Moses Lake Phosphorus TMDL Study

Quality Assurance Project Plan

Jim V. Carroll
and
Robert F. Cusimano

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Environmental Assessment Program
Olympia, WA 98504-7710

303(d) listings addressed in this study:

Moses Lake (WA-41-9250) – Total Phosphorus, Total Nitrogen
Crab Creek (WA-41-1010) – pH
Rocky Ford Creek (WA-41-2010) – pH, Dissolved Oxygen

Approvals:

David T. Knight, Eastern Regional Office	Date
Carl Nuechterlein, Section Manager, Eastern Regional Office	Date
Will Kendra, Section Manager, Watershed Ecology Section	Date
Stuart Magoon, Director, Manchester Environmental Laboratory	Date
Cliff Kirchmer, Ecology Quality Assurance Officer	Date
Karol Erickson, Unit Manager, Watershed Studies Unit	Date

Project Description

Problem Statement

The Washington State Department of Ecology (Ecology) recognizes Moses Lake as an important natural resource of Washington State, providing wildlife habitat, recreation, and water supply. Ecology's Eastern Regional Office (ERO) is concerned about the water quality in Moses Lake, a Class A waterbody, which is on the 1996 303(d) list for total nitrogen (TN) and total phosphorus (TP). Several restoration projects have been conducted on Moses Lake and its watershed over the last 20 years, including lake dilution, sewage diversion, agricultural best management practices (BMPs), and construction of a tributary nutrient retention pond. Despite improvement in lake water quality as a result of these projects, TN and TP levels remain elevated resulting in the persistence of blue-green algae blooms.

As a result, ERO requested that Ecology's Environmental Assessment (EA) Program report on the status of Moses Lake water quality and, if possible, develop a total maximum daily load (TMDL) for nutrient loading to the lake based on *historical data*. The federal Clean Water Act requires Washington State to establish a TMDL for each pollutant on the 303(d) list violating water quality criteria. The TMDL is then apportioned between point and nonpoint sources as wasteload and load allocations (WLAs and LAs), respectively. The primary goal of the ERO request was to have the EA Program develop an allocation strategy that could be used to improve lake water quality and ultimately lead to removing Moses Lake from the 303(d) list. EA completed the report "Moses Lake Proposed Phosphorus Criterion and Preliminary Load Allocations Based on Historical Data" in October 2000, Report No. 00-03-036 (Carroll *et. al.*, 2000).

Although Moses Lake is listed for both TP and TN on the 303(d) list, the historical studies on Moses Lake reviewed in the EA report show that TP is the nutrient to control to limit algal biomass. The strategy of managing TP to control the algal growth rate is supported in literature, even for lakes where nitrogen may be limiting growth. On this basis, the EA report recommended that Moses Lake be de-listed for TN from the 303(d) list and that future lake management activities and decisions focus on the control of TP to manage algal biomass in Moses Lake.

While the EA report presented preliminary phosphorus allocations, a major conclusion was that additional work should be completed before establishing a final TMDL and allocation strategy for the lake. The report recommended additional study of Moses Lake such that the results could be used, with the historical data, to finalize an allocation plan. The following were the major reasons for conducting an additional study of the lake listed in the EA report:

- No comprehensive water quality assessment of the lake has been done since the mid-1980s; multiple sources of data were used to develop the historical work, now 20 years old.
- Water quality data are needed to assign nutrient load allocations to the major nutrient sources. The historical work rarely addressed all the incoming loads at once and did not

model the lake in a way to set a maximum incoming load of TP to achieve the 50 ug/L criterion.

- New water quality data, together with findings and recommendations from the historical studies, are needed to set nutrient TMDLs for the lake.
- A TP TMDL for Moses Lake is needed to satisfy the requirements of the federal Clean Water Act and to help meet the water quality goals established for the lake by the previous studies.

Brief History of Moses Lake

Figure 1 shows Moses Lake, Rocky Ford Creek, and the lower part of "Upper Crab Creek." Moses Lake is a natural lake originally created by wind-blown sand dunes, which dammed part of the Crab Creek watershed. As one of the largest lakes in Washington State, Moses Lake is an important natural resource providing recreational and aesthetic opportunities. The primary water quality problem identified in the historical studies of Moses Lake is the hypereutrophic blooms of blue-green algae, which can impair the recreational uses for the lake during the summer months.

Excessive nutrient enrichment has accelerated the growth of algae in Moses Lake, resulting in the predominance of blue-green forms of algae. Blue-green algae form into unsightly floating mats, and are blown onto the beach where they decompose and cause odor problems. Localized fish kills are associated with periods of large algal blooms, and toxicity problems exist for some animals that drink the water. Several beaches have been closed to swimming at times, due to unsafe visibility in the water.

As a large, shallow hypereutrophic lake, Moses Lake has garnered the attention of limnologists and engineers in the last 30 years as a candidate for lake restoration. This attention has resulted in many studies that meet the requirements for site-specific diagnostic/feasibility lake studies, termed Phase I and Phase II Federal Clean Lake Projects.

Moses Lake and its watershed have been permanently altered since the inception of the Columbia Basin Irrigation Project (CBIP) in the early 1950s, when the U.S. Bureau of Reclamation (USBR) began importing Columbia River water into the upper Crab Creek watershed to promote the development of irrigated cropland. The Phase I studies indicate that anthropogenic activities, primarily agricultural practices and operations associated with the CBIP, were creating a hypereutrophic state in Moses Lake through nutrient enrichment.

Carroll *et. al.*, (2000) provides a detailed review of the historical studies of the lake and its watershed, and the beneficial uses of the lake.

Project Goal

The major goal of the proposed study is to assess the assimilative capacity of Moses Lake with respect to the in-lake TP criterion of 50 ug/L. Current data will be collected and used in this assessment. A phosphorus allocation plan will be recommended to achieve the in-lake TP criterion, if it is not currently being met.

Project Objectives

- Assess the current water quality condition of Moses Lake by conducting surface and ground water quality surveys.
- Measure lake inflows and lake outflows.
- Identify TP watershed loading contributions to the lake from surface and groundwater sources.
- Develop an approach for modeling the water quality of the lake, then use the model to assess the capacity of the lake to assimilate TP with respect to maintaining the in-lake TP criterion of 50 ug/L.
- Develop a phosphorus allocation plan based on meeting the in-lake TP criterion of 50 ug/L.

Study Design

Approach

Carroll *et. al.*, (2000) recommended that a dynamic computer model for Moses Lake be developed to look at the seasonal and spatial effects of annual phosphorus loading changes throughout the entire lake. Under this study plan, the EA Watershed Ecology Section (WES) is proposing to assess the tributary loading to Moses Lake for one year (October 2000-September 2001) and monitor lake water quality for seven to eight months during the study. The focus of the data collection efforts will be to collect data that can be used to develop a dynamic model of the lake in order to simulate the hydrodynamics of the lake and estimate the water column total phosphorus concentration in the lake (see water quality modeling section). Lake sampling will begin in late March. The lake will be sampled monthly through October 2001. Tributary samplings occurred monthly from October 2000 through February 2001 as part of a routine monthly monitoring conducted by Ecology. More intensive samplings, twice per month, will occur March through September 2001.

Field Sampling:

Figure 1 shows the proposed lake and tributary sampling locations. Table 1 lists the tributary and lake sampling stations that the WES Watershed Studies Unit (WSU) will monitor monthly for the Moses Lake TMDL study. Table 2 lists the parameters to monitor and frequency at each station. During the synoptic surveys, grab samples will be collected once or twice a day from the tributary stations on the first day of the survey and once from each of the lake stations on the second day of the survey.

As part of this project, the Environmental Monitoring and Trends (EMT) section's Freshwater Monitoring Unit (FMU) will sample the following four tributary and lake sampling stations from October 2000 through September 2001, once per month:

Rocky Ford Creek at mouth (below dam) (RF0)
Rocky Coulee Wasteway at Road K bridge (RC1)
Crab Creek at the USGS Gaging Station at Road 7 NE (CC1)
Moses Lake at the Outlet (ML7)

FMU will sample these stations for dissolved oxygen (DO), conductivity, pH, temperature, total suspended solids, turbidity, fecal coliform bacteria, and nutrients following their quality assurance procedures (Ehinger, 1995). WES and FMU will stagger their sampling times so that these sites will be monitored twice per month, approximately two weeks apart.

During each WES survey, water column data will be collected at 1-meter intervals at each lake station using a Hydrolab® Surveyor 2. In addition, *in situ* Hydrolab® dataloggers (Datasonde 3) will be placed at the mouth of Crab Creek and Rocky Ford Creek to collect continuous conductivity, pH, and temperature measurements for water entering the lake from March 2001 through the end of the study period. Water collection for laboratory analyses will follow the design outlined in Table 2. Parameters of interest include turbidity, total suspended solids, total dissolved solids, alkalinity, chlorophyll a, total and dissolved organic carbon, conductivity, pH, dissolved oxygen, temperature, chloride, biochemical oxygen demand, and nutrients. These parameters will allow the greatest assessment of the transport and fate of phosphorus in Moses Lake and its watershed.

Additional field measurements will be made to support the phosphorus assessment study. Vertical profiles of light extinction will be measured at 3 stations (ML2, ML3, and ML4) during each lake survey. Primary photosynthetic production and respiration will be measured at least twice during the study period using light and dark bottle tests of dissolved oxygen production and consumption (APHA et al., 1998). Light and dark bottles will be incubated at 1 and 3 meter depths for approximately six hours during the photo period of the day. Algal photosynthesis and respiration rates will be calculated by methods of APHA et al., (1998) and Thomann and Mueller (1987).

Phytoplankton samples will be collected at selected stations during each lake survey to provide data on species composition and biovolume.

Groundwater discharge to Moses Lake will be characterized for water quality parameters by the EA Contaminant Studies Unit (CSU) as outlined in the quality assurance project plan, "Characterization of the Groundwater Discharge to Moses Lake, Washington" (Pitz, draft in progress).

The EMT Stream Hydrology Unit (SHU) will measure tributary stream flows to the lake from October 2000 through September 2001. They will record continuous stage height data at two stations (RF0 and RC1; Table 1) and will develop rating curves to calculate continuous discharge from these sites. In addition, the USGS maintains a gaging sites at two stations (CC1 and RF2) and monitors the continuous stage height of Moses Lake.

Lake Water Quality Modeling:

The project requires a model capable of simulating the transport and fate of phosphorus in a lake environment, including a mechanism accounting for the settling and flux (release) of phosphorus to the sediments. In addition, the model needs to include hydraulic routing as a variable that can be easily changed, due to the managed hydrology of the watershed, and to also include groundwater phosphorus loading directly to the lake.

An appropriate model will be chosen (or a combination of models) which meets the above specifications. The model will be calibrated to the field data collected during the study. The calibrated model will then be used to assess the capacity of the lake to assimilate TP seasonally and spatially with respect to maintaining the in-lake TP criterion of 50 ug/L.

The model results will be used with the historical data to finalize an allocation plan. This allocation plan will include setting load allocations (LA) and waste load allocations (WLA) necessary to meet the in-lake TP criterion of 50 ug/L.

Data Quality Objectives and Analytical Procedures

The Manchester Laboratory (MEL, 2000) publishes reporting limits for the analytical methods they perform. These reporting limits have been deemed satisfactory to meet the data quality objectives for this project. Field measurements and laboratory analyses are listed in Table 3, including the methods, corresponding reporting limits, target precision and target bias acceptable range.

Sampling and Quality Control Procedures

Collecting replicate samples will assess total variation for field sampling and laboratory analysis and thereby provide an estimate of total precision. At least 10% of the total number of laboratory samples and field measurements per parameter will be replicated. In addition, field blanks and total phosphorus standards supplied by the Manchester Environmental Laboratory (MEL) will be submitted with routine samples to the laboratory to determine the presence of bias in the analytical methods. Concentrations of standards will approximate expected field concentrations.

All water samples for laboratory analysis will be collected in pre-cleaned containers supplied by MEL, except dissolved organic carbon and ortho-phosphate, which will be collected in a syringe and filtered into a pre-cleaned container. The syringe will be rinsed with ambient water at each sampling site three times before filtering. All samples for laboratory analysis will be preserved as specified by Manchester Environmental Laboratory (MEL, 2000) and delivered to MEL within 24 hours of collection. Laboratory analyses listed in Table 3 will be performed in accordance with MEL (2000).

Field sampling and measurement protocols will follow those specified in WAS (1993) for temperature (alcohol thermometer), pH (Orion Model 250A meter and Triode™ pH electrode), conductivity (Beckman Model RB-5 and YSI 33), dissolved oxygen (Winkler titration), streamflow (Marsh-McBirney 201 & 2000), and *in situ* temperature, dissolved oxygen, pH, and specific conductance (Hydrolab® multi-parameter meters). All meters will be calibrated and post-calibrated per manufacturer's instructions.

Data Assessment Procedures

Laboratory data reduction, review, and reporting will follow procedures outlined in MEL's Users Manual (MEL, 2000). All water quality data will be entered into Ecology's Environmental Information Management (EIM) system. Data will be verified, and 100% of data entry will be reviewed for errors.

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution transformations. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) will be made using SYSTAT/SYGRAPH8 and EXCEL software.

Project Schedule and Budget

The schedule for the proposed study is as follows:

Submit draft QAPP for internal review:	February 15, 2001
Finalize QAPP:	March 15, 2001
Intensive Sampling Surveys begin	March 2001
Intensive Sampling Surveys end	October 2001
Draft Report to Unit Manager	April 30, 2002
Draft to Client	May 15, 2002
External Draft	June 2002
Final Report	September 30, 2002

Project Responsibilities

The following individuals and organizations will be involved in the project:

Bob Cusimano (Ecology): Project Manager responsible for overall project supervision. (360-407-6688)

Jim Carroll (Ecology): Principal Investigator responsible for preparation of Quality Assurance Project Plan (QAPP), project design, collecting and analyzing data, modeling, developing graphs and figures, writing and editing draft and final reports. (360-407-6196)

Robert Plotnikoff (Ecology): Unit Supervisor of the Freshwater Monitoring Unit of the Environmental Assessment Program. Responsible for supervising the monthly water quality sampling at four monitoring stations during the study. (360-407-6687)

Charles Pitz (Ecology): Principle Investigator for the Contaminant Studies Unit of the Environmental Assessment Program. Responsible for assessing the water quality of the direct groundwater discharge to Moses Lake. (360-407-6775)

Brad Hopkins (Ecology): Unit Supervisor of the Stream Hydrology Unit of the Environmental Assessment Program. Responsible for providing discharge data for two project stations and lake outflow. (360-407-6686)

Will Kendra (Ecology): Section Supervisor of the Watershed Ecology Section of the Environmental Assessment Program. Responsible for approving the project QAPP, project budget, and project reports. (360-407-6698)

Karol Erickson (Ecology): Unit Lead of the Watershed Studies Unit of the Environmental Assessment Program. Responsible for internal review of the project QAPP and draft data summary reports. (360-407-6694)

Stuart Magoon, and Pam Covey (Ecology). Manchester Environmental Laboratory (MEL) staff responsible for analysis and reporting of chemical data. (360-871-8860)

Cliff Kirchmer (Ecology). Quality Assurance Section staff responsible for review of the project QAPP and providing technical assistance on QA/QC during implementation of the project. (360-407-6455)

References

APHA, et al., 1998. Standard Methods for the Examination of Water and Wastewater. Sixteenth edition. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Washington D.C.

Carroll, J.V., R.F. Cusimano, and W.J. Ward, 2000. Moses Lake Proposed Phosphorus Criterion and Preliminary Load Allocations Based on Historical Review. Publication No. 00-03-036. Washington State Department of Ecology, Environmental Assessments Program, Olympia, WA.

Ehinger, W., 1995. Freshwater Ambient Water Quality Monitoring Final Quality Assurance Project Plan. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA March 1996, 23pp. +appendices.

MEL, Manchester Laboratory, 2000. Manchester Environmental Laboratory Users Manual. Washington Department of Ecology, Manchester, WA.

Pitz, C.F., (draft in progress). Characterization of the Groundwater Discharge to Moses Lake, Washington. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA.

Thomann, R.V. and J.A. Mueller, 1987. Principles of Surface Water Modeling and Control. Harper and Row Publishers, Inc. New York, NY.

WAS, 1993. Field Sampling and Measurement Protocols for the Watershed Assessments Section. Ecology Manual, Washington State Department of Ecology, EAP Program. Olympia, WA.

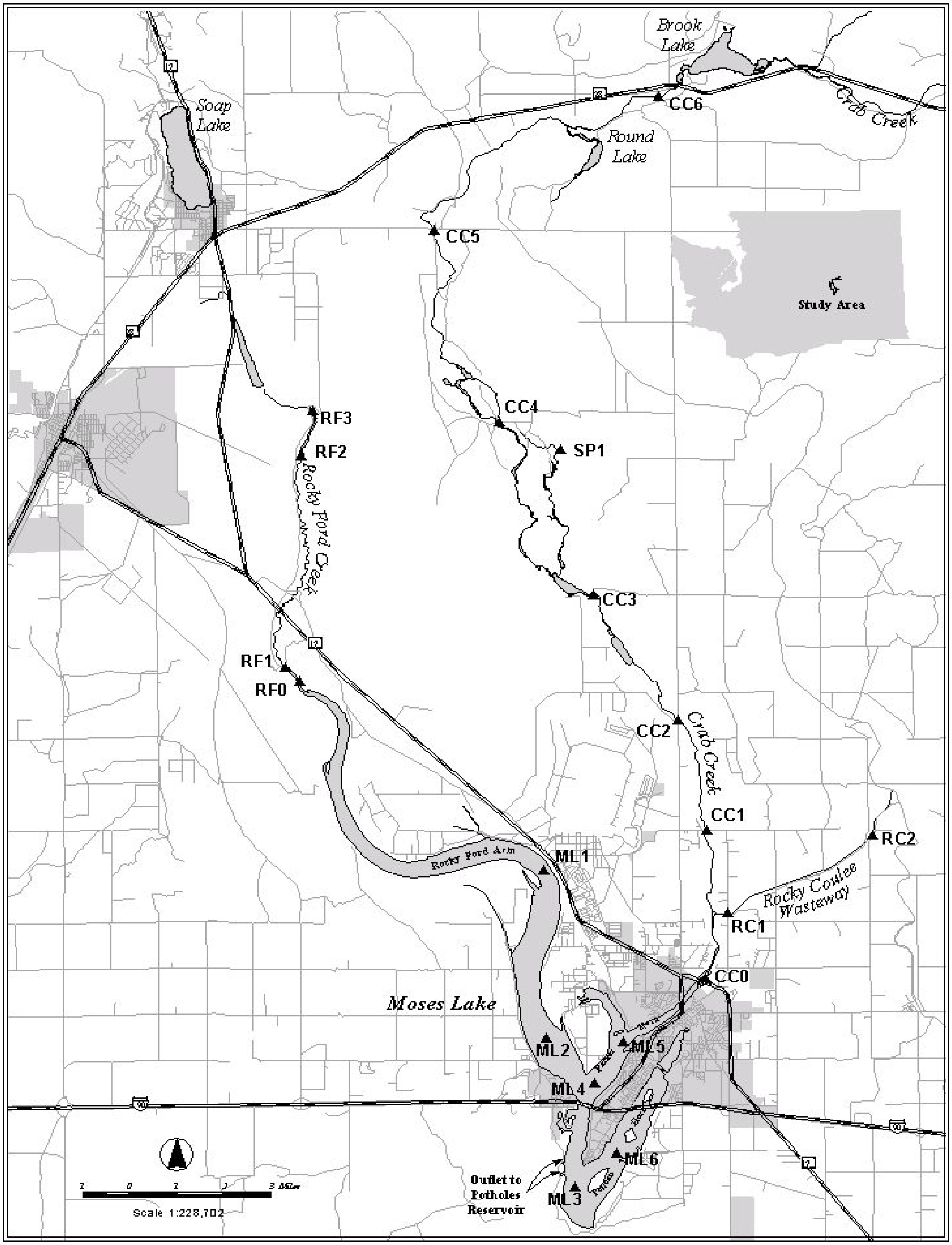

Figure 1. Vicinity map of Moses Lake and partial watershed with proposed sampling stations.

Table 1. Tributary and lake sampling sites for the Moses Lake Phosphorus TMDL.

	Site Name	**Location**
	RF0	Rocky Ford Creek at mouth (below dam)
	RF1	Rocky Ford Creek at mouth (above dam pool)
	RF2	Rocky Ford Creek at USGS gaging site
	RF3	Rocky Ford Creek headwater spring
	CC0	Crab Creek at mouth
	CC1	Crab Creek at Road 7 bridge (USGS gaging site)
	CC2	Crab Creek at Road J bridge
	CC3	Crab Creek at end of Road 12
	CC4	Crab Creel at Road 16 crossing
	CC5	Crab Creek at Road 20 (Adrian bridge)
	CC6	Crab Creek at Stratford
	SP1	Springs feeding Crab Creek in Gloyd Seeps
	RC1	Rocky Coulee Wasteway at Road K bridge
	RC2	Rocky Coulee Wasteway at near East Low Canal
	ML1	Moses Lake at Rocky Ford Arm bend
	ML2	Moses Lake at Rocky Ford Arm basin
	ML3	Moses Lake at south basin
	ML4	Moses Lake at lower Parker Horn
	ML5	Moses Lake at upper Parker Horn
	ML6	Moses Lake at lower Pelican Horn
	ML7	Moses Lake outlet

Table 2. Number of samples taken during each Watershed Studies Unit survey for the Moses Lake Phosphorus TMDL Study

Site Location	Type	Field	Turb	TSS	TDS	Alka	Chl a	Phyto	TOC	DOC	COND	Cl	TPN	Nut. 5	UBOD
RF0	Creek	2	1	2	2	2	1	1	1	1	2	2	1	2	1
RF1	Creek	1	1	1								1	1	1	
RF2	Creek	1		1								1	1	1	
RF3	Spring	1	1	1	1	1			1	1	1	1	1	1	
CC0	Creek	2	1	2	2	2	1	1	1	1	2	2	1	2	1
CC1	Creek	1	1	1	1	1	1		1	1	1	1	1	1	
CC2	Creek	1		1								1	1	1	
CC3	Creek	1		1								1	1	1	
CC4	Creek	1		1								1	1	1	
CC5	Creek	1		1								1	1	1	
CC6	Creek	1	1	1	1	1			1	1	1	1	1	1	
SP1	Spring	1	1	1	1	1			1	1	1	1	1	1	
RC1	Wasteway	1	1	1	1	1	1		1	1	1	1	1	1	
RC2	Wasteway	1	1	1	1							1	1	1	
QA			2	2	2	2	2		1	1	2	2	2	2	1
Day 1 Totals			11	18	12	11	6	2	7	7	11	18	16	18	3
ML1 (4 depths)	Lake	1	2		3	3	4	1	3	3	2	3	4	4	
ML2 (4 depths)	Lake	1	3		3	3	3	1	3	3	2	3	4	4	
ML3 (5 depths)	Lake	1	3		4	4	4	1	4	4	2	4	5	5	
ML4 (4 depths)	Lake	1	3		3	3	3	1	3	3	2	3	4	4	
ML5 (3 depths)	Lake	1	2		2	2	3	1	2	2	2	2	3	3	
ML6 (3 depths)	Lake	1	2		2	2	3	1	2	2	2	2	3	3	
ML7	Lake outlet	1			1		1		1	1		1	1	1	
QA			2		2	2	2	1	2	2	2	2	2	2	
Day 2 Totals			17		20	19	23	7	20	20	14	20	26	26	0
Two Day Total			27	17	32	30	29	9	27	27	25	38	42	44	3

Field Parameters: pH, DO, temperature, conductivity, (for lake sites field parameters at 1 meter intervals surface to bottom plus secchi disk; light attenuation at ML2, ML3, ML4 at 1 meter intervals)

Lab Parameters: Turbidity (Turb), total suspended solids (TSS), total dissolved solids (TDS), alkalinity (Alka), chlorophyll a (Chl a), phytoplankton biovolume and ID (Phyto), total organic carbon (TOC), dissolved organic carbon (DOC), conductivity (Cond), chloride (Cl), total persulfate nitrogen (TPN), ortho-phosphate, total phosphorus, ammonia, nitrate, nitrite (Nut. 5), and ultimate biochemical oxygen demand (UBOD)

Other notes: Lake Depths will be sampled every 3 meters from surface to bottom. UBOD will be sampled quarterly.

Table 3. Summary of parameters, methods, reporting limits and targets for precision and bias.

Parameter	Lower Reporting Limit	Target Precision RSD- (relative std. deviation) or acceptable range	Target Bias	Method[a]
Field Measurements				
Velocity	NA	± 0.05 f/s	NA	Current Meter
Temperature (Temp)	NA	± 0.2 /C	NA	Alcohol Thermometer
pH	NA	± 0.1 pH units	NA	Field Meter/Electrode
Dissolved Oxygen (DO)	NA	± 0.06 mg/L	NA	Winkler Titration
Specific Conductivity (Cond)	NA	± 20 μmhos/cm	NA	Conductivity Bridge
Secchi Disc Depth	NA	± 0.5 m	NA	Secchi Disc
Light Attenuation	0.0014 $\mu W/cm^2$	<15 % RSD	<10%	Irradiameter
General Chemistry				
Specific Conductance	1 μmhos/cm	<10 % RSD	<10%	SM16 2510
Ammonia nitrogen (NH3)	0.01 mg/L	<10 % RSD	<20%	EPA 350.1
Nitrate + nitrite nitrogen (NO2-3)	0.01 mg/L	<10 % RSD	<10%	EPA 353.2
Total persulfate nitrogen (TPN)	0.01 mg/L	<10 % RSD	<10%	SM 4500 NO3-F (Mod)
Turbidity	1 NTU	<10 % RSD	<10%	EPA 180.1
Orthophosphate (Ortho-P)	0.005 mg/L	<10 % RSD	<20%	EPA 365.3
Total phosphorus (TP)	0.01 mg/L	<10 % RSD	<15%	EPA 365.3
Chloride (Cl)	0.1 mg/L	<10 % RSD	<10%	EPA 300.0
Total Organic Carbon (TOC)	1.0 mg/L	<10 % RSD	<15%	EPA 415.1
Dissolved Organic Carbon[b] (DOC)	1.0 mg/L	<10 % RSD	<15%	EPA 415.1
Alkalinity	10 mg/L	<10 % RSD	<15%	EPA 310.2
Ultimate Carbonaceous BOD	2 mg/L	<15 % RSD	NA	NCASI (1987)[c]
Phytoplankton ID/Biovolume	NA	NA	NA	SM18 10200F; Sweet,1987
Total Suspended / Dissolved Solids	1.0 mg/L	<15 % RSD	< 10%	EPA 160.3
Chlorophyll *a* (Chl-a)	0.05 μg/L	<10 % RSD	<10%	Fluorometer, SM10200H(3)

[a] SM = Standard methods for the examination of water and wastewater. 20th edition (1998). American Public Health Association, American Water Works Association, and Water Environmental Federation. Washington, D.C.

[b] Filter in field with Whatman PURADISC™ 0.45 μm pore size syringe filter.

[c] A procedure for estimation of ultimate oxygen demand. National Council of the Paper Industry for Air and Stream Improvement. Inc. Special Report No. 87-06. May 6, 1987.