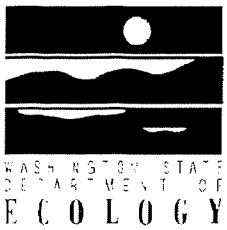

Water Quality in the Wapato Basin of Lake Chelan, Summer 1996

Abstract

In January 1993, the Environmental Protection Agency approved a total maximum daily load (TMDL) for total phosphorus in Lake Chelan. The TMDL was calculated to maintain the summer epilimnetic total phosphorus concentration in the Wapato Basin below a criterion of 4.5 µg/L, the ultra-oligotrophic threshold. In 1996 the volume-weighted mean summer epilimnetic total phosphorus concentration for the Wapato Basin of Lake Chelan was found to be less than 2.6 µg/L. This value is well below the 4.5µg/L TMDL criterion, and is lower than the value of 3.9 µg/L found in summer 1987 and comparable to the summer 1995 value of 2.2 µg/L. All other water quality samples and field measurements show excellent water quality in Lake Chelan. Recommendations include continued monitoring to ensure the TMDL criterion is being met.

Introduction

Study Area

Lake Chelan is located in the Northern Cascades of central Washington State (Figure 1). It is considered one of the most pristine waterbodies in North America with a high degree of clarity and extremely low nutrient levels. The lake extends 55 miles northwest from the town of Chelan to deep into the North Cascades. The average width is one mile and the Lake Chelan watershed encompasses approximately 924 square miles. Lake Chelan discharges into the Chelan River via a small hydroelectric dam in the City of Chelan. Beyond the dam the Chelan River flows a few miles before emptying into the Columbia River.

The lake consists of two distinct basins, separated by a relatively shallow sill 135 feet below the surface at the narrowest part of the lake. The larger Lucerne Basin encompasses the upper part of the lake and contains 92% of the water. The Lucerne basin is approximately 38 miles in length and has a maximum recorded depth of 1,486 feet. The upper 30 miles of the lake are inaccessible by road, so access to the remote town of Stehekin and the North Cascades National Park at the head of the lake is by foot, boat, or plane.

The smaller Wapato Basin is the focus of this study. The Wapato Basin contains 8% of the water and is approximately 12 miles long, with a maximum depth of approximately 141 feet (EPA, 1994). The lower basin is bordered by the city of Chelan and is subject to much greater human impacts.

by Debby Sargeant
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Waterbody No. WA-47-9020

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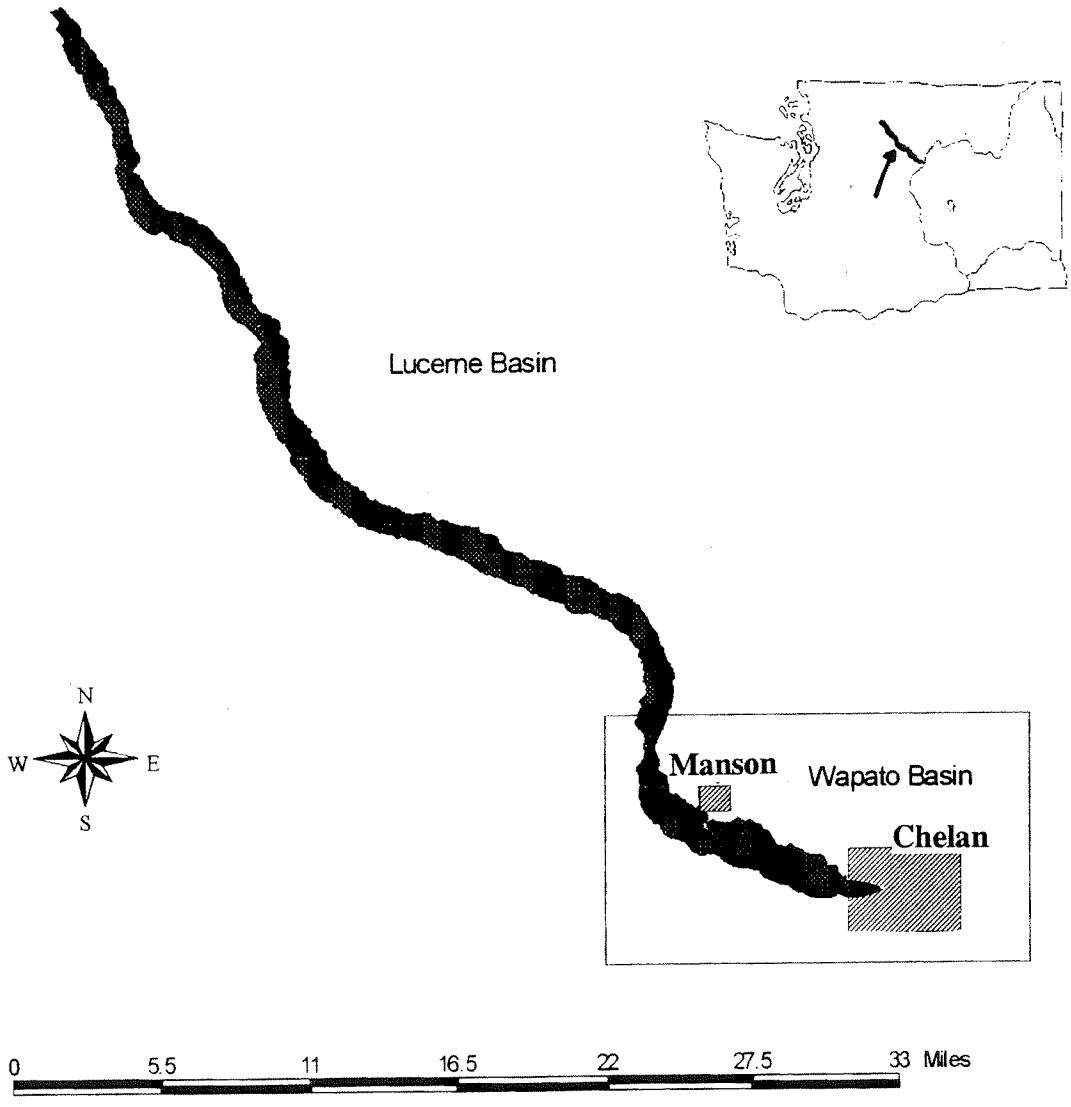

Figure 1 Lake Chelan.

History

Lake Chelan is classified as ultra-oligotrophic. The lake has extremely low nutrient levels and a high degree of clarity. In the 1980's increasing development pressures raised concerns about maintaining the lake's high water quality. In response to these concerns a comprehensive limnological study was completed in 1986-87 and published as "The Lake Chelan Water Quality Assessment" (Patmont *et al*, 1989). In response to the assessment, five local agencies formed the Lake Chelan Water Quality Committee. This Committee completed the Lake Chelan Water Quality Plan in December 1991 (Lake Chelan Water Quality Committee, 1991).

The federal Clean Water Act requires the Total Maximum Daily Load (TMDL) of a pollutant be established where the beneficial uses of a water body are being threatened or impaired by that pollutant. The Lake Chelan Water Quality Plan included a TMDL for total phosphorus (TP) that was approved by the Environmental Protection Agency (EPA) in January 1993. The TMDL for TP is 51.0 kg/day (Pelletier, 1991). It is believed that if the TMDL is met, the mean epilimnetic value of TP in the Wapato Basin will not exceed 4.5 µg/L. The 4.5 µg/L criterion is considered the upper threshold of ultra-oligotrophic conditions. The mean epilimnetic TP value in the Wapato Basin is calculated as a volume-weighted mean, which is used to evaluate the condition of the lake relative to the 4.5 µg/L criterion, and to determine if the TMDL is being exceeded.

In 1995, the Lake Chelan Water Quality Committee began long-term monitoring of the Wapato Basin of Lake Chelan. A Quality Assurance Project Plan (QAPP) was developed for the project (Congdon, 1995) and protocols for determining low-level phosphorus concentrations were developed by Ecology (Seiders *et al.*, 1995).

In 1996, the Lake Chelan Water Quality Committee did not obtain grant money for monitoring. At the request of Ecology's Central Regional Office, Ecology's Watershed Assessments Section conducted the 1996 monitoring of Lake Chelan. This report describes the results of the 1996 monitoring.

Project Objectives

- Determine the mean epilimnetic TP concentration in the Wapato Basin for comparison to previous data and the TMDL criterion of 4.5 µg/L TP.

- Gather information on other key water quality parameters in the Wapato Basin that might indicate degradation of water quality, including: total persulfate nitrogen (TPN), nitrite/nitrate nitrogen (NO3/2-N), chlorophyll *a* (Chl *a*), phaeopigments *a* (phaeo *a*), dissolved oxygen (DO), temperature, conductivity, pH, and secchi disk transparency.

Methods

Water Quality Sampling Procedures

For the 1996 sampling, an abbreviated QAPP was developed (Sargeant, 1996) based on Congdon (1995) and Seiders *et al.* (1995). The abbreviated QAPP describes any changes from the original QAPP and the low-level protocols developed in 1995.

Water samples were taken from four stations in the Wapato Basin (Figure 2) at the same locations as the 1995 sampling. A hand-held global positioning system (GPS) device was used to help locate the sampling stations. At stations 2, 3, and 4 samples were obtained from three depths, 0.3, 10 and 20 meters, and at station 1 samples were obtained at 0.3 meter only. The lake was sampled during seven surveys on the following dates: May 16, June 4, June 20, July 18, August 15, September 9, and October 3, 1996. Laboratory samples were obtained for TP, TPN, NO3/2-N, Chl *a*, and Phaeo *a*. Sample duplicates were collected in accordance with the QAPP. Field measurements for temperature, conductivity, pH, and dissolved oxygen were taken to a depth of 50 meters where possible. Secchi disk readings were obtained at each station.

Laboratory samples for all chemical parameters were collected with a Kemmerer water sampler. All water samples were collected and transferred directly into pre-cleaned containers supplied by Ecology's Manchester Environmental Laboratory (MEL). Samples were placed immediately in the dark on ice and shipped to Ecology headquarters. Chlorophyll *a* samples were filtered at Ecology headquarters the same day. Filters were placed in acetone tubes and stored in the freezer. Acetone tubes and other laboratory samples were shipped to MEL within 24 hours after sample collection. Samples were analyzed in accordance with the QAPP.

Field measurements were obtained using a Hydrolab® multi-parameter meter. Dissolved oxygen readings were paired with Winkler field verification measurements to evaluate the accuracy of the meter. Winkler DO samples were obtained using a Kemmerer sampler and analyzed at Ecology headquarters within 30 hours of collection.

On September 9, 1996, duplicate field samples for TP were obtained for laboratory analysis using both the inductively coupled plasma/mass spectrometry (ICP-MS) method and the spectrophotometric method. On May 16, 1996, some field measurements for temperature, conductivity, pH, and dissolved oxygen were not recorded because of equipment failure.

Laboratory Analysis

The primary objective of this study was to determine the mean summer epilimnetic concentration of TP in the Wapato Basin of Lake Chelan. Since the expected mean TP concentration is well below the usual reporting limit of 10 µg/L, a low-level TP spectrophotometric analysis technique was used by MEL with a reporting limit of 3.0 µg/L. However, out of 77 TP samples obtained (including field duplicates) using the spectrophotometric method, 74 of the samples were reported as below 3.0 µg/L.

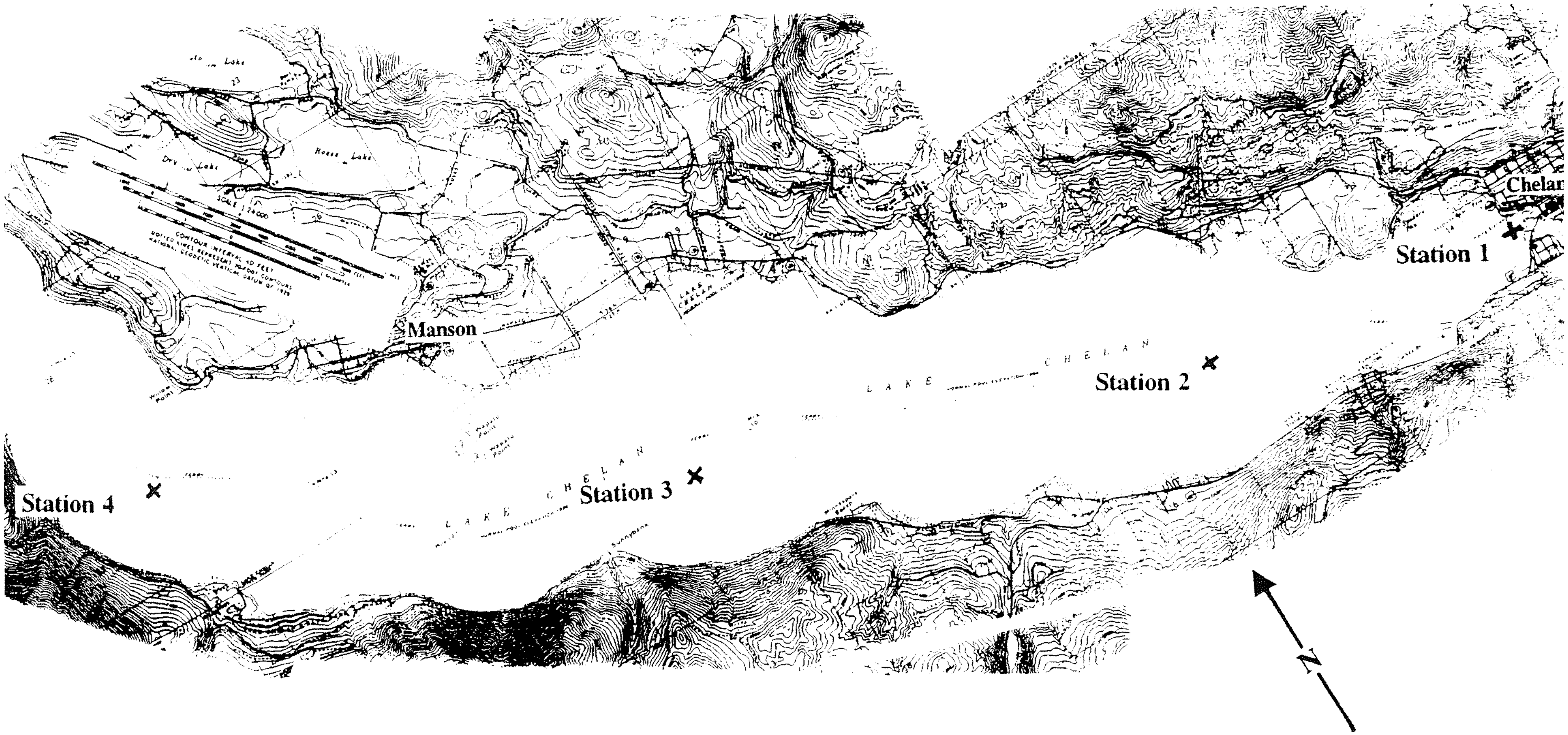

Figure 2: 1996 Lake Chelan Monitoring Sites.

For three of the sample events (July 18, August 15, and September 9, 1996), samples for TP were also analyzed using ICP-MS. The reporting limit for TP using the ICP-MS method is 0.2 µg/L. For laboratory analysis of the July 18 and August 15, 1996 TP samples, individual samples were split in the laboratory into two volumes for ICP-MS and spectrophotometric low-level TP analyses. For the September 9, 1996, TP analysis two separate field samples were collected for analysis with the two methods.

Quality Assurance

Quality assurance procedures and results are described in Appendix A. Data quality for TPN, NO3/2-N, Chl *a*, DO, and TP (ICP-MS) analyses were good. For Phaeo *a* and TP (spectrophotometric method) it was difficult to determine data quality, because almost all field duplicates were below detection limits.

Analysis of Data

The 1996 data were compared to historical data collected in 1995 and 1987. Data comparison of TP was difficult for values below the spectrophotometric detection limit of 3 µg/L, so ICP-MS TP data were used for data analysis whenever possible. Data that are reported as less than the reporting limit are sometimes referred to as "censored data." The reporting limit value was used for censored data in the data analysis. Results of field duplicates were averaged for summary statistical analysis and calculating the volume-weighted mean.

Both the ICP-MS and spectrophotometric data were used to calculate the volume-weighted mean epilimnetic TP concentration (Gilbert, 1987). An Ecology spreadsheet developed by Pelletier (1991) was used to calculate the volume-weighted mean. The following formulas were used in the spreadsheet for volume-weighted calculations:

- The volume-weighted mean is: the summation across all strata of (Wh*Xh),
  where:
  Wh= volume of stratum h/total volume of all strata
  Xh= mean value of stratum h across all sample events

- The square of the volume-weighted standard error is: the summation across all strata of [(Wh^2*Sh^2)/nh], where:
  Wh^2=Wh squared
  Sh^2= variance in stratum h
  nh= number of observations in stratum h

To compare the mean volume-weighted TP concentration to the TMDL threshold of 4.5 µg/L, the upper 95% confidence limit of the mean volume-weighted epilimnetic TP concentration was determined using the volume-weighted standard error. Then, a one-sided t-test was used to determine if the upper 95% confidence limit ≥4.5 µg/L. For the t-test, n represents the total number of sample results.

Summary statistics were done using MICROSOFT EXCEL (1994). The summary statistics and graphs illustrate the summer epilimnetic means unless otherwise noted. The summary statistics and graphs do not use volume-weighting techniques to calculate mean values.

Results

A summary of the 1996 field and laboratory monitoring data can be found in Appendices B and C, respectively. In the 1996 data set, the parameters NO3/2-N, TPN, TP, Chl *a*, and Phaeo *a* all contain values below the detection limit. The 1995 and 1987 data are presented in the 1996 report (Congdon, 1996) on Lake Chelan. Summary statistics for 1996 field and laboratory parameters are presented in Table 1. Summary statistics for 1995 and 1987 are presented in Tables 2 and 3 taken from Congdon (1996).

Table 1 1996 Summary Statistics for Lake Chelan.

Parameter	Units	Valid N	Mean	Confid. -95%	Confid. +95%	Median	Min.	Max.	Range	Stand. Dev.	Stand. Error*
TP	µg/L	70	2.6	2.5	2.8	< 3.0	1.2	4.0	2.8	0.6	0.07
NO3/2-N	µg/L	70	27	24	31	23	< 10	62	52	15	1.8
TPN	µg/L	70	53	47	58	56	< 10	113	103	23	2.8
Chl a	µg/L	70	0.86	0.76	0.96	0.75	< 0.50	3.10	2.6	0.43	0.05
Phaeo a	µg/L	70	0.56	0.51	0.61	< 0.50	< 0.50	1.60	1.10	0.20	0.02
Temp	C°	114	12.2	11.4	13.1	12.3	5.0	21.8	16.8	4.4	0.42
Cond	µmho/cm	99	56	55	57	59	43	66	23	7	0.7
pH	unit	99	7.7	7.7	7.8	7.8	7.0	8.8	1.8	0.3	0.03
DO	mg/L	102	10.5	10.3	10.7	10.6	8.4	12.2	3.8	0.9	0.09
DO%	%	101	103	102	104	104	84	116	32	0	0.0
Secchi	meters	21	12.0	11.2	12.9	11.7	9.1	15.8	6.7	1.9	0.42

Table 2 1995 Summary Statistics for Lake Chelan [from Congdon (1996)].

Parameter	Units	Valid N	Mean	Confid. -95%	Confid. +95%	Median	Min.	Max.	Range	Stand. Dev.	Stand. Error*
TP	µg/L	68	2.2	2.0	2.3	2.2	0.6	4.1	3.5	0.7	0.09
NO3/2-N	µg/L	70	18	16	21	12	10	35	25	9	1.1
TPN	µg/L	70	103	89	117	85	50	296	246	58	7.0
Chl a	µg/L	70	1.08	0.97	1.20	1.10	0.10	2.90	2.80	0.47	0.06
Phaeo a	µg/L	70	0.30	0.24	0.35	0.30	0.10	1.60	1.50	0.24	0.03
Temp	C°	69	16.2	15.5	16.9	16.4	9.2	21.8	12.6	3.0	0.36
Cond	µmho/cm	70	61	60	62	62	53	67	14	3	0.4
pH	unit	70	7.2	7.1	7.4	7.2	6.0	8.4	2.4	0.6	0.07
DO	mg/L	59	10.7	10.5	11.0	10.7	8.4	12.4	4.0	0.9	0.12
DO%	%	59	114	111	117	113	90	139	49	11	1.4
Secchi	meters	18	13.2	11.9	14.4	14.2	9.4	16.5	7.1	2.4	0.57

Table 3 1987 Summary Statistics for Lake Chelan [from Congdon (1996)].

Parameter	Units	Valid N	Mean	Confid. -95%	Confid. +95%	Median	Min.	Max.	Range	Stand. Dev.	Stand. Error*
TP	µg/L	69	3.5	3.0	3.9	3.2	1.5	10.0	8.5	1.8	0.29
NO3/2-N	µg/L	67	44	30	59	30	9	363	354	59	7.2
TPN	µg/L	67	105	91	120	91	23	317	294	60	7.3
Chl a	µg/L	64	0.66	0.58	0.74	0.62	0.13	1.66	1.53	0.32	0.04
Phaeo a	µg/L	64	0.28	0.23	0.33	0.27	-0.31	1.20	1.51	0.19	0.02
Temp	C°	70	15.9	15.0	16.7	16.5	7.8	21.0	13.2	3.7	0.44
Cond	µmho/cm	68	59	59	59	59	56	62	6	1	0.2
pH	unit	67	7.8	7.8	7.9	7.9	7.4	8.2	0.8	0.2	0.02
DO	mg/L	67	10.4	10.3	10.6	10.5	9.2	11.9	2.7	0.6	0.08
DO%	%	67	110	109	111	110	96	122	26	5	0.6
Secchi	meters	21	10.2	9.5	11.0	10.5	7.2	13.5	6.3	1.7	0.37

* standard error of the mean.

Laboratory Parameters

Total Phosphorus

Forty out of the 70 samples used to calculate the mean were samples analyzed using the spectrophotometric method. This method has a reporting limit of 3.0 µg/L. Thirty-eight out of these 40 samples were reported as <3.0 µg/L. Because the reporting limit value was used in calculating the summary statistics and volume-weighted mean epilimnetic TP concentration, estimates of the mean, median, and volume-weighted mean were higher than the true value. Appendix D presents volume-weighted statistics for 1996 and Table 1 presents the summary statistics. Tables 2 and 3 present summary statistics from 1995 and 1987 respectively.

The mean summer epilimnetic TP concentration for the Wapato Basin in 1996 was 2.6 µg/L. This value is well below the 1987 value of 3.5 µg/L and is comparable to the summer 1995 value of 2.2 µg/L.

The volume-weighted mean, which is a more accurate estimate of TP concentration in the epilimnion was 2.6 µg/L for 1996. In 1995, the volume-weighted mean was 2.2 µg/L, and in 1987 it was 3.9 µg/L. The upper bound of the 95% confidence interval for the volume-weighted mean is 2.8 µg/L for 1996 and 2.3 µg/L for 1995 (using a one-sided t-statistic).

Table 4 presents mean TP values by station and depth for 1996, 1995, and 1987 (information from 1995 and 1987 is taken from Congdon [1996]). Total Phosphorus values in 1996 are uniform throughout the basin, due in part to the number of values below the reporting limit (3.0 µg/L). This uniformity is noted in 1995, but in 1987 greater spatial variability was seen. Station 3 had a slightly higher overall mean TP value than the other stations, and the 0.3 meter depth had a lower mean TP concentration than depths 10 and 20 meters. This pattern is also seen in the 1995 data.

Table 4. Mean TP Values (ug/L) for each year by Station and Depth.

1996	Station				
Depth (meters)	**1**	**2**	**3**	**4**	Overall Mean
0.3	2.5	2.5	2.6	2.5	2.5
10		2.6	2.8	2.6	2.7
20		2.7	2.7	2.6	2.7
Overall Mean	2.5	2.6	2.7	2.6	

1995	Station				
Depth (meters)	**1**	**2**	**3**	**4**	Overall Mean
0.3	2.1	2.0	2.1	1.8	2.0
10		1.9	2.7	2.1	2.2
20		2.3	2.5	2.2	2.3
Overall Mean	2.1	2.1	2.4	2.0	

1987	Station				
Depth (meters)	**1**	**2**	**3**	**4**	Overall Mean
0.3	2.7	2.1	2.5	2.1	2.4
10		5.6	2.6	5.1	4.4
20		3.1	4.7	4.1	4.0
Overall Mean	2.7	3.6	3.3	3.7	

Nitrogen

The mean value for TPN in 1996 was 53 µg/L, which was quite a bit lower than the 1995 and 1987 values of 103 and 105 µg/L, respectively. The mean NO3-NO2/N value for 1996 of 27 µg/L is between 1995 and 1987 mean values of 18 and 44 µg/L. As in 1995, TPN and NO3-NO2/N values in 1996 tended to be higher earlier in the sample season.

Nitrogen to phosphorus ratios exceeding roughly 7:1 to 15:1 (by weight) indicate that phosphorus may be the more limiting nutrient (Congdon, 1996). Nitrogen to phosphorus ratios averaged 20:1 for 1996. The number of values at the TP reporting limit may give a low estimate of the N:P ratio. A ratio of 20:1 suggests that algal may be phosphorus limited, which is typical for most freshwater systems. Epilimnetic ratios for 1995 averaged 46:1, while 1987 values averaged 30:1 (Congdon, 1996).

Chlorophyll *a* and Phaeopigment *a*

Chlorophyll *a* is a measurement of phytoplankton biomass. Chlorophyll *a* is degraded into phaeopigments, primarily caused by zooplankton grazing. The Chl *a* and phaeo *a* means for 1996 were 0.86 and 0.56 µg/L, respectively. The mean for Chl *a* and phaeo *a* may be high because 20% of the Chl *a* and 84% of Phaeo *a* sample results used for analysis were below the reporting limit of 0.50 µg/L. The 1996 mean value for Chl *a* is between the 1995 mean of 1.08 µg/L and the 1987 mean of 0.66 µg/L. The 1996 mean for phaeo *a* is higher than the 1995 and 1987 values, but this is probably of little significance

due to the number of values below the reporting limit and the higher reporting limit for 1996 phaeo *a* laboratory analysis.

Field Measurements

Temperature

As would be expected, the mean temperature average was highest at station 1 and lower by station to the outermost station 4, with higher average temperatures at the surface getting cooler with depth. The location of the thermocline (the boundary between the epilimnion and hypolimnion) was between 30 and 40 meters for all sample events.

Average temperatures and surface temperatures were cooler at the start of the sampling season in May, peaking in August, then cooling again (Table 5).

Table 5. Mean Temperature for each Sample Event.

Date	Average Temperature	Average Surface Temperature
May 16, 1996	8.4° C	12.4° C
June 4, 1996	10.2° C	15.1° C
June 20, 1996	11.1° C	16.6° C
July 18, 1996	13.0° C	18.8° C
August 15, 1996	14.6° C	21.1° C
September 9, 1996	14.4° C	18.4° C
October 3, 1996	13.6° C	16.5° C

Mean temperature for 1996 was higher than in 1995 and 1987. In 1995 and 1987 n= 69 and 70 respectively while in 1996 n=114. It may be that cooler depths below 20 meters were not used to calculate the summary statistics for 1995 and 1987. For 1996, the 40 and 50 meter temperature readings were included in the analysis.

Secchi Disk Readings

Secchi depth measurements averaged 12.0 meters for 1996, 13.2 meters for 1995, and 10.2 meters for 1987. The 95% confidence limits for the 1996 and 1995 average secchi depths overlap, so the readings are not significantly different.

Conductivity and pH

The mean conductivity for 1996 was 56 µmho/cm and the mean pH was 7.7. These values are comparable to values seen in 1995 and 1987.

Dissolved Oxygen

The 1996 mean dissolved oxygen level of 10.5 mg/L did not differ substantially from 1995 or 1987 levels. The 1996 average DO saturation of 103% was slightly lower that 1995 and 1987 saturation levels of 114 and 110%. Figure 3 presents mean % DO saturation by depth.

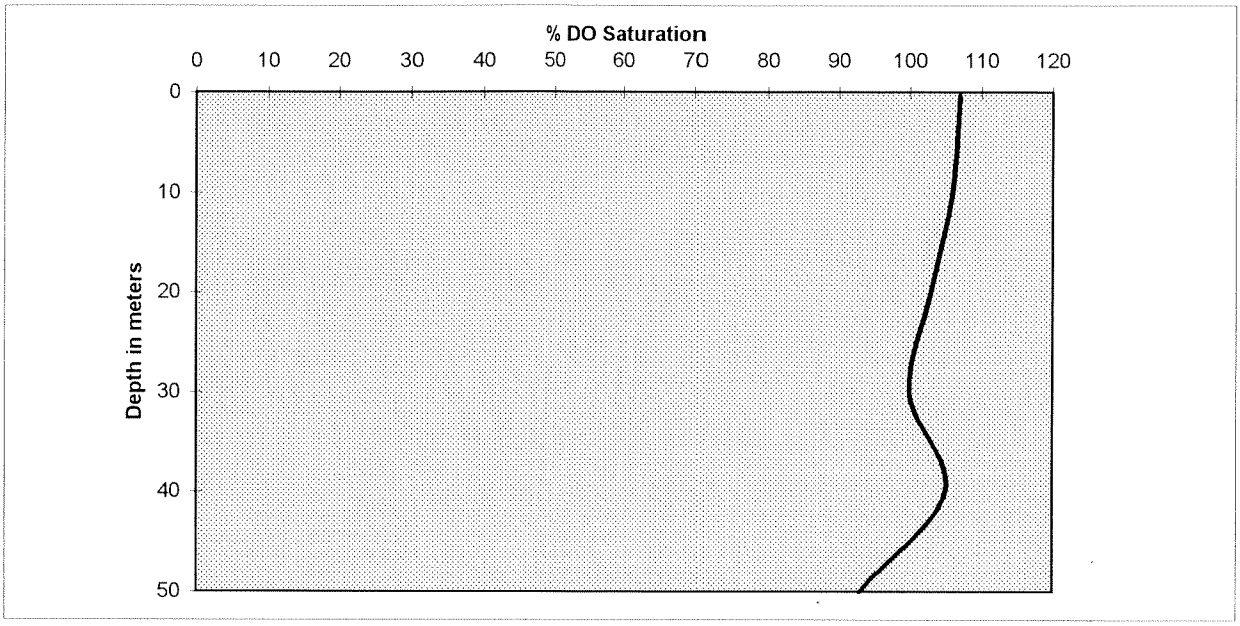

Figure 3: 1996 Lake Chelan Mean % DO Saturation by Depth.

Discussion

The 1996 volume weighted mean epilimnetic TP concentration of < 2.6 µg/L is well below the TMDL criterion of 4.5 µg/L. Congdon (1996) noted a surprising drop in the 1995 volume weighted mean for TP (2.21 µg/L) from the 1987 value of 3.9 µg/L. For all three studies different laboratories, TP laboratory methods, and sampling personnel were used. In addition TP levels for Lake Chelan are very low, often at or below reporting limits for the TP laboratory method. Precision usually decreases as results approach the detection limit. When analyzing and reporting data near the reporting limit this variability needs to be taken into consideration. Differences between years could also be due to seasonal variations in environmental conditions or pollutant loading.

Results for other laboratory parameters were not unusual, except for TPN. The mean value for 1996 was half that of mean values found in 1995 and 1987. The quality of the 1996 TPN data was good and only 11% of the TPN values were below the reporting limit. In 1995, the TPN method used had a reporting limit of 50 µg/L as compared to 10 µg/L for the 1996 laboratory method. This may have produced a higher estimate of the mean and median for 1995 than the true value. Differences between years could also be due to seasonal variation or differences in laboratory technique.

Conclusions

- The 1996 volume weighted mean epilimnetic TP concentration of <2.6 µg/L is well below the TMDL criterion of 4.5 µg/L, and comparable to 1995 levels.

- 1996 water quality data for Lake Chelan is excellent.

- 1996 results may vary from previous years due to differences in laboratories, analytical methods, detection limits, sampling personnel, sample timing, seasonal differences in environmental conditions, or pollutant loading. Long term monitoring with consistent methodology is necessary to determine water quality trends in Lake Chelan.

Recommendations

1. Continue monitoring to ensure the TMDL water quality criterion for TP is met.
2. Continue pollution control efforts to protect the excellent water quality of Lake Chelan.
3. To achieve more consistency in data:
   a) The laboratory method chosen for each parameter should have a reporting limit that is below the majority of values found in Lake Chelan. For example, for TP the lower reporting limit should be<1 µg/L.
   b) The same laboratory and laboratory method should be used if possible for all laboratory work, especially for low-level total phosphorus analysis.
   c) Field methodology should be kept consistent.

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Appendix A: Field Quality Assurance

Quality Assurance Procedures

Standard laboratory quality assurance (QA) procedures were followed for all samples, including calibration standards, spikes, and laboratory duplicates. All meters used in the survey were calibrated and used in accordance with user manuals. Field QA procedures are described in the QAPP (Sargeant, 1996). Laboratory methods are shown in Table A-1.

Table A-1. Laboratory Methods for 1996 Chelan Water Quality Monitoring

Parameter	Method	Detection Limit
Total Phosphorus		
Spectrophotometric	SM18 4500-P D	3.0 µg\L
Inductively coupled plasma/mass spectrometry (ICP-MS)	EPA 200.9 Modified	0.2 µg\L
Total persulfate nitrogen	SM 4500 NO3-F Modified	10 µg\L
Nitrite-nitrate nitrogen	EPA 353.2	10 µg\L
Chlorophyll *a*	EPA 446.0	0.5 µg\L
Phaeopigments	EPA 446.0	0.5 µg\L
Field Measurements		**Accuracy**
Dissolved Oxygen	field meter (polargraphic)	± 0.2 mg/L
	Winkler modified azide (EPA 360.2)	± 0.1 mg/L

SM: Standard Methods for the Examination of Water and Wastewater, 18th Ed. (APHA, 1992)
EPA: Methods for the chemical analysis of water and wastes. Environmental Monitoring supply Laboratory. U.S. Environmental Protection Agency (EPA, 1983).

Quality Assurance Results

To estimate the precision of field sampling the percent relative standard deviation (% RSD) was calculated for each duplicate pair. Duplicates are two field samples collected at the same site as close as possible in time. The RSD is calculated by dividing the standard deviation by the mean. This value is then multiplied by 100 so the RSD can be expressed as a percentage. The % RSD is sometimes termed the coefficient of variation.

The % RSD and SD are calculated for each duplicate pair and presented in the tables below for the following parameters: total phosphorus, total persulfate nitrogen, nitrite-nitrate nitrogen, chlorophyll *a*, and dissolved oxygen. Where one of the duplicates was below detection limits, half of the detection limit was used to calculate the % RSD. If both duplicates were below detection limits, the % RSD and SD were not calculated. For total phosphorus analyzed using the spectrophotometric method and phaeopigments, most of the duplicate pairs were below detection limits. Where one of the duplicate TP samples was above detection limit, for comparison the duplicate sample below the detection limit was set to half the detection limit. The % RSD and SD were not calculated for phaeopigments because none of the duplicates were above detection limits.

Post calibration data supported good quality for field meter results. The duplicates for dissolved oxygen (D.O.) represent a comparison of field meter readings to wet chemistry analysis. Comparisons of the wet chemistry DO duplicates are also presented.

Analysis of field duplicates

SD: standard deviation
% RSD: percent relative standard deviation (SD/mean * 100)
NC = not calculated

Pooled standard deviation: $S_p = \sqrt{\sum D^2}/2m$

where D = difference between the two results
m = # of pairs of duplicates

Table A-2. Total Phosphorus (Spectrophotometric method)

Date	Station	Depth (meters)	Sample (ug/L)	Duplicate (ug/L)	SD*	%RSD*
5/16/96	3	10	4.0	< 3.0	1.8	64.3
6/4/96	2	0.03	< 3.0	< 3.0	NC	NC
6/20/96	1	0.03	< 3.0	< 3.0	NC	NC
7/18/96	4	10	< 3.0	< 3.0	NC	NC
8/15/96	2	20	< 3.0	< 3.0	NC	NC
9/9/96	3	20	< 3.0	< 3.0	NC	NC
10/3/96	4	0.03	< 3.0	< 3.0	NC	NC

Pooled standard deviation:	NC
Number where both samples were below detection:	6
Number that did not meet target of 15% RSD:	1

Table A-3. Total Phosphorus (ICP-MS method)

Date	Station	Depth (meters)	Sample (ug/L)	Duplicate (ug/L)	SD*	%RSD*
7/18/96	4	10	2.9	2.3	0.42	16.3
8/15/96	2	20	2.1	2.1	0.00	0.0
9/9/96	3	20	2.1	1.6	0.32	17.4

Pooled standard deviation:	0.31
Number that met target of 15% RSD:	1
Number that did not meet target of 15% but were < 20% RSD:	2

The % RSD for total phosphorus samples analyzed using the spectrophotometric method is available for only one duplicate pair because most duplicates were below reporting limits. With one exception duplicates were both reported below detection. This shows data consistency, but the quality and usefulness of the data are uncertain.

On July 18, August 15, and September 9, 1996 samples for total phosphorus were also analyzed using inductively coupled plasma/mass spectrometry (ICP-MS). The % RSDs for total phosphorus duplicates using the ICP-MS method are close to the target level and are considered acceptable. The total phosphorus results for the ICP-MS method will be used for reporting and data analysis in place of data from the spectrophotometric method for the dates they are available.

Table A-4. Total Persulfate Nitrogen

Date	Station	Depth (meters)	Sample (ug/L)	Duplicate (ug/L)	SD	%RSD*
5/16/96	3	10	66	65	0.71	1.08
6/4/96	2	0.03	82	80	1.41	1.75
6/20/96	1	0.03	62	55	4.95	8.46
7/18/96	4	10	13	< 10	5.66	62.9
8/15/96	2	20	62	60	1.41	2.32
9/9/96	3	20	52	57	3.54	6.49
10/3/96	4	0.03	41	41	0.00	0.00

Pooled standard deviation: 3.24
Number that met target of 15% RSD: 6
Number that did not meet target of 15% RSD: 1

Field data quality for total persulfate nitrogen is good. The target % RSD was not met in one case where one of the values was below the detection limit.

Table A-5. Nitrite/Nitrate-Nitrogen

Date	Station	Depth (meters)	Sample (ug/L)	Duplicate (ug/L)	SD	%RSD*
5/16/96	3	10	51	51	0.00	0.00
6/4/96	2	0.03	40	39	0.71	1.79
6/20/96	1	0.03	28	27	0.71	2.57
7/18/96	4	10	19	18	0.71	3.82
8/15/96	2	20	26	25	0.71	2.77
9/9/96	3	20	18	15	2.12	12.86
10/3/96	4	0.03	< 10	< 10	NC	NC

Pooled standard deviation: 1.04
Number that met target of 15% RSD: 7
Number that did not meet target of 15% RSD: 0

Field data quality for nitrite-nitrate nitrogen is very good.

Table A-6. Chlorophyll *a*

Date	Station	Depth (meters)	Sample (ug/L)	Duplicate (ug/L)	SD	%RSD*
5/16/96	3	10	1.10	1.10	0.00	0.00
6/4/96	2	0.03	< 0.50	< 0.50	NC	NC
6/20/96	1	0.03	< 0.50	< 0.50	NC	NC
7/18/96	4	10	0.63	0.68	0.04	5.40
8/15/96	2	20	1.10	0.97	0.09	8.88
9/9/96	3	20	1.40	1.20	0.14	10.9
10/3/96	4	0.03	0.56	< 0.50	0.22	54.1

Pooled standard deviation: 0.12
Number that met target of 15% RSD: 6
Number that did not meet target of 15% RSD: 1

Field data quality for chlorophyll *a* is good. The target % RSD was not met in one case where one of the pairs was below detection limit.

Table A-7. Dissolved Oxygen (Hydrolab and Winkler Comparison)

Date	Station	Depth (meters)	Hydrolab (mg/L)	Winkler (mg/L)	SD	%RSD*
6/4/96	1	0.03	9.93	10.18	0.18	1.76
6/4/96	2	10	12.01	10.99	0.72	6.27
6/4/96	3	10	11.67	11.74	0.05	0.42
6/4/96	4	0.03	10.32	10.49	0.12	1.16
6/20/96	2	0.03	10.19	9.40	0.56	5.70
6/20/96	3	20	11.77	11.45	0.23	1.95
6/20/96	4	10	11.49	11.05	0.31	2.76
7/18/96	1	0.03	8.81	9.15	0.24	2.68
7/18/96	3	10	10.01	8.40	1.14	12.37
7/18/96	4	20	11.22	11.10	0.08	0.76
8/15/96	1	0.03	9.01	8.74	0.19	2.15
8/15/96	2	20	10.72	10.23	0.35	3.31
8/15/96	3	0.03	9.05	8.94	0.08	0.86
8/15/96	4	20	10.65	10.87	0.16	1.45
9/9/96	1	0.03	9.46	9.35	0.08	0.83
9/9/96	2	10	10.64	9.55	0.77	7.63
9/9/96	3	10	10.21	9.69	0.37	3.70
9/9/96	4	20	10.34	9.85	0.35	3.43
10/3/96	1	0.03	9.41	9.60	0.13	1.41
10/3/96	2	10	9.63	9.75	0.08	0.88
10/3/96	3	0.03	9.57	9.75	0.13	1.32
10/3/96	4	20	9.81	9.95	0.10	1.00

Pooled standard deviation: 0.14

The % RSD comparing the results from the Hydrolab and Winkler titrations for dissolved oxygen were excellent and met the requirements of the QAPP.

Table A-8. Dissolved Oxygen (Winkler Comparisons)

Date	Station	Depth (meters)	Winkler #1 (mg/L)	Winkler # 2 (mg/L)	SD	%RSD*
5/16/96	2	0.03	10.72	10.72	0.07	0.66
6/4/96	1	0.03	10.25	10.10	0.11	1.04
6/20/96	2	0.03	9.15	9.65	0.35	3.76
10/3/96	1	0.03	9.60	9.65	0.04	0.37

Pooled standard deviation: 0.19

The % RSD for dissolved oxygen Winkler titrations was excellent and met the requirements of the QAPP.

Bias

Bias due to field sampling and handling techniques was estimated using equipment blank samples. After all sampling was completed the field sampling device was filled with deionized water, which was then bottled and sent to the laboratory and analyzed for total phosphorus, total persulfate nitrogen, nitrite-nitrate nitrogen, chlorophyll *a*, and phaeopigments.

With the exception of one total persulfate nitrogen value of 18 ug/L on September 9, 1996 (Table A-9) and the total phosphorus values using the ICP-MS method, all the field blanks were reported as below the limit of detection. This indicates that there was negligible bias due to field operations for most parameters. The results of the equipment blank for total persulfate nitrogen will be taken into consideration during data analysis, but probably had negligible effect on results.

The field blanks for total phosphorus using the ICP-MS method ranged from 1.1 to 1.2 ug\L. On September 9, 1996 a blind lab blank (with deionized water) was submitted to the laboratory for total phosphorus testing using the ICP-MS method. The result was 0.64 ug\L. Some evidence of phosphorus in the equipment blank using the ICP-MS method may be due to phosphorus in the deionized water or contamination from the field equipment.

Table A-9. Results of Laboratory Analysis of Equipment Blanks.

Date	TP-Spect. ug\L	TP (ICP-MS) ug\L	TPN ug\L	NO3\2-N ug\L	Chloro *a* ug\L	Phaeo *a* ug/L
5/16/96	< 3.0	n\a	< 10	< 10	< 0.5	< 0.5
6/4/96	< 3.0	n\a	< 10	< 10	< 0.5	< 0.5
6/20/96	< 3.0	n\a	< 10	< 10	< 0.5	< 0.5
7/18/96	< 3.0	1.1	< 10	< 10	< 0.5	< 0.5
8/15/96	< 3.0	1.2	< 10	< 10	< 0.5	< 0.5
9/9/96	< 3.0	1.2	18	< 10	< 0.5	< 0.5
10/3/96	< 3.0	n\a	< 10	< 10	< 0.5	< 0.5

In Appendix B a "J" qualifier was used for chlorophyll *a* and phaeopigment samples collected on May 16, 1996. These samples were incorrectly acidified during analysis. An unacidified to acidified ratio was calculated for these samples and compared to the same ratio for samples acidified correctly as stated in the method. It was determined that the incorrect acidification was not detrimental to the data. Therefore, the data are not being rejected but are reported as estimates. The "J" qualifier was taken into consideration during analysis of the chlorophyll and phaeopigment data.

All data reported are considered usable, subject to laboratory quality assurance findings and the qualifications provided.

Appendix B:
1996 Lake Chelan Field Data

(paired data represent field duplicates)

Station	Date	Depth meters	Temp °C	Cond umho/cm 1	pH	D.O. meter mg/L	D.O. Winkler mg/L		D.O. % Sat. 2	Secchi meters
1	5/16/96	0.3	#	#	#	#	10.6			(at bottom) 5.2
2	5/16/96	0.3	13.5	#	#	#	10.8	10.7	107%	11.3
2	5/16/96	10	9.4	#	#	#				
2	5/16/96	20	7.8	#	#	#				
3	5/16/96	0.3	12.4	#	#	#				12.0
3	5/16/96	10	11.0	#	#	#				
3	5/16/96	20	8.1	#	#	#	11.3		100%	
3	5/16/96	30	7.3	#	#	#				
3	5/16/96	40	5.6	#	#	#				
3	5/16/96	47	5.0	#	#	#				
4	5/16/96	0.3	11.3	#	#	#				10.0
4	5/16/96	10	9.2	#	#	#				
4	5/16/96	20	8.3	#	#	#				
4	5/16/96	30	7.1	#	#	#				
4	5/16/96	40	5.6	#	#	#				
4	5/16/96	49	5.1	#	#	#				
1	6/4/96	0.3	15.9	56	7.7	9.9	10.3	10.1	107%	(at bottom) 5.3
2	6/4/96	0.3	15.1	60	7.6	10.4			108%	9.4
2	6/4/96	10	10.8	57	7.8	12.0	11.0		103%	
2	6/4/96	20	9.0	59	7.9	12.0			108%	
3	6/4/96	0.3	14.5	60	7.7	10.4			106%	9.1
3	6/4/96	10	10.6	58	8.0	11.7	11.7		109%	
3	6/4/96	20	9.6	58	7.9	11.9			109%	
3	6/4/96	30	8.3	57	7.9	12.0			106%	
3	6/4/96	40	5.2	57	8.8	11.1			91%	
4	6/4/96	0.3	14.7	60	7.8	10.3	10.5		108%	10.0
4	6/4/96	10	10.3	59	8.0	11.6			108%	
4	6/4/96	20	9.2	58	8.0	11.7			106%	
4	6/4/96	30	8.3	56	7.9	11.8			104%	
4	6/4/96	40	6.6	56	7.8	11.6			98%	
4	6/4/96	50	5.5	57	7.7	11.3			93%	
1	6/20/96	0.3	17.1	62	7.8	10.1			109%	(at bottom) 6.2
2	6/20/96	0.3	17.0	62	7.8	10.2	9.2	9.7	102%	11.0
2	6/20/96	10	12.2	60	7.8	11.7			113%	
2	6/20/96	20	11.2	59	7.9	12.2			116%	
2	6/20/96	30	8.9	59	7.9	12.1			109%	
3	6/20/96	0.3	17.0	62	7.8	10.1			109%	11.0
3	6/20/96	10	12.2	59	7.9	11.5			112%	
3	6/20/96	20	11.2	59	7.9	11.8	11.5		109%	
3	6/20/96	30	9.8	59	7.9	12.2			112%	
3	6/20/96	40	7.5	58	7.8	11.6			101%	
3	6/20/96	50	5.8	58	7.7	10.7			89%	
4	6/20/96	0.3	15.4	61	8.1	10.1			105%	10.3
4	6/20/96	10	11.6	59	8.1	11.5	11.1		106%	
4	6/20/96	20	10.9	59	8.1	11.6			109%	
4	6/20/96	30	9.3	59	8.0	11.9			108%	
4	6/20/96	40	6.7	58	7.9	11.3			96%	
4	6/20/96	50	5.6	58	7.8	11.0			91%	

1: Specific conductance at 25° C

2: %DO Sat.is calculated using the following formula:DO reading/(EXP(-139.34411+(157570.1/(T+273.15))-00/(T+273.15)^4))*(1-0.027*ELEV/760)). Where T=temperature and ELEV=1100ft..

#: 5/16/96 data lost due to equipment failure.

Appendix B:
1996 Lake Chelan Field Data

(paired data represent field duplicates)

Station	Date	Depth meters	Temp °C	Cond umho/cm 1	pH	D.O. meter mg/L	D.O. Winkler mg/L	D.O. % Sat. 2	Secchi meters
1	7/18/96	0.3	20.1	65	7.5	8.8	9.2	106%	(on bottom) 8.0
2	7/18/96	0.3	19.8	66	7.6	9.1		104%	13.2
2	7/18/96	10	15.7	63	7.9	10.7		112%	
2	7/18/96	20	12.3	62	8.2	11.4		111%	
2	7/18/96	25	11.1	62	7.9	11.2		106%	
3	7/18/96	0.3	18.2	65	7.7	8.7		96%	15.5
3	7/18/96	10	16.2	63	7.7	10.0	8.4	89%	
3	7/18/96	20	13.2	62	8.0	11.0		109%	
3	7/18/96	30	11.1	60	8.0	11.2		106%	
3	7/18/96	40	7.9	62	7.7	10.9		96%	
3	7/18/96	49	6.0	59	7.4	10.1		84%	
4	7/18/96	0.3	17.2	65	7.8	9.3		101%	14.3
4	7/18/96	10	15.3	63	7.8	10.0		104%	
4	7/18/96	20	12.3	63	8.1	11.2	11.1	108%	
4	7/18/96	30	11.1	61	7.8	10.8		102%	
4	7/18/96	40	8.8	61	7.8	11.1		99%	
4	7/18/96	49	5.6	61	7.6	10.3		85%	
1	8/15/96	0.3	21.8	52	7.7	9.0	8.7	103%	(at bottom) 7.0
2	8/15/96	0.3	21.2	52	7.8	9.1		107%	13.0
2	8/15/96	10	16.7	50	8.1	10.7	10.2	109%	
2	8/15/96	20	14.0	49	8.0	11.2		113%	
3	8/15/96	0.3	21.0	52	7.8	9.1	8.9	104%	12.0
3	8/15/96	10	16.9	50	8.1	10.5		113%	
3	8/15/96	20	14.2	49	8.1	11.2		114%	
3	8/15/96	30	12.3	49	7.7	11.3		110%	
3	8/15/96	40	8.6	49	7.4	11.0		98%	
3	8/15/96	47	6.0	49	7.4	10.4		87%	
4	8/15/96	0.3	20.4	52	7.8	9.3		107%	12.2
4	8/15/96	10	18.8	51	7.9	9.8		109%	
4	8/15/96	20	14.2	48	7.8	10.7	10.9	111%	
4	8/15/96	30	12.2	49	7.8	11.2		109%	
4	8/15/96	40	8.6	49	7.5	11.1		99%	
4	8/15/96	47	6.4	49	7.2	10.7		90%	
1	9/9/96	0.3	18.9	64	7.5	9.5	9.4	105%	(at bottom) 7.8
2	9/9/96	0.3	18.6	63	7.5	9.8		109%	11.2
2	9/9/96	10	17.5	63	7.7	10.6	9.6	104%	
2	9/9/96	20	15.7	62	7.6	11.0		115%	
2	9/9/96	25	14.2	61	7.5	10.8		110%	
3	9/9/96	0.3	18.2	64	7.5	9.8		108%	11.3
3	9/9/96	10	17.8	64	7.6	10.2	9.7	106%	
3	9/9/96	20	16.2	62	7.6	10.8		114%	
3	9/9/96	30	12.8	61	7.5	11.2		110%	
3	9/9/96	40	8.3	61	7.4	10.9		96%	
3	9/9/96	50	6.6	61	7.3	10.4		88%	
4	9/9/96	0.3	17.7	66	7.8	9.1		99%	11.7
4	9/9/96	10	17.8	66	7.6	9.6		105%	
4	9/9/96	20	15.8	63	7.6	10.3	9.9	104%	
4	9/9/96	30	13.3	63	7.5	10.9		108%	
4	9/9/96	40	8.8	62	7.4	10.9		98%	
4	9/9/96	50	6.6	61	7.3	10.8		92%	

1: Specific conductance at 25° C

2: %DO Sat.is calculated using the following formula:DO reading/(EXP(-139.34411+(157570.1/(T+273.15))-00/(T+273.15)^4))*(1-0.027*ELEV/760)). Where T=temperature and ELEV=1100ft..

Appendix B:
1996 Lake Chelan Field Data

(paired data represent field duplicates)

Station	Date	Depth meters	Temp °C	Cond umho/cm 1	pH	D.O. meter mg/L	D.O. Winkler mg/L		D.O. % Sat. 2	Secchi meters
1	10/3/96	0.3	16.6	44	7.6	9.4	9.6	9.7	103%	(at bottom) 6.7
2	10/3/96	0.3	16.6	45	7.7	9.5			101%	14.4
2	10/3/96	10	16.5	45	7.7	9.6	9.8		104%	
2	10/3/96	20	15.0	43	7.5	9.9			102%	
2	10/3/96	25	14.1	43	7.4	9.9			100%	
3	10/3/96	0.3	16.4	45	7.8	9.6	9.8		104%	13.7
3	10/3/96	10	16.4	45	7.8	9.6			102%	
3	10/3/96	20	14.9	43	7.6	9.8			101%	
3	10/3/96	30	12.3	43	7.3	10.2			99%	
3	10/3/96	40	9.2	43	7.1	10.3			93%	
3	10/3/96	50	7.2	44	7.0	10.0			86%	
4	10/3/96	0.3	16.2	45	7.9	9.5			101%	15.8
4	10/3/96	10	16.1	44	7.9	9.7			102%	
4	10/3/96	20	14.7	43	7.6	9.8	10.0		103%	
4	10/3/96	30	12.8	43	7.4	10.1			99%	
4	10/3/96	40	9.3	43	7.2	10.4			94%	
4	10/3/96	50	6.8	44	7.0	10.1			86%	

1: Specific conductance at 25° C

2: %DO Sat.is calculated using the following formula:DO reading/(EXP(-139.34411+(157570.1/(T+273.15))-00/(T+273.15)^4))*(1-0.027*ELEV/760)). Where T=temperature and ELEV=1100ft..

Appendix C:
1996 Lake Chelan Laboratory Data

(paired data represent field duplicates)

Station	Date	Depth meters	Total Phosphorus ug/L Spectro.		ICP-MS		Nitrite\nitrate Nitrogen ug/L		Total Nitrogen ug/L		Chlorophyll a ug\L		Pheopigments ug/L	
1	5/16/96	0.3	U 3.0				47		59		J 1.00		UJ 0.50	
2	5/16/96	0.3	3.4				45		64		J 0.76		UJ 0.50	
2	5/16/96	10	U 3.0				48		65		J 1.10		UJ 0.50	
2	5/16/96	20	U 3.0				53		71		J 1.40		UJ 0.50	
3	5/16/96	0.3	U 3.0				49		67		J 0.94		UJ 0.50	
3	5/16/96	10	4.0	U 3.0			51	51	66	65	J 1.10	J 1.10	UJ 0.50	UJ 0.50
3	5/16/96	20	U 3.0				33		72		J 1.20		UJ 0.50	
4	5/16/96	0.3	U 3.0				54		74		J 1.60		UJ 0.50	
4	5/16/96	10	U 3.0				55		73		J 3.10		UJ 0.50	
4	5/16/96	20	U 3.0				62		72		UJ 0.50		J 1.60	
1	6/4/96	0.3	U 3.0				37		85		U 0.50		U 0.50	
2	6/4/96	0.3	U 3.0	U 3.0			40	39	82	80	U 0.50	U 0.50	U 0.50	U 0.50
2	6/4/96	10	U 3.0				39		79		U 0.50		U 0.50	
2	6/4/96	20	U 3.0				42		76		0.72		U 0.50	
3	6/4/96	0.3	U 3.0				40		83		U 0.50		U 0.50	
3	6/4/96	10	U 3.0				40		112		0.95		U 0.50	
3	6/4/96	20	U 3.0				41		75		1.00		0.52	
4	6/4/96	0.3	U 3.0				42		78		U 0.50		U 0.50	
4	6/4/96	10	U 3.0				41		80		2.00		1.40	
4	6/4/96	20	U 3.0				44		113		0.99		1.10	
1	6/20/96	0.3	U 3.0	U 3.0			28	27	62	55	U 0.50	U 0.50	U 0.50	U 0.50
2	6/20/96	0.3	U 3.0				35		59		U 0.50		U 0.50	
2	6/20/96	10	U 3.0				38		56		0.52		0.52	
2	6/20/96	20	U 3.0				36		61		1.20		U 0.50	
3	6/20/96	0.3	U 3.0				31		51		U 0.50		U 0.50	
3	6/20/96	10	U 3.0				36		62		0.86		U 0.50	
3	6/20/96	20	U 3.0				40		59		0.75		1.00	
4	6/20/96	0.3	U 3.0				32		62		0.58		U 0.50	
4	6/20/96	10	U 3.0				38		59		0.75		U 0.50	
4	6/20/96	20	U 3.0				47		77		1.50		1.00	
1	7/18/96	0.3	U 3.0			2.2	10		U 10		0.54		U 0.50	
2	7/18/96	0.3	U 3.0			1.9	16		U 10		0.55		U 0.50	
2	7/18/96	10	U 3.0			2.3	U 10		U 10		0.65		U 0.50	
2	7/18/96	20	3.2			2.5	U 10		U 10		1.20		U 0.50	
3	7/18/96	0.3	U 3.0			2.9	24		U 10		0.49		U 0.50	
3	7/18/96	10	U 3.0			2.5	23		12		0.79		U 0.50	
3	7/18/96	20	U 3.0			2.6	16		U 10		0.89		U 0.50	
4	7/18/96	0.3	U 3.0			2.1	22		10		0.57		U 0.50	
4	7/18/96	10	U 3.0	U 3.0	2.3	2.9	18	19	U 10	13	0.63	0.68	U 0.50	U 0.50
4	7/18/96	20	U 3.0			2.4	15		U 10		1.30		U 0.50	
1	8/15/96	0.3	U 3.0			1.9	18		46		U 0.50		U 0.50	
2	8/15/96	0.3	U 3.0			1.5	20		42		U 0.50		U 0.50	
2	8/15/96	10	U 3.0			2.3	22		47		0.66		U 0.50	
2	8/15/96	20	U 3.0	U 3.0	2.1	2.1	26	25	60	62	1.10	0.97	U 0.50	U 0.50
3	8/15/96	0.3	U 3.0			2.0	21		51		U 0.50		U 0.50	
3	8/15/96	10	U 3.0			2.3	19		58		0.81		U 0.50	
3	8/15/96	20	U 3.0			2.5	21		62		1.10		U 0.50	
4	8/15/96	0.3	U 3.0			1.9	22		51		U 0.50		U 0.50	
4	8/15/96	10	U 3.0			2.2	23		59		0.62		U 0.50	
4	8/15/96	20	U 3.0			2.2	33		58		0.87		U 0.50	

Appendix C:
1996 Lake Chelan Laboratory Data

(paired data represent field duplicates)

Station	Date	Depth meters	Total Phosphorus ug/L Spectro.		ICP-MS		Nitrite\nitrate Nitrogen ug/L		Total Nitrogen ug/L		Chlorophyll a ug\L		Pheopigments ug/L	
1	9/9/96	0.3	U 3.0			1.7	U 10		58		0.63		U 0.50	
2	9/9/96	0.3	U 3.0			1.4	12		39		0.74		U 0.50	
2	9/9/96	10	U 3.0			1.7	U 10		55		0.91		U 0.50	
2	9/9/96	20	U 3.0			2.3	18		56		1.40		0.77	
3	9/9/96	0.3	U 3.0			1.2	U 10		43		0.59		U 0.50	
3	9/9/96	10	U 3.0			1.7	U 10		46		1.30		U 0.50	
3	9/9/96	20	U 3.0	U 3.0	2.1	1.6	18	15	52	57	1.40	1.20	U 0.50	0.82
4	9/9/96	0.3	U 3.0			1.8	U 10		44		0.76		U 0.50	
4	9/9/96	10	U 3.0			1.7	12		46		1.20		U 0.50	
4	9/9/96	20	U 3.0			1.6	19		54		1.10		U 0.50	
1	10/3/96	0.3	U 3.0				U 10		41		0.59		U 0.50	
2	10/3/96	0.3	U 3.0				U 10		37		0.65		U 0.50	
2	10/3/96	10	U 3.0				U 10		35		0.80		U 0.50	
2	10/3/96	20	U 3.0				21		46		1.20		U 0.50	
3	10/3/96	0.3	U 3.0				U 10		37		0.70		U 0.50	
3	10/3/96	10	U 3.0				U 10		39		U 0.50		0.56	
3	10/3/96	20	U 3.0				18		46		1.10		0.56	
4	10/3/96	0.3	U 3.0	U 3.0			U 10	U 10	41	41	0.56	U 0.50	U 0.50	U 0.50
4	10/3/96	10	U 3.0				U 10		44		0.53		U 0.50	
4	10/3/96	20	U 3.0				17		55		0.69		0.57	

U: less than the result noted.

J: 5/16/96 Samples incorrectly acidified during analysis. An unacidified to acidfied ratio was calculated for these samples and compared to the same ratio for samples acidified correctly as stated in the method. It was determined by the lab that the incorrect acidification was not detrimental to the data. Therefore, the data are not being rejected but reported as an estimate.

Volume-Weighted Mean Epilimnetic Total Phosphorus Concentration for Wapato Basin of Lake Chelan in 1996

Calculated Using Censored Spectrophotometric Total Phosphorus Data and ICP-MS Data Where Available.

Volume-weighted mean is: the summation across all strata of (Wh*Xh)
Wh=volume of stratum h/total volume of all strata
Xh= mean value of stratum h across all sample events

Station	Depth	Volume	Wh	Xh	V-W Mean (ug/L)
1	0.3	9.480E+06	1.205E-02	2.54	0.03
2	0.3	4.878E+07	6.202E-02	2.46	0.15
2	10	9.417E+07	1.197E-01	2.61	0.31
2	20	7.494E+07	9.527E-02	2.70	0.26
3	0.3	3.750E+07	4.767E-02	2.59	0.12
3	10	7.499E+07	9.534E-02	2.78	0.27
3	20	1.125E+08	1.430E-01	2.70	0.39
4	0.3	5.571E+07	7.082E-02	2.54	0.18
4	10	1.114E+08	1.416E-01	2.64	0.37
4	20	1.671E+08	2.125E-01	2.60	0.55

Volume-weighted mean ≤ 2.63 ug/L

Volume-weighted (standard error)^2 is: the summation across all strata of (Wh^2 * Sh^2)/nh
Wh^2= wh squared
sh^2= variance in stratum h
nh=number of observations in stratum h

Station	Depth	Wh^2	Sh^2	nh	[(Wh2*Sh2)/nh]
1	0.3	0.00014526	0.35	7	7.18E-06
2	0.3	0.00384615	0.69	7	3.81E-04
2	10	0.01433142	0.27	7	5.56E-04
2	20	0.00907597	0.15	7	2.01E-04
3	0.3	0.00227235	0.51	7	1.65E-04
3	10	0.00908942	0.50	7	6.52E-04
3	20	0.02045119	0.20	7	5.94E-04
4	0.3	0.00501579	0.33	7	2.39E-04
4	10	0.02006314	0.27	7	7.63E-04
4	20	0.04514207	0.31	7	1.98E-03

(standard error)^2= 0.005534
standard error = 0.074391

One-sided 95% confidence interval for the mean = Mean + t(α,v) * standard error
α =0.05
v =degrees of freedom= 69 (total # of samples measured over all strata - 1)
one -sided t-stat for (0.05, 69)=1.6675

2.63+1.6675 * 0.07439= 2.75

Volume-weighted upper bound (one-sided) 95% confidence interval for the mean = 2.75 ug/L

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