Baseline Characterization of Nine Proposed Freshwater Sediment Reference Sites, 2008

July 2009

Publication No. 09-03-032

DEPARTMENT OF
ECOLOGY
State of Washington

Publication and Contact Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/0903032.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, NBLA0006.

Ecology's Study Tracker Code for this study is 08-074.

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Cover photo: Lake Wenatchee, summer of 2008.

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by
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Western Washington Waterbody Numbers:

WA-08-9060	Chester-Morse Reservoir
WA-08-9200	Masonry Pool (Chester-Morse Reservoir)
WA-CR-1010	Columbia River
WA-20-9040	Lake Ozette
WA-02-9060	Mountain Lake

Eastern Washington Waterbody Numbers:

WA-45-9100	Lake Wenatchee
WA-55-1010	Little Spokane River
(No number)	McDowell Lake (LLID=1175716474185)
WA-34-1010	Palouse River
WA-62-9180	South Skookum Lake

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Abstract

Freshwater sediment contamination in Washington State is assessed through the use of biological (bioassays) and chemical testing. Reference or baseline conditions which are used in the interpretation of biological and chemical tests are not well defined in Washington State.

To fill this data gap, the Washington State Department of Ecology collected and analyzed sediments from nine proposed freshwater reference waterbodies during the summer of 2008. Waterbodies were chosen to represent diverse ecological zones statewide. Within each waterbody, three locations were sampled to represent a diverse range of sediment grain sizes and account for patchiness of sediments.

Four waterbodies were tested in western Washington:

- Chester-Morse Reservoir (King County).
- Columbia River at Beacon Rock State Park (Skamania County).
- Lake Ozette (Clallam County).
- Mountain Lake (San Juan County).

Five waterbodies were tested in eastern Washington:

- Lake Wenatchee (Chelan County).
- Little Spokane River (Spokane County).
- McDowell Lake (Spokane County).
- Palouse River at the confluence with the Snake River (Franklin/Whiteman Counties).
- South Skookum Lake (Pend Oreille County).

The bioassays used for testing included Microtox, 20-day Chironomid (*Chironomus tentans*), and 28-day Amphipod (*Hyalella azteca*).

Target chemical analyses included total organic carbon, percent solids, grain size, sulfides, ammonia, semi-volatile organic compounds, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), chlorinated pesticides, and metals including mercury.

None of the nine waterbodies tested met all reference area criteria. Recommendations are provided for further testing of several promising locations within these waterbodies.

Acknowledgements

The authors of this report would like to thank the following people for their contribution to this study:

- For allowing access to and providing information on various waterbodies:
    - Dwayne Paige at the City of Seattle, Chester-Morse Reservoir.
    - Staff at the Olympic National Park, Lake Ozette.
    - Chris Guidotti at Moran State Park, Mountain Lake.
    - Staff at Lake Wenatchee State Park, Lake Wenatchee.
    - Nancy Curry and Michael Rule at Turnbull National Wildlife Refuge, McDowell Lake.
    - Staff at the Colville National Forest, South Skookum Lake.
    - Robert Fimbel, Washington State Parks, permitting.
- For conducting bioassay tests and providing interpretation of the results: MaryAnn Rempel-Hester, Nautilus Environmental Laboratory.
- Washington State Department of Ecology staff:
    - Dave Sternberg for proposing this project and providing guidance on design and the final report.
    - Dale Norton, Peter Adolphson, and Laura Inouye for reviewing this document.
    - Tom Gries for guidance on data and guideline interpretations.
    - Casey Deligeannis, Jenna Durkee, Chad Furl, Callie Meredith, and Keith Seiders for help collecting sediment samples and shoreline descriptions.
    - Stuart Magoon, Karin Feddersen, Dean Momohara, John Weakland, Dickey Huntamer, and other staff at Manchester Environmental Laboratory for analysis of chemical analytes and contracting.
    - Brian Pickering for fabricating, modifying, and maintaining field equipment used for this project.
    - Joan LeTourneau and Cindy Cook for editing and publishing this report.

Introduction

Project Background

Evaluating sediment quality often requires the use of both bioassays and chemical analyses as described in the Washington State Department of Ecology (Ecology) Sediment Management Standards (SMS). Unlike marine (salt-water) sediments, freshwater sediments consist of narrative standards, not numerical criteria for acceptable bioassay responses and chemical concentrations: *The SMS do not recommend specific biological tests for use in freshwater sediment investigations, nor do they provide decision criteria for interpreting the results of such tests* (Ecology, 2008). Therefore, analysis of sediment from a reference area is required to aid in the interpretation of data from the investigation site. Areas under investigation for establishing permitting requirements or cleanup actions are often located in populated areas with a variety of pollution sources. Even areas adjacent to the site may be polluted and not suitable to use for use as reference sediment.

Detection limit issues for chemical analyses complicate marine and freshwater sediment investigations. Further, freshwater sediments lack criteria in SMS. Therefore, *biological testing may even be conducted prior to, or instead of, analyses of chemical contaminants in (freshwater) sediment* (Ecology, 2008). In addition, there are no established reference areas for biological and chemical testing of freshwater sediments, unlike marine sediments. Currently, project managers must use best professional judgment to locate a reference area. Use of established reference areas with reliable physical and chemical properties increases the predictability of reference performance and bioassay test usability.

Aerial deposition of contaminants and nominal contamination from other sources are unavoidable. Therefore, reference sites, for the purpose of this project, represent waterbodies with near natural conditions or waterbodies minimally influenced by human activities. Geographic differences in chemical concentrations and physical properties of the sediment instill a need to make comparisons localized in a small area. Therefore, distribution of reference sites throughout the state of Washington ensures adequate geographic coverage and accounts for varying environmental conditions.

This 2008 study collected sediments from nine purposed reference sites to produce bioassay and chemistry datasets. These datasets begin to address the lack of established reference areas for freshwater sediments.

Study Objectives

The results of this study are intended to:

- Screen freshwater areas in Washington State for acceptable biological and chemical responses to represent reference conditions.
- Provide data that represents relatively uncontaminated areas.
- Establish a dataset that incorporates both biological and chemical data.

Biological (Bioassay) Testing

Benthic macroinvertebrate abundance, counts of taxa in native sediment samples, is a typical marine sediment biological test. This marine test is recommended in Ecology's Sediment Sampling and Analysis Plan Appendix (SAPA; Ecology, 2008). However, use of the naturally occurring community of benthic macroinvertebrates as a test for freshwater systems is difficult. The natural variability of freshwater biological communities increases the complexity of comparing waterbodies. Some factors that contribute to this variability include depth, size, fetch, waterbody type (lake or stream), sediment grain size distribution, pH, and temperature of the waterbody as well as significant annual and seasonal variability within individual waterbodies. The SAPA does not recommend this test for freshwater.

As with marine sediment investigations, bioassays for freshwater sediments measure sediment quality. Bioassays examine the toxicity of sediments by evaluating exposure effects on a variety of organisms. Bioassays are useful because they integrate the toxicity of all factors associated with the sediment such as interactive effects between chemicals. For example, chemical A might be toxic at a high concentration, but if in the presence of chemical B, chemical A becomes toxic at a much lower concentration. Conversely, chemical C might be toxic at a low concentration, but in the presence of chemical D, chemical C becomes much less toxic and requires much greater concentrations to cause an effect. In addition, different organisms are sensitive to different chemical concentrations and mixtures. Therefore, conducting more than one type of bioassay ensures a broader picture of sediment toxicity.

Typically, bioassays are categorized into acute and chronic tests. Acute tests are usually short relative to the life cycle of the organism and identify toxicity that manifests quickly. Chronic tests are longer relative to the life cycle of the organism and therefore are generally more costly than acute tests. However, chronic tests integrate acute and cumulative toxicity of freshwater sediment, providing a higher degree of certainty of sediment conditions, toxic or non-toxic.

Bioassay tests

Three test organisms recommended by the SAPA for use in freshwater sediment evaluations are *Vibrio fischeri* (Microtox test, luminescent bacteria), *Chironomus tentans* (Chironomid test, aquatic midge larva) and *Hyalella azteca (*Amphipod test, small crustacean) (Ecology, 2008).

Microtox

The Microtox test uses sediment porewater, water extracted from the sediment, for testing toxic effects. This test measures light output of *Vibrio fischeri* at test initiation, and after 5 and 15 minutes of exposure to the porewater. Significant reduction in light output indicates sediment toxicity. This bioassay is very useful as a short-duration, relatively inexpensive toxicity test. However, even though it is short in duration, it is a chronic test for marine sediments in the SAPA because of the test length relative to the overall life cycle of the bacteria (Ecology, 2008).

Chironomus tentans

The chironomid chronic bioassay introduces 12 *Chironomus tentans* into a test chamber containing the sediment sample and clean overlying water. During the test, renewal of the overlaying water occurs two times per day, and feeding of 1.5 mL of Tetrafin® occurs once per day. After 20 days in the test chambers, technicians recover and count surviving larvae. Then they weigh the surviving larvae using an ash-free dry weight method. (ASTM, 2000.)

Hyalella azteca

Ten *Hyalella azteca* are introduced into a test chamber for the amphipod test. At 28 days, this test is slightly longer than the chironomid test. Overlaying water is renewed twice daily, and feeding occurs once daily with 1.0 mL yeast, Cerophyl ®, and trout chow (YCT). At test termination, percent survival and growth are determined similar to the chironomid test. (ASTM, 2000.)

A reduction in survival or growth for either the amphipod or the chironomid tests may indicate sediment toxicity due to either acute or cumulative effects (ASTM, 2000). Methods for these two tests do not specify the required number of replicates.

Bioassay Guidelines

Quality Control

Bioassay test guidelines establish quality control performance standards for both control samples and reference sediment samples. These performance standards ensure that the test procedures and organisms are acceptable. Failure of performance standards can render test results unusable.

There are two types of controls, positive and negative:

- Positive controls examine the test organism's sensitivity to a known toxicant. Failure of this performance measure indicates that the organism is highly resilient and may show no effect when exposed to toxic sediments.
- Negative controls, hereafter referred to as control, are conducted in the same manner as a test sediment except clean laboratory sediment is used. This performance measure tests whether the organism is capable of surviving in ideal conditions.

Reference tests are conducted in the same manner as the test sediment except the sediment comes from a local clean source. The purpose of this performance measure is to account for local sediment conditions unrelated to the contaminants of concern. This study is evaluating areas to be used for this purpose. Therefore, all samples were compared to both test and reference guidelines.

Test

Bioassay test guidelines compare sediment sample results to reference or control results, to account for inter-test variability. The SAPA outlines guidelines for the Microtox bioassay. These test guidelines are defined as sediment quality standards (SQS) or cleanup screening level (CSL). The Sediment Evaluation Framework (SEF) provides guidance on the interpretation of *Chironomus tentans* and *Hyalella azteca* bioassay tests. SEF guidelines provide two effect levels similar to the SAPA, 2-hit and 1-hit. Failure of any test guideline indicates an adverse effect on the test organism.

Overview of test guideline meanings (ordered by severity of effects predicted by the guideline):

- SQS and 2-hit bioassay guidelines indicate a minor adverse effect. This means that some stimuli caused a negative response from the test organisms.
    - If more than one bioassay test (ex. Amphipod and Chironomid tests) fail the 2-hit guideline for one sample, the sample is considered to have severe adverse effects and is equivalent to a 1-hit failure.
- CSL and 1-hit bioassay guidelines indicate a severe adverse effect. Some stimuli caused the observation of substantial negative impacts to the test organisms.

Chemical Testing

Chemical contamination can come from a variety of sources, and the contamination may involve a large number of individual chemicals. Chemical groups often examined include Aroclor polychlorinated biphenyl compounds (PCBs), semi-volatile organic compounds, polycyclic aromatic hydrocarbon compounds (PAHs), chlorinated pesticides, and metals. In addition to chemical contamination, it is important to analyze total organic carbon and grain size as these parameters are needed for comparison purposes and providing information on contaminant bioavailability and bioassay success. Analysis of ammonia and sulfides specifically addresses sediment toxicity related to benthic organisms, but these chemicals are not necessarily a human health risk.

Chemistry Guidelines

Freshwater guidelines exist for all of the chemical groups above. Although they are not SMS criteria, these guidelines provide a screening tool to assess sediment toxicity based on chemistry results. Ecology (2003) describes lowest apparent effects thresholds (LAET), sediment quality standards (SQS), and cleanup screening levels (CSL). These guidelines were developed using data from the states of Oregon and Washington. Bioassays used for the development of the guidelines were limited to acute tests, less than 10 days in duration. Probable apparent effects threshold (PAET) values which are similar to LAET guidelines were also developed using Washington data.

Canadian Sediment Quality Guidelines published in 2002 contain threshold effect level (TEL) and probable effects level (PEL) guidelines for freshwater sediments. These guidelines do not reliably predict toxicity in Washington freshwater sediments (Ecology, 2002 and 2003). However, for certain chemicals they are the only guidelines available. Ecology (2002) provides a summary of additional non-regional freshwater sediment guidelines.

Overview of guideline meanings (ordered by severity of effects predicted by the guideline):

- The TEL guideline indicates "the level below which adverse biological effects rarely occur" (Ecology, 2002). Therefore, samples that pass this guideline are not anticipated to have biological effects from that chemical.
- SQS and PEL guidelines describe "the level above which (minor) adverse biological effects occur frequently" (CCME, 1999; Ecology, 2008). Samples that have chemical failures of SQS or PEL guidelines are more likely to exhibit minor adverse biological effects; SQS or 2-hit bioassay failures.
- LAET and PAET guidelines indicate the level above which at least one Microtox, or acute Chironomid, or acute Hyalella test has always failed unless the test was considered an outlier. Samples that fail these guidelines are predicted to fail at least one of these bioassay tests.
- The CSL guideline indicates the level above which more severe adverse biological effects occur frequently Ecology, 2003. Samples that have chemical failures of the CSL guideline are more likely to exhibit more severe adverse biological effects or a greater number of effects; CSL, 1-hit, or more than one SQS or 2-hit bioassay failure.

Additional guideline details are provided in Appendix E.

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Methods

This study evaluated purposed reference waterbodies. This involved collecting sediment from three locations within each of nine selected waterbodies for a total of 27 sample locations. These waterbodies represented ecologically distinct areas.

Complete methods for this study are described in the final Quality Assurance Project Plan, *Evaluation of Candidate Freshwater Sediment Reference Sites* (Blakley, 2008).

Site Selection

There are nine Level III ecoregions[1] in Washington State (Figure 1). Ecoregions depict areas that are environmentally similar. Site selection emphasized representing the different ecoregions in Washington to increase the environmental diversity between the waterbodies.

Additional criteria used for waterbody selection included:

- Away from a known pollution source or human development.
- In protected areas such as a National or State Park.
- Close to current investigation sites, examples: portions of the Columbia River, Lake Roosevelt, portions of the Spokane River, and central Puget Sound lowlands.
- Geographically distributed throughout Washington.
- Range of waterbody types (example: river).

[1] Level III ecoregions are appropriate for regional analysis and decision-making. Levels I and II ecoregions are appropriate for national, continental, or intercontinental scales of comparison (National Atlas of the United States, 2009).

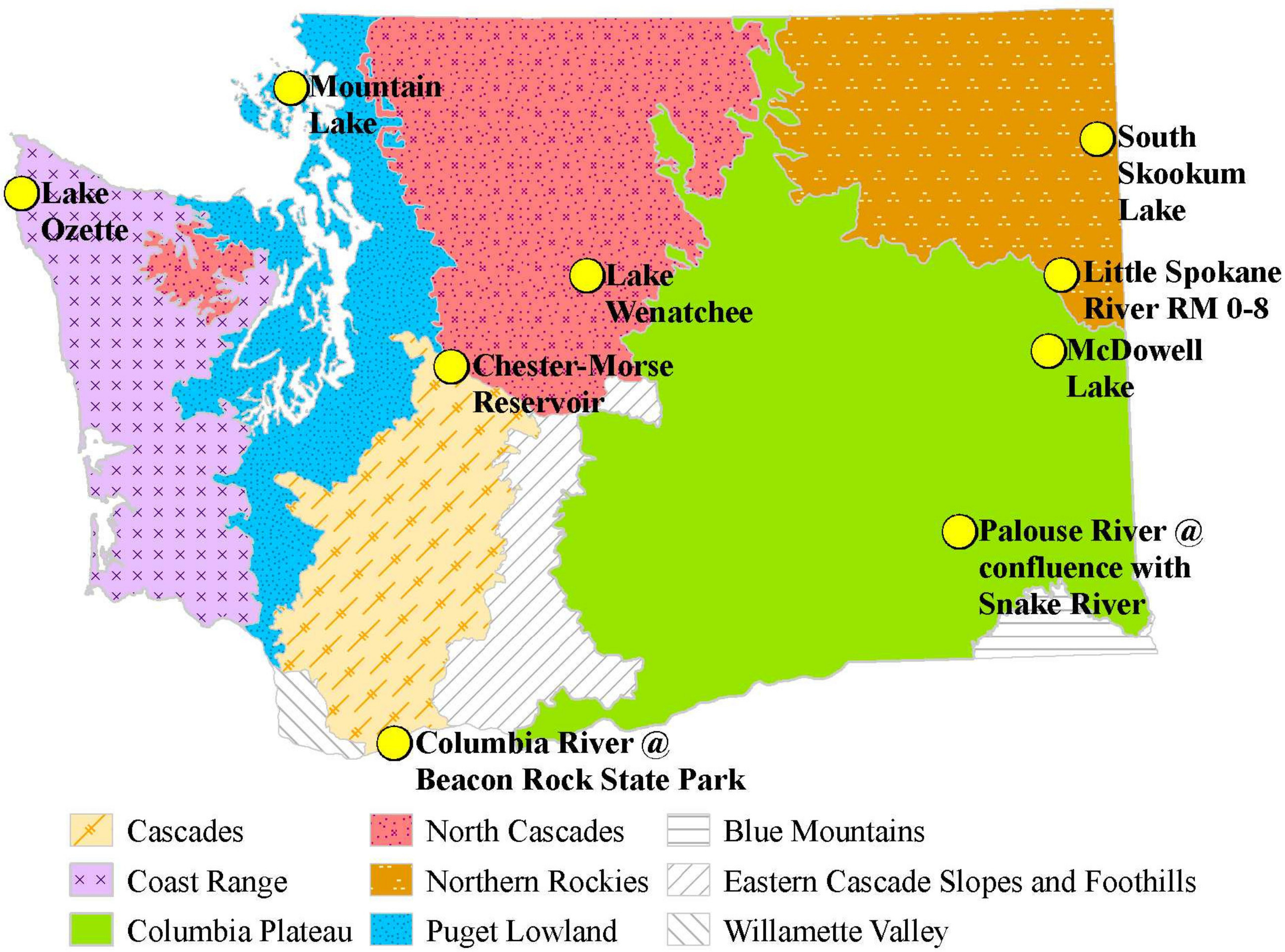

Figure 1. Nine proposed reference waterbodies in relation to Level III ecoregions.

After site selection, Ecology staff visited each waterbody prior to sampling. This step ensured the suitability of a waterbody as a purposed reference site. Additional details are available in Appendix B. The selected waterbodies represent near natural conditions and a diverse set of characteristics (Table 1).

The nine waterbodies selected for this study were:

Western Washington:

- Chester-Morse Reservoir.
- The Columbia River at Beacon Rock State Park.
- Lake Ozette.
- Mountain Lake.

Eastern Washington:

- Lake Wenatchee.
- Little Spokane River between river mile 0.0 and 8.0.
- McDowell Lake.
- Palouse River at the confluence with the Snake River.
- South Skookum Lake.

It was difficult to locate acceptable waterbodies in the Willamette Valley, Eastern Cascade Slopes and Foothills, and Blue Mountains ecoregions. Therefore one waterbody was located in each of these ecoregions: the Coast Range, Puget Lowlands, and North Cascades and two waterbodies were located in each of these ecoregions: Cascades, Northern Rockies, and Columbia Plateau (Figure 1). All waterbodies were located in protected areas with no obvious pollution sources.

Figure 2 shows each waterbody at a scale of 1:100,000 for comparison. Mountain, McDowell, and South Skookum Lakes are also shown at a scale of 1:30,000 due to their small size. This figure shows the sampling locations and identification codes within each waterbody.

Table 1. Waterbody characteristics.

Site	EPA Level III Ecoregion	County	Land Use (Ownership)	Type of Waterbody	Surrounding Area Vegetation Type[1]	Primary Riparian Vegetation[1]	Elevation (ft)	Area (acres)	Drainage Area ($miles^2$)
Western Washington									
Chester-Morse Reservoir (CM)	Cascades	King	Natural (City of Seattle)	Reservoir	Second timber coniferous forest	Deciduous trees and shrubs	1560[1]	1,536[2]	78.4[2]
Columbia River @ Beacon Rock (BR)	Cascades	Skamania	Recreation, Natural (Beacon Rock State Park)	River	Second timber deciduous forest	Shrubs and grasses	50[1]	----	240,000[2]
Lake Ozette (OZ)	Coast Range	Clallam	Recreation, Natural (Olympic National Park).	Lake	Second timber coniferous forest	Grasses and shrubs with a few trees	34[3]	7,550[3]	77[4]
Mountain Lake (ML)	Puget Lowland	San Juan	Recreation, Natural (Moran State Park)	Lake	Mature timber coniferous forest	Deciduous trees and grasses	940[1]	198	2[4]
Eastern Washington									
Lake Wenatchee (LW)	North Cascades	Chelan	Recreation, Low Residential (Wenatchee State Park and National Forest)	Lake	Mature coniferous forest	Shrubs and deciduous trees	1880[1]	2,480	275[3]
Little Spokane River, river mile 0.0-8.0 (LS)	Northern Rockies	Spokane	Recreation, Natural (Little Spokane Natural Area and State Park, Upstream Town of Dartford).	River	Second timber coniferous forest	Coniferous trees, grasses, and shrubs	1521[1]	-----	700[5]
McDowell Lake[6] (MD)	Columbia Plateau	Spokane	Natural, Recreation (Turnbull National Wildlife Refuge)	Lake	Second timber coniferous forest	Deciduous trees and grasses	2300[1]	54	<1[3]
Palouse River @ confluence with Snake River (PS)	Columbia Plateau	Franklin/ Whitman	Natural, Recreation (US Army Corps of Engineers, Lyons Ferry State Park)	River	Sagebrush with some deciduous trees	Shrubs or bare soil	540[1]	-----	3,303[7]
South Skookum Lake[8] (SS)	Northern Rockies	Pend Oreille	Natural, Recreation (Colville National Forest)	Lake	Second timber coniferous forest	Coniferous trees and shrubs	3500[1]	32.6[9]	6[3]

[1] Field data.
[2] USGS, 2009a.
[3] Haggerty et al., 2008.
[4] USGS, 2009b.
[5] Ecology, 1995.
[6] Alternate to Kepple Lake.
[7] Cook and Gilmore, 2004.
[8] Alternate to Browns Lake.
[9] Colville National Forest, 2009.

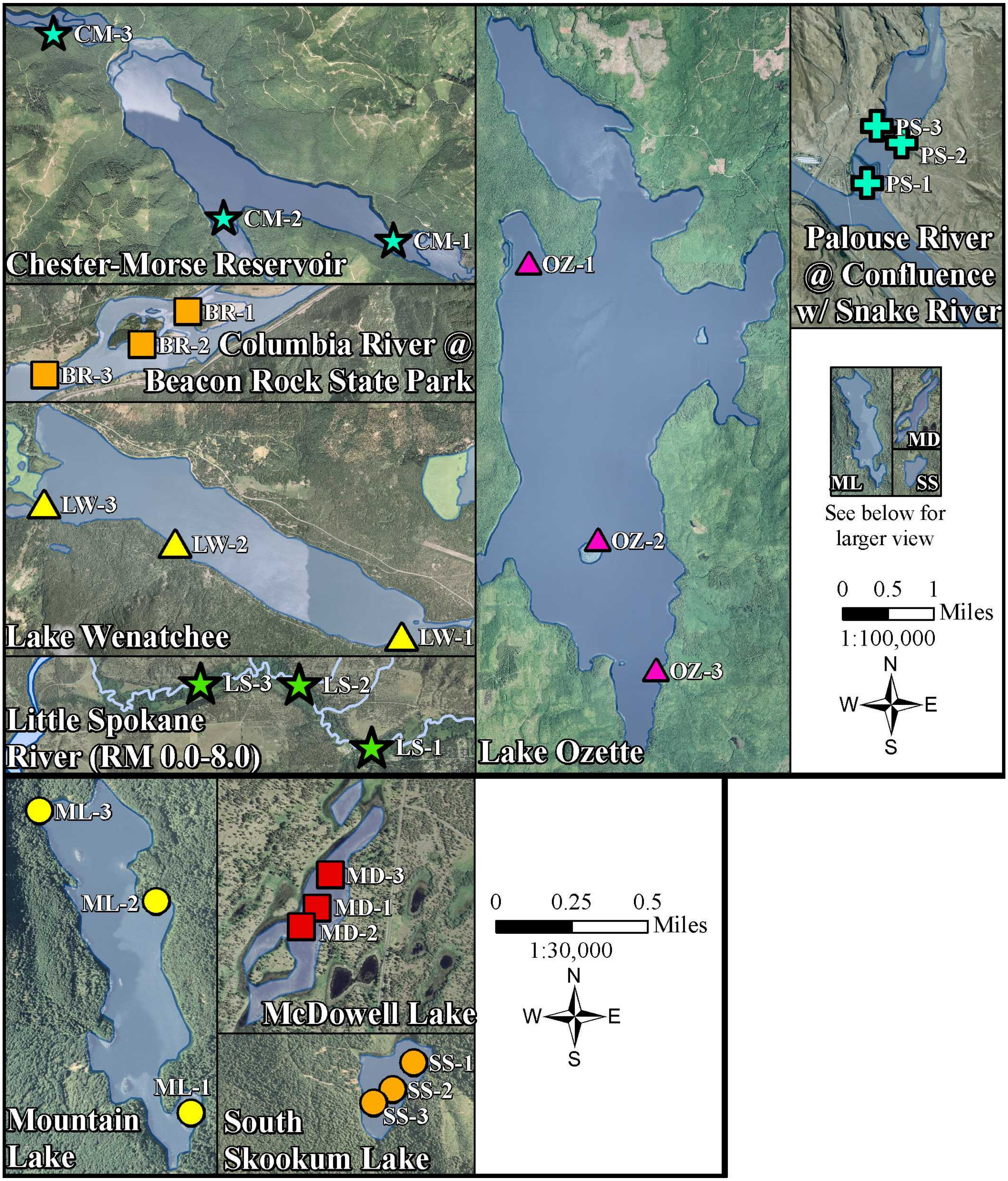

Figure 2. Satellite images of the nine selected waterbodies.

A scale of 1:100,000 was used for all waterbodies to show relative size. Due to their small size Mountain, McDowell, and South Skookum Lakes are also shown at the 1:30,000 scale. Sampling locations are indicated with a symbol and labeled with an identifying code.

Sampling Procedures

Ecology staff collected three sediment samples from each of the nine waterbodies in July and August of 2008 (Figure 3).

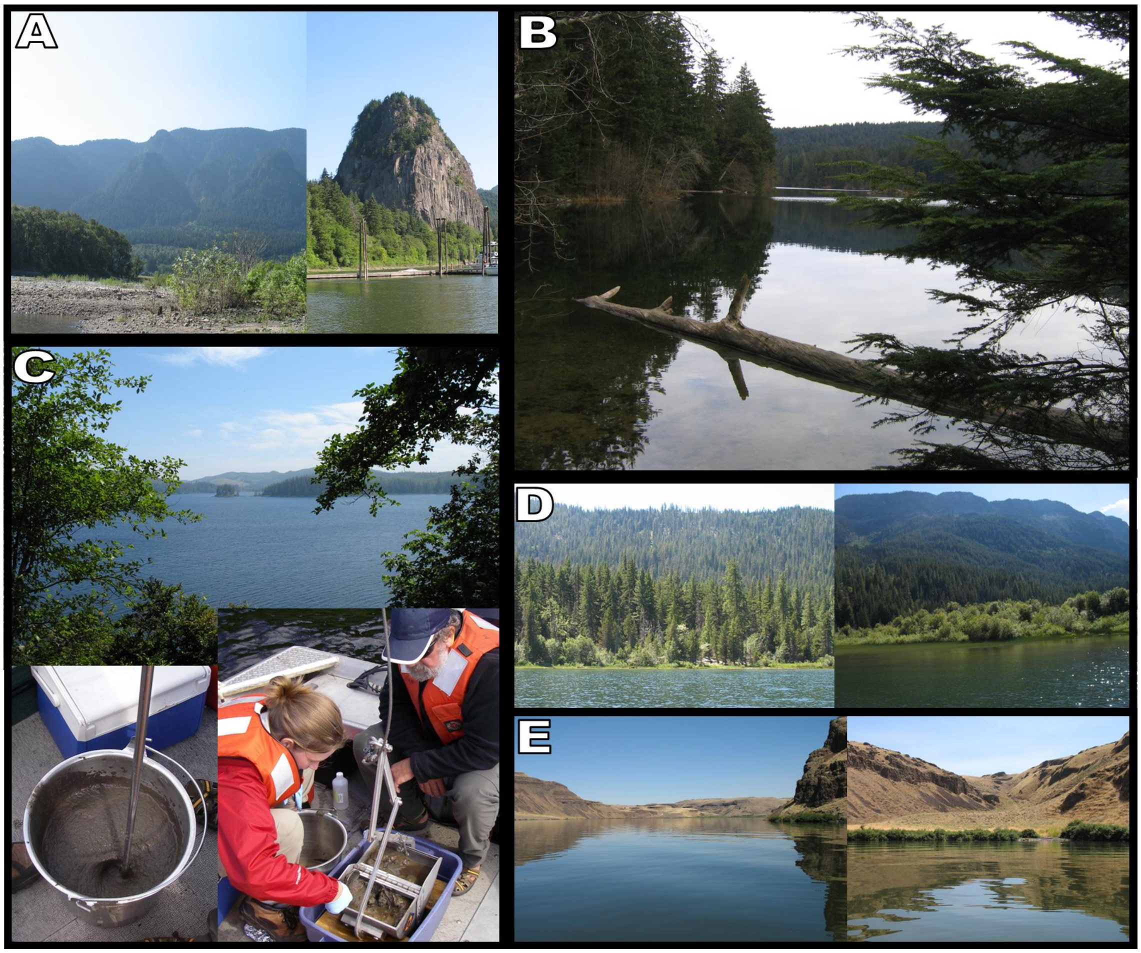

Figure 3. Fieldwork pictures.

A - Columbia River at Beacon Rock State Park, B - Mountain Lake, C - Lake Ozette, homogenization of sediment, and collection of sediment from standard ponar, D - Lake Wenatchee, E - Palouse River at the confluence with the Snake River.

Sample collection methods included the use of an Eckman grab sampler, a petite ponar grab sampler, a standard ponar grab sampler, or a bucket. After collection, samples were homogenized in the field and split into subsamples for analysis. Aroclor PCBs, PAHs, chlorinated pesticides, metals, ammonia, sulfides, grain size, total organic carbon, and semi-volatile organic compounds were analyzed. Three bioassays were conducted for each sample.

Positioning of the three target locations within each waterbody aimed at spreading the samples apart and choosing areas with differing substrates (ex. sandy area vs. silty area). Appendix B, Table B-1 shows the latitude, longitude, water depth, and debris found in the sample for each station.

Sampling procedure that deviated from the final Quality Assurance Project Plan (Blakley, 2008):

- Sampling with the petite ponar in the Little Spokane River proved to be an unfruitful method for collection of sediment. Alternatively a pre-cleaned stainless steel bucket was used to scoop sediment off the riverbed. Retrieval of collected sediment that had not contacted the bucket prevented sample contamination via equipment. All other methods were as described in the Quality Assurance Project Plan for sediment collection using the ponar and Eckman grabs.
- Obstruction of Kepple Lake by vegetation and low water levels prevented access to sampling areas with the research vessel. Consequently, McDowell Lake served as an alternative waterbody.
- Access to the boat launch at Browns Lake was not possible due to a large tree blocking the ramp. Therefore, nearby South Skookum Lake served as an alternative waterbody.

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Data Quality

All methods used in this study follow those outlined in the approved Quality Assurance Project Plan except for measuring total sulfides and solids (Blakley, 2008). Table 2 lists the analyses conducted and associated method. Method EPA 9030 for measuring sulfides was used for ML 1-3. The correct method, PSEP, 1986, was used for the remaining samples at the request of the principal investigator. This did not affect the interpretation of the results as Method EPA 9030 has lower detection limits than PSEP, 1986. Standard Method 2540G was used instead of PSEP, 1986 for measuring total solids; this method change did not influence interpretation of the results.

All bioassay and chemistry data have been reviewed for completeness, accuracy, and usability. Additional quality control details can be found in Appendix C.

Table 2. Parameters measured and methods used in this study.

Analysis	Analytical Method	Laboratory
Bioassay		
Microtox	Microtox, SAPA, 2003	Nautilus Environmental Laboratory
20 Day *Chironomus tentans*	EPA Method 100.5, ASTM E1706-00	
28 Day *Hyalella azteca*	EPA Method 100.4, ASTM E1706-00	
Chemistry		
Grain Size	PSEP, 1986	Columbia Analytical
Total Sulfides	PSEP, 1986, EPA 9030	
Ammonia	Plumb 1981, EPA 350.1	
Total Organic Carbon	PSEP, 1986/1997	Manchester Environmental Laboratory
Percent Solids	Standard Method 2540G	
Metals[1] (ICP/MS)	EPA Method 200.8 and 200.7	
Total Mercury (CVAA)	EPA 245.5; MEL SOP[2]	
Semi-volatile Organic Compounds (BNASQS)	EPA SW 846 Method 8270	
PAHs (PAHNOAA)	EPA SW 846 Method 8270 modified	
Chlorinated Pesticides and Aroclor PCBs (PEST1PCB)	EPA 8081/8082	

[1] Includes the following metals: Ag, Al, Sb, As, B, Ba, Be, Cd, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Se, Sn, Sr, Ti, Tl, V, Zn.
[2] Manchester Environmental Laboratory (MEL) modifications to analytical methods are documented in their Standard Operating Procedures.
BNASQS = Base/Neutral/Acids semivolatile organic compounds – Sediment Quality Standards list. Includes the following compounds: 1,2,4-Trichlorobenzene, 1,2-Dichlorobenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene, 2,4-Dimethylphenol, 2-Methylphenol, 3B-Coprostanol, 4-Methylphenol, Benzoic Acid, Benzyl Alcohol, Bis(2-Ethylhexyl) Phthalate, Butylbenzylphthalate, Caffeine, Cholesterol, Diethylphthalate, Dimethylphthalate, Di-N-Butylphthalate, Di-N-Octyl Phthalate, Hexachlorobenzene, Hexachlorobutadiene, Isophorone, N-Nitrosodiphenylamine, Pentachlorophenol, Phenol, 4-Nonylphenol.
CVAA = Cold vapor atomic absorption.
PAHNOAA = Polycyclic aromatic hydrocarbons – National Oceanic and Atmospheric Administration list. Includes the following compounds: Naphthalene, 2-Methylnaphthalene, 1-Methylnaphthalene, 1,1'-Biphenyl, 2-Chloronaphthalene, 2,6-Dimethylnaphthalene, Acenaphthylene, Acenaphthene, Dibenzofuran, 1,6,7-Trimethylnaphthalene, Fluorene, Dibenzothiophene, Phenanthrene, Anthracene, Carbazole, 2-Methylphenanthrene, Fluoranthene, Pyrene, Retene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo[e]pyrene, Benzo(a)pyrene, Perylene, Indeno(1,2,3-cd)pyrene, Dibenzo(a,h)anthracene, Benzo(ghi)perylene.
EPA = U.S. Environmental Protection Agency.
ICP/MS = Inductively coupled plasma mass spectrometry.
PSEP = Puget Sound Estuary Program.

Bioassay Quality

Positive controls were acceptable for all three bioassay tests (Table A-4).

Microtox

All Microtox bioassays were acceptable.

Chironomus tentans

Samples CM-1, CM-2, LS-1, and LS-2 had dissolved oxygen levels in the test chambers drop below the recommended level for *Chironomus tentans* (Table B-3). Upon discovery of low dissolved oxygen, aeration of the test chamber started immediately. No adverse effects from this drop in dissolved oxygen are anticipated. EPA guidance states that survival and growth effects begin at lower levels than those observed (EPA, 2000). Alkalinity and hardness were also outside of acceptable range; however, this only occurred in the control. The control performance was acceptable when compared to guidelines outlined in Appendix E, Table E-1.

Indigenous chironomid larvae were found in samples LS-1, LS-3, SS-2, and SS-3. Results for LS samples are consistent regardless of additional larvae being present; therefore, no effect on survival is predicted. SS-2 and SS-3 have differing results between samples; therefore, the presence of additional larvae did not affect the results. All *Chironomus tentans* tests were deemed acceptable.

Hyalella azteca

Sample LS-2 experienced low dissolved oxygen levels (Table B-3). Aeration began immediately, no adverse effects were observed, and survival and growth was high for this sample.

Survival for the control group in the *Hyalella azteca* bioassay was acceptable; however, growth failed the control guideline. The low growth in the control is attributed to the lack of available food. Growth for all the samples was higher than the control and met the reference performance guidelines; therefore, low growth in the control did not influence the results.

Indigenous chironomid larvae were found in samples LS-1, LS-2, SS-2, and SS-3. No adverse effects were noted in any of these tests; therefore, the results were not affected by the presence of these larvae. All *Hyalella azteca* tests were deemed acceptable.

Chemistry Quality

Due to the timing of sampling and laboratory logistics, Mountain Lake samples exceeded the holding times for ammonia and sulfides. Therefore, these results were qualified as estimates.

The high reporting limits for a few of the metals results were due to matrix interferences. These higher values did not influence the interpretation of the data. Therefore, all the metals results were acceptable.

Several individual PAHs had high matrix spike recoveries, affected results were qualified as estimates (J). This did not influence the interpretation of the results and therefore all PAH results were acceptable.

The semi-volatile compound benzoic acid was found in the blank samples and had low matrix spike recovery. Affected results were qualified as undetected (UJ) or estimates (J). Continuing calibration indicates that benzoic acid was also biased high; however, no additional data qualifiers were added. Semi-volatile organics and chlorinated pesticides results had some undetected values above the example SQS guidelines. These high reporting limits are common due to the innate difficulty in obtaining low values for these groups. Semi-volatile organic and chlorinated pesticide results were deemed acceptable.

Data Analysis

Bioassay

Bioassay data was analyzed using Microsoft Excel, SPSS 11, and U.S. Army Corps of Engineers Biostat software in accordance with ASTM (E 1706-05) and EPA (2000) guidelines. Bioassay results were compared to the Ecology 2008 guideline and Sediment Evaluation Framework (SEF) 2009 draft guidelines. Control results were used in place of references when comparing guidelines.

Details on guideline meanings can be found in Appendix E.

For the *Chironomus tentans* bioassay, samples BR-2 and PS-2 had numerical criteria hits but were not statistically significant. Therefore, power analysis was conducted. The coefficient of variation (CV) for BR-2 was 37% and PS-2 was 27%. The resulting power was <20% to detect a 15% reduction when compared to the control. A 15% reduction reflects the 2-hit numerical guideline for the Chironomid bioassay. Therefore, there is only a 20% probability of detecting a difference if a difference is truly present. For the purpose of this study, the strict interpretation of the guidelines was used, and these samples were considered no-hits.

For the Microtox and *Hyalella azteca* bioassays, all numerical criteria hits were statistically significant. No power analysis was conducted.

Chemistry

Chemistry results were first compared to freshwater LAET, SQS, and CSL values from Ecology 2003. Results were also compared to the TEL or PEL guidelines in CCME 2002, particularly in cases where LAET, SQS, and CSL guidelines were not available. PAET guidelines from Ecology 2002 were used where LAET guidelines were not available. Chemistry data were analyzed using Microsoft Excel, MyEIM, and SPSS 11 software.

Details on guideline meanings are located in Appendix E.

Results and Discussion

Bioassay

Bioassay results were compared to the interpretive guidelines for both test and reference samples.

If the bioassay failed the test guideline, some environmental factor/stimulus was presumed to cause the adverse effect observed in that sample. If the bioassay failed the reference guideline the sample would not be acceptable for use as reference sediment.

Waterbody

The primary objective for this study was to identify reference waterbodies that can be consistently used for bioassay comparisons. Based on results for all samples and bioassays, none of the nine waterbodies sampled would be acceptable for use as reference sites in their entirety (Table 3). In addition, bioassay results for several waterbodies indicated the presence of some negative environmental stimuli.

Bioassay results by waterbody are as follows:

- Mountain Lake showed the least evidence of sediment toxicity, with only one sample failing Ecology's guideline for an acceptable Microtox reference.
- Chester-Morse Reservoir and Lake Ozette showed increased toxicity, but only at the level of minor adverse effects (one 2-hit failure). These may prove to be good reference waterbodies after further testing to assess the variability of bioassay results.
- South Skookum Lake had a SQS failure for Microtox luminescence and a 2-hit failure for *C. tentans* survival, and therefore is not as preferable of a reference site.
- The Columbia River, Little Spokane River, Lake Wenatchee, McDowell Lake, and the Palouse River all had a 1-hit failure for the chironomid survival bioassay. This indicated environmental stimuli causing a higher (severe) level of adverse impacts in these sediments.

Table 3. Bioassay results compared to test and reference acceptability guidelines▲*.

Bioassay:	Microtox		*Chironomus tentans*				*Hyalella azteca*			
Endpoint:	15 minute Luminescence		Survival		Growth		Survival		Growth	
Acceptability Guidelines:	Test	Reference	Test	Reference	Test	Reference	Test	Reference	Test	Reference
BR**	3	3	1-hit	Fail	3	3	3	3	3	3
CM	3	Fail	2-hit	Fail	3	3	3	3	3	3
ML	3	Fail	3	3	3	3	3	3	3	3
OZ	3	Fail	2-hit	Fail	3	3	3	3	3	3
LS	3	3	1-hit	Fail	3	3	3	3	3	3
LW	3	Fail	1-hit	Fail	3	3	3	3	3	3
MD	3	Fail	1-hit	Fail	3	3	3	3	3	3
PS	3	3	1-hit	Fail	3	3	3	3	3	3
SS	SQS	Fail	2-hit	3	3	3	3	3	3	3

▲Samples were compared to both test and reference acceptability guidelines. Failure of test guidelines indicated some environmental stimuli causing toxicity. Failure of reference guidelines indicated the sample would not be acceptable for use as reference sediment. See Appendix E for guideline descriptions.

*Table arrangement: A guideline in the box indicates that at least 1 out of the 3 samples showed effects at that level. A 3 in the box indicates that all 3 samples passed the guidelines. The colors indicate the severity: yellow/minor→orange→red/severe.

**See Appendix A for definitions of these site abbreviations.

SQS=Sediment Quality Standard, minor adverse effect.

2-Hit=Minor adverse effect. Two bioassays tests must fail for the sample to fail as a whole. For example: If Sample B has a 2-hit result for Microtox and no other hits, the sample passes the test guidelines. If sample C has a 2-hit result for Microtox and a 2-hit result for *Chironomus tentans,* the sample fails the test guidelines at the 1-Hit level.

CSL=Cleanup Screening Level, severe adverse effect.

1-Hit=Severe adverse effect (2 2-hit's /sample = 1 1-hit for the sample). Only one bioassay test must fail for the sample to fail as a whole. For example: If Sample A has a 1-hit result for the Microtox test, the whole sample fails the test guidelines.

Sample Location

Most investigations require test sample results to be compared to reference sample results with a similar sediment grain size distribution. Therefore, even if one of the waterbodies studied is not ideal overall, specific locations within that waterbody are good reference locations.

Using percent fines for grain size comparisons, there was at least one sample classified as good or moderate in each of four size ranges (0-20%, 20-40%, 40-60%, and 60-100%). Samples classified as good had no bioassay test or reference failures, and moderate samples had one reference guideline failure and no test failures. Poor samples had at least one 2-hit or SQS failure, and very poor samples had at least one 1-hit failure (Table 4).

Western Washington samples that were in the good or moderate category included Chester-Morse Reservoir sample 1, Columbia River samples 1 and 2, Lake Ozette samples 1 and 3, and Mountain Lake samples 1-3. In eastern Washington, Lake Wenatchee samples 1 and 2, Palouse

River samples 1 and 2, and South Skookum Lake sample 1 had good or moderate bioassay results. The remaining sample locations were classified as poor or very poor. Detailed bioassay results can be found in Appendices B and D.

Before any of these sample locations are used as sole references, reliability of the location needs to be established. This involves repeated sampling to investigate the variability of bioassay results. This additional sampling may be conducted over time as these locations are used as references for investigations. However, more than one reference sample should be collected until enough data have been gathered.

Table 4. Individual sample location bioassay performances grouped by percent fines.

Bioassay Performance	% Fines			
	0-20	20-40	40-60	60-100
Good (no bioassay failures)	BR-1	LW-1		PS-2
	ML-2	LW-2		
		ML-3		
		OZ-1		
		PS-1		
Moderate (one reference failure)		BR-2	CM-1	
		OZ-3	SS-1	
		ML-1		
Poor (At least one 2-hit failure)	CM-3	OZ-2	CM-2	
			SS-2	
			SS-3	
Very Poor (At least one 1-hit failure)	LS-1	LS-2	BR-3	PS-3
	LS-3		MD-1	
	LW-3		MD-2	
			MD-3	

Chemistry

Sediment Grain Size

An objective of this project was to obtain samples from each waterbody with different grain size distributions. Palouse River samples had the largest difference between stations with 73% more fines in station 2 than station 1. A difference of just 5% fines between South Skookum Lake's stations made it the least diverse waterbody for grain size distribution.

SAPA guidance for marine investigations recommends reference sediment fines to be within 20% of the sediments under investigation. Combined, the stations cover the spectrum of grain sizes. However, only one waterbody, the Palouse River (PS-2 and 3), had % fines over 60% (Figure 4). Therefore, sediment investigations with % fines over 80% would be limited to comparing to the Palouse River sediments if the 20% guideline is followed.

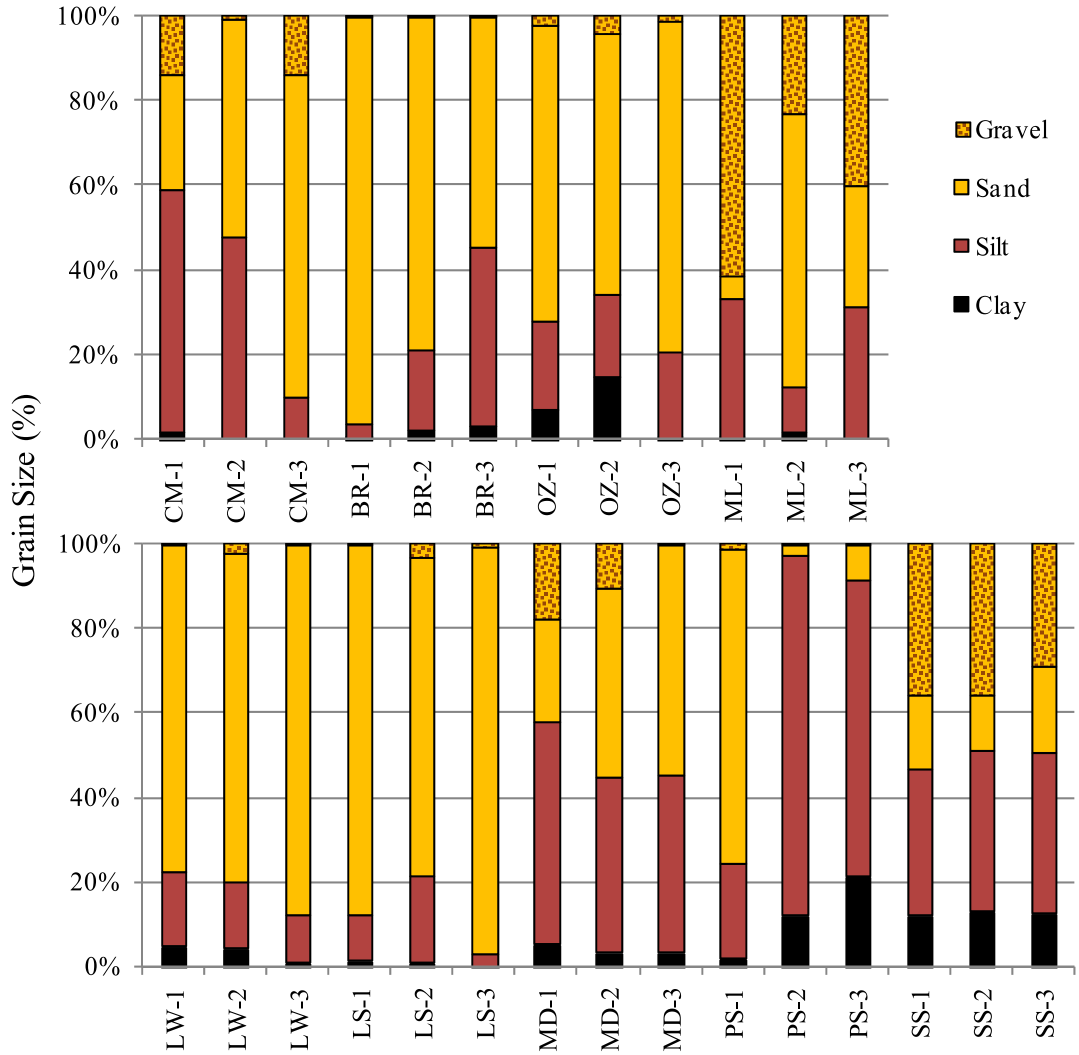

Figure 4. Sediment grain size distribution by sample for each waterbody.

Chemistry results have been compared to chemical guidelines and are summarized by waterbody in Tables 5-7 and 9-10. If a sample failed a guideline for any of the three samples, the type of guideline appears in the box. However, if a sample failed no guideline, the number of samples that had detectable quantities of the compound is noted. For example, the level of silver found in the Columbia River at Beacon Rock does not fail any guideline and only one of the three samples had detectable silver.

For simplicity, metals with no available guideline value were not included in comparisons. In addition, the beryllium LAET guideline does not reliably predict bioassay success and was omitted. All detected semi-volatile organic compounds, chlorinated pesticides, and PCBs are included regardless of whether a guideline exists.

Ammonia and Sulfides

Ammonia levels were within acceptable ranges for all 27 samples. Mountain and McDowell Lakes had sulfide results that failed the PAET guideline for one and three samples, respectively (Table 5). However, when sulfide levels in the porewater were tested as part of the bioassay methods, slightly elevated levels were only detected in one South Skookum Lake sample (Table B-3). Therefore, it is unlikely that sulfides were responsible for any bioassay effects.

Metals

Overall, most samples had metals levels below the TEL guideline value, indicating that metals are not likely the cause of toxicity in these sediments. Samples from Chester-Morse Reservoir, Mountain Lake, and Lake Wenatchee failed copper, cadmium, and nickel guidelines, respectively. Little to no toxicity was observed in samples from Mountain Lake and Lake Wenatchee that had CSL levels of cadmium and nickel. Mountain Lake also failed the LAET for nickel. A failure of the SQS guideline for copper at Chester-Morse Reservoir did not correlate well with bioassay effects either. It is likely that these metals, although present in high quantities, are not bio-available. The Columbia River and South Skookum Lake had mercury levels above the PAET guideline (Table 5). The bioassay results for these three sample locations ranged from only one reference failure to a 1-hit failure.

Table 5. Conventional and metals results compared to guidelines*.

Site	Ammonia	Sulfides	Total Organic Carbon	Antimony	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc
CM	3	2	PAET	0	TEL	3	3	SQS	3	3	3	3	3
BR	3	0	3	0	3	3	3	3	3	PAET	3	1	3
OZ	3	0	3	0	TEL	3	TEL	3	3	3	3	2	3
ML	3	PAET	LAET	3	TEL	CSL	TEL	TEL	TEL	3	LAET	3	3
LW	3	2	3	0	3	3	TEL	3	3	3	CSL	2	3
LS	3	3	3	1	3	1	3	3	3	1	3	0	3
MD	3	PAET	LAET	2	3	3	3	3	3	1	3	0	3
PS	3	3	3	2	3	3	3	3	3	2	3	2	3
SS	3	3	LAET	3	TEL	3	3	3	3	PAET	3	3	3

*If at least 1 out of 3 samples failed guidelines, the most severe guideline failure is noted. If none of the samples failed any guideline, the number of samples with detected quantities out of a possible 3 samples is shown. Colors indicate severity of the guideline: green/minor →yellow→orange→ red/severe.

PAH

All PAH totals and individual analytes were less than SQS or LAET guidelines values. In addition most values were also lower than the TEL guidelines indicating that PAHs likely did not contribute to any observed bioassay failures (Tables 6-7). However, it is important to note that most PAHs were present in detectable quantities in every waterbody.

Table 6. Low molecular weight PAH (LPAH) results compared to guidelines*.

Site	2-Methylnaphthalene	Acenaphthene	Acenaphthylene	Anthracene	Fluorene	Naphthalene	Phenanthrene	Retene	Total LPAH[1]
CM	TEL	1	2	2	3	3	TEL	3	3
BR	3	2	TEL	3	3	3	3	3	3
OZ	TEL	3	TEL	3	TEL	TEL	TEL	3	3
ML	3	TEL	TEL	3	TEL	TEL	TEL	3	3
LW	3	2	2	1	2	2	3	3	3
LS	3	3	3	3	3	3	3	3	3
MD	TEL	3	TEL	3	3	TEL	3	3	3
PS	3	2	3	2	3	3	3	3	3
SS	TEL	TEL	TEL	3	3	TEL	TEL	3	3

*If at least 1 out of 3 samples failed guidelines, the most severe guideline failure is noted. If none of the samples failed any guideline, the number of samples with detected quantities out of a possible 3 samples is shown. Colors indicate severity of the guideline: green/minor →yellow→orange→ red/severe.
[1]Total LPAH values were calculated in accordance with SAPA guidance for evaluating marine sediment quality (Ecology, 2008).

Table 7. High molecular weight PAH (HPAH) results compared to guidelines*.

Site	Benz[a]anthracene	Benzo(a)pyrene	Benzo(bk)flouranthene	Benzo(ghi)perylene	Chrysene	Dibenzo(a,h)anthracene	Fluoranthene	Indeno(1,2,3-cd)pyrene	Pyrene	Total HPAH[1]
CM	3	TEL	3	3	3	1	3	3	3	3
BR	3	3	3	3	3	3	3	3	3	3
OZ	3	3	3	3	TEL	3	3	3	3	3
ML	3	TEL	3	3	TEL	TEL	TEL	1	TEL	3
LW	2	3	3	2	2	0	3	3	3	3
LS	3	TEL	3	3	3	2	3	3	3	3
MD	3	TEL	3	3	3	3	3	3	3	3
PS	2	3	3	2	2	0	3	2	3	3
SS	3	TEL	3	3	TEL	TEL	3	3	3	3

*If at least 1 out of 3 samples failed guidelines, the most severe guideline failure is noted. If none of the samples failed any guideline, the number of samples with detected quantities out of a possible 3 samples is shown.
Colors indicate severity of the guideline: green/minor →yellow→orange→ red/severe.
[1]Total HPAH values were calculated in accordance with SAPA guidance for evaluating marine sediment quality (Ecology, 2008).

PCB Aroclors

Only three waterbodies had detectable quantities of Aroclor PCBs (Table 8). Undetected values ranged from 2.3-4.0 µg/kg dw.

Table 8. Detected aroclor-PCB results (ug/kg dw).

Site	PCB-aroclor 1248	PCB-aroclor 1254
ML-3		3.3
MD-1	3.5 J	
SS-2		6.1
SS-3		4.8

Chlorinated Pesticides

No detectable quantities of chlorinated pesticides were present in Lake Ozette. 4,4'-DDT and its isomers 4,4'-DDD and 4,4'-DDE were ubiquitous chlorinated pesticides. Eastern Washington sites, especially the Palouse River and South Skookum Lake, had more pesticides in detectable quantities than western Washington sites (Table 9). For this reason, these two eastern Washington waterbodies may not be suitable for use as reference sites.

Table 9. Chlorinated pesticides results compared to guidelines*.

Site	4,4'-DDD	4,4'-DDE	4,4'-DDT	Dieldrin	Endosulfan I ^	Endosulfan II ^	Endosulfan Sulfate ^	Endrin	Heptachlor Epoxide	Lindane	Toxaphene	trans-Chlordane
CM	0	1	0	0	0	0	0	0	0	0	0	0
BR	2	2	0	0	0	0	0	0	0	0	0	0
OZ	0	0	0	0	0	0	0	0	0	0	0	0
ML	1	2	0	0	0	0	0	0	0	0	TEL	0
LW	2	TEL	2	0	0	0	0	0	0	0	0	0
LS	0	1	0	0	0	0	0	0	0	0	0	0
MD	2	TEL	0	0	0	0	0	0	0	0	TEL	0
PS	2	PEL	2	1	0	0	0	0	0	1	0	1
SS	TEL	TEL	0	2	3	1	3	2	TEL	0	TEL	0

*If at least 1 out of 3 samples failed guidelines, the most severe guideline failure is noted. If none of the samples failed any guideline, the number of samples with detected quantities out of a possible 3 samples is shown.
Colors indicate severity of the guideline: green/minor →yellow→orange→ red/severe.
^Compounds that do not have LAET, SQS, CSL, PAET, TEL, or PEL guidelines available.

Semi-Volatile Organic Compounds

Cholesterol was found in all samples, and coprosterol was found in 60% of the samples. Even though these compounds were ubiquitous, they are not indicators of toxicity.

Other detected semi-volatile organic compounds included 2,4-dimethylphenol, benzoic acid, bis(2-ethylhexyl) phthalate, dibutyl phthalate, isophorone, p-Cresol, pentachlorophenol, and phenol. Of these, benzoic acid and phenol were the only compounds detected above LAET and PAET guidelines, respectively. However, these chemical failures did not consistently correlate with bioassay hits even within the same waterbody (Table 10).

Di-n-octyl phthalate was not detected in any sample, but the undetected values were above the SQS guidelines. This compound was not considered for determining bioassay success due to the inability to determine if it was indeed present in any sample.

Table 10. Semi-volatile organic compounds results compared to guidelines*.

Site	2,4-Dimethylphenol ^	Benzoic Acid	Bis(2-Ethylhexyl) Phthalate	Cholesterol ^	Coprosterol ^	Dibutyl phthalate ^	Isophorone ^	p-Cresol	Pentachlorophenol ^	Phenol
CM	1	LAET	0	3	2	0	0	0	0	0
BR	1	0	0	3	3	0	0	0	0	0
OZ	0	0	0	3	0	0	0	0	0	0
ML	0	LAET	0	3	1	0	0	1	1	PAET
LW	0	0	0	3	1	0	0	1	0	0
LS	0	1	2	3	2	0	0	1	0	0
MD	0	0	1	3	3	3	1	3	0	0
PS	0	0	1	3	2	0	0	3	0	0
SS	0	LAET	0	3	2	0	0	3	0	0

*If at least 1 out of 3 samples failed guidelines, the most severe guideline failure is noted. If none of the samples failed any guideline, the number of samples with detected quantities out of a possible 3 samples is shown.
Colors indicate severity of the guideline: green/minor →yellow→orange→ red/severe.
^Compounds that do not have LAET, SQS, CSL, PAET, TEL, or PEL guidelines available.

Frequency Plots

Comparison of chemical results to the various guidelines provides one line of evidence for a particular chemical causing toxicity. This approach does not provide a sense of how sediments in these waterbodies compare to other freshwater sediments.

Figures 5-7 display frequency plots for selected chemical results to show how the results from this study compare to freshwater sediment data in Ecology's EIM database. EIM contains results from studies conducted in the state of Washington, including active investigation sites. SAPA guidelines for summing LPAH and HPAH were followed. Otherwise, only detected results were compared.

Metals frequency plots (Figure 5):

- Metals frequency plots show the detected values for this 2008 study are at least one order of magnitude lower than the maximum result from the EIM database.
- Arsenic, chromium, copper, and nickel results from this study range from the 5th to 80th percentiles of EIM results.
- Lead results placed from the 6th to 64th percentile but were at least two orders of magnitude lower than the maximum EIM result.

- Mercury results were at least two and more often three orders of magnitude below the EIM results. Mercury results ranged from the 3rd to the 78th percentile.
- All of the detected silver and zinc results for this study were below the 50th percentile.
- Cadmium results were below the 50th percentile except for the two results from Mountain Lake that also failed the SQS guideline for cadmium.
- Cadmium, lead, and mercury measured in this study are generally on the low end of observed levels in EIM.

Most of the LPAH and HPAH results from this study are below the 50th percentile of the EIM dataset. In addition, the concentration of the maximum from this study is five orders of magnitude lower than the maximum from the EIM dataset (Figure 6).

Organic compound frequency plots (Figure 7):

- 4,4'-DDT, dieldrin, PCB Aroclors 1248 and 1254, and bis(2-ethylhexyl) phthalate show results from this study are at or below the 25th percentile when compared to EIM data.
- 4,4'-DDD and p-Cresol results for this study range from the 3rd to 32nd percentiles with only two and four results, respectively, above the 25th percentile.
- 4,4'-DDE results from this study are below the 50th percentile except for two sample results from the Palouse River site.
- Most of the results for the chlorinated pesticides and PCB aroclors were below the 50th percentile and many below the 25th percentile, it is reasonable to conclude that the results from this study are in the low range when compared to EIM data.
- Benzoic acid results are on the higher side of the EIM dataset with only two values below the 50th percentile. Mountain Lake had the highest benzoic acid result of 15,800 µg/kg dw (Figure 7). Method EPA SW 846/Method 8270 is not optimized for benzoic acid; therefore, results were biased high. Since the results from this study are substantially higher, it is unlikely that the high bias discounts the pattern observed. Therefore, benzoic acid is higher in some of these waterbodies than the majority of the EIM dataset.

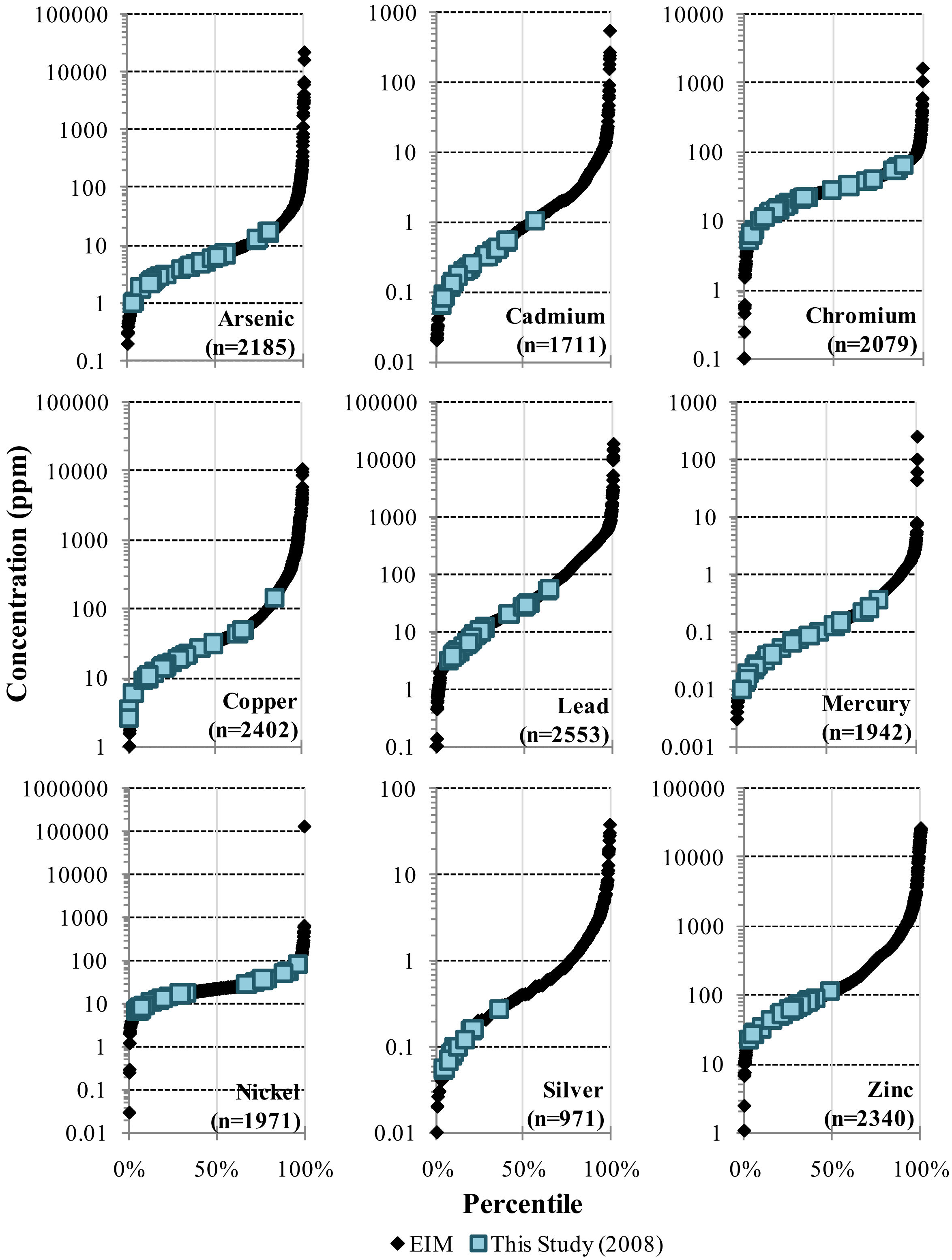

Figure 5. Frequency plots for selected metals.

Results from this study in comparison with other freshwater sediment results compiled from the EIM database. Only detected results are shown.

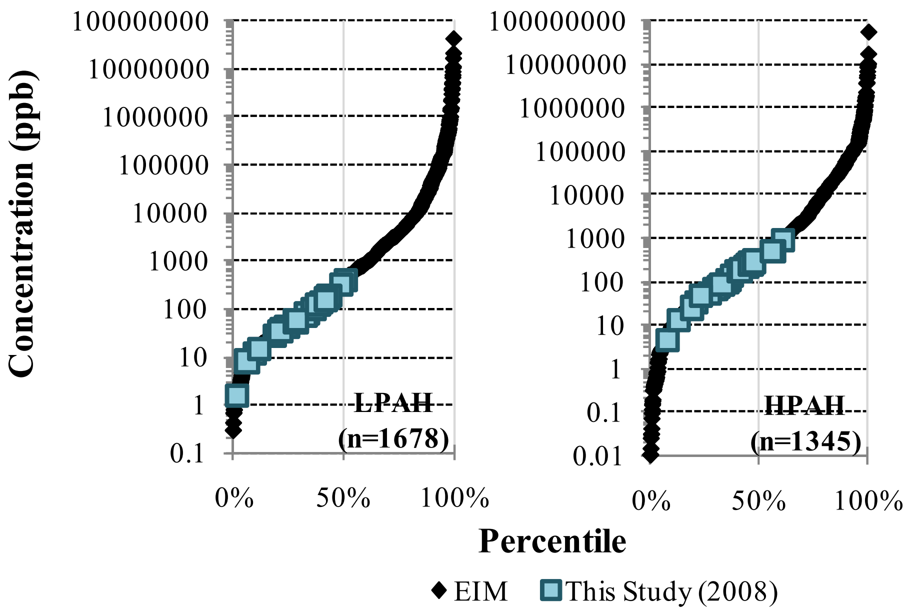

Figure 6. Frequency plots for LPAH and HPAH.

Results from this study in comparison with other freshwater sediment data compiled from the EIM database. Only samples that had results for all LPAH or HPAH compounds were used. Summing followed the guidelines for marine sediments (Ecology, 2008).

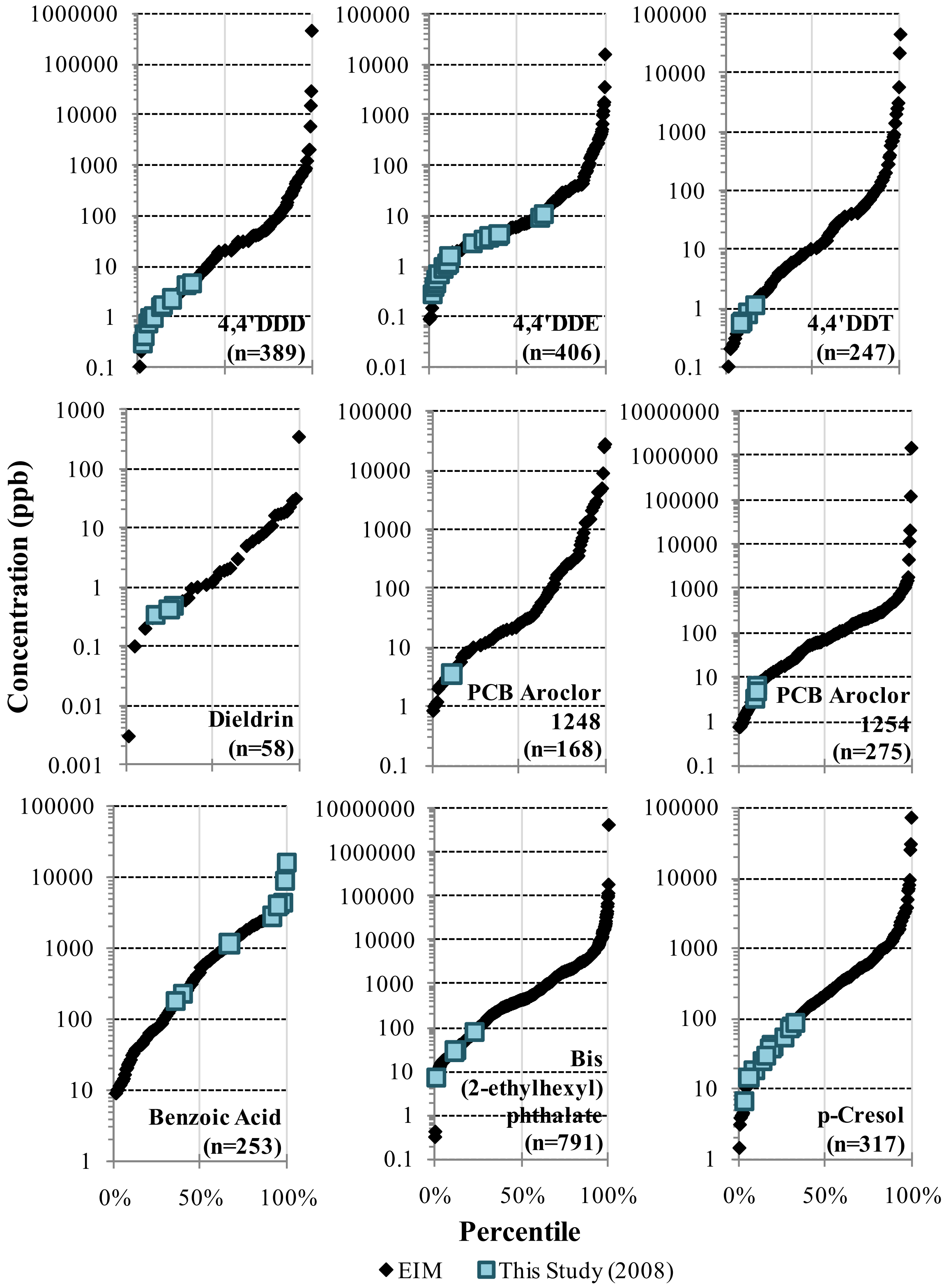

Figure 7. Frequency plots for selected organic compounds.

Results from this study in comparison with other freshwater sediment results compiled from the EIM database. Only detected results are shown.

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Conclusions

The nine waterbodies tested during this 2008 study were selected to represent baseline conditions with a diversity of characteristics. Bioassay and chemistry results were compared to guidelines to assess sediment toxicity. Determination of whether these are good reference waterbodies began by describing the ideal reference waterbody having the following properties:

- No bioassay test failures for either Ecology SMS or SEF guidelines.
- No bioassay reference failures for either Ecology SMS or SEF guidelines.
- No chemistry hits using the 2003 LAET or SQS/CSL guidelines.
- Accessible for use during investigations.
- Minimal influence of human activities now or in the future that could change the acceptability of the site.

Overall, none of the nine waterbodies tested were acceptable as a whole for use as reference sites. It is unlikely that with further testing of these or other waterbodies we would identify an entire waterbody that passes all of the above criteria. However, samples from individual locations within the waterbodies did meet all or most of the above criteria. The first two criteria above should be the focus of selecting reference locations within waterbodies. This is due to SMS guidance which places more emphasis on biological test results than on sediment chemistry. Therefore, those samples that passed all of the bioassay guidelines are best suited for use as reference locations.

Bioassay Results

Bioassay results were used to classify acceptability of individual sampling locations. Sampling locations with no bioassay guideline failures were given a rating of good. Those locations which failed only 1 reference guideline were considered good reference locations for the specific tests they passed and were moderate reference locations overall. Locations that failed at least 1 SQS or 2-hit guidelines received a poor rating, and those that failed at least 1 CSL or 1-hit guideline received a very-poor rating.

Four of the waterbodies, the Columbia River, Chester-Morse Reservoir, Lake Ozette, and Mountain Lake, are in western Washington. Eight of the 12 sampling locations in these waterbodies were classified as good or moderate based on the bioassay results (Table 11 and Figure 8).

Western Washington good or moderate sample locations:

- Columbia River locations 1 and 2.
- Chester-Morse Reservoir location 1.
- Lake Ozette locations 1 and 3.
- Mountain Lake locations 1, 2, and 3.

These eight sampling locations represent three distinct ecoregions, the Cascades, Puget Lowlands, and Coast Range, and three waterbody types, river, lake, and reservoir.

Chester-Morse Reservoir sample 1 was a moderate location but may be difficult to access consistently as it is located in a protected watershed. Permission to sample this lake needs to be obtained prior to sampling and may require City of Seattle staff to be present.

The remaining five waterbodies are in eastern Washington. They represent three ecoregions, Northern Rockies, North Cascades, and Columbia Plateau, and two waterbody types, river and lake. Only three of the waterbodies had sampling stations classified as good or moderate based on the bioassay results:

- Lake Wenatchee locations 1 and 2.
- Palouse River locations 1 and 2.
- South Skookum Lake location 1.

These represent only five of the 15 sampling locations in eastern Washington. All of the Little Spokane River and McDowell Lake sampling locations were classified as very poor based on the bioassay results (Table 11 and Figure 8).

Sample areas classified as good or moderate should be studied further to establish reliability of bioassay results. Use of an additional reference sample for site investigations, until reliability is established, should reduce the probability of expensive re-testing due to failure of a single reference sample.

Locations classified as poor or very poor should not be used as reference sediments.

Chemistry Results

The Columbia River, Lake Ozette, and the Little Spokane River had no PEL, SQS, LAET, PAET, or CSL failures for chemistry. Only three other samples also had no failures for those guidelines: Chester-Morse Reservoir sample 3, Lake Wenatchee sample 3, and the Palouse River sample 1.

Bioassay results did not necessarily correspond to chemistry failures. Good to moderate samples had 0-7 failures, and poor to very poor samples had 0-4 failures. Most notably Mountain Lake samples 1-2 and Lake Wenatchee sample 1 had CSL levels of cadmium and nickel, respectively, but no corresponding bioassay failures (Table 11 and Figure 8). Therefore, chemistry is not always an indicator of bioassay success. However, the chemical makeup of reference sediments may influence location selection. Presence of high levels of the contaminants under investigation for permitting or cleanup actions in reference sediments may be undesirable.

Physical factors, interactive chemical effects, and bio-availability may also influence sediment toxicity at these locations.

Table 11. Summary of bioassay and chemistry comparisons to guidelines for all nine sampling locations.

Reference Rating	Sampling Location	Bioassay		Chemistry						
		Test	Reference	TEL	PEL	SQS	LAET	PAET	CSL	Total[1]
Moderate	CM-1	0	1	4	0	1	2	1	0	4
Poor	CM-2	1	1	3	0	1	2	1	0	4
Poor	CM-3	1	2	1	0	0	1	0	0	1
Good	BR-1	0	0	1	0	0	0	0	0	0
Moderate	BR-2	0	1	0	0	0	0	0	0	0
Very Poor	BR-3	1	1	1	0	0	0	1	0	1
Good	OZ-1	0	0	2	0	0	0	0	0	0
Poor	OZ-2	1	1	5	0	0	0	0	0	0
Moderate	OZ-3	0	1	5	0	0	0	0	0	0
Moderate	ML-1	0	1	16	0	1	3	2	1	7
Good	ML-2	0	0	5	0	1	1	1	1	4
Good	ML-3	0	0	7	0	0	2	2	0	4
Good	LW-1	0	0	2	0	1	1	1	1	4
Good	LW-2	0	0	1	0	0	0	1	0	1
Very Poor	LW-3	1	2	1	0	0	0	0	0	0
Very Poor	LS-1	1	1	1	0	0	0	0	0	0
Very Poor	LS-2	1	1	1	0	0	0	0	0	0
Very Poor	LS-3	1	0	0	0	0	0	0	0	0
Very Poor	MD-1	1	1	4	0	0	1	2	0	3
Very Poor	MD-2	1	1	6	0	0	1	2	0	3
Very Poor	MD-3	1	0	0	0	0	1	2	0	3
Good	PS-1	0	0	0	0	0	0	0	0	0
Good	PS-2	0	0	1	1	0	1	0	0	2
Very Poor	PS-3	1	1	1	1	0	1	0	0	2
Moderate	SS-1	0	1	8	0	0	2	2	0	4
Poor	SS-2	1	1	12	0	0	2	2	0	4
Poor	SS-3	1	1	10	0	0	3	1	0	4

Numbers indicate the number of guidelines that were failed by the sample.
[1]Total (chemistry guideline failures) does not include TEL failures. TEL guidelines indicate a level below which effects are not expected, while the other five guidelines indicate levels above which effects are expected.

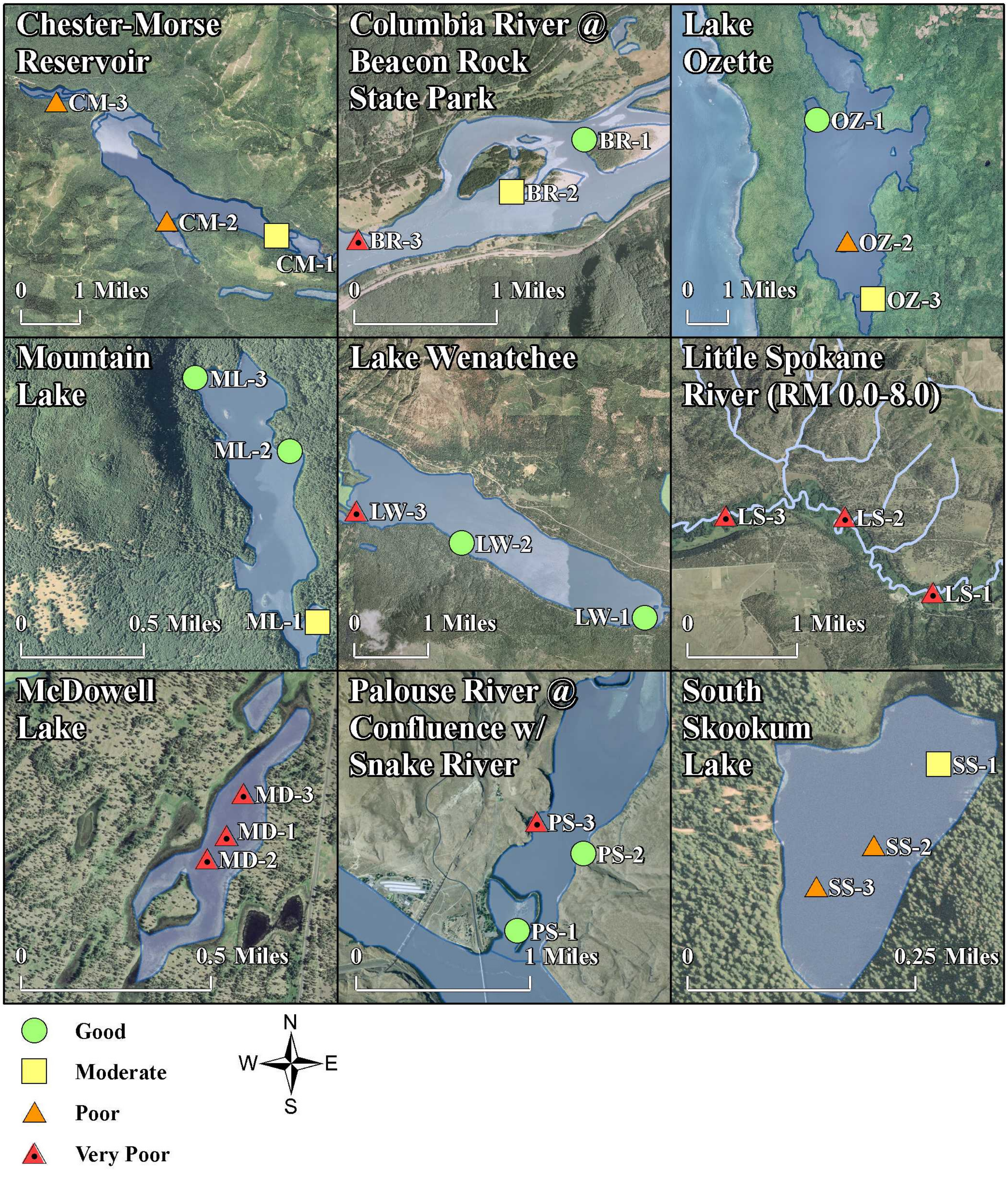

Figure 8. Classification of samples based on bioassay results.

Recommendations

As a result of this 2008 study, the following recommendations are made:

- All good and moderate reference sample locations should continue to be tested for bioassay success to establish the reliability of results, both spatially and seasonally. This can be conducted as the locations are used during permitting and cleanup investigations; a separate study is not recommended.

- Sample locations recommended for use as reference sediments:
  - The Columbia River at Beacon Rock State Park sample location 1.
  - Lake Ozette on the Olympic Peninsula sample location 1.
  - Mountain Lake on Orcas Island sample locations 2 and 3.
  - Lake Wenatchee on the east slope of the cascades sample locations 1 and 2.
  - Palouse River at the confluence with the Snake River sample locations 1 and 2.

- Sample locations recommended for use as moderate reference sediments:
  - The Columbia River at Beacon Rock State Park sample location 2.
  - Chester-Morse Reservoir on the west slope of the cascades sample location 1.
  - Lake Ozette on the Olympic Peninsula sample location 3.
  - Mountain Lake on Orcas Island sample location 1.
  - South Skookum Lake in the Colville National Forest sample location 1.

- Sample locations that should not be used as reference sediments:
  - Chester-Morse Reservoir on the west slope of the cascades sample locations 2 and 3.
  - The Columbia River at Beacon Rock State Park sample location 3.
  - Lake Ozette on the Olympic Peninsula sample location 2.
  - Lake Wenatchee on the east slope of the cascades sample location 3.
  - Little Spokane River north of Spokane, Washington sample locations 1-3.
  - McDowell Lake south of Spokane, Washington sample locations 1-3.
  - Palouse River at the confluence with the Snake River sample location 3.
  - South Skookum Lake in the Colville National Forest sample locations 2 and 3.

- Use of freshwater reference sediments should match waterbody type, grain size, total organic carbon, alkalinity, hardness, and in the case of rivers depth and flow to the investigation site sediment. Additional consideration should be given to avoiding sites with high levels of the contaminants of concern at the investigation site.

- Additional reference locations within these and other waterbodies should be tested to facilitate site investigations. Areas that are minimally impacted by human activities and close to investigation sites should continue to be the focus. In addition, the lack of eastern Washington locations supports the need for increased emphasis on this area of the state.

- Using more than one reference location is strongly recommended to avoid reference failures that may cause the need for additional sample collection and bioassay tests.

- Low performance for the *Hyalella azteca* control may have been due to the food source chosen in this study, yeast, Cerophyl ®, and trout chow (YCT). Anecdotal evidence that YCT has resulted in poor growth in control groups with low total organic carbon may explain the low growth seen here. It is recommended that YCT combined with the algae *Selenastrum* or ground tetramin be used as a food source instead of YCT, especially if total organic carbon levels are low.

- Future studies should add a method optimized for benzoic acid. High biased results for this compound signify a need for more resolution and greater certainty to aid in drawing distinct conclusions.

- Method EPA 9030 should be used to measure sulfides instead of PSEP (1986) which has relatively high detection limits.

- Testing of pH, hardness, and alkalinity in the overlaying water and the sediment porewater should be conducted to aid in understanding native sediment conditions. This information is useful for sediment matching and bioassay interpretations.

- Given the high variability for some of *Chironomus tentans* bioassays, additional replicates would provide more certainty of results. It is recommended that eight replicates be used rather than five replicates. This is also consistent with ASTM (2005), EPA (2000), and SEF (2009) recommendations to use eight replicates.

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Appendices

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Appendix A. Glossary, Acronyms, and Abbreviations

Acute: Short in duration relative to the organism's life cycle.

Benthic: Bottom-dwelling organisms.

Bioassay: Usually a laboratory test which exposes organisms to the medium of interest (ex. amphipod exposure to sediment). Results indicate the toxicity of the medium to that particular organism.

Bioassay Guidelines: See Appendix E (SQS, CSL, 1-Hit, 2-Hit, reference, control).

Chemical Guidelines: See Appendix E (TEL, PEL, PAET, LAET, SQS, CSL)

Chronic: Long is duration relative to the organism's life cycle.

Fetch: Long axis of a waterbody.

Macroinvertebrate: Organisms large enough to see with the naked eye that lack backbones.

N^{th} Percentile: A statistical number obtained from a distribution of a data set, above which (100-N)% of the data exists and below which N% of the data exists.

Pollution: Such 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 is 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.

Riparian: Relating to the banks along a natural course of water.

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

Taxa: Species or group of organisms having similar characteristics

Toxicity: Negative effect on an organism caused by some stimulus. Mortality, decreased growth, or abnormal growth are examples of negative effects.

Waterbody Type: Classification of the basic form of a body of water. Examples: river, lake, reservoir, pond, and wetland.

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.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BNA	Base/neutral/acids
BR	Columbia River at Beacon Rock State Park
CCME	Canadian Council of Ministers of the Environment
CM	Chester-Morse Reservoir
CSL	Cleanup Screening Level
DDD	Dichloro-diphenyl-dichloroethane
DDE	Dichloro-diphenyl-trichloroethylene
DDT	Dichloro-diphenyl-trichloroethane
DO	Dissolved oxygen
Ecology	Washington Department of Ecology
EIM	Environmental information management database
EPA	U.S. Environmental Protection Agency
LAET	Lowest apparent effects threshold
LS	Little Spokane River between river mile 0.0 and 8.0
LW	Lake Wenatchee
MD	McDowell Lake
ML	Mountain Lake
OZ	Lake Ozette
PAET	Probable apparent effects threshold
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyls
PEL	Probable effects level
PS	Palouse River at the confluence with the Snake River
RM	River mile
SAPA	Sediment Sampling and Analysis Plan Appendix
SEF	Sediment Evaluation Framework
SMS	Sediment Management Standards
SOP	Standard operating procedures
SQS	Sediment Quality Standard
SS	South Skookum Lake
TEL	Threshold effects level
USGS	U.S. Geological Survey

Units of Measurement

°C	degrees centigrade
dw	dry weight
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams.
mL	milliliters
ug/Kg	micrograms per kilogram (parts per billion)
mg/Kg	milligrams per kilogram (parts per million)
mg/ind	milligrams per individual
ppt	parts per thousand
ww	wet weight

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Appendix B. Site Information

Table B- 1. Site and sample collection descriptions.

Waterbody	Code	Latitude NAD 83	Longitude NAD 83	Grab Type	Depth (ft)	Debris
Western Washington						
Chester-Morse Reservoir	CM-1	47.3768	-121.6588	Ekman	25	Wood
	CM-2	47.3800	-121.6987	Ekman	19	Wood, Leaves
	CM-3	47.4091	-121.7394	Petite Ponar	19	Wood
Columbia River-Beacon Rock	BR-1	45.6244	-122.0001	Standard Ponar	3	Wood
	BR-2	45.6190	-122.0105	Standard Ponar	15	Wood
	BR-3	45.6140	-122.0326	Standard Ponar	16	Wood
Lake Ozette	OZ-1	48.1134	-124.6565	Standard Ponar	30	Wood, Vegetation
	OZ-2	48.0699	-124.6367	Standard Ponar	24	Wood
	OZ-3	48.0497	-124.6212	Standard Ponar	30	Wood
Mountain Lake	ML-1	48.6528	-122.8113	Ekman	25	Vegetation
	ML-2	48.6629	-122.8143	Standard Ponar	35	Wood, Vegetation
	ML-3	48.6671	-122.8229	Ekman	20	Vegetation
Eastern Washington						
Lake Wenatchee	LW-1	47.8066	-120.7334	Standard Ponar	20	Vegetation
	LW-2	47.8213	-120.7871	Standard Ponar	39	Wood, Vegetation
	LW-3	47.8275	-120.8182	Standard Ponar	25	Vegetation
Little Spokane River	LS-1	47.7684	-117.4658	Bucket	1	Wood, Vegetation
	LS-2	47.7789	-117.4824	Bucket	1	Wood, Vegetation
	LS-3	47.7798	-117.5058	Bucket	1	Wood
McDowell Lake	MD-1	47.4191	-117.5722	Standard Ponar	3.9	Shell Specks, Vegetation
	MD-2	47.4182	-117.5734	Standard Ponar	3.6	Shell fragments, Vegetation
	MD-3	47.4206	-117.5712	Standard Ponar	3.9	Shell fragments, Vegetation
Snake/Palouse River Confluence	PS-1	46.5938	-118.2152	Standard Ponar	5	Pebbles/Stones, Vegetation
	PS-2	46.6001	-118.2070	Standard Ponar	17	No
	PS-3	46.6029	-118.2126	Ekman	16	No
South Skookum Lake	SS-1	48.3935	-117.1798	Ekman	8	Vegetation
	SS-2	48.3923	-117.1814	Ekman	15	Vegetation
	SS-3	48.3917	-117.1828	Ekman	15	No

Chester-Morse Reservoir

The Chester-Morse Reservoir is approximately 4.5 miles long, covers 1536 acres, and drains 78.4 square miles (USGS, 2009a). Located on the west slope of the Cascade Range, it is in the Cascades ecoregion. The main inputs to the reservoir are the Cedar and Rex Rivers entering the southeast and south sides of the reservoir, respectively. Built in 1914 the Masonry Dam created Chester-Morse Reservoir (Seattle Public Utilities, 2009). The original reservoir level was 1530 feet; normal operations maintain the current reservoir level at 1540-1563 feet above sea level. The area surrounding the reservoir was clear cut in the 1920s and replanted in the late 1920s-early 1930s. Remnants of a railroad bed exist along the northeast side of the reservoir.

The southwest shore of the reservoir was a gathering place for Native Americans and is now an archeological site (personal communication with Dwayne Paige, Corsaletti, 1993). Currently, the city of Seattle owns the entire watershed of Chester-Morse Reservoir. The Cedar River which drains the reservoir is the main water supply for 1.4 million people in King County including the city of Seattle. (Figures 1-2 and Table 1, Seattle Public Utilities, 2009.)

Sampling notes: Chester-Morse Reservoir sample 3 was located in the Masonry Pool. This area of the reservoir completely dries up most years (Figure B-1). Ideally sediment samples should be taken from areas that are inundated with water year-round. Sample 3 was collected in this location because of the difficulty of finding sandier sediments in the main reservoir that were not located in an archeologically protected area.

Figure B- 1 Masonry Pool in Chester-Morse Reservoir.

Red arrow indicates approximate location where CM-3 sediments were collected. Photo courtesy of Dwayne Paige.

Columbia River at Beacon Rock State Park

The area of interest in the Columbia River was between river mile 140 and 143 near Beacon Rock State Park. This portion of the Columbia River forms the southern boundary of Washington and is in the Cascades ecoregion. The Oregon side of the river borders the Columbia River Gorge National Scenic Area. Bonneville Dam is located at river mile 146, just upstream of Beacon Rock State Park. The Columbia River at river mile 144 drains 239,900 square miles of land located in Idaho, British Columbia, Oregon, and Washington (USGS, 2009a). Shrubs and grasses dominate the riparian area of this portion of the Columbia while deciduous forests dominate the surrounding landscape. (Figures 1-2 and Table 1.)

Lake Ozette

Lake Ozette is located on a small coastal plain on the west side of the Olympic Peninsula Coastal range within the Olympic National Park. This is the largest lake selected for this study, at approximately 8 miles long and 7550 acres. Lake Ozette drains 77 square miles and is only 34 feet above sea level, the lowest elevation of the lakes selected. Prior logging activity is evident in the surrounding landscape as second timber forests dominate. (Figures 1-2 and Table 1; Haggerty et al, 2008.)

Sampling notes: Lake Ozette sample 2 had unusual blue sand that was incorporated into the sample. It was determined that this is most likely the mineral vivianite (hydrated iron phosphate). Since vivianite forms in reduced sediments, the likelihood of soluble/biologically available metals being present increases and may have influenced bioassay results (personal communication Andy Ritchie). Therefore, when sampling in Lake Ozette, field staff should avoid incorporating blue sand material into samples for bioassays.

Mountain Lake

Mountain Lake is located on Orcas Island in Moran State Park in the San Juan Island group. The lake is 198 acres, drains approximately 2 square miles, and classified in the Puget Lowland ecoregion. A dam on the south end of the lake regulates the outflow to Cascade Creek. Mountain Lake provides drinking water for the Doe Bay and Olga communities (Washington Water Trust, 2009).

There are no major stream inputs to this lake; therefore, water likely comes from precipitation, surface runoff, or groundwater sources. The surrounding coniferous forest, dominated by mature trees (50-90 cm diameter at breast height), is unlike forests around other waterbodies on the west side of the Cascade Range that feature smaller, less mature trees (30-50 cm diameter at breast height). (Figures 1-2 and Table 1.)

Lake Wenatchee

Lake Wenatchee covers 2,480 acres and drains 275 square miles in the Wenatchee National Forest (USGS, 2009b). Its southeast end is also a state park. The lake is located on the east slope of the Cascade Range within the North Cascades ecoregion. The White River and the Little Wenatchee River are the main inputs at the northwest end of the lake. The Wenatchee River drains the lake at its southeast end. Similar to Mountain Lake in western Washington, Lake Wenatchee was the only waterbody in eastern Washington to feature mature trees in this study. (Figure 2 and Table 1.)

Little Spokane River

The Little Spokane River drains 700 square miles in Idaho and Washington. Located northeast of Spokane, Washington, it is in the Northern Rockies ecoregion. Sampling occurred with the last 8 miles prior to joining the Spokane River, a designated scenic river corridor. Within the watershed, land uses are forest, agriculture, and urban development. (Figure 2 and Table 1; Ecology, 1995.)

McDowell Lake

McDowell Lake is located in the Turnbull National Wildlife Refuge south of Spokane, Washington. It lies in the Columbia Plateau ecoregion, covers an area of about 54 acres, and drains less than 1 square mile (USGS, 2009b). (Figure 2 and Table 1.)

Palouse River at the Confluence with the Snake River

The Palouse River widens as it enters the Snake River in southeast Washington. This wider and deeper portion was the area of interest for this site located in the Columbia Plateau ecoregion. The Palouse River and its tributaries traverse over 398 miles of stream and drain 3,300 square miles in Idaho and Washington. The dominant land uses in the basin are coniferous forest, grass/scrubland, agriculture, and urban development (Cook and Gilmore, 2004). This sampling site is located in a sagebrush-dominated area unlike the other sites chosen for this study that are in forest-dominated landscapes. (Figure 2 and Table 1.)

South Skookum Lake

South Skookum Lake drains approximately 6 square miles and has a surface area of 32.6 acres, the smallest lake chosen (USGS 2009b; Colville National Forest, 2009). It is located in the Colville National Forest in northeast Washington within the Northern Rockies ecoregion. (Figure 2 and Table 1.)

Table B- 2. Summary of bioassay results by sample.

Sample ID	Porewater Chemistry					Sediment Chemistry			
	Conductivity	Dissolved Oxygen	pH	Sulfide	Ammonia	Total Organic Carbon	Clay	Silt	Fines[1]
	µS/cm	mg/L		mg/L	mg/L	%	%	%	%
CM-1	89	5.5	5.78	0.058	3.3	7.35	1.22	54	59
CM-2	102	6.7	6.10	0.159	3.3	9.66	0	47.3	47
CM-3	63	6.1	6.42	0.145	<1.0	3.63	0	8.71	10
BR-1	254	7.4	7.11	0.040	<1.0	0.49	0.14	3.22	3
BR-2	393	6.5	7.20	0.037	1.2	0.48	1.53	18.9	21
BR-3	276	6.7	7.15	0.048	1.4	1.04	2.89	41.9	45
OZ-1	58	5.8	6.31	0.380	<1.0	1.75	6.77	20.5	27
OZ-2	55	5.6	5.75	0.930	1.8	4.19	13.9	19.4	34
OZ-3	65	6.3	6.04	0.269	1.5	2.66	0.47	18.5	20
ML-1	149	6.2	6.61	0.241	1.8	14.8	0.51	32.3	33
ML-2	130	6.9	6.74	0.139	<1.0	3.81	0.93	9.6	12
ML-3	191	6.0	6.21	0.141	2.8	10.7	0	29.6	31
LW-1	121	3.8	6.60	0.165	1.7	1.63	5.1	18.6	22
LW-2	71	6.9	6.27	0.097	<1.0	1.35	4.16	15.9	20
LW-3	108	3.4	6.01	<0.01	4.0	0.98	0.37	11	12
LS-1	299	5.6	7.43	0.073	1.2	0.53	0.98	10.4	12
LS-2	422	5.0	7.56	0.082	2.2	1.6	0.62	18.7	21
LS-3	312	7.4	7.80	0.047	<1.0	0.1	0.19	2.53	3
MD-1	1124	5.9	7.23	0.174	6.0	10.9	6.36	64.2	57
MD-2	941	4.9	7.07	0.079	6.2	15.9	2.62	38.1	44
MD-3	915	5.1	7.04	0.078	7.7	14.6	3.14	46.2	45
PS-1	435	5.9	7.78	0.069	1.2	0.24	1.58	21.8	24
PS-2	426	3.0	7.02	0.039	4.0	1.86	12.3	90.6	97
PS-3	461	3.3	6.97	0.051	5.1	2.02	23.1	78	91
SS-1	115	4.8	5.88	0.226	6.1	10.1	10.9	32.2	46
SS-2	50	4.6	5.87	0.330	1.6	11.9	11.8	35.1	51
SS-3	45	6.1	6.07	>0.600	2.5	11.1	12.6	38.6	50

Table B-2. Summary of bioassay results by sample, continued.

Sample ID	Bioassay Results Compared to Guidelines*						
	Reference Rating	Microtox		*Chironomus tentans*		*Hyalella azteca*	
		Test	Reference	Test	Reference	Test	Reference
CM-1	Moderate	Pass	Failed[3]	Pass	Pass	Pass	Pass
CM-2	Poor	Pass	Pass	Failed[5]	Failed[6]	Pass	Pass
CM-3	Poor	Pass	Failed[3]	Failed[5]	Failed[6]	Pass	Pass
BR-1	Good	Pass	Pass	Pass	Pass	Pass	Pass
BR-2	Moderate	Pass	Pass	Pass	Failed[6]	Pass	Pass
BR-3	Very Poor	Pass	Pass	Failed[4]	Failed[6]	Pass	Pass
OZ-1	Good	Pass	Pass	Pass	Pass	Pass	Pass
OZ-2	Poor	Pass	Pass	Failed[5]	Failed[6]	Pass	Pass
OZ-3	Moderate	Pass	Failed[3]	Pass	Pass	Pass	Pass
ML-1	Moderate	Pass	Failed[3]	Pass	Pass	Pass	Pass
ML-2	Good	Pass	Pass	Pass	Pass	Pass	Pass
ML-3	Good	Pass	Pass	Pass	Pass	Pass	Pass
LW-1	Good	Pass	Pass	Pass	Pass	Pass	Pass
LW-2	Good	Pass	Pass	Pass	Pass	Pass	Pass
LW-3	Very Poor	Pass	Failed[3]	Failed[4]	Failed[6]	Pass	Pass
LS-1	Very Poor	Pass	Pass	Failed[4]	Failed[6]	Pass	Pass
LS-2	Very Poor	Pass	Pass	Failed[4]	Failed[6]	Pass	Pass
LS-3	Very Poor	Pass	Pass	Failed[4]	Pass	Pass	Pass
MD-1	Very Poor	Pass	Failed[3]	Failed[4]	Pass	Pass	Pass
MD-2	Very Poor	Pass	Pass	Failed[4]	Failed[6]	Pass	Pass
MD-3	Very Poor	Pass	Pass	Failed[4]	Pass	Pass	Pass
PS-1	Good	Pass	Pass	Pass	Pass	Pass	Pass
PS-2	Good	Pass	Pass	Pass	Pass	Pass	Pass
PS-3	Very Poor	Pass	Pass	Failed[4]	Failed[6]	Pass	Pass
SS-1	Moderate	Pass	Failed[3]	Pass	Pass	Pass	Pass
SS-2	Poor	Failed[2]	Failed[3]	Pass	Pass	Pass	Pass
SS-3	Poor	Pass	Failed[3]	Failed[5]	Pass	Pass	Pass

*Results were compared to both the test and reference guidelines.
[1] Fines adjusted to 100% of sample.
[2] Failed SQS guideline.
[3] Failed Ecology reference performance guideline.
[4] Failed 1-hit SEF survival guideline.
[5] Failed 2-hit SEF survival guideline.
[6] Failed SEF reference performance guideline.

Table B- 3. Summary of water quality parameters for bioassay tests.

Analyte	Mean	Standard Deviation	Minimum	Maximum	Number of Readings	Met Requirements[4]
Microtox						
Initial Salinity (ppt)	0.1	0.2	0.0	0.6	29	N/A
Final Salinity (ppt)	19.7	0.9	18.2	20.8	29	Y
Initial DO (mg/L)	6.5	0.3	5.7	7.1	29	N/A
Final DO (mg/L)	6.6	0.2	6.1	7.1	29	Y
Initial pH	7.6	0.6	6.7	7.9	29	N/A
Final pH	8.0	0.1	7.9	8.2	29	Y
Final Concentration (%)	99.8	0.0	99.2	100	29	Y
Total NH3 (mg/L)	3.0[1]	2.0[1]	<1.0	7.7	29	N/A
Chironomus tentans						
Temperature (°C)	21.9	0.3	21.1	22.5	609	Y[2,3]
DO (mg/L)	7.0	1.3	2.3	8.9	609	N[3]
pH	7.44	0.36	6.15	8.17	609	Y
Conductivity (µS/cm)	179	33	100	283	609	N/A
Alkalinity (mg/L $CaCO_3$)	83	22	36	136	609	N[3]
Hardness (mg/L $CaCO_3$)	92	20	36	140	609	N[3]
Total NH3 (mg/L)	1.1[1]	0.3[1]	<1.0	2.0	58	Y
Total Sulfides (mg/L)	0.127	0.135	0.012	0.387	6	N/A
Hyalella azteca						
Temperature (°C)	22.1	0.1	21.9	22.6	841	Y
DO (mg/L)	6.2	0.8	3.2	8.4	841	N[3]
pH	7.29	0.29	5.88	8.23	841	Y
Conductivity (µS/cm)	179	27	89	329	841	N/A
Alkalinity (mg/L $CaCO_3$)	76	16	40	120	841	Y
Hardness (mg/L $CaCO_3$)	87	14	56	124	841	Y
Total NH3 (mg/L)	1.0[1]	0.1[1]	<1.0	1.8	58	Y
Total Sulfides (mg/L)	0.099	0.117	0.011	0.298	6	N/A

[1]Estimated value
[2]Average daily temperatures acceptable
[3]See text, not expected to affect results
DO=Dissolved oxygen
[4]N/A=not applicable; Y=yes; N=no

Table B- 4. Bioassay positive control test results.

Species	Test Date	Toxicant	LC50	Acceptable Range (mean ± 2SD)	CV (%)
Vibrio fischeri	8/4/2008	Phenol	5 min: 34.5 mg/L 15 min: 39.9 mg/L	5 min: 17.7-48.1 mg/L 15 min: 26.8-46.6 mg/L	23.1
	8/25/2008	Phenol	5 min: 37.8 mg/L 15 min: 41.6 mg/L		13.5
Chironomus tentans	8/25/2008	Copper	1040 µg/L	271-1235	32.0
	9/11/2008	Copper	918 µg/L		
Hyalella azteca	8/8/2008	Copper	404 µg/L	0-1487	66.0
	8/28/2008	Copper	352 µg/L		

LC50=median lethal concentration; SD-standard deviation; CV= coefficient of variation

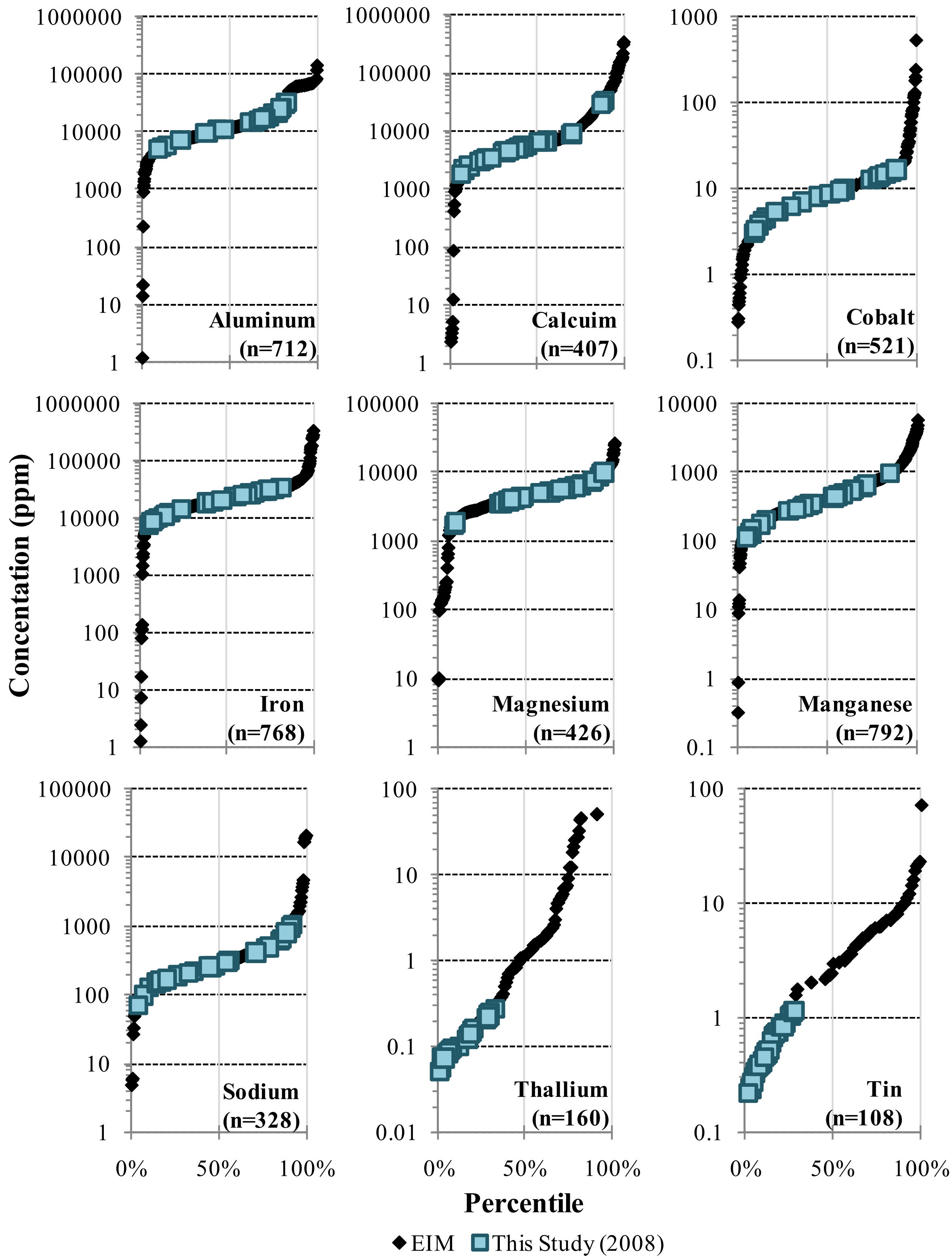

Figure B- 2. Frequency plots for other metals.

Results from this study in comparison with other freshwater sediment results compiled from the EIM database. Only detected results are shown.

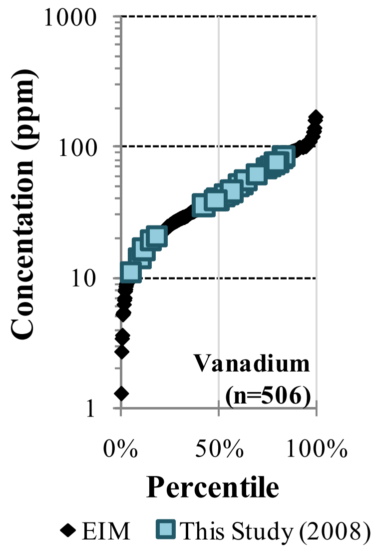

Figure B- 2 continued. Frequency plots for other metals.

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Appendix C. Quality Control

Acronyms frequently used in Appendix C tables:

BNASQS	Base/neutral/acids/sediment/quality/standard
N/A	Not applicable
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
RL	Reporting limit
RPD	Relative percent difference
RSD	Relative standard deviation
SW	Test Methods for Evaluating Solid Waste, Physical/Chemical Methods
TOC	Total organic carbon

Table C- 1. Conventionals, ammonia, and sulfides quality control.

QA review element → Parameter ↓	Methods	Holding/ handling	Calibrations/	Method Blank	Reporting Limits	Relative Percent Difference/ Relative Standard Deviation	Laboratory Control Standard	Matrix Spike Recovery/ Matrix Spike Deviation	Decision
Grain size (%)	PSEP, 1986	Acceptable							Acceptable
QAPP:	PSEP, 1986	6 month @ 4°C		-	0.1	RSD ≤ 20%	-	-	
TOC (%)	PSEP - TOC	Acceptable	Acceptable	0.1U	0.1	0%-18%	83%- 95%		Acceptable
QAPP:	PSEP, 1986/1997 (70°C)	14 days @ 4°C, 6 months frozen	Calibration Coefficient= 1.000-0.995[1]	<0.1	0.1	RSD ≤ 20%	-	-	
Percent Solids (%)	Standard Method 2540G	Acceptable	Acceptable	0.5U	0.5	0%-4%	100%		Acceptable
QAPP:	PSEP, 1986	14 days @ 4°C, 6 months frozen		-	0.1	-	-	-	
Total Sulfides (mg/kg dw)	PSEP, EPA 9030	ML1-3 exceeded 7 days holding time, results were qualified. All others acceptable.		Non detect		6%, non-detect	87%, 91%	101%, 75%	Acceptable
QAPP:	PSEP, 1986	7 days @ 4°C fixed with 2N zinc acetate		<10	5	RSD ≤ 20%	65-135% recovery	65-135% recovery	
Ammonia (µg/kg dw)	EPA 350.1	ML1-3 exceeded 7 days holding time, results were qualified		Non detects		4%, 4%	103%, 103%	100%, 103%	Acceptable
QAPP:	Plumb, 1981	7 days @4°C no head space		<100	100	RSD ≤ 20%	80-120% recovery	75-125% recovery	

[1]MEL provided, not present in the QAPP.

Table C- 2. Metals quality control.

QA review element → Parameter ↓	Methods	Holding/ handling	Calibrations/	Method Blank	Reporting Limits	RPD/ RSD	Laboratory Control Standard	Matrix Spike Recovery/ Matrix Spike Deviation	Decision
Metals Ag, Al, Sb, As, B, Ba, Be, Cd, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Se, Sn, Sr, Ti, Tl, V, Zn	EPA 200.8 & EPA 200.7	Acceptable	CM1 and CM3 continuing calibration were less than acceptable limits for Se qualified as estimates. All others acceptable.	Ag=0.05U, Al=25U, Sb=0.1U, As=0.05U, B=25U, Ba=0.05U, Be=0.05U, Cd=0.05U, Ca=2.5U, 25U, Co=0.05U, Cr=0.25U, Cu=0.05U, Fe=25U, K=250U, Mg=25U, Mn=5U, Mo=0.05U, Na=25U, Ni=0.05U, Pb=0.05U, Se=0.25U, Sn=0.1U, Sr=0.05U, Ti=0.05U, Tl=0.05U, V=0.25U, Zn=2.5U	- -	- -	86-109%	Matrix spike recoveries for Ba, Ca, K, Al, Fe, Mg, Mn, and Ti not calculated due to insufficient spike. Matrix spike recoveries for Sb, Mn, Na, V were outside the acceptance limits, the source was qualified. Matrix spike for B was 60% all results qualified, All others 82-111%.	Acceptable
QAPP:	EPA 200.8 or EPA 200.7	6 months @ 4°C	Calibration Coefficient =1.000-0.995[1]	<RL	Ag=0.1, Al=2.5, Sb=0.2, As=0.1, B=2.5, Ba=0.1, Be=0.1, Cd=0.1, Ca=2.5, Co=0.1, Cr=0.5, Cu=0.1, Fe=2.5, K=25, Mg=2.5, Mn=0.5, Mo=0.1, Na=2.5, Ni=0.1, Pb=0.1, Se=0.5, Sn=0.2, Sr=0.1, Ti=0.1, Tl=0.1, V=0.5, Zn=5	RPD ≤ 20%	80-120% recovery or performance-based intralaboratory control limits, whichever is lower	75-125% recovery applied when the sample concentration is < 4 times the spiked concentration; RPD ≤ 20%	- -

[1]MEL provided, not present in the QAPP.

Table C-2. Metals quality control continued.

QA review element → Parameter ↓	Methods	Holding/ handling	Calibrations/	Method Blank	Reporting Limits	RPD/ RSD	Laboratory Control Standard	Matrix Spike Recovery/ Matrix Spike Deviation	Decision
Total Mercury	EPA 245.5	Acceptable		0.005U/0.05U			100-103%	82-89%	Acceptable
QAPP:	EPA 245.5; MEL SOP	28 days @ 4°C	- -	<RL	0.005	- -	80-120% recovery or performance-based intralaboratory control limits, whichever is lower.	75-125% recovery applied when the sample concentration is < 4 times the spiked concentration; RPD ≤ 20%.	- -

Table C- 3. BNASQS quality control.

QA review element → Parameter ↓	Methods	Holding/ handling	Calibrations/	Method Blank	Reporting Limits	RPD/ RSD	Laboratory Control Standard	Matrix Spike Recovery/ Matrix Spike Deviation	Decision
Semi-volatile organic compounds (mg/L)	SW 846 Method 8270	Acceptable	Continuing calibration low N-nitrosodiphenylamine. All results J qualified. Back calculation acceptable except coprostanol and cholesterol. Nonylphenol and benzoic acid were biased high, no qualifier added.	Benzoic acid nonylphenol and 4-methylphenol detected. Considered native to sample if = or >5 times the blank concentration.		Benzoic acid (131%) and caffeine (160%) had high RPD and were J qualified. All others were acceptable.	Acceptable except benzoic acid (1.7%) results were J qualified.	Matrix spike recoveries acceptable except benzoic acid (23%, 4.9%), caffeine (20%,2.3%), and nonylphenol (157%, 142%). No qualifiers for nonylphenol due to one acceptable recovery. Surrogate recoveries were acceptable	Acceptable
QAPP:	EPA 8270	14 days @ 4°C, 1 year frozen	Calibration Coefficient= 1.000-0.995[1]	<RL	10-130	Compound Specific RPD ≤ 35%	50-150% recovery	50-150% recovery applied when the sample concentration is < 4 times the spiked concentration; RPD ≤ 40%	- -

[1] MEL provided, not present in the QAPP.

Table C- 4. PAH quality control.

QA review element → Parameter ↓	Methods	Holding/ handling	Calibrations/	Method Blank	RLs	RPD/ RSD	Laboratory Control Standard	Matrix Spike Recovery/ Matrix Spike Deviation	Decision
PAHs (mg/kg dry)	EPA SW 846 8270 modified	Acceptable	Back calculations 2-chloronaphthalene, 1,6,7-trimethylnaphthalene, & dibenzofuran at 2nd level. Carbazole & 1,6,7-trimethylnaphthalene at the 3rd level. Dibenzofuran at the 4th & 5th levels were outside of acceptance limits. 2-chloronaphthalene for PS1-3, LW1, LW3, KL1-3, LS2-3, BL1-3, CM1-3, & ML1-3. Biphenyl for CM1-3& ML1-3, & benzo(b)fluoranthene for PS1-3 were outside the continuing calibration limits. These results were qualified; Biphenyl and dibenzothiophene were biased high & qualified if detected.	2-chloronaphthalene =10U. 2-methylnaphthalene =1.1. 1,1'Biphenyl =5.5, 1.8. Dibenzofuran =4.8, 3.0. All others 1.0-2.0.	- -	Acceptable	2-chloronaphthalene=12%. 1,1'Biphenyl=163%. Dibenzothiophene=175%. All others 55-142%. Surrogates: 2-methylnaphthalene-D10 for site BR1. 1-methylnaphthalene-D10 for BR1. 2,6-dimethylnaphthene-D12 for BR1. Acenaphthene-D10 for BL3. Biphenyl-D10 for BR1. Fluorene-D10 for PS2, LW1, LW3, KL1-3, BL1-3, OZ3, CM1-3, ML2-3. Naphthalene for LW3, BR1, BR3. Perylene-D12 for BL3. Indeno(1,2,3-cd)pyrene-D12 for PS2-3, KL2, BL2-3, CM1, CM3. Benzo(g,h,i)perylene-D12 for KL1-2, BL1-2, ML3	1,1'Biphenyl= 166%. Benzo(a)anthracene = 166%. Benzo(b)fluoranthene = 216%. Benzo(e)pyrene = 166%. Benzo(a)pyrene = 204%. Benzo(g,h,i)perylene = 150%. Chrysene = 157%, 252%. Dibenzothiophene = 155%, 187%. Fluoranthene = 247%, 347%. Phenanthrene= 282%. Pyrene= 189% 279%. Retene= 850%. All others 86-132%.	Acceptable
QAPP:	EPA 8270	14 day @ 4°C, 1 year frozen	- -	<RL	0.5-2.0	Compound Specific RPD ≤ 35%	50-150% recovery Surrogates: 20-200%[1]	50-150% recovery RPD ≤ 40%	- -

[1] MEL provided, not present in the QAPP.

Table C- 5. Chlorinated pesticides and PCB quality control.

QA review element → Parameter ↓	Methods	Holding/ handling	Calibrations/	Method Blank	Reporting Limits	RPD/ RSD	Laboratory Control Standard	Matrix Spike Recovery/ Matrix Spike Deviation	Decision
Chlorinated Pesticides (µg/kg)	EPA 8081/ 8082	Acceptable	Endrin ketone, endosulfan sulfate, and methoxychlor were below calibration control standards for some samples; results appropriately qualified. Endrin degradation exceeded 15% for some BR and OZ samples; qualified appropriately.	Acceptable	- -	Acceptable	Some low recoveries resulted in some UJ qualified results.	Acceptable	Acceptable
QAPP:	EPA 8081/8082 or EPA 8270	14 day @ 4°C, 1 year frozen	- -	<RL	6-10	Compound specific RPD ≤ 35%	50-150% recovery	50-150% recovery applied when the sample concentration is < 4 times the spiked concentration. RPD ≤ 40%.	- -
PCB Aroclors (µg/kg)	EPA 8081/8082	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
QAPP:	EPA 8081/8082 or EPA 8270	14 day @ 4°C, 1 year frozen	- -	<RL	6-10	Compound specific RPD ≤ 35%	50-150% recovery	50-150% recovery applied when the sample concentration is < 4 times the spiked concentration. RPD ≤ 40%.	- -

Table C- 6. Bioassay quality control.

QA review element → Parameter ↓		Methods	Holding/ handling	Test conditions, water quality	Control performance	Reference sample performance	Decision
Toxicity	Microtox	Ecology, 2008	Acceptable	Acceptable	Acceptable	N/A	Acceptable
	Chironomus tentans	EPA, 2000 & ASTM, 2000	Acceptable	CM-1, CM-2, LS-1, & LS-2 dissolved oxygen dropped below recommended levels	Acceptable	N/A	Acceptable
	Hyalella Azteca	EPA, 2000 & ASTM, 2000	Acceptable	LS2 dissolved oxygen dropped below recommended levels	Survival Acceptable, Growth was below 0.15 mg/ind	N/A	Acceptable

Appendix D. Raw Results

Table D- 1. Conventionals raw data.

Sampling Location	Total Organic Carbon (%)	Solids (%)	Ammonia as Nitrogen (mg/Kg)	Sulfide (mg/Kg)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Fines (%)[1]	Coarse (%)[1]
CM-1	7.35	21.4	69.8	10.5	1.22	54.0	25.3	13.6	59%	41%
CM-2	9.66	23.6	66.1	5.6	0.00	47.3	51.5	1.17	47%	53%
CM-3	3.63	51.0	14.2	2.7 U	0.00	8.71	69.2	13.2	10%	90%
BR-1	0.49	73.1	2.4	1.4 U	0.14	3.22	95.7	0.07	3%	97%
BR-2	0.48	68.2	5.2	1.5 U	1.53	18.9	78.0	0.27	21%	79%
BR-3	1.04	56.1	23.6	1.7 U	2.89	41.9	55.1	0.01	45%	55%
OZ-1	1.75	51.2	1.2	2.2 U	6.77	20.5	69.5	2.81	27%	73%
OZ-2	4.19	33.4	1.8	3.5 U	13.9	19.4	60.4	4.55	34%	66%
OZ-3	2.66	49.3	10.8	2.1 U	0.47	18.5	74.4	1.57	20%	80%
ML-1	14.8	7.4	53.6 J	10.9 J	0.51	32.3	5.24	61.5	33%	67%
ML-2	3.81	28.3	1.4 J	7.1 J	0.93	9.6	56.6	20.8	12%	88%
ML-3	10.7	13.1	50.3 J	216 J	0.00	29.6	27.3	38.4	31%	69%
LW-1	1.63	37.6	11.6 J	21 J	5.1	18.6	84.6	0.36	22%	78%
LW-2	1.35	54.1	0.12 J	1.8 UJ	4.16	15.9	79.6	2.75	20%	80%
LW-3	0.98	63.2	22.9 J	2.6 J	0.37	11.0	83.5	0.06	12%	88%
LS-1	0.53	70.3	8.2	4.6	0.98	10.4	83.7	0.16	12%	88%
LS-2	1.60	60.6	0.620 J	14.5	0.62	18.7	69.6	3.18	21%	79%
LS-3	0.10	83.2	0.120 J	0.7	0.19	2.53	97.9	1.23	3%	97%
MD-1	10.9	16.7	40.3 J	261 J	6.36	64.2	29.9	22.6	57%	43%
MD-2	15.9	14.6	54.7 J	155 J	2.62	38.1	40.9	10.1	44%	56%
MD-3	14.6	16.3	82.3 J	437 J	3.14	46.2	60.2	0.44	45%	55%
PS-1	0.24	70.1	2.14 J	2.1 J	1.58	21.8	71.8	1.65	24%	76%
PS-2	1.86	37.8	67.2 J	26.7 J	12.3	90.6	3.2	0.27	97%	3%
PS-3	2.02	36.0	78.1 J	3.2 J	23.1	78.0	9.84	0.17	91%	9%
SS-1	10.1	9.5	127	27.2	10.9	32.2	16.4	33.8	46%	54%
SS-2	11.9	9.7	58.2	23.4	11.8	35.1	12.1	33.5	51%	49%
SS-3	11.1	10.7	38.7	34.8	12.6	38.6	20.9	30.1	50%	50%

[1]Corrected to 100%.
U-Analyte was not detected at or above the reported result.
UJ-Analyte was not detected at or above the reported result.
J-Analyte was positively identified but reported as an estimate.

Table D- 2. Metals raw data, mg/kg.

Sampling Location	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
CM-1	31300	0.10 U	12.4	86.9	0.52	25 U	0.32	6630	21	13.7	146	32000	11.8	9620
CM-2	31400	0.10 U	12.7	88.1	0.53	25 U	0.33	6550	22	13.8	147	32400	11.8	9600
CM-3	32500	0.10 U	2.81	80.9	0.61	25 U	0.13	6320	28.5	15.3	45.0	33800	7.03	10200
BR-1	9420	0.10 U	2.66	99.2	0.50 U	25 U	0.32	4900	15	6.99	13.9	18200	9.43	3610
BR-2	10700	0.10 U	3.02	109	0.50 U	25 U	0.42	4960	18	7.99	16.9	19100	8.86	3710
BR-3	16900	0.10 U	4.26	120	0.50 U	25 U	0.522	5600	17	8.63	22.7	23800	10.6	4510
OZ-1	21500	0.10 U	3.85	162	0.50 U	25 U	0.37	2890	32.6	12.5	22.7	26600	7.45	6620
OZ-2	25800	0.10 U	6.48	162	0.50 U	25 U	0.22	4330	38.7	13.1	26.8	33700	7.79	8690
OZ-3	14800	0.10 UJ	1.04	85.8	0.50 U	25 UJ	0.089	2130	22	6.19	12.0	23100	4.12	5920
ML-1	21000	0.23	16.6	117	0.50 U	25 U	1.01	8800	56.9	16.7	49.9	29400	53.0	6440
ML-2	20800	0.25	16.9	194	0.66 U	33 U	1.01	9010	57.1	16.4	48.9	29000	55.4	6300
ML-3	18400	0.13	7.05	151	0.50 U	25 U	0.40	6300	41.1	9.77	31.6	27800	31.1	5390
LW-1	15100	0.10 U	1.77	150	0.19	25 U	0.25	4180	59.5	14.6	21.3	26100	4.67	7490
LW-2	14300	0.10 U	2.47	126	0.17	25 U	0.12	3100	54.7	16.4	21.5	31500	4.02	7740
LW-3	17500	0.10 U	0.985	189	0.17	25 U	0.066	2470	65.0	9.30	19.0	24900	3.18	10100
LS-1	9370	0.12	2.17	72.6	0.36	25 U	0.050 U	2860	12.8	4.18	3.46	12100	4.37	3890
LS-2	11200	0.10 U	4.62	104	0.45	25 U	0.083	4510	13.4	5.29	6.07	14200	6.51	5020
LS-3	7230	0.10 U	4.21	60.7	0.27	25 U	0.050 U	1790	14.4	3.74	2.61	11000	3.75	4070
MD-1	5220	0.10 U	2.20	76.5	0.15	25 U	0.14	31500	5.32	4.50	15.4	9880	6.2	4140
MD-2	5860	0.14	2.88	91.8	0.19	25 U	0.17	33200	7.64	5.32	14.6	10800	7.83	5020
MD-3	4970	0.11	2.39	91.3	0.18	25 U	0.13	29100	6.49	4.27	14.0	9120	5.53	4430
PS-1	10700	0.13 J	5.17	126	0.38	25 U	0.12	5410	15.1	8.51	10.1	20700	6.44	5230
PS-2	25900	0.12	4.21	185	0.650	25 U	0.21	5090	22.7	9.91	20.0	30700	10.6	5790
PS-3	25200	0.11	4.01	182	0.656	25 U	0.20	4920	21.9	9.67	20.0	29300	10.2	5630
SS-1	16200	0.21	4.93	105	2.60	25 U	0.41	3320	10.1	3.04	9.07	7440	20.5	1770
SS-2	17000	0.28	5.83	99.3	2.76	25 U	0.529	3200	11.6	3.19	10.0	8300	27.4	1920
SS-3	16800	0.27	6.15	105	2.86	25 U	0.541	3460	11.7	3.34	10.7	8570	28.9	1910

U-Analyte was not detected at or above the reported result.
J-Analyte was positively identified but reported as an estimate.

Table D- 2. Metals raw data, mg/kg, continued.

Sampling Location	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Thallium	Tin	Titanium	Vanadium	Zinc
CM-1	476	0.074	4.09	10.8	1200	1.3 J	0.27	477	47.1	0.13	0.68	1740	82.8	80
CM-2	477	0.10	4.16	10.9	1200	1.4	0.27	499	47.9	0.13	0.71	1760	84.0	80
CM-3	626	0.068	0.30	28.8	710	0.42 J	0.056	268	38.0	0.051	0.75	964	71.3	68
BR-1	278	0.028	0.3	12.2	1000	0.25 U	0.050 U	611	40.2	0.16	0.47	1110	46.1	110
BR-2	340	0.0875	0.23	14.4	1000	0.25 U	0.050 U	636	44.5	0.15	0.49	1130	52.1	110
BR-3	440	0.229	0.24	13.0	1100	0.26	0.053	649	43.7	0.16	0.61	947	50.6	89
OZ-1	950	0.053	0.26	34.6	1000	0.61	0.079	130	26.1	0.10	0.36	288	55.3	78
OZ-2	558	0.032	0.33	31.5	1100	0.67	0.098	220	43.1	0.082	0.41	431	68.8	74
OZ-3	348	0.039	0.16	17.1	840	0.26	0.050 U	99.9	20.7	0.057	0.30	40.8	35.6	50
ML-1	316	0.13	2.60	57.2	510	2.96	0.15	260	75.7	0.091	1.05	1170	74.7	83
ML-2	313	0.15	2.66	56.4	520	3.1	0.16	260	75.1	0.096	1.02	1088	76.5	81
ML-3	206	0.066	2.01	38.5	530	1.8	0.097	190	54.6	0.075	0.74	971	61.9	54
LW-1	324	0.019	1.78	80.8	2300	0.25 U	0.085	417	26.6	0.24	0.39	1110	61.9	61.6
LW-2	486	0.013	1.68	49.2	2730	0.47	0.069	190	19.9	0.21	0.33	1030	61.9	68.0
LW-3	178	0.015	0.47	35.9	4290	0.25 U	0.050 U	190	14.7	0.22	0.52	1390	75.4	71.5
LS-1	134	0.0065 U	0.14	7.41	1300	0.25 U	0.050 U	150	17.4	0.12	0.38	535	14.1	33.3
LS-2	149	0.010	0.21	7.81	1400	0.25 U	0.050 U	160	23.4	0.14	0.45	572	16.3	43.3
LS-3	299	0.0060 U	0.16	8.66	940	0.25 U	0.050 U	73	23.0	0.073	0.22	292	11.1	26.9
MD-1	436	0.028 U	0.772	6.81	1200	0.44	0.050 U	1020	124	0.072	0.24	445	35.9	23
MD-2	457	0.041	0.908	8.17	1300	0.60	0.050 U	943	135	0.086	0.27	529	45.8	28.1
MD-3	443	0.027 U	0.805	7.06	1100	0.53	0.050 U	793	124	0.073	0.22	421	38.8	23
PS-1	659 J	0.0065 U	0.40	13.1	1800	0.25 U	0.050 U	321 J	33.8	0.16	0.61	943	39.8 J	43.8
PS-2	558	0.023	0.29	16.7	3460	0.25 U	0.10	305	33.9	0.27	0.89	1500	43.7	60.8
PS-3	554	0.026	0.26	16.5	3470	0.25 U	0.094	301	34.5	0.23	0.82	1440	42.7	61.5
SS-1	121	0.37	1.02	6.79	1000	0.34	0.10	170	34.5	0.50 U	0.83	441	16.6	52.6
SS-2	116	0.27	1.08	7.69	1100	0.40	0.12	210	34.3	0.50 U	1.13	436	19.2	64.1
SS-3	116	0.087	1.13	7.95	1100	0.38	0.12	258	36.4	0.50 U	1.14	454	20.7	62.1

Table D- 3. PAH raw data µg/Kg dw.

Sampling Location	1,1'-Biphenyl	1-Methylnaphthalene	2-Chloronaphthalene	2-Methylnaphthalene	2-Methylphenanthrene	Acenaphthene	Acenaphthylene	Anthracene	Benz[a]anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(ghi)perylene	Benzo(k)fluoranthene	Benzo[e]pyrene	Carbazole	Chrysene	Dibenzo(a,h)anthracene	Dibenzofuran
CM-1	17 J	53	10 UJ	46	69	2.1	2.7	1.1	4.2	5.7	16	9.0	2.0	19	4.0	41	2.2	12 J
CM-2	12 J	8.5	11 UJ	5.6	9.6	1.1 U	1.1 U	2.2	5.2	40	22	11	4.2	8.9	3.6	15	2.1 U	9.7 J
CM-3	6.2 J	2.7	10 UJ	4.0	1.7	1.0 U	1.1	1.0 U	1.5	4.8	10	5.8	1.5	4.1	1.6 J	8.1	2.0 U	9.3 J
BR-1	18 J	12 J	10 UJ	18 J	3.9	2.7	8.0	7.7	13	15	18	11	8.2	11	2.9	20	1.8 J	10 J
BR-2	5.4	1.0	9.9 U	1.5	0.70 J	0.99 U	1.3	0.86 J	1.9	5.3	4.3 J	3.5	1.7	2.8	1.2 J	4.6 J	0.53 J	3.8 J
BR-3	11	4.6	10 U	6.1	3.4	1.3	2.9	3.1	5.8	15	10	7.0	3.6	6.5	2.5	12	0.92 J	8.1 J
OZ-1	27	63	9.6 U	50	57	1.7	3.5	3.1	4.8	3.6	13	7.6	1.9	15	3.1	19	2.3	14 J
OZ-2	28 J	67	9.8 UJ	57	76	3.3	8.2	2.2	3.6	7.7	20 J	8.4	2.6	15	3.7	28	3.2	20
OZ-3	90	166	10 U	186	144	3.8 J	4.0	2.2	7.4	19	34	14	4.7	29	16	95	3.9	34 J
ML-1	18 J	37	15 UJ	19	19	7.4	17	18	29	51	164	147	42	82	8.4	78	13	46 J
ML-2	0.85 J	4.9	9.9 UJ	5.9	9.3	0.99 U	0.99 U	4.7	7.0	16	36	44	44	17	2.0	22	2.0 U	14 J
ML-3	19 J	15	11 UJ	15	1.1 U	4.3	9.0	9.4	14	56	60	12 J	14	30	9.3	38	2.2 U	22 J
LW-1	8.8 J	10	9.6 UJ	4.5	128	1.1	4.1	1.8	2.5	4.3	6.5	4.9	2.0	2.4	2.8	6.8	1.9 U	9.0
LW-2	2.7 UJ	2.5	4.6 U	1.7 J	2.0	0.34 J	1.2 J	1.8 U	0.62 J	1.6 J	2.0	0.96 J	1.8 U	1.0 J	1.8 J	2.9	1.8 U	4.2
LW-3	3.0 J	2.2	9.3 UJ	0.98	41	0.93 U	0.93 U	0.93 U	0.93 U	19	2.1	0.93 U	0.93 U	0.93 U	1.9 U	0.93 U	1.9 U	4.2
LS-1	1.5 UJ	3.0	2.6 U	1.6	2.2	3.9	1.2	5.5	22	32	34	20	16	19	5.8	34	4.3	2.2
LS-2	8.9 J	7 .0	9.9 UJ	4.1	7.7	4.0	1.9	6.3	19	36	32	19	14	20	6.0	37	4.3	6.7
LS-3	2.8 J	1.6	9.7 UJ	1.7	0.97 U	0.93 J	0.63 J	1.2	3.6	6.1	5.8	4.1	2.6	3.4	1.5 J	6.4	1.9 U	4.3
MD-1	22 J	34	11 UJ	19	16	3.9	6.3	1.5	3.0	14	11	9.7 J	2.8	9.3	15	5.3	1.7 J	21
MD-2	29 J	27	11 UJ	23	15	4.8	9.5	3.6	4.2	82	18	6.7 J	4.1	14	22	9.4	1.1 J	38
MD-3	2.9 J	1.9	11 UJ	1.8	1.8	2.7	0.86 J	4.4	14	28	21	14	9.9	13	3.9	25	2.4	5.0
PS-1	2.9 J	2.5	10 UJ	1.5	0.84 J	1.0 U	2.1	1.0 U	1 U	2.0	0.86 J	1 U	1.0 U	1.0 U	2.1 U	1 U	2.1 U	3.6
PS-2	11 J	13	10 UJ	6.4	1.0 U	0.78 J	3.2	2.4	2.8	17	7.9 J	4.1	2.5 J	4.7	4.1	8.2	2.0 U	9.3
PS-3	11 J	17	11 UJ	9	58	1.2	3.8	2.1	2.6	22	7.8 J	3.7	2.6	4.5	4.8	7.2	2.0 U	12
SS-1	19 J	47	16 UJ	24	513	3.6	12	5.2	8.9	64	51	12 J	18	31	10	26	5.7	19
SS-2	23 J	55	16 UJ	53	88	7.9	8.6	6.6	17	72	98	51 J	28	38	34	68	9.7	16
SS-3	22 J	44	14 UJ	45	642	5.1 J	8.4	5.8	15	90	84	57	26	38	46	58	11	14

U-Analyte was not detected at or above the reported result.
UJ-Analyte was not detected at or above the reported result.
J-Analyte was positively identified but reported as an estimate.

Table D-3. PAH raw data, µg/Kg dw, continued.

Sampling Location	Dibenzothiophene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Naphthalene, 1,6,7-Trimethyl	Naphthalene, 2,6-dimethyl-	Perylene	Phenanthrene	Pyrene	Retene
CM-1	13 J	12	10 J	3.6	23	39 J	58 J	3570 E	99	17	266
CM-2	2.2 J	19	3.6 J	7.8	27	1.1 U	43	124	20	14	320
CM-3	1.4 J	8.0	0.90 J	3.9 J	22	1.0 U	2.3	0.89 J	11	5.7	19
BR-1	2.9 J	43	4.0	7.8	34 J	5.2 J	8.8 J	12	25	38	26
BR-2	1.0 J	5.7 J	0.73 J	2.2	5.0	0.85 J	2.1	19	3.7	4.2 J	30 J
BR-3	2.5 J	17	2.8	5.5	21 J	3.1 J	10	74	12	14	326
OZ-1	14 J	9.7	7.5	2.3	25	49 J	58	1580	83	15	94
OZ-2	16	12	14	3.9 J	33	38	73	3030	108	19	207
OZ-3	38 J	32	35 J	7.4	65	63 J	172	671	284	32	269
ML-1	9.1 J	175	25	138	103	2.6 J	350	463	146	89	74
ML-2	2.2 J	43	6.1 J	0.99 U	31	1.1 J	25	255	38	27	68
ML-3	9.3 J	62	17 J	1.1 U	79	1.1 U	211	82	65	37	2280
LW-1	1.4 J	14	2.8 J	4.5	26	0.96 U	28	374	19	9.7	98
LW-2	1.8 U	2.5	1.0 J	1.2 J	19	1.8 U	1.4 J	7.6	4.7	1.8 J	19
LW-3	1.9 U	1.2	0.93 U	1.0	0.93 U	0.93 U	4.6	11	1.5	2.6	812
LS-1	1.8	47	3.0	21	7.3	1.0 U	5.3	35	30	47	12
LS-2	2.9	45	3.9	19	13	1.0 U	49	50	29	42	79
LS-3	1.9 U	9.0	0.90 J	3.2	3.5	0.97 U	2.5	9.2	6.9	8.7	2.1
MD-1	3.8	16	10 J	16	38	1.1 U	1010	12	16	8.0	15
MD-2	5.3	25	14 J	22 J	42	2.6	1010	9.3	28	12	22
MD-3	2.1 J	33	2.1 J	12	3.4	1.1 U	5.6	33	21	33	16
PS-1	2.0 U	1.1	0.85 J	1.0 U	3.6	0.77 J	1.3	2.0	1.4	0.87 J	1.8
PS-2	2.3	14	6.0 J	3.8 J	16	0.79 J	29	91	14	8.9	13
PS-3	1.6 J	14	6.0	3.5 J	23	0.96 J	40	56	15	8.8	13
SS-1	4.4	44	13 J	58	47	1.6 U	889	950	42	24	84
SS-2	9.1	76	15 J	79 J	64	3.9	1140	299 J	59	36	301
SS-3	8.0	67	18 J	78 J	56	3.1	1030	291 J	63	37	94

Table D- 4. Detected semi-volatile organic compounds raw data, µg/Kg dw.

Sampling Location	2,4-Dimethylphenol	Benzoic Acid	Bis(2-Ethylhexyl) Phthalate	Cholesterol	Coprosterol	Dibutyl phthalate	Isophorone	p-Cresol	Pentachlorophenol	Phenol
CM-1		4100 J		1420	365 J					
CM-2		4320 J		1760	383 J					
CM-3	2.3 J	228 J		1700						
BR-1				392	80 J					
BR-2	2.2 J			610 J	130 J					
BR-3				828 J	168 J					
OZ-1				151 J						
OZ-2				248 J						
OZ-3				254						
ML-1		8820 J		1500 J						
ML-2		2810 J		533					819	
ML-3		15800 J		2150 J	649 J			74 J		225 J
LW-1				422	155 J					
LW-2				182 J						
LW-3				1030				14 J		
LS-1				1320	131 J					
LS-2		182 J	30 J	1910	391			29 J		
LS-3			81	162						
MD-1				1640	681 J	14 J		38 J		
MD-2			7.5 J	2220	1230	4.0 J	44 J	40 J		
MD-3				1760	768	6.0 J		36 J		
PS-1				443				6.5 J		
PS-2				1090	258 J			18 J		
PS-3			32 J	849	261 J			24 J		
SS-1				1830				53 J		
SS-2		1160 J		5820	973 J			70 J		
SS-3		3950 J		5740	861 J			84 J		

J-Analyte was positively identified but reported as an estimate.

List of semi-volatile organic compounds analyzed.

- 1,2,4-Trichlorobenzene
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- 2,4-Dimethylphenol
- Benzoic Acid
- Benzyl Alcohol
- Bis(2-Ethylhexyl) Phthalate
- Butyl benzyl phthalate
- Caffeine
- Cholesterol
- Coprosterol
- Dibutyl phthalate
- Diethyl phthalate
- Dimethyl phthalate
- Di-N-Octyl Phthalate
- Hexachlorobenzene
- Hexachlorobutadiene
- Isophorone
- N-Nitrosodiphenylamine
- o-Cresol
- p-Cresol
- Pentachlorophenol
- Phenol
- Phenol, 4-nonyl-

Table D- 5. Detected chlorinated pesticides raw data, µg/Kg dw.

Sampling Location	4,4'-DDD	4,4'-DDE	4,4'-DDT	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan Sulfate	Endrin	Heptachlor Epoxide	Lindane	Toxaphene	trans-Chlordane
CM-1												
CM-2		0.29										
CM-3												
BR-1												
BR-2	0.31	0.56										
BR-3	1	1.2										
OZ-1												
OZ-2												
OZ-3												
ML-1		0.71									5.3 J	
ML-2												
ML-3	0.95	0.94									4.4 J	
LW-1	2.3	1.6	0.6									
LW-2	0.44	1.1	0.56									
LW-3												
LS-1												
LS-2		0.96										
LS-3												
MD-1	0.76	3.4									8.8 J	
MD-2	0.74	3.9									11 J	
MD-3		0.39										
PS-1		0.48										
PS-2	1.6	9.6	0.81									
PS-3	1.7	11	1.1	0.35 J						0.93		0.57
SS-1		2.9			0.56 J		0.98 J	0.4 J			10 J	
SS-2	4.6	4.4		0.49 J	0.85 J		1.7 J	0.52 J	1.8 J			
SS-3	4.2 J	4.2		0.44 J	0.65 J	0.59 J	1.9 J					

J-Analyte was positively identified but reported as an estimate.

List of chlorinated pesticides analyzed.

- 4,4'-DDD
- 4,4'-DDE
- 4,4'-DDT
- Aldrin
- alpha-BHC
- beta-BHC
- Chlordane, technical
- cis-Chlordane
- delta-BHC
- Dieldrin
- Endosulfan I
- Endosulfan II
- Endosulfan Sulfate
- Endrin
- Endrin Aldehyde
- Endrin Ketone
- Heptachlor
- Heptachlor Epoxide
- Lindane
- Methoxychlor
- Toxaphene
- trans-Chlordane

Table D- 6. Detected aroclor PCBs raw data, µg/Kg dw.

Sampling Location	PCB-aroclor 1248	PCB-aroclor 1254
CM-1		
CM-2		
CM-3		
BR-1		
BR-2		
BR-3		
OZ-1		
OZ-2		
OZ-3		
ML-1		
ML-2		
ML-3		3.3
LW-1		
LW-2		
LW-3		
LS-1		
LS-2		
LS-3		
MD-1	3.5 J	
MD-2		
MD-3		
PS-1		
PS-2		
PS-3		
SS-1		
SS-2		6.1
SS-3		4.8

J-Analyte was positively identified but reported as an estimate.

List of aroclor PCBs analyzed.

- PCB-aroclor 1016
- PCB-aroclor 1221
- PCB-aroclor 1232
- PCB-aroclor 1242
- PCB-aroclor 1248
- PCB-aroclor 1254
- PCB-aroclor 1260
- PCB-aroclor 1262
- PCB-aroclor 1268

Table D- 7. Microtox results and guideline comparisons*.

Sampling Location	Average Sample Results	Test Guidelines Did the sample pass test numerical guideline?	Test Guidelines Did the sample pass test numerical guideline?	Significantly lower than the control (α=0.05)?	Hit?	Reference Guideline Did the sample pass reference numerical guideline?
	Change in luminescence[1]	Ecology, 2008	SEF, 2009			
CM-1	72	Pass	Pass	No	No	**Failed**
CM-2	80	Pass	Pass	No	No	Pass
CM-3	76	Pass	Pass	No	No	**Failed**
BR-1	81	Pass	Pass	No	No	Pass
BR-2	81	Pass	Pass	No	No	Pass
BR-3	82	Pass	Pass	No	No	Pass
OZ-1	71	Pass	Pass	**Yes**	No	Pass
OZ-2	78	Pass	Pass	**Yes**	No	Pass
OZ-3	75	Pass	Pass	No	No	**Failed**
ML-1	78	Pass	Pass	No	No	**Failed**
ML-2	80	Pass	Pass	**Yes**	No	Pass
ML-3	77	Pass	Pass	No	No	Pass
LW-1	85	Pass	Pass	No	No	Pass
LW-2	81	Pass	Pass	No	No	Pass
LW-3	74	Pass	Pass	**Yes**	No	**Failed**
LS-1	73	Pass	Pass	No	No	Pass
LS-2	80	Pass	Pass	No	No	Pass
LS-3	76	Pass	Pass	No	No	Pass
MD-1	72	Pass	Pass	No	No	**Failed**
MD-2	82	Pass	Pass	No	No	Pass
MD-3	78	Pass	Pass	No	No	Pass
PS-1	78	Pass	Pass	No	No	Pass
PS-2	78	Pass	Pass	No	No	Pass
PS-3	75	Pass	Pass	**Yes**	No	Pass
SS-1	81	Pass	Pass	No	No	**Failed**
SS-2	61	**Failed**[SQS]	**Failed**[2]	**Yes**	**Yes**	**Failed**
SS-3	71	Pass	Pass	**Yes**	No	**Failed**

*See Appendix E for guideline descriptions.
[SQS]Failed SQS guideline.
[1]15 minute duration only.
[2]Failed 2-hit guideline.

Table D- 8. *Chironomus tentans* test results and guideline comparisons*.

Sampling Location	Average Sample Results		Test Guidelines Did the sample pass test numerical guideline?		Significantly different from the Control (α=0.05)?		Hit?	Reference Guidelines Did the sample pass reference numerical guideline?	
	Survival	Growth	Survival	Growth	Survival	Growth		Survival	Growth
CM-1	72	2.27	Pass	Pass	No	**Yes**	No	Pass	Pass
CM-2	62	2.05	**Failed**[2]	Pass	**Yes**	No	No[3]	**Failed**	Pass
CM-3	63	2.09	**Failed**[2]	Pass	**Yes**	**Yes**	No[3]	**Failed**	Pass
BR-1	75	2.09	Pass	Pass	No	**Yes**	No	Pass	Pass
BR-2	63	2.18	**Failed**[2]	Pass	No[3]	**Yes**	No	**Failed**	Pass
BR-3	43	2.49	**Failed**[1]	Pass	**Yes**	**Yes**	**Yes**	**Failed**	Pass
OZ-1	77	1.89	Pass	Pass	No	No	No	Pass	Pass
OZ-2	57	2.43	**Failed**[2]	Pass	**Yes**	**Yes**	No[3]	**Failed**	Pass
OZ-3	75	2.16	Pass	Pass	No	**Yes**	No	Pass	Pass
ML-1	70	2.04	Pass	Pass	No	No	No	Pass	Pass
ML-2	87	1.81	Pass	Pass	No	No	No	Pass	Pass
ML-3	83	2.03	Pass	Pass	No	No	No	Pass	Pass
LW-1	78	1.87	Pass	Pass	**Yes**	No	No	Pass	Pass
LW-2	80	2.04	Pass	Pass	**Yes**	**Yes**	No	Pass	Pass
LW-3	52	2.35	**Failed**[1]	Pass	**Yes**	**Yes**	**Yes**	**Failed**	Pass
LS-1	43	2.49	**Failed**[1]	Pass	**Yes**	**Yes**	**Yes**	**Failed**	Pass
LS-2	42	2.35	**Failed**[1]	Pass	**Yes**	**Yes**	**Yes**	**Failed**	Pass
LS-3	67	1.57	**Failed**[1]	Pass	**Yes**	No	**Yes**	Pass	Pass
MD-1	67	1.78	**Failed**[1]	Pass	**Yes**	**Yes**	**Yes**	Pass	Pass
MD-2	42	2.19	**Failed**[1]	Pass	**Yes**	**Yes**	**Yes**	**Failed**	Pass
MD-3	65	1.85	**Failed**[1]	Pass	**Yes**	**Yes**	**Yes**	Pass	Pass
PS-1	82	1.61	Pass	Pass	No	No	No	Pass	Pass
PS-2	77	1.62	**Failed**[2]	Pass	No[3]	No	No	Pass	Pass
PS-3	37	2.5	**Failed**[1]	Pass	**Yes**	**Yes**	**Yes**	**Failed**	Pass
SS-1	87	1.75	Pass	Pass	No	No	No	Pass	Pass
SS-2	85	1.66	Pass	Pass	No	No	No	Pass	Pass
SS-3	68	1.87	**Failed**[2]	Pass	**Yes**	No	No[3]	Pass	Pass

*See Appendix E for guideline descriptions.
[1] 1-hit failure.
[2] 2-hit failure.
[3] See Data Analysis section.

Table D- 9. *Hyalella azteca* results and guideline comparisons*

Sampling Location	Average Sample Results		Test Guidelines Did the sample pass test numerical guideline?		Significantly lower than the control (α=0.05)?		Hit?	Reference Guideline Did the sample pass reference numerical guideline?	
	Survival	Growth	Survival	Growth	Survival	Growth		Survival	Growth
CM-1	98	0.18	Pass	Pass	No	No	No	Pass	Pass
CM-2	96	0.17	Pass	Pass	No	No	No	Pass	Pass
CM-3	98	0.16	Pass	Pass	No	No	No	Pass	Pass
BR-1	98	0.21	Pass	Pass	No	No	No	Pass	Pass
BR-2	98	0.20	Pass	Pass	No	No	No	Pass	Pass
BR-3	94	0.17	Pass	Pass	No	No	No	Pass	Pass
OZ-1	96	0.17	Pass	Pass	No	No	No	Pass	Pass
OZ-2	96	0.15	Pass	Pass	No	No	No	Pass	Pass
OZ-3	98	0.18	Pass	Pass	No	No	No	Pass	Pass
ML-1	94	0.16	Pass	Pass	No	No	No	Pass	Pass
ML-2	100	0.18	Pass	Pass	No	No	No	Pass	Pass
ML-3	100	0.26	Pass	Pass	No	No	No	Pass	Pass
LW-1	96	0.26	Pass	Pass	No	No	No	Pass	Pass
LW-2	100	0.20	Pass	Pass	No	No	No	Pass	Pass
LW-3	100	0.28	Pass	Pass	No	No	No	Pass	Pass
LS-1	98	0.27	Pass	Pass	No	No	No	Pass	Pass
LS-2	98	0.34	Pass	Pass	No	No	No	Pass	Pass
LS-3	96	0.25	Pass	Pass	No	No	No	Pass	Pass
MD-1	100	0.19	Pass	Pass	No	No	No	Pass	Pass
MD-2	96	0.23	Pass	Pass	No	No	No	Pass	Pass
MD-3	98	0.19	Pass	Pass	No	No	No	Pass	Pass
PS-1	100	0.25	Pass	Pass	No	No	No	Pass	Pass
PS-2	100	0.19	Pass	Pass	No	No	No	Pass	Pass
PS-3	98	0.30	Pass	Pass	No	No	No	Pass	Pass
SS-1	100	0.31	Pass	Pass	No	No	No	Pass	Pass
SS-2	100	0.28	Pass	Pass	No	No	No	Pass	Pass
SS-3	98	0.27	Pass	Pass	No	No	No	Pass	Pass

*See Appendix E for guideline descriptions.

Appendix E. Bioassay and Chemistry Guidelines

Bioassay Guidelines

Performance Guidelines

Control: Lab-created sediment is used to evaluate test procedures and conditions that may influence test results.

Reference: Sediment is used as a point of comparison for the test results. Usually the reference is more representative of the native investigation site conditions than the control.

Test Guidelines (ordered by severity of effects predicted by the guideline)

2-Hit: A lower intensity response to a stimulus resulting in the observation of a minor adverse effect. This means that some stimuli caused some negative impact on the test organisms. If more than one bioassay test (ex. Amphipod and Chironomid tests) fail the 2-hit guideline for one sample, the sample is considered to have severe adverse effects and is equivalent to a 1-hit failure (SEF, 2009).

SQS: A minor adverse effect resulting in the observation of some negative impact on the test organisms (Ecology, 2008).

1-Hit: A marked response to a stimulus resulting in the observation of severe adverse effects. Some stimuli caused the observation of substantial negative impacts to the test organism (SEF, 2009).

CSL: A severe adverse effect resulting in the observation of substantial negative impacts to the test organism (Ecology, 2008).

Table E- 1. Bioassay acceptability guidelines. ▲

Bioassay Type	Duration	Endpoint	Source	Acceptability as Test Sample		Acceptability as a Reference Sample	Control Acceptability
				Minor Adverse Effects	Severe Adverse Effects		
Microtox	15 minute	Luminescence	Ecology 2008	SQS Hit: Test Mean / Control Mean < 0.90 and Sign.	CSL Hit: Test Mean / Control Mean < 0.75 and Sign.	Reference Final Mean / Control Final Mean ≥ 0.80	Control Final Mean / Control Initial Mean ≥ 0.72
Chironomus tentans	20 day	Survival	Ecology 2008	Not available		Not available	Control Mean ≥70%
		Survival	SEF 2009	2-Hit: Test Mean / Reference Mean < 85% and Sign.	1-Hit: Test Mean / Reference Mean < 75% and Sign.	Reference Mean ≥65%	Control Mean ≥68%
		Growth	SEF 2009	2-Hit: Test Mean / Reference Mean < 0.75 and Sign.	1-Hit: Test Mean / Reference Mean < 0.60 and Sign.	Reference Mean / Control Mean ≥0.8	Control Mean ≥ 0.48 mg/ind
Hyalella azteca	28 day	Survival	Ecology 2008	Not available		Not available	Control Mean ≥80%
		Survival	SEF 2009	2-Hit: Test Mean / Reference Mean < 90% and Sign.	1-Hit: Test Mean / Reference Mean < 75% and Sign.	Reference Mean ≥70%	Control Mean ≥80%
		Growth	SEF 2009	2-Hit: Test Mean / Reference Mean < 0.75 and Sign.	1-Hit: Test Mean / Reference Mean < 0.60 and Sign.	Reference Mean ≥0.15 mg/ind	Control Mean ≥0.15 mg/ind

▲Samples were tested for acceptability as a test and as a reference. Control acceptability assesses the performance of the lab-created control sediment.

SQS=Sediment Quality Standard, minor adverse effect.

2-Hit=Minor adverse effect. Two bioassays tests must fail for the sample to fail as a whole. For example: If Sample B has a 2-hit result for Microtox and no other hits, the sample passes the test guidelines. If sample C has a 2-hit result for Microtox and a 2-hit result for *Chironomus tentans,* the sample fails the test guidelines at the 1-Hit level.

CSL=Cleanup Screening Level, severe adverse effect.

1-Hit=Severe adverse effect (2 2-hit's /sample = 1 1-hit for the sample). Only one bioassay test must fail for the sample to fail as a whole. For example: If Sample A has a 1-hit result for the Microtox test, the whole sample fails the test guidelines.

Sign.=Statistically significant at the p=0.05 level.

Mean=Average of all replicates; values averaged depend on test and endpoint. Microtox Luminescence = Final Light Output/Initial Light Output, Microtox Luminescence Initial = Initial Light Output, Microtox Luminescence Final = Final Light Output, *C. tentans* and *H. azteca* Survival = Final surviving number of organisms/Initial number of organisms*,* *C. tentans* and *H. azteca* Growth = Final mg/individual.

Chemical Guidelines (ordered by severity of effects predicted by the guideline)

TEL: Threshold effects level. The level below which adverse biological effects rarely occur. Therefore, samples that pass this guideline are not anticipated to have biological effects from that chemical. (CCME, 1999.)

PEL: Probable effects level. The level above which (minor) adverse biological effects occur frequently. (CCME, 1999.)

SQS: Sediment quality standard. The level above which (minor) adverse biological effects occur frequently. (Ecology, 2003.)

PAET: Probable apparent effects threshold. The level above which at least one acute Microtox, Hyalella, or acute Chironomid test has always failed unless considered an outlier. Uses the 95^{th} percentile of the no-hits distribution to remove outliers. Uses Microtox and 10 and 14-day Hyalella bioassays. (Ecology, 2002.)

LAET: Lowest apparent effects threshold. The level above which at least one acute Microtox, Hyalella, or acute Chironomid test has always failed unless considered an outlier. The LAET guideline removed the highest concentration in the no-hit distribution only if it was 3 times higher than the second highest concentration. No more than 2 data points were removed from the no-hit distribution for LAET calculations. Uses Microtox, 10-day Hyalella, and 10-day Chironomid bioassays to determine the hit/no-hit distributions. (Ecology, 2003.)

CSL: Cleanup screening level. The level above which more severe adverse biological effects occur frequently. Samples that have chemical failures of the CSL guideline are more likely to exhibit more severe adverse biological effects or a greater number of effects: CSL, 1-hit bioassay failures, or more than one SQS or 2-hit failure. (Ecology, 2003.)

Table E- 2. Chemistry acceptability guidelines.

Parameter	TEL[1]	PEL[1]	SQS[3]	PAET[2]	LAET[3]	CSL[3]
Antimony	--	--	0.4	35	0.6	0.6
Arsenic	5.9	17.0	20	19	31.4	51
Beryllium	--	--	--	--	0.46	--
Cadmium	0.6	3.5	0.6	7.6	2.39	1.0
Chromium	37.3	90.0	95	70	95	100
Copper	35.7	197	80	340	619	830
Lead	35.0	91.3	335	240	335	430
Mercury	0.17	0.486	0.5	0.22	0.8	0.75
Nickel	--	--	60	39	53.1	70
Silver	--	--	2.0	3.9	0.545	2.5
Zinc	123	315	140	500	683	160
2-Methylnaphthalene	20.2	201	470	--	469	560
Acenaphthene	6.71	88.9	1060	3500	1060	1320
Acenaphthylene	5.87	128	470	1900	470	640
Anthracene	46.9	245	1200	2100	1230	1580
Benz(a)anthracene	31.7	385	4260	5000	4260	5800
Benzo(a)pyrene	31.9	782	3300	7000	3300	4810
Benzo(b,k)fluoranthenes	--	--	11000	--	11000	14000
Benzo(g,h,i)perylene	--	--	4020	1200	4020	5200
Chrysene	57.1	862	5940	--	5940	6400
Dibenzo(a,h)anthracene	6.22	135	800	230	800	840
Fluoranthene	111	2355	11000	11000	11100	15000
Fluorene	21.2	144	1000	3600	1070	3000
Indeno(1,2,3-c,d)pyrene	--	--	4120	730	4120	5300
Naphthalene	34.6	391	500	37000	529	1310
Phenanthrene	41.9	515	6100	5700	6100	7600
Pyrene	53.0	875	8800	9600	8790	16000
LPAHs	--	--	6600	36000	6590	9200
HPAHs	--	--	31000	36000	31640	54800
Retene	--	--	--	--	6020	--
Carbazole	--	--	--	140	923	--
Dibenzofuran	--	--	400	2400	399	440
4-Methylphenol (p-cresol)	--	--	--	--	760	--
Benzoic Acid	--	--	--	--	2910	--
Bis(2-ethylhexyl)phthalate	--	--	230	635	2520	320

Parameter	TEL[1]	PEL[1]	SQS[3]	PAET[2]	LAET[3]	CSL[3]
Butylbenzyl Phthalate	--	--	260	--	260	370
Dimethyl Phthalate	--	--	46	--	311	440
Di-n-butyl Phthalate	--	--	--	42	103	--
Di-n-octyl Phthalate	--	--	26	--	11	45
Phenol	--	--	--	48	--	--
4,4’-DDD	3.54	8.51	--	--	96	--
4,4’-DDE	1.42	6.75	--	--	21	--
4,4’-DDT	1.19	4.77	--	--	19	--
Chlordane	4.5	8.87	--	--	--	--
Dieldrin	2.85	6.67	--	--	--	--
Endrin	2.67	62.4	--	--	--	--
Lindane	0.94	1.38	--	--	--	--
Heptachlor Epoxide	0.6	2.74	--	260	--	--
Toxaphene	0.1	--	--	--	--	--
Aroclor 1248	--	--	--	21	--	--
Aroclor 1254	60	340	--	7.3	230	--
Total PCBs	34.1	277	60	21	62	120
Ammonia	--	--	--	340	--	--
Sulfides	--	--	--	127	702	--
Total Organic Carbon	--	--	--	7.1	9.82	--

Units: Metals and Sulfides in mg/kg dw, Organics in µg/kg dw, Butyltins in µg/kg ion, and Total Organic Carbon in %.
Modified from CCME, 1999[1], and Ecology, 2002[2] & 2003[3].