DEPARTMENT OF ECOLOGY
State of Washington

Quality Assurance Project Plan

Characterization of Metals in Sediment from the Lucerne Basin of Lake Chelan

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Quality Assurance Project Plan

Characterization of Metals in Sediment from the Lucerne Basin of Lake Chelan

April 2019

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Signatures are not available on the Internet version.
EAP: Environmental Assessment Program

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2.0 Abstract

Ecology's effectiveness monitoring program will collect surface sediment as well as sediment cores in the Lucerne Basin in Lake Chelan to characterize the occurrence and temporal trends of metals. Sediment cores will be analyzed for metal concentrations to reconstruct historical deposition profiles in relation to historic mine activities and reclamation efforts in Railroad Creek. Sediment cores will be age dated using ^{210}Pb techniques. In addition to core samples, surface sediment samples will be collected in order to quantify current metal concentrations in both shallow- and deep-water sediments.

3.0 Background

3.1 Introduction and problem statement

Holden Mine is an inactive underground mine located in the Railroad Creek watershed; Railroad Creek is a tributary to Lake Chelan and is a 303(d) impaired waterway in the Wenatchee National Forest near the boundary of Glacier Peak Wilderness. The impacts from past mining practices to surface waters in Railroad Creek are well-documented (Pine, 1967; Johnson, 1997; Dames and Moore, 1999; MWH, 2010; Collyard 2015); however, sediments in depositional areas near where Railroad Creek flows into the lake have not been assessed.

3.2 Study area and surroundings

Lake Chelan is located in north-central Washington State (Figure 1). It is the longest and deepest natural lake in the state and is considered pristine with its ultra-oligotrophic nutrient conditions. The Lake Chelan watershed drains a 924-square-mile area and is divided into two distinct basins partially separated by a glacial sill (Kendra and Singleton, 1987). The Lucerne Basin is the northern most basin; it contains over 92% of the total lake volume and reaches a maximum depth of approximately 1,500 ft. The smaller Wapato Basin receives most of its water input from the Lucerne Basin and has a maximum depth of 600 ft (Patmont et al., 1989).

The two major water sources to Lake Chelan are:

- Stehekin River, contributing roughly 70% of the total input (Williams and Pearson, 1985) at the northern terminus of the lake.
- Railroad Creek, accounting for about 10% of the total input, also located in the upper Lucerne Basin.

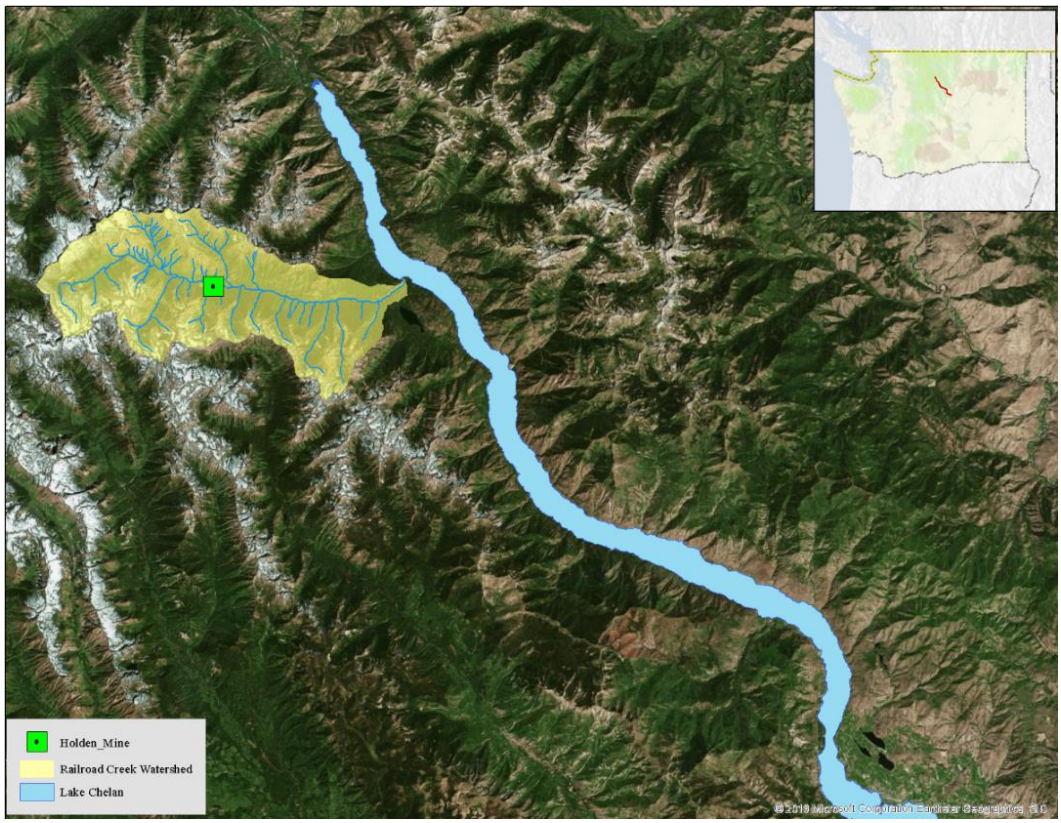

Figure 1. Map of larger study area.

3.2.1 History of study area

From 1937 to 1957, the Howe Sound Company conducted mining operations at the Holden Mine site. Their mine and mill facilities produced primarily copper concentrate and lesser quantities of zinc concentrate and gold concentrate. During the mine operation, about 57 miles of underground mine workings were developed. About 8.5 million tons of tailings were placed in piles covering a 90-acre area along Railroad Creek. Several piles of waste rock removed from the mine were located near the mine portals at various locations throughout the site. These activities have resulted in acid mine drainage (in the form of mine portal drainage, seeps, and upwelling groundwater), which contributed to the release of metals and acidity from the mine workings, waste rock piles, and tailings piles into surface water and groundwater at the site.

The effected site includes the 125-acre mining operation, a 10-mile segment of Railroad Creek downstream of the mine, and an approximately 10-acre area of Lake Chelan sediments where Railroad Creek flows into the lake.

During the late 1980s and early 1990s, the Forest Service reduced erosion of the tailings piles by installing streambank protection, rerouting drainage, and covering the piles with gravel, which also reduced dust generation and facilitated initial revegetation. This interim action improved site conditions; however, several potential threats to human health and the environment still existed. In 2012, the Forest Service issued a remedial plan in cooperation with EPA and Ecology (USDA Forest Service, 2012). The plan outlined remedial action

objectives (RAOs) that specify contaminants and media of concern, potential exposure pathways, and remediation goals.

3.2.2 Summary of previous studies and existing data

Sediment samples collected at Lucerne Bar near the mouth of Railroad Creek in 1998, 1999, and 2001 met proposed freshwater sediment quality values (FSQVs) with the exception of zinc at one sample location (URS, 2002). The highest concentrations of all metals were observed just downlake of Railroad Creek near the Lake Chelan Boat Club (Figure 2).

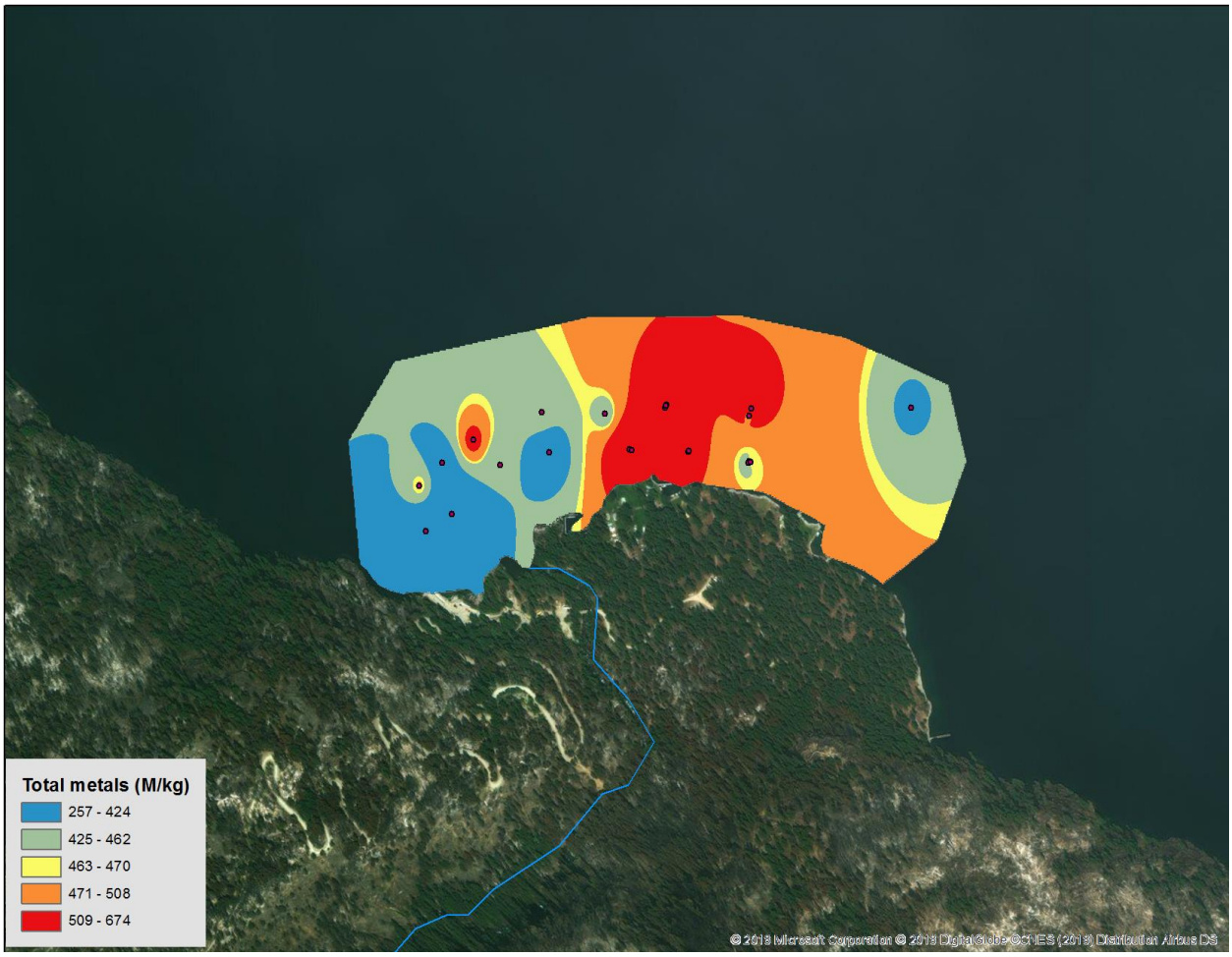

Figure 2. Concentrations of total metals from 1998 – 2001 sediment sampling.

Average sedimentation rates for the Lucerne Basin was measured at 0.19 cm/yr (Coots and Era-Miller, 2005), while rates ranged between 0.34 to 0.5 cm/yr outside the Stehekin River delta (Fricke et al., 2015).

3.2.3 Parameters of interest and potential sources

Target analytes for sediment include the metals aluminum (Al), arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), magnesium (Mn), mercury (Hg), nickel (Ni), lead (Pb), titanium (Ti)

and zinc (Zn). Potential sources of these metals include historical mining activities in the Railroad Creek watershed.

The following will also be analyzed to support age dating the cores, estimating deposition rates, and interpreting the sediment results:

- Sediment particle (grain) size.
- Total organic carbon (TOC).
- Total phosphorus (TP).
- Total nitrogen (TN).
- Loss on ignition (LOI).
- ^{210}Pb.

3.2.4 Regulatory criteria or standards

Toxic pollutants have significant potential to affect designated water uses, aquatic biota, and public health adversely when present at levels above those defined in water quality standards. Therefore, assessment decisions for toxic pollutants are based on detection of these substances above defined safe levels. For the purposes of this study, *toxic substances* refer to metals measured in freshwater sediment in Lake Chelan. Proposed freshwater sediment quality values for Lake Chelan are presented in Table 1.

For further information about the parameters, see WAC 173-201A[1] and WAC 173-204[2].

Table 1. Washington State Department of Ecology proposed Freshwater Sediment Quality Values for Lake Chelan.

Media	Metal	FSQV
Sediment (mg/kg)	Aluminum	NE
	Arsenic	NE
	Cadmium	5.1
	Chromium	NE
	Copper	390
	Iron	NE
	Lead	450
	Manganese	NE
	Mercury	0.280
	Nickel	NE

FSQV = Freshwater Sediment Quality Values
NE = Not estimated

3.3 Water quality impairment studies

N/A

[1] http://app.leg.wa.gov/WAC/default.aspx?cite=173-201A-240
[2] http://apps.leg.wa.gov/WAC/default.aspx?cite=173-204

3.4 Effectiveness monitoring studies

N/A

4.0 Project Description

Limited data suggest levels of metals in Railroad Creek may be declining, but current levels and the spatial extent of metals in Lake Chelan beyond the Lucerne Bar are unknown. Sediment focusing plays more of a role in the Lucerne Basin, where the lakebed slope is greater, which moves fine sediment deeper (Coots and Era-Miller, 2005). The Lucerne Basin is narrower and deeper with mountainous uplands higher in elevation and drastic slopes prone to event-related inputs like weather-induced mass wasting and higher annual rainfall. A comprehensive evaluation of sediment concentrations for target metals in the lake will be completed.

4.1 Project goals

The overall goals of this project are:

1. Determine the spatial extent of metal concentrations near where Railroad Creek flows into Lake Chelan.
2. Compare results with proposed sediment FSQVs.
3. Evaluate historical trends in metals loading to the lake and sedimentation rates for the Lucerne Basin using sediment cores.

4.2 Project objectives

The specific objectives of the study are to:

- Reconstruct metal deposition profiles by collecting two sediment cores from Lake Chelan and analyze selected horizons for:
  - Total metals
  - ^{210}Pb.
  - Loss on ignition (LOI).
  - Total organic carbon (TOC).
  - Total nitrogen (TN).
  - Grain size.
- Collect surface sediment samples in Lake Chelan and analyze selected horizons for:
  - Total metals
  - TOC.
  - TN.
  - Grain size.

4.3 Information needed and sources

This project is being conducted to generate new environmental data.

4.4 Tasks required

- Conduct desktop reconnaissance of waterbodies including bathymetry, access, etc.
- Compile existing information on target parameters for the study locations.
- Establish laboratory contracts for analysis not offered by Manchester Environmental Laboratory (MEL).

- Collect two sediment cores from depositional areas in Lake Chelan above and below where Railroad Creek discharges.
- Section cores into 1 cm horizons.
- Select core horizons for analysis based on length of core and field observations of the core.
- Collect up to 20 surface sediment grab samples.
- Send grab samples to MEL and contract laboratories for analyses of metals, grain size, TOC, and TN.
- Send core samples to MEL and contract laboratories for analyses of metals, grain size, LOI, TOC, TN, and ^{210}Pb.
- Age-date sediment core intervals using ^{210}Pb data.
- Construct contaminant profiles.
- Load data into EIM database.
- Assess quality and usability of all lab data.
- Analyze usable data (e.g., estimate deposition rates for sediment and metals).
- Draft and finalize project report.

4.5 Systematic planning process used

This QAPP represents the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 2. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
Valerie Bound Central Regional Office Phone: 509-454-7886	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Scott Collyard Directed Studies Unit Western Operation Section Phone: 360-407-6455	Project Manager, Principal Investigator	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the final report.
Jenny Wolfe Watershed Health and Effectiveness Monitoring Unit Phone: 360-407-7548	Field Lead	Assists with collection of samples.
Dave Serdar Toxic Studies Unit Phone: 360-407-6479	Skookum Captain	Responsible for piloting sediment sampling vessel and assists with collection of samples.
Will Hobbs Toxics Studies Unit Phone: 360-407-7512	Principal Investigator	Reviews QAPP addendum and reports, provides assists with sediment sampling and processing, data analysis and interpretation.
Niamh O'Rourke Watershed Health and Effectiveness Monitoring Unit Phone: 360-407-7614	Field Lead	Assists with post-processing of sampling
Stacy Polkowske Directed Studies Unit Western Operation Section Phone: 360-407-6730	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Jessica Archer Statewide Coordination Section Phone: 360-407-6596	Section Manager for the Project Manager	Reviews the draft QAPP, and approves the final QAPP.
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Manchester Lab Director	Reviews and approves the final QAPP.
Arati Kaza Quality Assurance Officer Phone: 360 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP. Approves 'Lab Accreditation Waiver' and QAPP addendums.

[1]All staff except the client are from EAP.
EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

All field crew carrying out sampling will have specialized training and experience in collection of sediment cores using a box corer.

5.3 Organization chart

See Table 2.

5.4 Proposed project schedule

Table 3 provides the project schedule for 2018 sampling.

Table 3. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work for 2018	**Due date**	**Lead staff**
Field work begins	10/15/2018	Scott Collyard
Field work completed	10/19/2018	
Post sample processing completed	10/26/2018	
Laboratory analyses completed	4/1/2019	
Environmental Information System (EIM) database		
EIM Study ID: SCOL006		
Product	**Due date**	**Lead staff**
EIM data loaded	6/1/2019	Niamh O'Rourke
EIM data entry review	7/1/2019	Scott Collyard
EIM complete	8/2019	Scott Collyard
Data Summary		
Author lead / Support staff: Scott Collyard /Will Hobbs		
Schedule for Web Reporting		
Summary data uploaded to web	7/2019	
Taxonomic summary uploaded to web	7/2019	
Schedule for Data Summary		
Draft data summary due to supervisor	8/2019	
Draft due to client/peer reviewer(s)	9/2019	
Final (all review done) due to publications coordinator	10/2019	
Final data summary report due on web	11/2019	

5.5 Budget and funding

Efforts will be made to keep the number of sample analyses within the estimated budget; however, the numbers shown in Table 4 are only estimates.

Table 4. Estimated expenses for Lake Chelan sediment analyses.

Parameter/ Analysis	Sample Type	Cost per Sample ($)	# of Samples	Field Duplicates	Total Samples	MEL Subtotal	Contract Subtotal
Metals	Core[1]	300	42	2	44	$13,200	
TOC, TN	Core[1]	50	42	2	44	$2,200	
^{210}Pb	Core[1]	200	42	2	34		$6,800
LOI	Core[1]	50	42	2	32	$1,600	
Grain size	Grab[2]	120	20	2	22		$2,640
TOC, TN	Grab[2]	50	20	2	22	$1,100	
Metals	Grab[2]	300	20	2	22	$6,600	
Subtotal						**$24,700**	**$9,440**
Total							**$34,140**

[1] Purpose is to estimate metal concentrations over time (1910 – present).
[2] Purpose is to estimate distribution of metals in depositional zone (600 ft) and Lucerne Bar.

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objectives (DQO) for this project are to:

- Collect sediment samples representing both transitional and depositional areas near where Railroad Creek discharges into Lake Chelan.
- Analyze the sediment samples for various chemical and physical attributes.

All analysis will be performed using standard methods to obtain data that meet measurement quality objectives (MQOs) described below and that are comparable to previous study results.

6.2 Measurement quality objectives

Field sampling procedures and laboratory analyses inherently have associated uncertainty, which results in data variability. Measurement quality objectives (MQOs) state the acceptable data variability for a project. *Precision* and *bias* are data quality criteria used to indicate conformance with MQOs. The term *accuracy* refers to the combined effects of precision and bias (Lombard and Kirchmer, 2016).

Field sampling precision will be addressed by submitting replicate samples. Ecology's Manchester Environmental Laboratory (MEL) will assess precision and bias in the laboratory using duplicates and blanks.

Table 5 outlines expected precision of sample duplicates and method reporting limits. MEL bases the targets for precision of field replicates on historical performance of environmental samples taken around the state by Ecology's Environmental Assessment Program (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's MQOs and QC procedures are documented in the MEL *Lab Users Manual* (MEL, 2016a).

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Table 5 below.

Table 5. Measurement quality objectives.

Parameter	LCS (Recovery)	Lab duplicates (RPD)	Method Blanks	Matrix Spike (Recovery)	Matrix Spike Duplicates
Various Metals[1]	85 – 115%	<20%	<LOQ	75 – 125%	<20%
Total Organic Carbon/ Total Nitrogen	---	<20%	---	---	---
^{210}Pb	80 – 120%	<30%	<LOQ	---	---
Grain size	---	<25%	---	---	---
Loss on ignition	---	<20%	---	---	---

[1] Al, As, Cd, Cu, Fe, Hg, Mn, Hg, Mg, Ni, P, Pb, Zn
LCS=Laboratory control sample
RPD=Relative percent difference

6.2.1.1 Precision

Precision is a measure of the variability in the results of replicate measurements due to random error. Laboratory analysis precision will be assessed through laboratory duplicate samples (split at the laboratory) for all analyses, with the exception of grain size. Precision for grain size analysis will be evaluated through triplicate analysis of a sample, split at the laboratory. Table 5 shows the MQOs for laboratory duplicate (triplicate for grain size) samples.

6.2.1.2 Bias

Bias is the difference between the population mean and the true value. Laboratory analysis bias will be assessed through laboratory control samples, matrix spikes, and surrogate standards. MQOs for these tests are included in Table 5.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance above background noise. Laboratory analysis sensitivity is defined for the study as the quantitation limit. See Table 8 for quantitation (reporting) limits.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Sediment grabs and cores will be collected according to Ecology's standard operating procedures (SOPs) to help ensure comparability between results from previous and future sampling events. All analytical methods used in this study are standard and analogous to similar Ecology studies. Section 8.1 discusses SOPs followed for this study.

6.2.2.2 Representativeness

Sediment cores provide a representative, time-integrated historical deposition profile of sediment-bound metals. Issues of representativeness for long-term monitoring studies, such as inconsistent reporting limits and missing data, are alleviated by using sediment cores; these samples from multiple dates are analyzed at once instead of over time. Surface sediment samples provide a representative spatial extent of current depositional patterns of sediment-bound metals from Railroad Creek. Sampling locations are selected to represent sediment conditions above and below the potential impact in Railroad Creek.

6.2.2.3 Completeness

The project manager will consider the study to have achieved completeness if 95% of the samples are analyzed acceptably.

6.3 Acceptance criteria for quality of existing data

Existing data to be used for comparison purposes were collected under an approved QAPP and are believed to be of comparable quality (URS, 2001).

6.4 Model Quality Objectives

N/A

7.0 Study Design

Although Railroad Creek has been monitored extensively for metals, concentrations and the spatial extent of metals in Lake Chelan beyond the Lucerne Bar is unknown. To fill this data gap, a comprehensive evaluation of sediment concentrations for target metals in the lake will be completed.

Surface Sediment

Surface sediment grab samples will be collected using a Van Veen sampler in the deepest part of the lake (600ft) along a longitudinal gradient of Lake Chelan, starting approximately 1 mile uplake of the Railroad Creek and continuing down lake every 0.25 miles. Surface sediments will be analyzed for ^{210}Pb, total Al, As, Cd, Cu, Fe, Hg, Mn, Ni, P, Pb, Ti, Zn, TOC, TN, and grainsize. Up to 10 total sediment samples will be collected from this area of Lake Chelan. In addition, for comparison purposes, up to 10 sediment samples will be collected from the Lucerne Bar at or nearby locations that have been previously sampled (URS, 2002). Sediment sample locations are shown in Figure 3, and their associated coordinates are presented in Table 6.

Sediment Cores

Decades have passed since Holden mine has been active. Over time, concentrations of these metals are expected to decline. However, data are not available to evaluate metal trends in Lake Chelan where deposition of fine sediments are expected to occur. To determine historical levels and sedimentation rates of metals, sediment cores will be collected from two sites in Lake Chelan: one site above Railroad Creek and one site below Railroad Creek. Cores will be collected at the deepest point possible both above and below where Railroad Creek discharges into Lake Chelan (~600 ft). Deep locations should give the best chance of sampling fine sediments in undisturbed areas. Analyzing discrete sediment layers will show the history metal deposition over time. These data coupled with current and historical information from Railroad Creek may be used to assess water quality improvements and predict future concentrations in sediment deposits over time.

A 50 cm box corer will be used for collecting sediment cores. One centimeter horizons will be sampled from the cores. Sediment horizons will be analyzed for ^{210}Pb, total Al, As, Cd, Cu, Fe, Hg, Mn, Ni, P, Pb, Ti, Zn, TOC, TN and LOI. Both TOC and LOI results will be compared with ^{210}Pb activity for purposes of calculating bulk sediment and organic carbon sedimentation rates. TN and total P will be used to calculate total nutrient sediment rates and may help validate timelines by comparing results with historic uplake forest fires. The final selection of horizons to be analyzed for metals will be determined after core dating using ^{210}Pb techniques. Horizons not initially analyzed will be archived for potential analysis at a later date. Sediment core sample locations are shown in Figure 3, and their associated coordinates are presented in Table 6.

7.1 Study boundaries

This study will focus on depositional sediment (~600ft of depth) in Lake Chelan within the Lucerne Basin above and below where Railroad Creek discharges (Figure 3). Surface sediment samples will also be collected in shallow water on the Lucerne Bar.

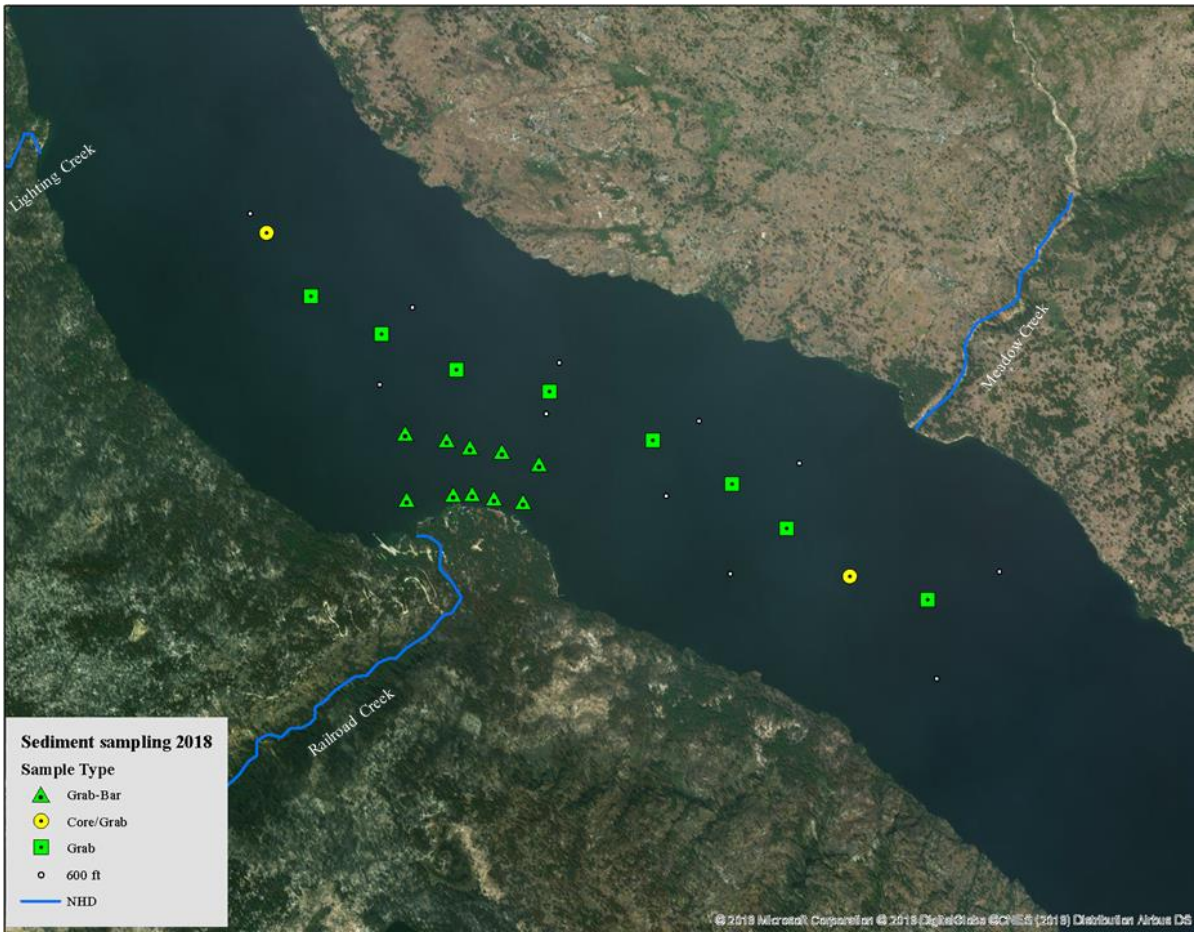

Figure 3. Map showing boundary of project study area.

7.2 Field data collection

See Figure 3.

7.2.1 Sampling locations and frequency

Table 6. Proposed sampling locations.

Location ID	Location Description	Sample Type	Latitude	Longitude
EFF16600-L40.37	Lake Chelan Lucerne Basin	Grab	48.19902	-120.56282
EFF16600-L40.62	Lake Chelan Lucerne Basin	Core/grab	48.20004	-120.56797
EFF16600-L40.87	Lake Chelan Lucerne Basin	Grab	48.20215	-120.57211
EFF16600-L41.12	Lake Chelan Lucerne Basin	Grab	48.20408	-120.57570
EFF16600-L41.37	Lake Chelan Lucerne Basin	Grab	48.20598	-120.58092
EFF16600-LC41.62	Lake Chelan Lucerne Basin	Grab	48.20814	-120.58771
EFF16600-LC41.87	Lake Chelan Lucerne Basin	Grab	48.20909	-120.59381
EFF16600-LC42.12	Lake Chelan Lucerne Basin	Grab	48.21065	-120.59872
EFF16600-L42.37	Lake Chelan Lucerne Basin	Grab	48.21231	-120.60338
EFF16600-L42.62	Lake Chelan Lucerne Basin	Core/grab	48.21506	-120.60627
EFF16600-LB01	Lucerne Bar	Grab	48.20327	-120.58940
EFF16600-LB02	Lucerne Bar	Grab	48.20342	-120.59131
EFF16600-LB03	Lucerne Bar	Grab	48.20362	-120.59274
EFF16600-LB04	Lucerne Bar	Grab	48.20359	-120.59398
EFF16600-LB05	Lucerne Bar	Grab	48.20335	-120.59705
EFF16600-LB06	Lucerne Bar	Grab	48.20494	-120.58833
EFF16600-LB07	Lucerne Bar	Grab	48.20547	-120.59078
EFF16600-LB08	Lucerne Bar	Grab	48.20568	-120.59287
EFF16600-LB09	Lucerne Bar	Grab	48.20597	-120.59443
EFF16600-LB010	Lucerne Bar	Grab	48.20627	-120.59714

7.2.2 Field parameters and laboratory analytes to be measured

Total length of the sediment core will be measured in the field, both immediately upon retrieval and after the core is stationed onto the sectioning apparatus table. A sediment coring log will be kept with field notes for each interval, including visual descriptions and characteristics of the core such as odor and debris present. Geographic coordinates and water depths of the coring and surface sediment locations will also be recorded in the field.

7.3 Modeling and analysis design

Sedimentation rates will be estimated using methods outlined in Yake 2001 and Hobbs 2017.

7.4 Assumptions in relation to objectives and study

This study makes the assumption that the target analytes are persistent in sediments and that concentrations measured at depth in the core are a preserved representation of what was deposited at the time of sedimentation. Smearing, bioturbation, and migration of analytes through porewater can affect the preservation of chemicals within the sediment profile and may affect this assumption. At least one deep horizon will be analyzed for total metals to attempt to reach sediment dated before major mining activities began (pre-1930). This will help inform the project manager if smearing of the horizons has occurred.

7.5 Possible challenges and contingencies

The study design was developed to achieve the desired goals and objectives of this program. However, logistical problems, practical constraints, and scheduling limitations do exist, which presents some challenges. These challenges and their resolutions are discussed in this section.

7.5.1 Logistical problems

Potential problems associated with sediment sampling logistics include the following:

Research vessel size, condition, and lake state: Ecology's 26' R/V Skookum will usually be used for sediment sampling. It is an efficient, cost-effective research vessel from which to sample Lake Chelan sediments. Its speed allows for rapid transit between monitoring stations, allowing more samples to be collected over large geographic areas each day. Its smaller size, however, can be restrictive during strong wind and high wave conditions; no sampling can be conducted during conditions necessitating small craft advisories from the National Weather Service. Under these conditions, the captain and lead crewmember will work together to alter the sampling schedule.

Sediment type: The target populations for this project are sediment grab samples (top 2 – 3 cm) and sediment core sample (+40 cm). Samples are collected with a modified Van Veen grab sampler and a 50 cm box corer. A representative soft sediment sample cannot be collected successfully from a location with a high proportion of wood, cobble, or rocks. If such locations are encountered, they must be rejected and replaced with nearby alternate stations.

7.5.2 Practical constraints

N/A

7.5.3 Schedule limitations

Logistical problems and practical constraints listed above may affect the proposed study schedule. Issues that may delay sampling, sample analysis, data review and analysis, and data reporting include, in part, the following:

Sampling and vessel conditions: Windy conditions, hard bottom sediments, and mechanical problems or failures with the research vessel and gear can cause delays in the field sampling schedule.

Staff capacity: There must be an adequate number of trained research vessel captains and sampling crew available and scheduled to participate in field sampling. Heavy workload and higher priority projects can cause lack of a sufficient pool of field crew, delaying sampling.

8.0 Field Procedures

8.1 Invasive species evaluation

Boat and sampling gear will be inspected and decontaminated following Ecology's SOP Number EAP070 for *Procedures to Minimize the Spread of Invasive Species Version 2.0* (Parsons et al., 2018).

8.2 Measurement and sampling procedures

Surface sediment
Sampling methods for surface sediment will follow standard protocols (Blakley, 2016). Surface sediment samples will be collected by boat using a 0.1 m^2 stainless steel Van Veen grab. All sediment stations will be located by differentially corrected GPS and recorded in field logs. Station position relative to significant on-shore structures will also be recorded (Janisch, 2006).

Following collection of each sediment grab, an evaluation of acceptability will be made. Information about each sediment grab will be recorded in the field log. A grab will be considered acceptable if:

- It is not overfilled.
- Overlaying water is present but is not overly turbid.
- Sediment surface appears intact.
- Grab reached the desired sediment depth.

Overlying water will be siphoned off prior to sub-sampling. Equal volumes of the top 2 cm of sediment will be subsampled. Stainless steel spoons and bowls will be used for sub-sampling and to homogenize sediments from each station to a uniform consistency and color. Debris on the sediment surface or materials contacting the sides of the Van Veen grab will not be retained for analysis. In addition to the top 2 cm, sediment collected on the bottom of the Van Veen may also be sub-sampled from sediments on or near the Lucerne Bar.

Homogenized sediments from each station will be placed in 4-ounce glass jars with Teflon-lined lids for analysis of total metals. Additionally, 4-ounce glass jars will be filled with homogenate for TOC and TN analysis, while 8-ounce plastic jars will be filled for determination of grain size.

All equipment used to collect sediment samples will be washed thoroughly with tap water and Liquinox detergent, followed by sequential rinses of hot tap water and de-ionized water. All equipment will then be air dried and wrapped in aluminum foil until used in the field. The same cleaning procedure will be used on the grab prior to going into the field. To avoid cross-contamination between sample stations, the grab will be thoroughly brushed down with on-site water at the next sample location.

Sediment samples will be placed in coolers on ice at 4°C immediately following collection, then transported to Ecology's MEL within 72 hours. Requirements for containers,

preservation, and holding times are listed in Table 7. The chain of custody will be maintained.

Sediment Cores

Sediment cores will be collected by boat using a Wildco stainless steel box corer fitted with a 13 cm x 13 cm x 50 cm acrylic liner following standard protocols outlined in Mathieu (2018). Based on previous sedimentation rate estimates, the corer will need to reach a minimum penetration depth between 20 cm and 40 cm. This will ensure the entire record of total metal loading to the lake will be represented.

After retrieving the core, overlying water will be carefully siphoned off and the acrylic liner removed from the corer. The sediment-filled liner will be placed on an extruder table outfitted with a gear-driven piston to push sediments up and out of the liner. Sediment layers will be sliced with thin aluminum plates to a uniform thickness of 1 cm. The acrylic liner allows for a maximum of 50 layers per core. Materials in contact with the liner will be excluded from the sample. Each sample layer will be placed in 8-oz glass jars, placed in plastic bags, and stored in coolers on ice until laboratory processing.

Prior to the analysis for total metals, layers will be analyzed for radioisotopes, ^{210}Pb, and total lead to estimate sediment age (Yake, 2001; Hobbs, 2017). Sub-samples will be selected for analysis that represent recent conditions (top layer), background conditions, which are used to calibrate the ^{210}Pb and dating (bottom layer), and equally divided layers throughout the core. Any significant identifiable markers in the cores will be recorded in field books.

Layers not selected for chemical analysis will be archived and frozen for possible later analysis. Sediment layers selected for analysis will be homogenized. Homogenized sediments will be split into sub-samples for analysis of total metals (4-ounce glass jars); TOC, TN, and LOI (4-oz glass jars), and ^{210}Pb (polystyrene containers) for dating.

Utensils used in collection and manipulation of core samples will be washed thoroughly with tap water and Liquinox detergent followed by sequential rinses of hot tap water and de-ionized water. Equipment will then be air dried and wrapped in aluminum foil until used in the field. The same cleaning procedure will be used on the corer prior to going into the field. New acrylic liners will be used for each sediment core, pre-cleaned using the procedure described above. To avoid cross-contamination between sample stations, the corer will be thoroughly brushed down with on-site water at the next sample location prior to collection of the subsequent sample.

8.3 Containers, preservation methods, holding times

Table 7. Requirements for containers, preservation, and holding times for sediment samples.

Analyte	Container Type	Sample Volume or Weight	Preservation	Holding Time
Sediment Total Metals	4-oz glass jar	25 g ww	Cool to <4° C, keep in dark/ Freeze to -18°C	12 months
TOC, TN	4-oz glass jar	20 g ww	Cool to <4° C, keep in dark/ Freeze to -18°C	6 months
^{210}Pb	Polystyrene	150 g ww	Freeze to -18° C	N/A
Surface Sediment Grain Size	8-oz plastic jar	50 g ww	Cool to <4 ° C	6 months
Loss on ignition, TOC	4-oz glass jar	25 g ww	Cool to <4° C/ Freeze to -18° C	Cool 7 days/ Freeze 6 months

8.4 Equipment decontamination

Field staff will follow Ecology's SOP Number EAP090, *Decontaminating Field Equipment for Sampling Toxics in the Environment* (Friese, 2014), to clean the certain field equipment prior to sample collection. Acrylic liners and subsectioning equipment will be scrubbed with Liquinox and hot tap water followed by sequential rinses with 10% nitric acid and deionized water. Equipment will be dried in a hood and then wrapped in aluminum foil for transport to the field location. While sectioning the sediment core in the field, equipment will be rinsed (and scrubbed, if necessary) with ambient water from the lake surface between 1 cm sediment intervals. Excess water will be shaken off prior to sectioning the next interval.

8.5 Sample ID

While sectioning the sediment core in the field, each 1 cm interval (0 – 2 cm for the top interval) will be placed into an 8-oz glass jar and labeled with the three-letter waterbody abbreviation plus sediment interval (e.g., EFF-00002) written on the jar and lid in permanent ink. Once intervals are homogenized and split into laboratory samples at Ecology's Headquarters, the samples will be assigned a sample ID using MEL's work order number followed by a consecutive number.

8.6 Chain of custody

Chain of custody will be maintained for all samples throughout the project. Samples will be stored in a cooler or freezer in Ecology's locked chain-of-custody room at Headquarters. MEL's chain of custody form will be used for documentation of shipment to laboratories.

8.7 Field log requirements

Field data will be recorded in a bound, waterproof notebook on Rite-in-the-Rain paper. Corrections will be made with single-line strikethroughs, initials, and date. The following information will be recorded in the field log:

- Name and location of project.
- Field personnel.
- Sequence of events.
- Any changes or deviations from the QAPP.
- Environmental conditions.
- Date, time, and location of sediment core collection.
- Length and description of full core.
- Description of core intervals, such as color, odor, and appearance.
- Unusual circumstances that might affect interpretation of results.

8.8 Other activities

N/A

9.0 Laboratory Procedures

9.1 Lab procedures table

All lab-analyzed samples will be analyzed at MEL with the exception of ^{210}Pb and grain size. Methods for all lab procedures are described in Table 8. QA/QC protocols are discussed in the *Quality Control* section of this plan. More details on laboratory procedures are described in the Manchester Laboratory *Lab Users Manual* (MEL, 2016a).

Table 8. Laboratory measurement methods.

Analyte	Sample Matrix	Expected Range of Results	Method	Method Detection Limit	Analytical Instrument
Al	Sediment	200 – 250,000 mg/kg	EPA6010D	1.1 mg/kg	ICP-MS
As	Sediment	0.05 – 500 mg/kg	EPA6020B	0.10 mg/kg	ICP-MS
Cd	Sediment	0.001 – 50 mg/kg	EPA6020B	0.34 mg/kg	ICP-MS
Cu	Sediment	0.5 – 2000 mg/kg	EPA6020B	0.36 mg/kg	ICP-MS
Fe	Sediment	300 – 500,000 mg/kg	EPA6010D	5.0 mg/kg	ICP-MS
Hg	Sediment	0.0036 – 5 mg/kg	EPA 245.5	0.0036	ICP-MS
Mn	Sediment	10 – 200,000 mg/kg	EPA6020B	0.14 mg/kg	ICP-MS
Ni	Sediment	0.5 – 500 mg/kg	EPA6020B	0.17 mg/kg	ICP-MS
TP	Sediment	0.05 – 500 mg/kg	EPA6020B	0.052 mg/kg	ICP-MS
Pb	Sediment	100 – 30,000 mg/kg	EPA6020B	1.71 mg/kg	ICP-MS
Ti	Sediment	100 – 5,000 mg/kg	EPA6020B	0.05 mg/kg	ICP-MS
Zn	Sediment	1 – 25,000 mg/kg	EPA6020B	0.43 mg/kg	ICP-MS
TOC, TN	Sediment	0.1 – 20% of DW	SM5310B (preacidified)	0.1% of DW	TM-440
^{210}Pb	Sediment Cores	< 0.45 – 30 pCi/g	Alpha spectroscopy	0.45 pCi/g	Alpha spectroscopy
Grain size	Sediment	N/A	PSEP, 1986	0.1%	Sieve-pipette
Loss on ignition, TOC	Sediment	0.1 – 20% of DW	ASTM D2584	0.1% of DW	Muffle furnace

9.2 Sample preparation method(s)

Metals will be prepared for analysis following EPA Method 3052B. Samples being analyzed for ^{210}Pb will be prepared following the contract laboratory's standard operating procedures. The contract laboratory's preparation method for ^{210}Pb will be reviewed by the project manager and MEL's QA coordinator and should include a digestion step using hydrofluoric acid. All other samples will be prepared for analysis following methods outlined in the analytical method (see Table 8). Per the method, samples analyzed for TOC must be pre-acidified to remove inorganic carbon.

9.3 Special method requirements

N/A

9.4 Laboratories accredited for methods

All chemical analysis, except for ^{210}Pb and grain size will be performed at MEL, which is accredited for all other methods except loss on ignition (Table 8). Test America (in Richland, WA) will perform ^{210}Pb analysis. Material Testing and Consulting in Olympia, WA will perform grain size analysis. Both laboratories are accredited for respective analyses.

The authors will use an Ecology waiver to waive the requirement to use an accredited lab for:

- MEL to analyze LOI.

10.0 Quality Control Procedures

10.1 Table of field and laboratory quality control

Table 9. Laboratory quality control samples, types, and frequency.

Parameter	LCS	Method blanks	Matrix spikes	Matrix spike duplicates	Laboratory duplicates	Surrogates
Various metals[1]	1/batch	1/batch	1/batch	1/batch	---	---
TOC and TN	1/batch	1/batch	---	---	1/batch	---
Grain Size	1/batch	1/batch	---	---	1/batch	---
^{210}Pb	1/batch	1/batch	---	---	1/batch	---
LOI	1/batch	1/batch	---	---	1/batch	---

[1] Al, As, Cd, Cu, Fe, Hg, Mn, Hg, Mg, Ni, P, Pb, Ti, Zn
LCS=Laboratory control sample

10.2 Corrective action processes

The project manager will work closely with the contract laboratory and MEL staff reviewing preliminary results to identify any data that fall outside of QC criteria. The project manager will determine whether data should be re-analyzed, rejected, or used with appropriate qualification.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

All field data and observations will be recorded on waterproof paper kept in field notebooks. Staff will transfer information contained in field notebooks to Excel spreadsheets after they return from the field. Data entries will be independently verified for accuracy by another member of the project team. Field and laboratory data for the project will be entered into Ecology's EIM database. Laboratory data will be uploaded into EIM using the EIM XML results template.

11.2 Laboratory data package requirements

After reviewing data packages from the contract laboratory, MEL will provide case narratives to the project manager with the final qualified results and a description of the quality of the contract laboratory data. MEL will also provide case narratives for in-house analyses performed.

Case narratives should include any problems encountered with the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers. Narratives will also address the condition of samples on receipt, sample preparation, methods of analysis, instrument calibration, and results of QC tests.

11.3 Electronic transfer requirements

MEL will deliver case narratives (in PDF format) and electronic data deliverables of contract laboratory data (in Excel spreadsheet format) to the project manager via email. Data generated by MEL (in-house analyses) will be delivered to the project manager via the Laboratory Information Management System (LIMS).

11.4 EIM/STORET data upload procedures

All appropriate laboratory data will be uploaded to Ecology's EIM database following internal procedures including a review process.

11.5 Model information management

N/A

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

MEL and contracted laboratories must participate in performance and system audits of their routine procedures. No audits are planned specifically for this project.

12.2 Responsible personnel

N/A. No audits are planned for this study.

12.3 Frequency and distribution of reports

A draft report of the sampling results will be completed in July of 2019 and a final report will be published on the internet in October of 2019. See Table 3 for the 2019 report schedule. Reports will include, at a minimum, the following:

- A map showing sampling locations.
- A brief description of field and laboratory methods.
- A discussion of data quality.
- Summary tables of contaminant concentrations and enrichment factors.
- Graphs showing contaminant profiles of sediment cores.
- A discussion of the results, including sedimentation rates and contaminant concentrations and fluxes.
- Recommendations based on the sampling results.

The additional metals being analyzed in the Deep Lake core will be reported to Ecology's Eastern Regional Office staff in a separate data submittal memo.

12.4 Responsibility for reports

The project manager/principal investigator will be the lead responsible for the final report.

13.0 Data Verification

Throughout field sampling, the field lead and all crew members are responsible for carrying out station positioning, and sample collection as specified in the QAPP and SOPs. Additionally, technicians systematically review all field documents (such as field logs, chain-of-custody sheets, holding times, and sample labels) to ensure data entries are consistent, correct, and complete, with no errors or omissions. A second staff person always checks the work of the staff person who primarily collected or generated data results.

13.1 Field data verification, requirements, and responsibilities

Field notes will be verified by the project manager. No data other than sampling location coordinates will be generated in the field.

13.2 Laboratory data verification

Data verification involves examining the data for errors, omissions, and compliance with QC acceptance criteria. MEL's SOPs for data reduction, review, and reporting will meet the needs of the project. MEL staff will perform laboratory verification following standard laboratory practices (MEL, 2016). MEL staff will provide a written report of their data review, which will include a discussion of whether:

1. MQOs were met.
2. Proper analytical methods and protocols were followed.
3. Calibrations and controls were within limits.
4. Data were consistent, correct, and complete, without errors or omissions.

The principal investigator/project manager is responsible for the final acceptance of the project data. The complete data package along with MEL's written report will be assessed for completeness and reasonableness. Based on these assessments, the data will either be accepted, accepted with qualifications, or rejected and re-analysis considered. Accuracy of data entered into EIM will be verified by someone other than the data engineer per the Environmental Assessment Program's EIM data entry business rules.

13.3 Validation requirements, if necessary

Independent data validation will not be required for this project.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After the project data have been reviewed and verified, the principal investigator/project manager will determine if the data are of sufficient quality to make determinations and decisions for which the study was conducted. The data from the laboratory's QC procedures will provide information to determine if MQOs have been met. Laboratory and QA staff familiar with assessment of data quality may be consulted. The project final report will discuss data quality and whether the project objectives were met. If limitations in the data are identified, they will be noted.

Some analytes will be reported near the detection capability of the selected methods. MQOs may be difficult to achieve for these results. Best professional judgment will be used in the final determination of whether to accept, reject, or accept the results with qualification. The assessment will be based on a review of laboratory QC results. This will include assessment of laboratory precision, contamination (blanks), accuracy, matrix interferences, and the success of laboratory QC samples meeting MQOs.

14.2 Treatment of non-detects

Laboratory data will be reported down to the method detection limit, with an associated "U" or "UJ" qualifier for non-detected results. When calculating total metals, non-detects will be assigned a value of half the detection limit. Summed values in the final report will include only results that are unqualified and/or that have been qualified "J" (indicating that the analyte was positively identified and the associated numerical value is approximate). Values that have been qualified "NJ" (indicating that the analyte has been "tentatively identified" and the associated value represents its approximate concentration) will not be included. If a sample is comprised of all non-detected congener results, then the final value will be assigned "ND" for not detected. Values will be qualified "J" if more than 10% of the total result is composed of values containing "J" qualifiers.

14.3 Data analysis and presentation methods

A summary of the data will be presented in the final report. Results will be presented as both concentrations and fluxes. The constant-rate-of-supply (CRS) model will be used to establish rates of sediment deposition from the ^{210}Pb activity (Appleby and Oldfield, 1978). Dating by ^{210}Pb methods has a limit of approximately 150 years based on the radioisotope half-life of 22.3 years. Other components to be included in the final report are described in Section 12.3.

14.4 Sampling design evaluation

Since the goal of the study is to measure metals concentrations in Lake Chelan sediment beyond the Lucerne Bar, the number and type of samples collected for this study will be reviewed in relation to results to meet study objectives.

14.5 Documentation of assessment

Documentation of assessment will occur in annual final reports.

15.0 References

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16.0 Appendices

Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will,

or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

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.

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

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

Acronyms and Abbreviations

e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
LOI	Loss on ignition
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
QC	Quality control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
TOC	Total organic carbon
USFS	United States Forest Service
WAC	Washington Administrative Code

Units of Measurement

g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
mg/kg	milligrams per kilogram (parts per million)
mole	an International System of Units (IS) unit of matter

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 sample 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 quality control (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 are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.

- REJ – data are 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: A discrete sample 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

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