Quality Assurance Project Plan

Lake Ballinger Total Maximum Daily Load Effectiveness Monitoring Study

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Approvals

Approved by:	January 3, 2006
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Approved by:	January 3, 2006
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Abstract

Lake Ballinger was listed by the State of Washington under Section 303(d) of the federal Clean Water Act for failing to meet the U.S. Environmental Protection Agency (EPA) human health criteria for total phosphorus. A Total Maximum Daily Load (TMDL) study for Lake Ballinger was submitted by Ecology and approved by EPA in 1993. This Quality Assurance Project Plan describes the procedure that will be used to monitor the effectiveness of the TMDL.

The objectives of the study are to determine if (1) past restoration treatments have been effective in restoring Lake Ballinger to its designated uses and (2) current phosphorus concentrations are consistent with the load allocations set in the TMDL.

Background Statement

Lake Ballinger was 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 Kramer, Chin and Mayo, Inc. in 1985-86. 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 is an analysis of the pollutant load a waterbody can assimilate without violating water quality standards. A TMDL for Lake Ballinger was submitted by Ecology and approved by EPA in 1993.

This Quality Assurance (QA) Project Plan describes the procedure that will be used to evaluate the effectiveness of the TMDL in restoring 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

Lake Ballinger lies just north of the King County – Snohomish County border, located in the Cities of Mountlake Terrace and Edmonds between Interstate-5 and Highway 99 (see Appendix A). The lake has a surface area of approximately 40.5 hectares (100 acres), a maximum depth of 11 meters (35 feet) and an average depth of 5 meters (15 feet). Lake Ballinger is a monomictic lake, which means the water mixes throughout the winter and early spring. Thermal stratification is significant during the summer months in Lake Ballinger. The lake is productive and is classified as a eutrophic lake.

The shoreline is dominated by single family dwellings. Two golf courses are on the north and east ends of the lake. The major surface inlet is Hall Creek with stormwater outlets contributing the remaining inflow to the lake. The single outlet is McAleer Creek which drains to Lake Washington. The lake receives considerable stormwater runoff during rain events, primarily from the urban areas of Lynnwood, Edmonds, Mountlake Terrace and northern King County. The watershed is five (5) square miles and highly urbanized, consisting of the Cities of Lynnwood, Edmonds, Mountlake Terrace and Shoreline, and south Snohomish and north King Counties.

Lake Ballinger is very popular for various recreational activities including fishing, swimming, boating and wind surfing.

In the "Water Quality Standards for Surface Waters of the State of Washington" (Chapter 173-201A WAC), Lake Ballinger is listed as a lake class waterway . 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
- Total Phosphorus - 30.0 ug/L for Lake Ballinger (Ecology recommendation)

Waterbody Studies

Historic (Pre TMDL)

In a 1972 study by METRO (1973), the water quality problems listed for Lake Ballinger were excessive nutrient loading, algal blooms, sediment loading, and bacterial contamination. Subsequent sewering of the watershed removed most of the human generated bacterial problems. A 1977 study by METRO estimated 67% of the external nutrient loading was via Hall Creek; this inflow also was low in dissolved oxygen and high in ammonia concentrations. The sediment load was determined to be excessive due to erosion in the watershed as well as from the streambank. The extensive development of the basin coincides with the decline in lake water quality.

The range of total phosphorus concentrations determined by earlier studies is shown in Table 2.

Table 1. Epilimnion Phosphorus Concentrations (μg/L) Determined by Previous Studies

Study	Data Year	Range	Average/(Sample #)
Water Quality Problems and Alternatives for the Restoration of Lake Ballinger (METRO, 1977)	1975-76	19 to 50	31 (33)
Restoration of Lake Ballinger, Phase III Final Report (KCM, 1986)	1985-86	12 to 80	36 (27)
Lake Ballinger Water Quality (Aldrich, 1988)	1985-87	10 to 104	32 (30)
Water Quality Report (Khan, 1993)	1990-91	10 to 250	25 (32)

TMDL Implementation

The proposed TMDL for Lake Ballinger established a phosphorus load allocation of 0.28 kilograms/day (102 kilograms/year). This loading allocation is shown to be consistent with a mean summer total phosphorus concentration of 30 ug/L.

Post Implementation Studies

As part of the restoration efforts for Lake Ballinger, Phase II construction work began in 1980. Phase IIa consisted of construction of two regional sedimentation facilities on Hall Creek, and the rehabilitation of the lower creek reach. Rehabilitation consisted of stabilizing stream banks and revegetation of riparian areas. These two measures were intended to increase dissolved oxygen, oxidize ammonia to nitrate, control sediment loading into the lake, reduce sediment production within the creek and reduce phosphorus loading to the lake. In addition, stormwater control ordinances concerning construction on and development of the land were established.

Phase IIb, started in late fall 1982, was the construction of a hypolimnetic injection (of dissolved oxygen) and hypolimnetic withdrawal (of nutrient laden water) system. A Phase III report concluded that after the installation of the hypolimnetic withdrawal system, internal loading by the mechanism of release from anoxic sediments was no longer significant. However, external loading increases have more than replaced the internal sediment component of the loading and appears to be directly and indirectly (through recycling of increased productivity) driving the lake ecosystem.

In 1990, the City of Mountlake Terrace treated Lake Ballinger with alum to reduce the excessive phosphorus concentration in the lake. The clarity of the lake was increased by 40% and the phosphorus levels were reduced by 70% within 48 hours of the treatment. Although the short term result of the alum treatment was satisfactory, the longevity of the treatment has become limited by continued external phosphorus loading.

Aquatic Research was hired by the City of Mountlake Terrace to conduct a lake monitoring program; samples were collected in September and October of 1994. The results showed total phosphorus levels of 30 ug/L in September and 34 ug/L in October.

Since 1988, the City of Mountlake Terrace has been requiring Best Management Practices (BMP's) for the mitigation of stormwater pollution. The following recommendations were made by the City of Mountlake Terrace (Khan, 1993):

- Water quality monitoring programs should continue for Lake Ballinger, Hall Creek and the stormwater conveyance system
- Develop and implement a comprehensive watershed basin plan that involves all the jurisdictions within the watershed
- Update the City's storm drainage and pollution control ordinance
- Control fertilizer and pesticide run-off from golf courses, play fields and lawns by requiring BMP's
- Develop a stormwater facility inspection and maintenance program
- Conduct comprehensive public education projects

Project Description

The objective of the study will be to determine if past restoration treatments have been effective in restoring Lake Ballinger to its 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 of the TMDL
- Analyze and interpret data to determine effectiveness of TMDL
- Make recommendations based on interpretation of results
- Produce final report (Technical Memorandum) to Ecology's Water Quality Program

Organization, Schedule, and Laboratory Cost Estimate

Ecology staff will sample monthly from November 2005 to October 2006. The proposed sampling schedule is shown in Table 2. Following are the key personnel involved with the project:

- EAP project lead – Maggie Bell-McKinnon (360) 407-6124
- EAP field personnel – Dave Hallock (360) 407-6124
- Ecology NWRO Lakes Coordinator – Tricia Shoblom (425) 649-7288
- Manchester Environmental Laboratory Director – Stuart Magoon (360) 871-8801
- Ecology Quality Assurance Officer – Cliff Kirchmer (360) 407-6455

A reconnaissance visit to the study site will be conducted in October. Preparation and approval of the Quality Assurance Project Plan will occur in November, 2005 prior to the beginning of the sampling activities. Delivery of the field collected water samples will be to Manchester Environmental Laboratory the day following sample collection.

Table 2. Sampling Schedule Table and Lab Cost Estimates

Date	Sets of Samples[a]	QC[a] (Sets of Field dup)	Field[b]	Lab	$ amount
Nov 2005	**3** (1 lake-E, 2-creeks)		T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU[a]	300
Dec 2005	**3** (1 lake-E, 2-creeks)		T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	300
Jan 2006	**3** (1 lake-E & H, 2-creeks)	**4** (2 lake-E & H, 2- creeks)	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	800
Feb 2006	**3** (1 lake-E, 2-creeks)		T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	300
Mar 2006	**3** (1 lake-E, 2-creeks)		T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	300
Apr 2006	**3** (1 lake -E, 2-creeks)		T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	300
May 2006	**3** (1 lake-E & H, 2-creeks)	**4** (2 lake-E & H, 2-creeks)	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	800
Jun 2006	**3** (1 lake-E & H, 2-creeks)		T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Jul 2006	**3** (1 lake-E & H, 2-creeks)		T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Aug 2006	**3** (1 lake-E & H, 2-creeks)	**4** (2 lake-E & H, 2-creeks)	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	800
Sep 2006	**3** (1 lake-E & H, 2-creeks)		T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	350
Oct 2006	**3** (1 lake-E & H, 2-creeks)	**4** (2 lake-E & H, 2-creeks)	T,pH,DO,conductivity	TP,OP,TPN,chl-a,TU	800
					TOTAL= $5750

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

Sampling Design

Water samples for lab analysis and lake profiles will be collected at the deepest spot in the lake. Duplicate samples will be collected four times during the twelve month sampling period at this same location. In addition, at a second deep site on the lake at least 100 meters from the first site, a second set of duplicate water samples will be collected. The purpose of this second set of samples will be to determine if any spatial variability occurs within the waterbody. Water samples will additionally be collected near the mouth of Hall Creek and in McAleer Creek near its outlet from the lake. (See Appendix B for a detailed map of the sampling locations). Sampling will occur monthly from November 2005 to October 2006.

Lab analyzed parameters will be total phosphorus, orthophosphorus, total persulfate nitrogen, chlorophyll-a and turbidity. If the lake is stratified, nutrients (total phosphorus, orthophosphorus and total persulfate nitrogen) 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 and stream measurements will be completed for each sample site. Field measured parameters will include temperature, conductivity, dissolved oxygen and pH. Water clarity will be measured using a Secchi disk. Secchi depth and chlorophyll will be used to assess algal biomass.

Representativeness

Because of the relative uniformity of Lake Ballinger, 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.

Quality Objectives

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 QA Project Plan 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 of bias will mostly occur at the laboratory.

Precision

MQOs for the lab analyzed parameters are given in Table 3.

Rules for evaluating precision change at very low concentrations. At levels near the lowest concentration of interest, it will not be possible to meet the percentage MQOs in Table 3 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 Manchester Environmental Laboratory's (MEL) method performance and control limits.

Table 3 is intended to indicate the quality of the result from a particular sample and therefore to apply to lab splits.

Table 3. Measurement Quality Objectives for Lab Analyzed Parameters

Parameter	Check Standard (LCS) (% recovery limits)	Duplicate Samples (RPD)	Matrix Spikes (% recovery limits)	Matrix Spike Duplicates (RPD)	Lowest Concentrations of Interest (units of concentration)
Lab Constituents					
Chlorophyll	80-120	20	75-125	20	0.05 ug/L
Orthophosphate	80-120	20	75-125	20	3 ug/L
Total Nitrogen	80-120	20	75-125	20	25 ug/L
Total Phosphorus	85-115	20	75-125	20	1.0 ug/L
Turbidity	80-120	20	N/A	N/A	0.5 NTU

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.

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 4. Orthophosphate will be field filtered; chlorophyll samples will be filtered by the lab.

Table 4. 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	ICPMS	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 lake co-located (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. In addition, a second set of samples will be collected at another deep spot of the lake to determine if any variability exists between the two spatially separated deep spots of the lake.

The results from the original sample and its duplicate sample are used to calculate the expected variance that is due to short term environmental factors (including temporal and spatial variability), field collection and processing. Quality control evaluations of discrete samples will use the pooled standard deviation of the duplicate samples. These values will be converted to a relative standard deviation by dividing by the mean of all results and expressed as a percent. (%RSDp). A level of 20% RSDp is set for all the parameters. For Secchi depth duplicate values, the quality control criterion will be ± 0.5 feet.

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 "transfer blanks" for constituents where there is no field processing of the sample (e.g., total phosphorus), and "filter blanks" for filtered constituents (e.g. orthophosphate). Blank results are expected to be below reporting limits.

Instrumentation

Profile data will be collected using a Hydrolab© multiparameter probe, calibrated according to manufacturer's instructions and Bell-McKinnon (2002). Table 5 indicates calibration limits that will be used to ensure accuracy of the field instruments.

Table 5. Calibration Limits for Field Instruments

Parameter	Limit
Conductivity	± 10 µS/cm at 100 µS/cm
Oxygen	± 0.4 mg/L
pH	± 0.2 std. units
Temperature	± 1.0 ºC

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.

Data Reduction and Management Procedures

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

Data Verification 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.

Field staff will verify the calibration values for the field instruments and note any environmental conditions that may affect instrument veracity.

Quality Assurance 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 3). The standard deviation of individual QC split pairs may be compared against MQO's if individual results will be used (for example, compared to a water quality criterion). The standard deviation of QC split pairs may be pooled to estimate a mean concentration.

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 $\mathbf{s_p}$ 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.

Data entry will be completed by January 2007; completion of the QC review and loading the data into EIM will be completed by March 2007. Preparation of the technical memorandum to Ecology's Water Quality Program will be accomplished by June 2007.

Data Quality Assessment

TMDL effectiveness will be evaluated by comparing mean summer total phosphorus concentrations to expected values based on criteria specified in the TMDL. A t-test will be used to compare the total phosphorus sample mean to the TMDL criteria in order to determine whether any significant differences exist.

In addition to the total phosphorus evaluation, the values of the other collected parameters will be used to help disclose a more complete picture of the lake environment and how they relate to the phosphorus concentrations observed. Trophic state will be calculated from total phosphorus, total nitrogen and Secchi depth values; these values will be compared to see if any differences in trophic state appear. In addition, the ratio of total phosphorus to chlorophyll-a will be calculated.

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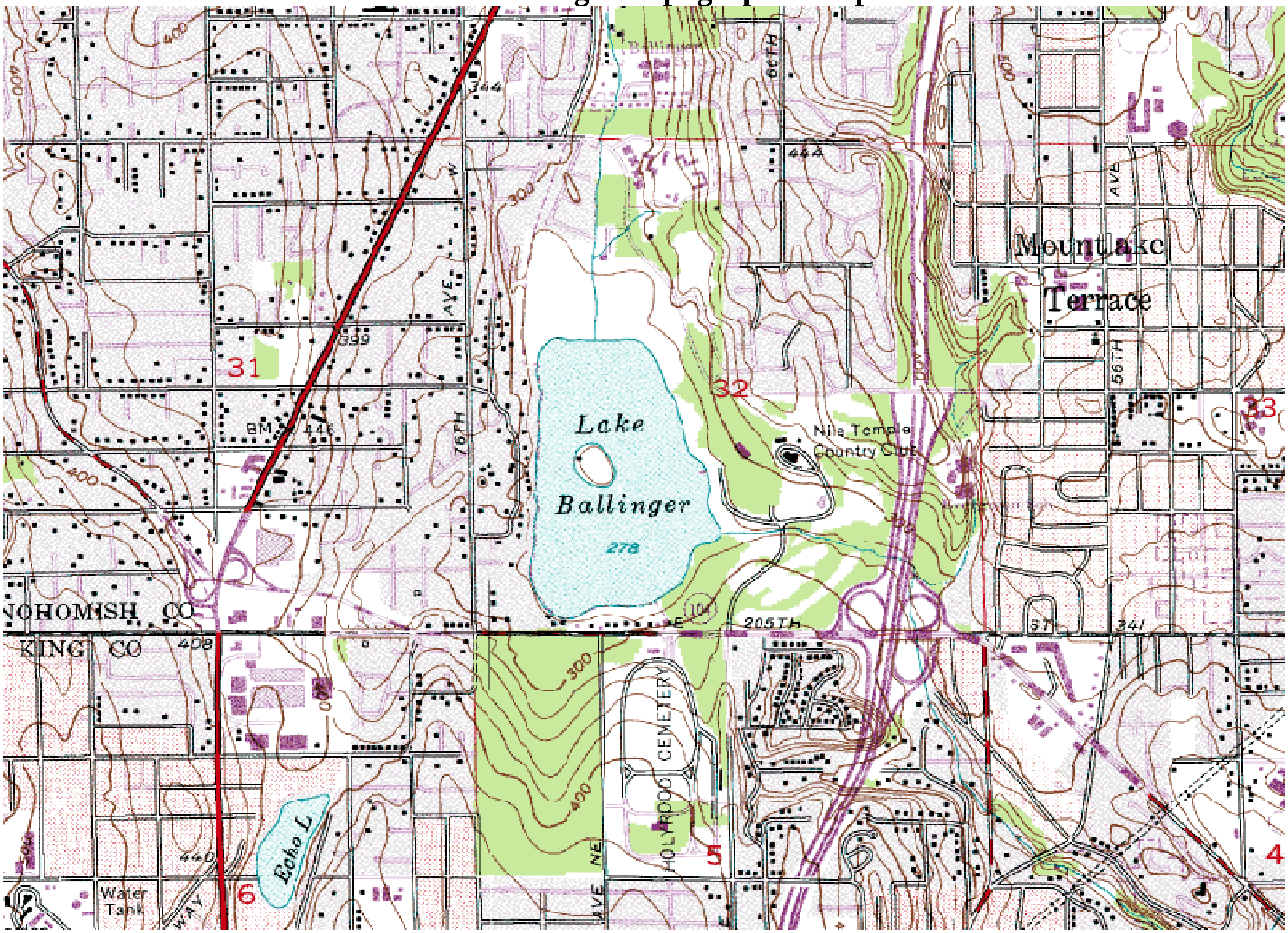
Appendix A

Lake Ballinger Topographic Map



Appendix B

Lake Ballinger Monitoring Locations (X marks the sampling spots)