DEPARTMENT OF
ECOLOGY
State of Washington

Quality Assurance Project Plan

Deep Lake (Stevens County) Monitoring

May 2014

Publication No. 14-03-109

Publication Information

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

The plan for this study is available on Ecology's website at
https://fortress.wa.gov/ecy/publications/SummaryPages/1403109.html

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search Study ID, JROS0024.

Ecology's Activity Tracker Code for this study is 15-004.

Author and Contact Information

Tighe Stuart
4601 N. Monroe St.
Environmental Assessment Program
Washington State Department of Ecology
Spokane, WA 99205-1295

For more information contact: Communications Consultant, phone 360-407-6834.

Washington State Department of Ecology - www.ecy.wa.gov

o	Headquarters, Olympia	360-407-6000
o	Northwest Regional Office, Bellevue	425-649-7000
o	Southwest Regional Office, Olympia	360-407-6300
o	Central Regional Office, Yakima	509-575-2490
o	Eastern Regional Office, Spokane	509-329-3400

Quality Assurance Project Plan

Deep Lake (Stevens County) Monitoring

May 2014

Approved by:

Signature: Date: May 2014
Martyn Quinn, Client, Water Quality Program, ERO

Signature: Date: May 2014
Dave Knight, Client's Unit Supervisor, Water Quality Program, ERO

Signature: Date: May 2014
James Bellatty, Client's Section Manager, Water Quality Program, ERO

Signature: Date: May 2014
Tighe Stuart, Author, EAP, ERO

Signature: Date: May 2014
Jim Ross, Author's Unit Supervisor, Project Manager, Principal Investigator, EAP, ERO

Signature: Date: May 2014
Tom Mackie, Author's Section Manager, EAP, ERO

Signature: Date: May 2014
Joel Bird, Director, Manchester Environmental Laboratory, EAP

Signature: Date: May 2014
Bill Kammin, Ecology Quality Assurance Officer

Signatures are not available on the Internet version.
ERO: Eastern Regional Office
EAP: Environmental Assessment Program

Table of Contents

List of Figures and Tables

Page

Figures

Tables

Abstract

Local residents of Deep Lake, in Stevens County, have reported water quality problems including blue-green algae blooms and have expressed desire for lake monitoring. A one-year study will assess lake eutrophication as well as pollutant loading to and from the lake. Parameters to be monitored will include fecal coliform, total suspended solids, ammonia, nitrite-nitrate nitrogen, total persulfate nitrogen, ortho-phosphorus, total phosphorus, pH, dissolved oxygen, conductivity, temperature, lake clarity, and inlet/outlet streamflow.

Background

Study Area Description

Deep Lake is located approximately 10 miles southeast of Northport, Washington, in Stevens County (Figure 1). The lake is located in Water Resource Inventory Area (WRIA) 61 (Upper Lake Roosevelt), and level 8 HUC 17020001 (Franklin D. Roosevelt Lake). It has a surface area of 0.32 square mi, and a maximum depth of about 45 ft.

The lake is located along North Fork Deep Creek, which drains a mostly forested area along the western slope of a north-south range of the western Rocky Mountains. North Fork Deep Creek flows into Deep Lake at the north end of the lake, and flows out at the south end. From the outlet of Deep Lake, the creek flows southwest to join with South Fork Deep Creek, forming Deep Creek, which empties to Lake Roosevelt near Northport.

Much of Deep Lake is surrounded by residential development including vacation homes. The surrounding landscape is primarily forestland. For about four miles upstream of Deep Lake, North Fork Deep Creek flows along a fairly level valley bottom, which is dominated by livestock grazing for a part of the year. The Anderson-Calhoun Mine, an open pit mine which formerly produced lead and zinc, is located along North Fork Deep Creek, about four miles upstream of Deep Lake.

Reported Water Quality Problems

There have been a number of complaints from local residents about water quality in Deep Lake, representing a perception that water quality in Deep Lake has been declining. Residents also expressed concerns about blue-green algae. One blue-green algae bloom was confirmed by Ecology in November 2012. Local residents have expressed a desire for monitoring of the lake. Potential sources of nutrients, fecal coliform, and sediment include upstream livestock activities as well as possible residential sources adjacent to the lake.

Ecology last sampled Deep Lake in 1997, collecting nutrient data twice and secchi and field measurement data seven times during spring, summer, and fall. At that time, Deep Lake was estimated to be oligo-mesotrophic, with total phosphorus concentrations ranging from 10-40 ug/L.

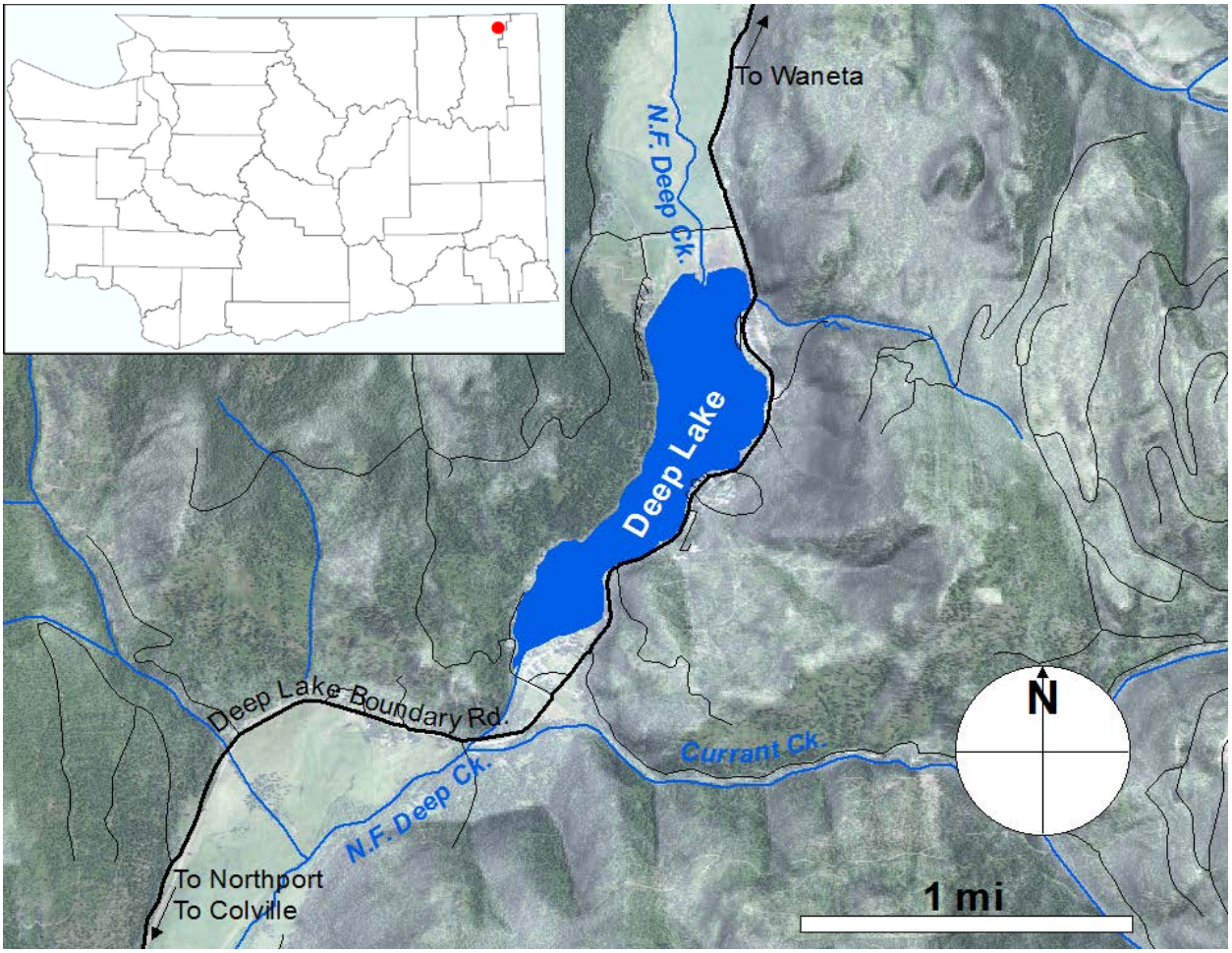

Figure 1. Location of Deep Lake in northeastern Washington.

Water Quality Standards and Beneficial Uses

The 2006 Water Quality Standards for Surface Waters of the State of Washington Chapter 173-201A WAC (Ecology, 2006a) designates all lakes for the beneficial use, *Core Summer Salmonid Habitat.* This designation protects year-round uses by salmon and trout, including spawning and rearing. Lakes are also given a recreational use, *Extraordinary Primary Contact Recreation*. This use provides extraordinary protection against waterborne disease. Each beneficial use has associated water quality criteria.

Table 1 lists the criteria that are applicable in Deep Lake.

Table 1. Water quality criteria applicable to Deep Lake.

Parameter	Criteria
Fecal Coliform	Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies /100 mL.
Dissolved Oxygen	Dissolved oxygen (DO) concentrations are not to fall below 9.5 mg/L at a probability frequency of more than once every ten years on average. When a water body's DO is lower than 9.5 mg/L (or within 0.2 mg/L) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the DO of that water body to decrease more than 0.2 mg/L. For lakes, human actions considered cumulatively may not decrease the DO concentration more than 0.2 mg/L below natural conditions.
pH	pH shall be within the range of 6.5 to 8.5 with a human-caused variation within above range of less than 0.2 units.
Temperature	7-day average of the daily maximum temperature (7-DADMax) is not to exceed 16°C at a probability frequency of more than once every ten years on average. When a water body's temperature is warmer than 16°C (or within 0.3°C) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-DADMax temperature of that water body to increase more than 0.3°C. For lakes, human actions considered cumulatively may not increase the 7-DADMax temperature more than 0.3°C above natural conditions.

Project Description

Goals and Objectives

The goals of this project are to:

- Provide baseline water quality data to support future monitoring by citizen groups or other agencies.
- Assess eutrophication and fecal coliform status of Deep Lake.

These goals will be served by meeting the following objectives:

- Take depth profiles and collect nutrient samples at two deep locations in the lake.
- Take samples of fecal coliform and nutrients at lake inlet and outlet, and at four shallow locations in the lake.
- Sample monthly from May through October 2014.

Citizen Involvement

This project resulted from a desire for lake monitoring by local residents at Deep Lake. At this time residents have already collected some water quality samples and had them analyzed for microbiology parameters. It is Ecology's desire that this monitoring project be conducted in concert with interested local residents, a small number of which have already offered their direct involvement. Ecology is probably limited to being able to monitor for one sampling season, with monthly sampling events. Local residents will be given the opportunity to:

- Accompany Ecology field crews during monitoring events, allowing them to learn and practice monitoring techniques.
- Visually check for signs of blue-green algae blooms, and if a bloom appears to be occurring, take a sample for algal toxin analysis. This can be accomplished through Ecology's Freshwater Algae Control Program: http://www.ecy.wa.gov/programs/wq/plants/algae/monitoring/index.html with project staff helping to make sure that residents have the necessary sampling kits/containers on hand.
- Conduct independent monitoring studies in 2014 and/or thereafter. Such monitoring would be the responsibility of the involved residents and would be outside of Ecology's purview. However, Ecology staff would be available to advise and review data if residents so desire.

Sampling Design

A field crew of at least two people will collect samples monthly from May through October 2014. Nutrient samples will be collected at two deep sampling sites, one representing the north and the other representing the south half of the lake (DEEPLK-1, DEEPLK-2). Profiles of pH, conductivity, DO, and temperature as well as secchi disc depths will also be measured at the deep sampling sites. Fecal coliform samples will be collected at three shallow sampling sites

near the edges of the lake (DEEPLK-A, DEEPLK-B, and DEEPLK-C) and also at DEEPLK-1 to compare a far-shore location. To assess loads entering and leaving the lake, nutrient, fecal coliform, total suspended solids, pH, conductivity, DO, temperature, and flow at the inlet and the outlet of the lake. Figure 2 and Table 2 present the sampling locations to be used during this study.

Fecal coliform samples will be taken from approximately 0.5m below the surface at each fecal sampling location. Measurements of pH, conductivity, DO, and temperature will be taken at 1- to 2-meter intervals throughout the water column using a Hydrolab MiniSonde® at the nutrient sampling sites. The Hydrolab profile will be used to find the thermocline, which will define the boundary between the epilimnion and the hypolimnion. Composite nutrient samples will be taken from the epilimnion and the hypolimnion at each sampling location. Each composite sample will consist of samples taken at three depths in the appropriate layer. Sample collection depths will be determined by dividing each layer into thirds, and taking a sample from each third. If the lake is not stratified, a single composite sample will be taken. Nutrient parameters to be collected include ammonia, nitrite-nitrate, total persulfate nitrogen, orthophosphate, and total phosphorus.

The most likely practical constraint on completing this study as planned would occur if Ecology field crews cannot gain permission to access the inlet and/or outlet sites via private land. In this case, samples could most likely still be collected from road bridges, but wading, and therefore flow measurements, might not be possible.

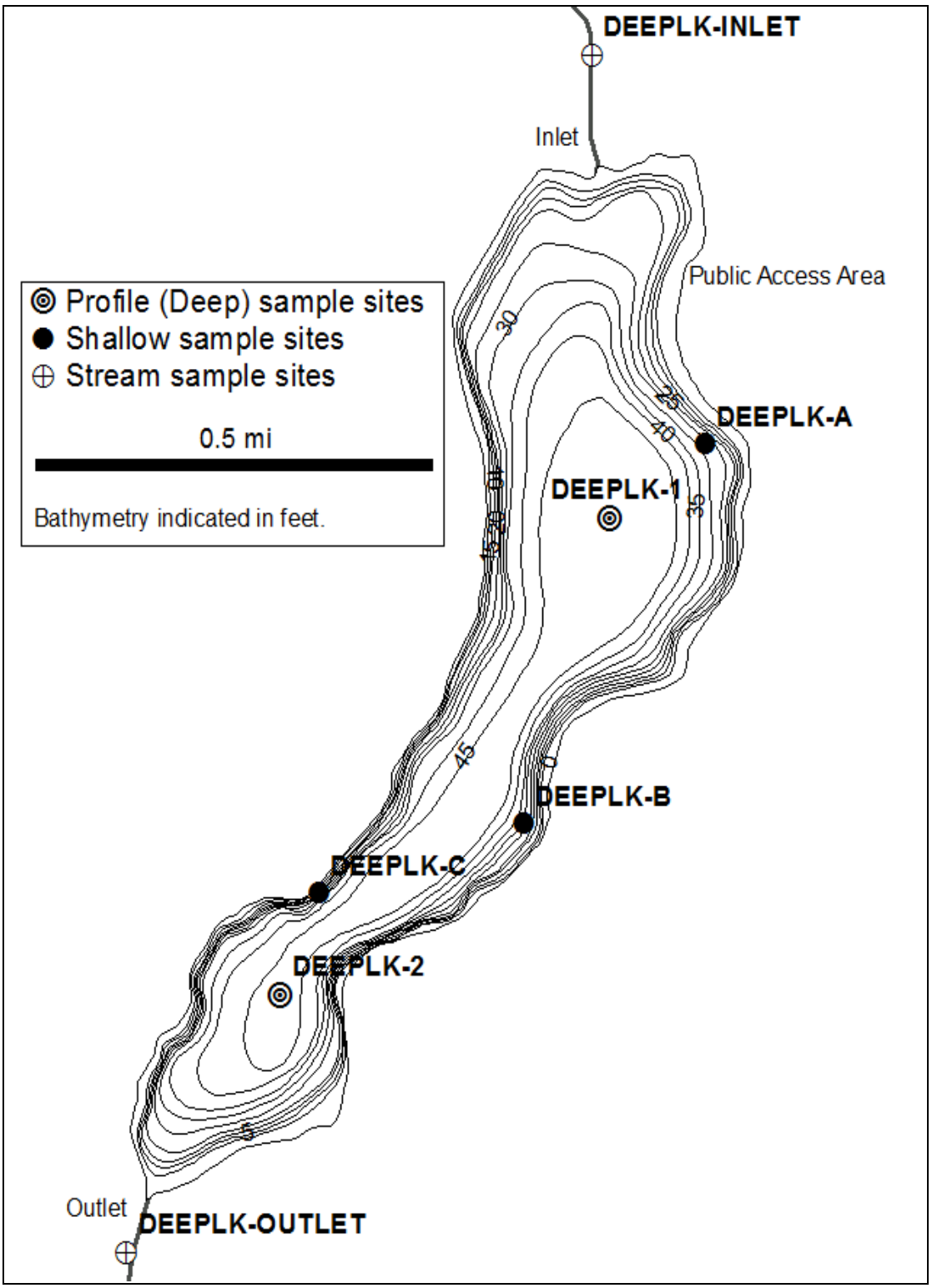

Figure 2. Map showing sampling locations on Deep Lake.

Table 2. Description of sampling locations.

Station ID	Station Description	Latitude	Longitude	Fecal Coliform	Nutrients	Tot Susp Solids	Secchi	Hydrolab *profile	Flow
DEEPLK-1	Deep location in northern half of lake	48.8613	-117.6029	X	X		X	*X	
DEEPLK-2	Deep location in southern half of lake	48.8534	-117.6124		X		X	*X	
DEEPLK-INLET	Inlet at Deep Lake North Shore Way	48.8691	-117.6030	X	X	X		X	X
DEEPLK-OUTLET	Outlet at Deep Lake South Shore Rd.	48.8491	-117.6168	X	X	X		X	X
DEEPLK-A	Shallow location northeast	48.8625	-117.6002	X					
DEEPLK-B	Shallow location east	48.8561	-117.6056	X					
DEEPLK-C	Shallow location west	48.8551	-117.6112	X					

Organization and Schedule

Table 3 lists the people involved in this project. All are employees of the Washington State Department of Ecology. Table 4 presents the proposed schedule for this project. Table 5 gives the laboratory costs for this project. There are no known limitations on adhering to the project schedule.

Table 3. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Martyn Quinn Water Quality Program Eastern Regional Office Phone: 509-329-3472	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Helps collect field samples and records field information.
Jim Ross Eastern Regional Office Phone: 509-329-3425	Unit Supervisor, Project Lead, Principal Investigator	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP. Directs data collection, helps collect field samples, enters data into EIM, and records field information.
Tighe Stuart Eastern Regional Office Phone: 509-329-3476	Field assistant	Writes the QAPP. Helps collect field samples and records field information.
Andy Albrecht Eastern Regional Office Phone: 509-329-3417	Field assistant	Helps collect field samples and records field information.
Tom Mackie Central Regional Office Phone: 509-454-4244	Section Manager	Approves the final QAPP.
Joel Bird Manchester Environmental Laboratory Phone: 360-871-8801	Laboratory Director	Approves the final QAPP.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Approves the draft and final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

Table 4. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	10/2014	Jim Ross
Laboratory analyses completed	11/2014	
Environmental Information System (EIM) database		
EIM user study ID	JROS0024	
Product	Due date	Lead staff
EIM data loaded	1/2015	Jim Ross
EIM quality assurance	2/2015	TBD
EIM complete	3/2015	Jim Ross
Final technical memo to client		
Author lead	Jim Ross	
Due Date	4/2015	

Table 5. Laboratory cost estimate.

Sample Type	Parameter	Sites	QA (Field duplicate)	Visits	Field Blanks	Analytical cost per sample	Subtotal
Surface Water	Nutrients[1]	(2 deep sites x 2 composite samples) + 2 stream sites = 6	4 during project (a QA of a deep site counts as 2)	6	2	$83	$3486
	Fecal Coliform	6	4 during project	6	0	$25	$1000
	Total Susp. Solids	2	2 during project	6	1	$12	$180
						Total laboratory cost estimate:	$4666

[1]Includes ammonia, nitrite-nitrate, total persulfate nitrogen, orthophosphate, and total phosphorus.

Measurement Quality Objectives

Field sampling procedures and laboratory analyses inherently have associated uncertainty which results in data variability. Measurement quality objectives state the desired data variability for a project. *Precision* and *bias* are data quality criteria used to indicate conformance with measurement quality objectives. The term *accuracy* refers to the combined effects of precision and bias.

Precision is the measure of variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for replicate samples will be expressed as percent relative standard deviation (%RSD).

Bias is the difference between the population mean and true value of the parameter being measured. Bias will be minimized by strictly following sampling and handling protocols. Field equipment will be pre-calibrated and post-checked. Relative percent difference (RPD) will be used as a measure of bias where appropriate.

Field sampling precision and bias will be addressed by submitting field blanks and replicate samples. Manchester Environmental Laboratory (MEL) will assess precision and bias in the laboratory through the use of check standards, duplicates, spikes, and blanks.

Field equipment and laboratory analytical methods, precision and bias objectives, method reporting limits and resolution, and estimated range for field and laboratory measurements are shown in Table 6. The targets for analytical precision of laboratory analyses are based on historical performance by MEL for environmental samples taken around the state by the Environmental Assessment Program (Mathieu, 2006). The laboratory's measurement quality objectives and quality control procedures are documented in the MEL *Lab Users Manual* (MEL, 2008).

Table 6. Measurement quality objectives.

Analysis	Equipment Type / Method	Precision (Percent Relative Standard Deviation, %RSD)	Bias (Relative Percent Difference, RPD)	Method Lower Reporting Limit and/or Resolution	Estimated Range
Field Measurements					
Water Temperature[1]	Hydrolab MiniSonde®	+/- 0.2 °C	NA	0.01 °C	0 – 30 °C
Specific Conductivity	Hydrolab MiniSonde®	5%	10%	0.1 umhos/cm	20 – 1000 umhos/cm
pH[1]	Hydrolab MiniSonde®	+/- 0.05 s.u.	NA	0.01 s.u.	1 – 14 s.u.
Dissolved Oxygen[1]	Hydrolab MiniSonde®	+/- 0.2 mg/L	NA	0.1 mg/L	0 – 15 mg/L
Dissolved Oxygen[1]	Winkler Titration	+/- 0.2 mg/L	NA	0.1 mg/L	0 – 15 mg/L
Streamflow	Marsh McBirney®	20%	NA	0.01 ft/s (velocity)	0 – 4 ft/s (velocity)
Laboratory Analyses					
Fecal Coliform - MF	SM 9222D	50% of replicate pairs <20% RSD; 90% of replicate pairs < 50% RSD[2]	40%	1 cfu/100 mL	1 - >5000 cfu/100 mL
Ammonia	SM 4500-NH_3 H	10%[3]	If sample is >5 times reporting limit, then 20% RPD	0.01 mg/L	0.01 – 20 mg/L
Nitrate/Nitrite	SM 4500-NO_3 I	10%[3]	See above	0.01 mg/L	0.01 – 10 mg/L
Total Persulfate Nitrogen	SM 4500-N B	10%[3]	See above	0.025 mg/L	0.025 – 20 mg/L
Orthophosphate	SM 4500-P G	10%[3]	See above	0.003 mg/L	0.003 – 1 mg/L
Total Phosphorus	SM 4500-P F	10%[3]	See above	0.005 mg/L	0.005 – 10 mg/L
Total Suspended Solids	SM 2540D	15%[3]	See above	1 mg/L	1 – 100 mg/L

[1] as units of measurement, not percentages.
[2] replicate results with a mean of less than or equal to 20 cfu/100 mL will be evaluated separately.
[3] replicate results with a mean of less than or equal to 5X the reporting limit will be evaluated separately.
SM: Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, 1998).

Representativeness

The study is designed to have enough sampling sites and sufficient sampling frequency to meet study objectives. Some parameter values, especially fecal coliform, are known to be highly variable over time and space. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the parameter value.

Resources limit the number of samples that can be taken at one site spatially or over various intervals of time.

Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard and Kirchmer, 2004). The goal for this project is to correctly collect and analyze 100% of the samples from all of the sampling sites. However, problems occasionally arise during sample collection that cannot be controlled; this can interfere with the goal. A lower limit of five samples per site will be required for comparison to Washington State criteria. This should easily be met with the current sampling design, provided not more than one sample is missed per site. For bacteria, WAC 173-201A states:

> *When averaging bacteria sample data for comparison to the geometric mean criteria, it is preferable to average by season and include five or more data collection events within each period….and [the period of averaging] should have sample collection dates well distributed throughout the reporting period.*

For this project, all bacteria data will be analyzed together, without being split by season.

Sampling and Measurement Procedures

Field sampling and measurement protocols will follow those listed in an Environmental Assessment Program protocols manual (Ecology, 1993). Safety procedures detailed in the Environmental Assessment Program's Safety Manual (Ecology, 2006b) will be followed for all sampling.

Field measurements will follow approved Environmental Assessment Program Standard Operation Procedures (SOPs). The applicable procedures are included, with web link, in References.

Deep Lake is not located in an area of extreme concern for aquatic invasive species. Field crews will adhere to the procedures outlined in the SOP EAP070 Standard Operating Procedures to Minimize the Spread of Invasive Species Version 2.0 (Parsons et al., 2012).

Sampling sites will be located using a handheld GPS, the boat's depth finder, and easily-recognized landmarks on the lake shore.

Nutrient samples will be taken using a Kemmerer sampler with a graduated rope to ensure that samples are taken from the correct depth. The Kemmerer sampler will be triple-cleaned with deionized water between each station. The process of lowering the open sampler will also provide a local-water rinse prior to sample collection. Individual samples composing the composite sample will be emptied into the composite container. Sample bottles will be filled from the composite container. The composite container will be triple-rinsed with deionized water between each composite sample.

Fecal coliform samples will be taken with a sampling pole. This will allow the sampler to reach far enough away from the boat to ensure that the water being sampled has not been disturbed by the boat. This will also prevent the sampler from collecting water from the surface layer. At DEEPLK-1, where fecal coliform and other parameters will be collected at the same location, fecal coliform will be collected first.

Conductivity, temperature, pH, and DO will be profiled using a Hydrolab® multiprobe. The profile will consist of discrete measurements taken at depths of 0.5m, 1m, then at 1-meter intervals to 10m or until the thermocline has been passed, then at 2-meter intervals to the bottom.

Secchi disk depths will be recorded at each nutrient sampling site as a measure of lake clarity.

Table 7 lists the sample size, containers, preservation, and holding time for each parameter in this study. Sample containers will be provided by MEL. Sample containers will be filled, tagged, and put on ice.

Table 7. Sample containers, preservation, and holding times.

Parameter	Sample Matrix	Container	Preservative	Holding Time
Ammonia	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Nitrate/Nitrite	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Total Persulfate Nitrogen	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Orthophosphate	Surface water	125 mL amber poly with Whatman Puradisc™ 25PP 0.45 um filters	Filter in field with 0.45 um pore size filter; Cool to 4°C	48 hours
Total Phosphorous	Surface water	125 mL clear poly	1:1 HCl to pH<2; Cool to 4°C	28 days
Total Suspended Solids	Surface water	1 L clear poly	Cool to 4ºC	7 days
Fecal Coliform	Surface water	250 mL autoclaved clear poly	Cool to 4ºC	24 hours

Quality Control Procedures

Hydrolab meter measurements will conform to the quality control parameters in Table 6 and the calibration drift parameters in Table 8. Meter DO measurements will be compared to Winkler samples. At least three Winklers will be taken during each sampling event to assess DO meter accuracy or correct results. Winklers will be taken using the Kemmerer sampler at depths corresponding to particular Hydrolab readings, simultaneously with those readings. Winkler bottles will be filled by attaching a length of surgical tubing to the nozzle of the Kemmerer sampler and flushing the Winkler bottle from the bottom with three times the volume of the bottle, similar to the use of a standard DO funnel.

Table 8. Hydrolab® equipment individual probe calibration end drift requirements.

Parameter	Calibration Drift End Check
Dissolved Oxygen	± 4%
Temperature	N/A
Conductivity	± 10%
pH	± 0.2 s.u.

Conductivity, pH, temperature, and DO data from the Hydrolab will be verified using pre- and post-deployment calibration checks, which will be recorded and kept with field data. Calibration checks will be performed after each sampling event.

To assess field variability, a duplicate Hydrolab profile will be taken at least twice during the course of the project. A duplicate secchi disk measurement will be taken each time a duplicate Hydrolab profile is taken. A duplicate flow measurement will be taken twice during the study.

Total variability for laboratory analysis will be assessed by collecting replicate samples. Quality control samples will be taken at intervals summarized in Table 9. This represents 11% duplication for nutrient and fecal coliform samples, and 17% duplication for total suspended solids samples. MEL routinely duplicates sample analyses in the laboratory (lab duplicate) to determine laboratory precision. The difference between field variability and lab variability is an estimate of the sample field variability.

Field blanks and filter blanks for nutrient parameters will be submitted four times during the project to assess some areas of bias. Field and filter blanks will be made by sampling deionized water, following exactly the same procedures used to take regular stream samples and using the same compositing container and syringe, as applicable.

MEL will inform the project manager or principal investigator as soon as possible if any sample is lost, damaged, has a lost tag, or gives an unusual result.

Table 9. Sample quality control samples and intervals.

Analysis	Field Replicates	Check Standard	Method Blank	Duplicate	Matrix Spikes
Total Nitrogen	4 replicates during project (replicating both layers of a deep site counts as 2)	1/batch	1/batch	1/20 samples	1/20 samples
Ammonia Nitrogen		1/batch	1/batch	1/20 samples	1/20 samples
Nitrate + Nitrite Nitrogen		1/batch	1/batch	1/20 samples	1/20 samples
Orthophosphate		1/batch	1/batch	1/20 samples	1/20 samples
Total Phosphorus		1/batch	1/batch	1/20 samples	1/20 samples
Total Suspended Solids	2 replicates during project	1/batch	1/batch	1/20 samples	1/20 samples
Fecal Coliform	4 replicates during project	N/A	1/batch	1/20 samples	N/A

Data Management Procedures

Field measurement data will be entered into a field book with waterproof paper in the field and then entered into EXCEL® spreadsheets as soon as practical after returning from the field. This data will be used for preliminary analysis and to create a table to upload data into Ecology's EIM system.

Sample result data received from MEL by Ecology's Laboratory Information Management System (LIMS) will be added to a spreadsheet for laboratory results. This spreadsheet will be used to informally review and analyze data during the course of the project. Any anomalous or unusual results will be reviewed to determine if a data quality problem exists, and

All monitoring data will be available in EIM, via the Internet, once the project data have been validated. The URL address for this geospatial database is www.ecy.wa.gov/eim/index.htm. All data will be uploaded to EIM after the data have been reviewed for quality assurance and finalized.

All spreadsheet files, paper field notes, and Global Information System (GIS) device products created as part of the data analysis will be kept with the project data files.

Audits and Reports

At the conclusion of this study, the project lead will write a technical memo to the client, summarizing the study findings. This memo will include all data collected during the project. It will also include a brief analysis of lake eutrophication, as well as calculations of nutrient, fecal coliform, and sediment loads entering and leaving the lake.

Data Verification

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL *Lab Users Manual* (MEL, 2008). Lab results will be checked for missing and improbable data. Variability in lab duplicates also will be quantified using the procedures outlined in the *Lab Users Manual*. Any estimated results will be qualified and their use restricted as appropriate. MEL will send a standard case narrative of laboratory quality assurance/quality control results for each set of samples to the project manager.

Field staff will check field notebooks for missing or improbable measurements before leaving each site. The EXCEL® (Microsoft, 2007) Workbook file containing field data will be labeled DRAFT until data verification is complete. Data entry will be checked against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation. Valid data will be moved to a separate file labeled FINAL.

The project manager will check data received from LIMS for omissions against the Request for Analysis forms. Field replicate sample results will be compared to quality objectives in Table 7. The project manager will review data requiring additional qualifiers.

After data verification and data entry tasks are completed, all field and laboratory data will be entered into a file labeled FINAL and then into the EIM system. Another field assistant will independently review EIM data for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

Data Quality (Usability) Assessment

After the project data have been reviewed and verified, the project lead will determine if the data are of sufficient quality to meet the study objectives. The project memo from the project lead to the client will discuss data quality and whether project objectives were met. Precision will be analyzed by calculating %RSD of field and laboratory replicate pairs, and bias will be estimated from matrix spike and instrument post-check results. Any blank results that are not non-detects will be noted as possible evidence of sample contamination.

References

APHA, AWWA, and WEF, 1998. Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington, D.C.

Ecology, 1993. Field Sampling and Measurement Protocols for the Watershed Assessments Section. Washington State Department of Ecology, Olympia, WA. Publication No. 93-e04. https://fortress.wa.gov/ecy/publications/SummaryPages/93-e04.html

Ecology, 2006a. WAC 173-201A. Water Quality Standards for Surface Waters in the State of Washington. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/laws-rules/ecywac.html

Ecology, 2006b. Environmental Assessment Program Safety Manual. Washington State Department of Ecology, Olympia, WA.

Ecology, 2014. Environmental Assessment Program Standard Operating Procedures. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/eap/quality.html:

- Anderson, M. and T. Swanson, 2011. Standard Operating Procedures for the Collection of Fecal Coliform Bacteria Samples in Surface water. Washington State Department of Ecology, Olympia, WA. SOP Number EAP030. www.ecy.wa.gov/programs/eap/quality.html
- Janisch, J., 2006. Standard Operating Procedure for Determining Coordinates Via Hand-held GPS Receivers. Washington State Department of Ecology, Olympia, WA. SOP Number EAP013. www.ecy.wa.gov/programs/eap/quality.html
- Kardouni, J., 2013. Standard Operating Procedure for Estimating Streamflow. Washington State Department of Ecology, Olympia, WA. SOP Number EAP024. www.ecy.wa.gov/programs/eap/quality.html
- Nipp, B., 2006. Standard Operating Procedures for Instantaneous Measurements of Temperature in Water. Washington State Department of Ecology, Olympia, WA. SOP Number EAP011. www.ecy.wa.gov/programs/eap/quality.html
- Parsons, J., D. Hallock, K. Seiders, B. Ward, C. Coffin, E. Newell, C. Deligeannis, and K. Welch, 2012. Standard Operating Procedures to Minimize the Spread of Invasive Species Version 2.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP070. www.ecy.wa.gov/programs/eap/quality.html
- Swanson, T., 2006. Standard Operating Procedure for Manually Obtaining Surface Water Samples. Washington State Department of Ecology, Olympia, WA. SOP Number EAP015. www.ecy.wa.gov/programs/eap/quality.html
- Swanson, T., 2007. Standard Operating Procedures for Hydrolab DataSonde® and MiniSonde® Multiprobes. Washington State Department of Ecology, Olympia, WA. SOP Number EAP033. www.ecy.wa.gov/programs/eap/quality.html

- Ward, W., 2007. Standard Operating Procedures for the Collection, Processing, and Analysis of Stream Samples. Washington State Department of Ecology, Olympia, WA. SOP Number EAP034. www.ecy.wa.gov/programs/eap/quality.html
- Ward, W. and N. Mathieu, 2013. Standard Operating Procedures for the Collection and Analysis of Dissolved Oxygen (Winkler Method). Washington State Department of Ecology, Olympia, WA. SOP Number EAP023. www.ecy.wa.gov/programs/eap/quality.html

Lombard, S. and C. Kirchmer, 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-030. https://fortress.wa.gov/ecy/publications/summarypages/0403030.html

Mathieu, N., 2006. Replicate Precision for 12 Total Maximum Daily Load (TMDL) Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-044. https://fortress.wa.gov/ecy/publications/summarypages/0603044.html

MEL, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Microsoft, 2007. Microsoft Office XP Professional, Version 10.0. Microsoft Corporation.

Appendix. Glossary, Acronyms, and Abbreviations

General Glossary

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Eutrophication: An increase in productivity resulting from nutrient loads to a water body.

Fecal coliform: That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Salmonid: Fish that belong to the family *Salmonidae*. Any species of salmon, trout, or char.

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

Acronyms and Abbreviations

EAP	Ecology's Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GPS	Global Positioning System
LIMS	Laboratory Information Management System
MEL	Manchester Environmental Laboratory
QA	Quality assurance
QAPP	Quality assurance project plan
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area
7-DADMax	7-day average maximum
DO	Dissolved oxygen

Units of Measurement

°C	degrees centigrade
cfu	colony forming units
ft	feet
m	meters
mi	miles
mg/L	milligrams per liter (parts per million)
mL	milliliters
s	second
s.u.	standard units
ug/L	micrograms per liter (parts per billion)
um	micrometer
umhos/cm	micromhos/centimeter (a unit of conductivity)

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

Bias: The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV): A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean. (Kammin, 2010)

Data Integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
(USEPA, 2006)

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set. (Ecology, 2004)

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters." (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split sample: The term split sample denotes when a discrete sample is further subdivided into portions, usually duplicates. (Kammin, 2010)

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

References for QA Glossary

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. http://www.ecy.wa.gov/biblio/0403030.html

Kammin, B., 2010. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.

USEPA, 1997. Glossary of Quality Assurance Terms and Related Acronyms. U.S. Environmental Protection Agency. http://www.ecy.wa.gov/programs/eap/quality.html

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. U.S. Environmental Protection Agency. http://www.epa.gov/quality/qs-docs/g4-final.pdf

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. U.S. Geological Survey. http://ma.water.usgs.gov/fhwa/products/ofr98-636.pdf