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Lake Campbell and Lake Erie Total Phosphorus Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

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Lake Campbell and Lake Erie Total Phosphorus Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

by
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March 2007

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Abstract

The Washington State Department of Ecology (Ecology) is required, under Section 303(d) of the federal Clean Water Act, to develop a list of impaired waters within Washington State. For waters included on the list, a Total Maximum Daily Load (TMDL) study is required for analysis of the pollutants. Following the TMDL study and subsequent clean-up plan implementation activities, effectiveness monitoring is required to ensure water quality improvements have occurred.

Lake Campbell and Lake Erie were listed by Washington State under Section 303(d) of the Clean Water Act for non-attainment of beneficial uses based on Phase I and Phase II restoration projects. The parameter of concern identified for both lakes was total phosphorus. TMDL studies based on lake restoration plans for both Lake Campbell and Lake Erie were submitted by Ecology and approved by the Environmental Protection Agency in 1997.

The objectives of this study were:

- Determine if past restoration treatments have been effective in restoring Lake Campbell and Lake Erie to their designated uses.
- Determine if current phosphorus concentrations are consistent with the load allocations set in the TMDL.

This study found the total phosphorus results for both Lake Campbell and Lake Erie indicate restoration activities have been successful and the lakes are in compliance with the TMDL goals set for total phosphorus. However, the TMDL goals for chlorophyll-a were not met during the course of this study.

Acknowledgements

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- Dave Hallock, for doing all the really hard work.
- Craig Homan, for assisting with the field work.
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- The Manchester Laboratory who managed the samples and produced high quality results.

What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act Requirements

The Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, every state has its own water quality standards designed to protect, restore and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of waterbodies - lakes, rivers, streams and marine waters - that do not meet water quality standards. This list is called the 303(d) list or water quality assessment. To develop the list, Ecology compiles its own water quality data along with data submitted by local, state and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the 303(d) list. Data are evaluated using Ecology Water Quality Program listing policy WQP 1-11.

TMDL Process Overview

The Clean Water Act requires that a Total Maximum Daily Load or TMDL be developed for each of the waterbodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. Then the local community works with Ecology to develop a strategy to control the pollution and a monitoring plan to assess effectiveness of the water quality improvement activities.

Elements Required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a discrete source (referred to as a point source) such as a municipal or industrial facility’s discharge pipe, that facility’s share of the loading capacity is called a wasteload allocation. If it comes from a set of diffuse sources (referred to as a nonpoint source) such as general urban, residential, or farm runoff, the cumulative share is called a load allocation.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety and any reserve capacity must be equal to or less than the loading capacity.

Water Quality Assessment / Categories 1-5

The 303(d) list identifies polluted waters in Washington. The Water Quality Assessment is a list that tells a more complete story about the condition of Washington's water. This list divides waterbodies into one of five categories:

- Category 1 – Meets tested standards for clean water.
- Category 2 – Waters of concern.
- Category 3 – No data available.
- Category 4 – Polluted waters that do not require a TMDL since the problems are being solved in one of three ways:
    - 4a – Already has an approved TMDL that is being implemented.
    - 4b – Has a pollution control plan in place that should solve the problem.
    - 4c – Impaired by a non-pollutant such as low water flow, non-native plant species, etc.
- Category 5 – Polluted waters that require a TMDL – also known as the 303(d) list.

TMDL Analyses: Loading Capacity

Identification of the pollution loading capacity for a waterbody is an important step in developing a TMDL. EPA defines the loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (EPA, 2001). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a waterbody into compliance with standards. The portion of the waterbody's loading capacity assigned to a particular source is a load or wasteload allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

Background

What is Effectiveness Monitoring?

An effectiveness monitoring evaluation determines if the interim targets and water quality standards have been met. This is an essential component of any restoration or implementation activity since it measures to what extent the work performed or recommended has attained the waterbody restoration objectives or goals.

The benefits of effectiveness evaluation include:

- More efficient allocation of funding.
- Optimization in planning/decision-making (i.e., program benefits).
- Watershed recovery status (i.e., how much restoration has been achieved, how much more effort is required).
- Adaptive management or technical feedback to refine restoration treatment design and implementation.

The effectiveness evaluation addresses four fundamental questions with respect to restoration or implementation activity:

1. Is the restoration or implementation work achieving the desired objectives or goals (significant improvement)?
2. How can restoration or implementation techniques be improved?
3. Is the improvement sustainable?
4. How can the cost-effectiveness of the work be improved?

Study area

Lake Campbell and Lake Erie are located on Fidalgo Island in Skagit County, Washington in the same 1471 hectare (3635 acres) watershed (Figure 1). Flow to the lakes consists primarily of direct runoff and shallow subsurface seepage. Both are shallow kettle lakes of glacial origin and generally remain unstratified throughout the year.

Lake Erie has a maximum depth of 3.6 meters and a surface area of 45 hectares (111 acres). It receives runoff from several small drainageways, all on a seasonal intermittent basis, and discharges to Lake Campbell.

Lake Campbell has a maximum depth of 6.7 meters and a surface area of 166 hectares (410 acres). The lake receives overflow from Lake Erie, Whistle Lake, and Trafton Lake as well as input from intermittent streams. Lake Campbell then flows via Campbell Creek into Puget Sound.

Land use in the watershed is mixed rural/residential, with homes and pasture land along the shores of both lakes. There are 61 homes located on the shoreline of Lake Campbell and 38 homes on the shoreline of Lake Erie. Between 1985 and 2004, a total of 48 new homes were built in the Lake Erie watershed and 104 homes were added in the Lake Campbell watershed.

The predominant forest type is mixed coniferous. The watershed lies in the Olympic Mountain rainshadow and receives approximately 66 centimeters (26 inches) of rain annually.

Lake Campbell and Lake Erie are located in unincorporated Skagit County. The Samish Indian Nation owns property in the Lake Campbell watershed.

Next Page:

Figure 1. Topographic map of Lake Campbell and Lake Erie showing watershed boundaries.


LAKE ERIE & CAMPBELL WATERSHEDS
DEVELOPMENT
N
W
E
S
1 inch equals 2,000 feet
0
0.125
0.25
0.5
0.75
1
Miles
SKAGIT COUNTY
GIS
4/1/2004
JDG188
Watershed of Lakes
Lake Erie
Lake Campbell
Heart Lake
Pass Lake
Whistle Lake
BURROWS BAY
SIMILK BAY
FIDALGO
ISLAND
Mt Erie
Sugarloaf
Trafton Lake
Mud Lake
Ginnett Hill
Rodger Bluff
Rodger Hill
Mount Erie
Devils Elbow
Dewey
Alexander Beach
Edith Point
Rosario Beach
Rosario Head
Bowman Bay
Bowman Hill
Yokeko Point
Deception Pass
Lighthouse Point
Strawberry Island
SKAGIT ISLAND
Cougar Gap
Boat Ramp

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Pollutants Addressed By This TMDL

The TMDLs for Lake Campbell and Lake Erie addressed total phosphorus as the parameter of concern. High levels of phosphorus in a lake can lead to excessive algal and macrophyte growth. Subsequent decomposition of this plant material could cause dissolved oxygen levels to decrease and potentially cause fish kills as well as adversely affect the beneficial uses (such as swimming, fishing and aesthetic enjoyment) of the waterbody.

Watershed Implementation or Restoration Activities

Implementation Studies

In 1981, a Phase I Diagnostic Study (Entranco, 1983) was initiated to determine the cause of water quality problems in both lakes and to recommend a restoration plan. This study concluded that both lakes could be classified as eutrophic and identified phosphorus as the nutrient controlling algal growth.

The Phase I Diagnostic Study recommended four main elements for improving water quality:

- Alum treatment.
- Mechanical plant harvesting.
- Watershed management plan.
- Performance monitoring.

In 1985, as part of the restoration plan developed in the Phase I Diagnostic Study, both lakes received an alum treatment to reduce phosphorus levels. Harvesting of the aquatic macrophytes followed in the summer of 1986.

In 1986, Entranco (1987) conducted post- alum treatment monitoring on both Lake Campbell and Lake Erie. In Lake Campbell, mean summer total phosphorus concentrations were reduced by 43% (from 49 µg/L to 28 µg/L), chlorophyll-a concentrations were reduced by 44% (from 18 µg/L to 10 µg/L) and Secchi depth visibility increased by at least 16% (from 1.6 meters to 1.8 meters).

Entranco's monitoring also showed improvements in water quality for Lake Erie. Mean summer total phosphorus concentrations were reduced by 77% (from 115 µg/L to 26 µg/L), chlorophyll-a concentrations were reduced by 91% (from 58 µg/L to 5 µg/L) and Secchi depth visibility increased by at least 47% (from 1.7 meters to more than 2.5 meters).

Prior to restoration activities, historic data showed mean summer chlorophyll-a to total phosphorus ratios of 0.36 for Lake Campbell and 0.22 for Lake Erie. After the alum treatment and plant harvesting at both lakes, these ratios were 0.31 for Lake Campbell and 0.22 for Lake Erie. A typical lake ratio for chlorophyll-a to total phosphorus is 0.35.

The Phase I Watershed Management Plan identified six areas which could impact lake water quality:

- Land use and development density.
- Streambank and wetland protection.
- Surface drainage and erosion control practices.
- Forestry practices.
- On-site wastewater treatment.
- Community education.

Over the years, Skagit County has developed ordinances which address the first five areas identified in the watershed plan. The Skagit Conservation District is currently developing a lake stewardship program but no educational activities are planned for Lake Campbell and Lake Erie at this time.

Water Quality Standards and Beneficial Uses

In the “Water Quality Standards for Surface Waters of the State of Washington” (Chapter 173-201A WAC), Lake Campbell and Lake Erie are listed as lake class waterways. This classification assumes the waterbody will meet or exceed criteria for water supply, stock watering, fish migration and propagation, wildlife habitat and recreation. The following are the water quality criteria for lakes:

- Temperature - No measurable change from natural conditions.
- Dissolved Oxygen - No measurable decrease from natural conditions.
- Fecal Coliform – Geometric mean less than 50 cfu/100 mL and no more than 10% of the samples obtained for determining the geometric mean exceed 100 cfu/100mL.
- pH - No measurable change from natural conditions.
- Turbidity - Not exceed 5 NTU over background conditions.

Recommended values for total phosphorus were not developed for Washington lakes until 1997. Mean summer total phosphorus levels of 26.0 µg/L for Lake Erie and 28.0 µg/L for Lake Campbell were set in the TMDL approved in July, 1997.

The main beneficial uses to be protected by the TMDLs for Lake Campbell and Lake Erie were recreation (including primary contact recreation), sport fishing, boating and aesthetic enjoyment. Total phosphorus was identified as the parameter of concern. Table 1 identifies the waterbodies listing:

Table 1. Study area waterbodies on the 2004 303(d) list for total phosphorus.

Waterbody	Listing ID	Township	Range	Section
Lake Campbell	22557	34N	01E	13
Lake Erie	6335	34N	01E	11

Lake Campbell and Lake Erie have other water quality issues that will not be addressed in this study. Table 2 identifies the following Category 4c listings for parameters other than total phosphorus that occur in the study area, but are not addressed in this report.

Table 2. Additional 303(d) listings not addressed by this report.

Waterbody	Parameter	Listing ID	Township	Range	Section
Lake Campbell	Invasive Exotic Species	4655	34N	01E	13
Lake Erie	Invasive Exotic Species	4657	34N	01E	11

The invasive exotic plant discovered in 2000 at both lakes was identified as *Myriophyllum spicatum* (Eurasian water-milfoil). In 2001 the Campbell and Erie lake community voted to establish a Lake Management District for a ten year period with the purpose of eradicating the *Myriophyllum spicatum* (Eurasian water-milfoil) plant community from both lakes. The eradication strategy included application of the herbicide SONAR© at Lake Erie and 2,4,-D at Lake Campbell. There are also plans to stock grass carp at both lakes.

Goals and Objectives

Project Goals

The goal of this study was to determine if past restoration treatments have been effective in restoring Lake Campbell and Lake Erie to their designated uses and whether current phosphorus concentrations are consistent with the load allocations set in the TMDL. This study is not intended to recalculate a phosphorus budget for both lakes.

Study Objectives

The objectives of this study were:

- Review historic documentation regarding the TMDL.
- Compile data generated after implementation of the TMDL.
- Review data for representativeness, comparability, and quality.
- Perform monitoring using field and analytical procedures discussed herein to obtain additional data needed to determine the effectiveness of the TMDL.
- Analyze and interpret data to determine effectiveness of TMDL.
- Make recommendations based on evidence gathered.
- Produce final effectiveness monitoring report (technical memorandum) to Ecology's Water Quality Program.

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Methods

Sampling Design

Lake profiles and water samples for lab analysis were collected at the deepest spot at each lake. See Appendix B for a detailed map of the sampling locations. Sampling occurred monthly from August 2004 to August 2005. Lake Campbell and Lake Erie are very similar to each other in that both lakes are shallow and typically don't form stable thermal stratification during the summer. Because of this relative uniformity, one sampling station at the deepest point of each lake provided representative data.

Water samples were collected using a Kemmerer water sampler. At the deep spot of the lake, three water samples were collected at three different depths (depending on the depth of the epilimnion and/or hypolimnion if the lake was stratified) and composited for analysis. Vertically, composites ensured the epilimnion lake samples were representative of the entire water column. The hypolimnion is not typically as well mixed as the epilimnion. Composite samples are a compromise and potentially could indicate whether significant internal nutrient release is occurring, but may not be adequate for internal nutrient load calculations.

Laboratory analyzed parameters were total phosphorus, orthophosphorus, total persulfate nitrogen, chlorophyll-a and turbidity. When the lake was stratified, nutrients (total phosphorus, orthophosphorus and total persulfate nitrogen) were analyzed in epilimnion and hypolimnion composite samples. All remaining parameters were analyzed in epilimnion composite samples only.

Using a HydroLab ® DataSonde 4a multiparameter probe, a monthly lake profile was completed for each lake. Field measured parameters included temperature, conductivity, dissolved oxygen, and pH. Water clarity was measured using a Secchi disk. Secchi depth and chlorophyll measurements were used to assess algal growth.

Field Procedures

Standard Ecology protocols (Ward, 2001) were used to collect, preserve, and ship samples to Manchester Environmental Lab (MEL) for analysis. In addition, other field protocols as described in Bell-McKinnon (2002) and Hallock (1995) were followed.

Field meters were maintained and calibrated according to manufacturer's instructions.

Laboratory Procedures

MEL conducts laboratory analyses following Standard Operating Procedures (SOPs) and other guidance documents (Ecology, 2001 and Ecology, 2005). Methods for constituents are listed in Table 3.

Table 3. Laboratory Analytical Methods.

Analyte	Sample Fraction	Sample Container (mL)	Method	Reference [a]	Reporting Limit	Holding Time (days)
Chlorophyll-a	Filterable	1000 brown	Fluorometric	SM10200H	0.05 mg L^{-1}	1 to filtration, 28 after filtration
Turbidity	Total	500 clear	Nephelometric	EPA180.1	0.5 NTU	2
Orthophosphate	Dissolved	125 amber	Automated Ascorbic acid	SM4500PG	0.003 mg L^{-1}	2
Total Nitrogen	Total	125 clear	Persulfate digestion, cadmium reduction	SM4500N B	0.025 mg L^{-1}	28
Total Phosphorus	Total	60 clear	ICP	EPA 200.8M	0.001 mg L^{-1}	28

[a] SM=Standard Methods (APHA, 1998); EPA=Environmental Protection Agency (EPA, 1983)

TMDL Summary

There are no point sources discharging into either Lake Campbell or Lake Erie. The potential non-point sources are on-site septic systems, agricultural run-off and residential use of fertilizers.

In 1981, a Phase I Diagnostic Study (Entranco, 1983) identified phosphorus as the nutrient controlling algal growth; sediment phosphorus (internal loading) represented the most controllable source of phosphorus to both lakes. A summer rise in total phosphorus for both Lake Campbell and Lake Erie occurred when external nutrient loading was minimal, indicating that internal supplies for phosphorus were responsible for the summer algal blooms (Entranco, 1987).

In August, 1992, TMDLs were written for both Lake Campbell and Lake Erie based on the results from both the Phase I study (Entranco, 1983) and the Phase II study (Entranco, 1987).

Lake Campbell

The Entranco, 1987 report calculated the following phosphorus budget for Lake Campbell:

Internal loading	52%
Groundwater	13%
Surface water tributaries	30%
Precipitation	5%

In the Total Maximum Daily Load (TMDL) study, a loading capacity for total phosphorus of 0.87 kilograms (kg) per day (317 kg phosphorus/year) was established. This loading rate is consistent with a mean summer total phosphorus concentration of 28 µg/L and a mean summer chlorophyll-a concentration of 10 µg/L.

The TMDL phosphorus loading allocations for Lake Campbell are as follows:

Internal loading	155 kg/year
Groundwater	53 kg/year
Surface water tributaries	76 kg/year
Precipitation	33 kg/year

Lake Erie

For Lake Erie, the Entranco, 1987 report calculated the following phosphorus budget:

Internal loading	85%
Groundwater	4%
Surface water tributaries	9%
Precipitation	2%

The TMDL study established for Lake Erie a total phosphorus loading capacity of 0.28 kilograms (kg) per day (102 kg phosphorus/year). This loading rate is consistent with a mean summer total phosphorus concentration of 26 µg/L and a mean summer chlorophyll-a concentration of 5 µg/L.

The TMDL phosphorus loading allocations for Lake Erie are as follows:

Internal loading	62 kg/year
Groundwater	18 kg/year
Surface water tributaries	12 kg/year
Precipitation	10 kg/year

The loading allocations for each lake were set based on estimated loadings attained through implementation of various restoration activities to the lakes which would improve water quality and produce levels of aesthetic enjoyment acceptable to the lake user community.

Results and Discussion

Historic data indicate that both Lake Campbell and Lake Erie are biologically productive, with extensive macrophyte beds and occasional blooms of both cyanobacteria and green algae (Ecology, 1999a and 1999b; Entranco, 1983 and 1987). The productive period for both lakes occurs during the summer months when conditions are favorable for increasing photosynthetic activity and subsequent algal and macrophyte growth.

Historic climate data for the closest weather station to both lakes (Anacortes, WA) showed an average annual precipitation of 26.28 inches of rain annually. The precipitation data for 2004 showed 29.20 inches of rain. Since the combined calculated loading allocations for groundwater, surface water tributaries and precipitation for both lakes was quite small, this higher amount of precipitation for 2004 should not have affected overall phosphorus loading to both lakes.

In addition to the Phase I and Phase II reports, water quality data was collected by the Washington State Department of Ecology (Ecology) in 1999 (Ecology, 1999a and 1999b) and by Western Washington University (WWU) in 2002 (Hilles et al, 2003). Ecology's data showed mean total phosphorus concentrations of 40 µg/L at Lake Campbell and 29 µg/L at Lake Erie. WWU's data indicated mean total phosphorus concentrations of 29 µg/L at Lake Campbell and 22 µg/L at Lake Erie. A summary of the range of total phosphorus concentrations determined by earlier studies is shown in Table 4.

HydroLab® profiles were taken monthly at both lakes (Appendix D). Stratification did not occur at either lake during the entire study period except for a weak stratification occurring at Lake Campbell in May 2005. Anoxic conditions did occur on occasion at both lakes near the sediment/water interface. Lack of stratification and anoxia would allow nutrients bound in sediments to solubilize and move throughout the water column.

Table 4. Total Phosphorus Concentrations Determined by Previous Studies.

Study	Data Year	Range (µg/L TP)	Average - µg/L TP (sample number)
Lake Campbell			
WWU Monitoring Report (Hilles, et. al: 2003)	2002	12.1 to 67.1	29 (23)
Ecology Lake Water Quality Assessment (O'Neal, et. al; 2001)	1999	17 to 78	40 (4)
Restoration, Implementation and Evaluation (Entranco, 1987)	1985	18 to 67	31 (26)
Restoration (Entranco, 1983)	1981-82	10 to 68	41 (15)
Reconnaissance Survey (Bortleson, et. al; 1976)	1973	45	45 (1)
Lake Erie			
WWU Monitoring Report (Hilles, et. al: 2003)	2002	13.4 to 34.4	22 (17)
Ecology Lake Water Quality Assessment (Ecology, 1999a &1999b)	1999	25 to 32	29 (4)
Restoration, Implementation and Evaluation (Entranco, 1987)	1985	11 to 280	62 (25)
Restoration (Entranco, 1983)	1981-82	42 to 337	82 (15)
Reconnaissance Survey (Bortleson, et. al; 1976)	1973	62	62 (1)

Table 5. Summary of Total Phosphorus, Chlorophyll-a and Secchi Depth Values.

	Lake Campbell			**Lake Erie**		
	Total Phosphorus (µg/L)	Chlorophyll-a (µg/L)	Secchi Depth (M)	Total Phosphorus (µg/L)	Chlorophyll-a (µg/L)	Secchi Depth (M)
TMDL Criterion	28.0	10.0	N/A	26.0	5.0	N/A
Mean Summer (June, July & Aug.)	19.7	17.1	1.7	24.5	14.5	2.0
Minimum	12.3	3.4	1.5	16.6	2.5	0.9
Maximum	30.7	25.9	4.0	32.9	51.0	2.9
Standard Deviation	2.53	3.66	3.19	4.21	14.66	1.61
Number of Samples	13	13	13	13	13	13

Lake Campbell Results

Table 5 summarizes the total phosphorus, chlorophyll-a, and Secchi depth values for Lake Campbell.

In Lake Campbell, the mean total phosphorus concentration over the sampling period of this study was 15.9 µg/L with a range from 12.3 µg/L in October 2004 to 30.7 µg/L in January 2005. The mean chlorophyll-a concentration over the sampling period was 13.2 µg/L with a range from 3.4 µg/L in January 2005 to 25.9 µg/L in August 2004. For comparison with the TMDL criterion (28.0 µg/L), the mean summer (June through August) total phosphorus result was 19.7 µg/L. The TMDL criterion for chlorophyll-a was 10.0 µg/L; the mean summer result in Lake Campbell was 17.1 µg/L.

Secchi depths for Lake Campbell ranged from 1.5 meters in August 2005 to 3.9 meters in January 2005 with a mean of 2.5 meters.

The annual average TN:TP ratio at Lake Campbell was 39 indicating phosphorus was the limiting nutrient. The summer mean chlorophyll-a to total phosphorus ratio was 0.86.

The Trophic State Index (TSI) values were calculated as:

- Total Phosphorus = 46
- Chlorophyll-a = 53
- Secchi Transparency = 47

Considering all three parameters, the trophic state index for Lake Campbell was mesoeutrophic.

At Lake Campbell the total phosphorus results are all below the TMDL target limit of 28.0 µg/L, except in January 2005. The sampler noted over thirty six hours of unusually heavy rainfall prior to the January 2005 sampling event. This storm event, with the potential for causing on-site septic systems to malfunction and/or an increase in stormwater runoff, may have been the reason for the observed elevated total phosphorus result.

Only 31 % of the chlorophyll-a samples (4 of 13) met the TMDL criteria. There is no Washington State water quality standard for chlorophyll-a.

Figure 2 shows the monthly total phosphorus and chlorophyll-a concentrations for Lake Campbell.

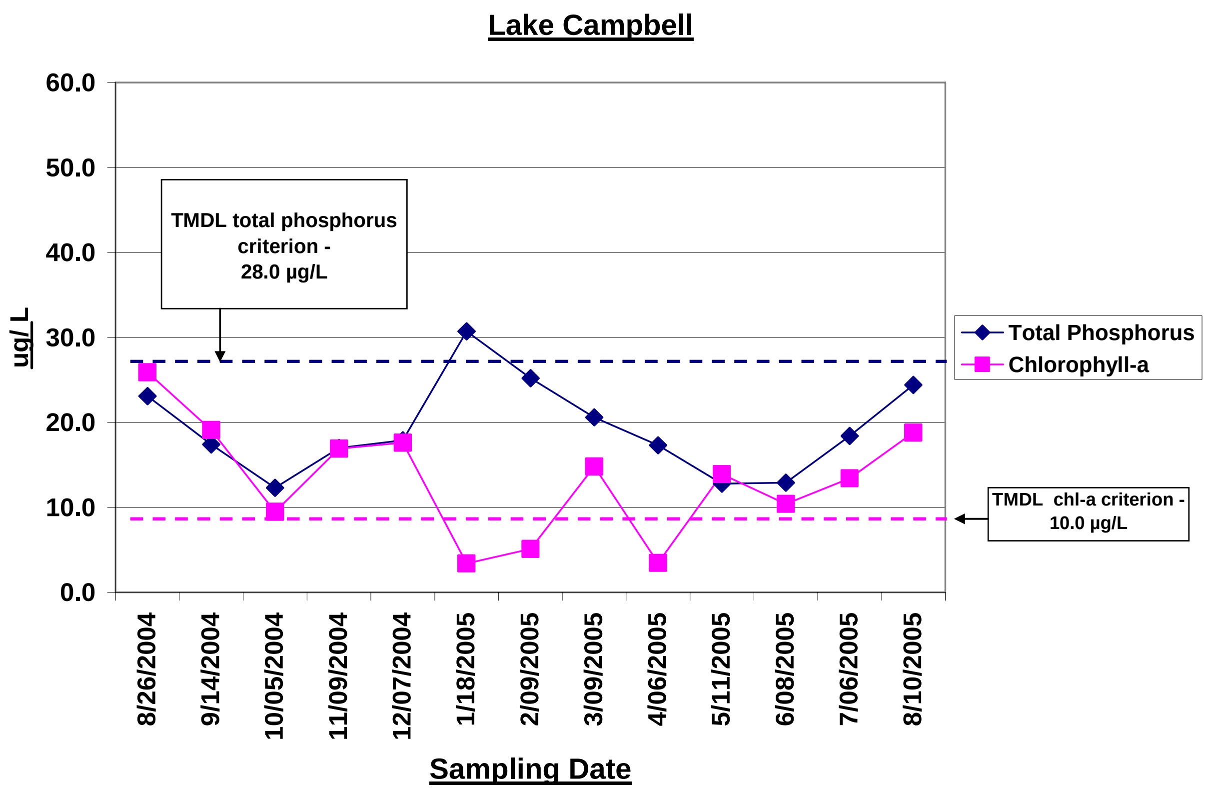

Figure 2. Monthly total phosphorus and chlorophyll-a concentrations for Lake Campbell.

Lake Erie Results

Table 5 summarizes the total phosphorus, chlorophyll-a, and Secchi depth values for Lake Erie.

In Lake Erie the mean total phosphorus concentration during the sampling period was 21.9 µg/L with a range from 16.6 µg/L in January 2005 to 32.9 µg/L in August 2005. The mean chlorophyll-a concentration over the sampling period was 27.7 µg µg/L with a range from 2.5 µg/L in October 2004 to 51.0 µg/L (January 2005). For comparison with the TMDL criterion (26.0 µg/L), the mean summer (June through August) total phosphorus result was 24.5 µg/L. The TMDL criterion for chlorophyll-a was 5.0 µg/L; the mean summer result in Lake Erie was 14.5 µg/L.

Secchi depths for Lake Erie ranged from 0.9 meters in August 2005 to 2.9 meters in July 2005 with a mean of 2.0 meters.

The annual average TN:TP ratio at Lake Erie was 36 indicating that phosphorus was the limiting nutrient. The summer mean chlorophyll-a to total phosphorus ratio was 0.53.

The Trophic State Index (TSI) values were calculated as:

- Total Phosphorus = 47
- Chlorophyll-a = 58
- Secchi Transparency = 50

Using all three parameters, the trophic state index for Lake Erie was eutrophic.

At Lake Erie, only one of the monthly total phosphorus concentrations was above the TMDL target limit of 26.0 µg/L (collected 8/10/2005). Only 15% of the chlorophyll-a samples (2 of 13) met the TMDL criteria.

Figure 3 shows the monthly total phosphorus and chlorophyll-a concentrations for Lake Erie.

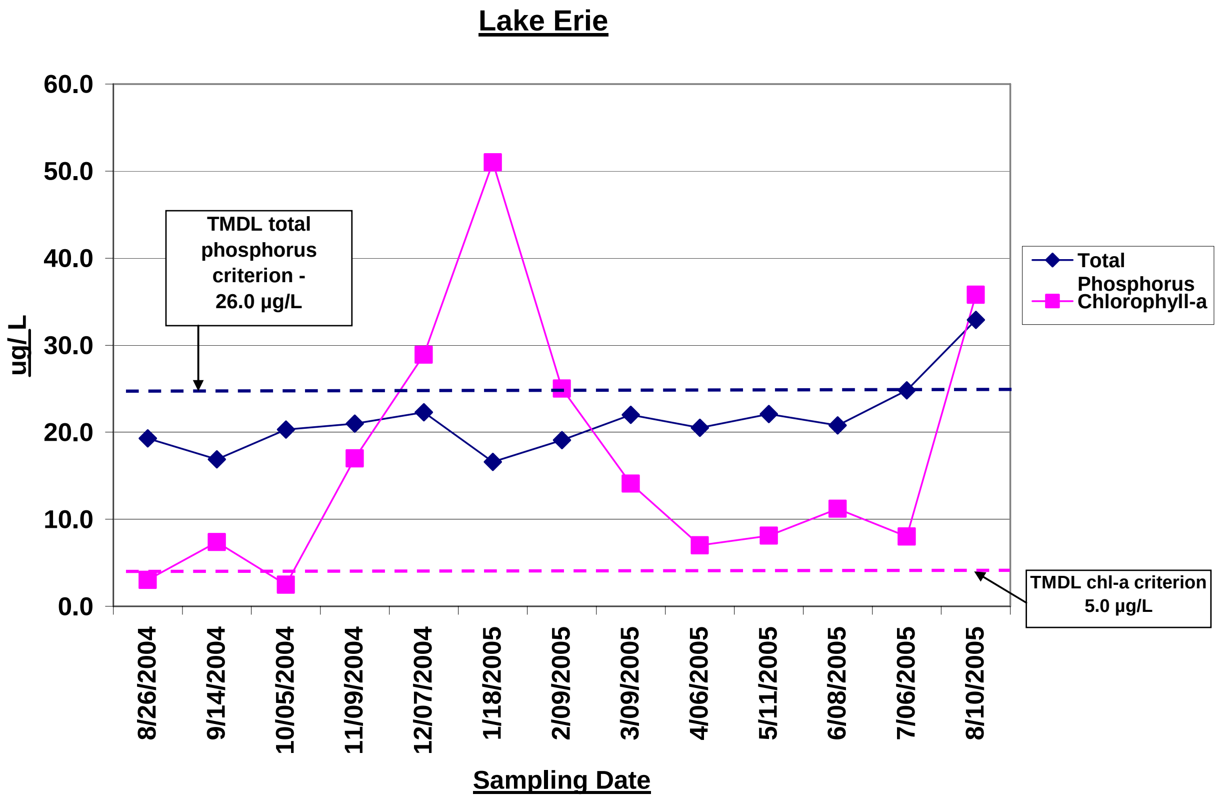

Figure 3. Monthly total phosphorus and chlorophyll-a concentrations for Lake Erie.

Quality Control Analysis

The performance of the HydroLab® DataSonde 4a profiling instrument resulted in no problems for temperature measurements. The instrument was not checked for temperature calibration prior to each sampling event because the temperature probe is inherently more stable than the other parameters. Periodic checks during the course of the sampling season comparing the instrument to a NIST thermometer were within criteria (Appendix E; Bell-McKinnon, 2004).

The pH and dissolved oxygen probes failed calibration on three occasions; those data were coded as estimates ("J"). The quality control (QC) criterion for both dissolved oxygen and pH was more stringent than that specified in many studies; two of the three failed dissolved oxygen calibrations would have passed with a criterion of ± 0.4 mg/L. One of the three failed pH calibrations would have passed with a higher criterion of ± 0.2 standard units.

The conductivity calibration check failed only on one occasion.

The 95th percent confidence intervals on the average difference between the original results and the QC results included "0" for pH and temperature but not for conductivity and dissolved oxygen (Table 6).

Table 6. Difference between original and duplicate profile results.

Constituent	Maximum Difference	Average Difference	Number of Pairs	Standard Deviation	Lower 95th Percent Confidence Interval	Upper 95th Percent Confidence Interval
Conductivity (µS/cm)	8.00	0.5000	54	1.4890	-0.9063	-0.0937
Dissolved Oxygen (mg/L)	0.85	0.1847	47	0.2113	0.1227	0.2467
pH (std. units)	0.79	0.0422	46	0.1718	-0.0088	0.0932
Temperature (°C)	1.01	0.0118	55	0.1631	-0.0324	0.0561

Laboratory samples were processed according to procedures specified in Manchester Environmental Laboratory User's Manual and quality control guidance (Ecology, 2001 and Ecology, 2005). Lab quality control requirements were met in all but one case: one chlorophyll duplicate exceeded the acceptance range.

Quality Control (QC) evaluations of samples used the pooled standard deviation of sequentially collected samples, converted to a relative standard deviation by dividing by the mean of all the results and expressed as a percent (%RSDp). The Quality Assurance Project Plan (Bell-McKinnon, 2004) establishes criteria based on lab split samples. Comparing sequential samples (i.e. the QC sample was collected immediately after the primary sample) is more stringent than comparing lab split samples because sequential samples include environmental and sampling variability in addition to variability due to field processing and lab analyses.

All sequentially sampled duplicates met the QC criteria (See Table 7).

Table 7. Quality control results for samples collected sequentially.

Analyte	No. of sequential sample pairs	Average Result	%RSDp of Difference [a]	QC Precision Criteria
Nitrogen, total (mg/L)	11	0.716	2.9%	10%
Phosphorus, total (µg/L)	11	19.7	9.3%	10%
Phosphorus, orthophosphate (µg/L)	11	3.2	3.1%	10%
Chlorophyll-a (µg/L)	11	17.3	4.5%	20%
Turbidity (NTU)	11	2.3	5.2%	10%
Secchi depth (meters)	10	2.35 M	0.05 M	± 0.5 M

[a] %RSDp is the pooled relative standard deviation (pooled standard deviation divided by the mean of all samples) expressed as a percent. For Secchi depth, the test value is the mean difference between duplicates.

All lab blank results were less than reporting limits.

Conclusions

The total phosphorus results for both Lake Campbell and Lake Erie indicate compliance with the TMDL goals and beneficial uses at both lakes appear to be supported.

However, chlorophyll-a concentrations in both Lake Campbell and Lake Erie were above their respective TMDL goals the majority of the time during this study. The calculated summer mean chlorophyll-a to total phosphorus ratio in the original TMDL was 0.36 for Lake Campbell and 0.19 for Lake Erie. This study found summer mean ratios of 0.86 in Lake Campbell and 0.53 in Lake Erie.

Nutrient and chlorophyll trophic state indicators will not always agree. Carlson (1991) pointed out that under low light conditions, chlorophyll may increase relative to biomass. Hence, the chlorophyll trophic state index may (falsely) indicate a higher biomass than would be expected from the phosphorus trophic state index. Both Lake Campbell and Lake Erie have significant aquatic plant communities and somewhat colored water which could potentially cause lower light conditions in the lakes, resulting in higher chlorophyll-a to total phosphorus ratios.

In addition, both lakes are stocked annually by the Washington State Department of Fish and Wildlife. Many of the fish species in both lakes are planktivores which graze heavily on copepods and other algae eating organisms thereby allowing the algal community to flourish.

The data collected in this study do not allow for an analysis of why the chlorophyll-a to total phosphorus ratios are so high. It is possible the chlorophyll-a criteria were set too low in the original TMDL. This question should be addressed in a future study. I recommend a review of the data and calculations used to derive the original TMDL criteria.

This Total Maximum Daily Load effectiveness evaluation addresses four fundamental questions with respect to restoration or implementation activity:

1. Is the restoration or implementation work achieving the desired objectives or goals (significant improvement)?

In this study, it appears the implementation of the alum treatments and the mechanical plant harvesting achieved the desired effect of reducing phosphorus loading to both Lake Campbell and Lake Erie.

The continuation of aquatic plant management activities, including the addition of grass carp to reduce the macrophyte population, potentially could have the effect of allowing more algal growth due to higher light conditions and less competition for nutrients. Careful consideration should be given to future plant management activities.

2. How can restoration or implementation techniques be improved?

Implementation activities can be improved by expanding restoration activities to include the entire lake watershed. This will ensure all nutrient loading inputs are being identified and addressed.

3. Is the improvement sustainable?

At some point, alum treatments begin to break down and lose their effectiveness. With the results from this study, it is not possible to say whether the alum treatments done back in 1985 are still responsible for the current phosphorus levels found in both Lake Campbell and Lake Erie. Continued water quality monitoring of both lakes will allow for better decision making as to whether future restoration activities are needed to maintain nutrient levels below the TMDL criteria.

4. How can the cost effectiveness of the work be improved?

Cost effectiveness of lake restoration efforts can be improved by ensuring that any restoration techniques considered for future use are suitable for the lake restoration goals and that any chemical applications are applied at the dosage appropriate for the lake.

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Appendices

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Appendix A – Glossary and Acronyms

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Clean Water Act (CWA): Federal Act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the CWA establishes the TMDL program.

Designated Uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each waterbody or segment, regardless of whether or not the uses are currently attained.

Load Allocation (LA): The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading Capacity: The greatest amount of a substance that a waterbody can receive and still meet water quality standards.

Nonpoint Source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Point Source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, saltwaters, wetlands and all other surface waters and water courses within the jurisdiction of the state of Washington.

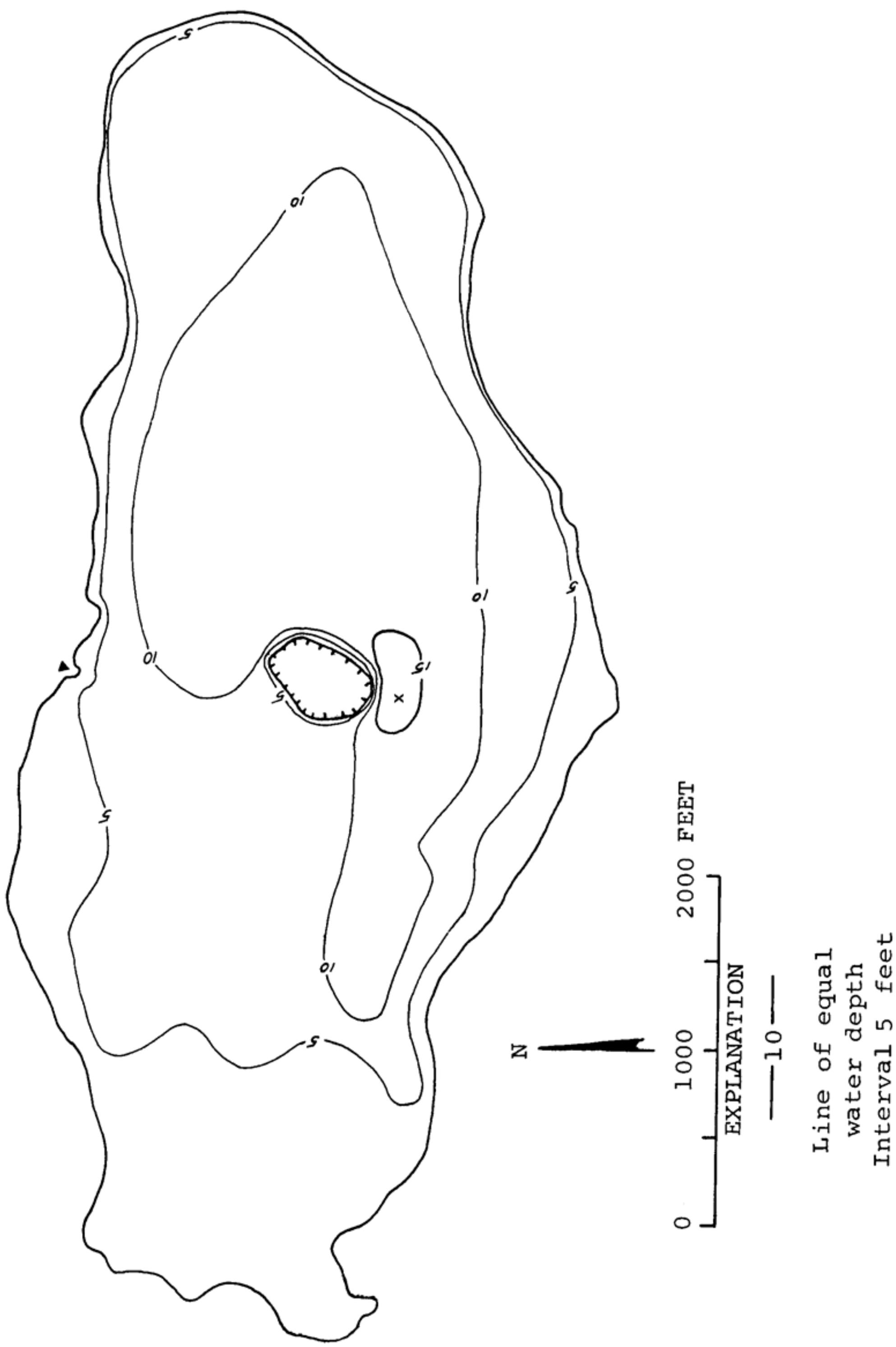
Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: 1) individual wasteload allocations (WLAs) for point sources, 2) the load allocations (LAs) for nonpoint sources, 3) the contribution of natural sources, and 4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Wasteload Allocation (WLA): The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. WLAs constitutes one type of water quality-based effluent limitation.

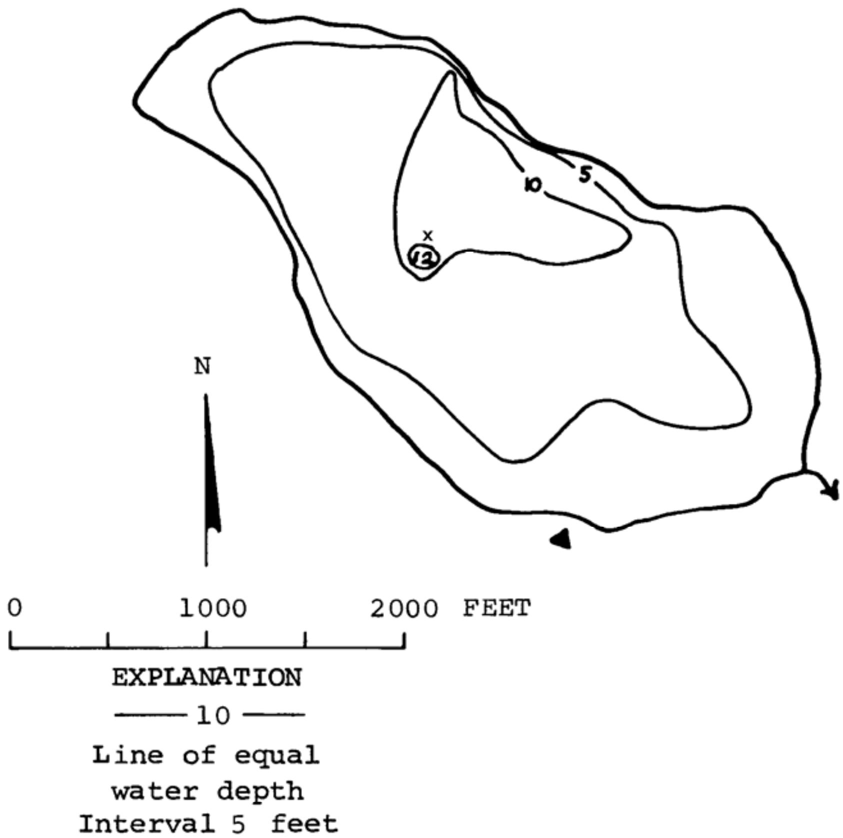
Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Appendix B – Study Sites and Sampling Locations

Lake Campbell Monitoring Location (X marks the spot)



Lake Erie Monitoring Location (X marks the spot)



Appendix C – Discrete/ Composite Results

Table C-1 – Lake Campbell Discrete/Composite Results.

Date	Strata [a]	Total Nitrogen (mg/L)	Total Phosphorus (µg/L)	Orthophosphate (µg/L)	Chlorophyll-a (µg/L)	Turbidity (NTU)	Secchi Depth (feet)
08/26/2004	E	0.700	23.1	3.0 U	25.90	3.0	5.0
08/26/2004	H	0.664	21.3	3.0 U	******	******	******
09/14/2004	E	0.694	17.4	3.0 U	19.10	3.1	6.5
10/05/2004	E	0.707	12.3	14.0	9.46	3.1	5.8
11/09/2004	E	0.832	17.0	3.0 U	16.90	2.0	8.6
12/07/2004	E	0.839	17.9	3.0 U	17.60	2.2	8.7
01/18/2005	E	0.974	30.7	4.9	3.41	1.3	13.0
02/09/2005	E	0.930	25.2	4.7	5.10	1.1	12.7
03/09/2005	E	0.859	20.6	4.5	14.80	1.2	12.6
04/06/2005	E	0.831	17.3	3.0 U	3.45	1.2	12.1
05/11/2005	E	0.650	12.8	3.0 U	13.90	2.1	6.0
05/11/2005	H	0.814	19.4	3.0 U	******	******	******
06/08/2005	E	0.642	12.9	3.0 U	10.40	2.6	6.0
06/08/2005	H	0.616	13.3	3.0 U	******	******	******
07/06/2005	E	0.637	18.4	3.0 U	13.40	2.6	6.0
07/06/2005	H	0.669	18.8	3.0 U	******	******	******
08/10/2005	E	0.711	24.4	3.0 U	18.80	2.8	4.9

[a] E = epilimnion; H = Hypolimnion
****** parameter not sampled

Table C-2 – Lake Erie Discrete/Composite Results.

Date	Strata [a]	Total Nitrogen (mg/L)	Total Phosphorus (µg/L)	Orthophosphate (µg/L)	Chlorophyll-a (µg/L)	Turbidity (NTU)	Secchi Depth (feet)
08/26/2004	E	0.728	19.3	3.0 U	3.04	1.6	7.7
08/26/2004	H	0.725	19.1	3.0 U	******	******	******
09/14/2004	E	0.780	16.9	3.0 U	7.38	1.0	7.7
10/05/2004	E	0.793	20.3	3.0 U	2.50	1.8	7.0
11/09/2004	E	0.716	21.0	3.0 U	17.00	1.3	7.5
12/07/2004	E	0.727	22.3	4.1	28.90	2.2	7.0
01/18/2005	E	0.842	16.6	3.6	51.00	3.6	5.0
02/09/2005	E	0.691	19.1	3.2	25.00	2.5	5.2
03/09/2005	E	0.740	22.0	3.0 U	14.10	2.4	7.1
04/06/2005	E	0.841	20.5	3.0 U	7.01	1.7	7.0
05/11/2005	E	0.687	22.1	3.0 U	8.13	2.0	6.0
06/08/2005	E	0.687	20.8	3.0 U	11.20	3.6	6.0
06/08/2005	H	0.710	19.0	3.0 U	******	******	******
07/06/2005	E	0.765	24.8	3.0 U	8.02	2.4	9.6
08/10/2005	E	0.772	32.9	3.0 U	35.80	6.5	3.0

[a] E = epilimnion; H = Hypolimnion

****** parameter not sampled

Appendix D – Profile Results

Table D-1. Lake Erie Profile Results.

Date	Depth (M)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (Std. Units)	Temperature (°C)
08/26/2004	0.0	239	7.63	9.78	19.75
	1.0	239	7.58	9.76	19.75
	2.0	287	0.35	8.33	19.94
09/14/2004	0.0	267	8.86	10.18	17.18
	0.5	268	8.80	10.19	17.16
	1.0	268	8.80	10.18	17.13
	1.5	269	8.80	10.20	17.11
	1.9	278	7.69	9.91	17.27
10/05/2004	0.0	293	8.86	9.71	15.45
	0.5	293	8.90	9.72	15.47
	1.0	293	8.95	9.74	15.47
	1.5	293	8.85	9.71	15.44
	1.9	293	3.67	9.52	15.47
11/09/2004	0.0	289	11.08	8.15	9.02
	0.5	289	10.90	8.13	9.02
	1.0	289	10.90	8.15	9.01
	2.0	290	10.30	8.02	9.02
	2.3	342	3.90	7.31	9.17
12/07/2004	0.0	273	11.49	7.03 J	5.24
	1.0	273	11.49	7.05 J	5.24
	2.0	274	11.40	7.05 J	5.25
	2.8	320	3.40	6.05 J	5.68
01/18/2005	0.0	258	13.25	7.95	3.70
	1.0	258	13.26	7.91	3.65
	2.0	258	13.20	7.91	3.63
	2.7	258	12.51	7.77	3.63
02/09/2005	0.0	254 J	9.20 J	9.20	6.20
	1.0	254 J	9.25 J	9.25	6.07
	2.0	254 J	9.20 J	9.20	5.87
03/09/2005	0.0	260	11.55 J	8.27	10.56
	1.0	260	11.47 J	8.24	10.47
	2.0	260	11.45 J	8.22	10.21
	3.0	285	6.80 J	7.33	10.44

Date	Depth (M)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (Std. Units)	Temperature (°C)
04/05/2005	0.0	257	10.70	7.94	9.41
	1.0	257	10.53	7.98	9.41
	2.0	258	10.50	7.98	9.41
	2.6	315	5.42	7.30	9.67
05/11/2005	0.0	258	7.90 J	7.92 J	18.17
	1.0	257	7.81 J	7.89 J	19.19
	2.0	257	7.67 J	7.83 J	18.11
	2.9	266	0.30 J	6.96 J	17.83
06/08/2005	0.0	264	7.77	8.42	18.20
	1.0	264	7.75	8.40	18.20
	2.0	264	7.59	8.36	18.20
07/06/2005	0.0	282	6.88	7.42 J	20.70
	1.0	282	6.76	7.41 J	20.70
	2.0	282	6.69	7.39 J	20.70
	2.5	282	6.33	7.36 J	20.70
8/10/2005	0.0	310	8.37	8.25	22.10
	1.0	311	8.24	8.27	22.10
	2.0	311	7.92	8.23	22.10

Table D-2. Lake Campbell Profile Results.

Date	Depth (M)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (Std. Units)	Temperature (°C)
08/26/2004	0.0	244	8.29	8.33	20.44
	1.0	243	8.03	8.33	20.42
	2.0	243	7.86	8.28	20.37
	3.0	243	7.75	8.26	20.34
	4.0	243	7.53	8.21	20.28
	4.6	257	0.50	7.72	20.26
09/14/2004	0.0	276	8.73	8.65	18.08
	1.0	278	8.55	8.59	18.05
	2.0	278	8.56	8.57	17.87
	3.0	278	8.37	8.54	17.81
	4.0	278	8.23	8.50	17.81
	4.7	323	0.51	7.14	17.93
10/05/2004	0.0	302	10.15	8.71	16.57
	1.0	302	10.05	8.71	16.46
	2.0	302	9.92	8.70	16.44
	3.0	303	9.51	8.62	16.21
	4.0	305	7.95	8.22	16.12
	5.0	306	6.94	7.99	16.01
	5.3	346	1.60	6.97	16.05
11/09/2004	0.0	292	10.91	8.30	9.36
	1.0	292	10.80	8.30	9.33
	2.0	292	10.94	8.27	9.23
	3.0	292	10.86	8.25	9.15
	4.0	292	10.55	8.21	9.11
	5.0	301	5.20	7.47	9.25
12/07/2004	0.0	272	11.07	6.96 J	5.75
	1.0	272	10.80	6.97 J	5.75
	2.0	272	10.72	6.97 J	5.75
	3.0	272	10.64	6.97 J	5.74
	4.0	271	10.51	6.97 J	5.75
	4.8	274	3.71	6.97 J	6.13
01/18/2005	0.0	263	12.62	7.90	2.69
	1.0	263	12.48	7.86	2.65
	2.0	263	12.40	7.83	2.65
	3.0	263	12.32	7.81	2.63
	4.0	263	12.21	7.81	2.64
	5.0	263	12.21	7.80	2.65
	5.6	298	6.08	7.52	3.11

Date	Depth (M)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (Std. Units)	Temperature (°C)
02/09/2005	0.0	256 J	8.87 J	8.05	5.93
	1.0	257 J	8.86 J	8.19	5.91
	2.0	256 J	8.88 J	8.23	5.89
	3.0	257 J	8.84 J	8.24	5.89
	4.0	256 J	8.77 J	8.24	5.82
	5.0	256 J	8.59 J	8.22	5.72
03/09/2005	0.0	264	12.20 J	8.54	10.70
	1.0	263	12.30 J	8.50	10.02
	2.0	263	12.17 J	8.51	9.78
	3.0	264	11.88 J	8.35	9.26
	4.0	265	10.20 J	8.10	8.42
	5.0	268	9.43 J	7.96	8.14
	5.5	285	4.50 J	7.50	8.03
04/05/2005	0.0	259	10.52	8.19	10.03
	1.0	258	10.33	8.19	10.01
	2.0	259	10.22	8.16	10.00
	3.0	259	10.21	8.16	9.92
	4.0	259	10.12	8.15	9.84
	5.0	259	10.01	8.13	9.83
	5.3	307	3.72	7.81	9.86
05/11/2005	0.0	257	10.40 J	9.11 J	18.77
	1.0	257	10.04 J	9.10 J	18.40
	2.0	256	9.93 J	9.05 J	18.28
	3.0	256	9.62 J	8.99 J	18.21
	4.0	263	6.48 J	8.01 J	17.38
	5.0	279	0.50 J	7.43 J	15.55
	6.0	325	0.32 J	7.53 J	13.51
06/08/2005	0.0	264	8.24	8.60	18.00
	1.0	264	8.18	8.60	18.00
	2.0	264	8.22	8.58	18.00
	3.0	264	8.18	8.56	18.00
	4.0	264	8.00	8.54	18.00
	5.0	264	7.96	8.48	17.90
07/06/2005	0.0	280	8.24	7.74 J	20.60
	1.0	279	7.85	7.70 J	20.40
	2.0	280	7.78	7.66 J	20.40
	3.0	280	7.30	7.53 J	20.30
	4.0	283	4.10	7.28 J	19.70
	5.0	285	1.90	7.17 J	19.40

Date	Depth (M)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (Std. Units)	Temperature (°C)
8/10/2005	0.0	293	7.34	8.27	22.70
	1.0	294	7.43	8.27	22.70
	2.0	294	7.37	8.26	22.60
	3.0	294	7.16	8.25	22.50
	4.0	295	6.50	8.06	22.40
	4.9	386	1.20	6.62	21.50

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Appendix E – Profiling Instrument Post-Calibration Results

Results rejected or qualified for failing quality control requirements (Bell-McKinnon, 2004) are shown in bold italics. The difference between expected and reported results is given in parentheses (for pH this is the difference for either the pH 7 or pH 9 buffer).

Table E-1. Instrument Post-Calibration Results.

Calibration Date	pH (criteria ± 0.15 std. units)	Dissolved Oxygen (criteria ± 0.20 mg/L)	Conductivity (criteria ± 10 µS/cm)	Temperature (criteria ± 0.20 °C)	Comments
8/26/2004	Pass	Pass	Pass		
10/6/2004	Pass	Pass	Pass		Probe was given maintenance and pH shock soak prior to this calibration.
11/10/2004	Pass	Pass	Pass		
12/8/2004	***Fail (1.2)***	Pass	Pass		
2/8/2005				Pass	Temperature calibration only.
2/10/2005	Pass	***Fail (1.93)***	***Fail (25)***		Soaked probe in acid prior to post-calibration.
3/10/2005	Pass	***Fail (0.36)***	Pass		Probe was dropped into sediments and may have been "poisoned" during sampling of 3/9/05 - could have affected the post-calibration.
4/6/2005	Pass	Pass	Pass		
5/11/2005	***Fail (.18)***	***Fail (0.40)***	Pass		pH very slow to stabilize.
6/9/2005	Pass	Pass	Pass		Prior to calibration, probe cleaned thoroughly, DO membrane changed and pH probe given "shock" treatment with acid.
7/6/2005	***Fail (.30)***	Pass	Pass		
7/21/2005				Pass	Temperature calibration only.
8/11/2005	Pass	Pass	Pass		

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Appendix F – Field Notes

Sampling Date	Field Notes - Erie	Field Notes - Campbell
8/26/2004	Lots of fine leafed *Potamogeton sp.*; sparse to moderate blue-green clumps; Abundant small algae specks; sediment on anchor light brown and very loose - almost clumpy; covered with what might be a *Spirogyra sp.*	Numerous small blue-green algal colonies.
9/14/2004	Secchi disk at 7.7 feet and still clear to bottom of lake; lots of algae specks throughout water column; Aquatic plants (narrow leaf pondweed) not quite so prevalent as last month but still abundant throughout the lake	Water is noticeably more hazy than Lake Erie though algae species throughout the water column are similar to Erie.
10/5/2004	Aquatic plants still near water surface throughout the lake but not as great a navigation hazard; long thin-leaved pondweed beginning to senesce; clumps of blue green algae visible throughout water column; east end of lake has less visible algae than west end (nearer to the sample location) - may bias average lake chlorophyll-a concentration.	Lots of clumps of whitish algae from boat launch halfway to island; water at sample location is hazy but no obvious clumps.
11/9/2004	Near shore plants almost gone; 100-200 ducks on water; lots of goose poop at boat ramp; no obvious algae in water column; plants still present at 1M below water surface; wind from the SE.	Fisherman at boat ramp caught a 16 inch trout - remains of several larger fish in water at the launch; wind from the SE; obvious blue green algae in water; 3 otters near island.
12/7/2004	Apparent heavy rain before sampling - lots of puddles and slight flooding in trailer park driveway; lake level high; water brown with tannin but no obvious algae; a few cormorants and lots of small ducks; wind from the SE.	Water level high; some ducks; fisherman caught one large trout; more algae specks visible here than at Erie; lots of zooplankton, especially *Daphnia*; dark day with low clouds but no rain.
1/18/2005	Heavy rain last 36 hours; lake level same as last month - flooding lower end of the trailer park; heavy rain during sampling; wind from the SE.	Heavy rain last 36 hours; wind from the SE; lake level high.

Field notes (cont.)

Sampling Date	Field Notes - Erie	Field Notes - Campbell
2/9/2005	Wind from NW; 100-200 ducks on the water	Saw 8 geese and 1 bald eagle; blue green algae clumping (about 1 inch by 3/8 inch) mostly on the surface - breaks apart easily; water level same as the last two months; many zooplankton in water sample but smaller than previously; *Ceratophyllum* and *Elodea* fragments.
3/9/2005	Wind from the NW rather than from the usual SE; light rain; lots of ducks as usual; large zooplankton visible against Secchi disk; tiny algae colonies relatively thick; lake level down a few inches from last month.	Lake level 6-8 inches down from last month; lots of algae clumps in water but faded - may be senescing; lots of zooplankton in 2M grab fewer in 4M grab and fewer still in 1M grab.
4/5/2005	Saw osprey, couple dozen ducks but fewer than usual - no coots; hazy water; lots of *Daphnia sp.;* water level same as last month.	Four people fishing at boat ramp; water level same as last month - about 8 inches below sign; saw osprey, about a dozen waterfowl and a few geese; Not as many *Daphnia sp* as Erie but these are bigger.
5/11/2005	A few small zooplankton were visible in water sampler.	Water level about 8 inches below black line of sign; fisherman reports some big channel catfish in lake.
6/8/2005	Two people fishing in 1 boat; rainy, gray day; water hazy; no plants visible; a few zooplankton in each sample cast along with lots of algal colonies (whitish in color - possibly senescent).	Milfoil near island; Some algal clumps in water sample but not much; filamentous green algae growing on rocks of the island (about 4 inches above water level); water level of lake down about 4 inches from last month; foam at boat launch.
7/6/2005	No waterfowl; Algae specks throughout the water column; Possible purple loosestrife patch to left of mobile home park at SE end of lake.	Hazy water compared to Erie - smaller algae particles; No H2S smell in 5M sample - smells like a productive lake in the summer; Water level about 7 inches below algae on rocks - about where it was last month; milfoil washed up on boat launch.
8/10/2005	Water very dark brown - took algal sample	Water level about 2 feet below black line on sign; undated sign says lilies spot treated lakewide with AquaPro (glyphosate) by Aquatechnic (360) 330-0152; Some lilies are turning yellow; about 20 geese, several terns, duck & eagle; Water not nearly as hazy as Erie but still a bit hazy.