Quality Assurance Project Plan

Total Maximum Daily Load Effectiveness Monitoring Study: Lakes Erie and Campbell

by
Maggie Bell-McKinnon

Environmental Monitoring & Trends Section (EMTS)
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

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Approvals

Approved by:	September 7, 2004
Tricia Shoblom, Northwest Regional Office, TMDL Lead	Date
Approved by:	August 19, 2004
Maggie Bell-McKinnon, Project Manager, Freshwater Monitoring Unit Environmental Monitoring & Trends Section	Date
Approved by:	August 19, 2004
George Onwumere, Acting Unit Supervisor, Freshwater Monitoring Unit, Environmental Monitoring & Trends Section	Date
Approved by:	August 18, 2004
Darrel Anderson, Acting Section Manager, Environmental Monitoring & Trends Section	Date
Approved by:	August 25, 2004
Stuart Magoon, Director, Manchester Environmental Laboratory	Date
Approved by:	September 10, 2004
Cliff Kirchmer, Ecology Quality Assurance Officer	Date

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Abstract

Lakes Campbell and Erie were listed by the State of Washington under Section 303(d) of the Clean Water Act for non-attainment of the U.S. Environmental Protection Agency (EPA) human health criteria for total phosphorus. Total Maximum Daily Loads (TMDL) for both Lake Campbell and Lake Erie were submitted by Ecology and approved by EPA in 1997. This Quality Assurance Project Plan (QAPP) describes the procedure that will be used to monitor the effectiveness of the TMDL.

The objectives of the study are to determine if past restoration treatments have been effective in restoring Lakes Campbell and Erie to their designated uses and whether current phosphorus concentrations are consistent with the load allocations set in the TMDL.

Background/Problem Statement

Lakes Campbell and Erie were listed by the State of Washington under Section 303(d) of the Clean Water Act for non-attainment of the U.S. Environmental Protection Agency (EPA) human health criteria for total phosphorus. The listing was based on sampling done by Entranco Engineers in 1981-82. EPA requires the states to set priorities for cleaning up 303(d) listed waters and to establish a Total Maximum Daily Load (TMDL) for each. A TMDL entails an analysis of how much of a pollutant load a waterbody can assimilate without violating water quality standards. TMDL's for both Lake Campbell and Lake Erie were submitted by Ecology and approved by EPA in 1997.

This Quality Assurance Project Plan (QAPP) describes the procedure that will be used to monitor the effectiveness of the TMDL in returning the water body to its designated use classification. The study will be conducted by the Freshwater Monitoring Unit of Ecology's Environmental Assessment Program (EAP).

Waterbody Description

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

Lake Erie has a maximum depth of 3.6 meters and a surface area of 45 hectares. Lake Erie 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. 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. The predominant forest type is mixed coniferous. The watershed lies in the Olympic Mountain rainshadow and receives approximately 26 inches (66 centimeters) of rain annually.

In the "Water Quality Standards for Surface Waters of the State of Washington", Lakes Campbell and Erie are listed as a lake class waterway (Table 1). This classification assumes the waterbody will meet or exceed criteria for water supply, stock watering, fish migration and propagation, wildlife habitat and recreation.

Table 1. Selected Lake Class Criteria

Temperature	No measurable change from natural conditions	
Dissolved Oxygen	No measurable decrease from natural conditions	
Fecal Coliform	Geomean < 50 cfu/100 mL	<10% samples > 100 cfu/100mL
pH	No measurable change from natural conditions	
Total Phosphorus	33.7 ug/L for Lake Erie; 32.6ug/L for Lake Campbell	Ecology recommendation
Turbidity	Not exceed 5 NTU over background conditions	

Waterbody Studies

Historic (Pre TMDL)

Historic data indicate that both Lakes Campbell and 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). 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. Internal loading was identified as the main source of phosphorus. The range of phosphorus concentrations determined by earlier studies is shown in Table 2.

Table 2. Epilimnion Phosphorus Concentrations (µg/L) Determined by Previous Studies

Study	Data Year	Range	Average (number)
Campbell			
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)
Erie			
Ecology Lake Water Quality Assessment (1999)	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)

The recommended Phase I Restoration Plan contained four main elements for improving water quality:

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

TMDL Implementation

The proposed TMDL for Lake Campbell set a phosphorus load allocation of 0.87 kilograms/day (317 kilograms/year). This loading allocation is shown to be consistent with a mean summer total phosphorus concentration of 28 ug/L and a mean summer chlorophyll-a concentration of 10 ug/L.

The phosphorus load allocation for Lake Erie, as proposed in its TMDL, was set at 0.28 kilograms/day (102 kilograms/year). This loading allocation is shown to be consistent with a mean summer total phosphorus concentration of 26 ug/L and a mean summer chlorophyll-a concentration of 5ug/L.

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

Post Implementation Studies

In 1986, Entranco (1987) conducted post- alum treatment monitoring on both Lakes Campbell and Erie. In Lake Campbell, mean summer total phosphorus concentrations were reduced by 43% (from 49 ug/L to 28 ug/L), chlorophyll-a concentrations were reduced by 44% (from 18 ug/L to 10 ug/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 ug/L to 26 ug/L), chlorophyll-a concentrations were reduced by 91% (from 58 ug/L to 5 ug/L) and Secchi depth visibility increased by at least 47% (from 1.7 meters to more than 2.5 meters).

Additional 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 total phosphorus concentrations of 40 ug/L at Lake Campbell and 29 ug/L at Lake Erie. WWU's data had total phosphorus concentrations of 29 ug/L at Lake Campbell and 22 ug/L at Lake Erie.

Project Description

The objective of the study will be to determine if past restoration treatments have been effective in restoring Lakes Campbell and Erie to their designated uses and whether current phosphorus concentrations are consistent with the load allocations set in the TMDL.

The course of this study will be to:

- 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 report (technical memorandum) to Ecology's Water Quality Program

Organization, Schedule, and Laboratory Cost Estimate

Ecology staff will sample monthly from August 2004 to July 2005. The proposed sampling schedule is shown in Table 3. Following are the key personnel involved with the project:

- EAP project lead – Maggie Bell-McKinnon (360) 407-6124
- Ecology NWRO Watershed Lead – Sally Lawrence (425) 649-7036
- Manchester Environmental Laboratory Director – Stuart Magoon (360) 871-8801
- Ecology Quality Assurance Officer – Cliff Kirchmer (360) 407-6455

Table 3. Sampling Schedule Table and Lab Cost Estimates

Date	Samples	QC (Field dup)	Field	Lab	$ amount
Aug 2004	2	1	T,pH,DO,conductivity[a]	TP,OP,TPN,chl-a,TU[a]	350
Sept 2004	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Oct 2004	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Nov 2004	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Dec 2004	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Jan 2005	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Feb 2005	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Mar 2005	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Apr 2005	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
May 2005	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Jun 2005	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Jul 2005	2	1	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350

[a] T=temperature, DO=dissolved oxygen, TP=total phosphorus, OP=orthophosphorus, TPN=total persulfate nitrogen, chl-a=chlorophyll *a*, TU=turbidity

Data entry will be completed by September 2005; completion of the QC review and loading the data into EIM will be completed by December 2005. Preparation of the technical memorandum to Ecology's Water Quality Program will be accomplished by March 2006.

Data Quality Objectives and Decision Criteria

Specific quality objectives for this project are discussed below.

Bias

Sampling bias will be minimized by strictly adhering to the protocols discussed and referenced herein. This QAPP provides procedures for collecting representative and valid samples, but, as is true for all sampling, some bias due to sampling, even if not measurable or knowable, is likely present in the results. Assessment and management of bias will mostly occur at the laboratory. We expect that bias in the chemical analyses will be corrected so that long-term bias will not occur within a single method. Measurement Quality Objectives (MQOs) for bias are listed in Table 4.

Precision

MQOs are given in Table 4.

At concentrations near the lowest concentration of interest, it will not be possible to meet the percentage MQOs in Table 4 because errors expressed as a percentage increase at lower concentrations. However, at lower concentrations, the acceptable error is generally greater. The precision MQO is in line with MEL's historic performance for most constituents. Chlorophyll, which is inherently more variable, has a less stringent MQO.

Table 4 is intended to indicate the quality of the result from a particular sample (or pooled set of samples) and therefore to apply to lab or field *splits*. Field duplicate samples (i.e., sequentially collected), which include some environmental variability, may be used to determine in MQOs have been met; however, some judgment may be required regarding the amount of environmental variability in the sample.

Table 4. Measurement Quality Objectives

Analyte	Accuracy (deviation or % deviation from true value)	Precision (% RSD)	Bias (% deviation from true value)	Required Reporting Limit
Field Constituents				
Conductivity	± 10 µs/cm at 100 µs/cm	NA	NA	NA
Oxygen	± 0.2 mg/L	NA	NA	NA
pH	± 0.15 std. units	NA	NA	NA
Temperature	± 0.2 ºC	NA	NA	NA
Secchi Depth	NA	± 0.5 m	NA	NA
Lab Constituents				
Chlorophyll	NA	20 % RSD	NA	0.05 mg L^{-1}
Orthophosphate	25%	10 %RSD	5%	0.003 mg L^{-1}
Total Nitrogen	25%	10 %RSD	5%	0.025 mg L^{-1}
Total Phosphorus	25%	10 %RSD	5%	0.01 mg L^{-1}
Turbidity	25%	10 %RSD	5%	0.5 NTU

Sampling Design

Water samples for lab analysis and lake profiles will be collected at the deepest spot at each lake. See Appendix 1 for a detailed map of the sampling locations. Sampling will occur monthly from August 2004 to July 2005.

Lab analyzed parameters will be total phosphorus (TP), orthophosphorus (OP), total persulfate nitrogen (TPN), chlorophyll-a (chl-a) and turbidity (TU). If the lake is stratified, nutrients (TP, OP and TPN) will be analyzed in epilimnion and hypolimnion composite samples. All remaining parameters will be analyzed in epilimnion composite samples only.

Using a HydroLab © multiparameter probe, a monthly lake profile will be completed for each lake. Field measured parameters will include temperature (T), conductivity, dissolved oxygen (DO) and pH. Water clarity will be measured using a Secchi disk. Secchi depth and chlorophyll will be used to assess algal growth.

Representativeness

Lake Campbell and Lake Erie are very similar to each other. Both lakes are shallow and typically don't form stable thermal stratification during the summer. Because of this relative uniformity, one station at the deepest point of the lake will provide representative data.

Vertically, composites should ensure that epilimnion lake samples are adequately representative. The hypolimnion is not typically as well-mixed as the epilimnion; composite samples are a compromise and will indicate whether significant internal nutrient release is occurring, but may not be adequate for internal nutrient load calculations.

Comparability

All measurement and analytical procedures are documented so that the data will be comparable with samples collected and analyzed in a like manner.

Field Procedures

Standard Ecology protocols (Ward, 2001) will be 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) will be followed.

Field meters will be maintained and calibrated according to manufacturer's instructions. Profiles will be collected with a Hydrolab© multiparameter probe.

Laboratory Procedures

MEL conducts laboratory analyses following Standard Operating Procedures (SOPs) and other guidance documents (Ecology, 2001 and Ecology, 2003). Methods for constituents are listed in Table 5.

Table 5. 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	SM4500NB	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)

Quality Control Procedures

Field Quality Control

Two co-located samples will be collected to estimate overall variability due to sampling and analysis. The site chosen for the co-located (duplicate) sample will alternate between each lake (e.g. Lake Campbell will have a duplicate sample taken in July 2004, Lake Erie in August 2004, etc.). The duplicate sample will be taken sequentially (taken at the same location and depth as the original sample) and will include all parameters scheduled for collection at that point.

The results from an original sample and its duplicate (sequentially collected) sample are used to calculate the expected variance that is due to short-term environmental factors, field collection and processing, and laboratory analyses.

Contamination will be assessed by the submission of field blanks. Once during the course of the project, fresh distilled water will be submitted rather than the co-located (duplicate) sample. These will be "transport blanks" for constituents where there is no field processing of the sample (e.g., nutrients), and "rinsate blanks" for filtered constituents. Blank results are expected to be below reporting limits.

Lab Quality Control

Laboratory QC will follow MEL's internal procedures. We request that MEL do duplicate analyses on our field duplicates. Using field QC samples will allow us to better partition sources of error between lab and field.

Instrumentation

Profile data will be collected using a Hydrolab© multiparameter probe, calibrated according to manufacturer's instructions and Bell-McKinnon (2002).

Data Reduction and Management Procedures

Data will be entered into our lake monitoring data Access® database and provided in spreadsheet form to the client.

Data Review and Validation

The laboratory verifies its measurement results. In addition, the following procedures will be followed:

- Standard lab and field QC procedures will be adhered to.
- The data will be checked for data entry errors and completeness.
- Results will be checked for reasonableness.
- Lab and Field QC results will be evaluated to ensure that the measurement quality objectives (MQOs) were met. Data failing to meet MQOs will be either coded as estimates or discarded.

These steps are the responsibility of the project lead.

Data Quality Assessment

QA assessments for precision will be made by comparing calculated standard deviations of split sample pairs (from the lab) and co-located sample duplicates (from the field) to the percent relative standard deviation times the mean of the sample pair tabulated in the MQOs (Table 4). MQOs may be applied to the standard deviation of individual QC split pairs if individual results will be used (for example, compared to a water quality criterion). However, where results are pooled, for example, to estimate a mean concentration, the standard deviation of QC split pairs may be pooled.

Standard deviation for paired samples may be calculated according to Equation 1:

$$s = \sqrt{(r_1 - r_2)^2 / 2} \qquad 1)$$

Where s is the standard deviation and r_1 and r_2 are paired results.

Where results are to be combined then QC pairs may be pooled using Equation 2:

$$s_p = \sqrt{\sum (r_1 - r_2)^2 / 2m} \qquad 2)$$

Where s_p is the pooled standard deviation and m is the number of pairs. The value s_p may then be compared to the MQOs in Table 3.

TMDL effectiveness will be evaluated by comparing mean summer total phosphorus and chlorophyll *a* concentrations to expected values based on load reductions specified in the TMDL.

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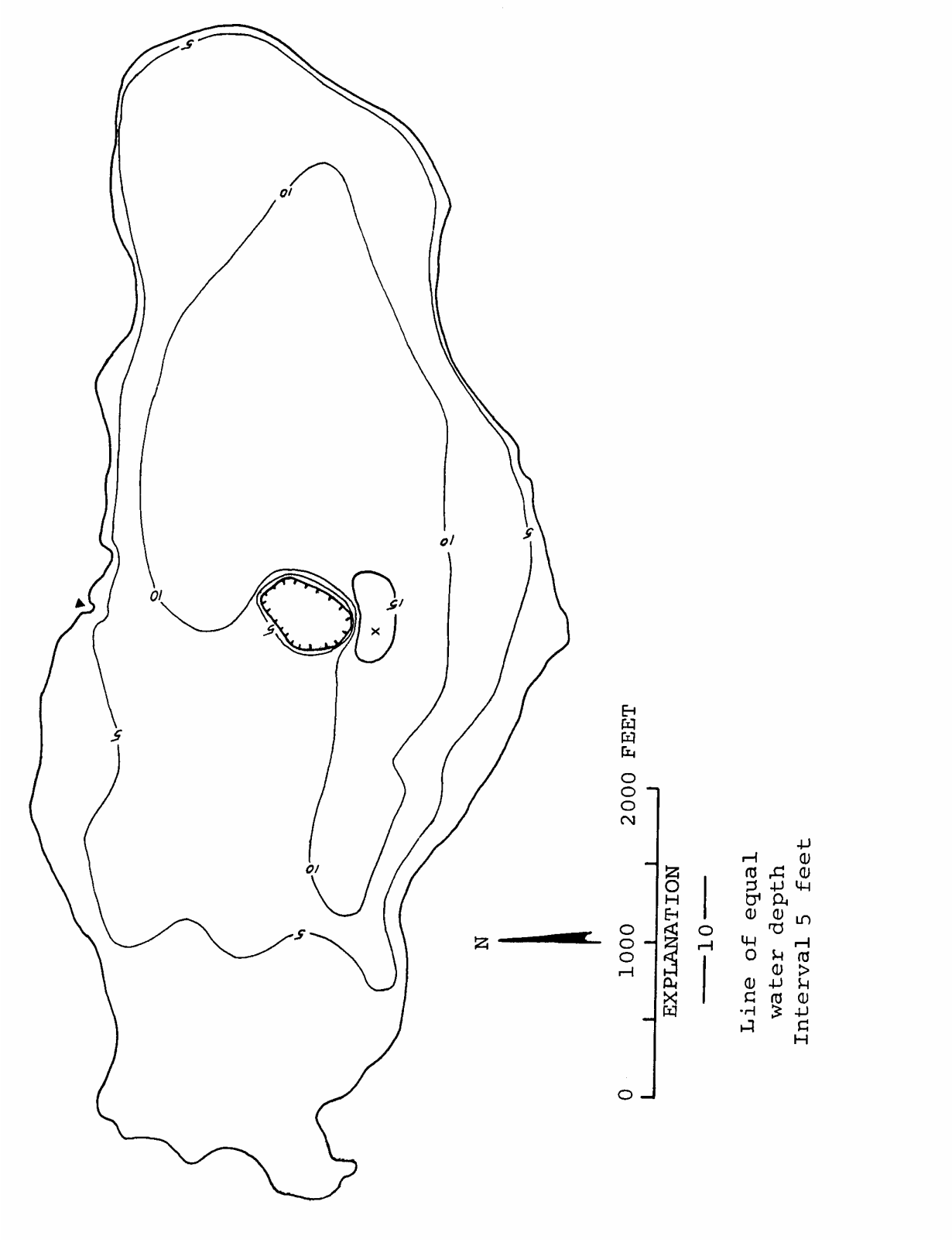
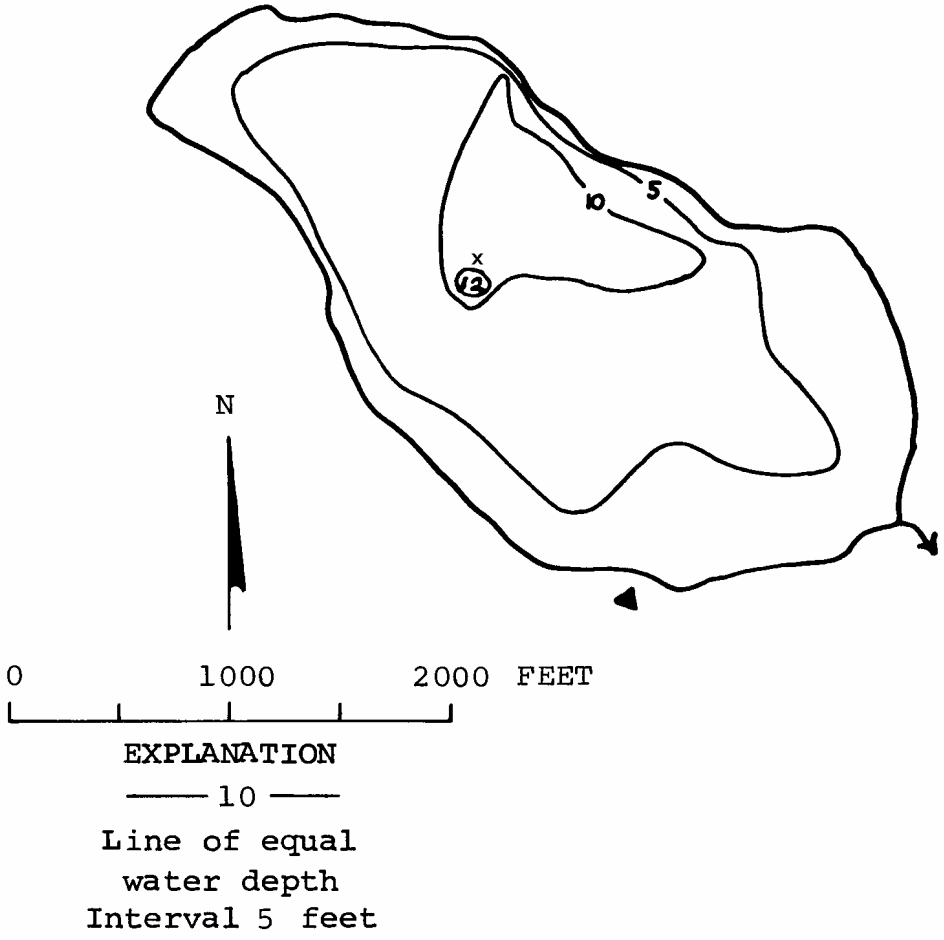
Appendix A

Lake Campbell Monitoring Location (X marks the spot)


5
10
15
N
0
1000
2000 FEET
EXPLANATION
10
Line of equal
water depth
Interval 5 feet

Appendix B

Lake Erie Monitoring Location (X marks the spot)


10
5
x
12
N
0
1000
2000 FEET
EXPLANATION
10
Line of equal
water depth
Interval 5 feet