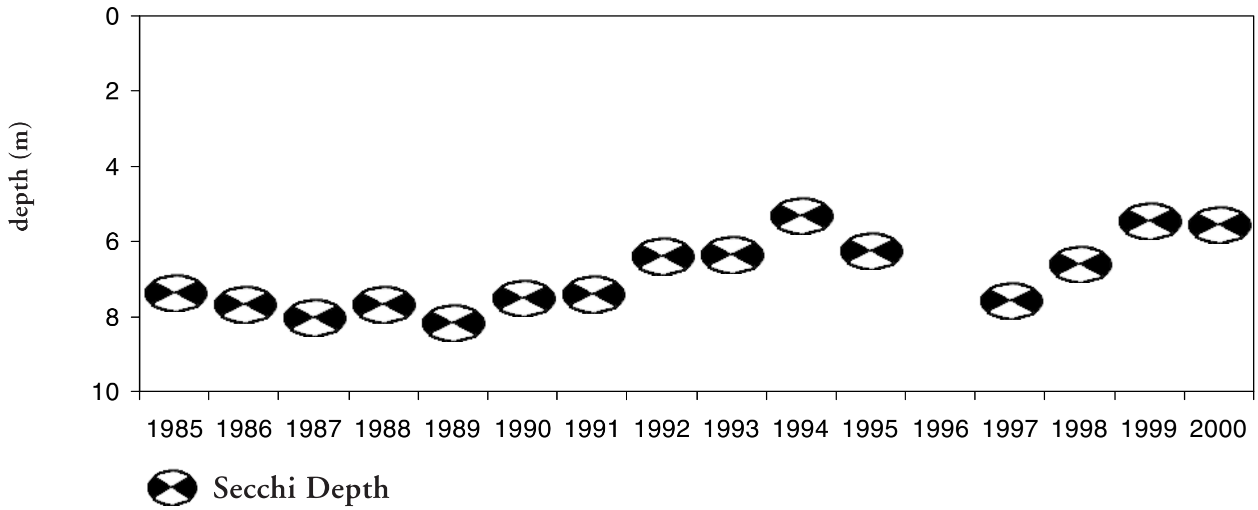
To evaluate whether statistically significant changes in water quality have occurred at Angle Lake, trend analyses were performed on the data using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant downward trend in Secchi depth was found (n=15; p=0.01; slope=-0.14) suggesting a slight decline in water clarity has occurred at Angle Lake since 1985. Significant upward trends were also noted for TSI Secchi (n=15; p=0.01; slope=0.32) and TSI Average (n=15; p=0.006; slope=0.28). The significant trends for TSI Secchi and TSI Average are related given TSI Secchi is a calculated from Secchi data and TSI average includes TSI Secchi in the calculation. Chlorophyll and Total Phosphorus also showed increasing trend, but both were at 90 percent level rather than at 95 percent, so were not as strongly indicated.

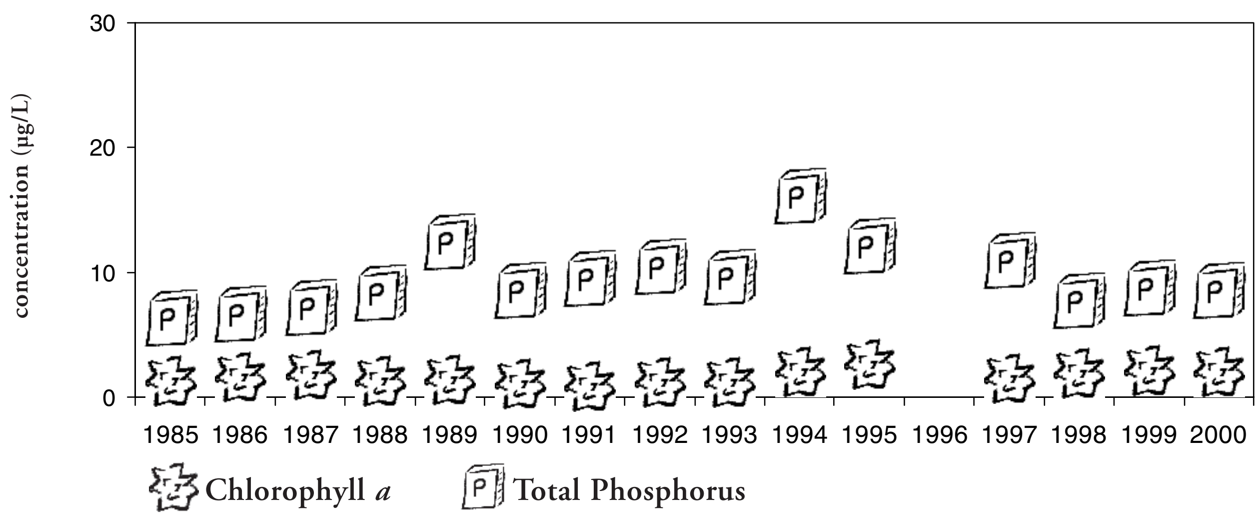
Overall, water quality is excellent at Angle Lake where groundwater is the primary source of water to the lake. Local stewardship by residents remains important to ensure ongoing erosion and nutrient control measures take place as new land development or local shoreline alteration occurs.

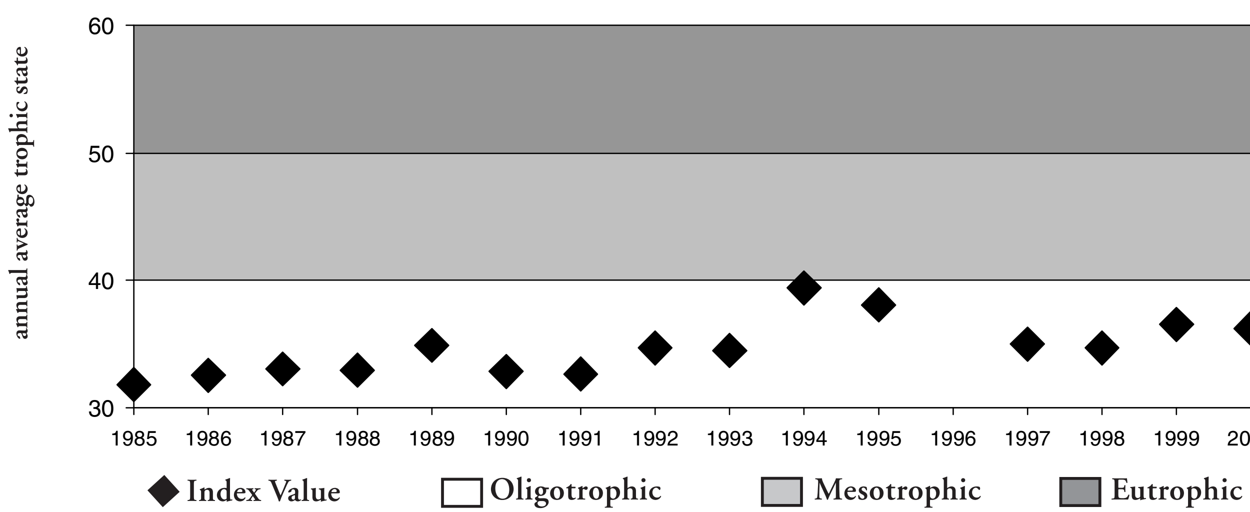
Average Values for Select Trophic Parameters at Angle Lake

Year	No. of Samples	Secchi (meter)	Chl *a* * (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	7.3	1.3	6	31	33	31	32
1986	12	7.6	1.6	7	31	35	32	33
1987	12	8.0	1.9	7	30	37	33	33
1988	12	7.6	1.3	8	31	33	35	33
1989	12	8.1	1.5	13	30	34	41	35
1990	10	7.5	1.2	9	31	32	35	33
1991	9	7.4	0.9	10	31	30	37	33
1992	12	6.4	1.2	11	33	33	38	35
1993	11	6.3	1.3	10	33	33	37	34
1994	12	5.3	2.1	16	36	38	44	39
1995	9	6.2	2.8	12	34	41	40	38
1996	---	---	---	---	---	---	---	---
1997	9	7.5	1.6	11	31	35	39	35
1998	13	6.6	2.0	8	33	37	34	35
1999	13	5.4	2.3	9	36	39	35	37
2000	13	5.5	2.1	9	35	38	35	36

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Beaver 1

In 1997, volunteers began collecting monitoring data on Beaver Lake 1 (the northernmost lake waterbody in the Beaver Lake chain) located in Sammamish. Because the data record is relatively short, no statistical trend analyses were completed for Beaver Lake 1. Generally, productivity was moderate to high (mesotrophic to eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state values. Visual analysis reveals a reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels show more variation from year to year.

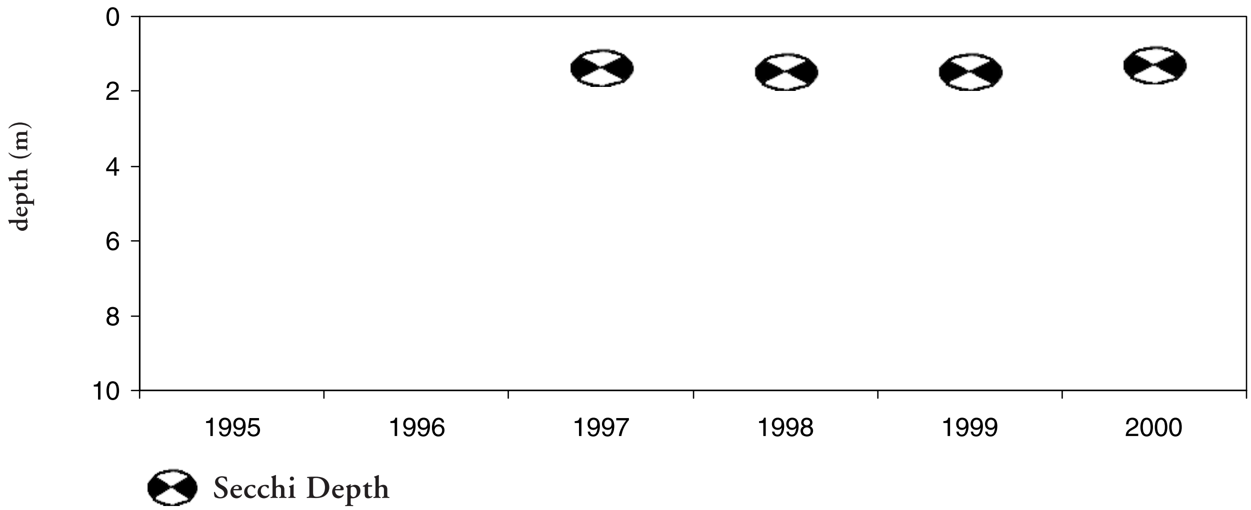
Overall, water quality is fair at Beaver 1, influenced by wetland chemistry that gives the lake its dark color and low Secchi depth. The eutrophic character of the lake is a natural function of the basin which receives inflow directly from an upstream bog. Ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as new land development or local shoreline alteration occurs.

Through the Beaver Lake Management District, local residents updated the original 1993 Beaver Lake Management Plan in 2000 (King County, 2000a). The updated plan emphasizes preservation of upland wetlands, enforcing development guidelines, managing stormwater, and implementing local shoreline and watershed preservation activities. Residents are currently forming a second lake management district to implement plan recommendations.

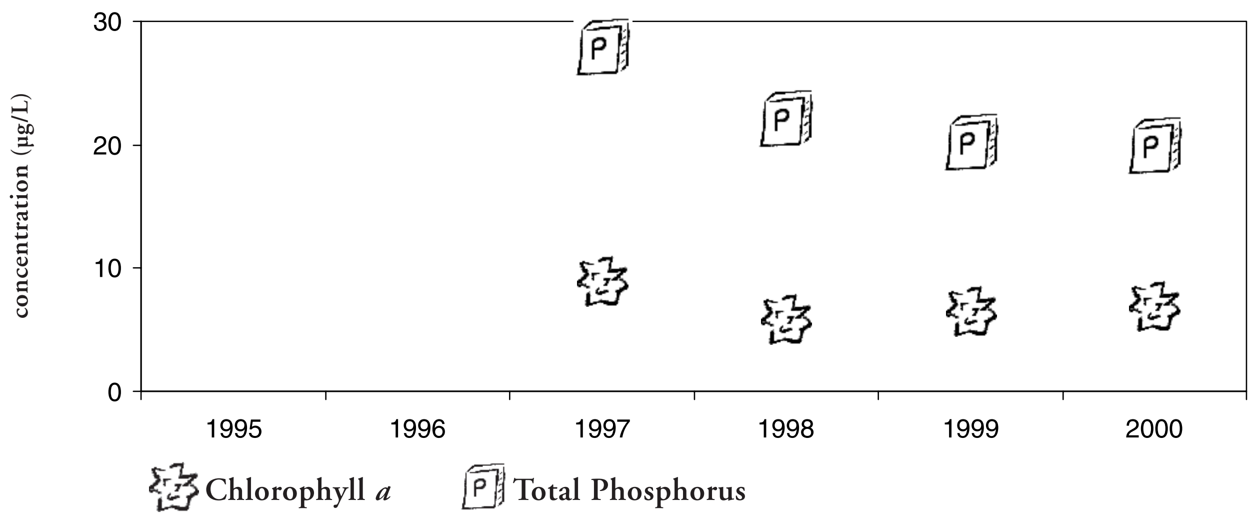
Average Values for Select Trophic Parameters at Beaver Lake 1

Year	No. of Samples	Secchi (meter)	Chl *a* * (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1997	12	1.3	9.0	28	56	52	52	53
1998	13	1.4	5.9	22	55	48	49	51
1999	13	1.4	6.6	20	55	49	48	51
2000	13	1.3	6.9	20	57	50	47	51

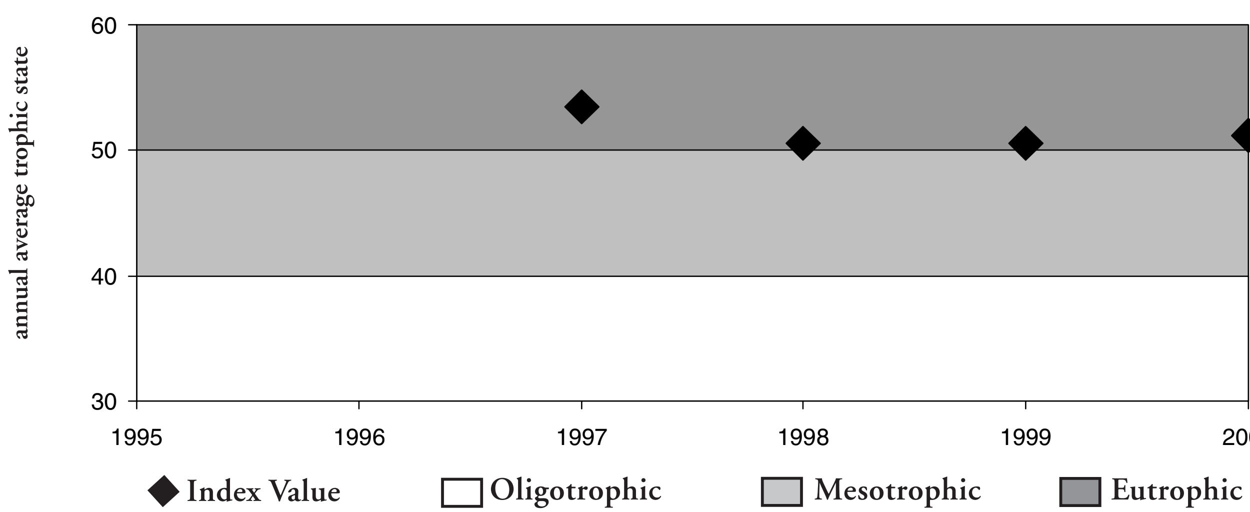
*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index



depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth



concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll a
Total Phosphorus



annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Beaver 2

Volunteers have collected monitoring data since 1985 on Beaver Lake 2 located in Sammamish. The data record is nearly complete with data missing only during 1990 and 1992. Generally, productivity was moderate (mesotrophic), characterized by moderate water clarity, chlorophyll *a*, and phosphorus levels (see below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state values. Visual analysis reveals a minor decrease in Secchi depth and a slight increase in chlorophyll levels during the 16-year record. Additionally, phosphorus levels have varied from year to year with a peak average value occurring in 1994.

To evaluate whether statistically significant changes in water quality have occurred at Beaver Lake 2, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant downward trend in Secchi depth was found (n=14; p=0.03; slope= -0.08) while an upward trend was noted for chlorophyll *a* (n=14; p=0.02; slope=0.11) suggesting a slight decline in water quality has occurred at Beaver Lake since 1985. Significant upward trends were also noted for TSI Secchi (n=14; p=0.03; slope=0.38), TSI Chl *a* (n=14; p=0.02; slope=0.30) and TSI Average (n=14; p=0.02; slope=0.25). The significant trends for TSI Secchi, TSI Chl *a*, and TSI Average are related given TSI Secchi is a calculated from Secchi data while TSI Chl *a* is a calculated from the chlorophyll *a* data and the TSI average includes both values in the calculation.

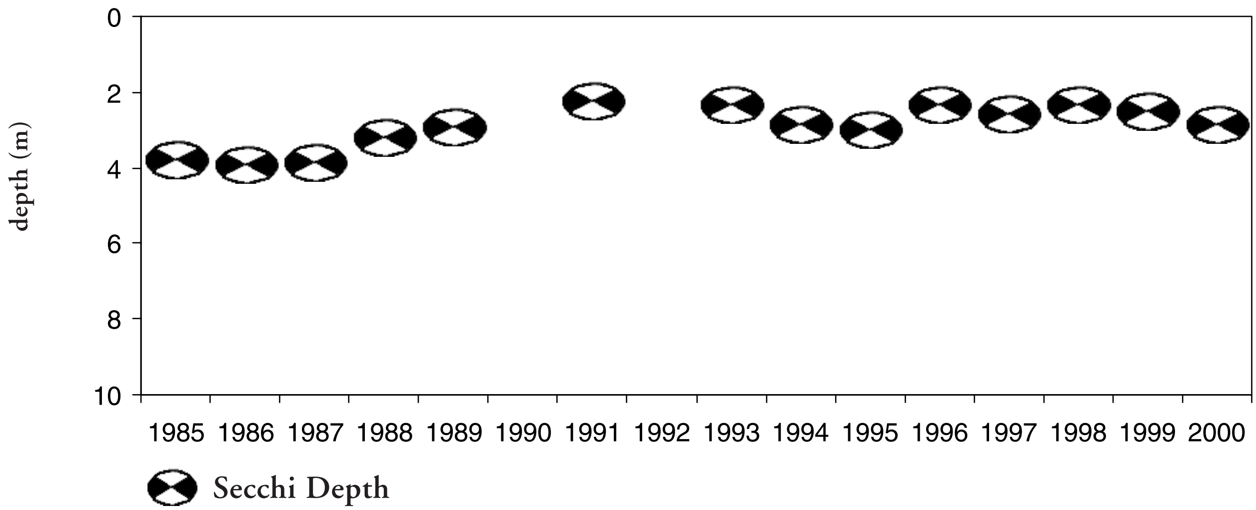
Overall, water quality is moderately good (mesotrophic) with both surface and groundwater flows influencing lake chemistry. Wetland inflows still influence lake water quality at Beaver Lake 2, but to a lesser degree than observed in Beaver Lake 1.

Through the Beaver Lake Management District, local residents updated the original 1993 lake management plan in 2000 (King County, 2000a). The updated plan emphasizes preservation of upland wetlands, enforcing development guidelines, managing stormwater, and implementing local shoreline and watershed preservation activities.

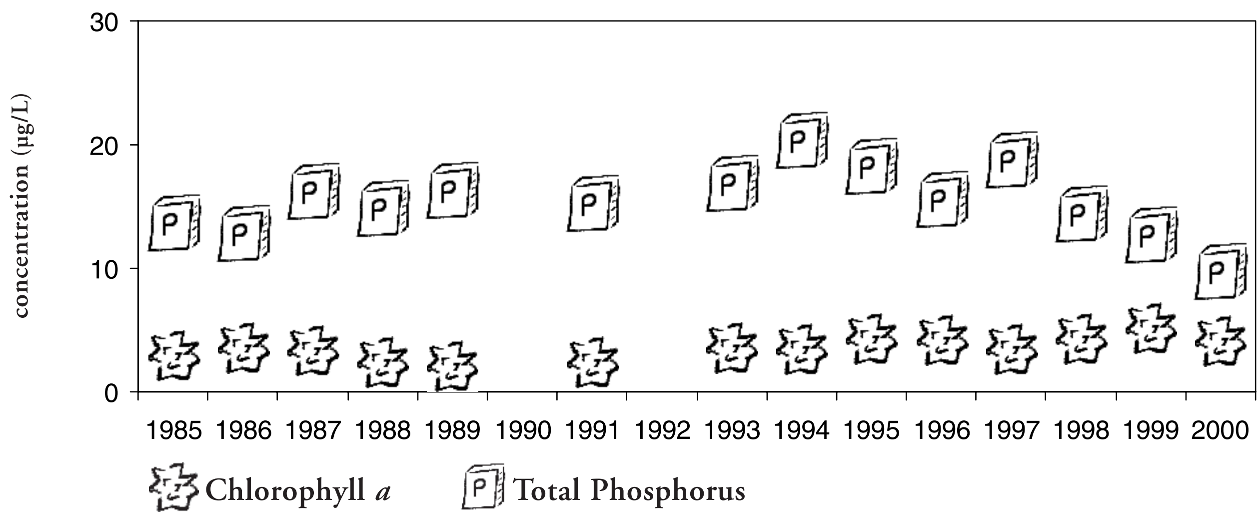
Average Values for Select Trophic Parameters at Beaver Lake 2

Year	No. of Samples	Secchi (meter)	Chl *a* * (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	12	3.7	3.0	14	41	41	42	41
1986	12	3.9	3.6	13	41	43	41	42
1987	12	3.8	3.4	16	41	43	44	43
1988	10	3.1	2.5	15	43	39	43	42
1989	10	2.9	2.1	16	45	38	44	42
1990	---	---	---	---	---	---	---	---
1991	12	2.2	2.5	15	49	39	44	44
1992	---	---	---	---	---	---	---	---
1993	10	2.3	3.6	17	48	43	45	45
1994	6	2.8	3.5	20	45	43	48	45
1995	11	2.9	4.4	18	44	45	46	45
1996	9	2.3	4.3	16	48	45	44	46
1997	12	2.5	3.6	19	47	43	46	45
1998	13	2.3	4.4	14	48	45	43	45
1999	13	2.5	5.2	13	47	47	41	45
2000	13	2.8	4.2	10	45	45	37	42

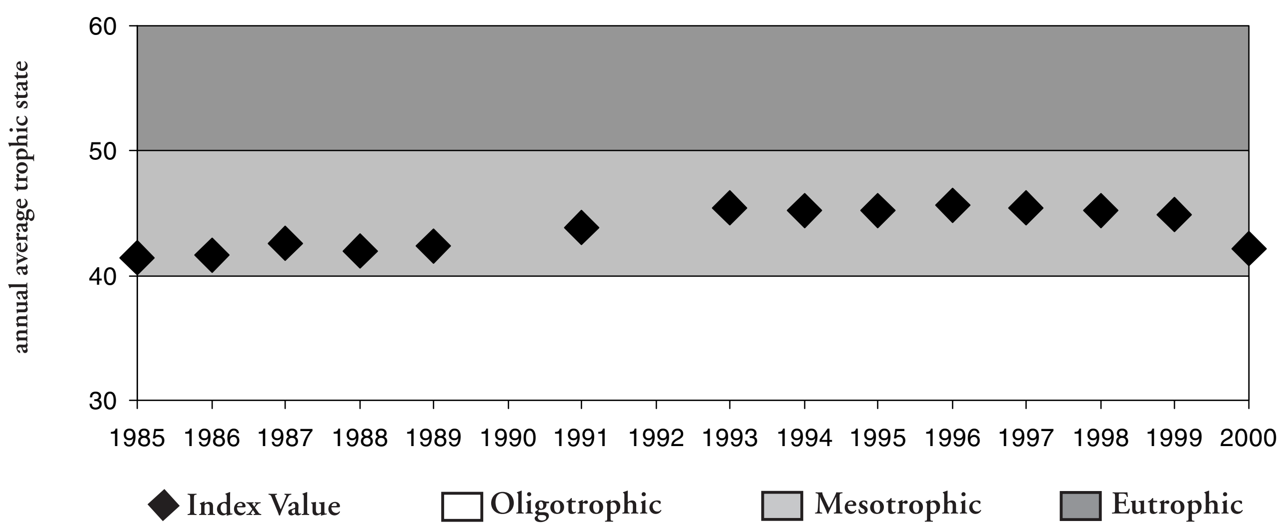
*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index



depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth



concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus



annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Bitter

Since 1986, volunteers have collected monitoring data on Bitter Lake located in Seattle. The data record is mostly complete with data missing during 1985, 1987, and from 1994 to 1996. Generally, productivity was moderate (mesotrophic), characterized by very good water clarity, low chlorophyll *a* values, and low to moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state values. Visual analysis reveals a gradual decrease in Secchi depth and an increase in overall trophic state during the 16-year record. Additionally, phosphorus levels have been variable from year to year with a peak value occurring in 1991.

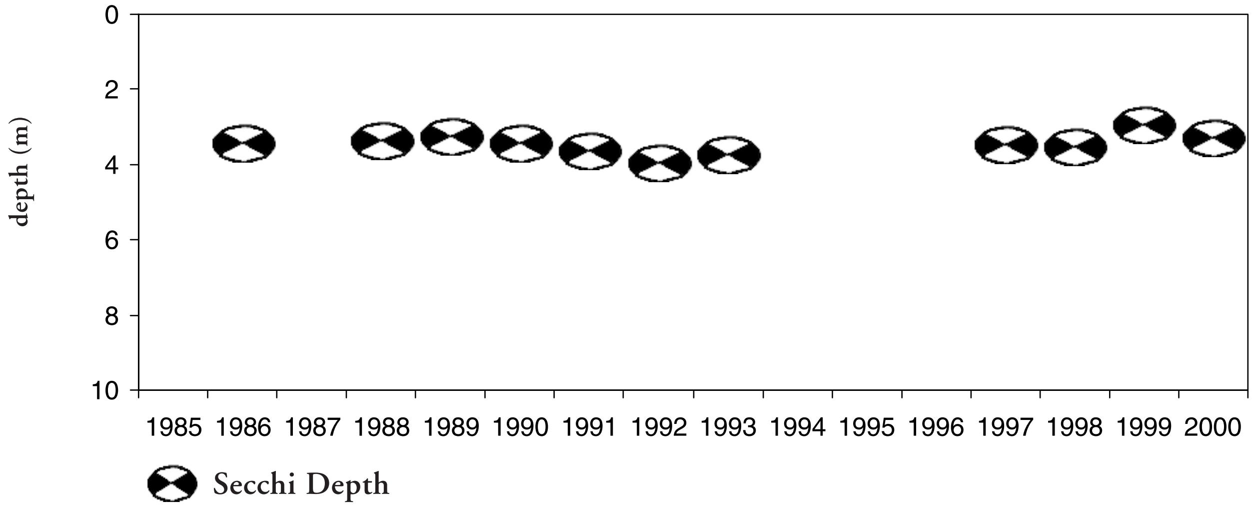
To evaluate whether statistically significant changes in water quality have occurred at Bitter Lake, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant upward trend was noted for chlorophyll *a* (n=10; p=0.008; slope=0.12) suggesting a slight increase in algal levels has occurred at Bitter Lake since 1986. A significant upward trends was also noted for TSI Chl *a* (n=15; p=0.01; slope=0.32). The significant trend for TSI Chl *a* is predictable given TSI Chl *a* is a calculated from chlorophyll *a* data.

Overall, water quality is moderately good (mesotrophic) at Bitter Lake. Local stewardship by lake residents, however, remains important to ensure ongoing erosion and nutrient control measures take place as new land development or local shoreline alteration occurs.

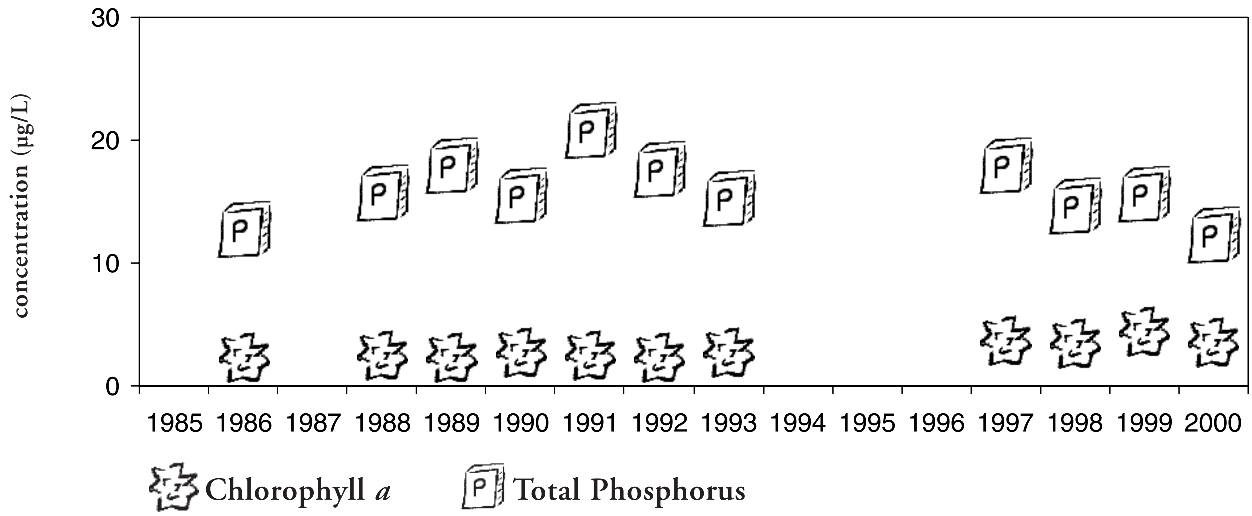
Average Values for Select Trophic Parameters at Bitter Lake

Year	No. of Samples	Secchi (meter)	Chl *a* * (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	---	---	---	---	---	---	---	---
1986	8	3.4	2.3	13	42	39	41	41
1987	---	---	---	---	---	---	---	---
1988	7	3.3	2.5	16	43	40	44	42
1989	12	3.2	2.3	18	43	39	46	43
1990	12	3.4	2.8	16	42	41	44	42
1991	10	3.6	2.6	21	42	40	48	43
1992	11	3.9	2.4	18	40	39	46	42
1993	10	3.7	2.7	15	41	40	43	42
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	---	---	---	---	---	---	---	---
1997	9	3.4	3.7	18	42	43	46	44
1998	11	3.5	3.5	15	42	43	43	43
1999	12	2.9	4.5	16	45	45	44	45
2000	13	3.2	3.7	12	43	43	40	42

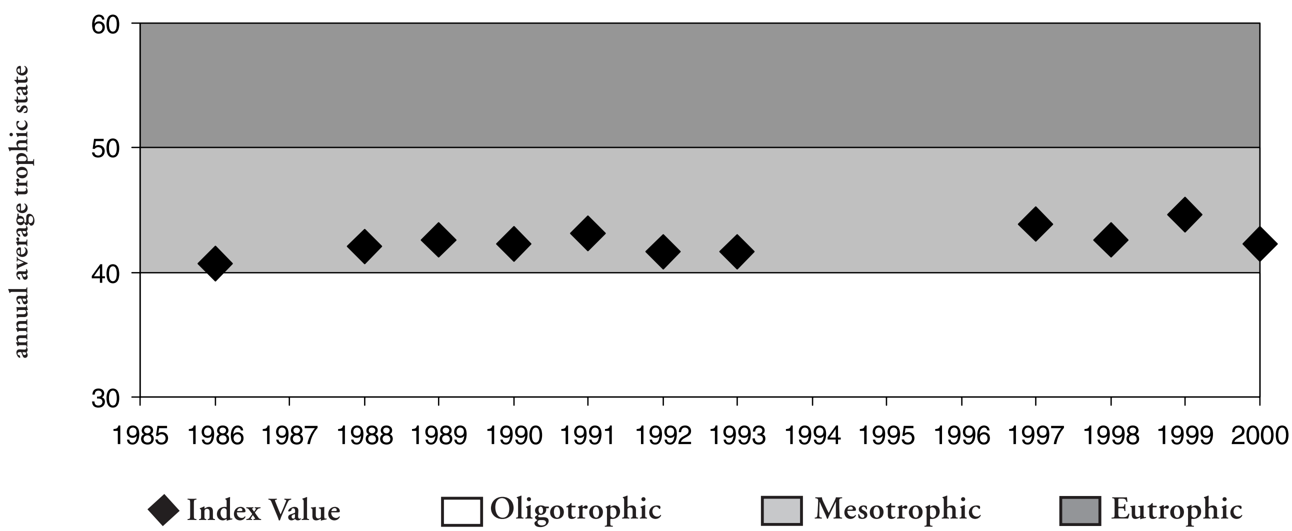
*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index



depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth



concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus



annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Boren

Volunteers have collected monitoring data since 1988 on Lake Boren located in Newcastle. The data record is only partially complete with data missing during eight of 16 years. Generally, productivity was moderate (mesotrophic), characterized by good water clarity, low chlorophyll *a* values, and low to moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state values. Visual analysis reveals little variation in Secchi depth and chlorophyll *a* during the 16-year record while phosphorus levels have varied from year to year with a peak value occurring in 1994.

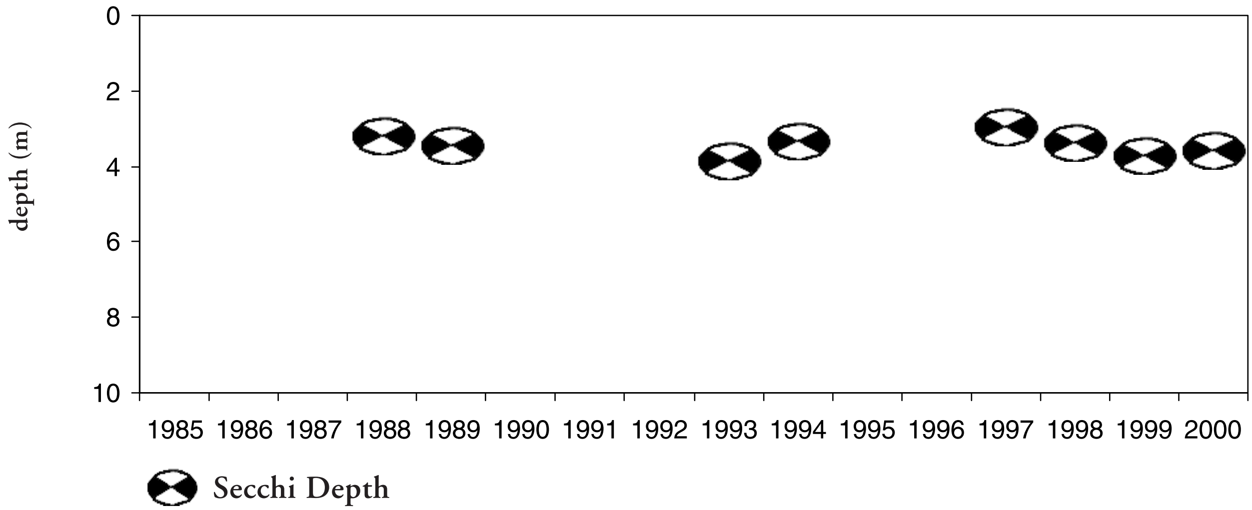
To evaluate whether statistically significant changes in water quality have occurred at Lake Boren, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the available data.

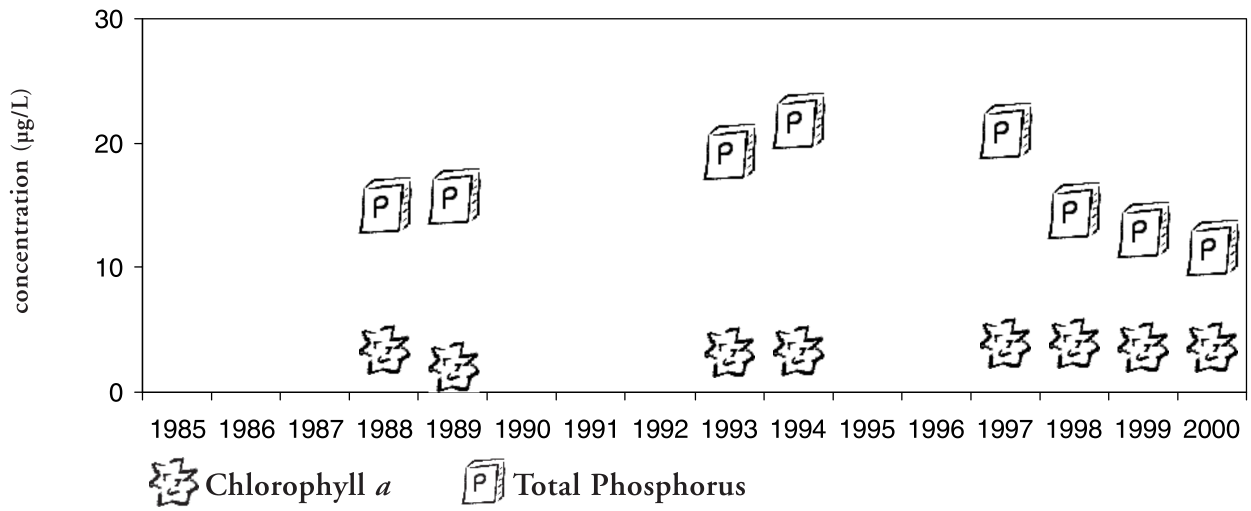
Overall, water quality remains good at Lake Boren where trophic state values have been in the middle to lower 40s. Local stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as new land development or local shoreline alteration occurs.

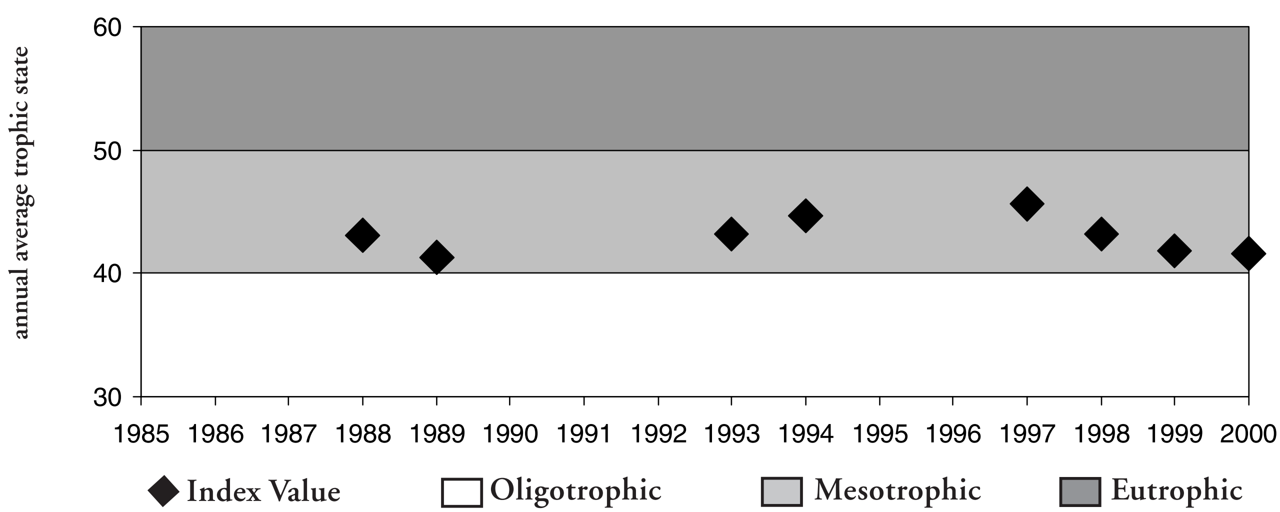
Average Values for Select Trophic Parameters at Lake Boren

Year	No. of Samples	Secchi (meter)	Chl *a* * (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	---	---	---	---	---	---	---	---
1986	---	---	---	---	---	---	---	---
1987	---	---	---	---	---	---	---	---
1988	11	3.1	3.4	15	43	43	43	43
1989	10	3.4	2.1	16	42	38	44	41
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	11	3.8	3.2	19	41	42	47	43
1994	13	3.3	3.4	22	43	43	49	45
1995	---	---	---	---	---	---	---	---
1996	---	---	---	---	---	---	---	---
1997	11	2.9	4.0	21	45	44	48	46
1998	13	3.3	3.9	15	43	44	43	43
1999	13	3.7	3.6	13	41	43	41	42
2000	12	3.5	3.7	12	42	43	40	42

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Burien

In 1998, volunteers began collecting monitoring data on Lake Burien located in Burien. Because the data record is relatively short, no statistical trend analyses were completed for Lake Burien. Generally, productivity is moderate (mesotrophic), characterized by intermediate water clarity, chlorophyll *a,* and phosphorus levels (see data table below).

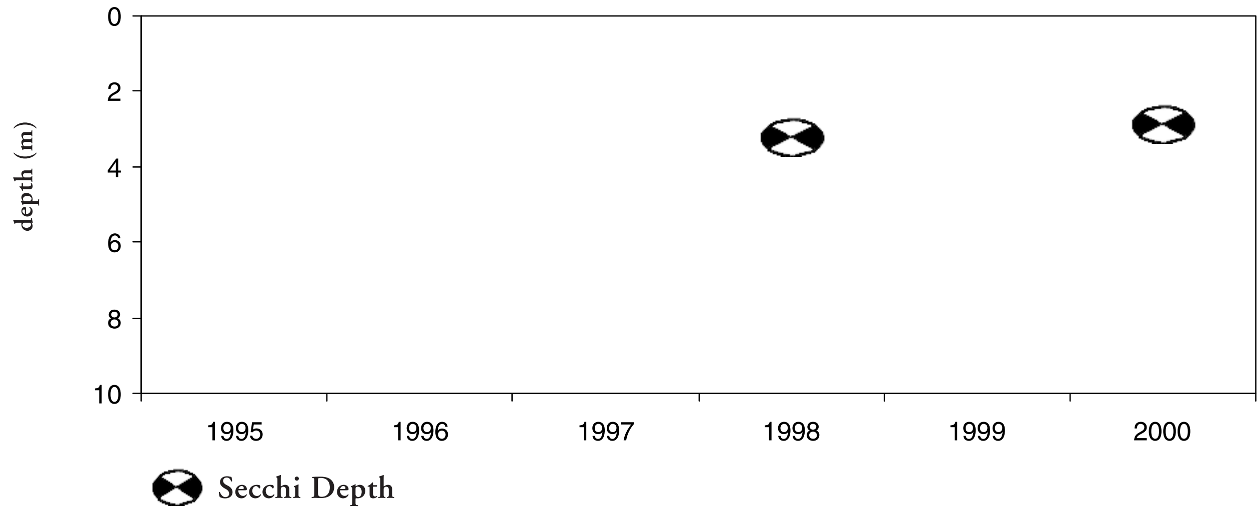
Average values for May through October, are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state values. Data for two years is reasonably consistent for all parameters.

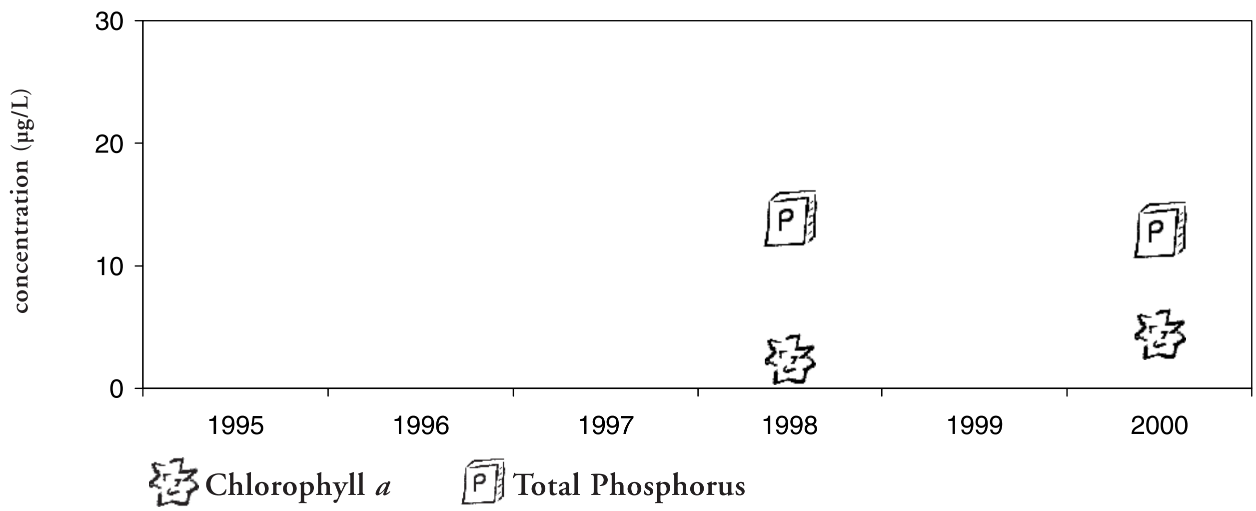
Overall, water quality is moderately good at Lake Burien even though the lake receives surface flow primarily from an urban residential watershed. The mesotrophic character of the lake is typical for most small lakes in the Puget Sound region. Ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as land redevelopment or local shoreline alteration occurs.

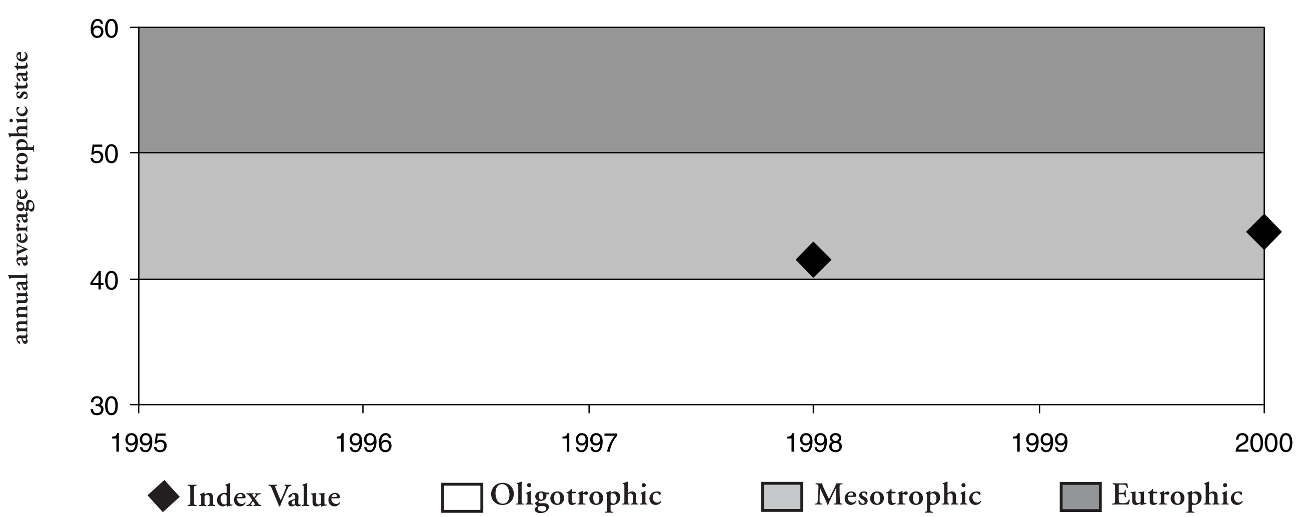
Average Values for Select Trophic Parameters at Lake Burien

Year	No. of Samples	Secchi (meter)	Chl *a* * (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1998	6	3.2	2.4	14	43	39	42	42
1999	---	---	---	---	---	---	---	---
2000	11	2.8	4.4	13	45	45	41	44

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


0
2
4
6
8
10
depth (m)
1995
1996
1997
1998
1999
2000
Secchi Depth


30
20
10
0
concentration (µg/L)
1995
1996
1997
1998
1999
2000
Chlorophyll a
Total Phosphorus


60
50
40
30
annual average trophic state
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Cottage

In 1995, volunteers began collecting monitoring data on Cottage Lake located in north King County near Woodinville. Because the data record is relatively short, no statistical trend analyses were completed for Cottage Lake. Generally, productivity was high (eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals reasonably consistent annual average summer values for Secchi depth while both phosphorus and chlorophyll *a* levels show considerable variation from year to year.

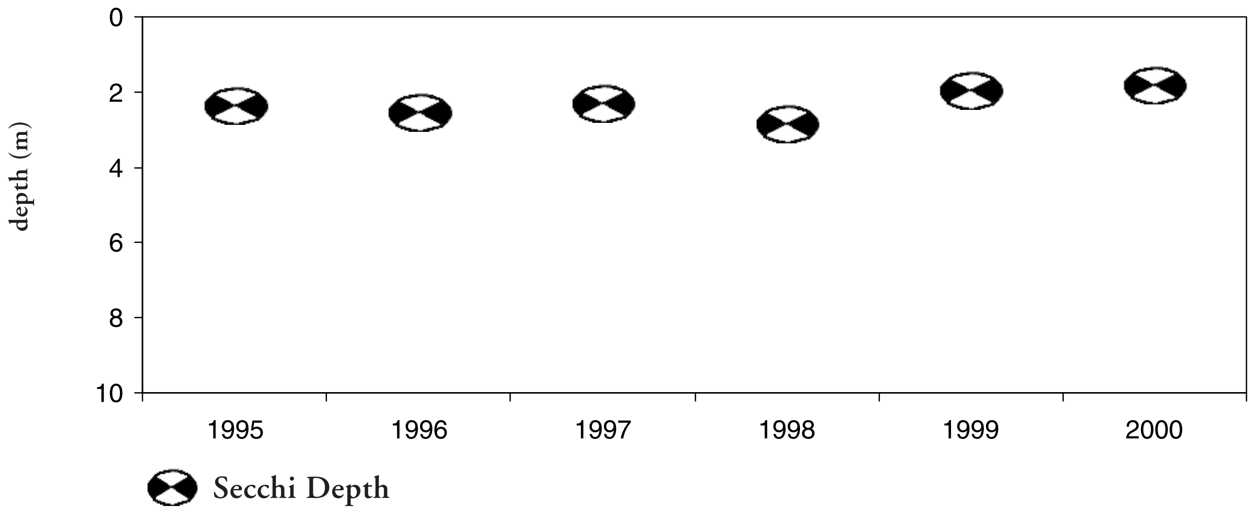
Overall, water quality is fair at Cottage Lake, influenced by wetland chemistry that gives the lake its dark color and low Secchi depth. The eutrophic character of the lake is influenced directly by basin characteristics which includes a large (231 acres) wetland system as well as surface flow from agricultural and residential areas. Ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as new land development or local shoreline alteration occurs.

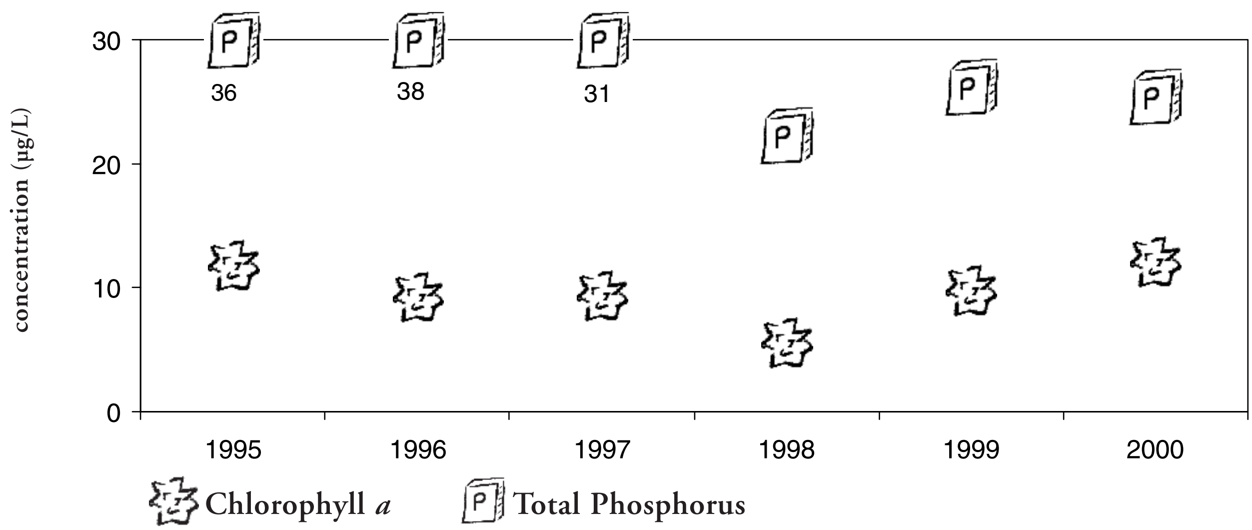
As part of the Cottage Lake Management Plan (King County, 1996a), King County has been working with local farms to implement best management practices to improve the quality of water entering the lake. Local residents have also considered formation of lake management district to implement recommendations associated with the management plan.

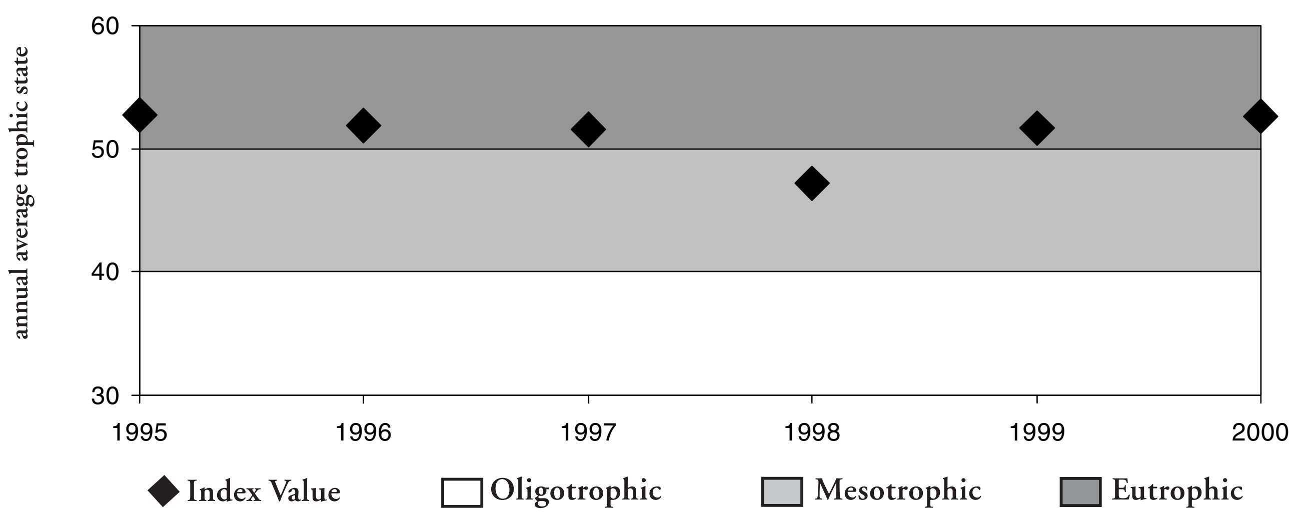
Average Values for Select Trophic Parameters at Cottage Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1995	11	2.3	11.8	36	48	55	56	53
1996	12	2.5	9.3	38	47	52	56	52
1997	12	2.3	9.4	31	48	53	54	52
1998	12	2.8	5.6	22	45	47	49	47
1999	9	1.9	9.9	26	51	53	51	52
2000	11	1.8	12.1	26	52	55	51	53

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
36
38
31
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Deep

Since 1988, volunteers have collected monitoring data on Deep Lake located in southeast King County. The data record is only partially complete with data collected during six of the past 16 years. Because the data record is limited, no statistical analyses for trend were completed for Deep Lake. Generally, productivity was low (oligotrophic), characterized by high water clarity, low chlorophyll *a* values, and low to moderate phosphorus levels (see data table below).

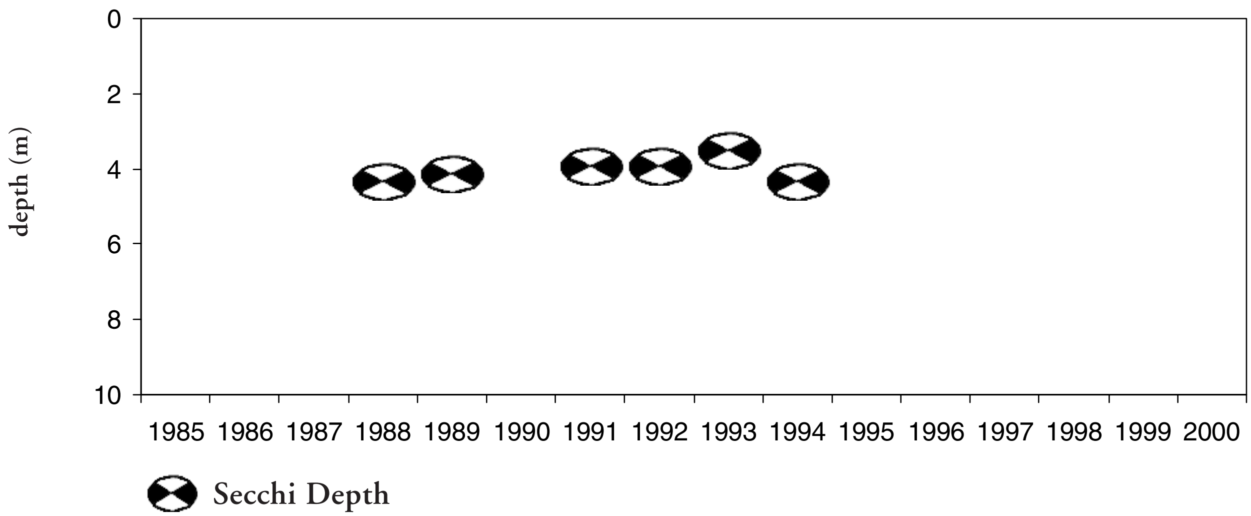
Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values between 1988 and 1994. Visual analysis reveals more variability in Secchi depth and phosphorus levels between 1992 and 1994 as well as a slight increase in overall trophic state during the abbreviated record.

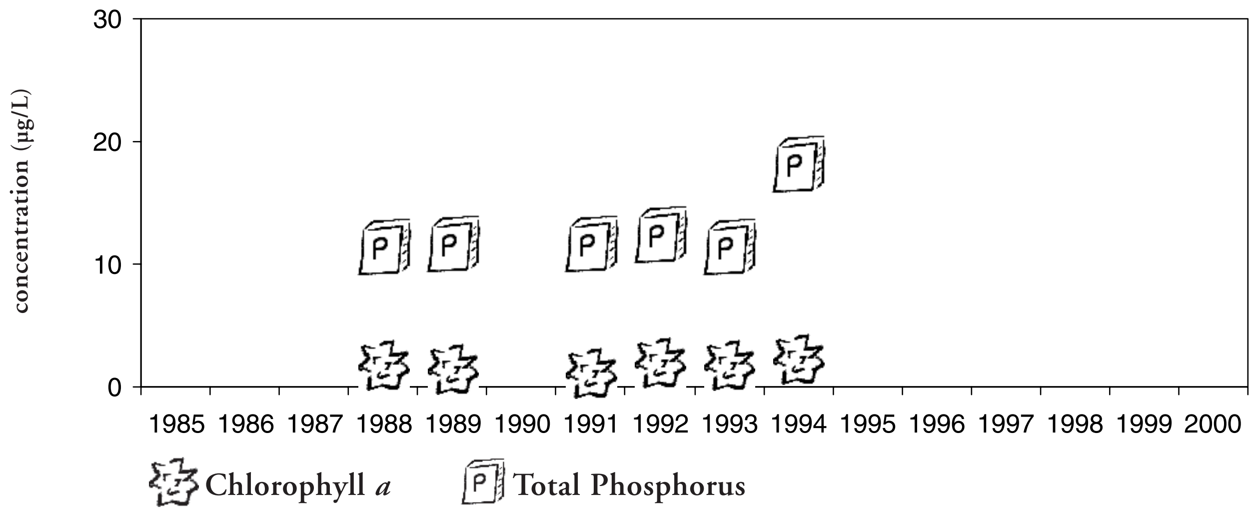
Water quality remains excellent at Deep Lake due to the lake's remoteness and largely forested watershed. Additionally, the shoreline is owned predominately by Washington State Parks with no residential development occurring on the lake. Because of the absence of shoreline residents, participation in the volunteer monitoring program has been limited for Deep Lake. Stewardship by watershed residents and state government remains important to ensure water quality continues to be preserved at Deep Lake.

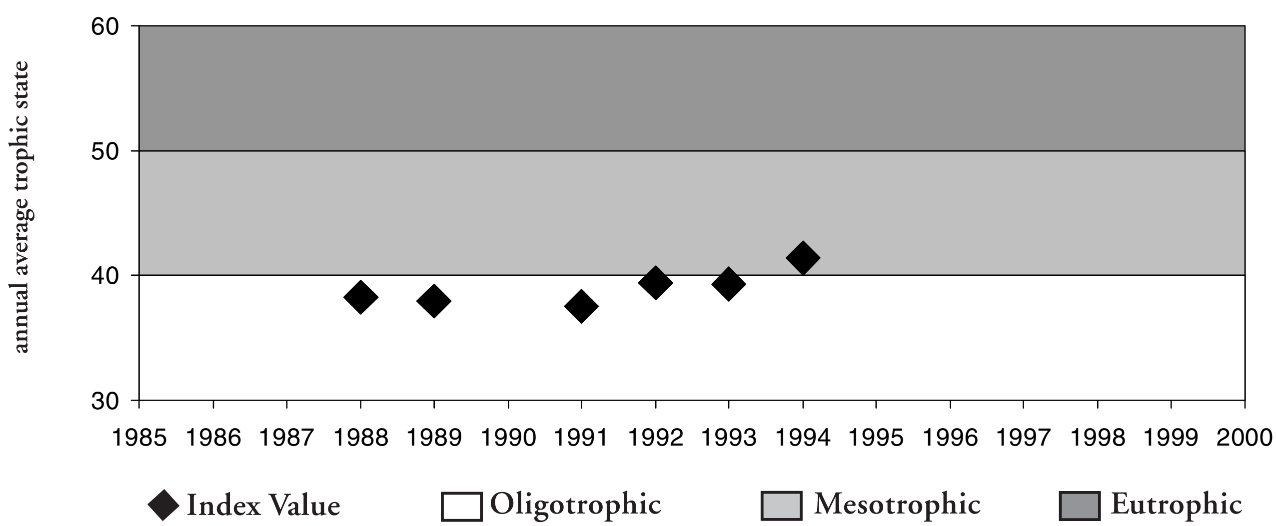
Average Values for Select Trophic Parameters at Deep Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (μg/L)	TP* (μg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	---	---	---	---	---	---	---	---
1986	---	---	---	---	---	---	---	---
1987	---	---	---	---	---	---	---	---
1988	12	4.3	1.8	12	39	36	39	38
1989	11	4.1	1.5	12	40	35	40	38
1990	---	---	---	---	---	---	---	---
1991	9	3.9	1.2	12	40	32	40	38
1992	12	3.9	2.0	12	40	37	40	39
1993	10	3.5	1.8	11	42	37	39	39
1994	12	4.3	2.4	18	39	39	46	41
1995	---	---	---	---	---	---	---	---
1996	---	---	---	---	---	---	---	---
1997	---	---	---	---	---	---	---	---
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Desire

Since 1985, volunteers have collected monitoring data at Lake Desire located in south King County. The data record is nearly complete with data missing only for 1993. Overall, productivity was high (eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals a minor decrease in Secchi depth and a slight increase in algal levels during the 16-year record. Additionally, phosphorus levels vary from year to year with peak values occurring between 1996 and 1997.

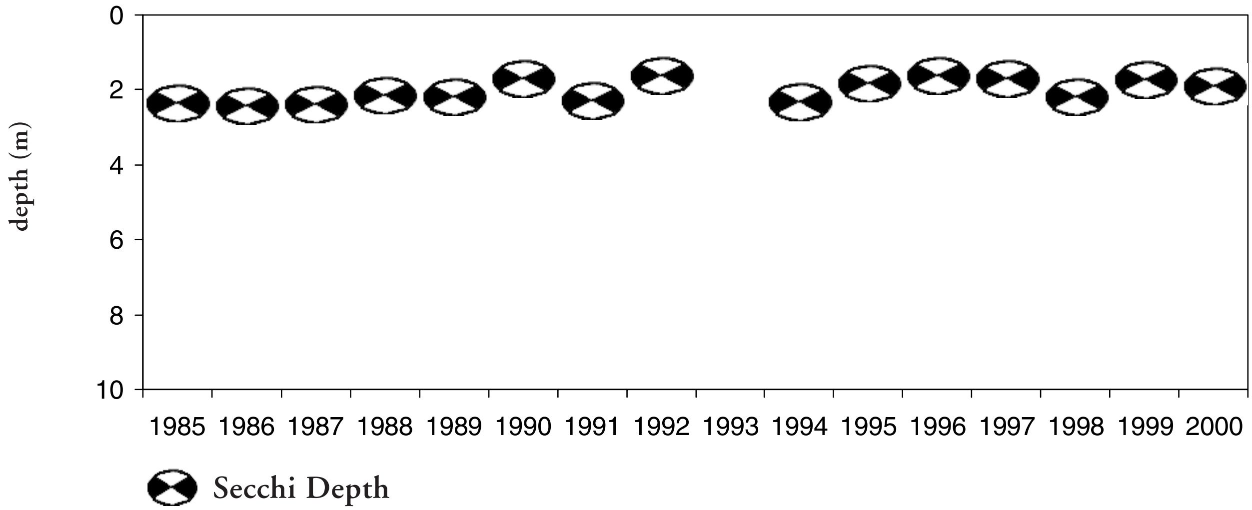
To evaluate whether statistically significant changes in water quality have occurred at Lake Desire, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant downward trend in Secchi depth was found (n=15; p=0.04; slope= -0.04) while an upward trend was noted for chlorophyll *a* (n=15; p=0.01; slope=0.50) suggesting a slight decline in water quality has occurred at Desire since 1985. Significant upward trends were also noted for TSI Secchi (n=15; p=0.04; slope=0.27), TSI Chl *a* (n=15; p=0.013; slope=0.42) and TSI Average (n=15; p=0.017; slope=0.28). The significant trends for TSI Secchi, TSI Chl *a*, and TSI Average are somewhat predictable given TSI Secchi is a calculated from Secchi data while TSI Chl *a* is a calculated from chlorophyll *a* data and the TSI average includes both values in the calculation.

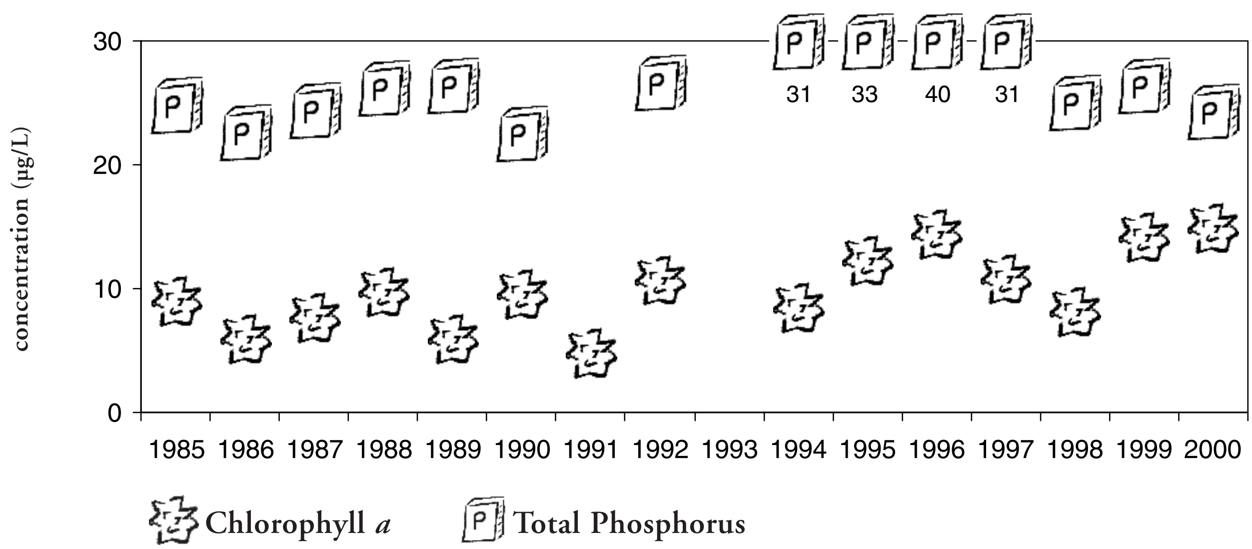
Overall, water quality is fair at Lake Desire and is influenced by wetland inflow that originates along the northern end of the lake. This inflow gives the lake its distinct dark tea color and low Secchi depth. Although the trophic character of the lake is natural, stewardship by lake residents remains important to ensuring ongoing preservation of water quality based on the findings of the lake management plan (King County, 1995). Additionally, appropriate erosion and nutrient control measures must take place as new land is developed or local shoreline alteration occurs.

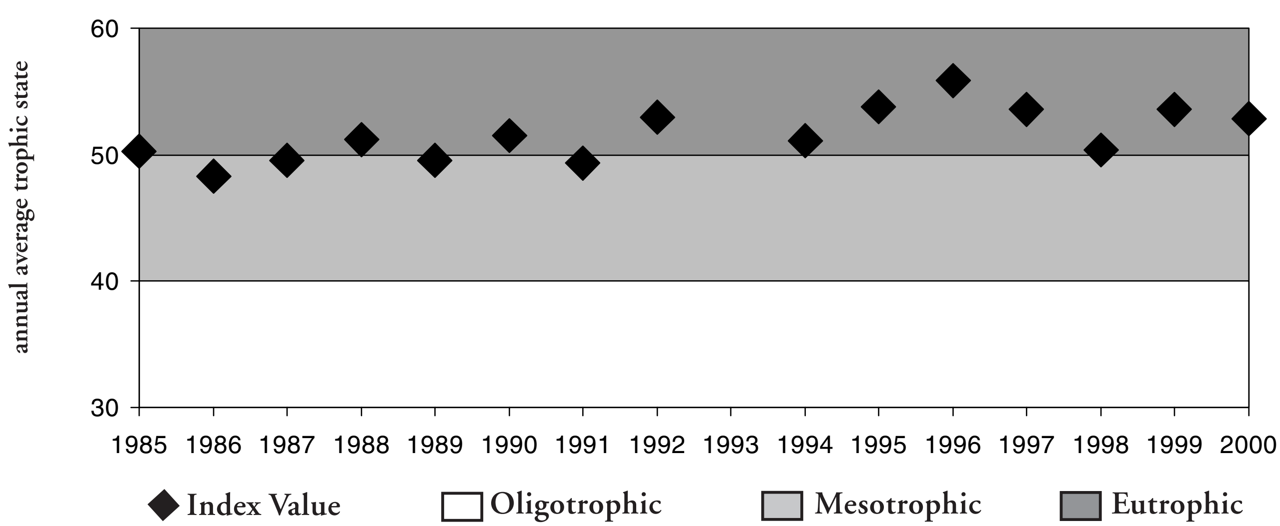
Average Values for Select Trophic Parameters at Lake Desire

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	12	2.3	9.0	25	48	52	51	50
1986	11	2.4	6.0	23	48	48	49	48
1987	11	2.3	7.7	24	48	51	50	50
1988	10	2.1	9.8	26	49	53	51	51
1989	11	2.1	6.0	26	49	48	51	50
1990	12	1.7	9.6	23	53	53	49	52
1991	6	2.2	4.8	31	48	46	54	49
1992	8	1.6	10.7	27	54	54	52	53
1993	---	---	---	---	---	---	---	---
1994	10	2.3	8.6	31	48	52	53	51
1995	12	1.8	12.3	33	52	55	54	54
1996	12	1.6	14.4	40	53	57	57	56
1997	12	1.6	10.8	31	53	54	54	54
1998	12	2.1	8.2	25	49	51	51	50
1999	13	1.7	14.2	26	53	57	51	54
2000	13	1.8	15.0	24	51	57	50	53

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
31
33
40
31
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Dolloff

Since 1985, volunteers have collected monitoring data at Lake Dolloff located in southwest King County. The data record is largely complete with data only missing between 1990 and 1993. Overall, productivity was consistently high (eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variability in Secchi depth while algal and phosphorus levels have varied from year to year during the 16-year record.

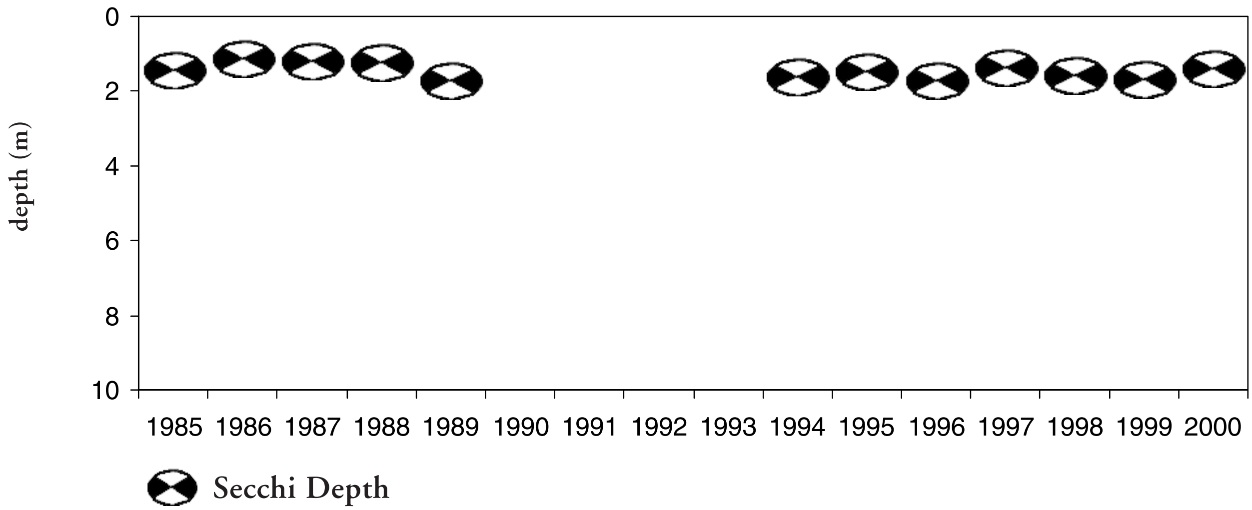
To evaluate whether statistically significant changes in water quality have occurred at Lake Dolloff, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the data record.

Overall, water quality remains fair at Lake Dolloff and is influenced by wetland inflow that originates along the northern end of the lake. This inflow gives the lake its distinct dark tea color and low Secchi depth. Although the trophic character of the lake is natural, local stewardship by lake residents remains important to ensuring ongoing preservation of water quality. Additionally, appropriate erosion and nutrient control measures must take place as new land is developed or local shoreline alteration occurs.

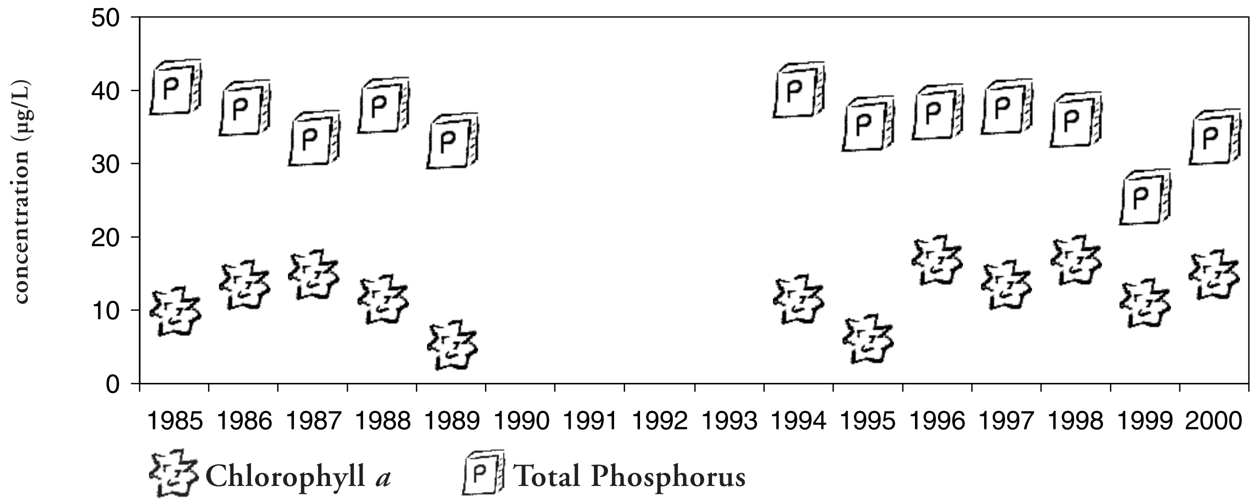
Average Values for Select Trophic Parameters at Lake Dolloff

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	1.4	10.1	41	55	53	58	55
1986	10	1.1	13.7	38	59	56	57	57
1987	6	1.2	14.9	34	58	57	55	57
1988	8	1.2	11.7	38	57	55	57	56
1989	10	1.7	5.3	33	53	47	55	51
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	12	1.6	11.6	40	54	55	57	55
1995	11	1.4	6.2	36	55	49	56	53
1996	12	1.7	17.0	37	53	58	56	56
1997	11	1.3	13.6	38	56	56	57	56
1998	11	1.5	17.0	36	54	58	56	56
1999	11	1.6	11.1	25	53	54	51	53
2000	8	1.3	15.0	34	56	57	55	56

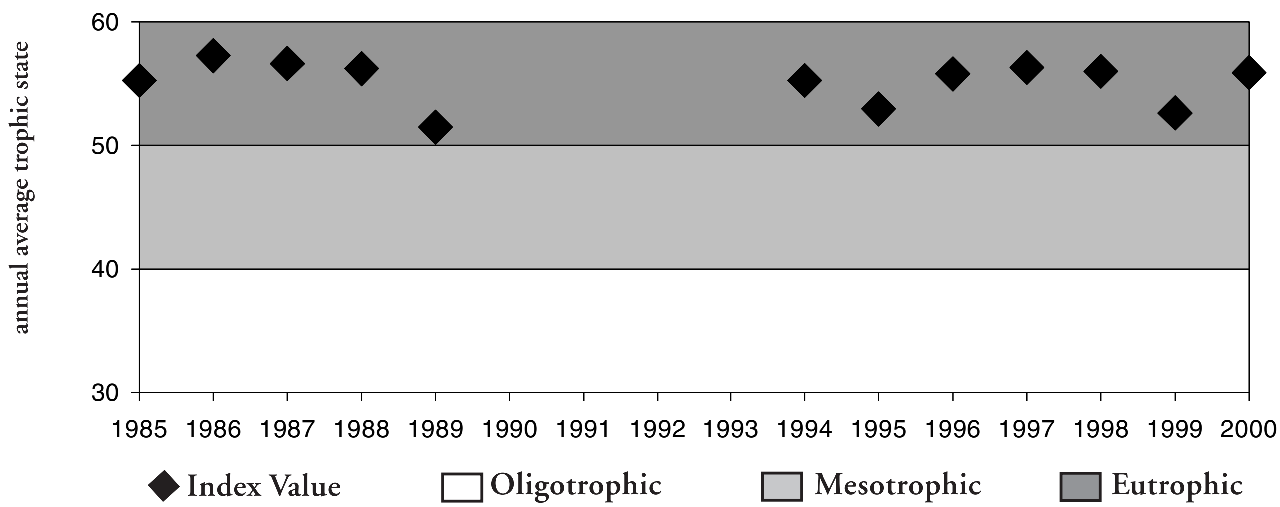
*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index



depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth



concentration (µg/L)
50
40
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus



annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Fenwick

Since 1985, volunteers have collected monitoring data at Lake Fenwick located in Kent. The data record is only partially complete with data collected during nine of the past 16 years. Generally, productivity was moderate (mesotrophic), characterized by moderate water clarity and intermediate chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals a gradual increase in phosphorus levels and overall trophic state during the available record. Additionally, water clarity and chlorophyll *a* values varied from year to year.

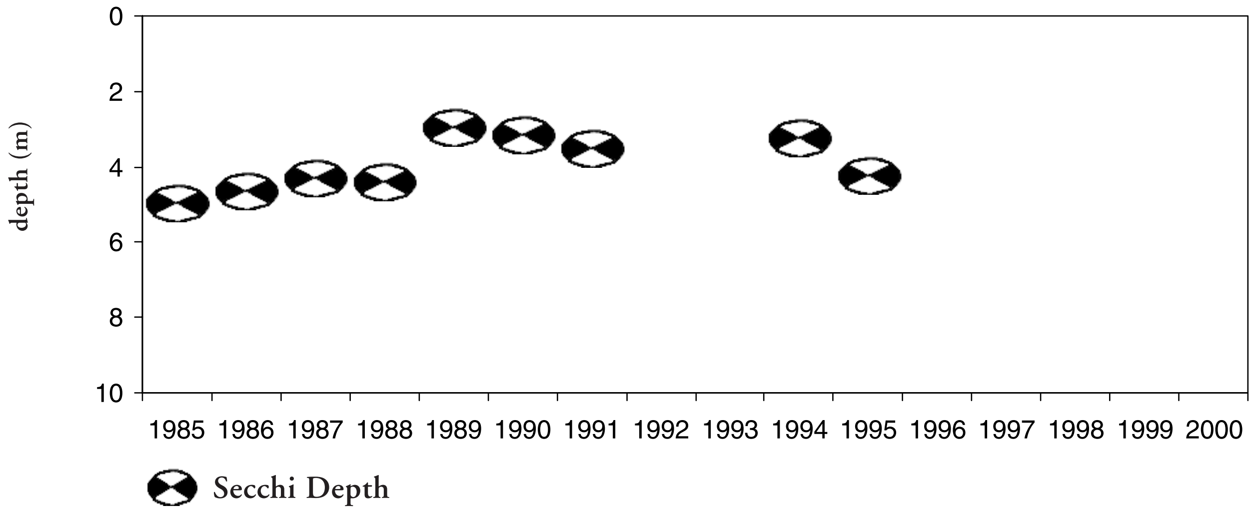
To evaluate whether statistically significant changes in water quality have occurred at Lake Fenwick, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant upward trend in total phosphorus was found (n=9; p=0.02; slope=1.02) suggesting nutrient levels have increased slightly at Fenwick since 1985. Significant upward trends were also noted for TSI TP (n=9; p=0.03; slope=0.61) and TSI Average (n=9; p=0.009; slope=0.52). The significant trends for TSI TP and TSI Average are related given TSI TP is a calculated from total phosphorus data and TSI average includes TSI TP in the calculation.

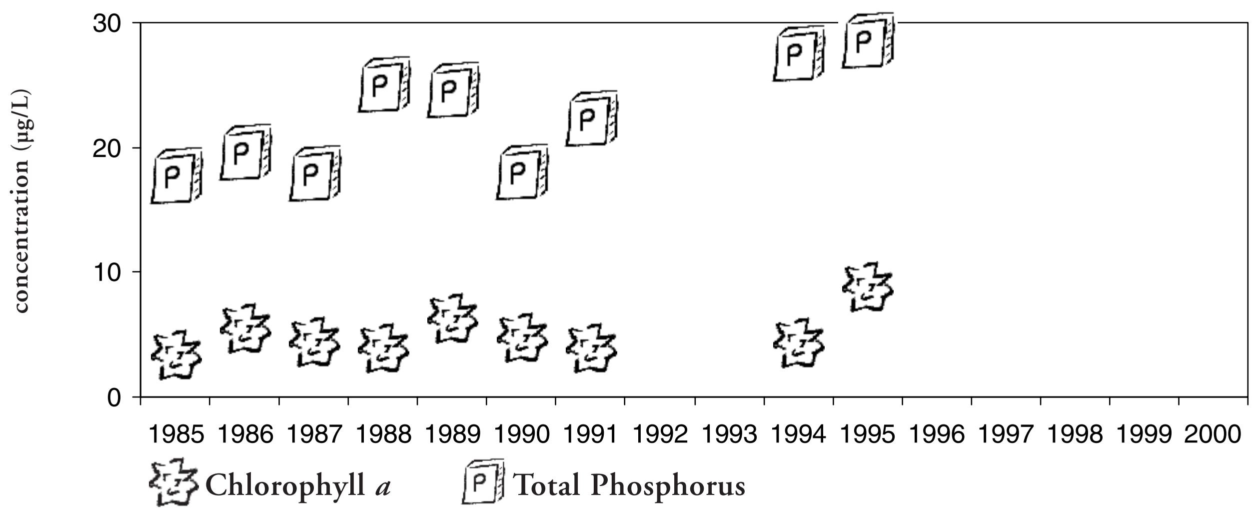
Overall, water quality is moderately good at Fenwick. The lake has large shallow areas that are dominated by the noxious weed *Egeria densa* (Brazialian elodea), which may result in additional phosphorus being recycled to surface waters as plants decay. Although the lake is a popular fishing spot for residents of the Kent area, participation in the volunteer monitoring program by shoreline residents has been limited. Ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as new land development or local shoreline alteration occurs.

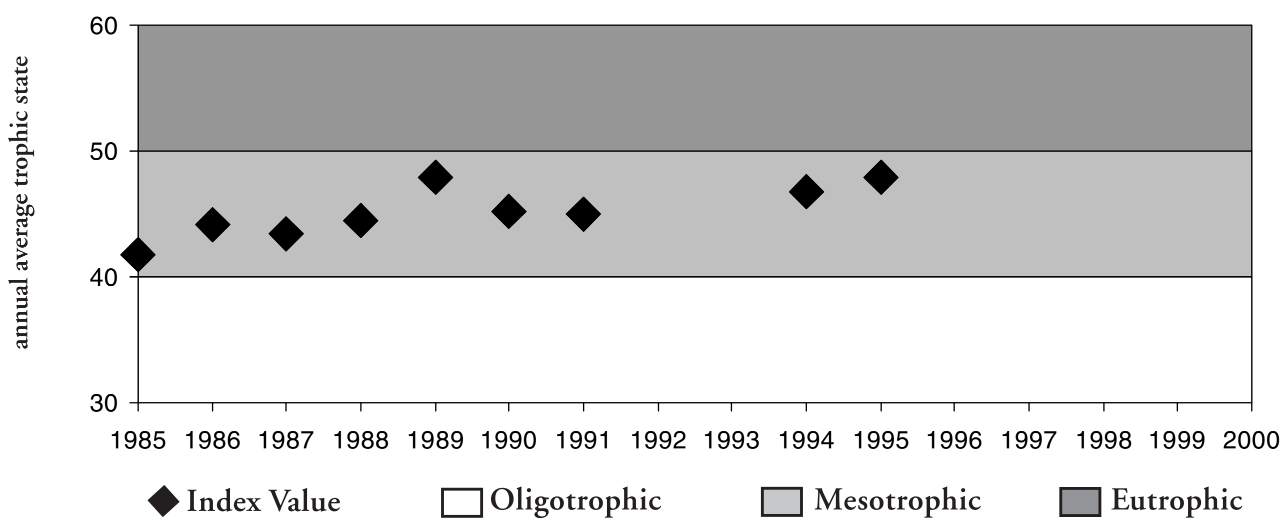
Average Values for Select Trophic Parameters at Lake Fenwick

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	4.9	3.4	18	37	43	46	42
1986	12	4.6	5.6	20	38	47	47	44
1987	11	4.3	4.5	18	39	45	46	43
1988	10	4.4	4.0	25	39	44	51	44
1989	12	2.9	6.3	25	45	49	50	48
1990	12	3.1	4.9	18	44	46	46	45
1991	9	3.5	4.0	22	42	44	49	45
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	12	3.2	4.4	28	43	45	52	47
1995	9	4.2	8.8	29	39	52	53	48
1996	---	---	---	---	---	---	---	---
1997	---	---	---	---	---	---	---	---
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Fivemile

Since 1985, volunteers have collected monitoring data on Fivemile Lake located in southwest King County. The data record is largely complete with data only missing between 1990 and 1993. Overall, productivity is moderately high (mesotrphic to eutrophic), characterized by low water clarity, slightly elevated chlorophyll *a* values, and elevated phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variation in Secchi depth while phosphorus, chlorophyll *a*, and trophic state values have varied somewhat from year to year with no discernable pattern.

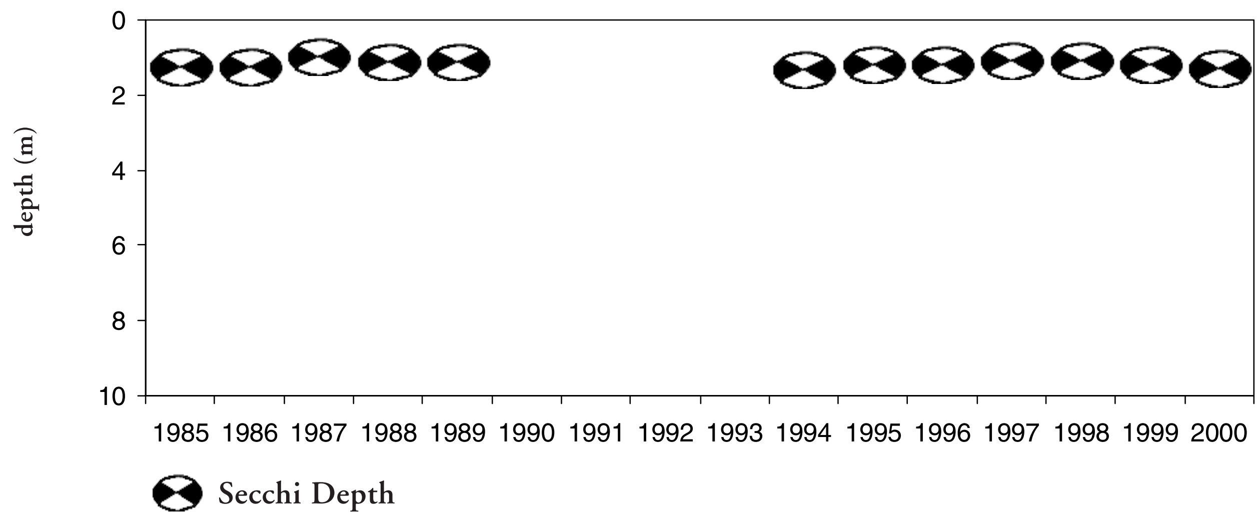
To evaluate whether statistically significant changes in water quality have occurred at Fivemile Lake, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the available data.

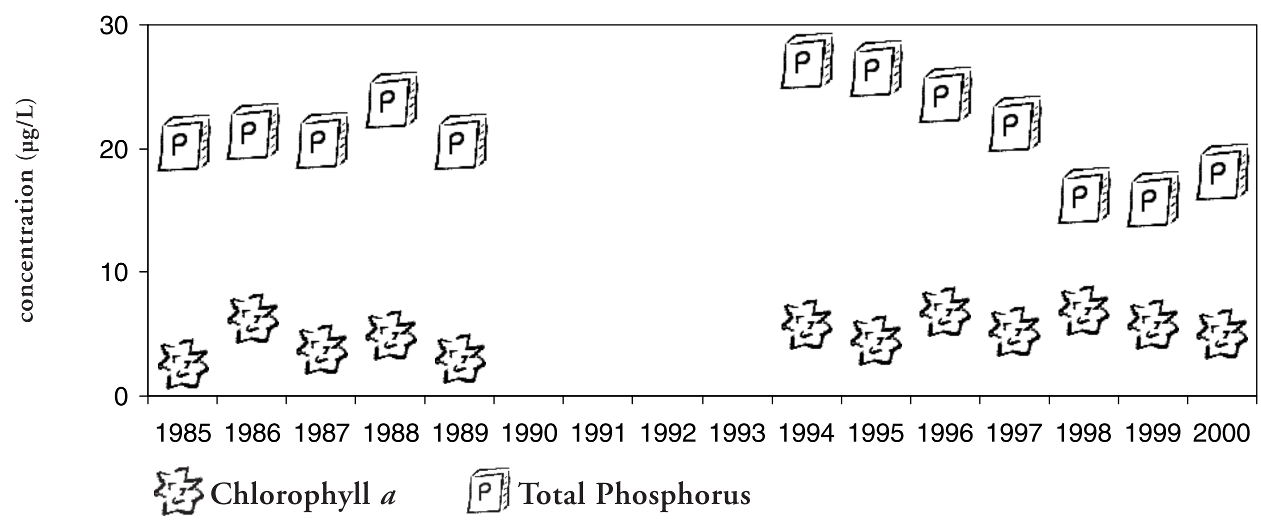
Overall, water quality is moderately good to fair, influenced by wetland chemistry that gives the lake its dark color and low Secchi depth. The eutrophic character of the lake is a natural function of the basin, which receives inflow directly from wetland areas on the northern end of the lake. Ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as new land development or local shoreline alteration occurs.

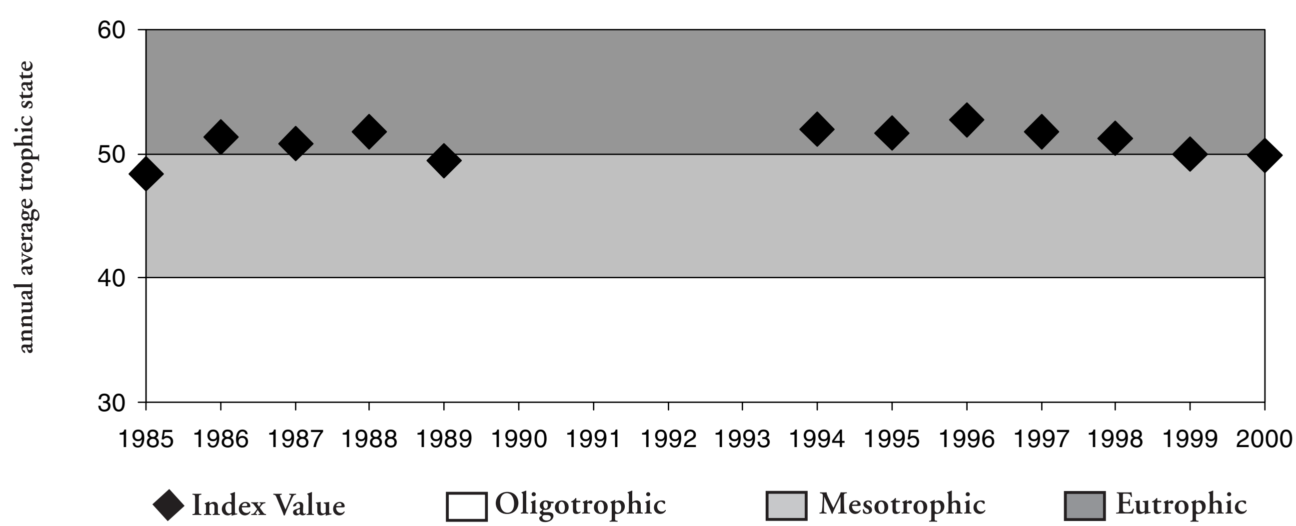
Average Values for Select Trophic Parameters at Fivemile Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	1.2	2.6	21	57	40	48	48
1986	12	1.2	6.3	21	57	49	48	51
1987	11	0.9	3.8	21	61	44	48	51
1988	11	1.1	4.9	24	59	46	50	52
1989	11	1.1	3.1	21	59	42	48	49
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	11	1.3	5.8	27	56	48	52	52
1995	12	1.1	4.5	27	58	45	51	52
1996	12	1.1	6.9	24	58	50	50	53
1997	12	1.0	5.3	22	60	47	49	52
1998	13	1.0	6.9	16	60	50	44	51
1999	13	1.2	5.8	16	58	48	44	50
2000	13	1.2	5.0	18	57	46	46	50

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Francis

In 1996, volunteers began collecting monitoring data at Lake Francis located in south King County. Because the data record is relatively short, no statistical trend analyses were completed for the lake. Generally, productivity was moderate to high (mesotrophic to eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

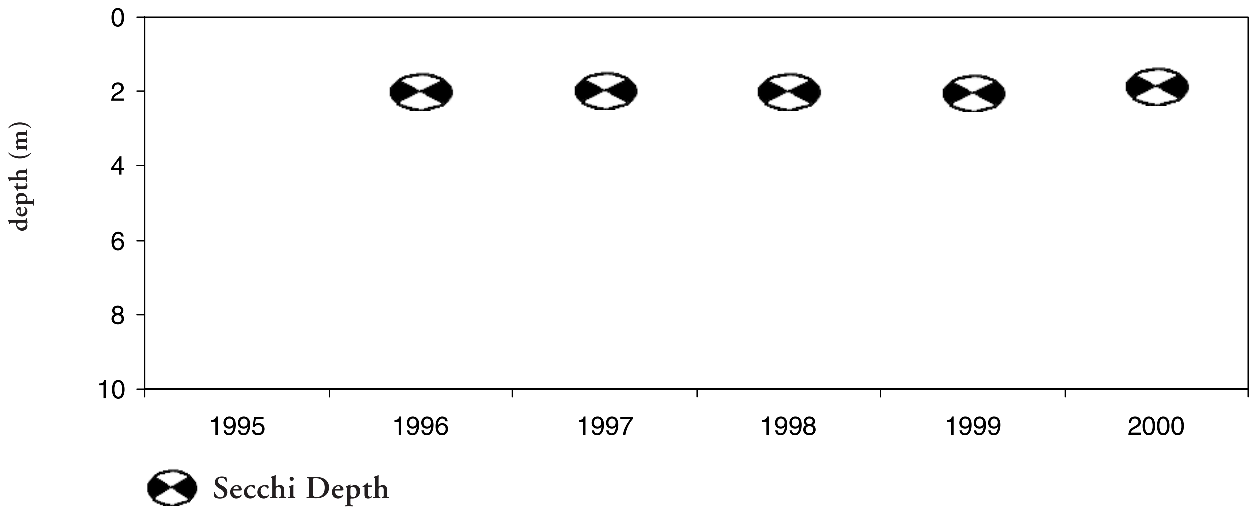
Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels show some variation from year to year.

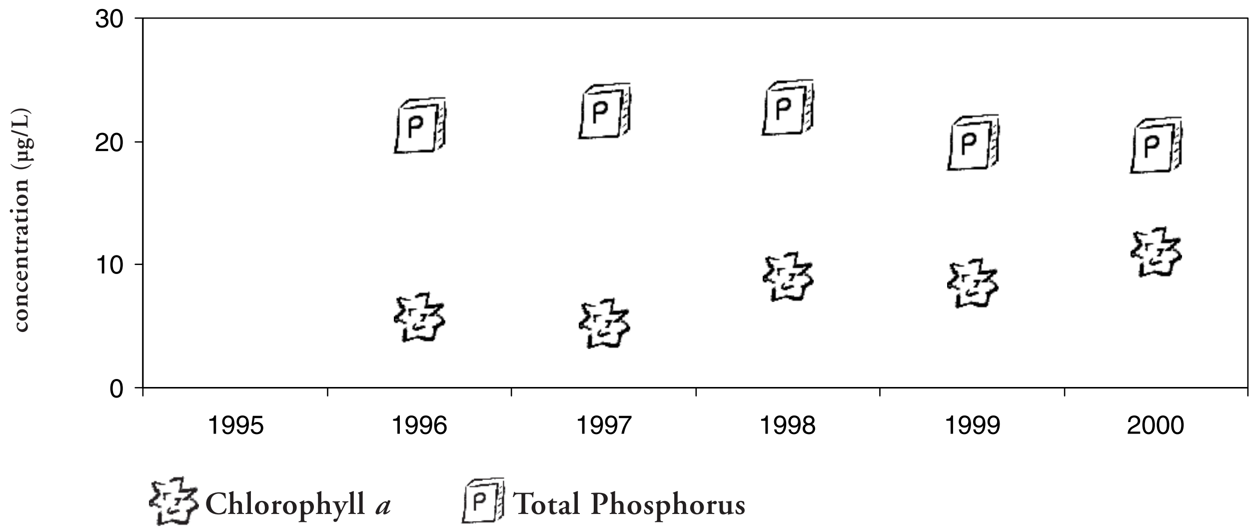
Overall, water quality is good to fair at Lake Francis, influenced by wetland chemistry that gives the lake its dark color and low Secchi depth. The eutrophic character of the lake is natural. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as new land development or local shoreline alteration occurs.

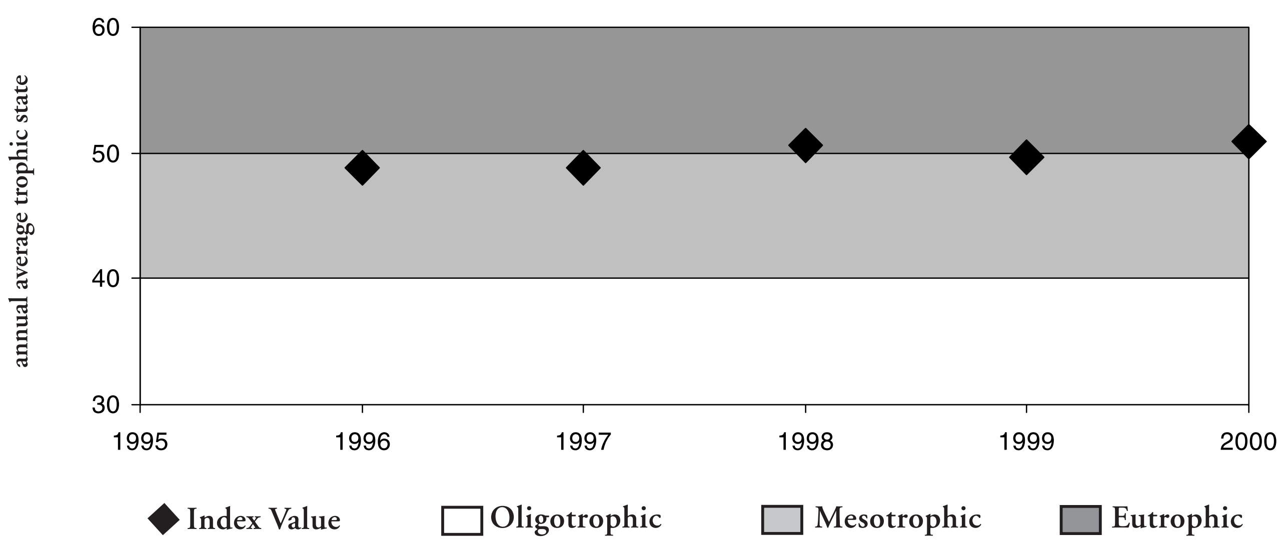
Average Values for Select Trophic Parameters at Lake Francis

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	12	2.0	5.8	21	50	48	48	49
1997	11	1.9	5.2	22	51	47	49	49
1998	13	1.9	9.1	23	50	52	49	51
1999	13	2.0	8.5	20	50	52	47	50
2000	12	1.8	11.1	20	51	54	47	51

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Garrett

In 1996, volunteers began collecting monitoring data on Lake Garrett located north of Burien. Because the data record is relatively short, no statistical trend analyses were completed for Garrett. Generally, productivity is high (eutrophic), characterized by low water clarity with elevated chlorophyll *a* and phosphorus levels (see data table below).

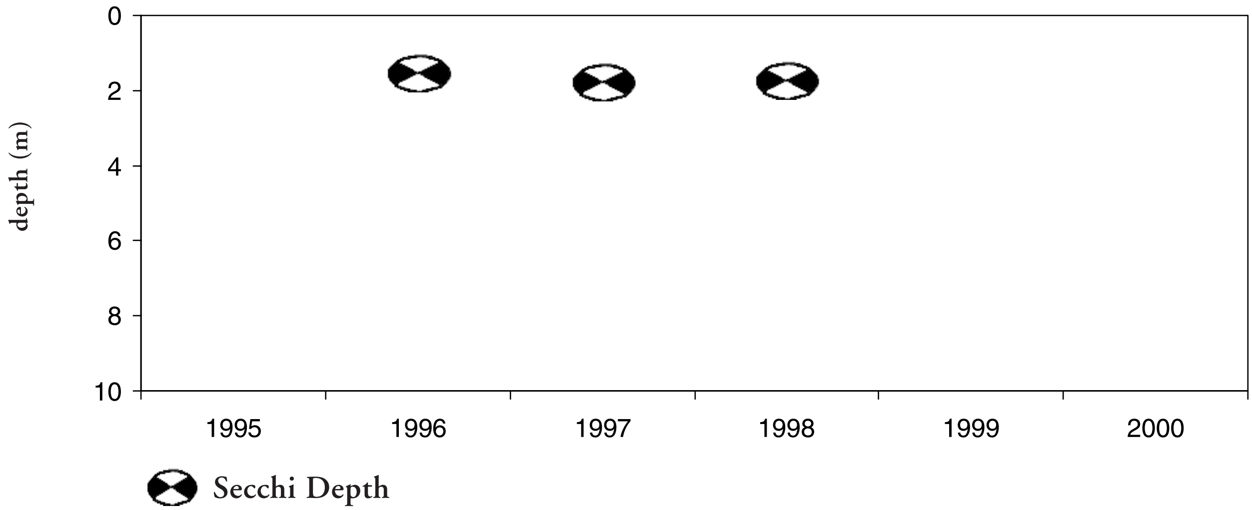
Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values. Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels show some variation from year to year.

Overall, water quality is fair at Lake Garrett, which receives mostly undetained stormwater flows from the surrounding residential area. This poor quality water source contributes to the eutrophic character of the lake, which experiences periodic blooms of blue-green algae. Implementation of flow and nutrient control measures in the watershed remain important to restoring lake water quality and stabilizing the trophic character of the lake.

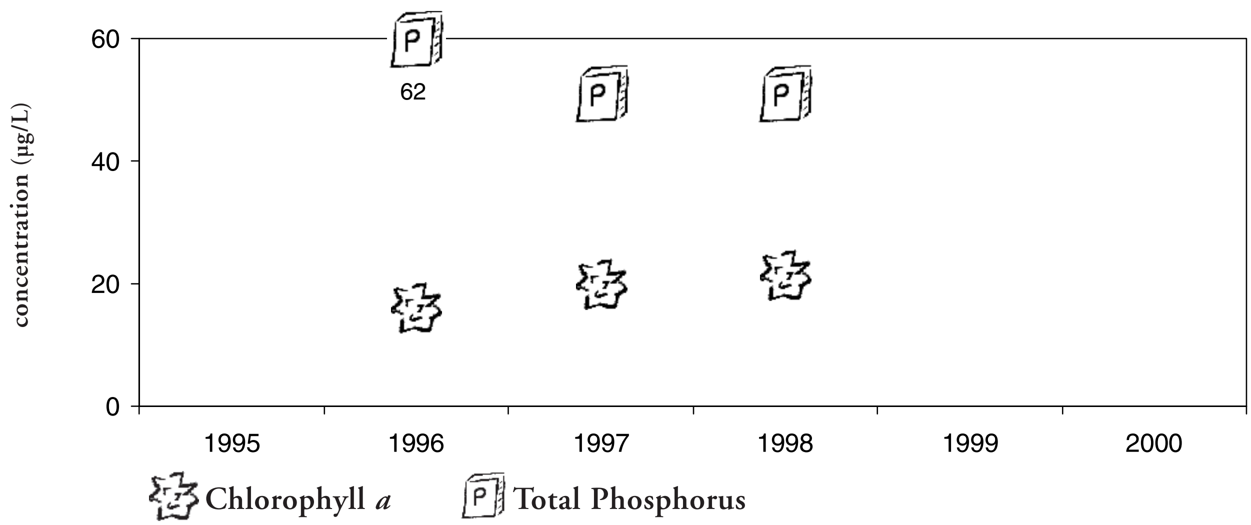
Average Values for Select Trophic Parameters at Lake Garrett

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	12	1.5	16.1	62	54	58	64	59
1997	12	1.7	19.9	51	52	60	61	58
1998	13	1.7	21.4	51	52	61	61	58
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---

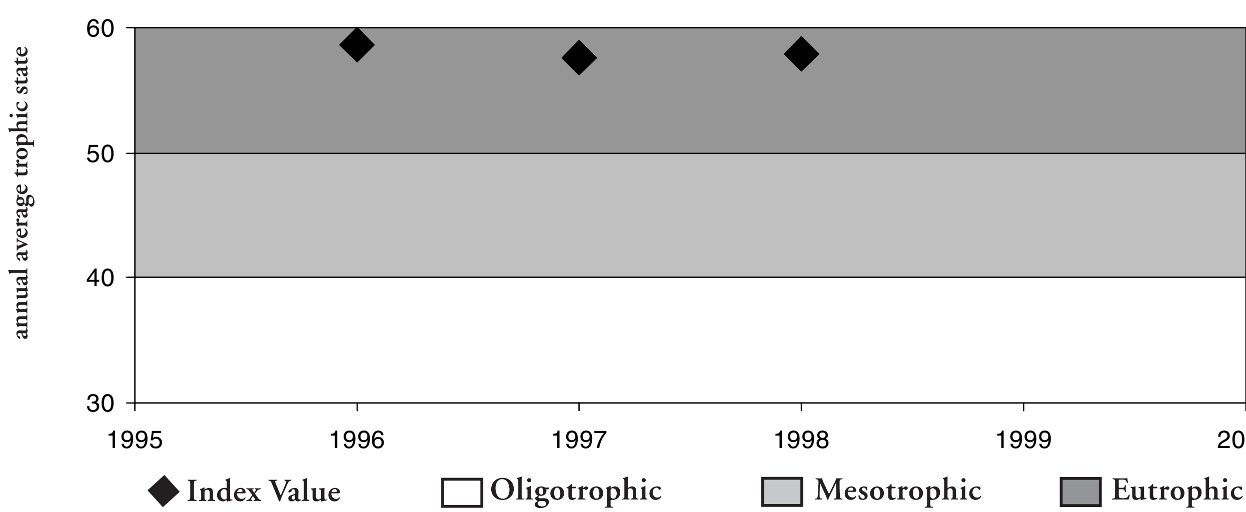
*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index



depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth



concentration (µg/L)
60
40
20
0
62
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus



annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Geneva

Since 1985, volunteers have collected monitoring data on Lake Geneva located in south King County. The data record is largely complete with data only missing between 1990 and 1993. Overall, productivity was moderate (mesotrophic), characterized by moderate water clarity and slightly elevated phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variation in Secchi depth while phosphorus, chlorophyll *a*, and trophic state values have varied somewhat from year to year although no discernable pattern is apparent.

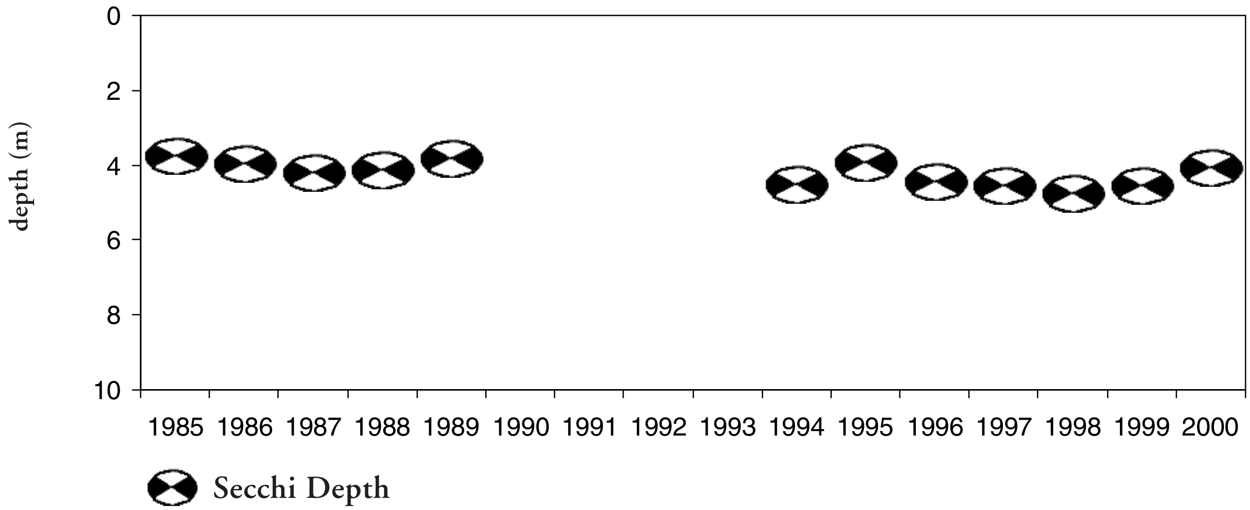
To evaluate whether statistically significant changes in water quality have occurred at Lake Geneva, trend analysis was performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant upward trend was noted for Secchi depth (n=11; p=0.05; slope=0.04) suggesting a slight improvement in water clarity has occurred at Geneva since 1985. A significant downward trend was also noted for TSI Secchi (n=11; p=0.05; slope= -0.14). This significant trend for TSI Secchi is predictable given TSI Secchi is calculated from Secchi depth data.

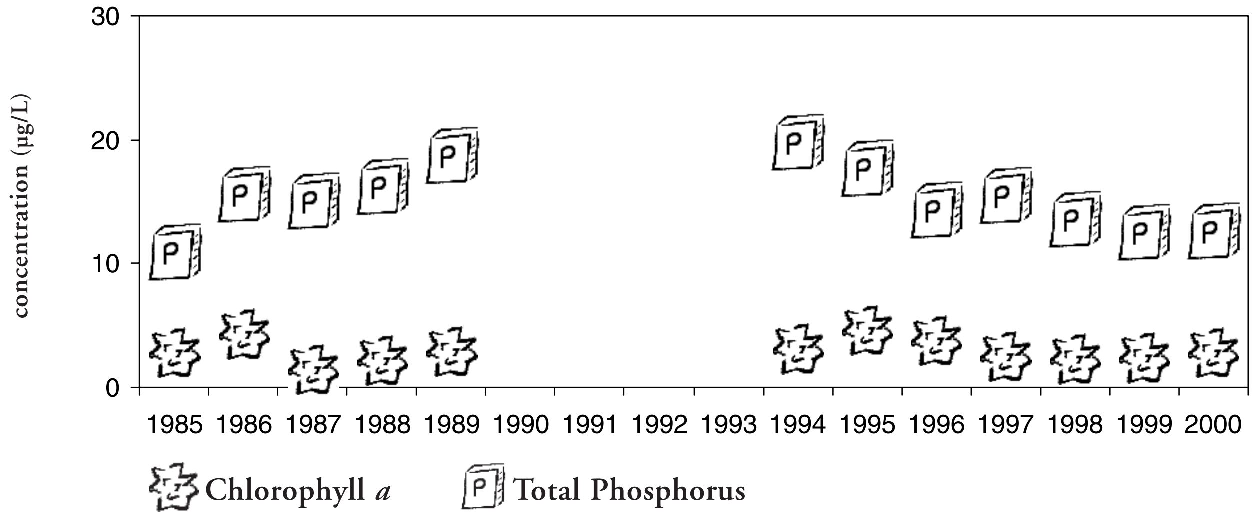
Overall, water quality is moderately good at Lake Geneva. Wetland chemistry influences lake water quality somewhat as indicated by more variable phosphorus levels. To preserve existing lake water quality, local stewardship by residents remains important to ensure ongoing erosion and nutrient control measures take place as new land development or local shoreline alteration occurs.

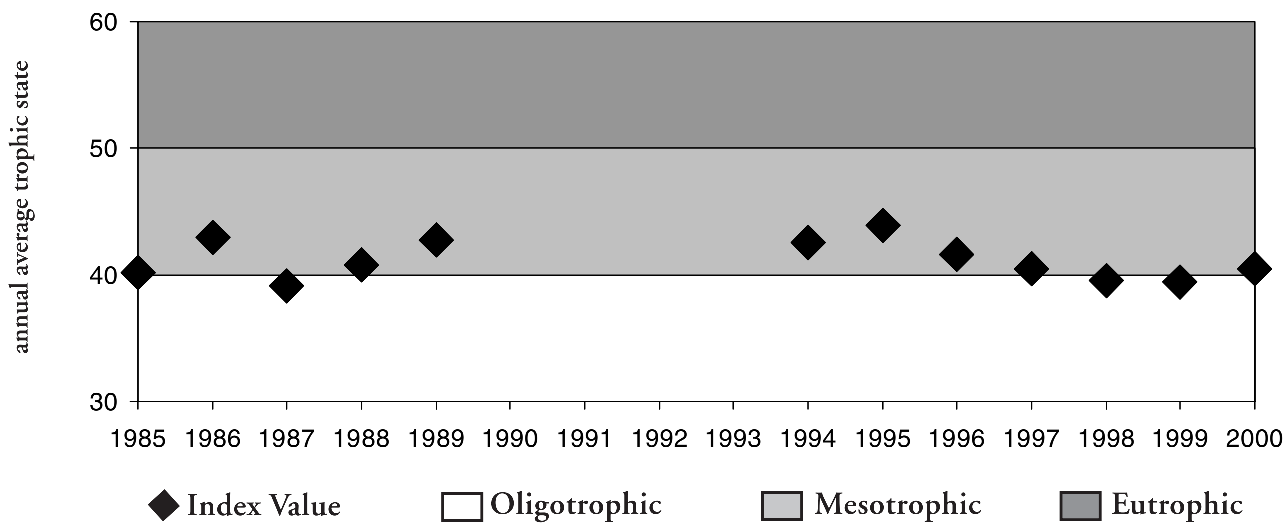
Average Values for Select Trophic Parameters at Lake Geneva

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	3.7	2.8	11	41	41	39	40
1986	12	3.9	4.3	16	40	45	44	43
1987	11	4.1	1.5	15	39	35	43	39
1988	9	4.1	2.2	16	40	38	44	41
1989	9	3.8	2.9	19	41	41	46	43
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	11	4.5	3.2	20	38	42	47	43
1995	11	3.9	4.7	18	40	46	46	44
1996	12	4.4	3.8	14	39	44	43	42
1997	12	4.5	2.5	16	38	40	44	41
1998	11	4.7	2.4	14	38	39	42	40
1999	12	4.5	2.5	13	38	39	41	39
2000	12	4.0	2.8	13	40	41	41	40

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Haller

In 1997, volunteers began collecting monitoring data at Haller Lake located in Seattle. Because the data record is relatively short, no statistical trend analyses were completed for the lake. Generally, productivity was moderate (mesotrophic), characterized by average water clarity, chlorophyll *a,* and phosphorus levels (see data table below).

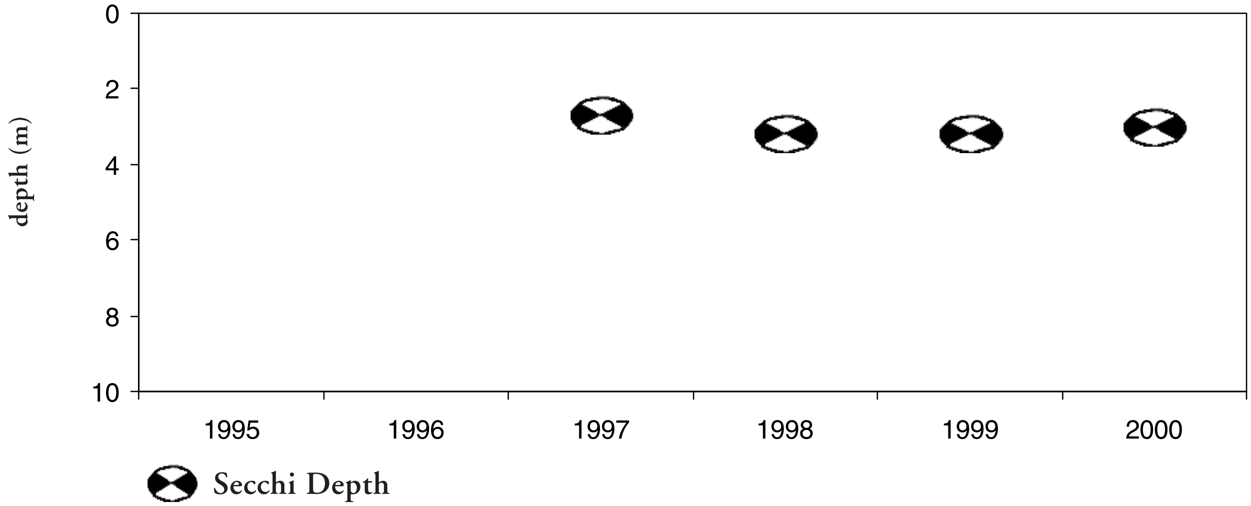
Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values. Visual analysis reveals reasonably consistent values from year to year for Secchi depth, phosphorus, and chlorophyll *a*.

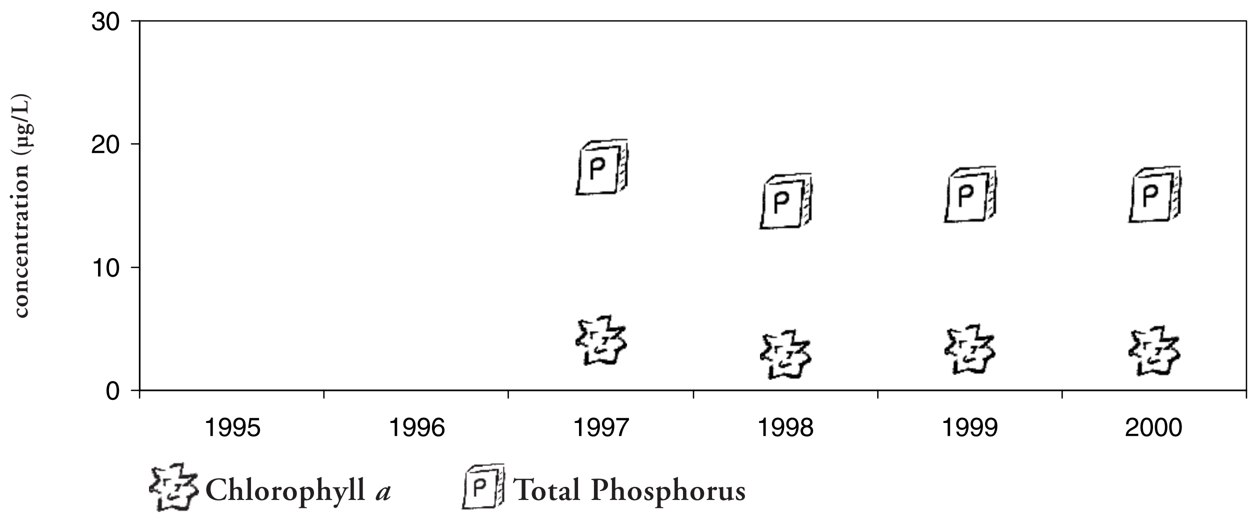
Overall, water quality is moderately good at Haller Lake even though the lake receives surface flows from a largely urban watershed. Local residents are working with the City of Seattle to improve the quality of inflows to the lake.

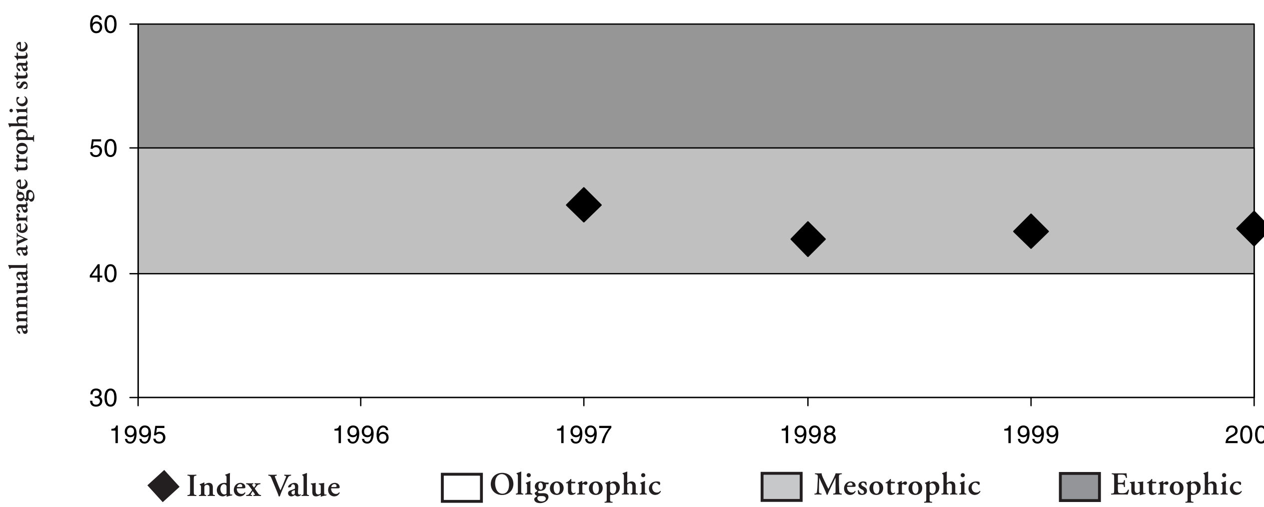
Average Values for Select Trophic Parameters at Haller Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1997	12	2.7	4.2	18	46	45	46	45
1998	13	3.1	3.0	15	43	41	44	43
1999	13	3.1	3.4	16	44	43	44	43
2000	13	3.0	3.2	16	44	42	44	44

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Horseshoe

In 2000, volunteers began collecting trophic state monitoring data on Horseshoe Lake when the services of the Lake Stewardship Program were extended to southeast King County through the Rural Drainage Program. Because the data record consists of only a single year, no statistical trend analyses were completed for Horseshoe Lake. In the summer of 2000, productivity was moderate (mesotrophic) at Horseshoe Lake, characterized by low to moderate water clarity and moderate chlorophyll *a* and phosphorus levels (see data table below).

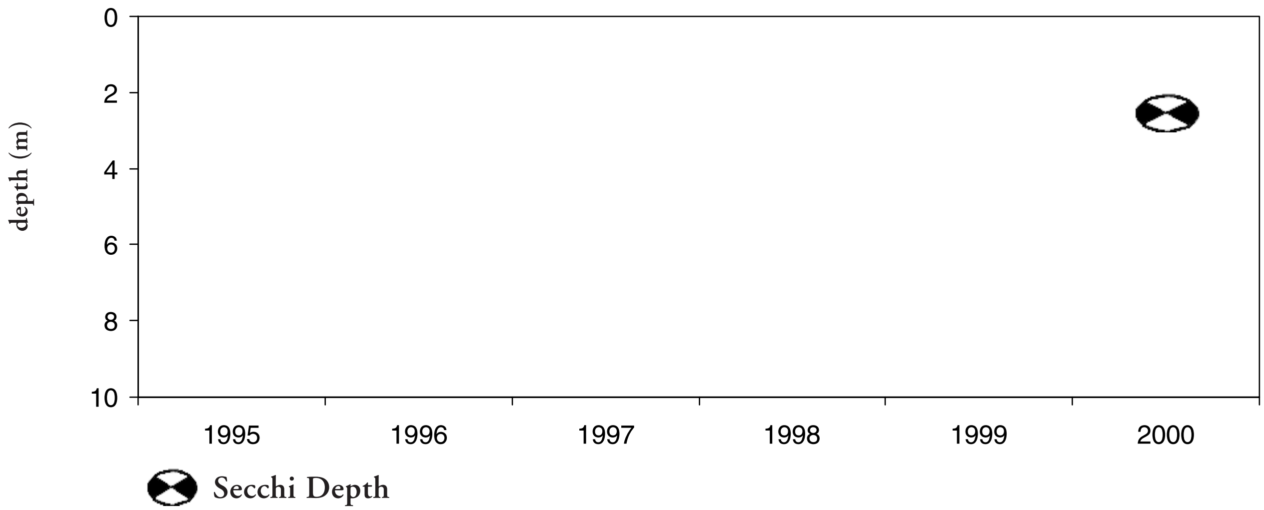
Average values for May through October are shown for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state during 2000. These values are illustrated here to allow visual comparison with other lakes that have participated in the program for longer time periods.

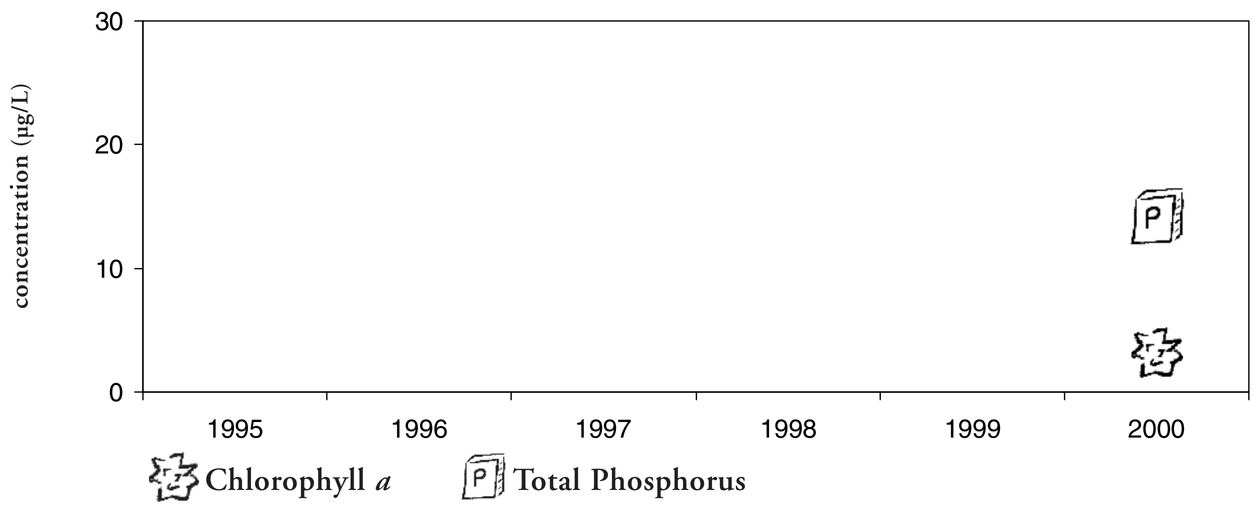
Based on this limited data, water quality is fairly good at Horseshoe Lake. The lake watershed is largely forested which contributes to high quality surface flows to the lake. However, lake water quality is influenced primarily by regional groundwater levels. Year-to-year fluctuations in groundwater result in a wide range of lake levels, from local flooding one year to the lake drying out in the next. Still, erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as new development in the watershed or local shoreline alteration occur.

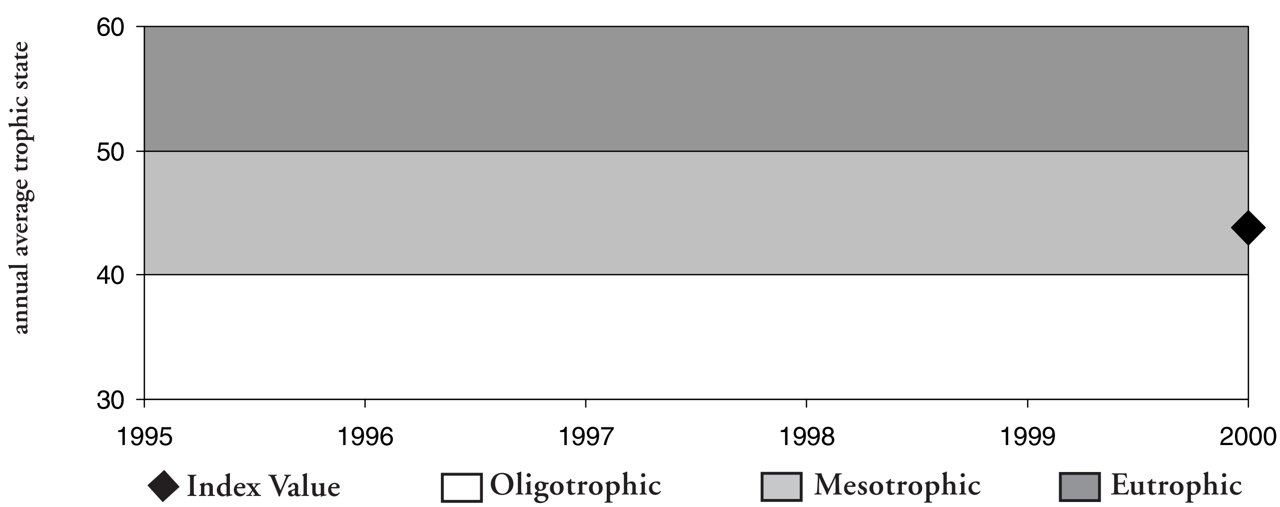
Average Values for Select Trophic Parameters at Horseshoe Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
2000	12	2.5	3.3	14	47	42	43	44

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Joy

In 2000, volunteers began collecting trophic state monitoring data on Lake Joy when the services of the Lake Stewardship Program were extended to northeast King County through the Rural Drainage Program. Because the data record consists of only a single year, no statistical trend analyses were completed for Lake Joy. In the summer of 2000, productivity was low (oligotrophic) at Lake Joy, characterized by moderate water clarity and low chlorophyll *a* and phosphorus levels (see data table below).

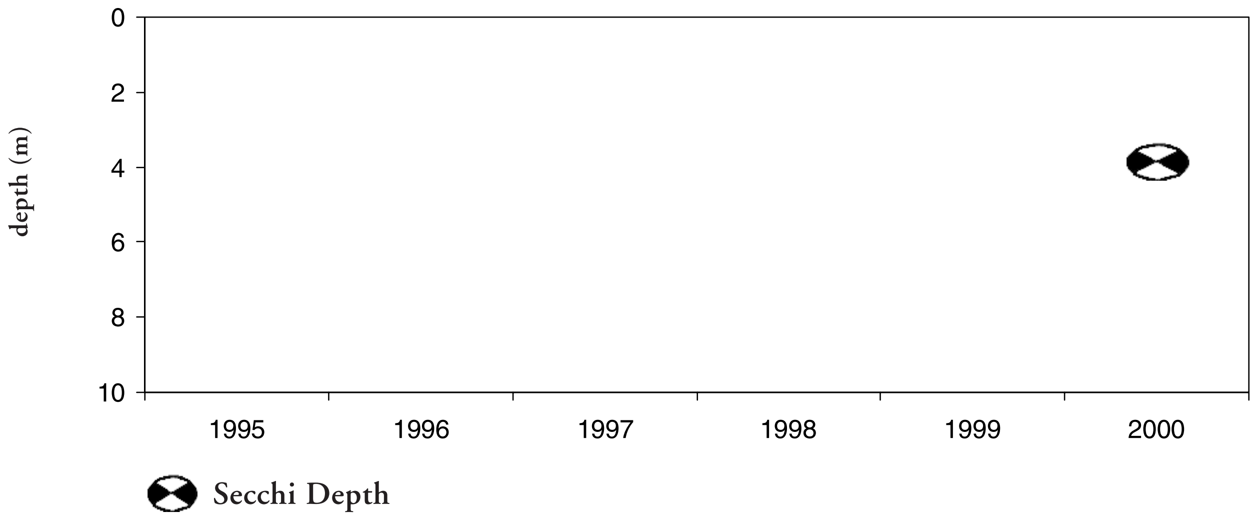
Available data are shown for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state during 2000. These values are illustrated here to allow visual comparison with other lakes that have participated in the program for longer time periods.

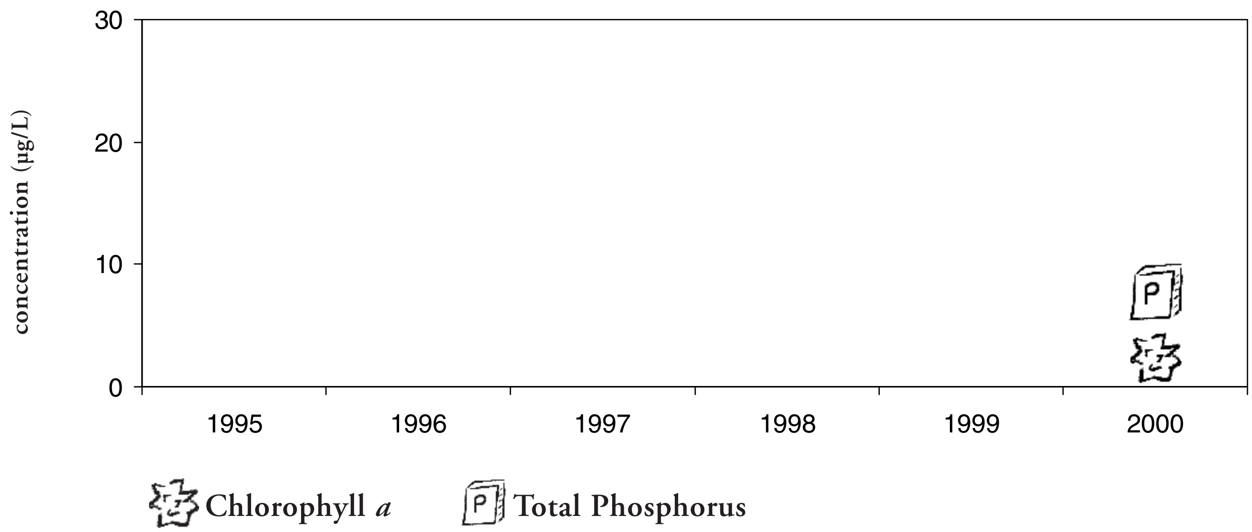
Based on this limited data, water quality is very good at Lake Joy. The lake watershed is largely forested which contributes to high quality surface flows to the lake. However, erosion and nutrient control measures in the watershed are becoming increasingly important to preserving existing lake water quality as new land is develop in the watershed or local shoreline alteration occurs.

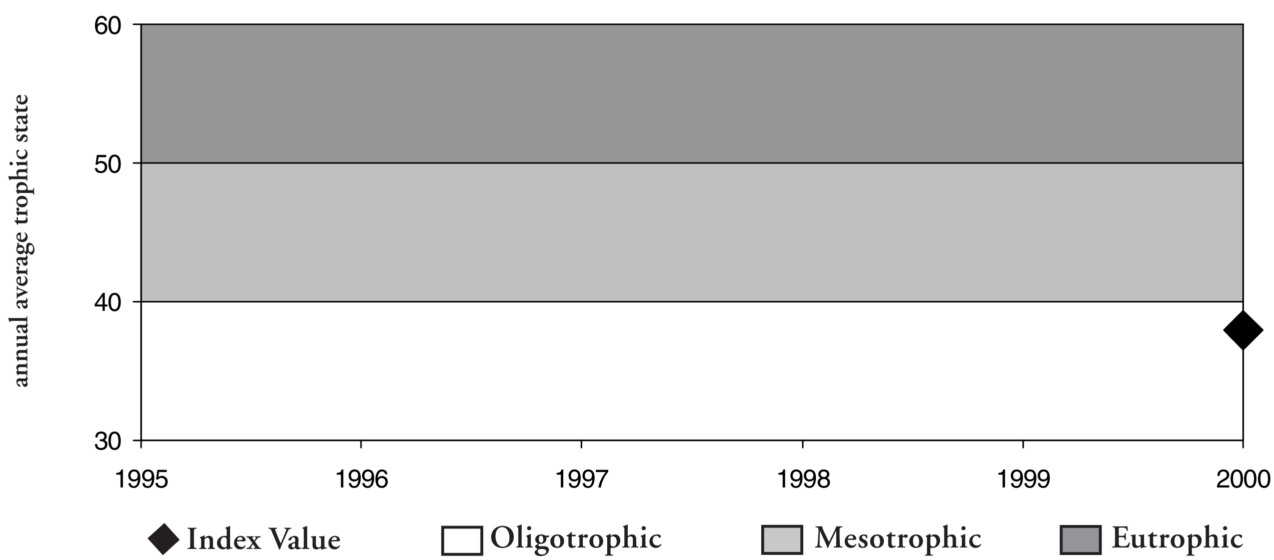
Average Values for Select Trophic Parameters at Lake Joy

Year	No. of Samples	Secchi (meter)	Chl *a** (μg/L)	TP* (μg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
2000	10	3.8	2.4	8	41	39	34	38

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Kathleen

In 1996, volunteers began collecting monitoring data at Lake Kathleen located east of Renton. Because the data record is relatively short, no statistical trend analyses were completed for the lake. Generally, productivity was moderate to high (mesotrophic to eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

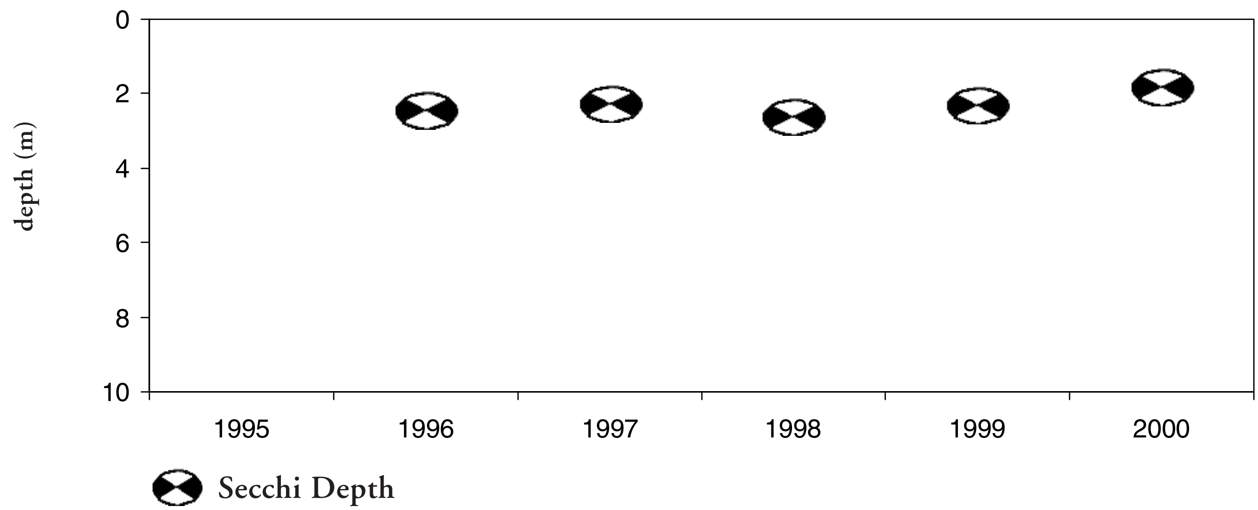
Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels show some variation from year to year.

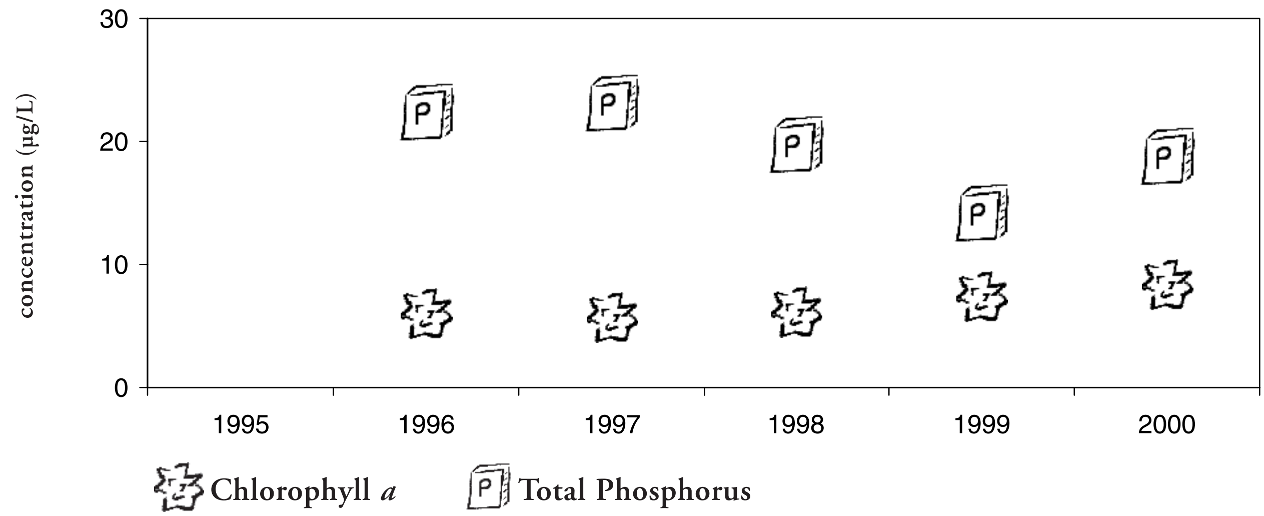
Overall, water quality is fairly good at Lake Kathleen, influenced by wetland chemistry that gives the lake its darker color and lower Secchi depth. The mesotrophic character of the lake is natural. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as new land is developed in the watershed or local shoreline alteration occurs.

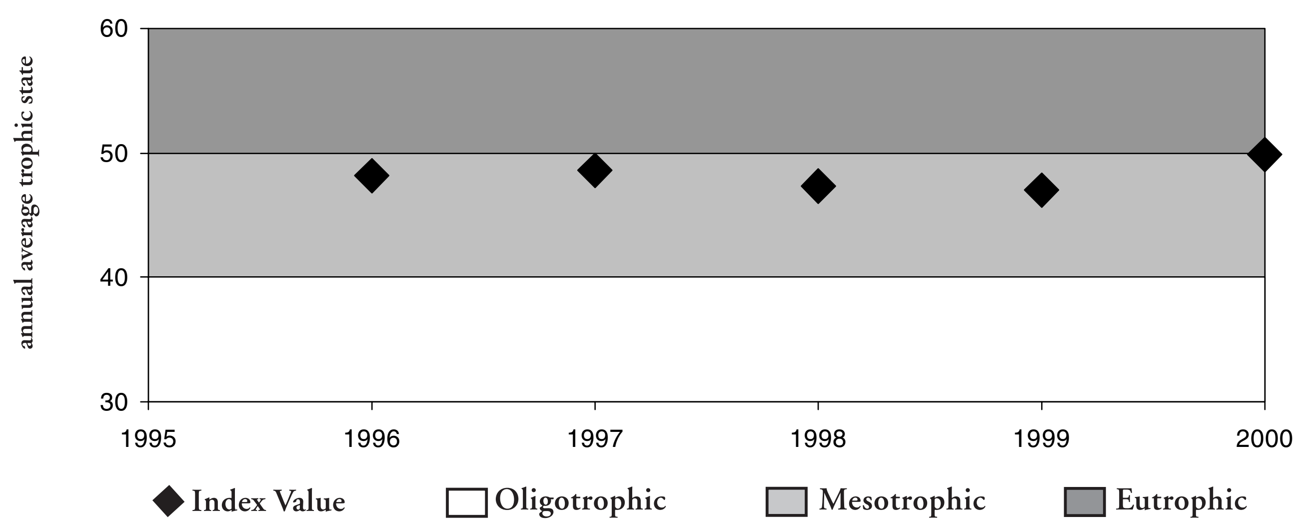
Average Values for Select Trophic Parameters at Lake Kathleen

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	11	2.4	6.0	22	47	48	49	48
1997	7	2.2	5.7	23	48	48	50	49
1998	9	2.6	6.2	20	46	48	47	47
1999	7	2.3	7.5	14	48	50	42	47
2000	13	1.8	8.4	19	52	51	46	50

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Killarney

Since 1989, volunteers have collected monitoring data on Lake Killarney located in southwest King County. The data record is largely complete with data only missing for 1990. Productivity is moderate to high (mesotrophic to eutrophic), characterized by moderate water clarity, and chlorophyll *a*, with slightly elevated phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values. Visual analysis reveals little variation in Secchi depth while phosphorus levels have declined somewhat and chlorophyll *a* levels may have increased slightly.

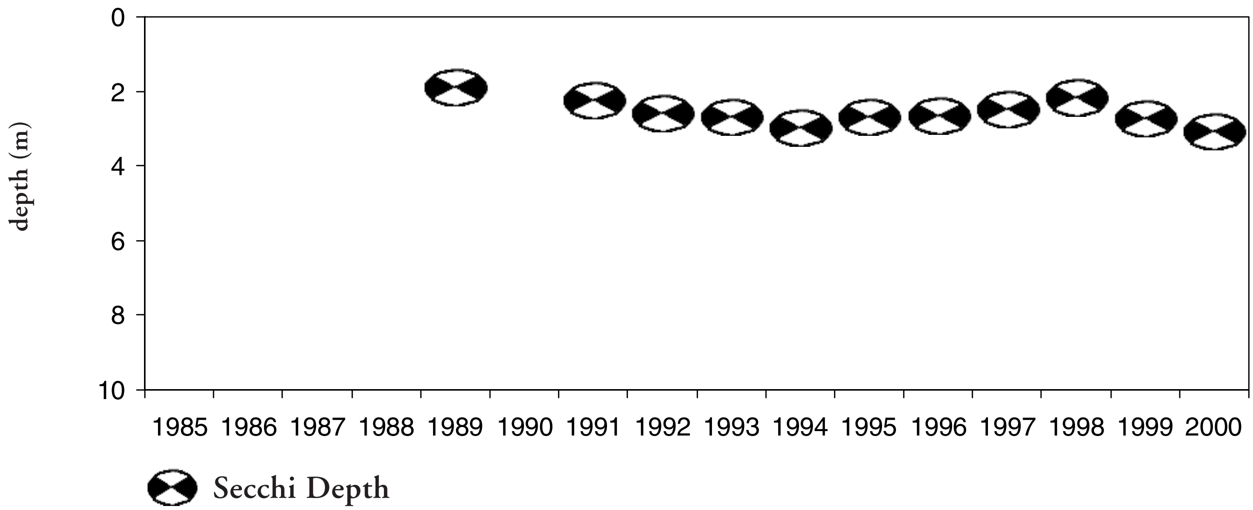
To evaluate whether statistically significant changes in water quality have occurred at Lake Killarney, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant downward trend was noted for total phosphorus (n=11; p=0.03; slope=-1.11) while a significant upward trend was noted for chlorophyll *a* (n=11; p=0.02; slope=0.28). These results suggest that although nutrient levels have declined slightly since 1989, a corresponding decrease in algal levels has not occurred. A downward trend was also noted for TSI TP (n=11; p=0.03; slope= -0.56) while an upward trend was noted for TSI Chl *a* (n=11; p=0.02; slope=0.51). The significant trend for TSI TP and TSI Chl *a* is predictable given that TSI TP and TSI Chl *a* are respectively calculated from total phosphorus and chlorophyll *a* data.

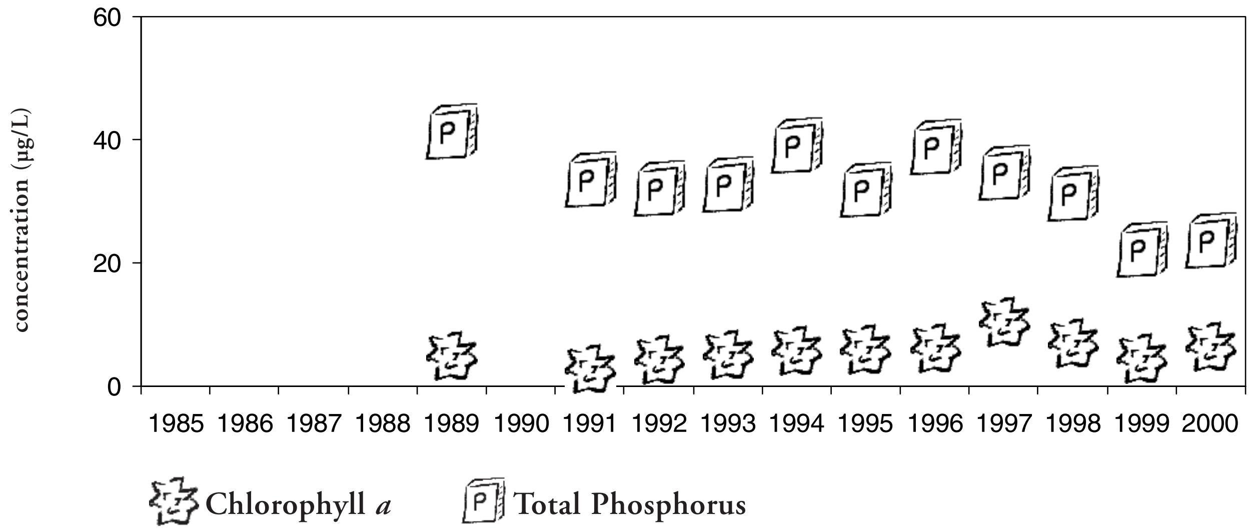
Overall, water quality is moderately good to fair. Wetland chemistry influences lake water quality somewhat as indicated by more variable phosphorus levels and lower water clarity. Over the years, residents have used herbicide to control both algal and aquatic plant growth. These repeated herbicide treatments are likely reflected in the lower chlorophyll *a* levels observed the last 11 years relative to the amount of phosphorus in the lake available for plant growth. Erosion and nutrient control measures still remain important to preserving existing lake water quality as new land is develop in the watershed or local shoreline alteration occurs.

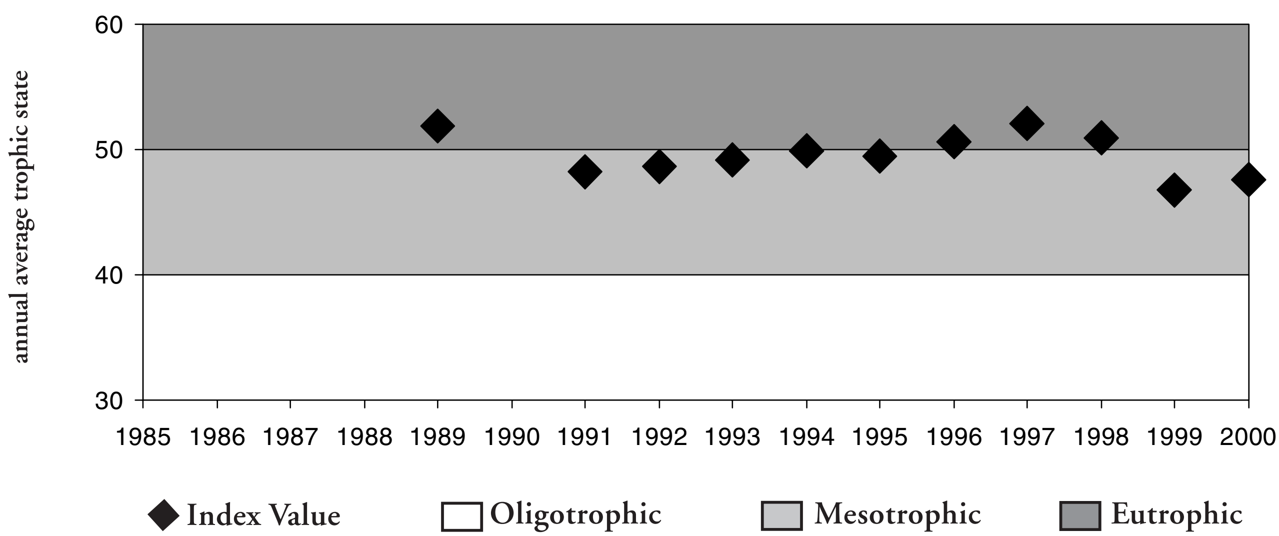
Average Values for Select Trophic Parameters at Lake Killarney

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	---	---	---	---	---	---	---	---
1986	---	---	---	---	---	---	---	---
1987	---	---	---	---	---	---	---	---
1988	---	---	---	---	---	---	---	---
1989	11	1.8	5.1	41.4	51	47	58	52
1990	---	---	---	---	---	---	---	---
1991	8	2.2	2.9	34	49	41	55	48
1992	12	2.5	4.3	32	47	45	54	49
1993	11	2.6	5.3	33	46	47	55	49
1994	12	2.9	6.0	39	44	48	57	50
1995	12	2.7	6.1	32	46	48	54	49
1996	12	2.6	6.4	39	46	49	57	51
1997	10	2.4	10.5	35	47	54	55	52
1998	12	2.1	7.1	31	49	50	54	51
1999	12	2.7	4.7	22	46	46	49	47
2000	11	3.0	6.5	24	44	49	50	48

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
60
40
20
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Leota

In 1998, volunteers began collecting monitoring data at Lake Leota located in Woodinville. Because the data record is relatively short, no statistical trend analyses were completed for the lake. Generally, productivity is moderate (mesotrophic), characterized by low water clarity and somewhat elevated chlorophyll *a* and phosphorus levels (see data table below).

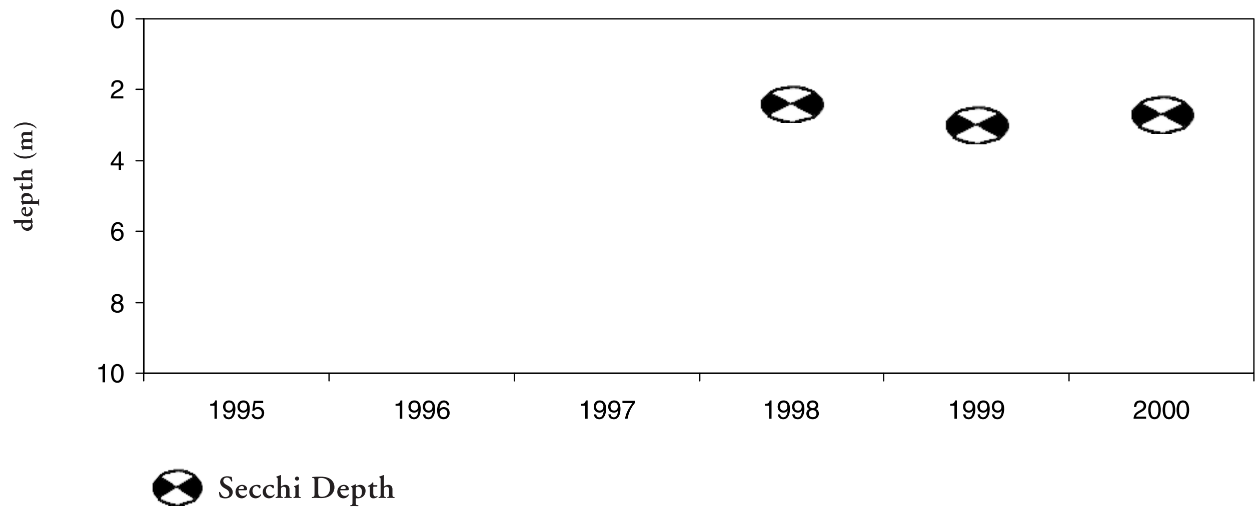
Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values. Visual analysis reveals reasonably consistent values from year to year for Secchi depth while phosphorus, chlorophyll *a,* and trophic state values have increased slightly during the brief three-year record.

Overall, water quality is fairly good at Lake Leota where the immediate shoreline consists of older, low-density residential development. In recent years, the larger watershed has seen substantial development as the Woodinville area has grown. As development of the watershed continues and as local shoreline alteration occurs, implementation of erosion and nutrient control measures remain important to preserving lake water quality.

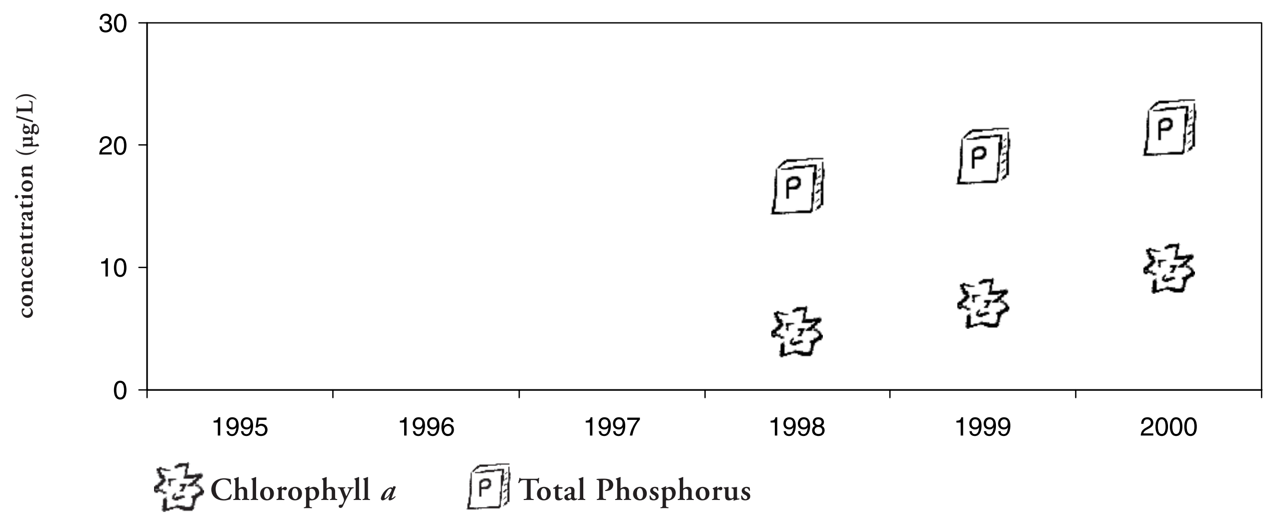
Average Values for Select Trophic Parameters at Lake Leota

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1998	7	2.4	4.8	17	48	46	45	46
1999	11	3.0	7.2	19	44	50	47	47
2000	13	2.6	10.0	21	46	53	48	49

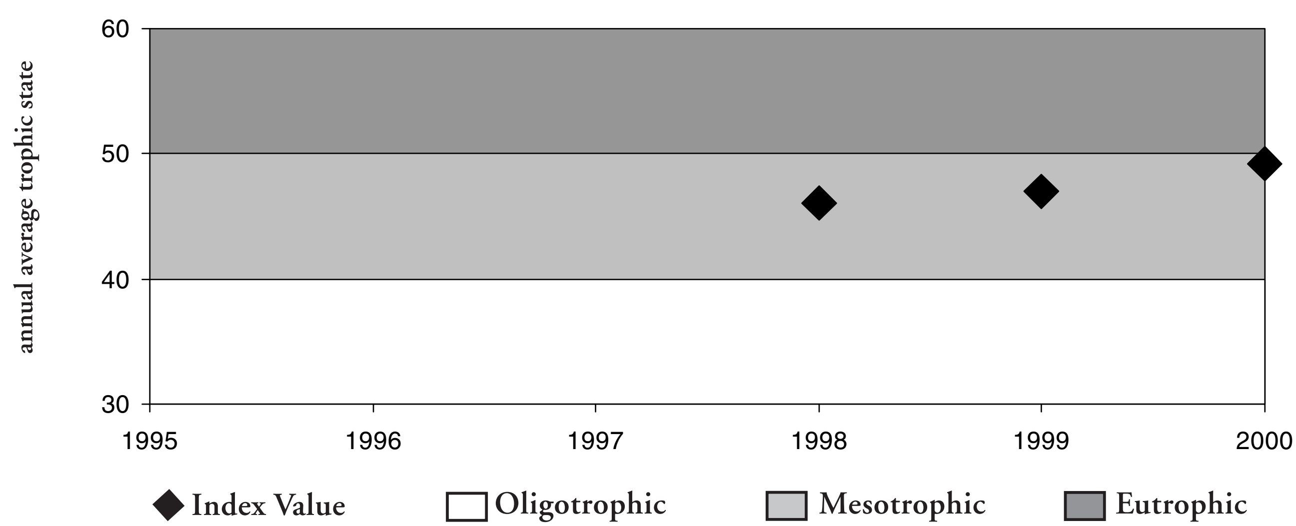
*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index



depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth



concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus



annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Lucerne

Since 1985, volunteers have collected monitoring data on Lake Lucerne located in Maple Valley. The data record is largely complete with data only missing between 1989 and 1992. Overall, productivitiy was low (oligotrophic), characterized by excellent water clarity, low chlorophyll *a* values, and slightly elevated phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variation in chlorophyll *a* values while Secchi depth, phosphorus, and trophic state values have varied somewhat from year to year.

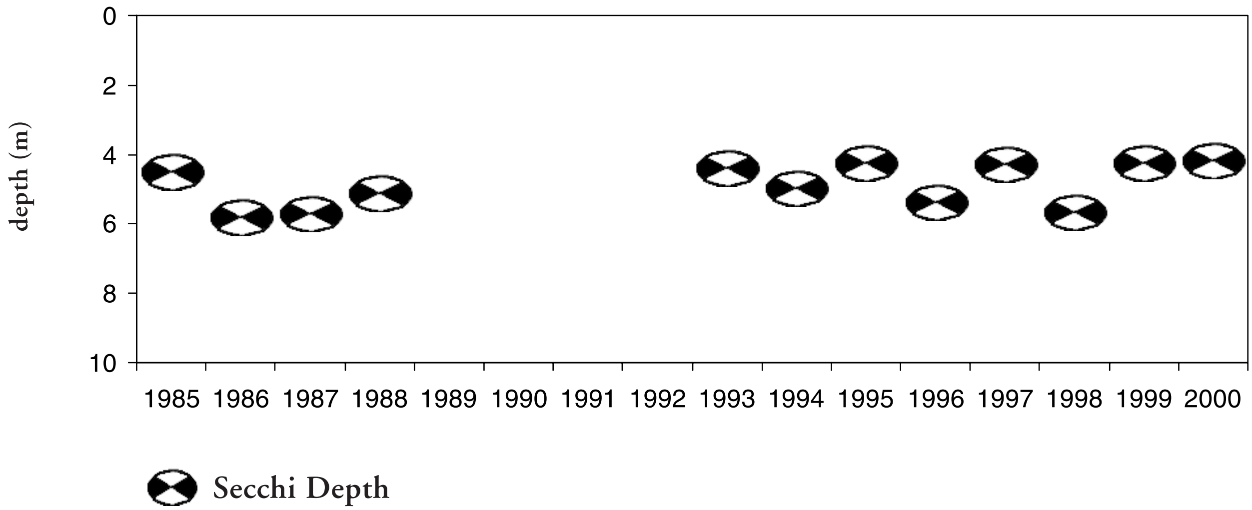
To evaluate whether statistically significant changes in water quality have occurred at Lake Lucerne, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant downward trend in Secchi depth was found (n=12; p=0.05; slope= -0.04) suggesting a slight decline in water clarity has occurred at Lake Lucerne since 1985. A significant upward trend was also noted for TSI Secchi (n=12; p=0.05; slope= 0.11). This significant trend for TSI Secchi is predictable given TSI Secchi is calculated from Secchi depth data.

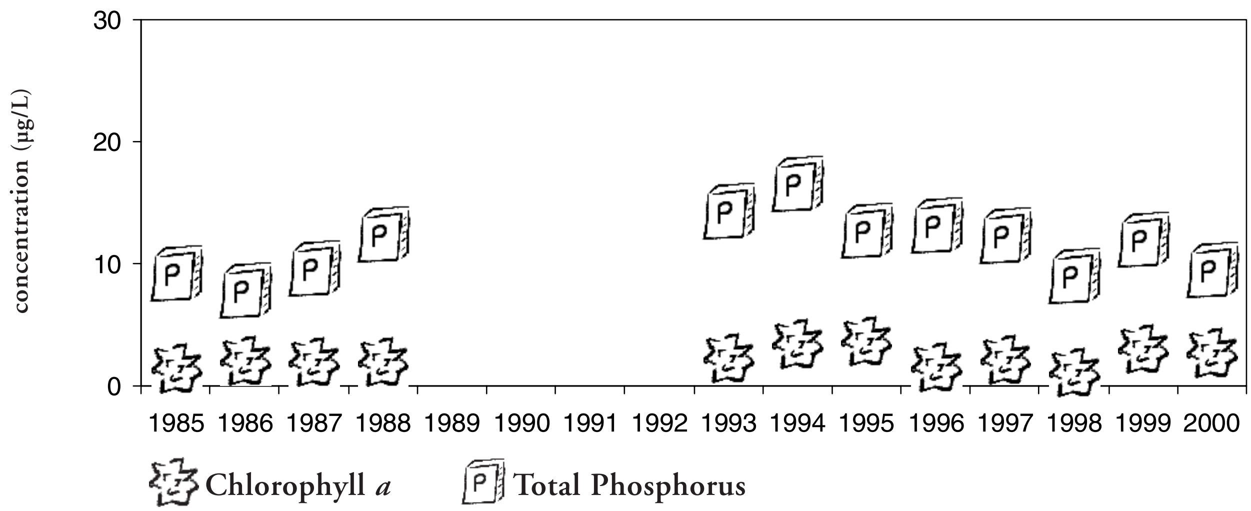
Overall, water quality at Lake Lucerne is very good, partially because groundwater is a primary source of water to the lake. Stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as land is developed in the watershed or local shoreline alteration occurs.

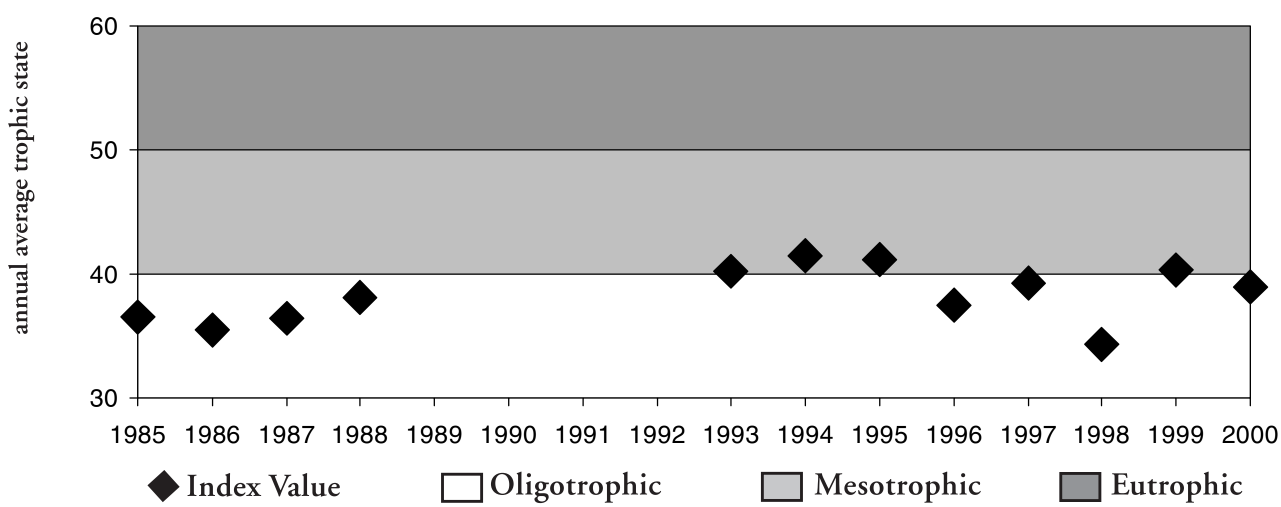
Average Values for Select Trophic Parameters at Lake Lucerne

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	8	4.4	1.5	9	39	35	36	36
1986	11	5.8	2.1	8	35	38	34	35
1987	12	5.7	2.0	10	35	37	37	36
1988	16	5.1	2.0	13	37	37	41	38
1989	---	---	---	---	---	---	---	---
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	11	4.3	2.4	14	39	39	43	40
1994	10	4.9	3.5	17	37	43	45	41
1995	7	4.2	3.7	13	39	43	41	41
1996	7	5.3	1.6	13	36	35	41	37
1997	12	4.2	2.2	12	39	38	40	39
1998	13	5.6	1.2	9	35	32	36	34
1999	13	4.2	3.1	12	39	42	40	40
2000	12	4.1	2.7	10	40	40	37	39

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Marcel

In 2000, volunteers began collecting trophic state monitoring data on Lake Marcel when the services of the Lake Stewardship Program were extended to northeast King County through the Rural Drainage Program. Because the data record consists of only a single year, no statistical trend analyses were completed for Lake Marcel. In the summer of 2000, productivity was high (eutrophic) at Lake Marcel, characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

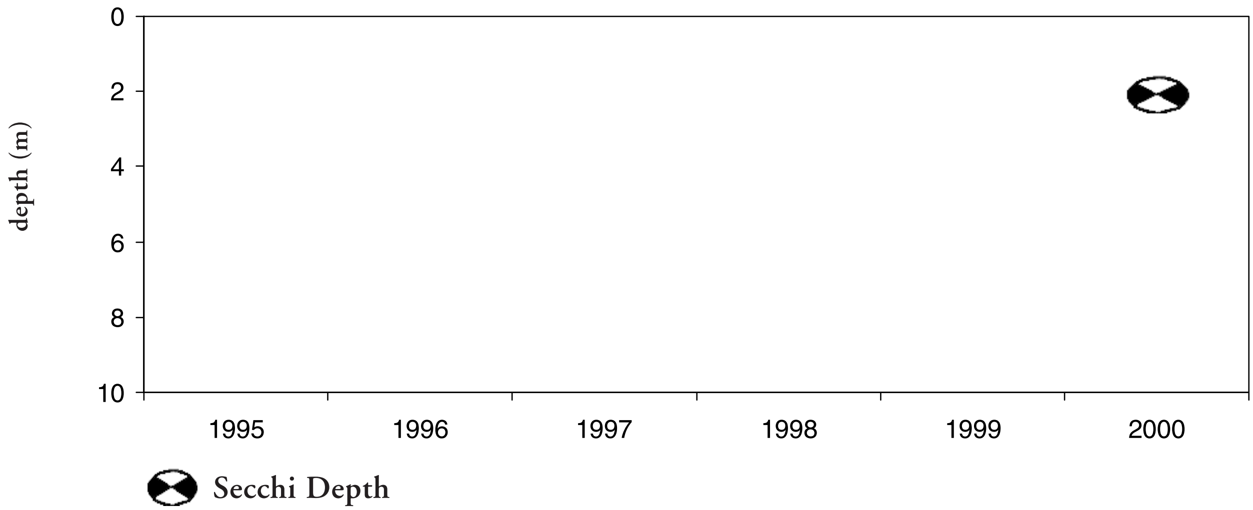
Available data are shown for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state during May through October. These values are illustrated here to allow visual comparison with other lakes that have participated in the program for longer time periods.

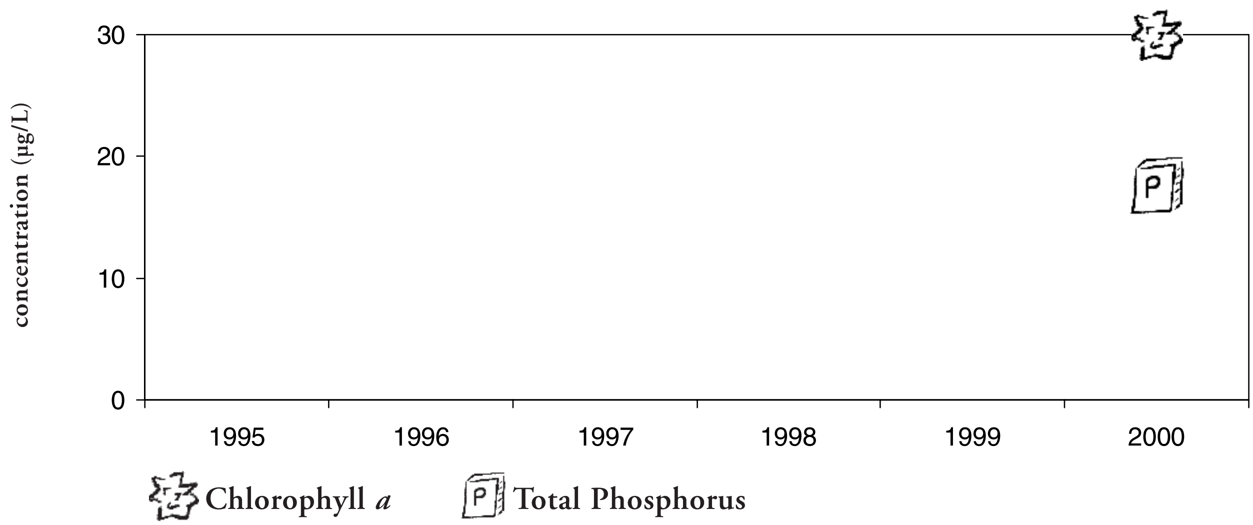
Based on this limited data, water quality is fair at Lake Marcel. The lake watershed includes moderate residential development that contributes surface flows to the lake. The lake itself is fairly shallow, with most of the lake area available for rooted plant growth. The shallow character of the lake contributes to the eutrophic status. Increasingly, erosion and nutrient control measures in the watershed are becoming important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

Average Values for Select Trophic Parameters at Lake Marcel

Year	No. of Samples	Secchi (meter)	Chl *a** (μg/L)	TP* (μg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
2000	13	2.0	31.3	17.7	50	64	46	53

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Margaret

In 2000, volunteers began collecting trophic state monitoring data at Lake Margaret when the services of the Lake Stewardship Program were extended to northeast King County through the Rural Drainage Program. Because the data record consists of only a single year, no statistical trend analyses were completed for Lake Margaret. In the summer of 2000, productivity was low (oligotrophic) at Lake Margaret, characterized by high water clarity and low chlorophyll *a* and phosphorus levels (see data table below).

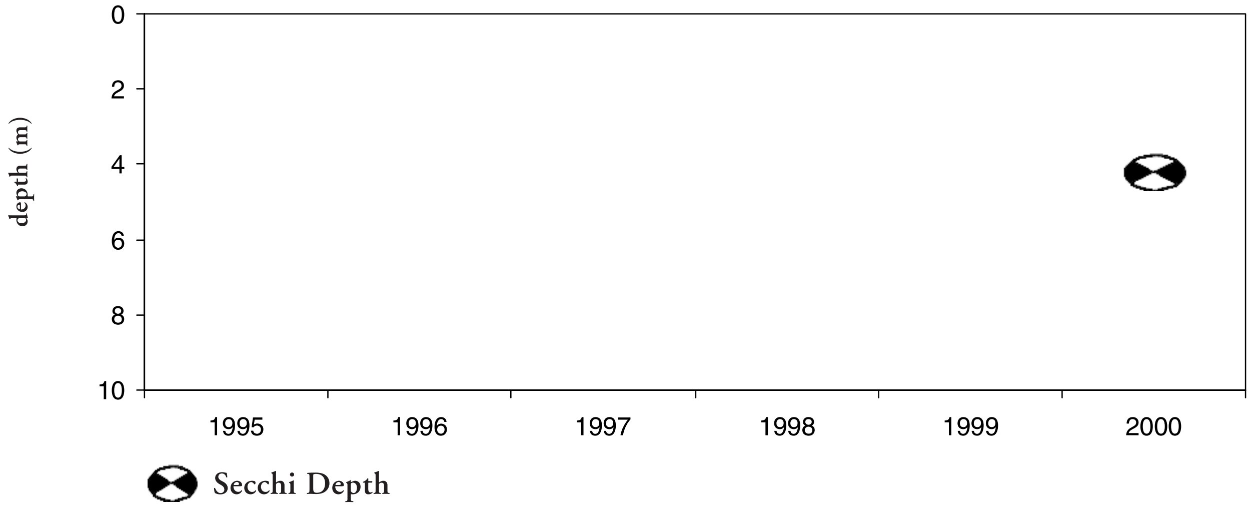
Available data are shown for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, as well as average trophic state during May through October. These values are illustrated here to allow visual comparison with other lakes that have participated in the program for longer time periods.

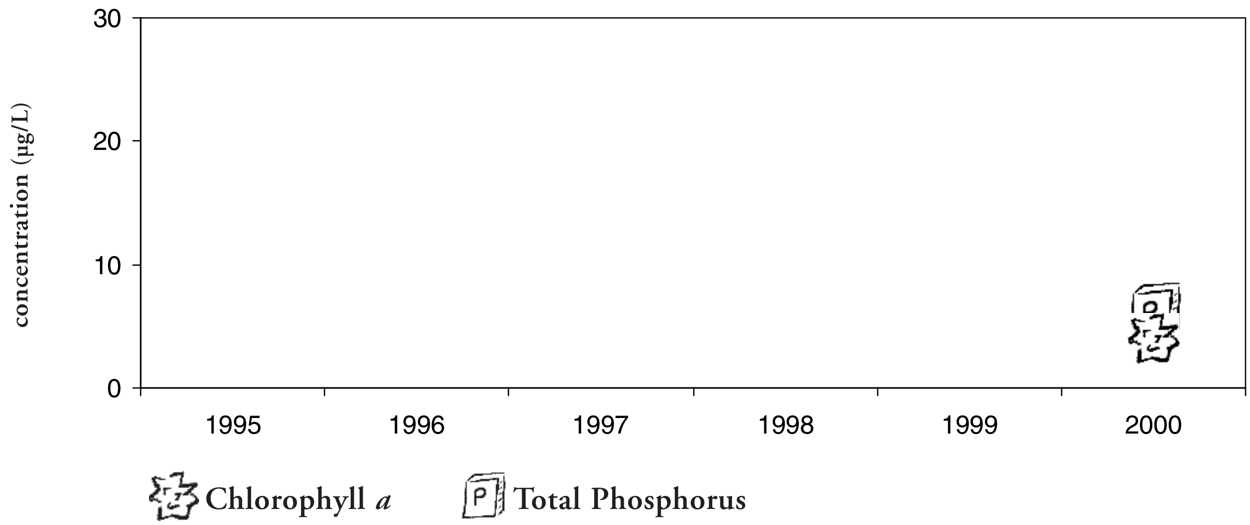
Based on this limited data, water quality is very good at Lake Margaret. The lake watershed is largely forested which contributes to high quality surface flows to the lake. However, erosion and nutrient control measures in the watershed are becoming increasingly important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

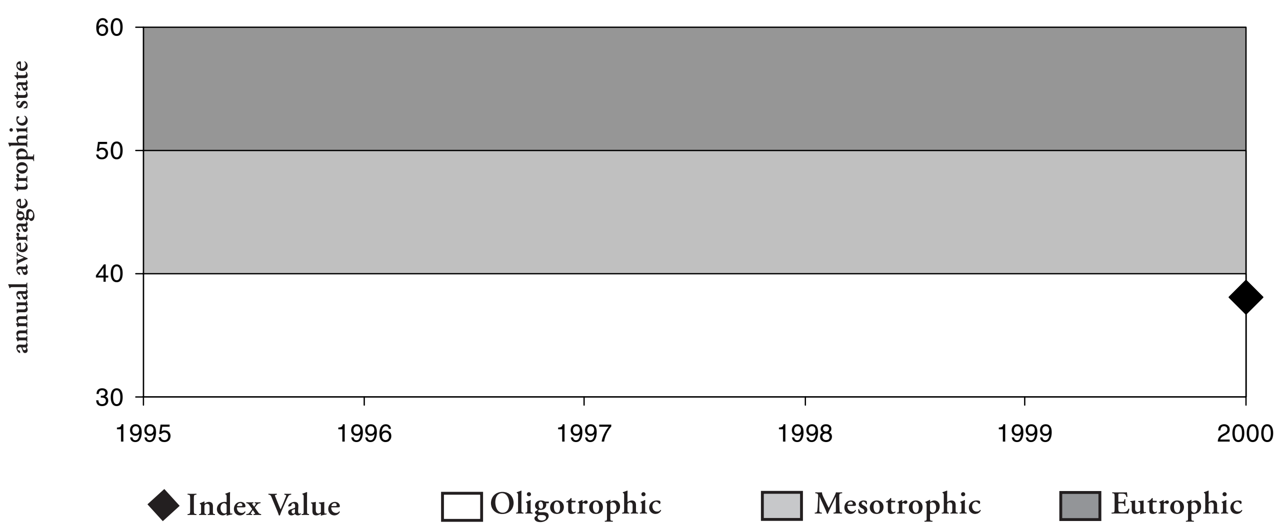
Average Values for Select Trophic Parameters at Lake Margaret

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
2000	13	4.2	4.0	6	39	44	31	38

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

McDonald

In 1996, volunteers began collecting monitoring data on Lake McDonald located east of Renton. Because the data record is relatively short, no statistical trend analyses were completed for Lake McDonald. Generally, productivity was high (eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

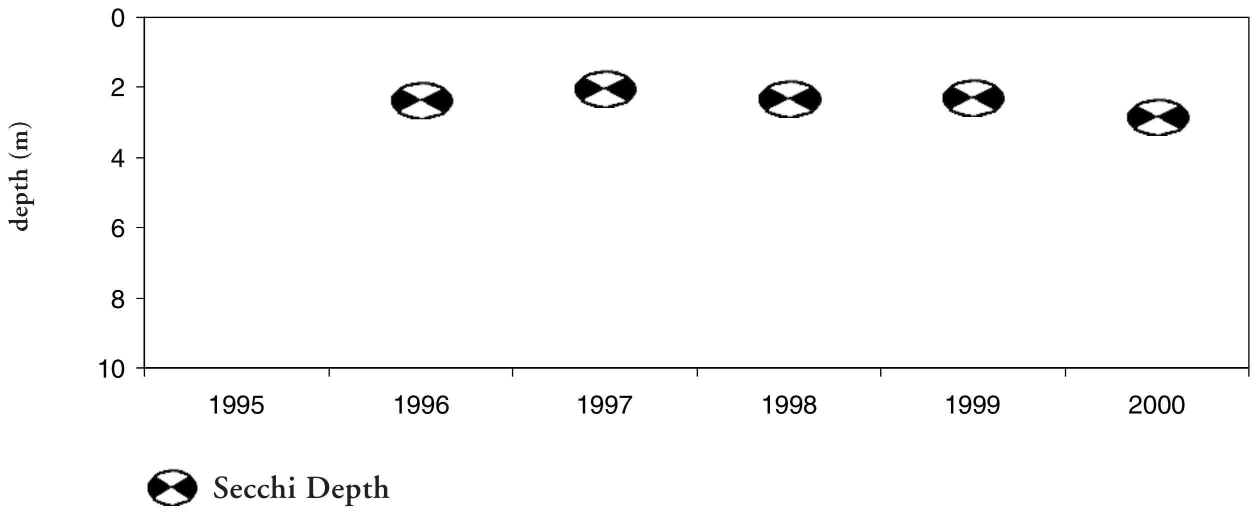
Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values. Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels are variable from year to year.

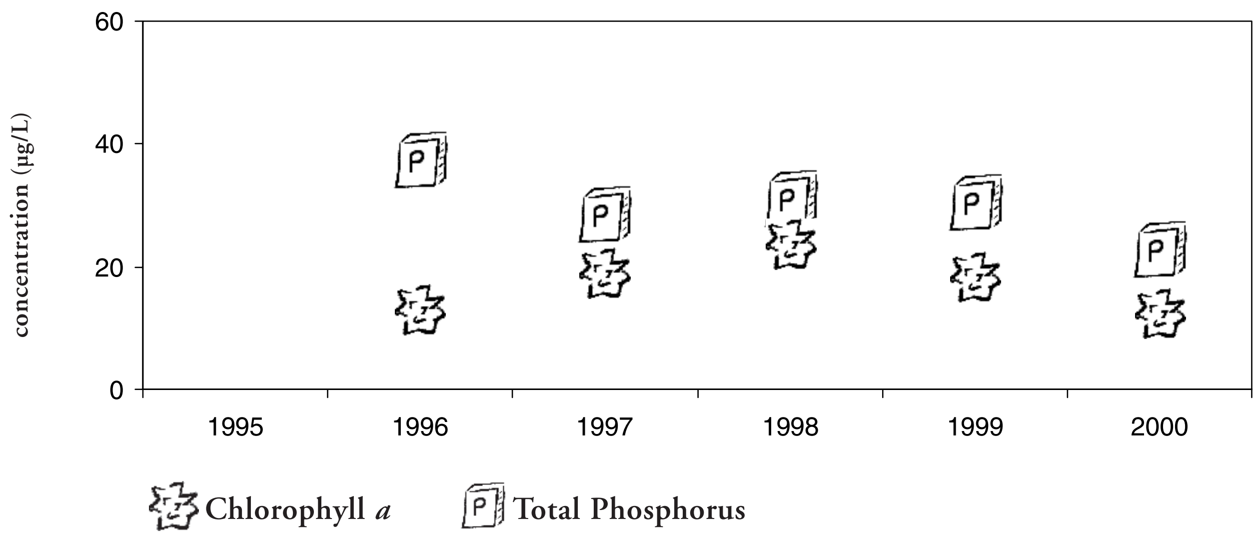
Overall, water quality is fair at Lake McDonald, influenced by wetland chemistry that gives the lake its dark color and low Secchi depth. The eutrophic character of the lake is natural. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

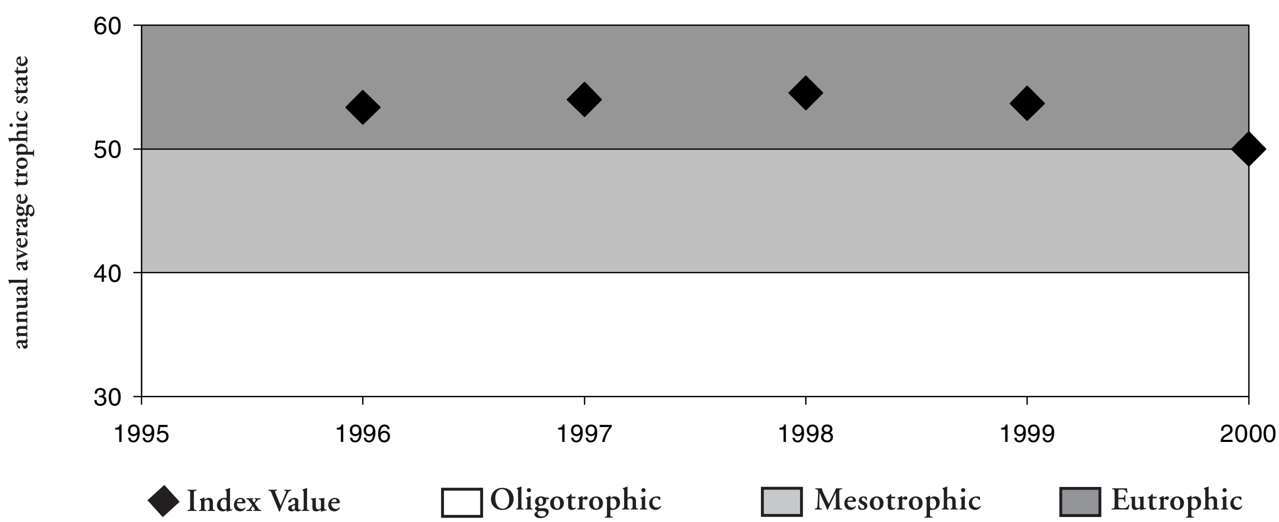
Average Values for Select Trophic Parameters at Lake McDonald

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	8	2.3	13.2	38	48	56	56	53
1997	9	2.0	19.1	29	50	59	52	54
1998	12	2.3	23.8	31	48	62	54	55
1999	13	2.3	18.5	31	48	59	53	54
2000	10	2.8	12.6	23	45	55	49	50

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
60
40
20
0
1995
1996
1997
1998
1999
2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Meridian

Since 1985, volunteers have collected monitoring data on Lake Merdian located in Kent. The data record is nearly complete with data missing only during 1996. Generally, productivity is low (oligotrophic), characterized by excellent water clarity, low chlorophyll *a* values, and low to moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values. Visual analysis reveals little variability in algal levels while Secchi depth and phosphorus levels have varied somewhat from year to year during the 16-year record.

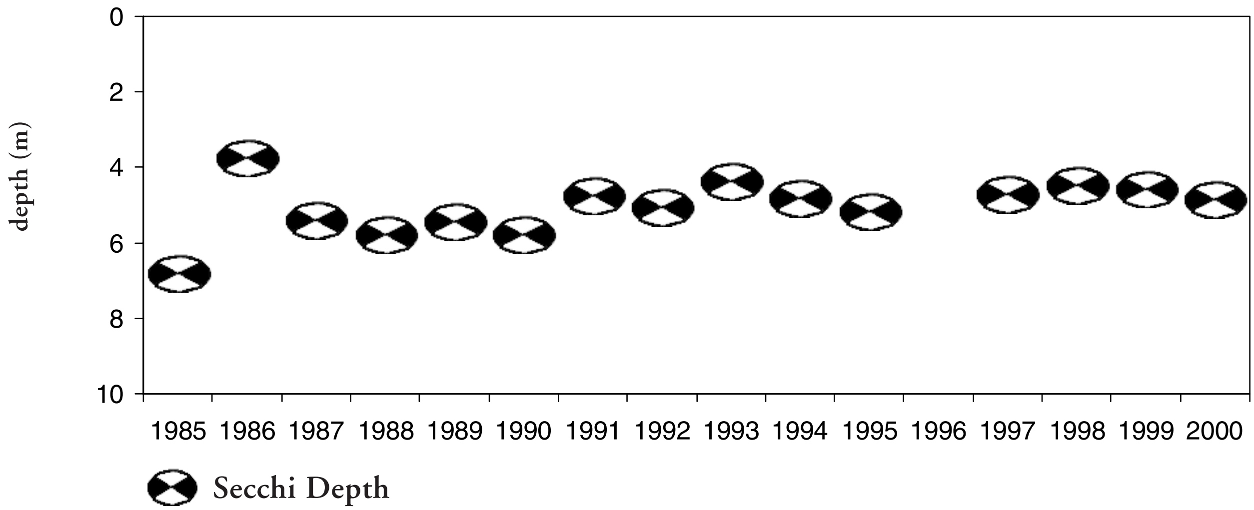
To evaluate whether statistically significant changes in water quality have occurred at Lake Meridian, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the data record.

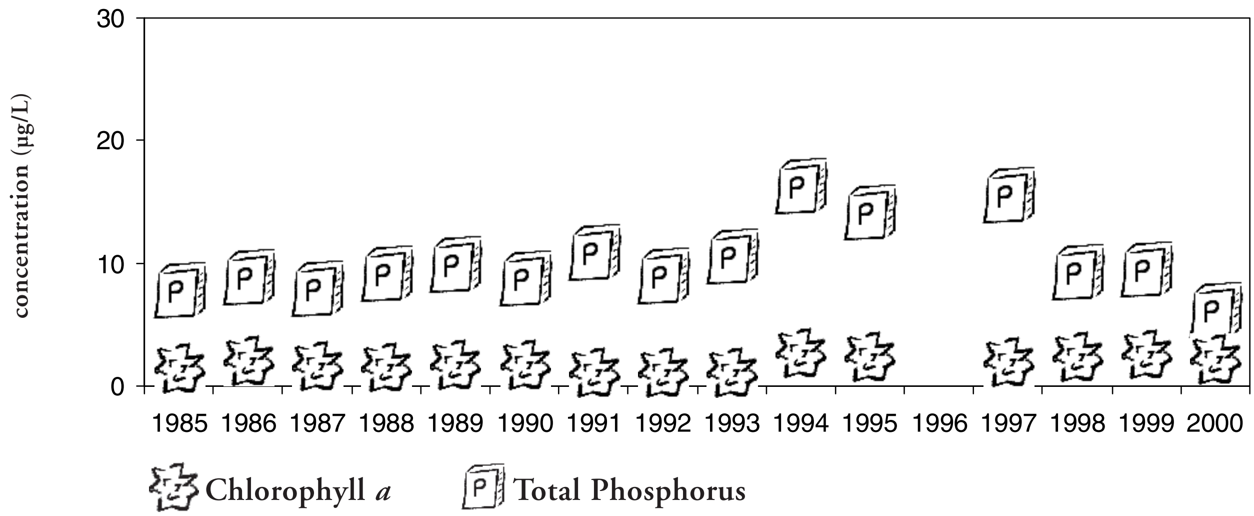
Overall, water quality is very good at Lake Meridian where groundwater is an important source of water to the lake. Stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as additional land in the watershed is developed or where local shoreline alteration occurs.

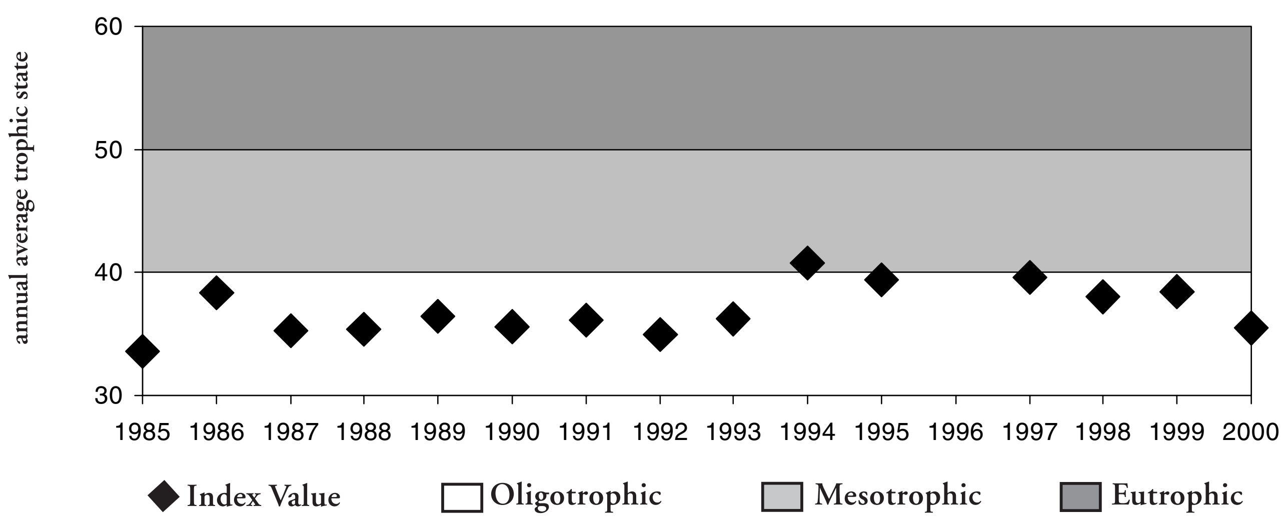
Average Values for Select Trophic Parameters at Lake Meridian

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	6.8	1.5	8	32	34	34	34
1986	10	3.7	2.2	9	41	38	36	38
1987	11	5.4	1.7	8	36	36	34	35
1988	11	5.8	1.6	9	35	35	36	35
1989	12	5.4	1.8	10	36	36	37	36
1990	11	5.7	1.8	9	35	37	35	36
1991	9	4.7	1.2	11	38	32	39	36
1992	11	5.0	1.2	9	37	32	36	35
1993	10	4.3	1.1	11	39	32	38	36
1994	12	4.8	2.7	16	37	40	44	41
1995	11	5.1	2.5	14	36	39	42	39
1996	---	---	---	---	---	---	---	---
1997	10	4.7	2.0	16	38	37	44	40
1998	13	4.4	2.4	9	38	39	36	38
1999	13	4.5	2.7	10	38	40	37	38
2000	12	4.8	2.2	6	37	38	31	35

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Mirror

In 1997, volunteers began collecting monitoring data at Mirror Lake located in Federal Way. Because the data record is relatively short, no statistical trend analyses were completed for the lake. Generally, productivity is moderate (mesotrophic), characterized by average water clarity with somewhat elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

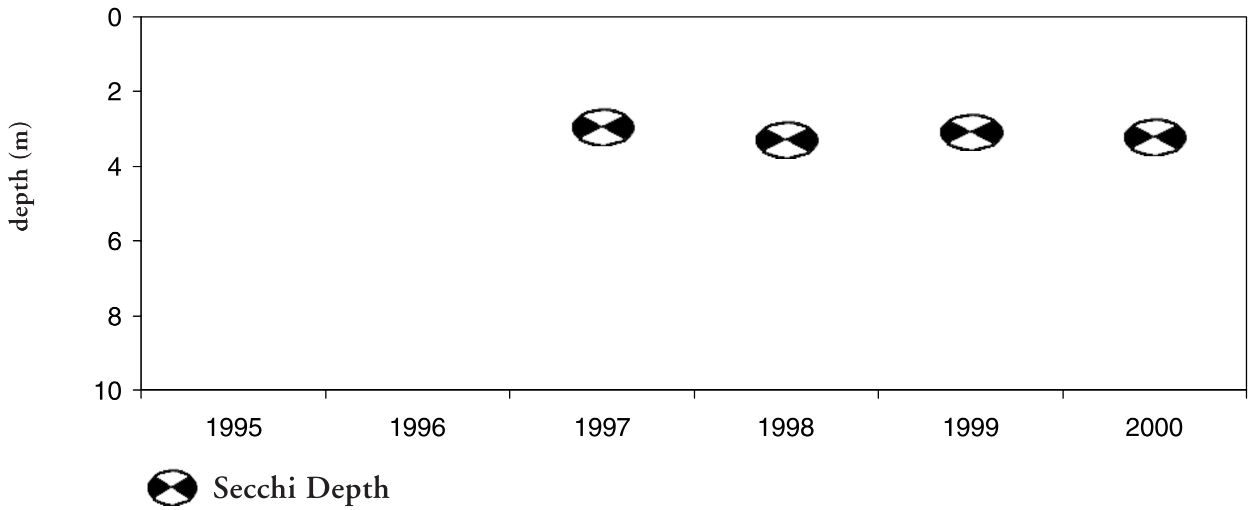
Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels show some variation from year to year.

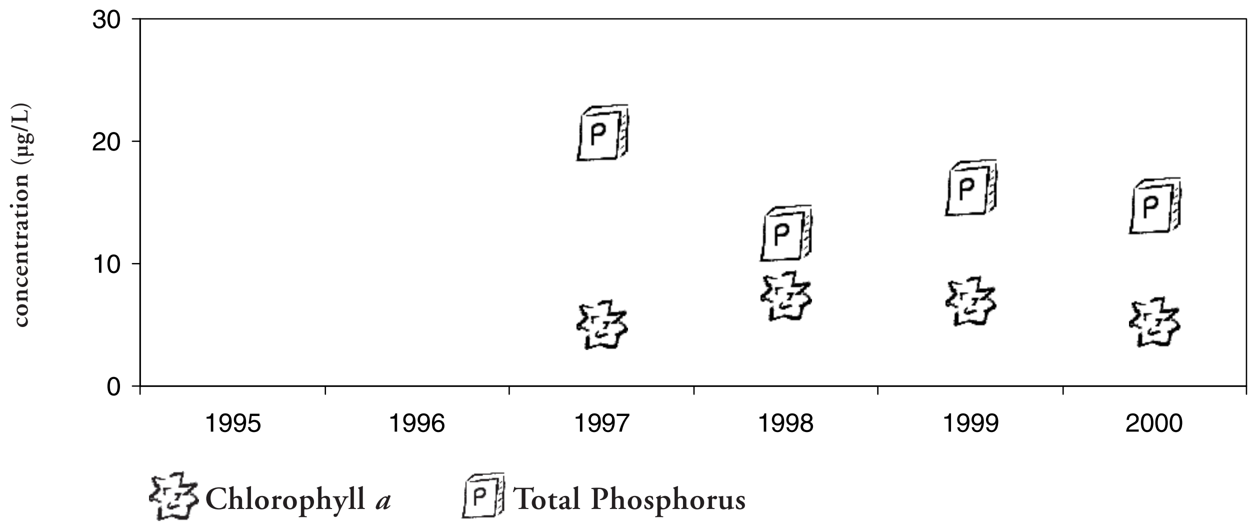
Overall, water quality is fairly good at Mirror Lake even though the lake receives substantial surface flows from a suburban watershed. To preserve existing lake water quality, continued implementation of erosion and nutrient control measures remain important as land is developed in the watershed or as local shoreline alteration occurs.

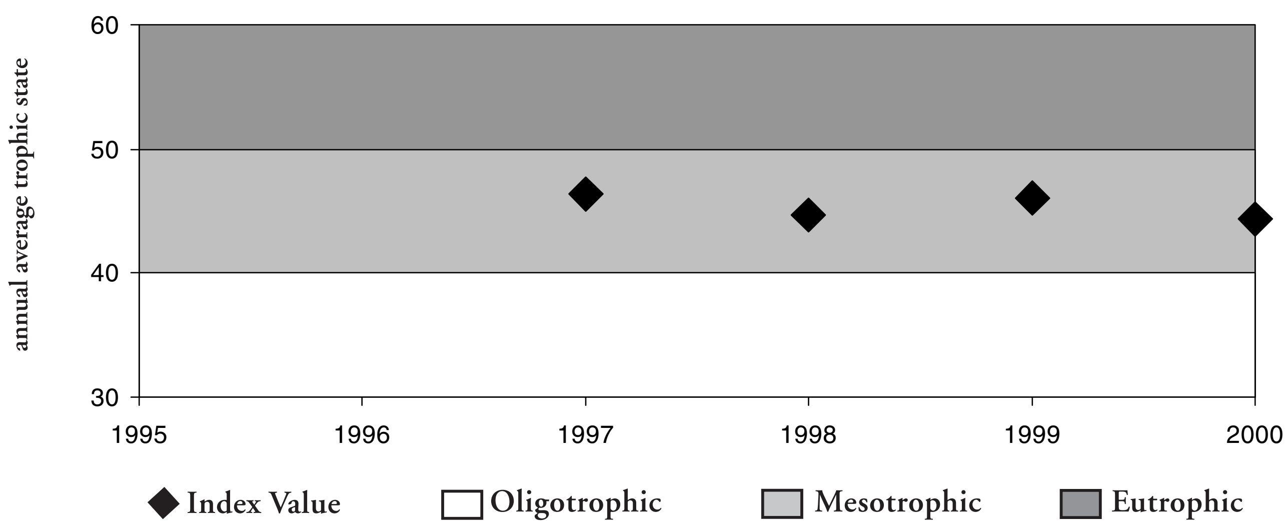
Average Values for Select Trophic Parameters at Mirror Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (μg/L)	TP* (μg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1997	12	2.9	5.1	21	45	47	48	46
1998	13	3.2	7.5	13	43	50	41	45
1999	13	3.0	7.0	16	44	50	44	46
2000	13	3.2	5.3	15	43	47	43	44

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Morton

Since 1985, volunteers have collected monitoring data on Lake Morton located in south King County. The data record is complete for the 16-year record. Generally, productivity was low to moderate (oligotrophic to mesotrophic), characterized by average water clarity, low chlorophyll *a* values, and low to moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variability in algal levels and Secchi depth while phosphorus levels have varied somewhat from year to year during the 16-year record.

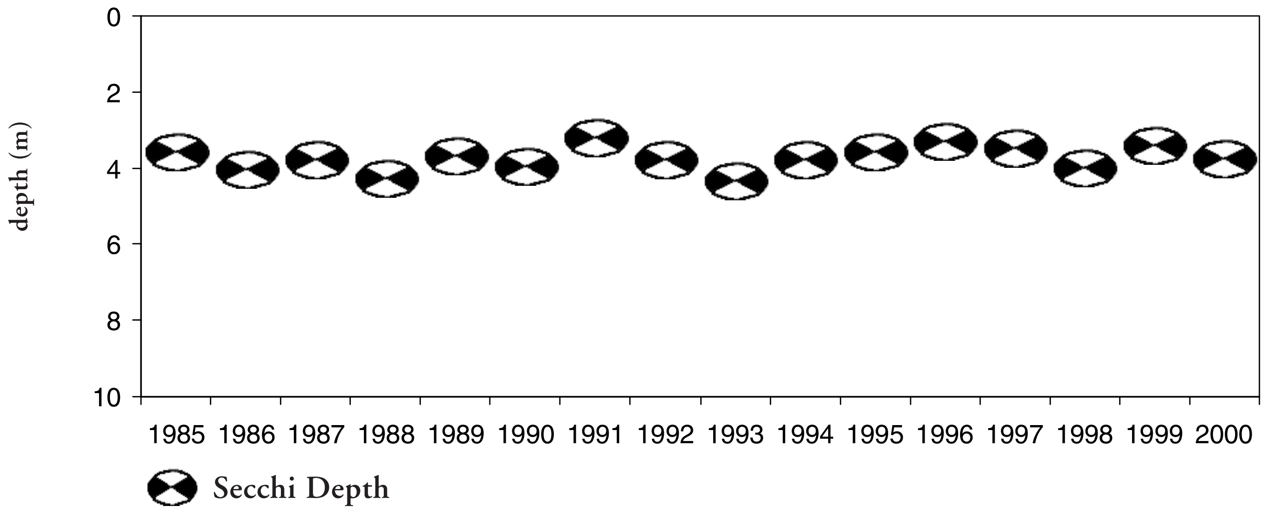
To evaluate whether statistically significant changes in water quality have occurred at Lake Morton, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the data record, indicating water quality has not likely changed over the 16-year data record.

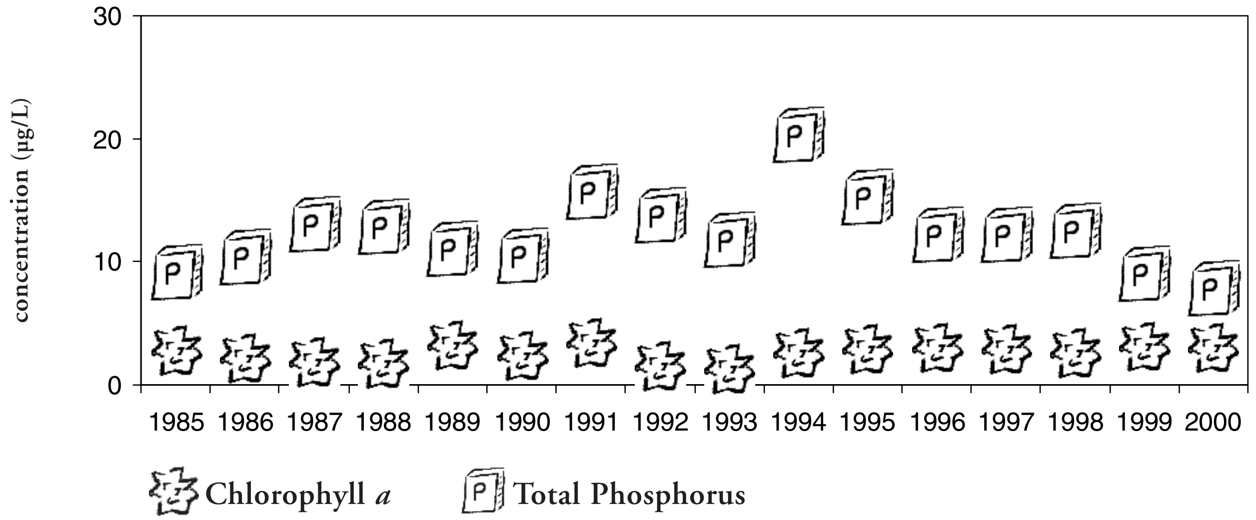
Overall, water quality borders between good to moderate at Lake Morton where high quality groundwater is a likely factor influencing lake water quality. Local stewardship by lake residents remains important , however, to ensure ongoing erosion and nutrient control measures take place as additional land in the watershed is developed or where local shoreline alteration occurs.

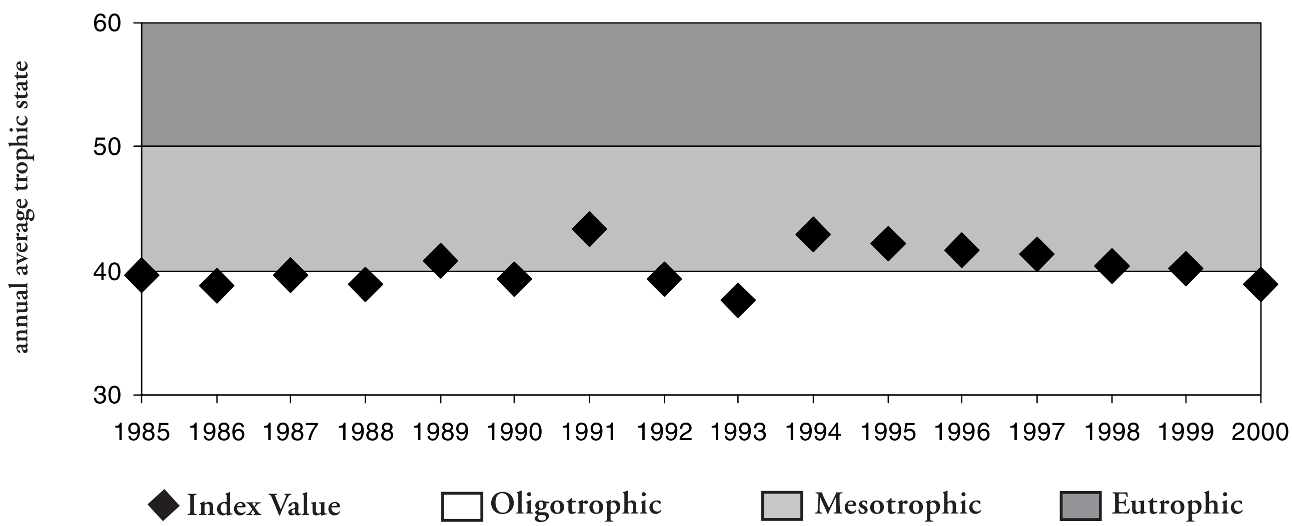
Average Values for Select Trophic Parameters at Lake Morton

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	12	3.5	2.8	9	42	41	36	40
1986	12	4.0	2.2	10	40	38	38	39
1987	12	3.8	1.9	13	41	37	41	40
1988	12	4.2	1.8	13	39	37	41	39
1989	12	3.6	3.3	11	41	42	39	41
1990	10	3.9	2.4	11	40	39	38	39
1991	11	3.1	3.5	16	44	43	44	43
1992	12	3.7	1.6	14	41	35	42	39
1993	10	4.3	1.4	12	39	34	40	38
1994	12	3.7	2.6	20	41	40	48	43
1995	12	3.5	3.0	15	42	41	44	42
1996	12	3.3	3.1	12	43	42	40	42
1997	12	3.4	3.0	12	42	41	40	41
1998	13	3.9	2.7	13	40	40	41	40
1999	12	3.3	3.2	9	43	42	36	40
2000	13	3.7	3.1	8	41	42	34	39

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Neilson

In 1997, volunteers began collecting monitoring data at Lake Neilson located in south King County. Because the data record is relatively short, no statistical trend analyses were completed for the lake. Generally, productivity was moderate (mesotrophic), characterized by average water clarity, chlorophyll *a,* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

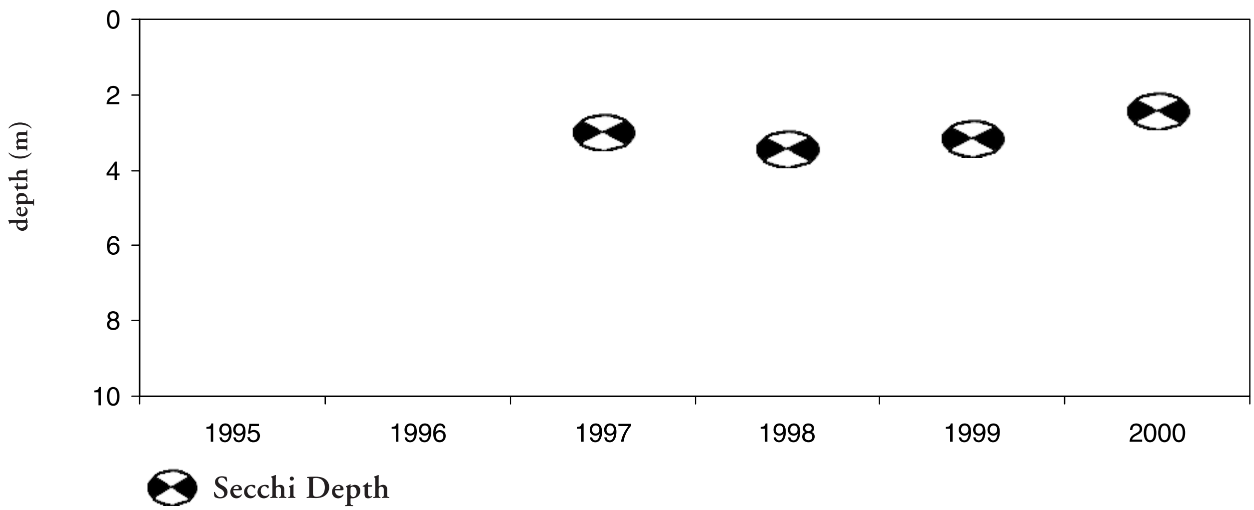
Visual analysis reveals reasonably consistent values from year to year for Secchi depth, phosphorus, and chlorophyll *a*.

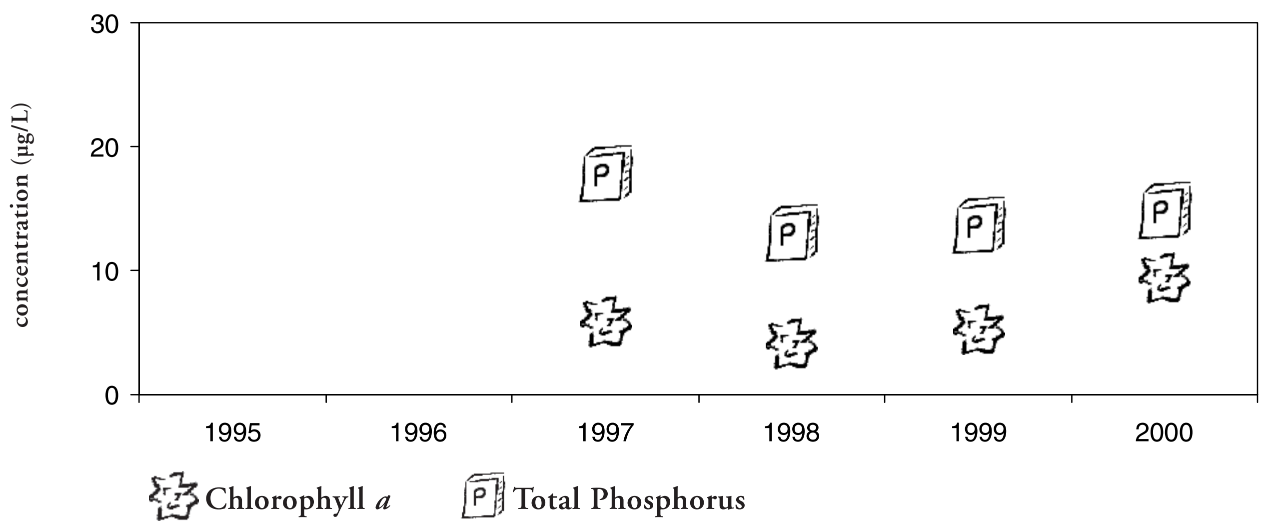
Overall, water quality is fairly good at Lake Neilson which is influenced by groundwater flows to the lake. The mesotrophic character of the lake is natural, reflecting the wetland character of the watershed. Ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

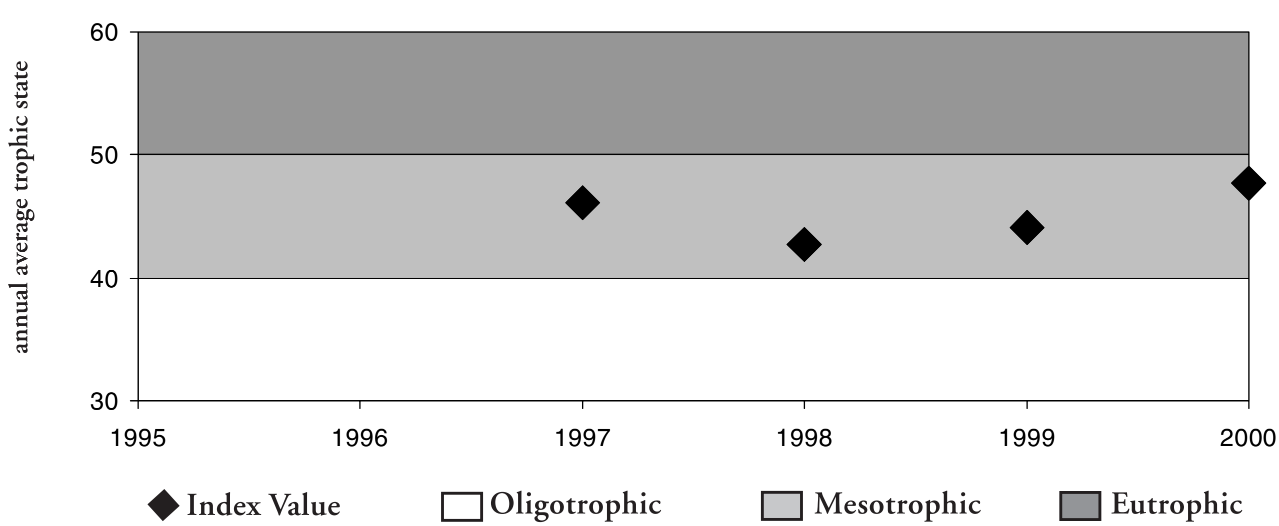
Average Values for Select Trophic Parameters at Lake Neilson

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1997	12	2.9	6.0	18	45	48	46	46
1998	13	3.4	4.1	13	42	45	41	43
1999	13	3.1	5.3	14	44	47	42	44
2000	13	2.4	9.5	15	47	53	43	48

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

North

Since 1985, volunteers have collected monitoring data on North Lake located in southwest King County. The data record is only partially complete with data collected during 9 of the past 16 years, including a five-year gap between 1990-1994. Overall, productivity was moderate (mesotrophic), characterized by moderate water clarity and chlorophyll *a* with slightly elevated phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variation in Secchi depth while phosphorus, chlorophyll *a*, and trophic state values have varied somewhat from year to year although no discernible pattern is apparent.

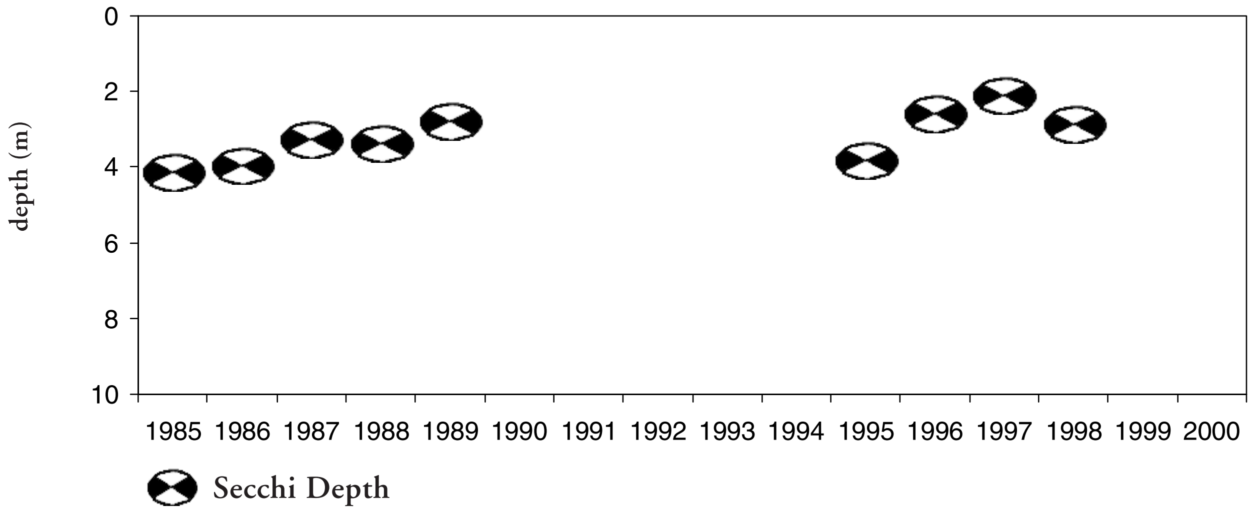
While nine years of data could be used to analyze trends employing the non-parametric Mann-Kendall's test for trend, the existing pattern of missing data points made trend analysis inaccurate. Therefore, trend analyses were not completed for North Lake.

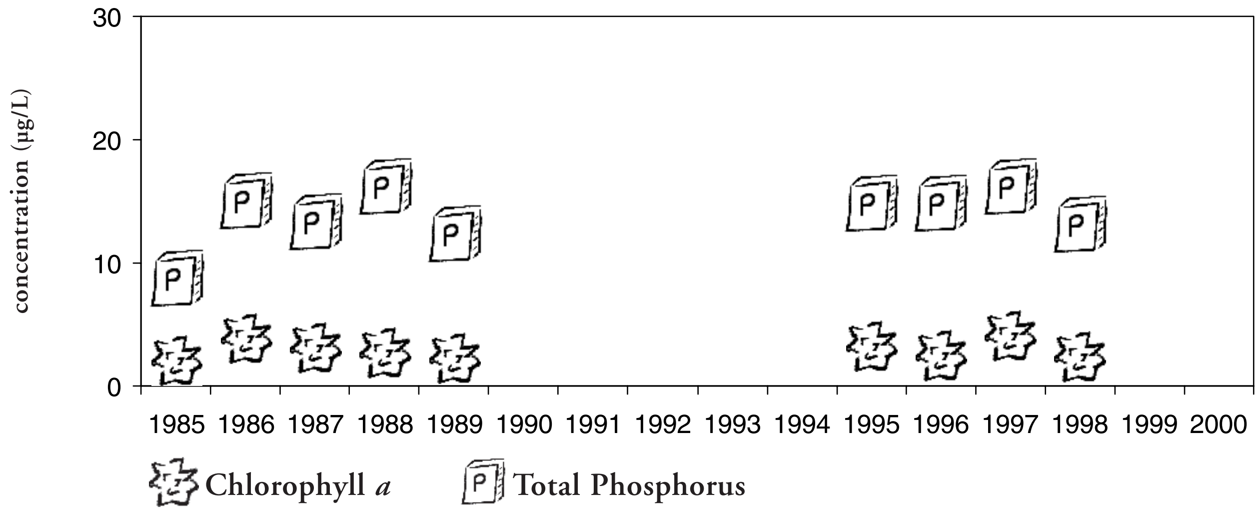
Overall, water quality is moderately good at North Lake based on the available data. The largely forested watershed contributes to high quality surface flows entering the lake. Ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as land development or local shoreline alteration occurs.

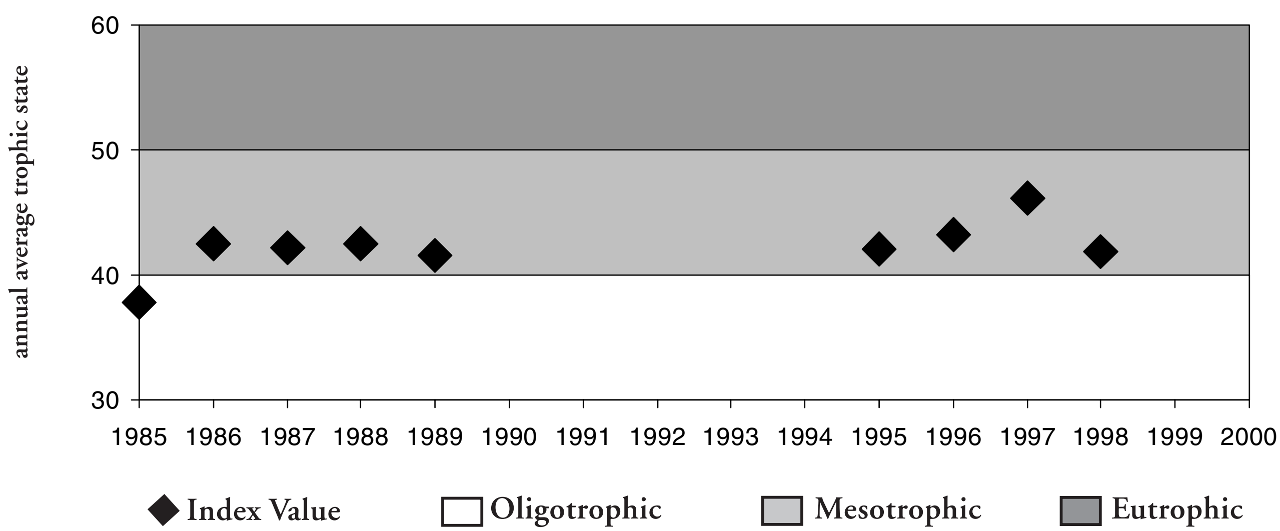
Average Values for Select Trophic Parameters at North Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	8	4.1	2.2	9	40	38	36	38
1986	8	3.9	3.9	15	40	44	43	43
1987	8	3.2	3.2	13	43	42	42	42
1988	8	3.3	2.7	16	43	40	44	42
1989	9	2.7	2.3	13	45	39	41	42
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	11	3.8	3.3	15	41	42	43	42
1996	9	2.5	2.6	15	47	40	43	43
1997	9	2.1	4.2	16	50	45	44	46
1998	12	2.8	2.4	13	45	39	41	42
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Panther

Since 1985, volunteers have collected monitoring data on Panther Lake located in south King County. The data record is only partially complete with data collected during 6 of the past 16 years, including a seven-year gap between 1989-1995. The change in Chlorophyll values between the early years and the last two years of data collection suggests that the productivity level of the lake may be changing from moderate to high (mesotrophic to eutrophic). There was an accompanying decrease in Secchi transparency and a possible increase in total phosphorus as well , but more data would be necessary to confirm the changes. (see data table below).

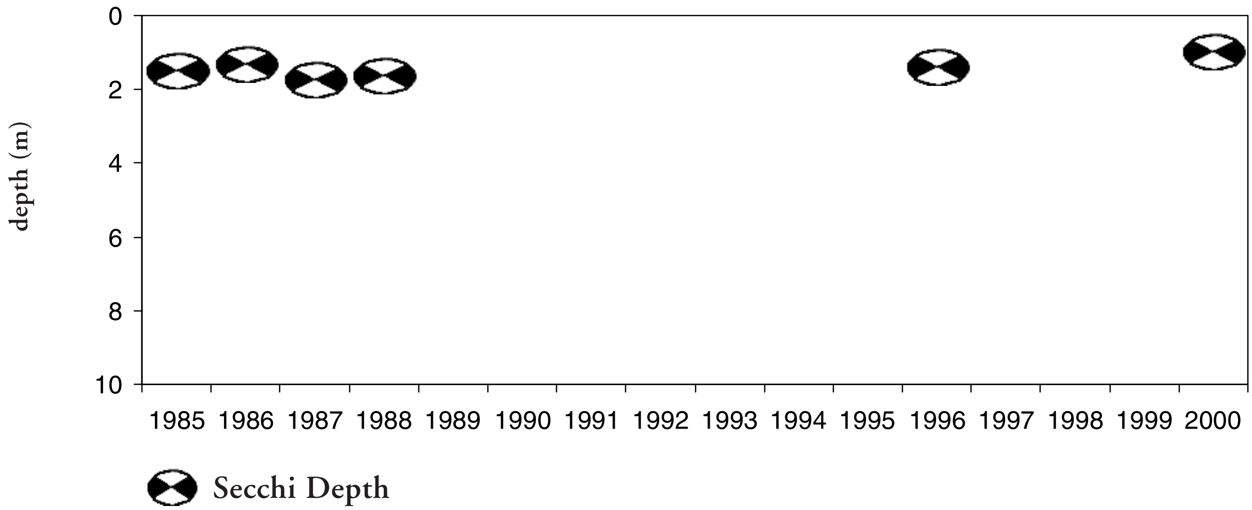
Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variation in Secchi depth while phosphorus, chlorophyll *a*, and trophic state values have varied from year to year. Given that more than half the data record is missing, trend analyses were not completed for Panther Lake.

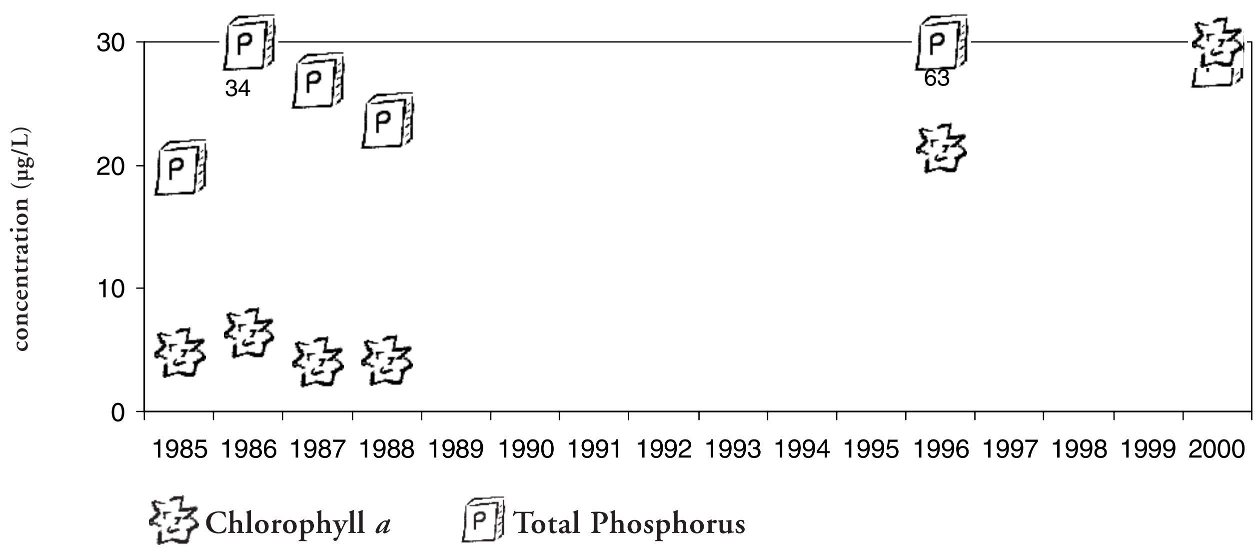
Overall, water quality is currently fair at Panther Lake based on the available data. The eutrophic character of the lake may be natural, a function of wetland chemistry and shallow depth of the lake. Ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as land redevelopment or local shoreline alteration occurs.

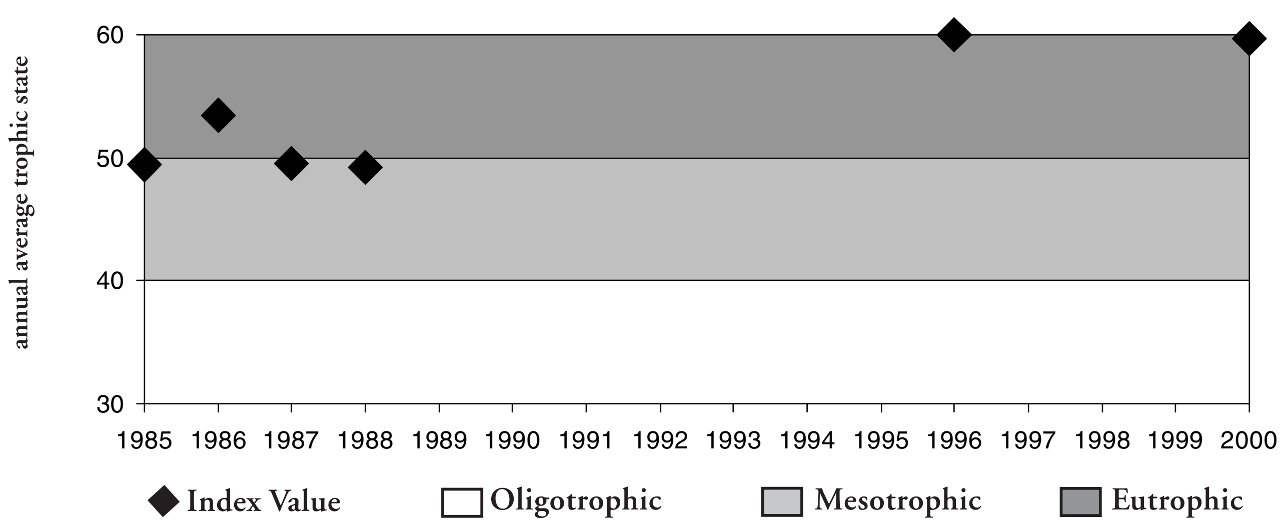
Average Values for Select Trophic Parameters at Panther Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	1.4	4.9	20	55	46	47	49
1986	11	1.3	6.4	34	57	49	55	53
1987	11	1.7	4.1	27	53	44	52	50
1988	8	1.6	4.2	24	53	45	50	49
1989	---	---	---	---	---	---	---	---
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	10	1.3	21.5	63	56	61	64	60
1997	---	---	---	---	---	---	---	---
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	12	0.9	34.3	29	61	65	53	60

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
0
10
20
30
34
63
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
30
40
50
60
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Paradise

In 1996, volunteers began collecting monitoring data on Paradise Lake located in north King County. Because the data record is relatively short, no statistical trend analyses were completed for Paradise Lake. Generally, productivity was high (eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

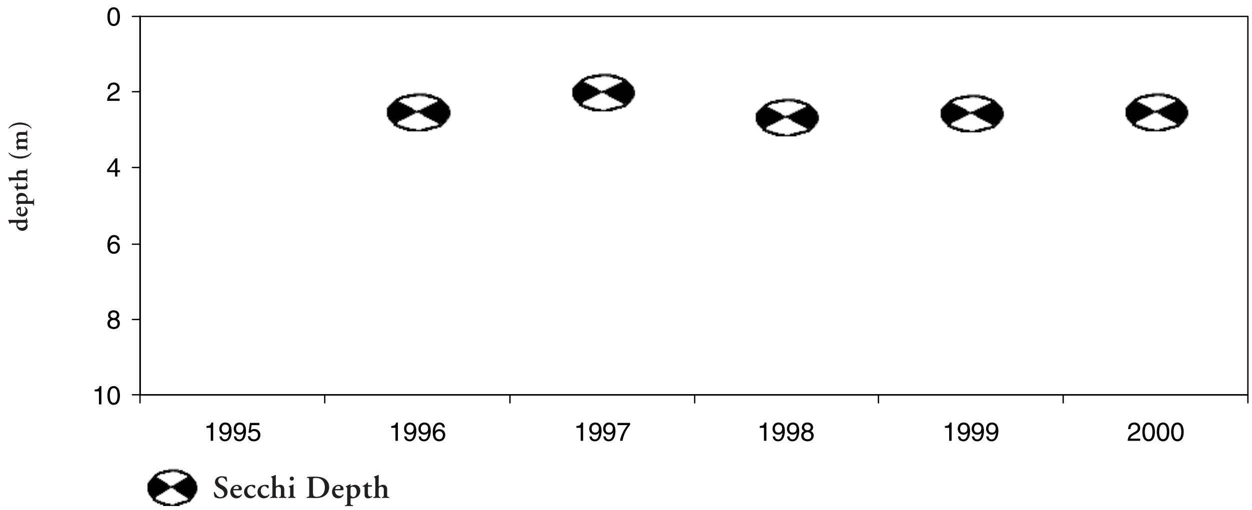
Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels show considerable variation from year to year.

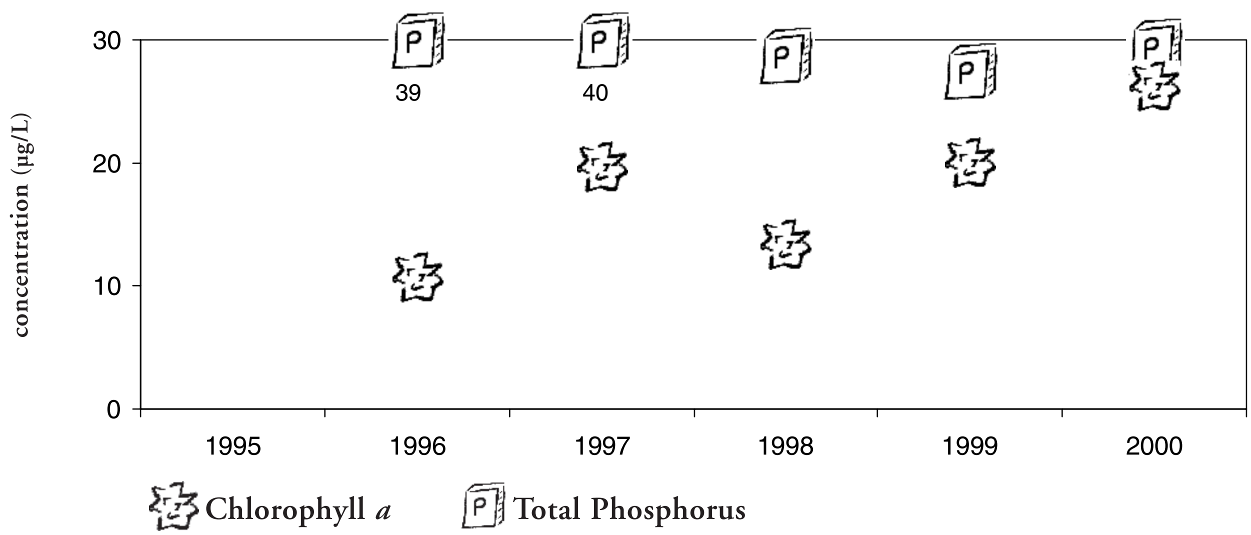
Overall, water quality is fair at Paradise Lake, influenced by wetland chemistry that gives the lake its dark color and lower Secchi depth. The eutrophic character of the lake is natural. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

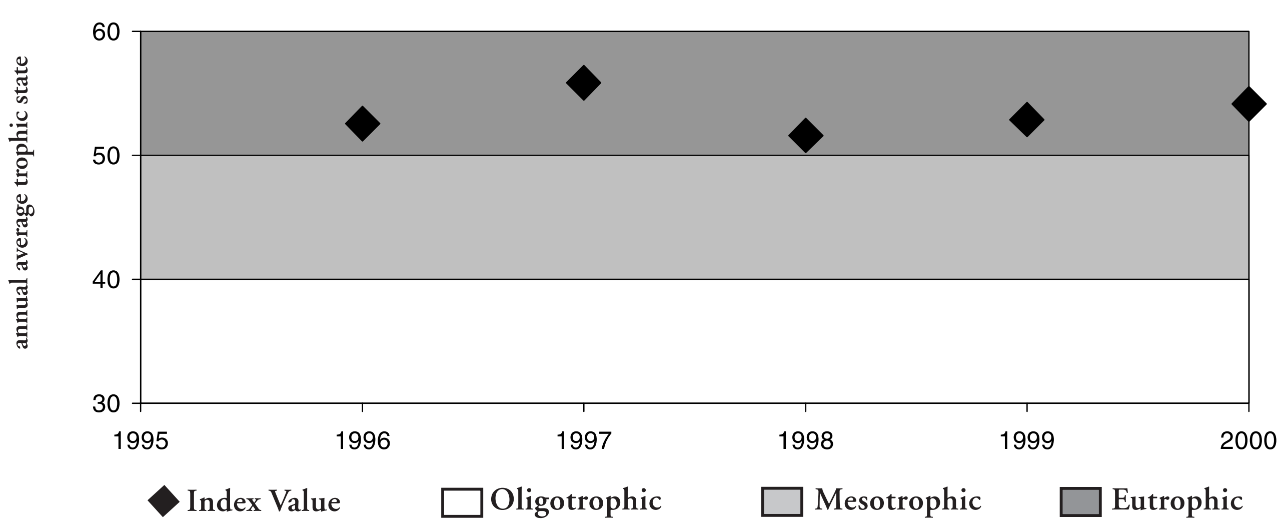
Average Values for Select Trophic Parameters at Paradise Lake

Year	**No. of Samples**	**Secchi (meter)**	**Chl *a** (µg/L)**	**TP* (µg/L)**	**TSI* Secchi**	**TSI* Chl *a***	**TSI* TP**	**TSI* Average**
1996	12	2.5	10.7	39	47	54	57	53
1997	12	2.0	19.8	40	50	60	57	56
1998	13	2.6	13.4	29	46	56	53	52
1999	13	2.5	20.1	28	47	60	52	53
2000	12	2.5	26.3	29	47	63	53	54

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
39
40
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Pine

Since 1985, volunteers have collected monitoring data on Pine Lake located in Sammamish. The data record is largely complete with data only missing for 1990–1992 and 1994. Generally, productivity is moderate (mesotrphic), characterized by moderate water clarity and phosphorus levels and low chlorophyll *a* values (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values. Visual analysis reveals a slight decrease in phosphorus levels and overall trophic state during the available record. Additionally, chlorophyll *a* values have shown little variation from year to year.

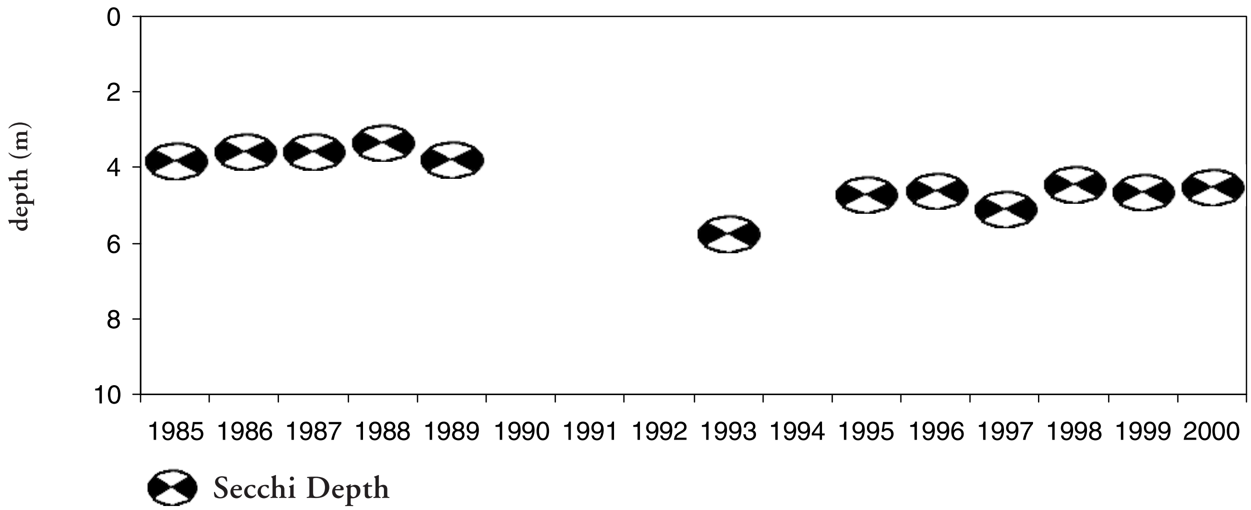
To evaluate whether statistically significant changes in water quality have occurred at Pine Lake, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant downward trend in total phosphorus was found (n=12; p=0.05; slope= -0.33) suggesting nutrient levels have decreased slightly at Pine Lake since 1985. Significant downward trends were also noted for TSI TP (n=12; p=0.05; slope= -0.41) and TSI Average (n=12; p=0.02; slope= -0.20). The significant trends for TSI TP and TSI Average are related given TSI TP is a calculated from total phosphorus data and TSI average includes TSI TP in the calculation.

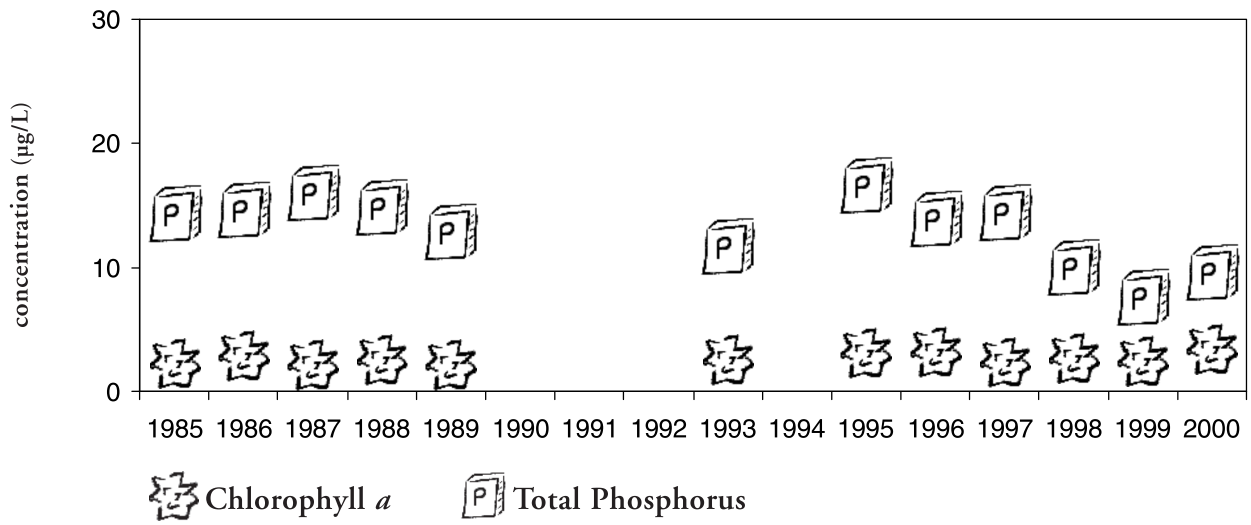
Overall, water quality is good at Pine Lake. The slight decrease in lake phosphorus levels may be related to the permanent diversion of wetland inflow to the lake outlet which was completed by King County in 1990 (Anderson and Welch, 1991). To ensure nutrient levels remain lowered, ongoing erosion and nutrient control measures in the watershed remain important as land is developed in the watershed or local shoreline alteration occurs.

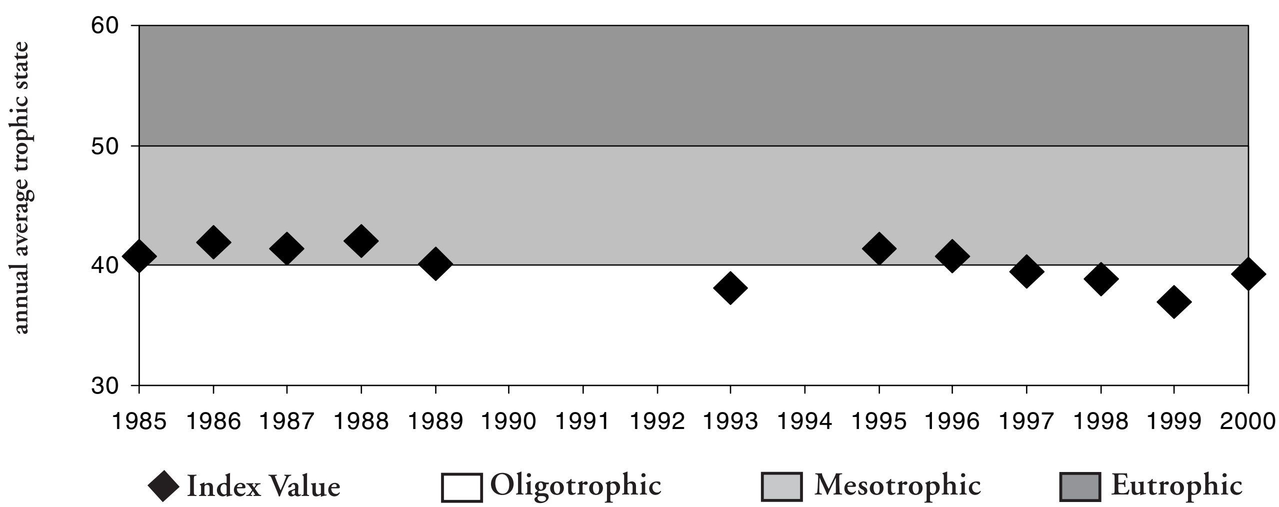
Average Values for Select Trophic Parameters at Pine Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	12	3.8	2.3	14	41	39	43	41
1986	11	3.6	2.9	15	42	41	43	42
1987	12	3.5	2.2	16	42	38	44	41
1988	11	3.3	2.6	15	43	40	43	42
1989	12	3.8	2.2	13	41	38	41	40
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	11	5.7	2.6	12	35	40	40	38
1994	---	---	---	---	---	---	---	---
1995	12	4.7	3.1	17	38	42	45	41
1996	11	4.6	3.2	14	38	42	42	41
1997	13	5.0	2.4	14	37	39	43	39
1998	13	4.4	2.7	10	39	40	38	39
1999	13	4.6	2.5	8	38	39	34	37
2000	11	4.5	3.4	10	38	43	37	39

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Pipe

Since 1985, volunteers have collected monitoring data on Pipe Lake located in Maple Valley and Covington. The data record is largely complete with data only missing between 1989 and 1992. Overall, productivity was low (oligotrophic), characterized by excellent water clarity, low chlorophyll *a* values, and slightly elevated phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values. Visual analysis reveals little variation in chlorophyll *a* values while Secchi depth, phosphorus, and trophic state values have varied somewhat from year to year.

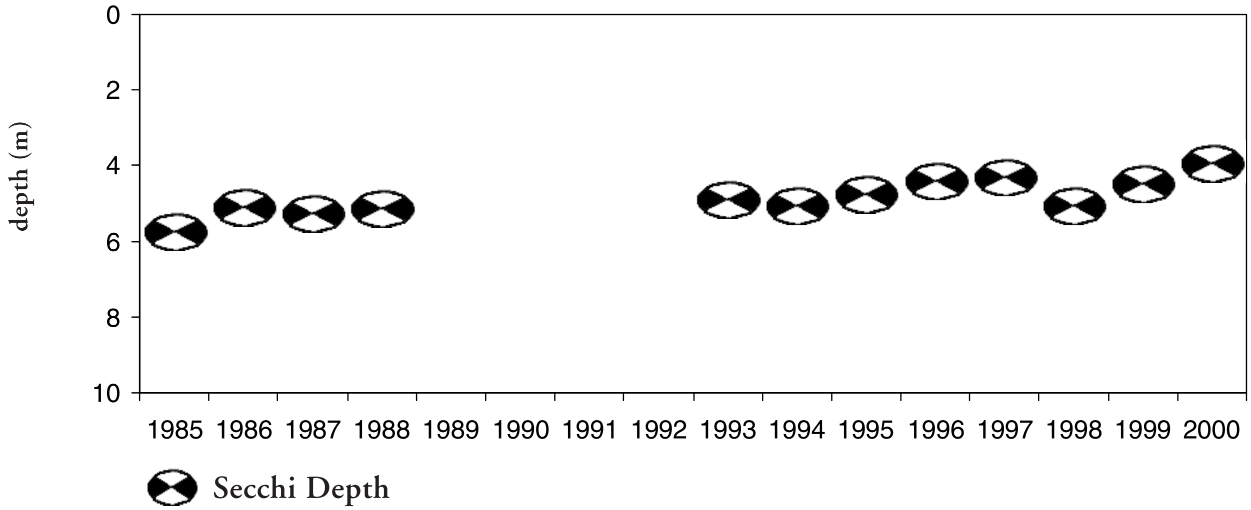
To evaluate whether statistically significant changes in water quality have occurred at Pipe Lake, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant downward trend in Secchi depth was found (n=12; p=0.002; slope= -0.09) suggesting a slight decline in water clarity has occurred at Pipe Lake since 1985. A significant upward trend was also noted for TSI Secchi (n=12; p=0.002; slope= 0.26). This significant trend for TSI Secchi is predictable given TSI Secchi is calculated from Secchi depth data.

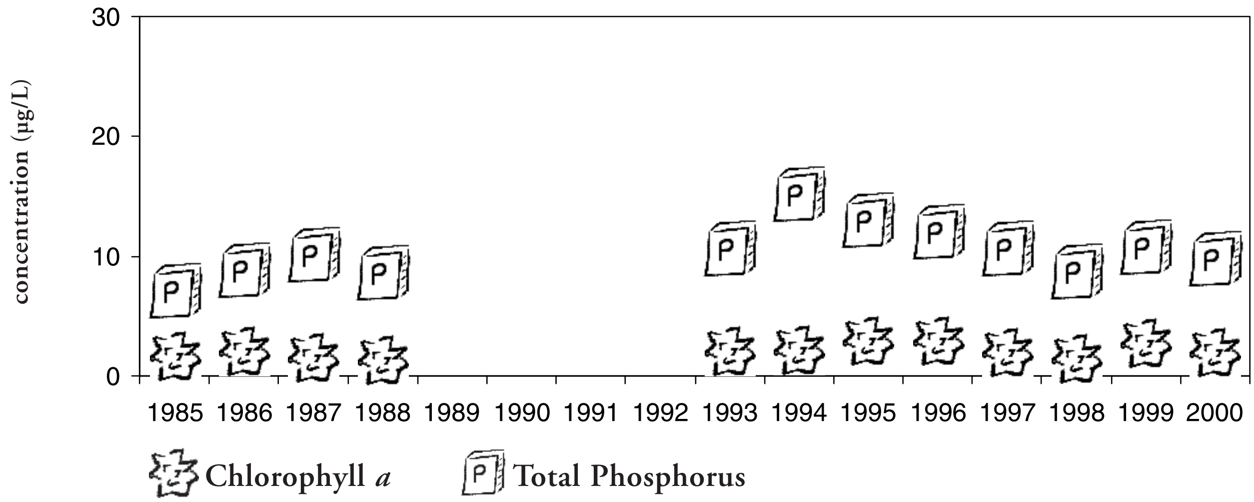
Overall, water quality is very good at Pipe Lake where groundwater is the primary source of water to the lake. Stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as land is developed in the watershed or local shoreline alteration occurs.

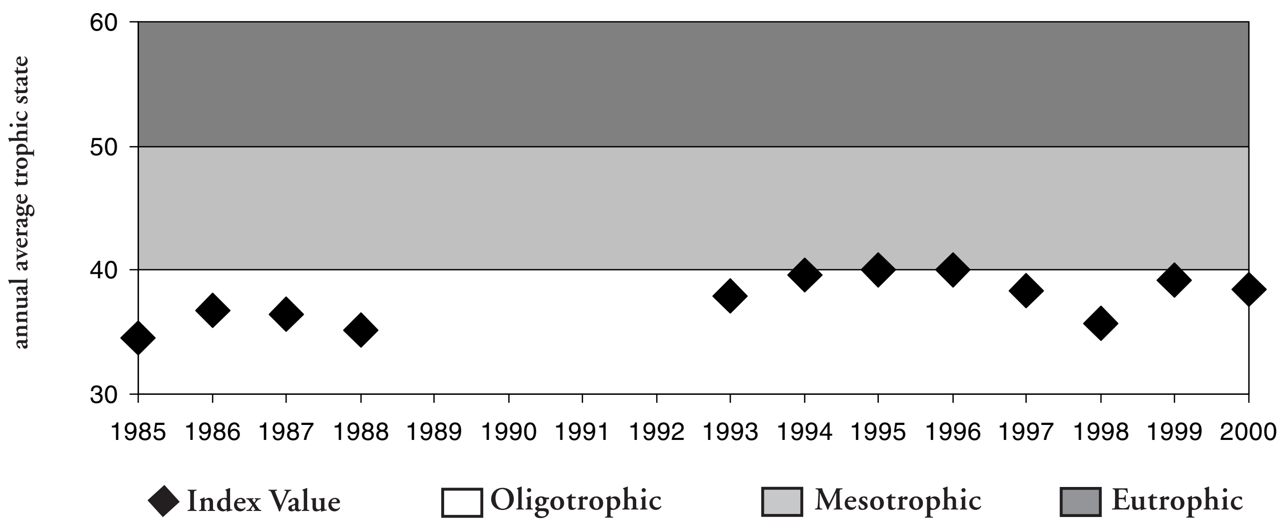
Average Values for Select Trophic Parameters at Pipe Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	12	5.7	1.8	7	35	36	33	35
1986	12	5.1	2.2	9	37	38	36	37
1987	12	5.2	1.7	10	36	36	38	36
1988	12	5.1	1.4	9	37	34	35	35
1989	---	---	---	---	---	---	---	---
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	11	4.9	2.1	11	37	38	38	38
1994	11	5.0	2.3	15	37	39	43	40
1995	10	4.7	3.0	13	38	41	41	40
1996	12	4.4	3.0	12	39	41	40	40
1997	12	4.3	2.0	11	39	38	38	38
1998	11	5.0	1.5	9	37	35	36	36
1999	10	4.5	2.8	11	38	41	39	39
2000	11	3.9	2.1	10	40	38	37	38

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Ravensdale

In 1996, volunteers began collecting monitoring data at Ravensdale Lake located in south King County. Because the data record is relatively short, no statistical trend analyses were completed for the lake. Generally, productivity was low (oligotrophic), characterized by excellent water clarity, low chlorophyll *a* values, and slightly elevated phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

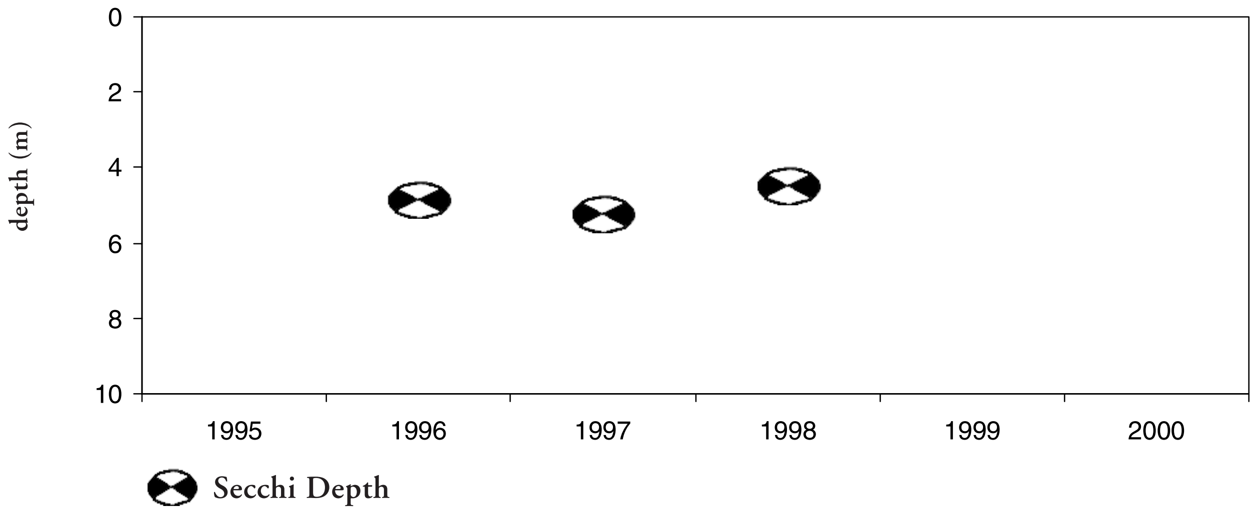
Visual analysis reveals reasonably consistent values from year to year for Secchi depth and chlorophyll *a* values.

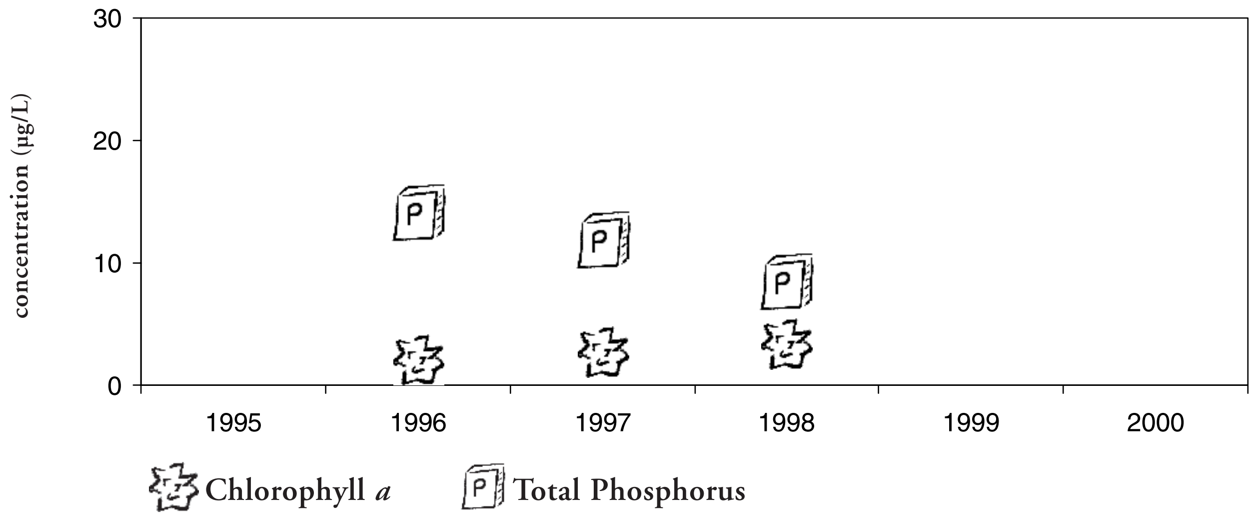
Overall, water quality is very good at Ravensdale Lake which is largely influenced by high quality groundwater flows to the lake. Erosion and nutrient control measures in this relatively undeveloped watershed remain important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

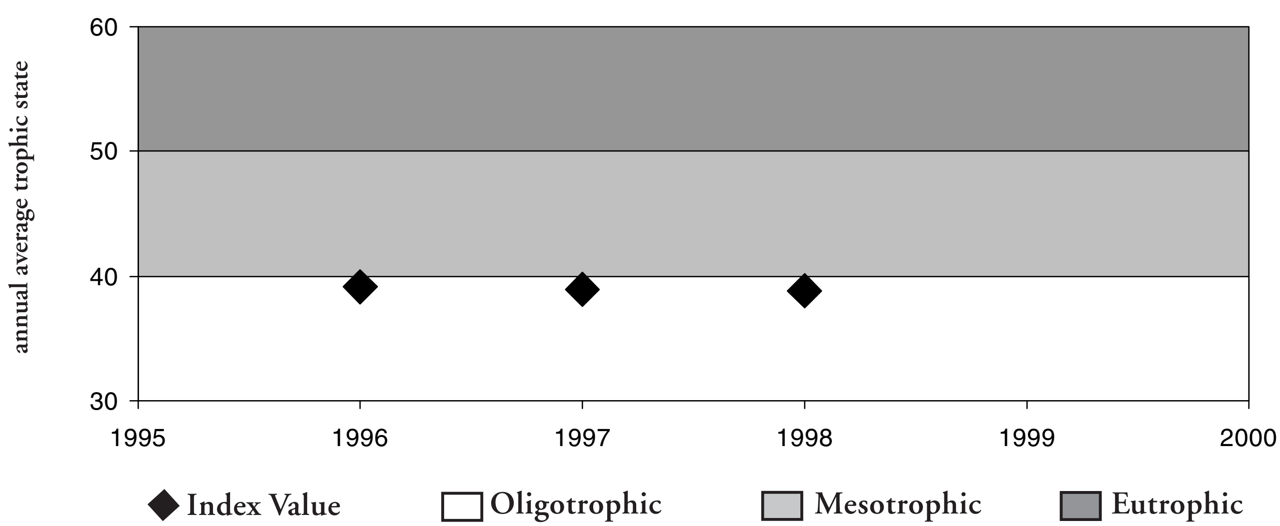
Average Values for Select Trophic Parameters at Lake Ravensdale

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	9	4.8	2.1	14	37	38	42	39
1997	10	5.2	2.8	12	36	41	40	39
1998	12	4.4	3.4	9	39	43	35	39
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Retreat

In 1996, volunteers began collecting monitoring data at Lake Retreat located in south King County. Because the data record is relatively short, no statistical trend analyses were completed for the lake. Generally, productivity was low (oligotrophic), characterized by excellent water clarity, low chlorophyll *a* values, and slightly elevated phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

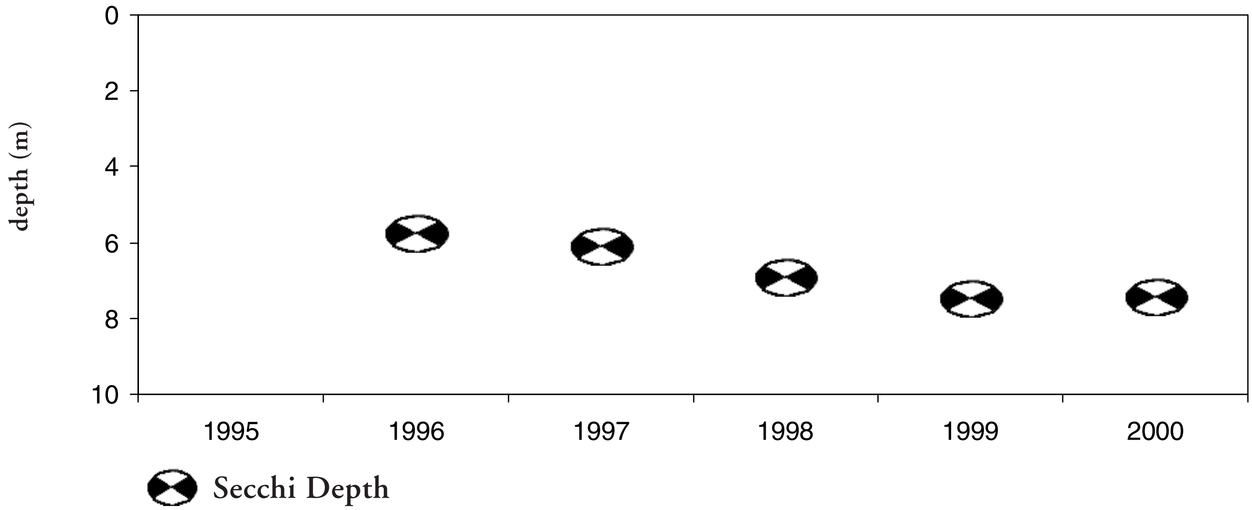
Visual analysis reveals reasonably consistent values from year to year for Secchi depth and chlorophyll *a* values.

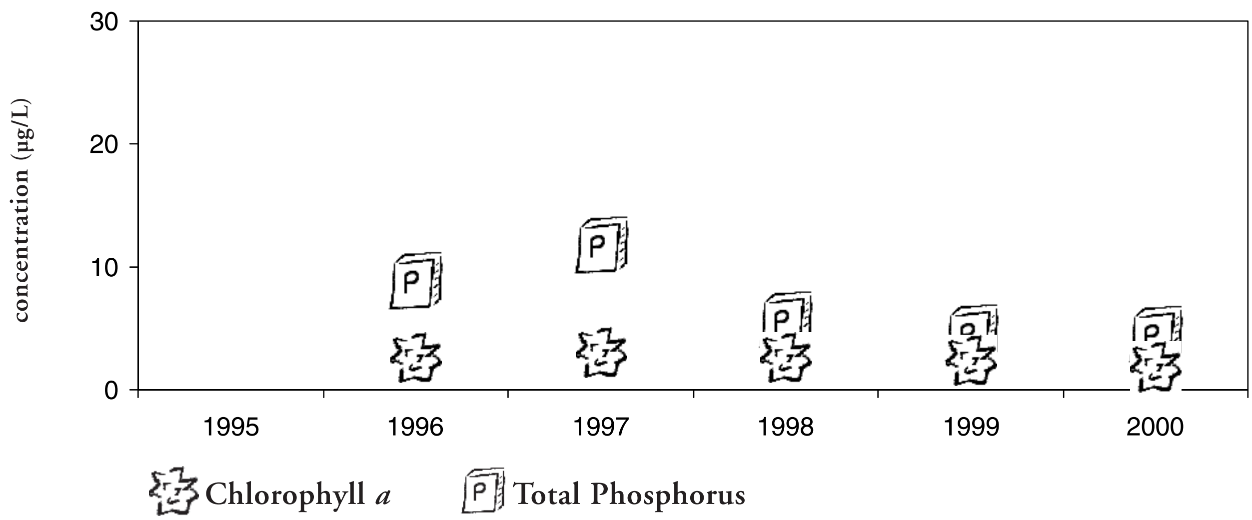
Overall, water quality is very good at Lake Retreat which is largely influenced by high quality groundwater flows to the lake. Erosion and nutrient control measures in this relatively undeveloped watershed remain important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

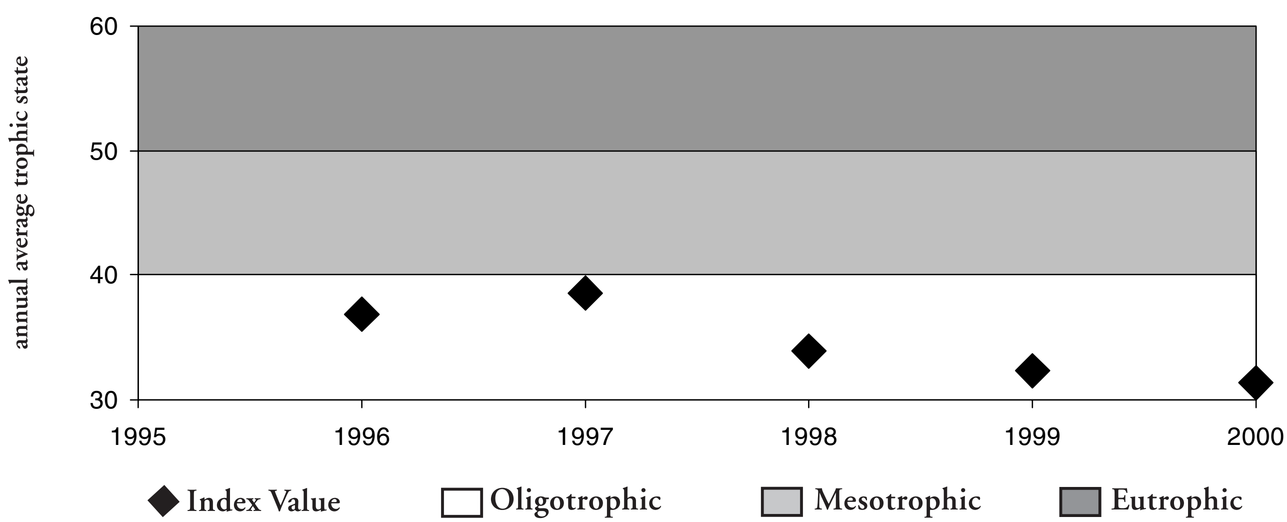
Average Values for Select Trophic Parameters at Lake Retreat

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	12	5.7	2.6	9	35	40	36	37
1997	12	6.0	3.1	12	34	42	40	39
1998	12	6.9	2.7	6	32	40	29	34
1999	11	7.4	2.4	5	31	39	26	32
2000	13	7.4	1.9	5	31	37	26	31

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Sawyer

Since 1985, volunteers have collected monitoring data on Lake Sawyer located in Black Diamond. The data record is complete for the 16-year record. Generally, productivity is low to moderate (oligotrophic to mesotrophic), characterized by high water clarity, low chlorophyll *a* values, and moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals some variability in all trophic parameters during the 16-year record.

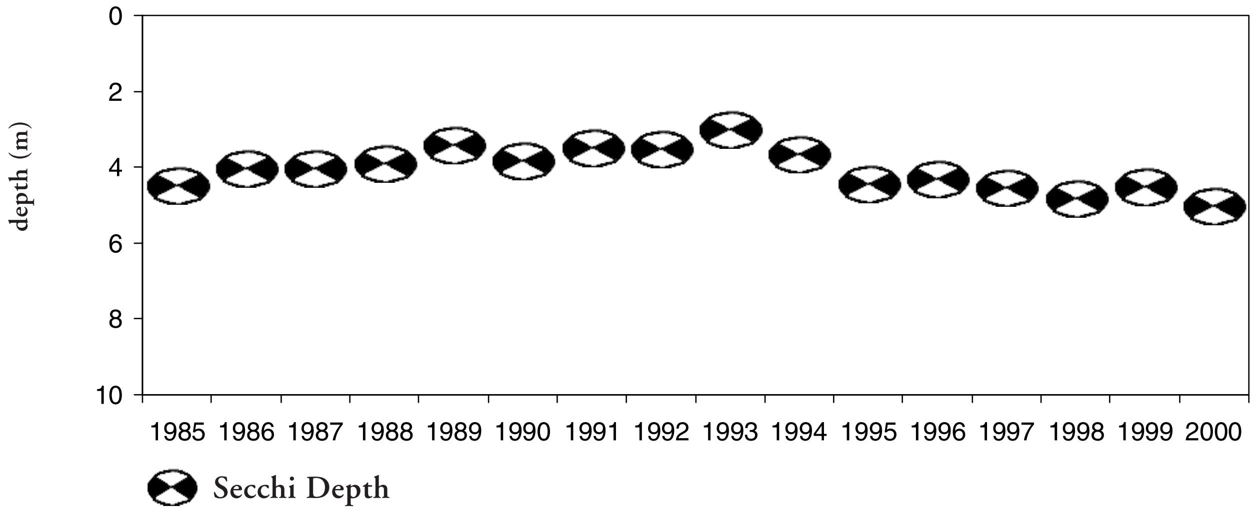
To evaluate whether statistically significant changes in water quality have occurred at Lake Sawyer, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant upward trend was noted for chlorophyll *a* (n=16; p=0.034; slope=0.13) suggesting a slight increase in algal levels has occurred at Lake Sawyer since 1985. A significant upward trends was also noted for TSI Chl *a* (n=16; p=0.034; slope=0.41). The significant trend for TSI Chl *a* is predictable given TSI Chl *a* is a calculated from chlorophyll *a* data.

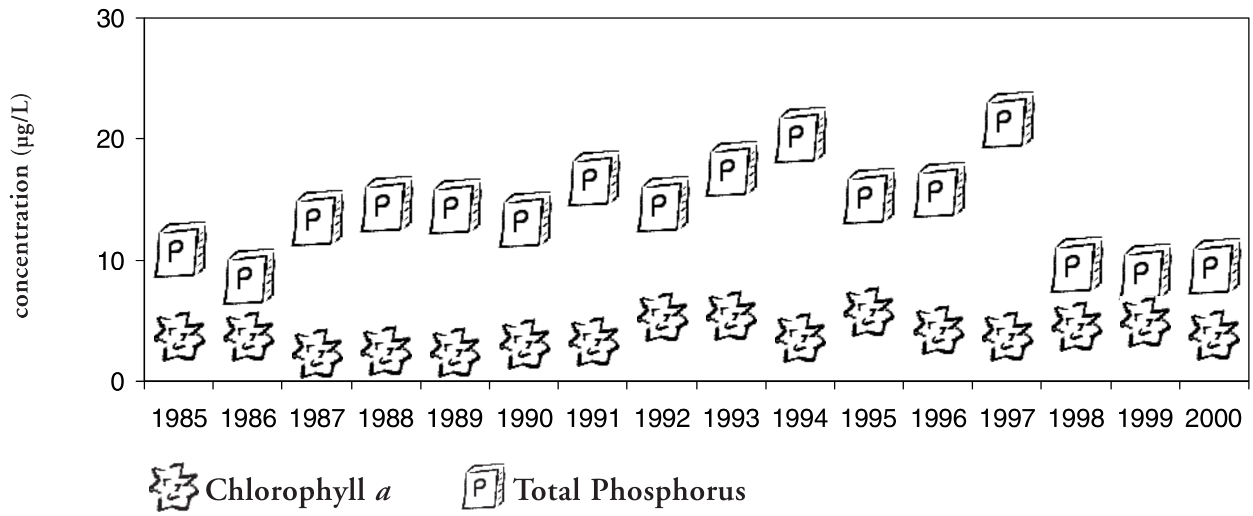
Overall, water quality is good to very good at Lake Sawyer. The lake receives inflow from a watershed that is moderately developed. In the near future, more residential development is anticipated for major portions of the watershed (King County, 2000b). Stewardship by lake residents, city, and county government remains important to ensure ongoing erosion and nutrient control measures take place as land is developed or local shoreline alteration occurs.

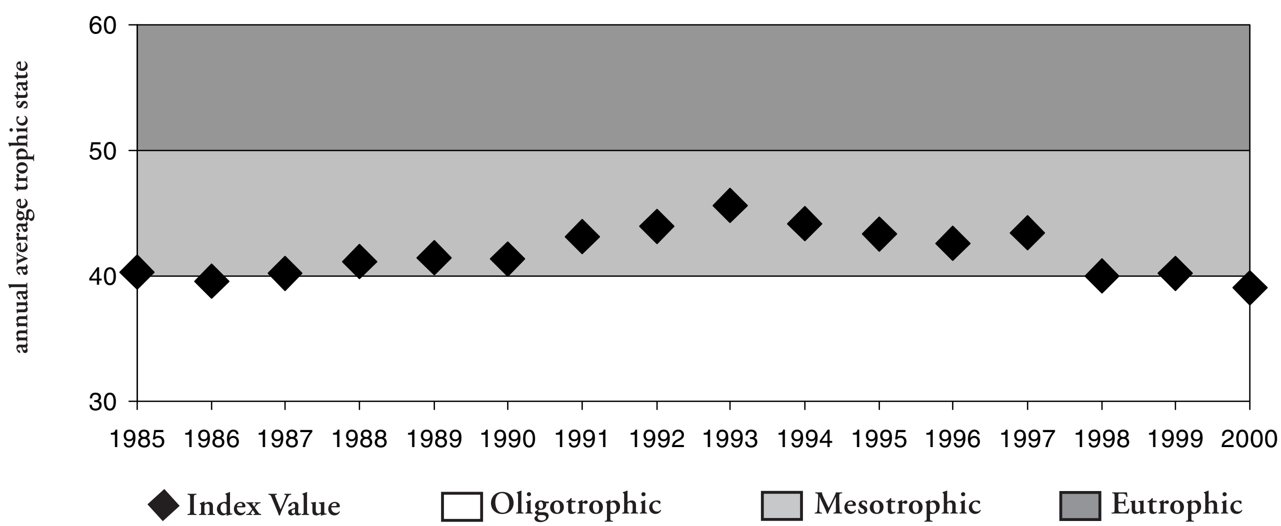
Average Values for Select Trophic Parameters at Lake Sawyer

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	4.4	3.8	11	39	44	39	40
1986	11	4.0	3.8	9	40	44	35	40
1987	11	4.0	2.4	13	40	39	42	40
1988	11	3.9	2.6	15	41	40	43	41
1989	12	3.4	2.4	14	42	39	43	41
1990	9	3.8	3.1	13	41	42	42	41
1991	8	3.4	3.3	17	42	42	45	43
1992	6	3.5	5.4	15	42	47	43	44
1993	11	3.0	5.5	18	44	47	45	46
1994	7	3.6	3.7	20	41	43	48	44
1995	9	4.4	5.8	15	39	48	43	43
1996	12	4.3	4.2	16	39	45	44	43
1997	12	4.5	3.7	22	38	44	49	43
1998	13	4.8	4.6	10	37	46	37	40
1999	13	4.5	5.0	9	38	46	36	40
2000	13	5.0	3.9	10	37	44	37	39

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Shadow

Since 1985, volunteers have collected monitoring data on Shadow Lake located in south King County. The data record is largely complete with data only missing for 1987, 1988, 1996, and 1999. Generally, productivity was moderately low (mesotrophic), characterized by moderate water clarity, chlorophyll *a,* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals some variability in all trophic parameters during the 16-year record.

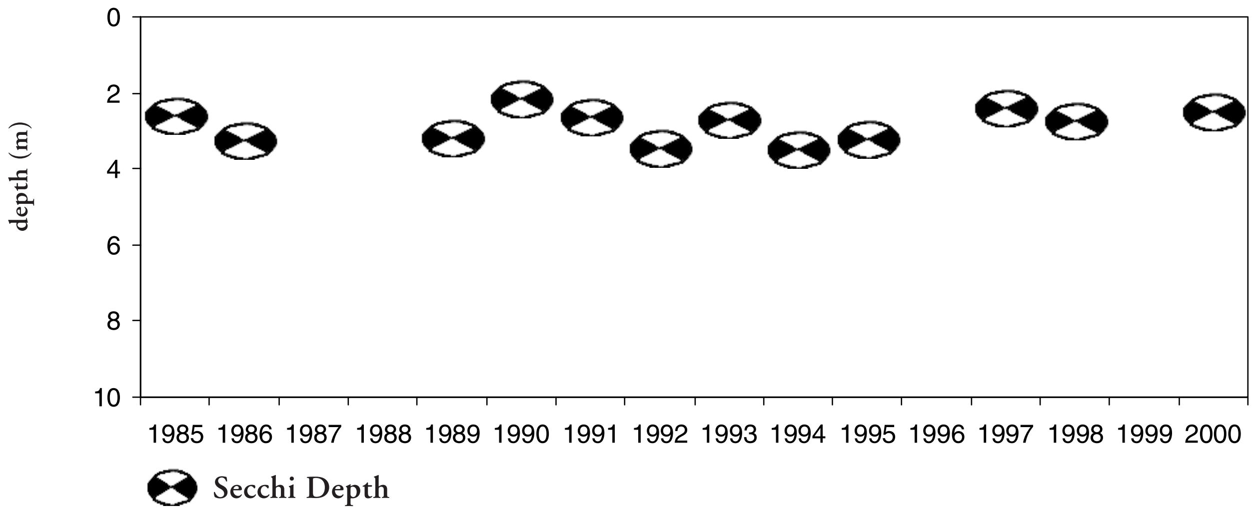
To evaluate whether statistically significant changes in water quality have occurred at Shadow Lake, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). A significant upward trend in total phosphorus was found (n=12; p=0.034; slope=0.47) suggesting nutrient levels have increased slightly at Shadow Lake since 1985. A significant upward trend was also noted for TSI TP (n=12; p=0.033; slope=0.44). The significant trend for TSI TP is predictable given TSI TP is a calculated from total phosphorus data.

Overall, water quality is moderately good at Shadow Lake. Although phosphorus levels have increased slightly, groundwater flows to the lake may have a moderating effect, resulting in good lake water quality overall. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

Average Values for Select Trophic Parameters at Shadow Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	12	2.6	2.5	13	46	39	41	42
1986	12	3.2	3.2	11	43	42	39	41
1987	---	---	---	---	---	---	---	---
1988	---	---	---	---	---	---	---	---
1989	12	3.1	2.3	13	44	39	41	41
1990	12	2.1	3.2	14	49	42	42	44
1991	11	2.6	2.5	14	46	39	42	43
1992	9	3.4	1.7	18	42	36	46	41
1993	10	2.7	3.1	19	46	42	46	45
1994	11	3.4	4.1	28	42	44	52	46
1995	7	3.2	3.7	17	43	43	45	44
1996	---	---	---	---	---	---	---	---
1997	6	2.4	3.5	14	48	43	42	44
1998	12	2.7	2.9	18	46	41	46	44
1999	---	---	---	---	---	---	---	---
2000	9	2.4	3.3	15	47	42	43	44

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index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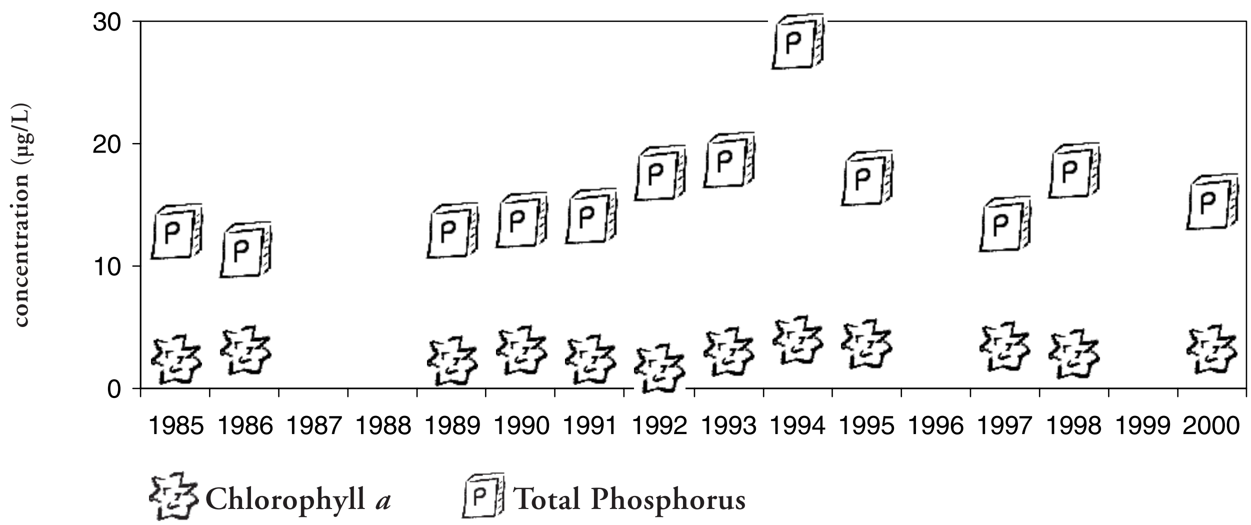
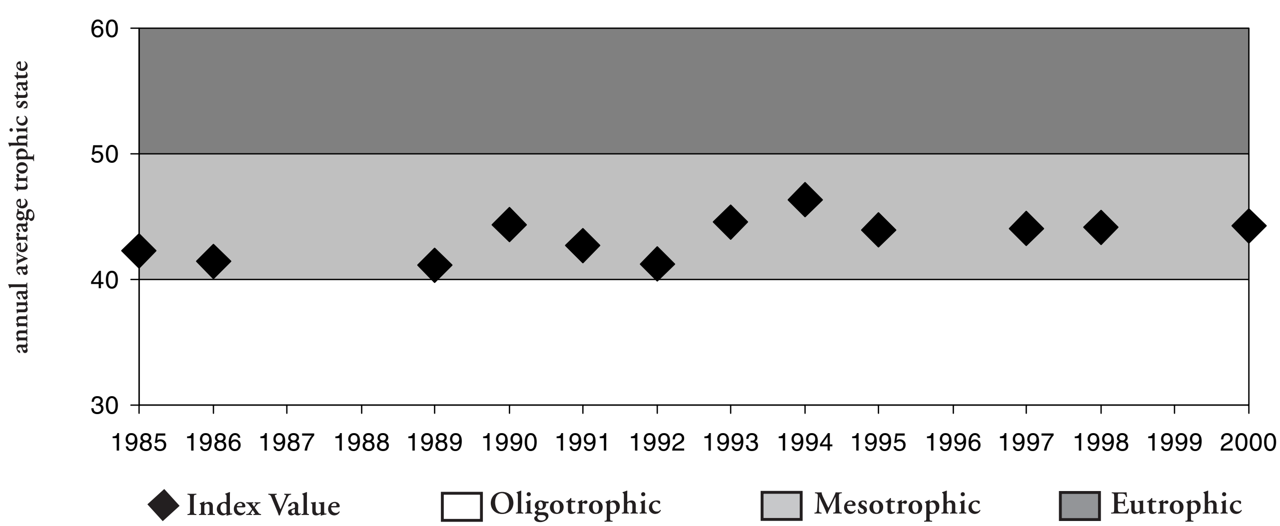
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Shady

Since 1985, volunteers have collected monitoring data on Shady Lake located in south King County. The data record is complete for the 16-year record. Generally, productivity was low to moderate (oligotrophic, bordering on mesotrophic), characterized by excellent water clarity, low chlorophyll *a* values, and low to moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals some variability in Secchi depth, algal levels and phosphorus levels especially between 1993-1997.

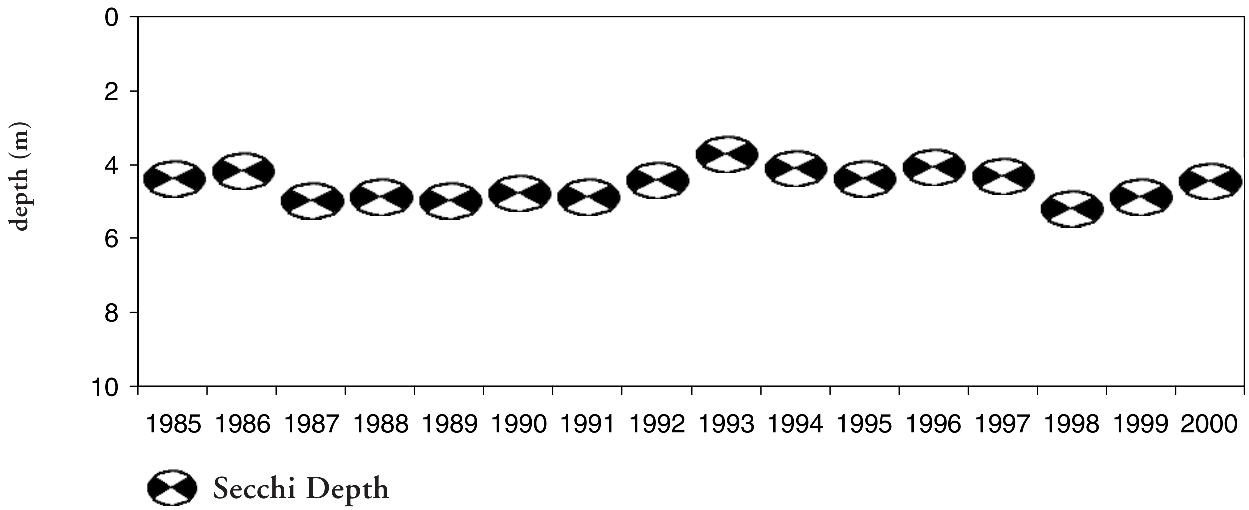
To evaluate whether statistically significant changes in water quality have occurred at Shady Lake, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the data record.

Overall, water quality is very good at Shady Lake where groundwater is an important source of water to the lake. Stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as land in the watershed is developed or where local shoreline alteration occurs.

Average Values for Select Trophic Parameters at Shady Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	12	4.3	2.6	11	39	40	39	39
1986	12	4.1	3.8	7	40	44	32	39
1987	12	4.9	2.9	10	37	41	38	39
1988	12	4.8	3.0	9	37	41	36	38
1989	11	4.9	2.6	12	37	40	40	39
1990	12	4.7	2.6	10	38	40	37	38
1991	10	4.8	2.5	10	37	40	37	38
1992	12	4.4	3.3	9	39	42	36	39
1993	12	3.7	3.7	12	41	43	40	42
1994	12	4.0	5.7	17	40	48	45	44
1995	12	4.3	4.0	11	39	44	39	41
1996	12	4.0	3.3	12	40	42	40	41
1997	12	4.3	2.4	14	39	39	42	40
1998	13	5.1	2.2	8	36	38	34	36
1999	13	4.8	2.5	6	37	40	31	36
2000	13	4.4	2.9	6	39	41	31	37

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index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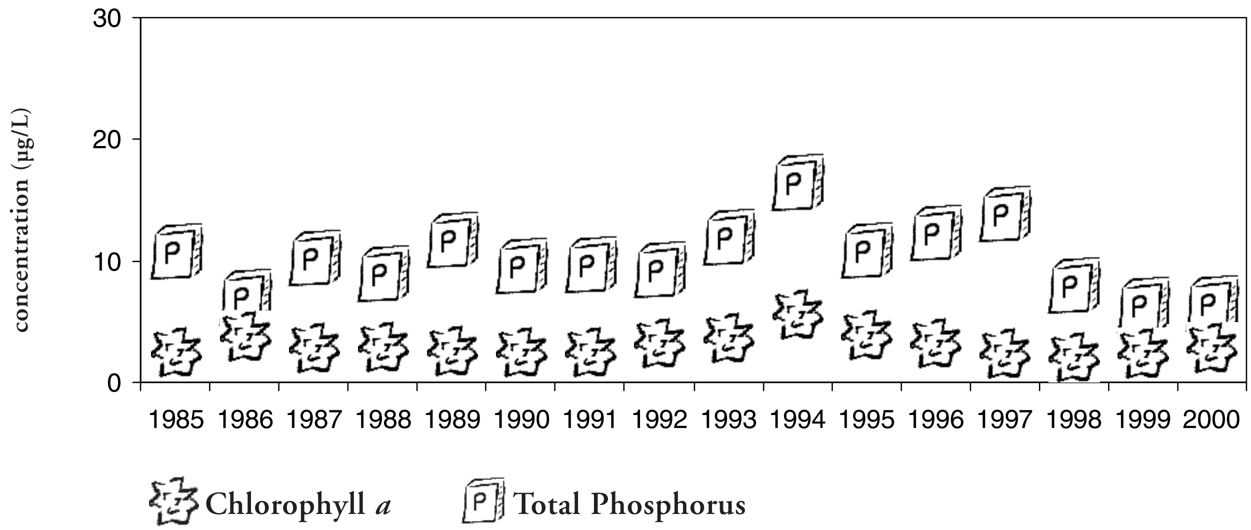
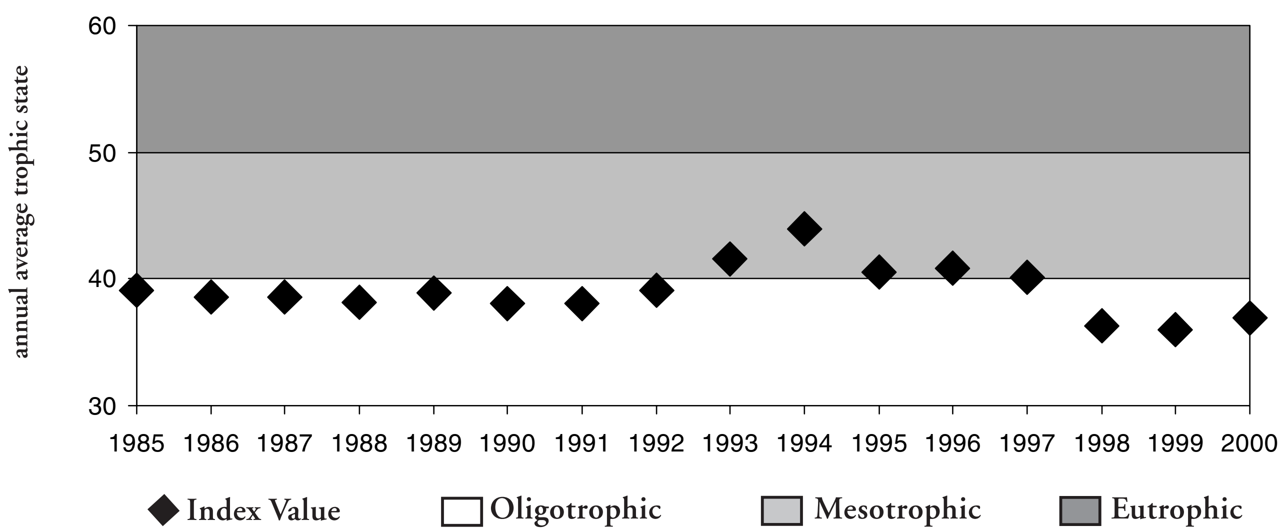
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Spring

Since 1985, volunteers have collected monitoring data on Spring Lake located in south King County. The data record is largely complete with data only missing for 1995. Generally, productivity is moderate (mesotrophic), characterized by moderate water clarity and chlorophyll *a* values, and low to moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals a little variation in Secchi depth during the 16-year record. Additionally, phosphorus levels have varied somewhat from year to year with a peak value occurring in 1994.

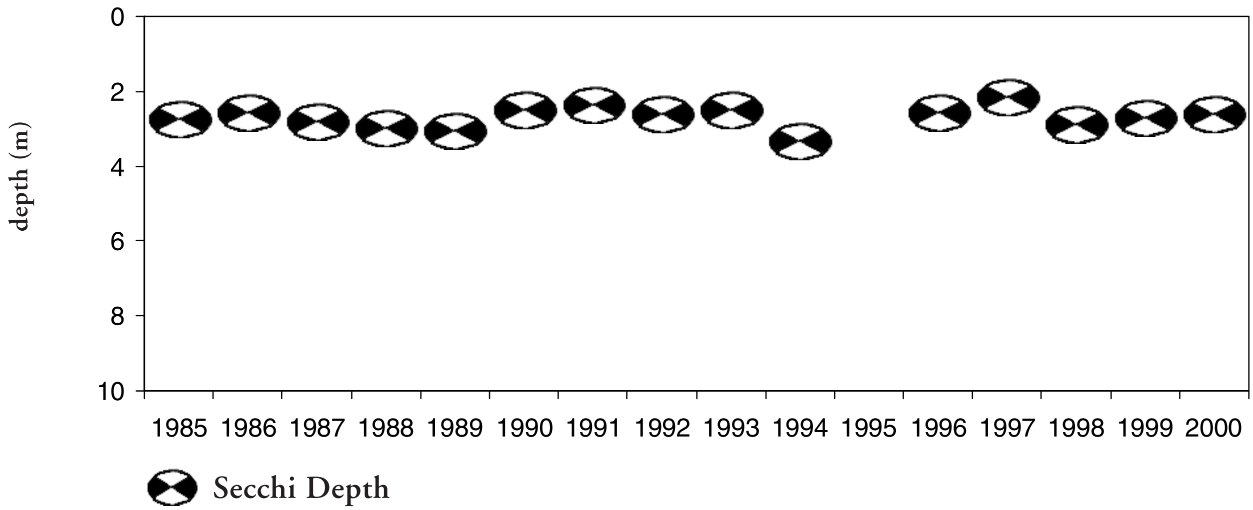
To evaluate whether statistically significant changes in water quality have occurred at Spring Lake, trend analysis was performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval ($\alpha\sigma$=0.05 significance level). A significant upward trend was noted for chlorophyll *a* (n=15; p=0.05; slope=0.098) suggesting a slight increase in algal levels has occurred at Spring Lake since 1985. A significant upward trends was also noted for TSI Chl *a* (n=15; p=0.05; slope=0.25). The significant trend for TSI Chl *a* is predictable given TSI Chl *a* is a calculated from chlorophyll *a* data.

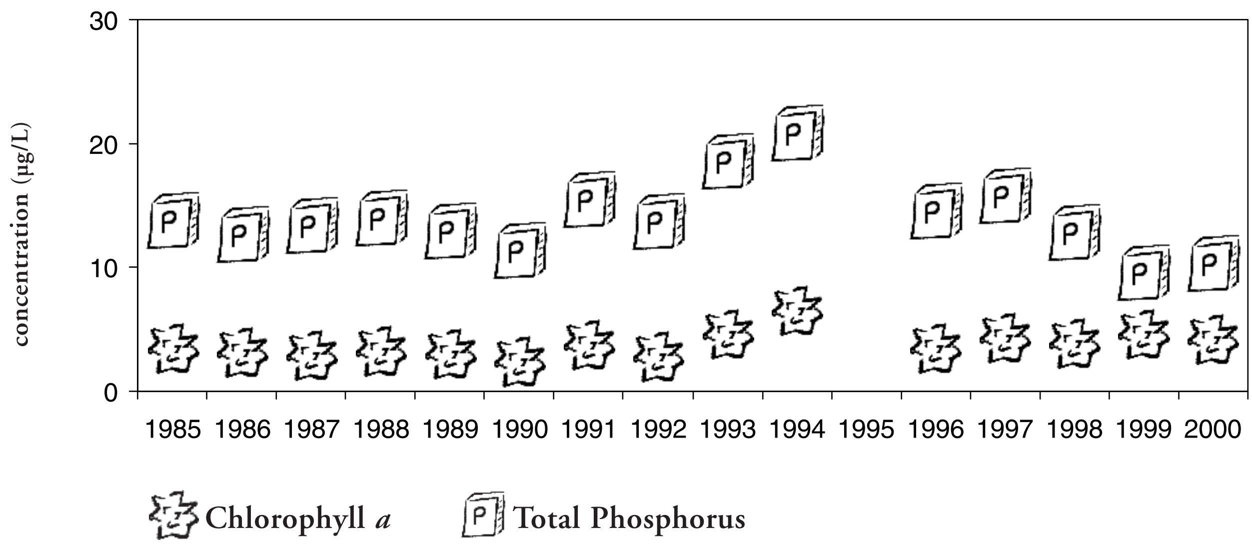
Overall, water quality is good at Spring Lake, influenced by a large wetland area to the south of the lake. Groundwater also plays an important role in maintaining good lake water quality. Long-term, local stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as land is developed in the watershed or local shoreline alteration occurs.

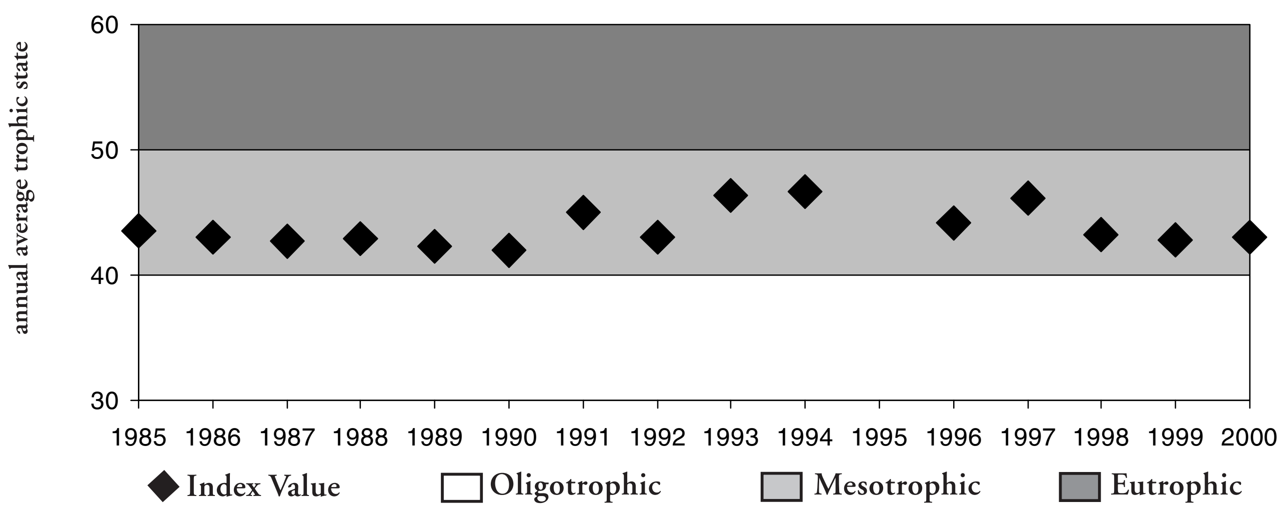
Average Values for Select Trophic Parameters at Spring Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	2.7	3.5	14	46	43	42	44
1986	8	2.5	3.1	13	47	42	41	43
1987	11	2.8	3.0	13	45	41	42	43
1988	10	2.9	3.2	14	44	42	42	43
1989	10	3.0	3.0	13	44	41	41	42
1990	11	2.5	2.5	11	47	39	39	42
1991	11	2.3	3.8	16	48	44	44	45
1992	10	2.6	2.9	14	46	41	42	43
1993	10	2.5	4.7	19	47	46	46	46
1994	11	3.3	6.6	21	43	49	48	47
1995	---	---	---	---	---	---	---	---
1996	12	2.5	3.5	15	47	43	43	44
1997	12	2.1	4.4	16	49	45	44	46
1998	13	2.9	3.9	13	45	44	41	43
1999	13	2.7	4.6	10	46	46	37	43
2000	13	2.6	4.2	10	46	45	38	43

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Star

Since 1985, volunteers have collected monitoring data on Star Lake located in southwest King County. The data record is nearly complete with data missing only during 1992 and 1994. Generally, productivity was low (oligotrophic), characterized by excellent water clarity, low chlorophyll *a* values, and moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variability in algal levels while Secchi depth and phosphorus levels have varied somewhat from year to year during the 16-year record.

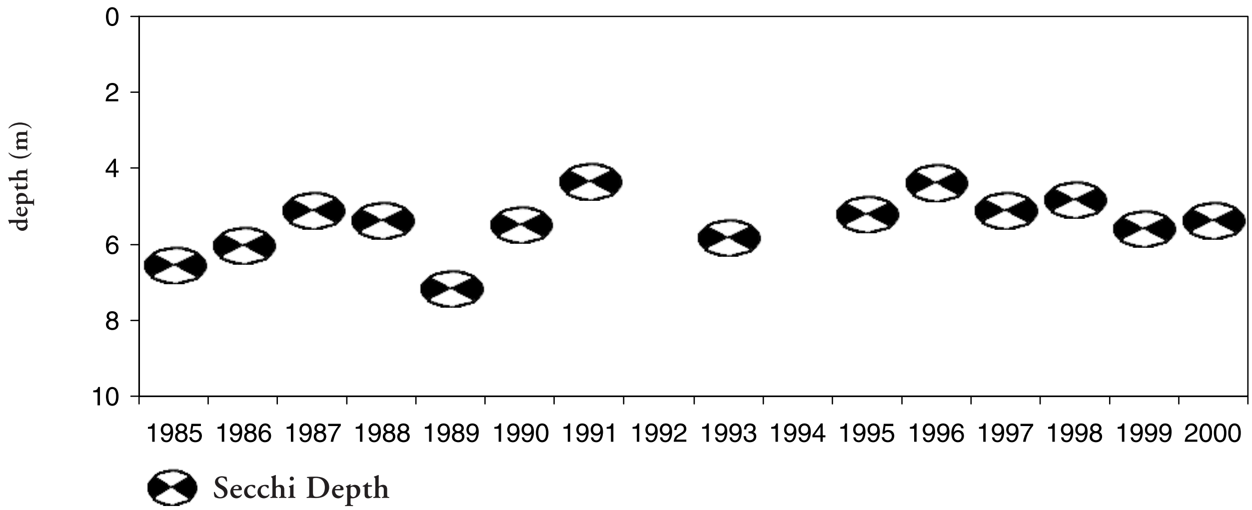
To evaluate whether statistically significant changes in water quality have occurred at Star Lake, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (v=0.05 significance level). No significant trends in water quality were found based on the data record.

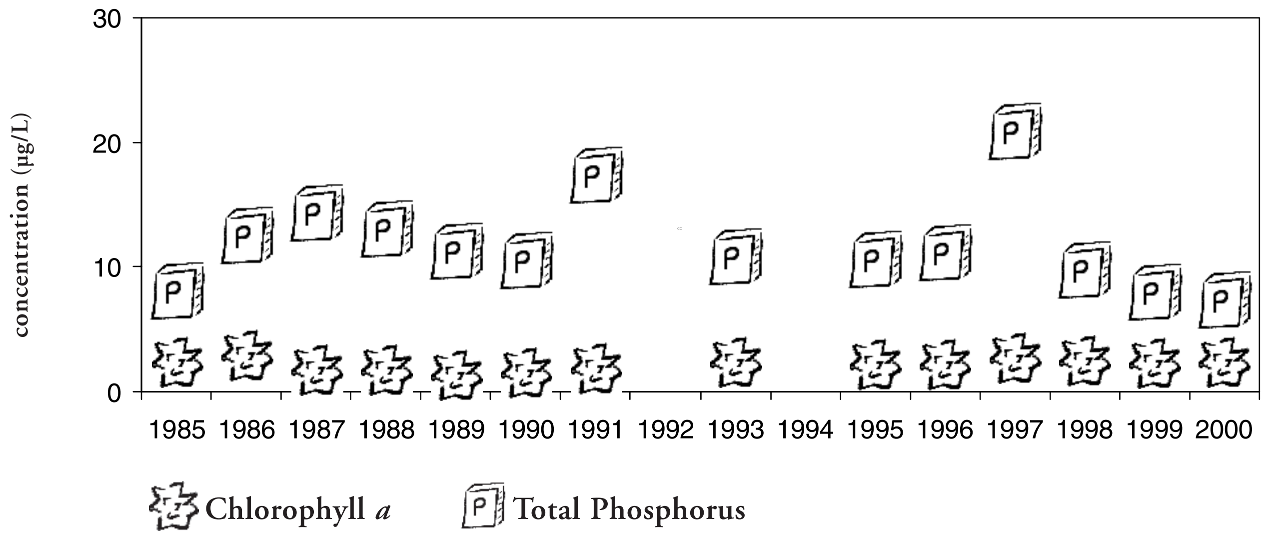
Overall, water quality is very good at Star Lake where groundwater is an important source of water to the lake. Local stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as remaining land in the watershed is developed or where local shoreline alteration occurs.

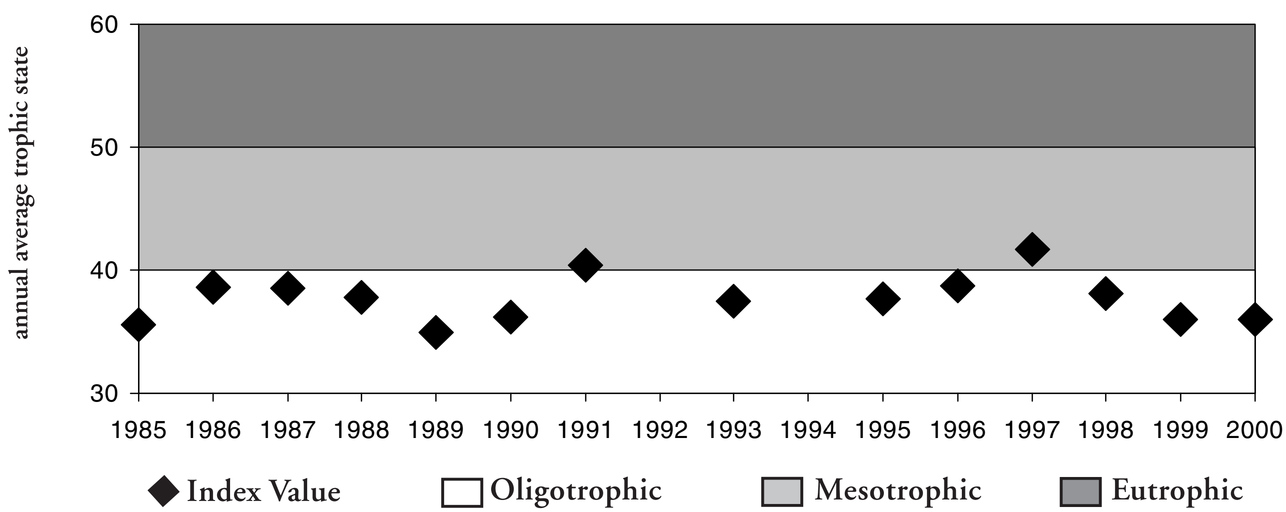
Average Values for Select Trophic Parameters at Star Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	6.5	2.5	8	33	39	34	36
1986	12	6.0	2.9	13	34	41	41	39
1987	11	5.0	1.8	14	37	36	43	39
1988	10	5.3	1.8	13	36	36	41	38
1989	10	7.1	1.4	11	32	34	39	35
1990	10	5.4	1.6	11	36	35	38	36
1991	10	4.3	1.9	17	39	37	45	40
1992	---	---	---	---	---	---	---	---
1993	10	5.8	2.4	11	35	39	39	37
1994	---	---	---	---	---	---	---	---
1995	11	5.2	2.2	11	36	38	38	38
1996	12	4.3	2.2	11	39	38	39	39
1997	10	5.0	2.7	21	37	40	48	42
1998	9	4.8	2.6	10	37	40	37	38
1999	11	5.5	2.3	8	35	39	34	36
2000	13	5.3	2.4	7	36	39	33	36

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Steel

Since 1985, volunteers have collected monitoring data on Steel Lake located in Federal Way. The data record is nearly complete with data missing only between 1991 and 1993. Generally, productivity was moderate (mesotrophic), characterized by moderate water clarity, chlorophyll *a*, and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals little variability in algal levels while Secchi depth and phosphorus levels have varied somewhat from year to year during the 16-year record.

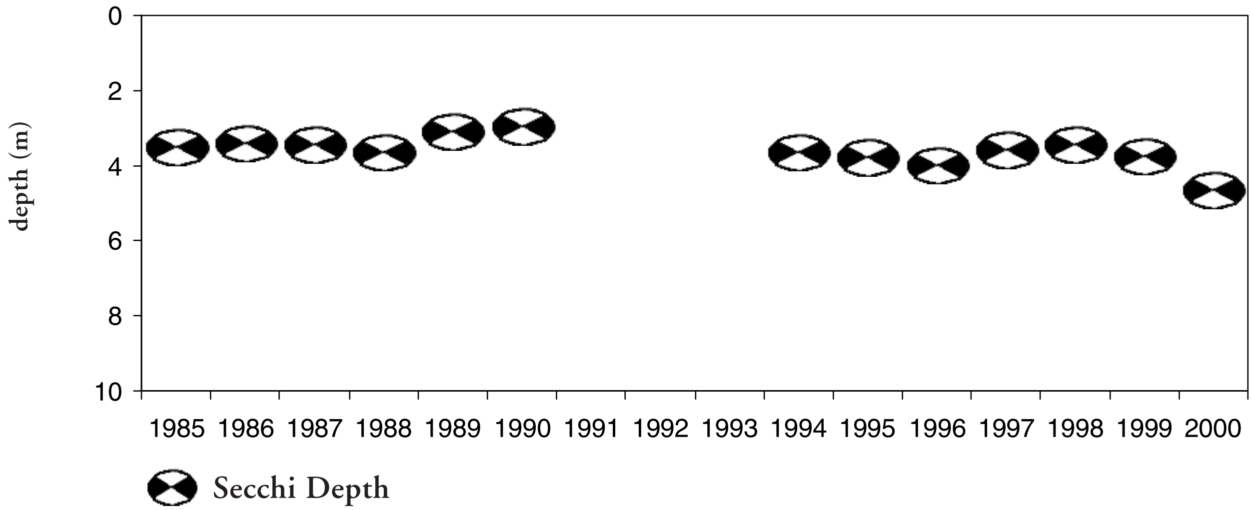
To evaluate whether statistically significant changes in water quality have occurred at Steel Lake, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the data record.

Overall, water quality is moderately good at Steel Lake which receives surface flows from a residentially developed watershed. Stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as additional land in the watershed is developed or where local shoreline alteration occurs.

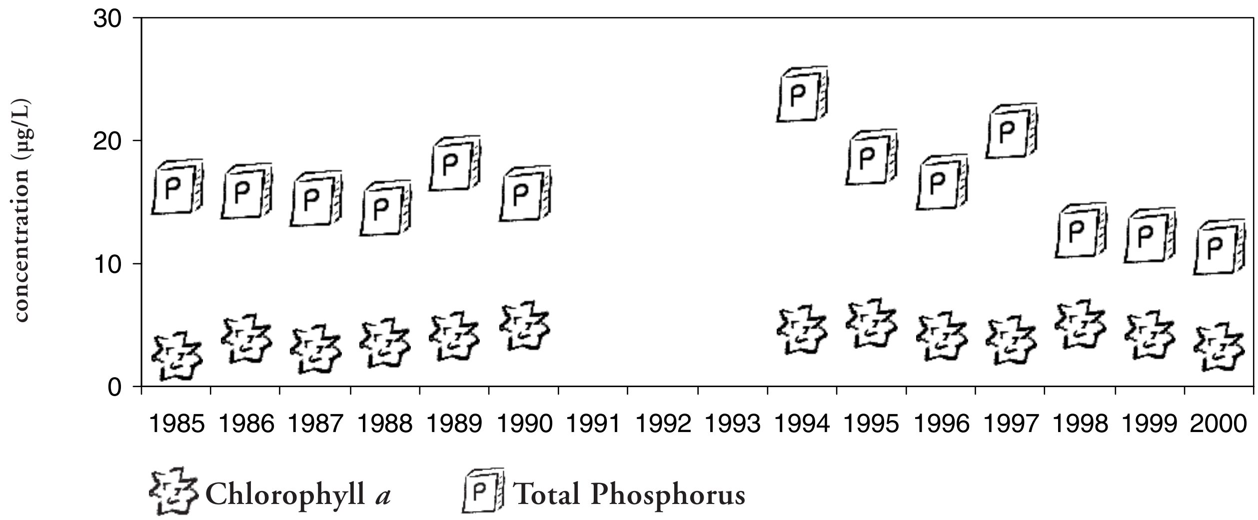
Average Values for Select Trophic Parameters at Steel Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	12	3.5	2.6	16	42	40	44	42
1986	11	3.4	3.9	16	43	44	44	44
1987	11	3.4	3.1	15	42	42	43	43
1988	11	3.6	3.6	15	42	43	43	42
1989	12	3.0	4.1	18	44	44	46	45
1990	9	2.9	5.0	16	45	46	44	45
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	12	3.6	4.6	24	42	46	50	46
1995	12	3.7	5.3	19	41	47	46	45
1996	10	3.9	4.2	17	40	45	45	43
1997	12	3.5	3.8	21	42	44	48	44
1998	13	3.4	5.1	13	42	47	41	43
1999	12	3.7	4.3	12	41	45	40	42
2000	8	4.6	3.3	11	38	42	39	40

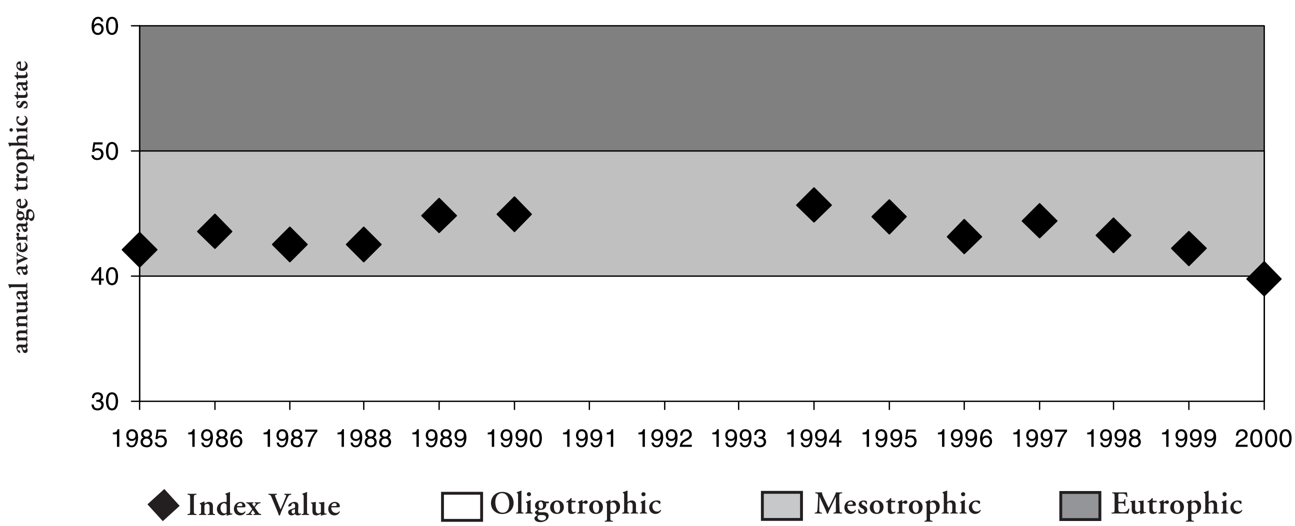
*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index



depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth



concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus



annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Trout

In 1996, volunteers began collecting monitoring data on Trout Lake located in southwest King County. Because the data record is relatively short, no statistical trend analyses were completed for Trout Lake. Generally, productivty was high (eutrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

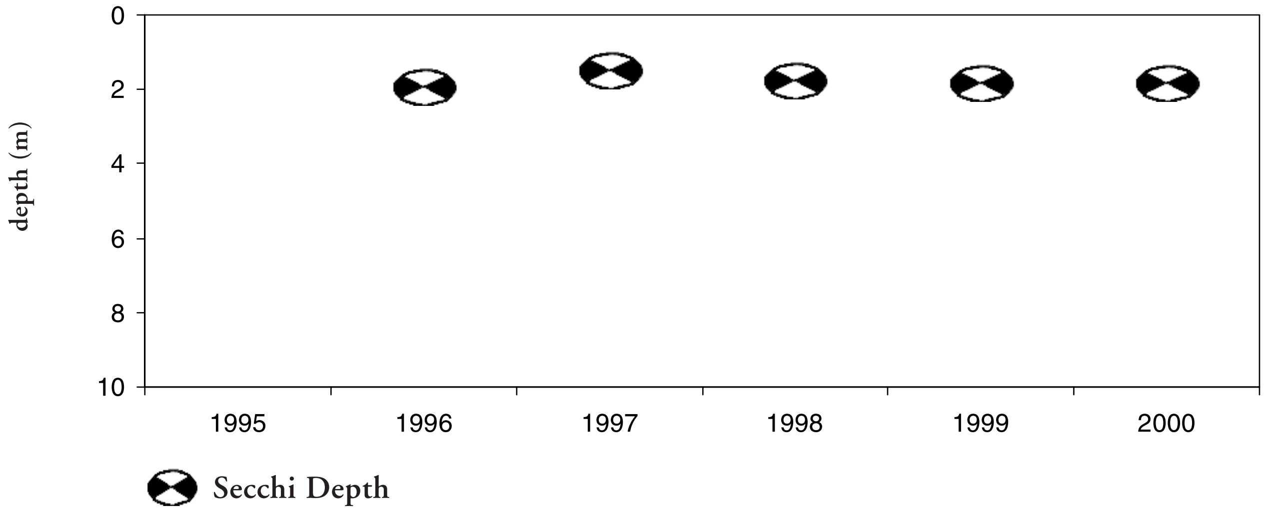
Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels show more variation from year to year.

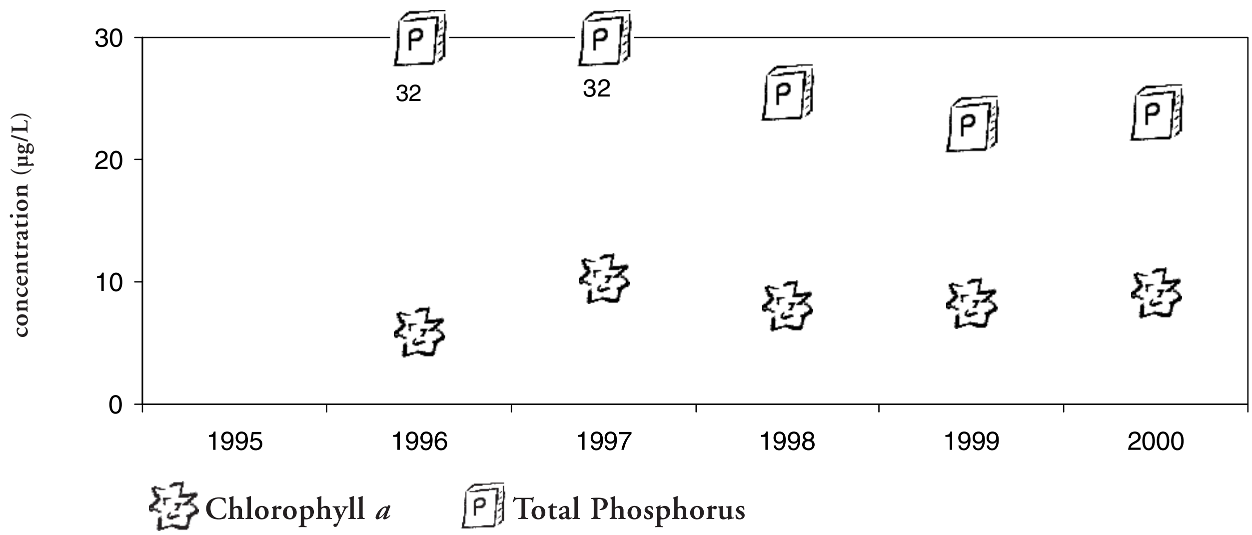
Overall, water quality is fair at Trout Lake, influenced by wetland chemistry which gives the lake its dark color and low Secchi depth. The eutrophic character of the lake is natural. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as additional land is developed in the watershed or local shoreline alteration occurs.

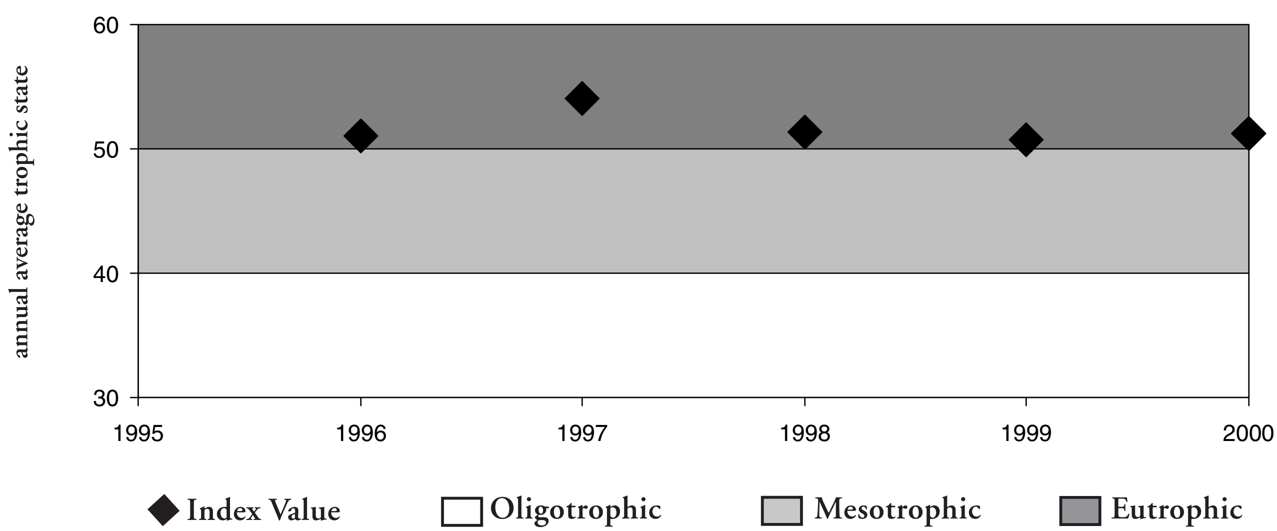
Average Values for Select Trophic Parameters at Trout Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	11	1.9	6.0	32	51	48	54	51
1997	12	1.5	10.3	32	55	53	54	54
1998	13	1.7	8.1	26	52	51	51	51
1999	13	1.8	8.3	23	52	51	49	51
2000	13	1.8	9.1	24	52	52	50	51

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


0
2
4
6
8
10
depth (m)
1995
1996
1997
1998
1999
2000
Secchi Depth


30
20
10
0
concentration (µg/L)
32
32
1995
1996
1997
1998
1999
2000
Chlorophyll a
Total Phosphorus


60
50
40
30
annual average trophic state
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Twelve

Since 1985, volunteers have collected monitoring data on Lake Twelve located in south King County. The data record is nearly complete with data missing only during 1997 and 1999. Generally, productivity ranged from good to moderate (oligotrophic to mesotrophic), characterized by excellent water clarity, low to moderate chlorophyll *a* values, and moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals some variability in all trophic parameters from year to year during the 16-year record.

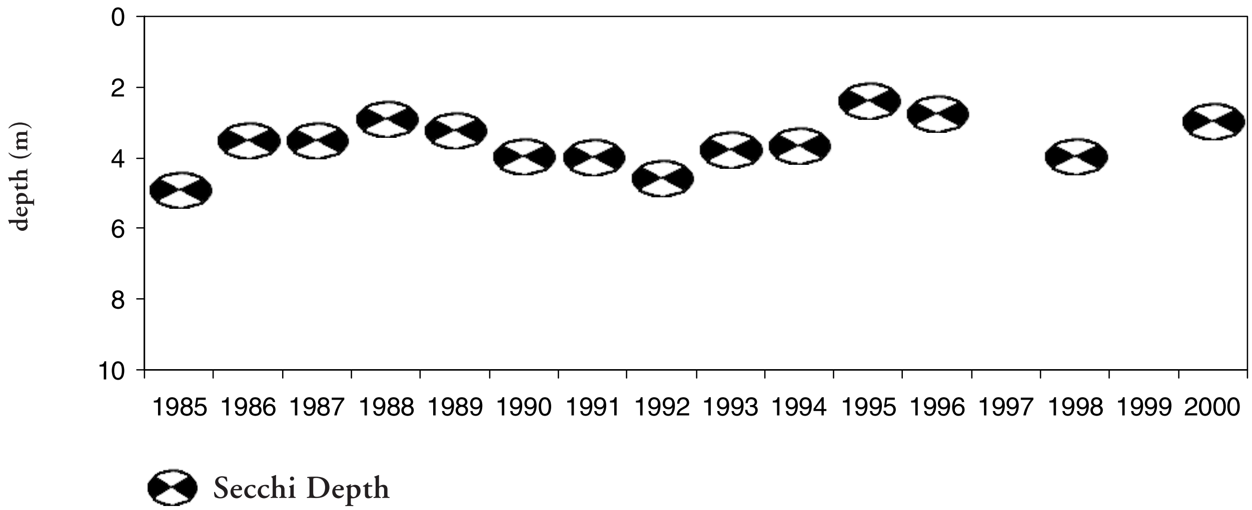
To evaluate whether statistically significant changes in water quality have occurred at Lake Twelve, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the data record.

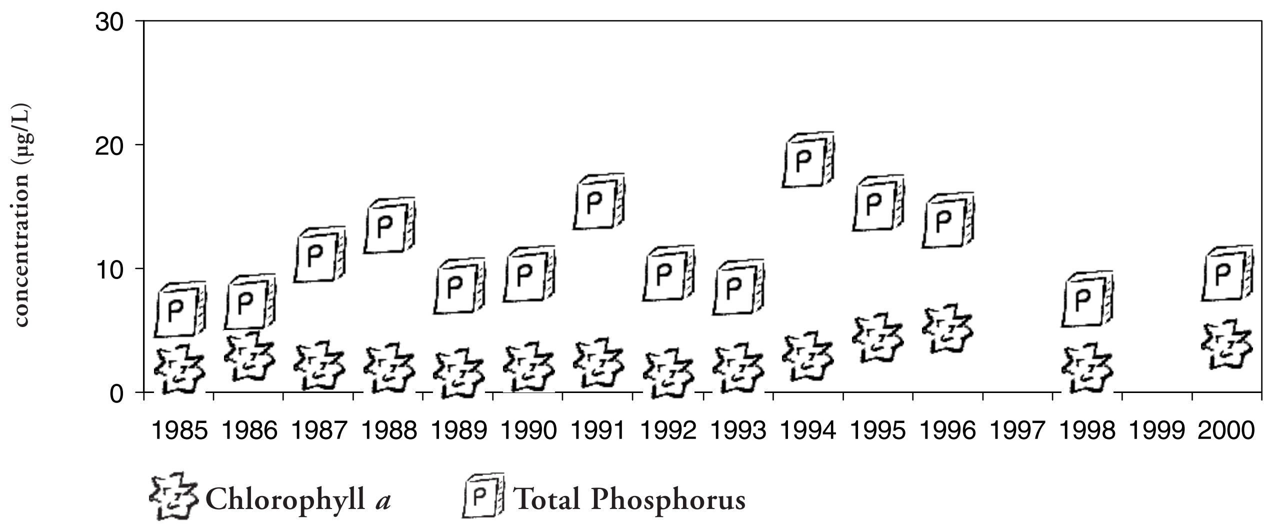
Overall, water quality ranges from good to moderate at Lake Twelve where groundwater is an important source of water to the lake. Local stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as additional land in the watershed is developed or where local shoreline alteration occurs.

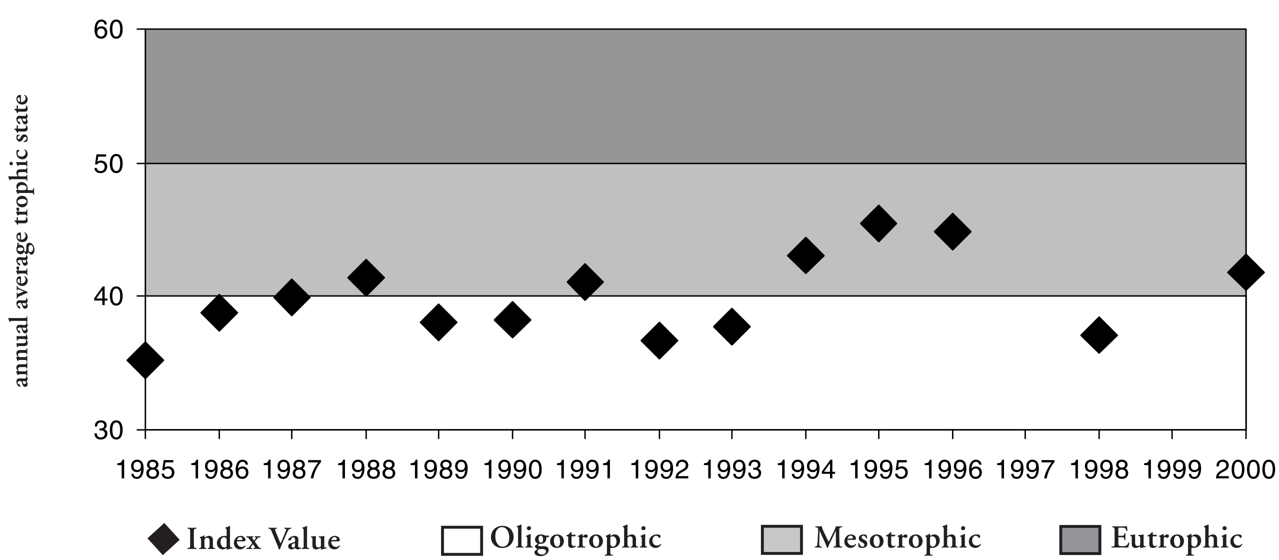
Average Values for Select Trophic Parameters at Lake Twelve

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	4.8	1.9	7	37	37	32	35
1986	10	3.5	3.0	7	42	41	33	39
1987	11	3.5	2.3	11	42	39	39	40
1988	11	2.8	2.0	14	45	38	42	41
1989	12	3.2	1.6	9	43	35	35	38
1990	11	3.9	2.1	10	40	38	37	38
1991	8	3.9	2.5	15	40	39	44	41
1992	10	4.5	1.6	10	38	35	37	37
1993	8	3.7	2.0	9	41	37	35	38
1994	9	3.6	3.0	19	41	41	47	43
1995	9	2.3	4.5	15	48	45	44	46
1996	11	2.7	5.3	14	46	47	42	45
1997	---	---	---	---	---	---	---	---
1998	11	3.9	2.1	7.6	40	38	33	37
1999	---	---	---	---	---	---	---	---
2000	12	2.9	4.0	10	45	44	37	42

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Walker

In 2000, volunteers began collecting trophic state monitoring data on Lake Walker when the services of the Lake Stewardship Program were extended to southeast King County through the Rural Drainage Program. Because the data record consists of only a single year, no statistical trend analyses were completed for Lake Walker. In the summer of 2000, productivity was low (oligotrophic) at Lake Walker, characterized by high water clarity and low chlorophyll *a* and phosphorus levels (see data table below).

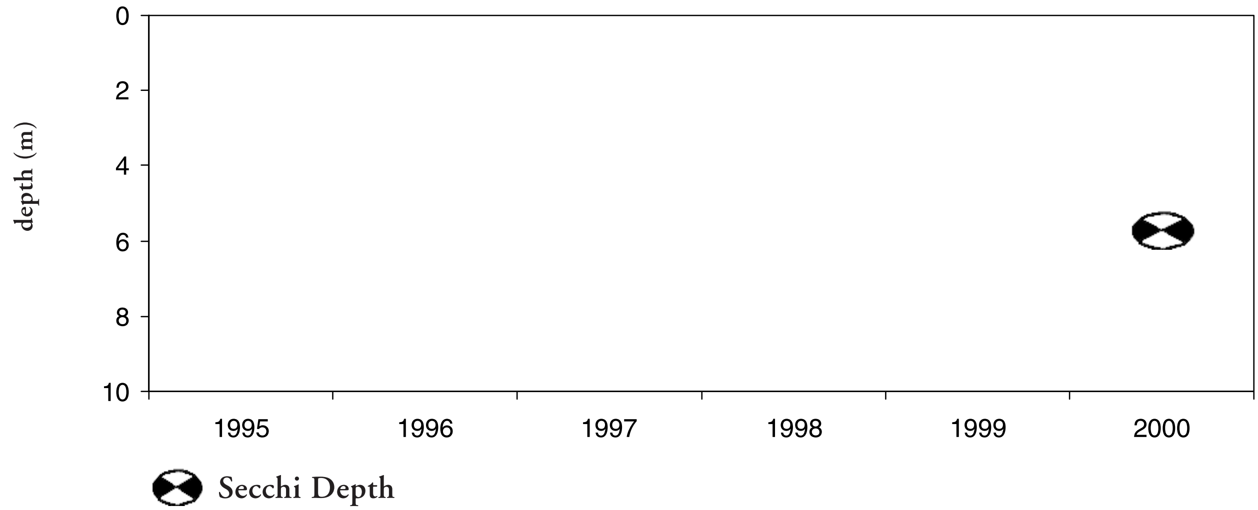
Available data are shown for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a*) levels, and average trophic state during May through October. These values are illustrated here to allow visual comparison with other lakes that have participated in the program for longer time periods.

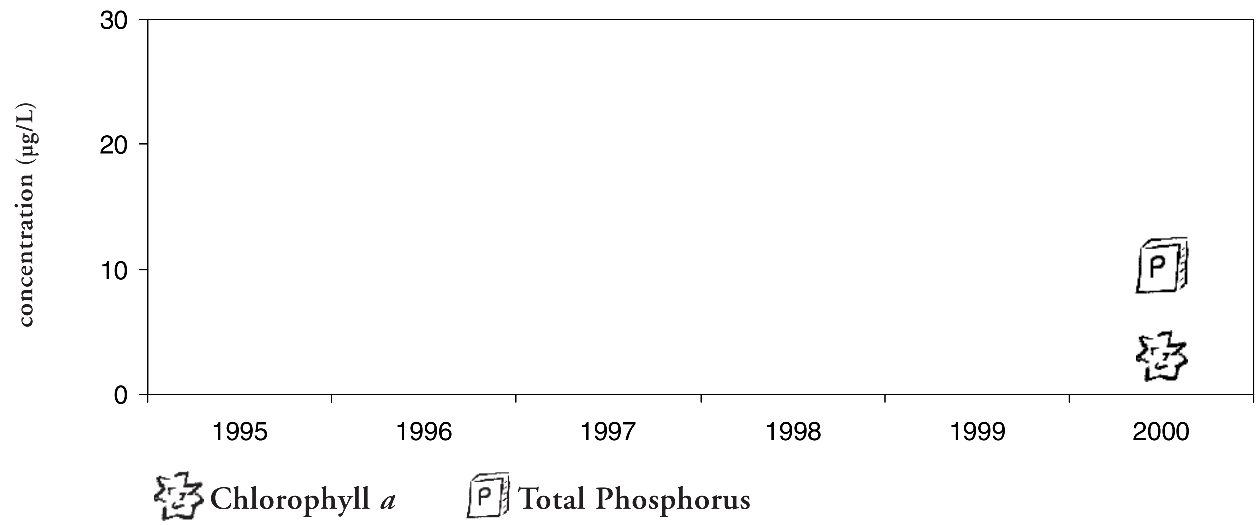
Based on this limited data, water quality is very good at Lake Walker. The lake watershed is largely forested which contributes to high quality surface flows to the lake. Groundwater also plays an important role in lake water quality. However, erosion and nutrient control measures in the watershed will increasingly be important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

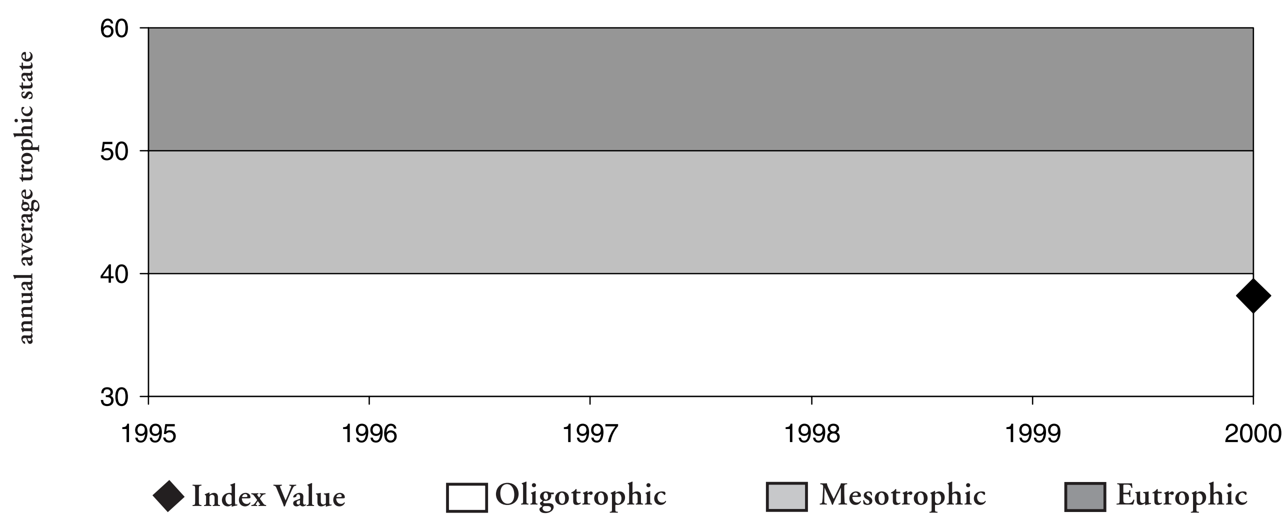
Average Values for Select Trophic Parameters at Lake Walker

Year	No. of Samples	Secchi (meter)	Chl *a** (μg/L)	TP* (μg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
2000	9	5.7	3.1	10.4	35	42	38	38

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Webster

In 1996, volunteers began collecting monitoring data on Lake Webster located in south King County. Because the data record is relatively short, no statistical trend analyses were completed for Lake Webster. Generally, productivity was high (eutrophic), characterized by low water clarity, elevated phosphorus levels, and somewhat elevated chlorophyll *a* values (see data table below).

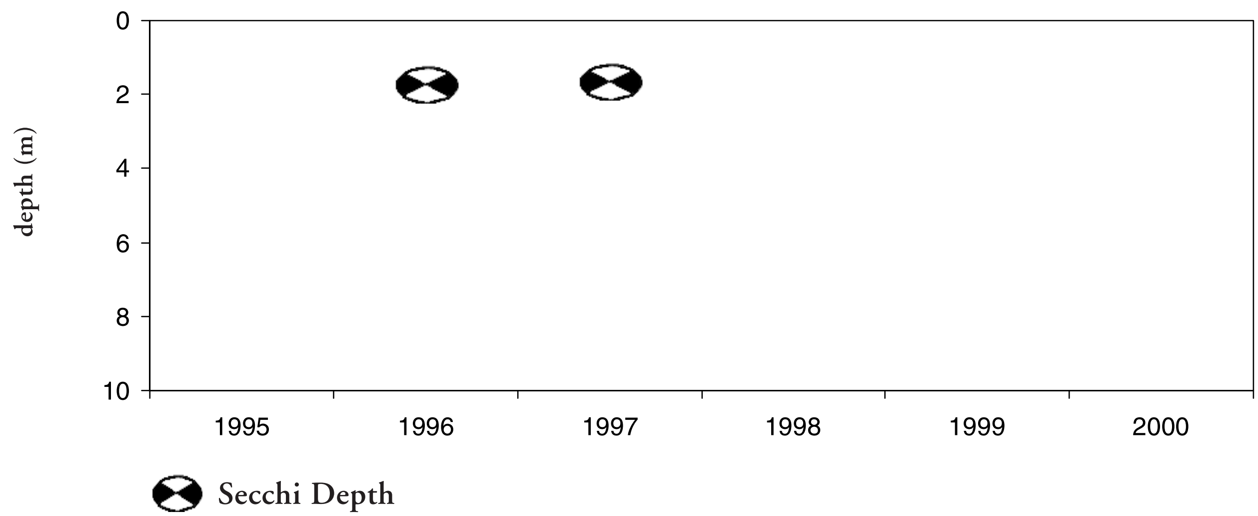
Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels were more variable for the two years where data is available.

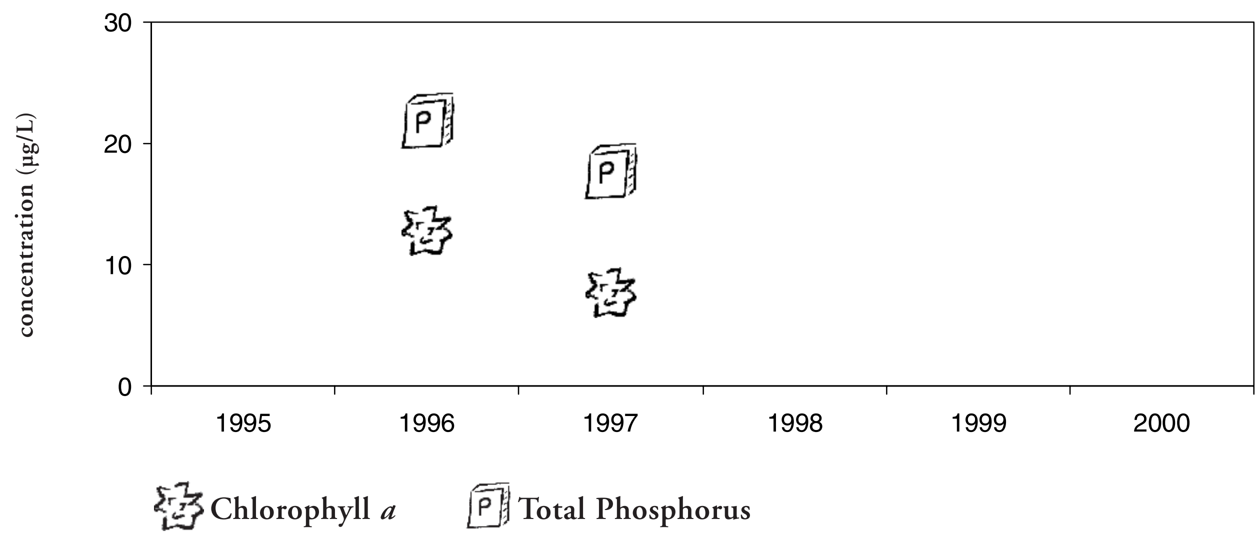
Overall, water quality is fair at Lake Webster which is classified as a bog in the King County Wetland Inventory (King County, 1990). The influence of wetland chemistry gives the lake its dark color and low Secchi depth. The eutrophic character of the lake is natural. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality (and the bog character) as land is developed in the watershed or local shoreline alteration occurs.

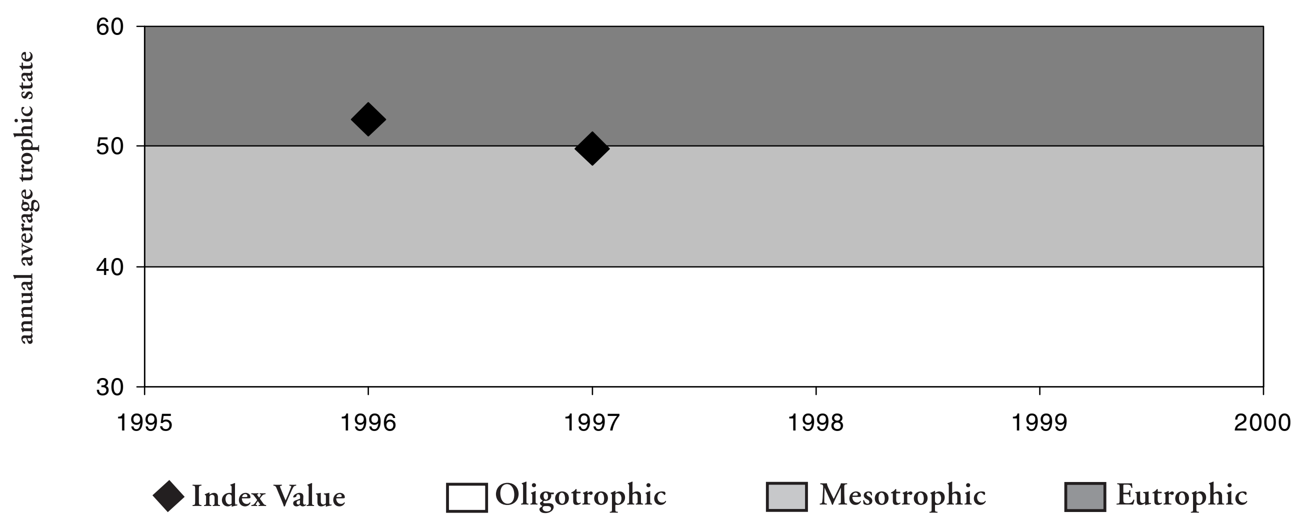
Average Values for Select Trophic Parameters at Lake Webster

Year	**No. of Samples**	**Secchi (meter)**	**Chl *a** (µg/L)**	**TP* (µg/L)**	**TSI* Secchi**	**TSI* Chl *a***	**TSI* TP**	**TSI* Average**
1996	11	1.7	12.8	22	52	56	49	52
1997	7	1.6	7.7	18	53	51	46	50
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus


annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Welcome

In 1996, volunteers began collecting monitoring data on Welcome Lake located in north King County. Because the data record is relatively short, no statistical trend analyses were completed for Welcome Lake. Generally, productivity was moderate (mesotrophic), characterized by low water clarity and elevated chlorophyll *a* and phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, as well as average trophic state values.

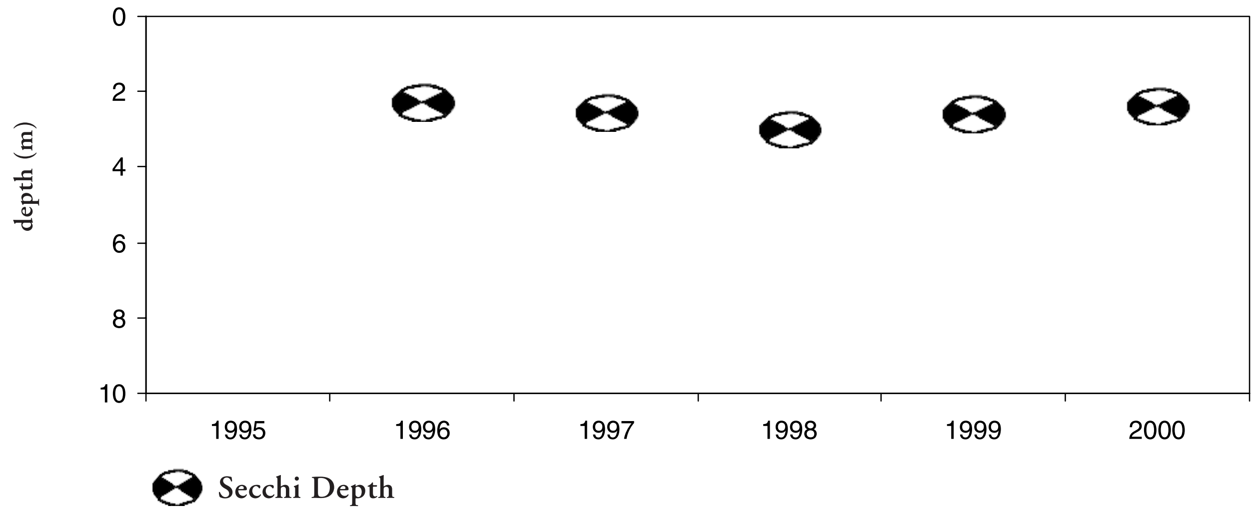
Visual analysis reveals reasonably consistent annual average values for Secchi depth while both phosphorus and chlorophyll *a* levels have been more variable from year to year.

Overall, water quality is good at Welcome Lake, somewhat influenced by wetland chemistry, giving the lake its dark color and lower Secchi depth. The mesotrophic character of the lake is natural. However, ongoing erosion and nutrient control measures in the watershed remain important to preserving existing lake water quality as land is developed in the watershed or local shoreline alteration occurs.

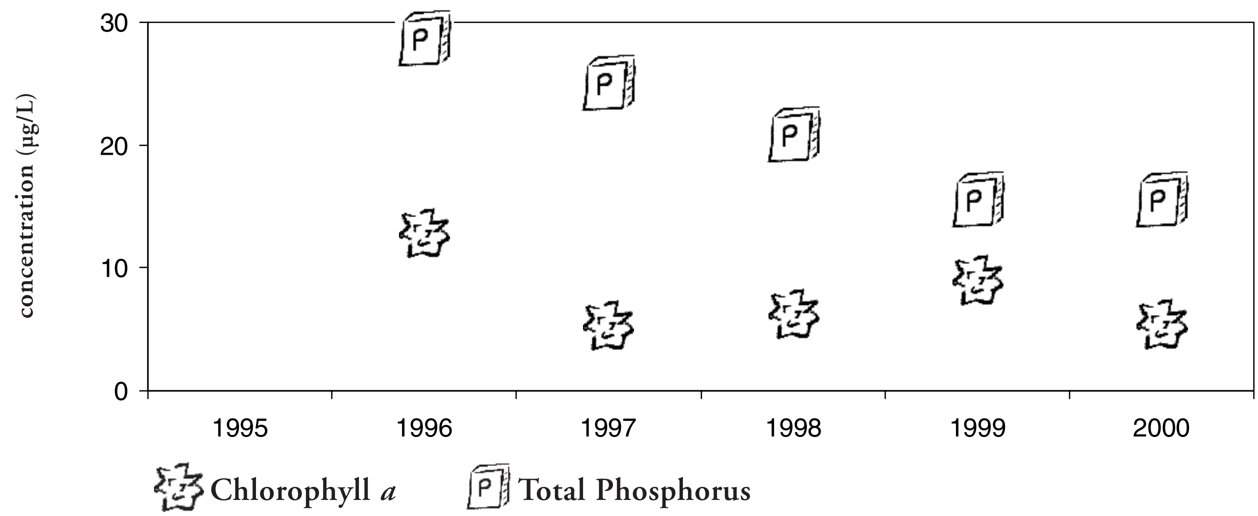
Average Values for Select Trophic Parameters at Welcome Lake

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1996	12	2.2	12.9	29	48	56	53	52
1997	12	2.5	5.4	25	47	47	51	48
1998	13	2.9	6.3	21	44	49	48	47
1999	13	2.6	9.1	16	46	52	44	47
2000	13	2.3	5.5	16	48	47	44	46

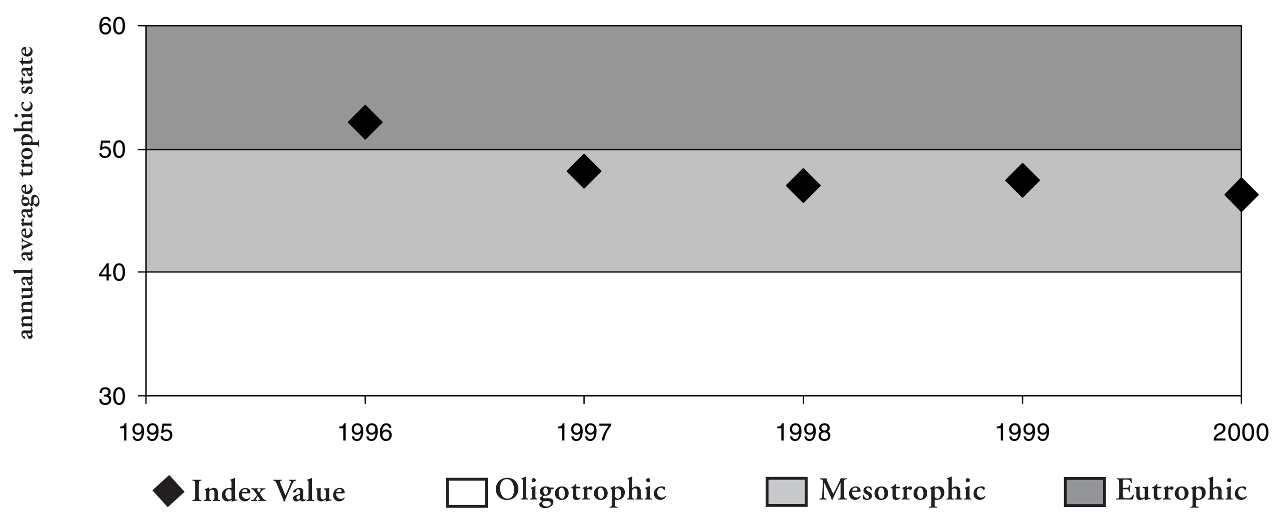
*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index



depth (m)
0
2
4
6
8
10
1995
1996
1997
1998
1999
2000
Secchi Depth



concentration (µg/L)
30
20
10
0
1995
1996
1997
1998
1999
2000
Chlorophyll *a*
Total Phosphorus



annual average trophic state
60
50
40
30
1995
1996
1997
1998
1999
2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

Wilderness

Since 1985, volunteers have collected monitoring data on Lake Wilderness, located in Maple Valley. The data record is complete for the 16-year record. Generally, productivity was moderate (mesotrophic), characterized by excellent water clarity, low chlorophyll *a* values, and moderate phosphorus levels (see data table below).

Average values for May through October are illustrated for water clarity (Secchi depth), nutrient (total phosphorus) and algal (chlorophyll *a)* levels, and average trophic state values. Visual analysis reveals some variability in trophic parameters from year to year during the 16-year record.

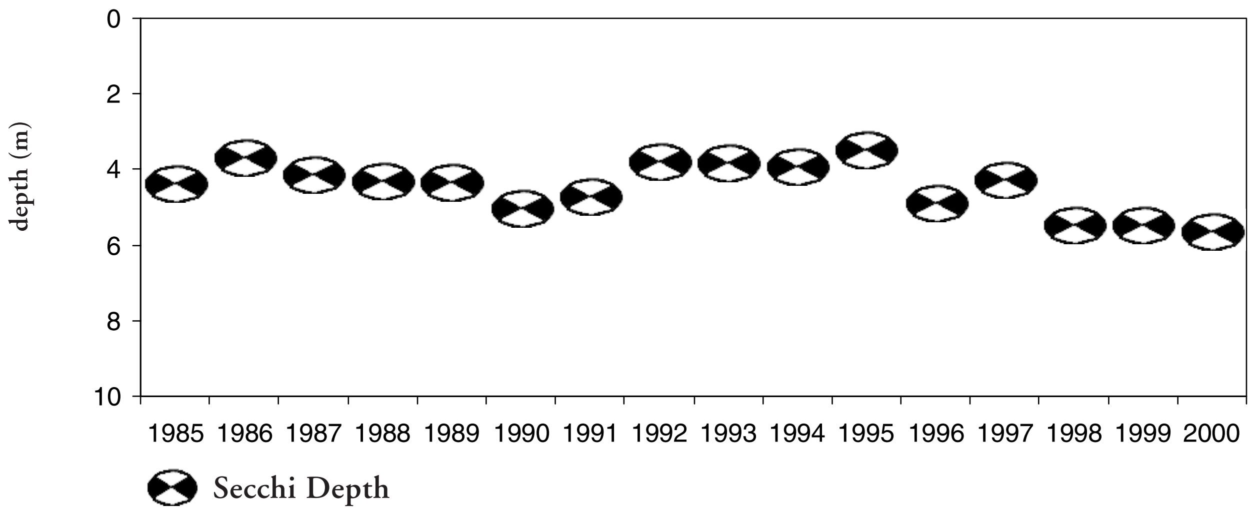
To evaluate whether statistically significant changes in water quality have occurred at Lake Wilderness, trend analyses were performed on the data below using the non-parametric Mann-Kendall's test for trend at the 95 percent confidence interval (α=0.05 significance level). No significant trends in water quality were found based on the data record.

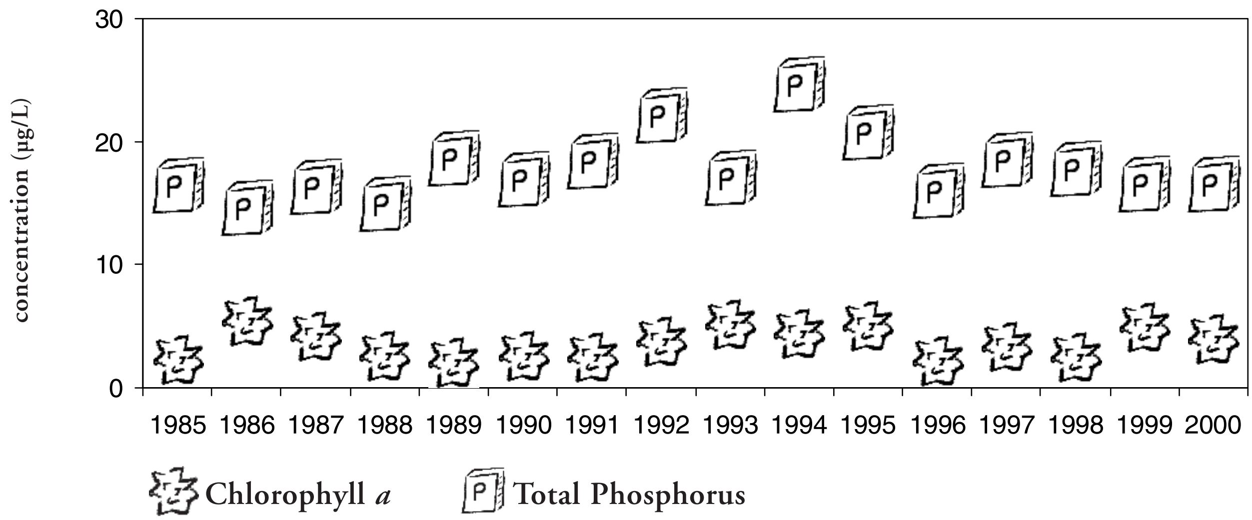
Overall, water quality is moderately good at Lake Wilderness where groundwater is an important source of water to the lake. Local stewardship by lake residents remains important to ensure ongoing erosion and nutrient control measures take place as additional land in the watershed is developed or where local shoreline alteration occurs.

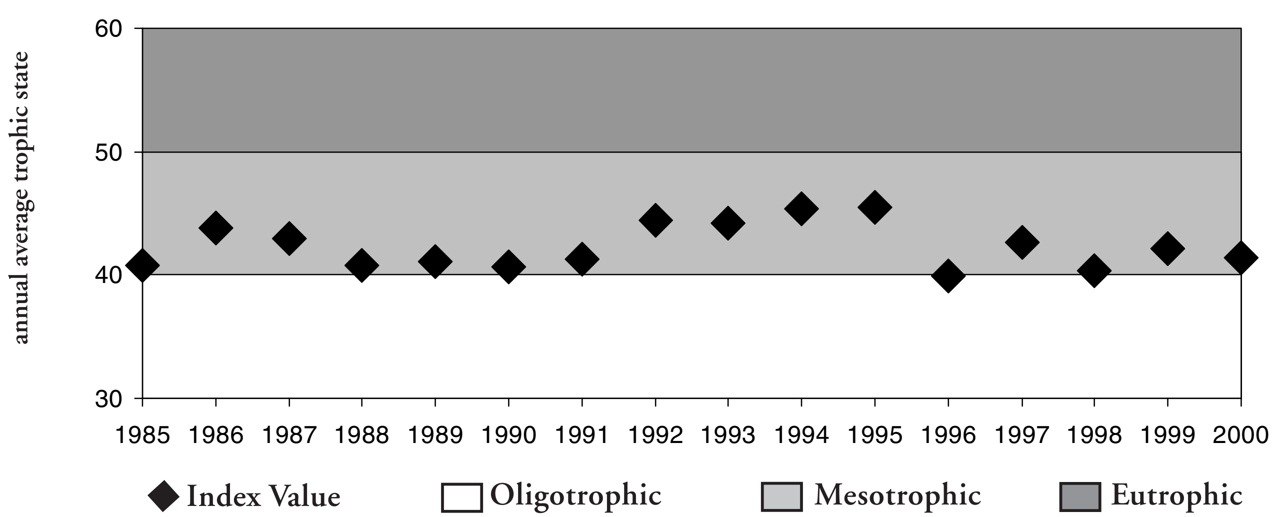
Average Values for Select Trophic Parameters at Lake Wilderness

Year	No. of Samples	Secchi (meter)	Chl *a** (µg/L)	TP* (µg/L)	TSI* Secchi	TSI* Chl *a*	TSI* TP	TSI* Average
1985	11	4.3	2.3	17	39	39	45	41
1986	12	3.7	5.5	15	41	47	43	44
1987	12	4.1	4.3	16	40	45	45	43
1988	12	4.3	2.6	15	39	40	43	41
1989	13	4.3	2.1	19	39	38	46	41
1990	12	5.0	2.7	17	37	40	45	41
1991	10	4.7	2.5	18	38	40	46	41
1992	12	3.8	3.8	22	41	44	49	44
1993	8	3.8	5.2	17	41	47	45	44
1994	12	3.9	4.4	25	40	45	50	45
1995	12	3.4	5.0	21	42	46	48	45
1996	12	4.9	2.2	16	37	38	44	40
1997	12	4.2	3.4	19	39	42	46	43
1998	12	5.4	2.5	18	36	40	46	40
1999	13	5.4	4.9	17	36	46	45	42
2000	13	5.6	4.0	17	35	44	45	41

*Chl *a*=chlorophyll *a*, TP=total phosphorus, and TSI=Trophic State Index


depth (m)
0
2
4
6
8
10
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Secchi Depth


concentration (µg/L)
30
20
10
0
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Chlorophyll a
Total Phosphorus


annual average trophic state
60
50
40
30
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Index Value
Oligotrophic
Mesotrophic
Eutrophic

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