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Survey of Potential Hanford Site Contaminants in the Upper Sediment for the Reservoirs at McNary, John Day, The Dalles, and Bonneville Dams, 2003

February 2005

A Cooperative Environmental Monitoring Project of:

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Hanford Site Surface Environmental Surveillance Project
Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

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Summary

Staff from the Oregon Department of Energy (ODOE) (representing the Oregon Hanford Waste Board) met with representatives of the Washington Department of Health (DOH) in the spring of 2003 and requested that an environmental survey of the upstream pools of the four lower Columbia River dams, (McNary Dam, John Day Dam, The Dalles Lock and Dam, and Bonneville Dam) be conducted.

In July of 2003, Washington Departments of Health and Ecology met with the U.S. Department of Energy (U.S. DOE) and U.S. DOE's contractor Pacific Northwest National Laboratory (PNNL) to discuss this effort. It was agreed to collect sediment samples and adjacent beach sediment (where available) from each pool. In addition, river water samples would be collected at McNary Dam. The results from this study were compared to background values from sediment and water samples collected from the pool upstream of Priest Rapids Dam (upstream of the Hanford Site) by the Hanford Site Surface Environmental Surveillance Project (Poston et al. 2003). Samples were analyzed for radionuclides, chemicals, and physical parameters. In addition, sediment porewater (i.e. the water associated with the sediments) bioassays were conducted. This report presents the results from this multi-agency study.

Abstract

In the summer of 2003, staff from the Oregon Department of Energy (ODOE) (representing the Oregon Hanford Waste Board) met with representatives of the Washington Department of Health, Washington Department of Ecology, U.S. DOE, and U.S. DOE's contractor Pacific Northwest National Laboratory. At the request of Oregon, the Washington agencies and U.S. DOE agreed to conduct a multi-agency cooperative environmental surveillance study of the four pools (McNary Dam, John Day Dam, The Dalles Lock and Dam, and Bonneville Dam) that are downriver from Hanford Site operations. Sediment samples and adjacent beach sediment (where available) were collected from each pool. In addition, river water samples were collected at McNary Dam. Results from this study were compared to background values from sediment and water samples collect from the pool upstream of Priest Rapids Dam (upstream of the Hanford Site) by the Hanford Site Surface Environmental Surveillance Project (Poston et al. 2003). Samples were analyzed for radionuclides, chemicals, and physical parameters. In addition, sediment porewater (i.e., the water associated with the sediments) bioassays were conducted. This report presents the results from this multi-agency study.

Sediment was readily available at the McNary, John Day, and The Dalles dams; however, there was only limited sediment available at Bonneville Dam. Beach sediment was limited in the sections of the lower reservoirs adjacent to the sampling locations with sediment only available at McNary Dam and at the mouth of Eagle Creek near Bonneville Dam. In general, the river sediment samples were composed primarily of very fine sand, silt, and clay, whereas the beach sediment was composed primarily of medium and coarse sand.

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The authors would like to acknowledge Ken Niles (Oregon Department of Energy), Lynn Albin (Washington State Department of Health), and Robert Fulton (Pacific Northwest National Laboratory) for their assistance in collecting river sediment and water samples. Larry Gadbois (U.S. Environmental Protection Agency) observed the sediment sampling at the John Day Dam and provided peer review comments for this report. Lynn Albin coordinated analytical support for the samples analyzed by the Washington State Department of Health. Erwin Schutfort of Oregon State University provided analytical support for the samples analyzed by the Oregon Department of Energy. Brenda Lasorsa (Pacific Northwest National Laboratory) coordinated analytical support for the non-radiological samples analyzed by Pacific Northwest National Laboratory. Lynn Bisping (Pacific Northwest National Laboratory) provided support for all sample scheduling, generation of sample custody sheets and labels, and database support. Dana Ward (DOE Richland Operations Office), Debra McBaugh (Washington State Department of Health), and Ted Poston (Pacific Northwest National Laboratory) provided input to the sampling design during the initial coordination meeting. Launa Morasch and Jo Lynn Draper (Pacific Northwest National Laboratory) provided editorial support and Kathy Neiderhiser provided text processing. Kristin Felix (Washington State Department of Health) and Eileen Kramer (Washington State Department of Health) provided editorial support.

Contents

Summary iii

Abstract iii

Acknowledgments v

1.0 Introduction 1

2.0 Objectives 3

3.0 Experimental Methods 3

3.1 Sample Locations 3

3.2 Contaminants of Concern 5

3.3 Sample Collection 5

3.4 Radiological and Chemical Analysis 7
3.4.1 Radiological 7
3.4.2 Metals 7
3.4.3 Grain Size and Total Organic Carbon Assays 7
3.4.4 Pesticides 7
3.4.5 Polychlorinated Biphenyls 7
3.4.6 Semi-Volatile Organic Compounds 7
3.4.7 Bioassays 8

4.0 Results and Discussion 8

4.1 Columbia River and Beach Sediment 8
4.1.1 Radiological Results 8
4.1.2 Chemical Results 18
4.1.3 Microtox® and *Daphnia* IQ Toxicity Test 26

4.2 Radionuclides in Columbia River Water 28

5.0 Conclusions 29

6.0 References 30

Figures

1 Map of Sediment Sampling Locations. 4

2 Potassium-40 in Columbia River Sediment..... 10

3 Cobalt-60 in Columbia River Sediment. 11

4 Strontium-90 in Columbia River Sediment. 14

5 Cesium-137 in Columbia River Sediment..... 15

6 Europium-152 in Columbia River Sediment 16

7 Total Uranium in Columbia River Sediment..... 17

8 Plutonium-239/240 in Columbia River Sediment. 19

9 Concentrations of Metals in Columbia River Sediment 20

10 Average Simultaneously Extracted Metals/Acid Volatile Sulfide Concentrations in Columbia River Sediment. 22

11 Sediment Grain Size Distribution for Columbia River Sediment. 24

12 Sediment Grain Size Distribution for Columbia River Beach Sediment..... 25

13 Total Organic Carbon Content for Columbia River Sediment. 26

14 Relationship Between *Dapnia* IQ Test Results for Sediment Porewater and Average Acid Volatile Sulfide Concentrations in Associated Sediments. 28

Tables

1 Sediment Sampling Locations, 2003 4

2 Locations Where Sediment Samples were Successfully Collected 9

3 Median Effective Dose for Microtox® and *Daphnia* IQ Toxicity Tests..... 27

1.0 Introduction

As a result of past Hanford Site operations, large quantities of radioactive materials and chemicals were discharged to the Columbia River. Some of these materials deposited on the riverbed as sediment. Fluctuations in the river stage from dam operations, high river flows during the spring runoff period, and occasional floods have resulted in resuspension, transport, and redeposition of the sediment material. The largest releases of radioactivity and chemicals to the Columbia River occurred from 1956 to 1965 when the single-pass (i.e., Columbia River water was used for direct cooling) nuclear reactors were operating at Hanford (HEDR 1994; DOE 2002). Since the shutdown of the single-pass reactors in the early 1970s, the contaminant burden in the surface sediments has been decreasing as a result of radioactive decay and the subsequent deposition of uncontaminated sediment (Cushing et al. 1981). Radionuclides with long half lives deposited during the operational period of the single pass reactors are still present in the deep sediment of the lower reservoirs and are now covered with layers of more recently deposited sediment. Currently, the upper layer sediments in the Columbia River contain low concentrations of radionuclides and chemicals of Hanford Site origin as well as radionuclides from nuclear weapons testing fallout and chemicals from multiple non-Hanford sources (Beasley et al. 1986; Robertson and Fix 1977; Woodruff et al. 1992; Blanton et al. 1995; DOE 1998; Gibbons 2000). Potential public exposures to radionuclides in surface sediment layers are below the level at which routine surveillance of Columbia River sediments are required (Sula 1980; Wells 1994). However, annual sampling is conducted by the Hanford Site Surface Environmental Surveillance Project and the Washington Department of Heath (DOH) to confirm the low levels and to ensure that no significant changes have occurred for this pathway (Poston et al. 2003; Wells 1994). This annual sampling is conducted at Priest Rapids Dam (upstream from Hanford), at sediment accumulation locations in the Hanford Reach, and at McNary Dam.

The Oregon Health Division conducted environmental sampling at eleven locations from McNary Dam to Astoria on the Columbia River from 1961 to 1993. Sampling included water, river sediment, aquatic vegetation, and fish. Measured levels of radioactive materials were below then-recommended federal and international standards (OHD 1994). Peak concentrations of radioactive materials were detected in the mid-1960s, when Hanford's nine reactors were operating. Radioactivity levels in the Columbia River measured by the Oregon Health Division dropped dramatically following the shutdown the last single-pass reactor. At the time sampling ended, the Oregon Health Division noted "there was no Hanford radioactivity detectable in the Columbia River or the Oregon seacoast" (OHD 1994). In 2003, the Oregon Hanford Waste Board (an advisory board to the Governor and the Legislator of Oregon) issued a report entitled *River Without Waste* that included recommendations for Columbia River protection (OHWB 2002). One of the recommendations was to resume limited radiological monitoring of the Columbia River, downstream of the Washington border, to ensure that potential contaminants from the Hanford Site do not reach Oregon undetected.

In the summer of 2003, staff from the Oregon Department of Energy (ODOE) (representing the Oregon Hanford Waste Board) approached DOH and expressed an interest in environmental monitoring of surface sediment in the Columbia River, behind the four pools (McNary Dam, John Day Dam, The Dalles Lock and Dam, and Bonneville Dam) that are downriver from Hanford Site operations. Staff from DOH organized a meeting between those two agencies and representatives of the Washington Department of

Ecology, U.S. DOE, and U.S. DOE's contractor Pacific Northwest National Laboratory. At the request of Oregon, the Washington agencies and U.S. DOE agreed to conduct a multi-agency cooperative environmental surveillance study of surface sediment from the four pools on the lower Columbia River (Figure 1). Sediment samples and adjacent beach sediment (where available) were collected from each pool. In addition, river water samples were collected at McNary Dam. Samples were analyzed for radionuclides, chemicals, and physical parameters. In addition, sediment porewater (i.e., water associated with the sediment) bioassays were conducted. The study was conducted in August 2003 with additional sampling and analysis planned in 2004.

Background on Contaminants of Concern

Radionuclides typically observed in river sediment have three sources: natural occurring (potassium-40, uranium), atmospheric fallout (cobalt-60, strontium-90, cesium-137, uranium, plutonium), and potential Hanford releases (cobalt-60, strontium-90, cesium-137, europium, uranium, plutonium).

Metals measured in this study have both natural and man-made sources (e.g. upriver mining operations). Many metals are essential nutrients at trace levels and are required for the survival of river flora and fauna. However, elevated levels of metals can cause a wide range of toxic effects. In addition, selected environmental conditions can result in metals combining with other chemicals to form compounds which alter their bioavailability and toxicity (e.g., methylmercury, dimethyarsenic, arsenocholine, arsenosugars). Chemicals containing trace metals were used and discharged in past Hanford Site reactor and chemical processing operations, or have been identified as contaminants of concern as part of site restoration studies because they were suspected of being used and disposed of in the environment. Chromium was used extensively at the Hanford Site. In the 100 Area reactors, sodium dichromate was added to cooling water as a corrosion inhibitor. Residual chromium in soil and groundwater has been found through recent remediation efforts. Chromium was also used for decontamination in the 100, 200, and 300 Areas and for oxidation-state control in the Reduction-Oxidation Plant process. Hexavalent chromium is highly mobile in the groundwater and has been measured in near-shore groundwater wells and Hanford Site riverbank springs (Poston et al. 2003).

The lower Columbia River sediment contains pesticide residues because of their extensive use in Washington and Oregon agriculture. Following World War II, pesticide use on field and tree crops in Washington increased dramatically. In 1992, there were about 35,500 commercial farms in Washington State, with ~$178 million invested in the application of pesticides (Washington Agricultural Statistics Service 1994). Pesticides were routinely detected in groundwater samples in Washington State are Dacthal (DCPA); 1,2-dichloropropane, atrazine, simazine, ethylene dibromide (EDB); 1,2-dichloropropane (DCP); and dibromochloropropane (DBCP) (Washington State Department of Ecology 1996). The Hanford Site is not considered to be an important source of pesticides to the Columbia River because pesticide usage was limited compared to the large agricultural usage in the region.

Polychlorinated biphenyls (PCBs) were widely used in electrical equipment such as capacitors and transformers. PCBs are persistent in the environment and tend to bioaccumulate. They can cause damage to the liver and reproductive systems and are suspected of being carcinogenic. PCBs have been shown to be widely distributed in the environment (Erickson 1997). The largest potential Hanford source is from hydraulic fluids from the Hanford Plutonium Finishing Plant; however, the Hanford Site is not considered

to be a significant source of PCBs in the Columbia River since these compounds have not been routinely detected in Hanford Site groundwater. Historic regional use of PCBs and atmospheric deposition in the Columbia River basin air shed are the most likely source of PCBs in Columbia River sediment (Patton et al. 1994; Patton et al. 1997a; Patton et al. 1997b).

Other organic compounds currently found in Hanford Site groundwater came from waste sites, contaminated soils, and from the large volume of liquid effluents discharged to cribs and trenches during reactor operations. Some organic contaminants continue to migrate into the groundwater and may eventually reach the Columbia River; however, for most compounds, this process has slowed because the major driving force (discharge of liquid effluents to the ground) has ended. Most organic compounds of interest in Hanford Site groundwater are volatile organic compounds (typically organic solvents) which would have little tendency to accumulate in river sediment. A suite of semi-volatile compounds was analyzed for this study because some were detetected in fish tissues in the Columbia River basin (EPA 2002). Semi-volatile compounds detected in fish tissues included guaicols, ethers, phenols, and polycyclic aromatic hydrocarbons (PAHs). The Hanford Site is not considered to be a significant source of semi-volatile organic compounds in the Columbia River since these compounds have not been routinely detected in Hanford Site groundwater (Poston et al. 2003). Regional use of semi-volatile organic compounds and atmospheric deposition in the Columbia River basin air shed are the most likely source of semi-volatile organic compounds for Columbia River sediment (Patton et al. 1994; Patton et al. 1997b).

2.0 Objectives

The objectives of this study were to characterize the radiological and chemical conditions existing in the upper-level sediment found in the pools upstream of McNary Dam, John Day Dam, The Dalles Lock and Dam, and Bonneville Dam. Additionally, this study evaluated beach sediment (where available). Water samples were collected at McNary Dam to assist in evaluating potential Hanford contaminants in the lower Columbia River. Water samples were limited to McNary Dam.

3.0 Experimental Methods

3.1 Sample Locations

Sampling locations are shown in Figure 1 and global positioning system (GPS) coordinates are provided in Table 1. Where available, a beach sediment sample was collected on each shore. For each location, an attempt was made to collect three “deep water sediment” samples from a transect line across the river channel. All sampling locations were identified using a GPS. River sediment samples were compared to upstream control reference data (i.e., sediment not influenced by Hanford operations) from previously collected Pacific Northwest National Laboratory (PNNL) and DOH sediment samples from the impoundments at Priest Rapids Dam (Columbia River) and Ice Harbor Dam (Snake River) (Bisping 2003; Poston et al. 2003).

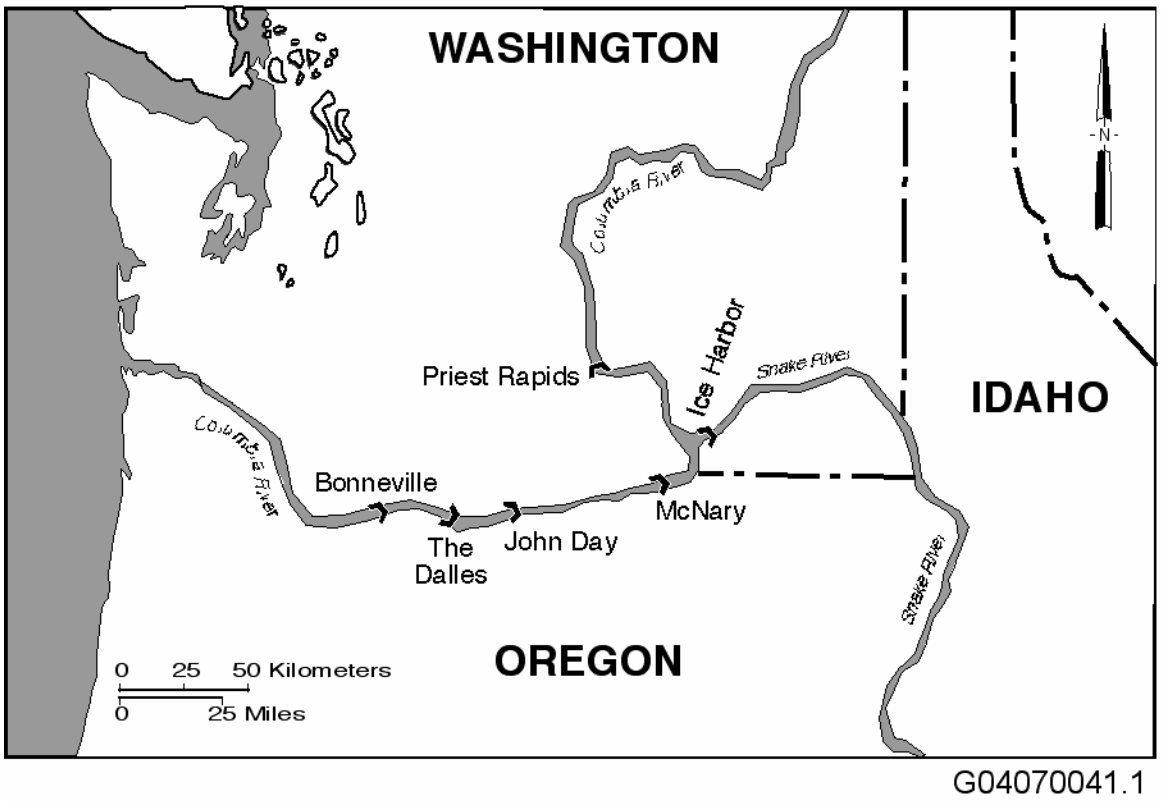


Figure 1. Map of Sediment Sampling Locations.

Table 1. Sediment Sampling Locations, 2003 (degrees_minutes.decimal minutes)

Impoundment	Location	Latitude	Longitude
Bonneville	OR Shore	45° 38.349’	121° 56.725’
	OR Beach	45° 34.477’	121° 55.952’
The Dalles	OR Shore	45° 37.340’	121° 06.796’
	WA Shore	45° 37.599’	121° 07.212’
John Day	OR Shore	45° 43.075’	120° 40.763’
	Midway	45° 43.250’	120° 40.836’
	WA Shore	45° 43.568’	120° 41.081’
McNary	OR Beach	45° 55.879’	119° 15.997’
	OR Shore	45° 55.999’	119° 15.562’
	2/3 From OR Shore	45° 56.545’	119° 15.388’
	WA Shore	45° 56.784’	119° 15.377’
	WA Beach	45° 56.775’	119° 14.692’

Bonneville Dam river sediment sampling was only successful on the Oregon side of the river between the ship lock and Bradford Island; attempts to collect sediment at mid-river and on the Washington side of Bradford Island were unsuccessful. Beach sediment was available only on the Oregon shore near the mouth of Eagle Creek. No beach sediment accumulation areas on the Washington shore were observed from the boat launch at Bridge of the Gods to the boat exclusion area at the dam.

The Dalles Lock and Dam river sediment samples were collected ~1.6 km upstream from the dam on the Oregon and Washington side of the river; no mid-river sediment was recovered despite multiple attempts with the sediment dredge. No beach sediment accumulation areas were observed on either shoreline from the boat launch at Horse Thief Lake State Park to the boat exclusion buoys at the dam.

John Day Dam river sediment samples were collected at a cross river transect ~1.6 km upstream of the dam, ~0.4 km upstream of the boat exclusion buoys. No beach sediment accumulation areas were observed on either shoreline from the boat launch at John Day River to the boat exclusion buoys at the dam.

McNary Dam river sediment samples were collected at a cross-river transect location, roughly 1.6 km upstream from the Oregon shore boat launch at McNary Dam. The McNary Dam sampling locations were used for routine sample collection by the Hanford Site Surface Environmental Surveillance Project and four cross-river locations were typically sampled (Poston et al. 2000). The names of the locations (beginning on the Oregon shore and moving to the Washington shore) are McNary OR Shore, McNary 1/3 OR Shore, McNary 2/3 OR Shore, and McNary WA Shore. Samples were not collected at McNary 1/3 OR Shore, because this study only required three sampling locations and McNary 2/3 OR Shore was used for the "mid-river" sample. Water samples were collected at the 2/3 OR Shore location. Beach sediment samples were collected on both the Oregon and Washington shores.

3.2 Contaminants of Concern

The radiological contaminants of concern for this study were strontium-90, gamma emitting radionuclides (primarily potassium-40, cobalt-60, cesium-137), europium, uranium, and plutonium. Radionuclides in river sediment have three sources: naturally occurring (potassium-40, uranium), atmospheric fallout (cobalt-60, strontium-90, cesium-137, uranium, plutonium), and potential Hanford releases (cobalt-60, strontium-90, cesium-137, europium-152, europium-154, europium-155, uranium-234, uranium-235, uranium-238, plutonium-238 and plutonium-239/240).

The chemical contaminants of concern were metals (Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, K, Se, Ag, Na, Tl, V, Zn and Hg), pesticides, PBCs, PAHs, semi-volatile organic compounds, simultaneously extracted metals/acid volatile sulfide (SEM/AVS; Cd, Cu, Hg, Ni, Pb, and Zn), and total organic carbon. In addition, samples from each location were analyzed for sediment grain size.

3.3 Sample Collection

Samples were collected according to the *Surface Environmental Surveillance Procedures Manual* (PNNL 2003). Samples of the upper sediment layer were collected with a petite Ponar dredge. The dredge has a 235-cm^2 opening and collects sediment to a maximum depth of 15 cm. The dredge has a pair of weighted

jaws held open during descent to the sediment surface by tension from the retrieval cable to a catch bar. Upon contact with the sediment, the tension on the cable is released, the catch bar releases, and the overlapping jaws close. Upon retrieval, the tension on the cable keeps the jaws closed. A mesh screen with rubber flaps covers the upper portion of the dredge. The rubber flaps allow water to flow through the dredge during descent but close to minimize sediment losses during retrieval. Ponar dredges are suitable for most sediment types except for hard clays. Samples of beach sediment were collected using either the petite Ponar dredge or a large plastic scoop.

To allow for sufficient sample mass to meet the detection requirements for the various agencies and analytical tests, multiple deployments of the Ponar dredge were required. The sediment from each location was placed into a large plastic container lined with a clean plastic bag. The sediment was thoroughly mixed by hand and sample aliquots were transferred to containers appropriate for each agency's analytical requirements. At most locations, ~6 to 8 kg of sediment was collected. For most samples, doubled plastic bags provided a suitable container. Samples for SEM/AVS assays are extremely sensitive to air; thus, bottles for these samples were rapidly filled with sediment taken from a single Ponar dredge sample. All non-radiological sediment samples were placed into ice-filled coolers. Chain-of-custody documentation and labels were provided by PNNL and samples were sealed with evidence tape. Geographic positioning system coordinates were collected for each location. Sediment samples were distributed among the groups according to the interests of the specific agencies and the availability of specialized analytical recourses. To aid in evaluating laboratory performance, multiple groups analyzed samples for some analytes (e.g., gamma-emitting radionuclides).

Water samples were collected according to the *Surface Environmental Surveillance Procedures Manual* (transect water-sampling procedure; PNNL 2003). All water samples were unfiltered and analyzed for strontium-90, and selected samples were analyzed for gamma-emitting radionuclides, isotopic uranium, and isotopic plutonium.

The quality assurance and quality control process for the sampling and analytical process is described in Appendix A.

3.4 Radiological and Chemical Analysis

3.4.1 Radiological

DOH samples for radiological constituents were analyzed at their laboratory in Shoreline, Washington. Oregon DOE samples for gamma-emitting radionuclides were analyzed by the Oregon State University (Corvallis, Oregon). PNNL samples for radiological analysis were conducted by the Severn Trent Laboratories (Richland, Washington).

3.4.2 Metals

The Washington State Department of Ecology samples for metals were analyzed through their contract labs. Total metals were analyzed by U.S. Environmental Protection Agency (EPA) SW-846 method 6010. Mercury was analyzed separately by EPA SW-846 Method 7470. EPA Method SW-846 7196 was used for analysis of sediment samples for hexavalent chromium at the Washington State Department of Ecology's contract laboratory.

PNNL samples for metals and SEM/AVS were analyzed at the Sequim Marine Sciences Facility (Sequim, Washington) using the methods described in Patton and Crecelius (2001).

3.4.3 Grain Size and Total Organic Carbon Assays

PNNL samples for sediment grain size distributions were analyzed at the Sequim Marine Sciences Facility using an analytical subcontract with Columbia Analytical Services (Kelso, Washington). PNNL samples for total organic carbon content were analyzed by the Severn Trent Laboratories (Saint Louis, Missouri) using EPA SW 846 Method 9060.

3.4.4 Pesticides

Twenty-one pesticides were extracted using EPA SW 846 Method 3540C and analyzed using EPA SW 846 Method 8081A at the Washington State Department of Ecology's contract laboratory.

3.4.5 Polychlorinated Biphenyls (PCBs)

The Washington State Department of Ecology samples for PCBs were extracted using EPA SW 846 Method 3540C and analyzed by EPA SW- 846 Method 8082 at their contract laboratory.

3.4.6 Semi-Volatile Organic Compounds (Polycyclic Aromatic Hydrocarbons and Phthalates)

The Washington State Department of Ecology's contract analytical laboratory extracted the sediments using EPA SW 846 Method 3540C and then analyzed the extracts for 16 polycyclic aromatic hydrocarbons (PAHs) and three phthalate ester plasticizers using EPA SW-846 Method 8270.

3.4.7 Bioassays (Sediment Toxicity Tests)

The Microtox® and *Daphnia* IQ rapid toxicity tests for porewater (i.e., water associated with the sediment samples) derived from the sediment samples were performed by Aqua Survey, Inc. (Flemington, New Jersey) under subcontract to the Washington Department of Ecology. Toxicity tests were conducted for sediment samples collected from four dams on the lower Columbia River.

The Microtox® test measures reduction of bacterial luminescence (inhibition of luciferase) upon exposure to potential inhibitors, as an index of toxicity (Bulich 1979). The degree of light loss indicates the degree of toxicity. The test employs a lyophilized strain of marine luminescent bacteria, *Vibrio fischeri*, which is reconstituted. The toxicant concentration inhibiting luminescence by 50% [effective concentration; (EC_{50})] was determined for each sample with a control (2% NaCl) and four sample dilutions (5.62, 11.2, 22.5, and 45% v/v) after 5- and 15-minute exposure periods at 20°C. These tests were conducted on both filtered (0.2 µm) and non-filtered porewater samples.

The *Daphnia* IQ test measures inhibition of galactosidase, reducing in vivo cleavage of a fluorometric substrate, methylumbelliferyl (MUF) galactoside (Hayes et al. 1993; Janssen and Persoone 1993). Galactosidase is a vital enzymatic system in the aquatic invertebrate *Daphnia magna.* Inhibited enzymatic activity, measured by fluorescence, can be used as an index of toxicity. EC_{50} values were determined for each sample with a control (EPA moderately hard reconstituted water) and five sample dilutions (6.25, 12.5, 25, 50, and 100% v/v) after a 1-hour exposure to the sample at 20°C, followed by an additional 15-minute exposure to the MUF galactoside substrate. These tests were conducted in triplicate using non-filtered sediment porewater samples.

4.0 Results and Discussion

4.1 Columbia River and Beach Sediment

The following section describes the results for Columbia River sediment and Columbia shoreline beach sediment that were analyzed for radionuclides, chemicals, and sediment grain size distributions.

4.1.1 Radiological Results

Sediment samples collected by the DOH and PNNL were analyzed for gamma-emitting isotopes, uranium, plutonium, and strontium-90. Samples collected for the Oregon DOE were analyzed for gamma-emitting isotopes. All results are reported on a dry weight basis and are presented in Appendix B, Table B.1.

The field team attempted to collect samples at all scheduled locations; however, the absence of sediment at several locations made it impossible to collect all samples. Locations where sediment samples were successfully collected are listed in Table 2.

Table 2. Locations Where Sediment Samples were Successfully Collected

Location	Oregon Beach	Oregon Near Shore	Mid-River	Washington Near Shore	Washington Beach
Bonneville	X	X			
The Dalles		X		X	
John Day		X	X	X	
McNary	X	X	X	X	X
X = Sediment was collected. Blanks = No sediment was available.					

In general, radionuclides of Hanford origin would be indicated by a particular trend in that nuclide's concentrations in river sediment. Material of Hanford origin is likely indicated by a rise in concentration above the concentration measured at the Priest Rapids Dam background location, peaking at the McNary Dam pool (closest downstream sediment reservoir to the Hanford Site), and gradually declining in the lower reservoirs due to dilution from other sediment sources.

In the below analysis, the concentrations of radionuclides in beach sand have been excluded from the discussion because the mechanisms for concentrating radionuclides in the sand might be different from those of river sediment. The radionuclide concentrations for beach sand samples are recorded in Appendix B, Table B.1.

No federal or state freshwater sediment criteria for radionuclides are available to assess the sediment quality of the Columbia River (EPA 822-R-96-001).

4.1.1.1 Potassium-40 (130,000,000 yr half-life)

Naturally-occurring potassium-40 was present at levels above detection in all sediment samples taken by each agency. The highest concentration in sediment from the river was 18.7 pCi/g (Oregon DOE) near the Oregon shore at the John Day Dam and the lowest concentration, 8.2 pCi/g (DOH), was found in Bonneville Dam sediment near the Oregon shore (Figure 2). Background sediments collected upriver from the Priest Rapids Dam contained 12.3 pCi/g and 12.2 pCi/g in the sediment from the Grant County and Yakima County sides of the river, respectively. Generally the concentration of potassium-40 remained constant downriver with no discernable cross-river pattern.

4.1.1.2 Cobalt-60 (5.3 yr half-life)

Cobalt-60 was detected in some of the sediment samples collected. All three agencies analyzed sediment samples for cobalt-60. The highest concentration of cobalt-60, 0.08 pCi/g (Oregon DOE) was found for sediment from the McNary pool (McNary 2/3 OR Shore; Figure 3). Cobalt-60 in sediment samples from the background location at Priest Rapids Dam were below a nominal detection limit of 0.02 pCi/g. No particular trend was seen in concentrations downstream or laterally across the impoundments.

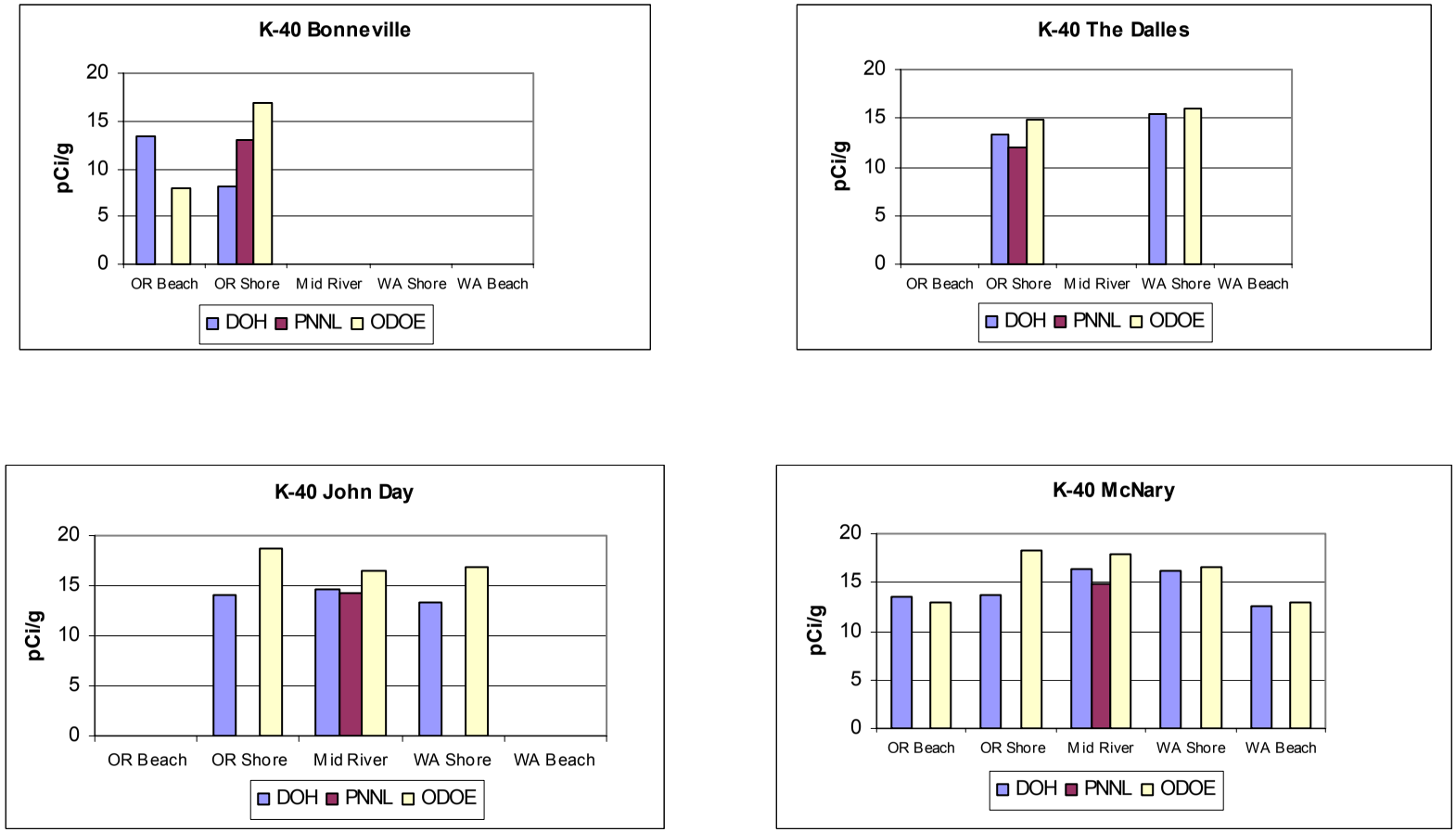
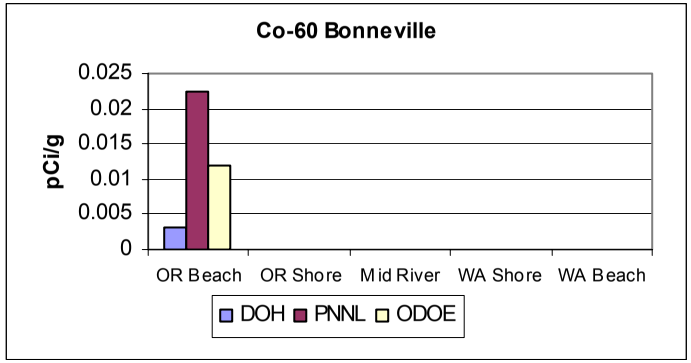
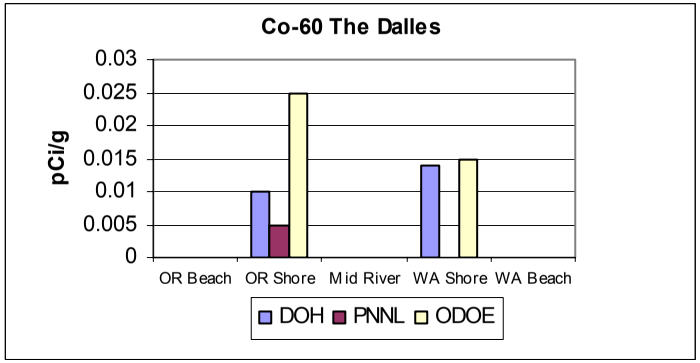
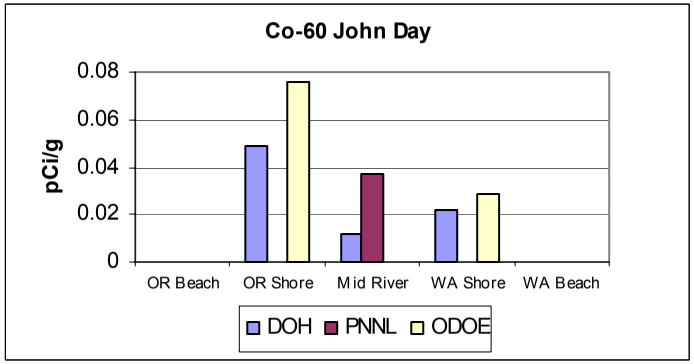


Figure 2. Concentrations of Potassium-40 in Columbia River Sediment, 2003. All values for potassium-40 were above detection limits. Potassium-40 concentrations for sediment from the pool upstream from Priest Rapids Dam were 12.2 ± 1.6 and 12.3 ± 1.6 pCi/g (PNNL).







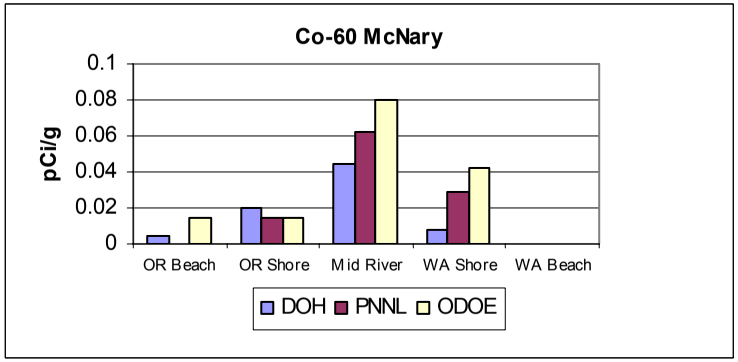


Figure 3. Concentrations (pCi/g dry wt.) of Cobalt-60 in Columbia River Sediment, 2003. All PNNL values were below a nominal detection limit of 0.06 pCi/g, except for McNary Dam mid-river. Some DOH values were below a nominal detection limit of 0.01 pCi/g. All ODOE results were greater than the associated 3-sigma counting errors. Cobalt-60 concentrations for sediment from the pool upstream from Priest Rapids Dam were below the detection limit; -0.003 ± 0.012 and 0.004 ± 0.011 pCi/g (PNNL).

4.1.1.3 Strontium-90 (29.1 yr half-life)

Strontium-90 was detected in most of the sediment samples analyzed by DOH, whereas most sediment samples analyzed by PNNL were reported as undetected. The DOH had a lower limit of detection for strontium-90 in sediment samples than PNNL. The highest detectable concentration of strontium-90 (0.032 pCi/g, DOH) in sediment was found on the Oregon side of the John Day Dam pool. The background samples analyzed by PNNL from Priest Rapids contained 0.00326 ± 0.021 and 0.0104 ± 0.024 pCi/g of strontium-90 (Figure 4), with both values reported as undetected by the analytical laboratory. Again, no particular trend was seen in concentrations downstream or laterally across the impoundments.

The Hanford Site Surface Environmental Surveillance Project and the Washington Department of Health collect annual sediment samples from Priest Rapids Dam, the Hanford Reach, and McNary Dam sediment basins. Strontium-90 concentrations were below the detection limits for most sediment samples for years 2000 to 2002 (Poston et al. 2003), with no obvious differences in concentrations for strontium-90 between upriver and downriver locations.

4.1.1.4 Cesium-137 (30 yr half-life)

Cesium-137 was present at levels above detection in all of the river sediment samples. Values for cesium-137 ranged from 0.094 (DOH, Bonneville OR Shore) to 0.63 pCi/g (ODOE, John Day OR Shore) (Figure 5). There was no discernable pattern to the distribution of cesium-137 laterally across the river. Typically the concentrations of cesium-137 in sediment for the lower Columbia River were higher than the background location, indicating a possible Hanford contribution. The background concentration of cesium-137 in river sediment at the Priest Rapids Dam pool ranged from 0.285 to 0.324 pCi/g.

4.1.1.5 Europium-152 (13.3 yr half-life)

Europium-152 was detected in river sediment by PNNL and DOH. Europium-152 concentrations detected downstream from Hanford ranged from below detectable limits on the Oregon side of McNary Dam to 0.286 pCi/g mid-river (2/3 OR Shore) at the McNary Dam (Figure 6). The background samples analyzed by PNNL at the Priest Rapids Dam pool ranged from 0.009 to 0.026 pCi/g, with both values reported as undetected by the analytical laboratory. In general, the concentrations of europium-152 downstream from the Hanford Site were slightly elevated, indicating a possible Hanford contribution.

4.1.1.6 Total Uranium [Sum of U-234 (240,000 yr half-life), U-235 (700,000,000 yr half-life), and U-238 (4,500,000,000 yr half-life)]

Isotopic uranium was measured in all sediment samples at levels above detection for both DOH and PNNL samples. The majority of the chemical mass of uranium was uranium-238. On an activity basis, the concentrations of uranium-234 and uranium-238 were similar. No enrichment of uranium-235 was observed, which would have indicated a possible Hanford signature. For river sediment the highest concentration of total uranium, 3.56 pCi/g (DOH), was found near the Washington shore of The Dalles Dam pool (Figure 7). The lowest total uranium concentration, 0.9 pCi/g (DOH), was found near the Oregon shore of the Bonneville impoundment. The concentration of total uranium in river sediment upriver from the pool at Priest Rapids Dam ranged from 1.3 to 1.4 pCi/g (PNNL data from Appendix B,

Table B.1). Total uranium concentrations downstream were fairly constant. For most samples analyzed for total uranium, the values for the DOH were higher than the values reported by PNNL. This difference in total uranium concentrations may be the result of differences in the extraction processes.

4.1.1.7 Isotopic Plutonium [Plutonium-238 (87.7 yr half-life) and Plutonium-239/240 (24,000 yr and 6,500 yr half lives)]

DOH and PNNL analyzed sediment samples for isotopic plutonium. Plutonium-238 concentrations were below DOH's low limit of detection (0.03 pCi/g) for all samples. Plutonium-238 was reported above the detection limit for 3 of 5 samples analyzed by PNNL, with detected values ranging from 0.00027 to 0.00053 pCi/g. The highest concentration of plutonium-238 was reported for the mid-river sample at McNary Dam (2/3 from Oregon shore). The maximum concentration of plutonium-238 was detected in river sediment upriver from Priest Rapids Dam 0.00064 pCi/g, which was slightly higher that the maximum value measured for McNary Dam.

Plutonium-239 and plutonium-240 are not resolved by the analytical method and are reported as combined plutonium-239/240 activity. Plutonium-239/240 was found in river sediment at levels above the detection limits for most of the samples collected. The highest concentration of plutonium-239/240 was 0.049 pCi/g (DOH) and was found in river sediment near the Washington shore of The Dalles Dam pool (Figure 8). Plutonium-239/240 levels in sediment at Priest Rapids Dam ranged from 0.0095 to 0.0116 pCi/g.

At all locations with detectable values, plutonium-238 concentrations were typically an order of magnitude below the plutonium-239/240 concentrations.

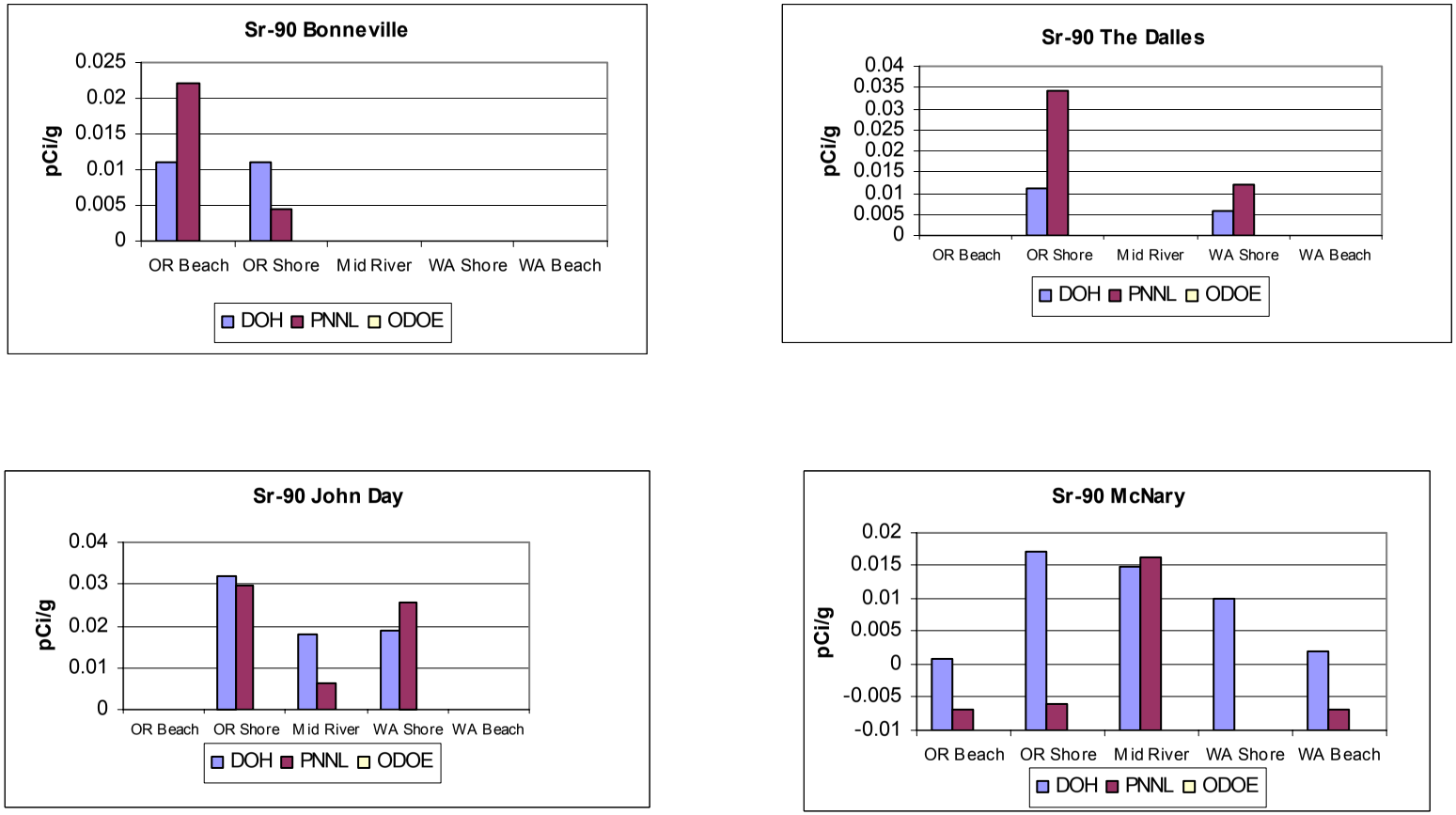
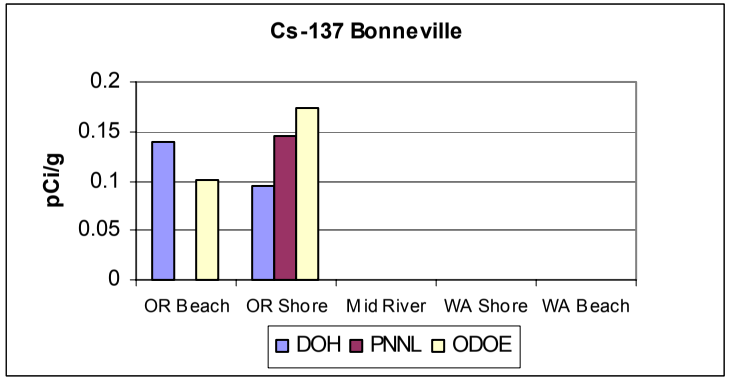
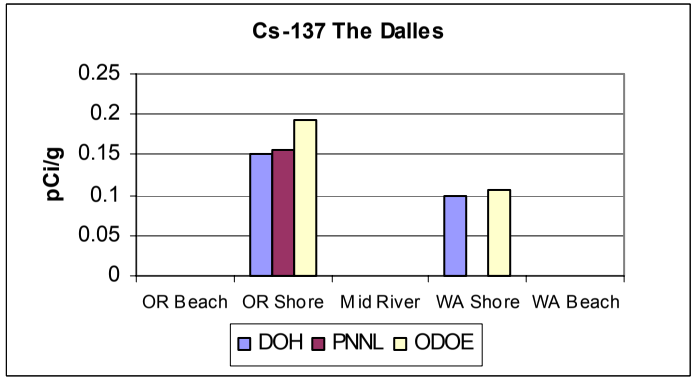
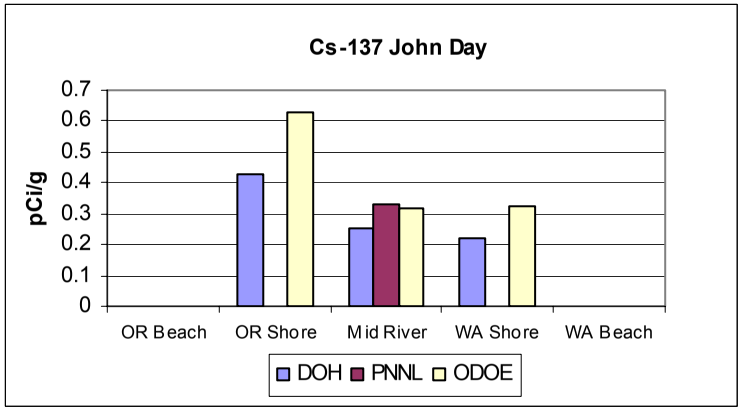


Figure 4. Concentrations of Strontium-90 in Columbia River Sediment, 2003. All DOH results for river sediment were above the detection limit. All PNNL results were below a nominal detection limit of 0.04 pCi/g; except for John Day OR shore which had a value of 0.030 ± 0.018 pCi/g. Strontium-90 concentrations for sediment by PNNL from the pool upstream from Priest Rapids Dam were below the detection limit; 0.0033 ± 0.021 and 0.010 ± 0.024 pCi/g.







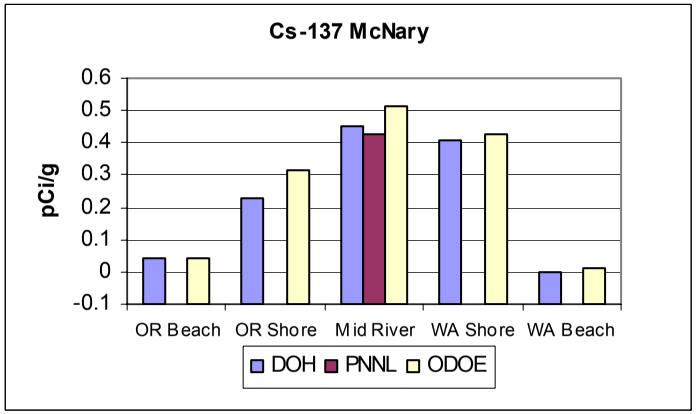
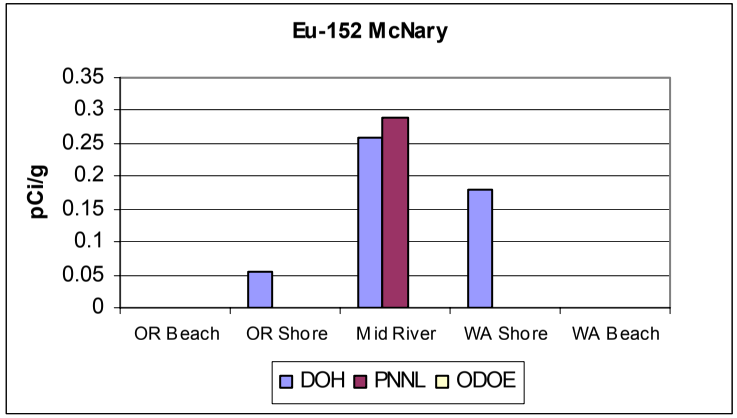
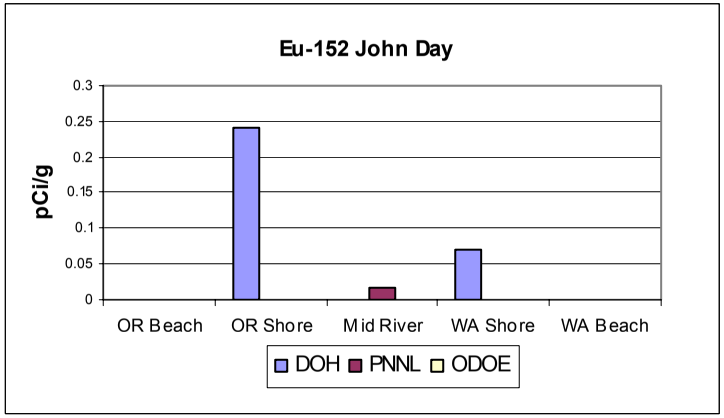
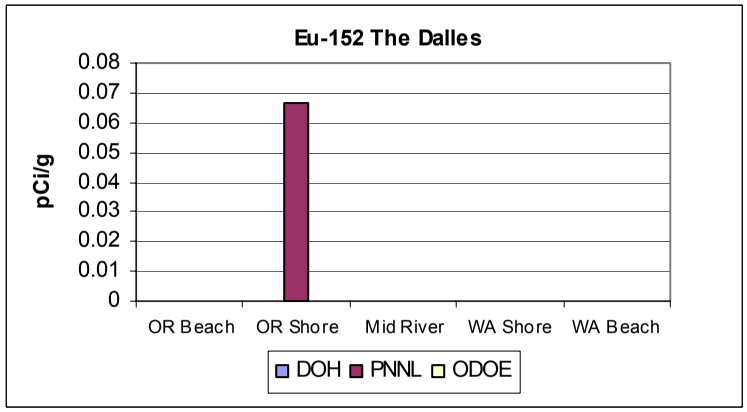


Figure 5. Concentrations of Cesium-137 (pCi/g dry wt.) in Columbia River Sediment, 2003. All values for river sediment were above detection limits. Cesium-137 concentrations for sediment from the pool upstream from Priest Rapids Dam were 0.285 ± 0.041 and 0.324 ± 0.048 pCi/g (PNNL).







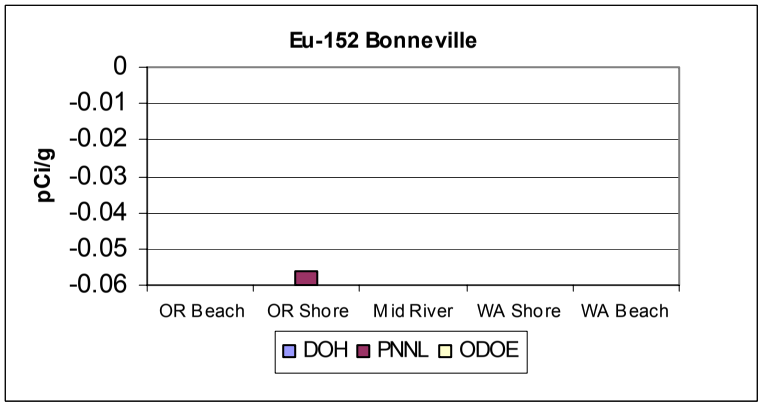


Figure 6. Concentrations of Europium-152 (pCi/g dry wt.) in Columbia River Sediment, 2003. All DOH values were above the detection limit. All PNNL values were below a nominal detection limit of 0.15 pCi/g, except for McNary Dam mid-river. Europium-152 concentrations for sediment from the pool upstream from Priest Rapids Dam were below the detection limit with values of 0.0095 ± 0.027 and 0.026 ± 0.032 pCi/g (PNNL).

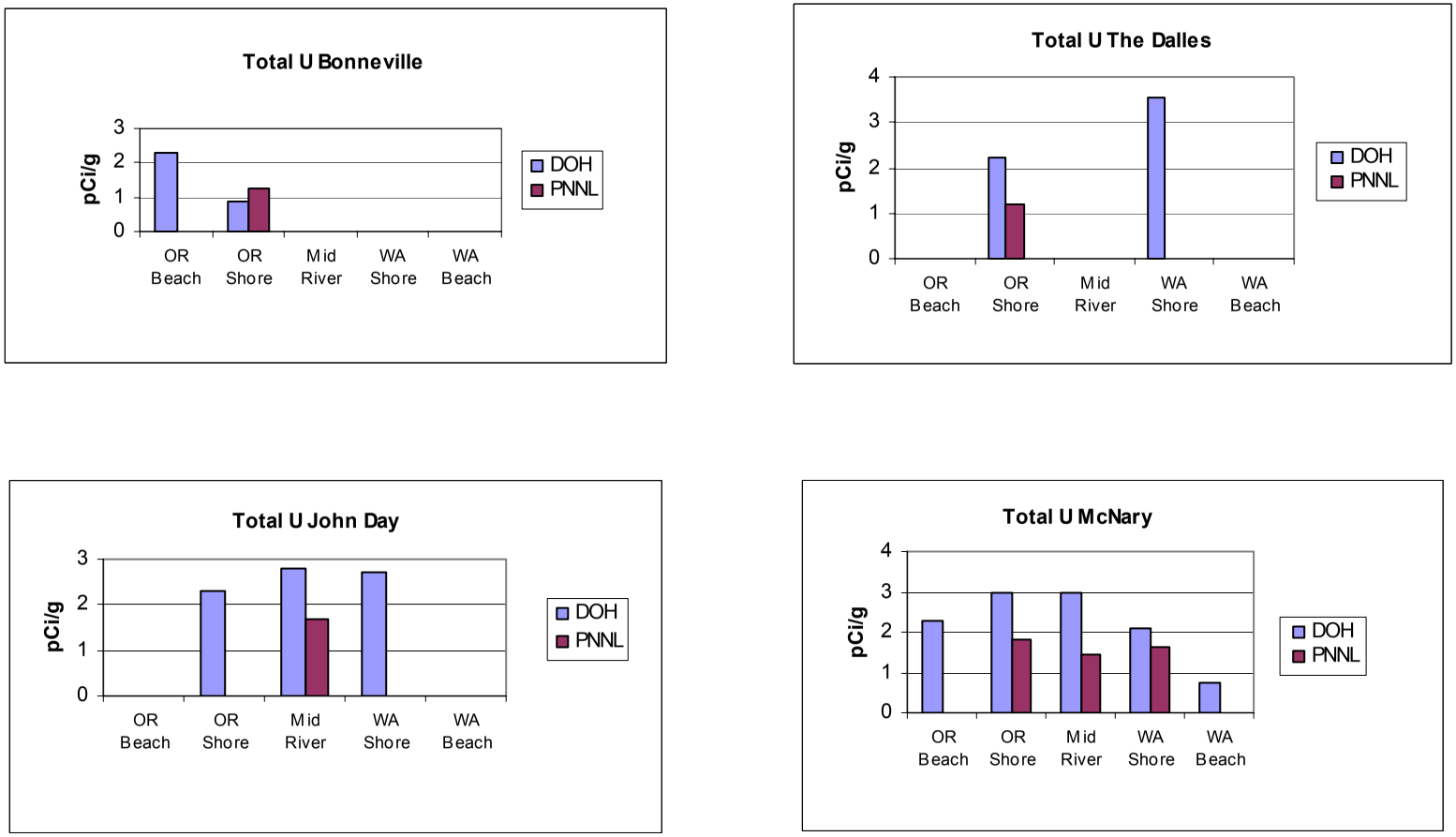


Figure 7. Concentrations (pCi/g dry wt.) of Total Uranium (U-234 + U-235 + U-238) in Columbia River Sediment, 2003. All values for river sediment were above detection limits. Total uranium concentrations for sediment from the pool upstream from Priest Rapids Dam were 1.26 ± 0.16 and 1.41 ± 0.016 pCi/g (PNNL).

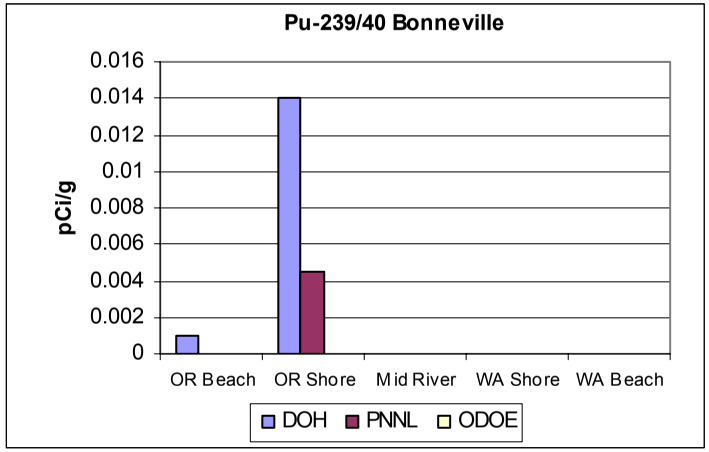
4.1.2 Chemical Results

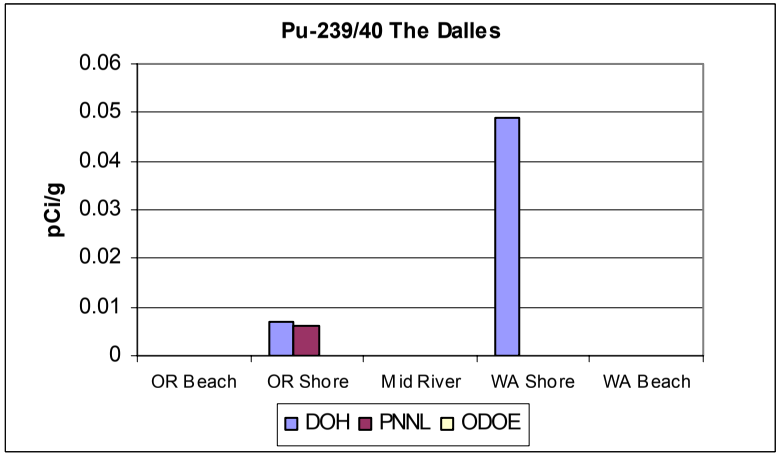
Sediment samples collected by the Washington State Department of Ecology and PNNL were analyzed for organic compounds (pesticides, PCBs, and semi-volatiles), metals (including hexavalent chromium), SEM/AVS, sediment grain size distributions, and total organic carbon content. In addition, sediment porewater was used to conduct two bioassay evaluations.

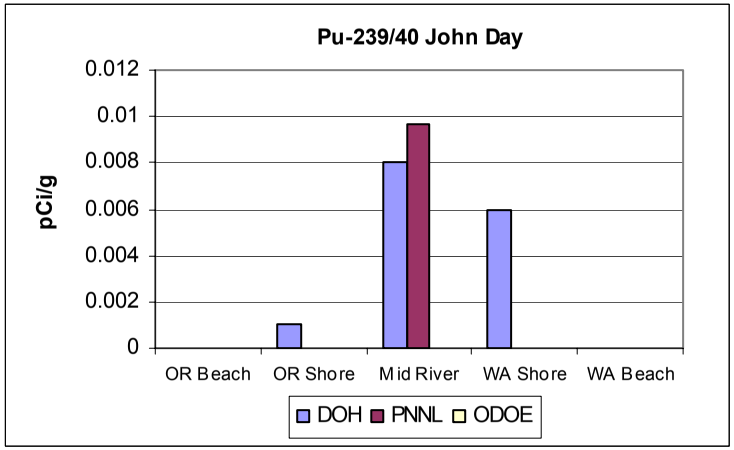
In 2002, the Washington State Department of Ecology embarked on a project to identify, update, and ultimately select freshwater sediment quality values (SQVs) for use in the Washington State Department of Ecology's sediment management programs. The first phase of this effort was completed in December 2002 (SAIC and Avocet 2002) and included compilation of existing freshwater SQVs in North America and an assessment of their reliability in predicting effects in Washington State. The results of this work indicated that additional Phase II work was needed to update existing freshwater apparent effects thresholds (AETs) and calculate more reliable SQVs for Washington State, as none of the existing guidelines were adequately predictive of toxicity in the Washington State data set. In 2003, the Washington State Department of Ecology proposed freshwater sediment quality criteria for selected chemical contaminants for Washington State (Michelsen 2003). Where applicable, sediment concentrations will be compared to the proposed sediment quality criteria. The Washington State proposed SQVs are provided for metals in Appendix B, Table B.2 and for semi-volatile organics in Appendix B, Table B.5.

4.1.2.1 Metals

Detectable amounts of most metals were found in river and beach sediment samples analyzed by WDOE and PNNL (Figure 9 and Appendix B, Table B.2) The metal concentrations reported for this study were similar to previously reported values (Patton and Crecelius 2001; Poston et al. 2003). Median concentrations of cadmium, arsenic, nickel, copper, lead, chromium, and zinc were highest for sediment collected at the Priest Rapids impoundment. Compared to Priest Rapid Dam sediment, the median concentrations of mercury, silver, selenium, antimony, and thallium were generally higher for the downriver pools, particularly for samples collected at the John Day Dam pool. There was no indication of a unique Hanford Site contribution for metals in Columbia River sediment. Median sediment concentrations for antimony, cadmium, silver (John Day Dam only), and zinc were above the proposed Washington State sediment quality criteria (Michelsen 2003).







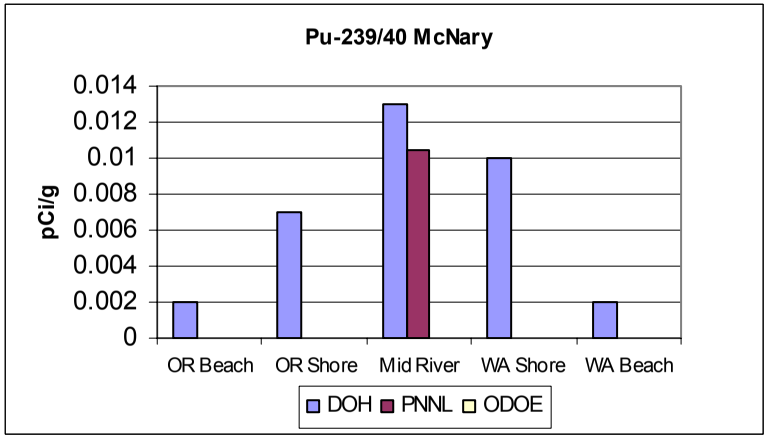


Figure 8. Concentrations (pCi/g dry wt.) of Plutonium-239/240 in Columbia River Sediment, 2003. All PNNL values were above the detection limit. Some DOH results were below a nominal detection limit of 0.006 pCi/g. Plutonium-239/240 concentrations for sediment from the pool upstream from Priest Rapids Dam were 0.00956 ± 0.0023 and 0.0116 ± 0.0023 pCi/g (PNNL).

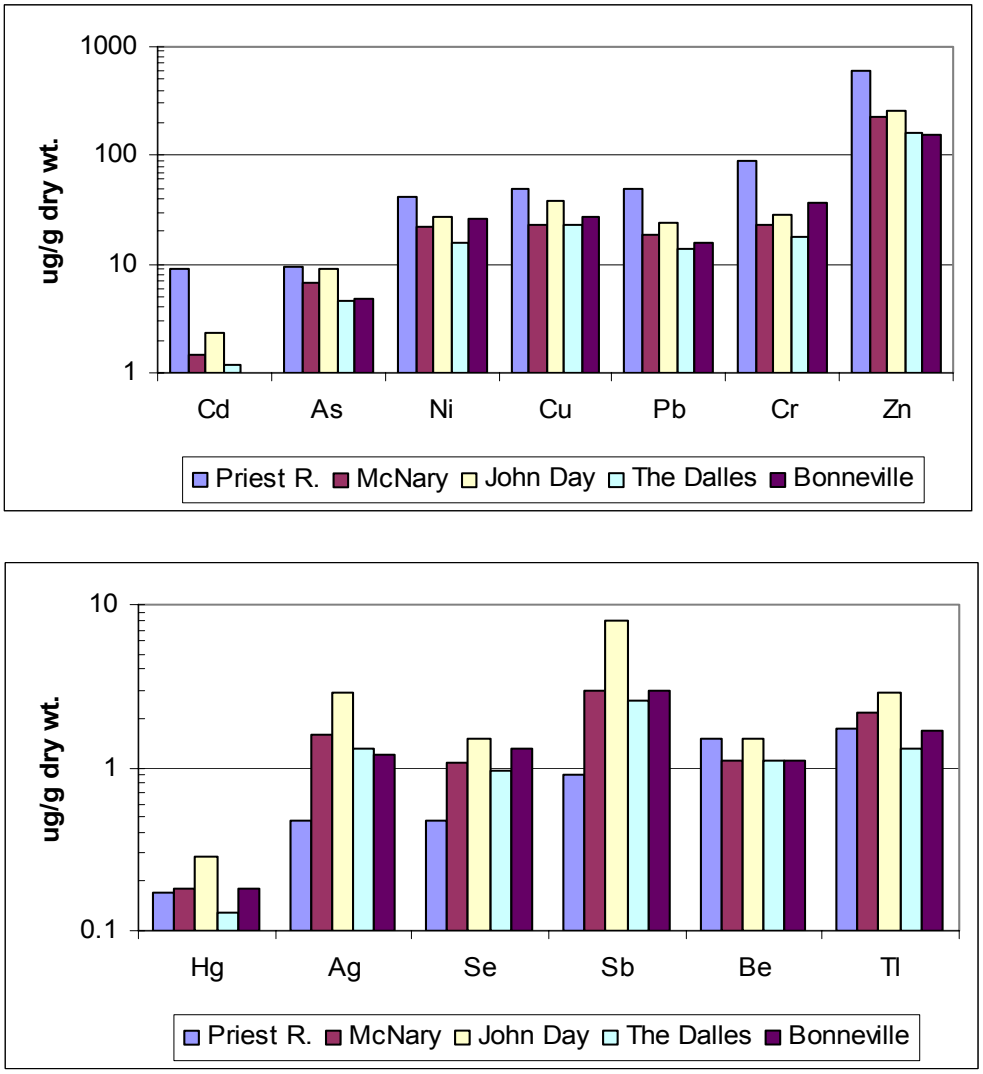


Figure 9. Median Concentrations (µg/g dry wt.) of Metals in Columbia River Sediment (Combined WDOE and PNNL Results).

The Washington State Department of Ecology sediment samples that were analyzed for hexavalent chromium were all below the detection limit of 2 µg/g dry wt.

4.1.2.2 Simultaneously Extracted Metals/Acid Volatile Sulfide (SEM/AVS)

Columbia River sediments were analyzed for SEM/AVS. This analysis involves a cold acid extraction of the sediments followed by analysis for sulfide and metals. The molar ratios of SEM metals to the acid volatile sulfide are an indicator of potential sediment toxicity (DeWitt et al. 1996; Hansen et al. 1996). Acid volatile sulfide is an important binding phase for divalent metals (i.e., metals with a valance state of 2+, such as Pb^{2+}) in sediment. Metal sulfide precipitates are typically very insoluble; this limits the

amount of dissolved metal available in the sediment porewater. For an individual metal, when the amount of AVS exceeds the amount of the metal (i.e., the SEM/AVS molar ratio is below one), the metal concentration in the sediment porewater will be low because of the limited solubility of the metal sulfide. For a suite of divalent metals, the sum of the SEMs must be considered, with the assumption that the metal with the lowest solubility will be the first to combine with the AVS.

The concentrations of SEM metals and AVS are provided in units of µmol of analyte per gram of sediment (µmol analyte/g). The molar-based units are required to directly compare the pool of available sulfide (AVS) to the pool of divalent metals (SEM). Conversion to the more typically reported µg/g unit is made using Equation (1) or µmol/g x molecular weight = µg/g (Note: molecular weight = g/mol = µg/µmol).

$$\frac{\mu\text{mol analyte}}{\text{g sediment}} \times \frac{\mu\text{g analyte}}{\mu\text{mol analyte}} = \frac{\mu\text{g analyte}}{\text{g sediment}} \qquad \textbf{Equation (1)}$$

The average SEM/AVS results for the sediment collected during 2003 in the reservoirs upriver from Priest Rapids, McNary, John Day, The Dalles, and Bonneville dams are shown in Figure 10 and the individual results are provided in Appendix B, Table B.3. In general, the results were similar to values reported by Patton and Crecelius (2001) for sediment analyzed from upriver of Priest Rapids Dam and McNary Dam. For all locations, zinc was the primary SEM metal present. AVS concentrations ranged from 0.05 to 8.4 µmol/g. Overall, sediment from the McNary Dam reservoir had the lowest concentrations of AVS, with an average value of 1.4 µmol/g. The SEM/AVS average molar ratios for sediment from the Priest Rapids Dam and McNary Dam reservoirs were above 1.0, indicating a potential for some dissolved metals to be present in the sediment porewater. Samples from John Day, The Dalles, and Bonneville Dams had average SEM/AVS molar ratio below one (i.e., low potential for dissolved metals in sediment porewater).

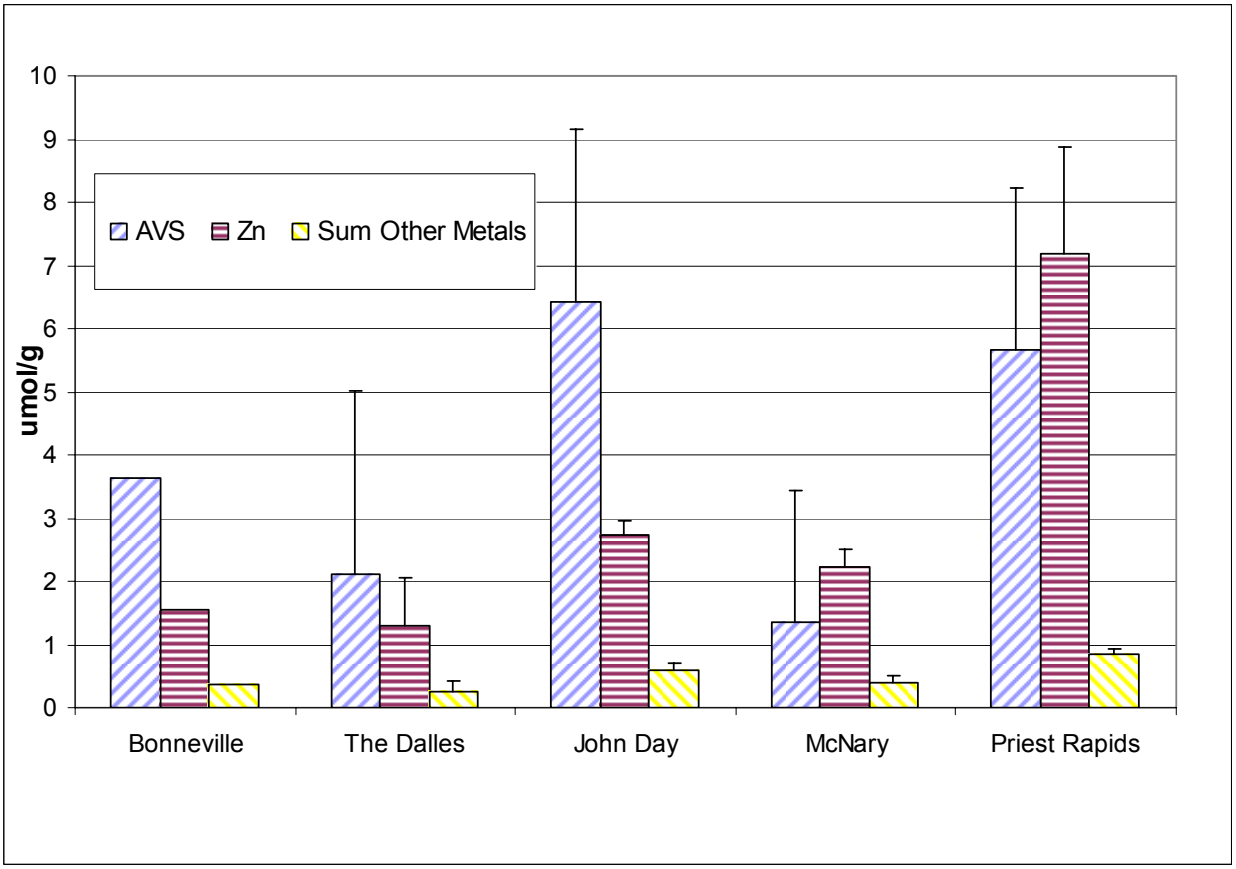


Figure 10. Average (± 1 Standard Deviation) Simultaneously Extracted Metals/Acid Volatile Sulfide (SEM/AVS) Concentrations in Columbia River Sediment. Sum of Other Metals are Cadmium, Copper, Mercury, Nickel, and Lead.

An apportionment of AVS by divalent metals according to solubility values revealed that sufficient AVS should exist in all locations to limit the porewater concentrations of cadmium, copper, lead, and mercury. However, for Priest Rapids Dam and McNary Dam sediment, the average zinc concentrations were higher than the available mean AVS pool, indicating the potential for zinc and possibly other dissolved metals to be present in the sediment porewater.

4.1.2.3 Pesticide, Semi-Volatile Organics, and PCB Results

Twenty-one organochlorine pesticides were analyzed by gas chromatography using electron capture detection. Pesticide classes included hexachlorocyclohexanes, chlordanes, DDT-group, dieldrin, aldrin, endosulfanes, and toxaphene. These compounds were below the method detection limit for all samples (Appendix B, Table B.4).

Analysis was conducted for 71 semi-volatile compounds by gas chromatography using mass spectrometry detection. Compounds include polycyclic aromatic hydrocarbons, chlorinated hydrocarbons and pesticides, phthalate esters, organophosphate esters, nitrosamines, halogenated ethers, aldehydes, ethers,

ketones, anilines, pyridines, quinolines, aromatic nitrocompounds, nitrophenols, and phenols. All compounds were below the method detection levels at all locations (Appendix B, Table B.5).

Sediment samples were analyzed for PCBs as seven Aroclor mixtures using gas chromatography with electron capture detection. All compounds were below the method detection level for all sites sampled (Appendix B, Table B.5).

The analytical detection limits for sediment samples analyzed for semi-volatile organic compounds were below the proposed Washington State sediment quality limits (Appendix B, Table B.5).

4.1.2.4 Sediment Grain Size Results

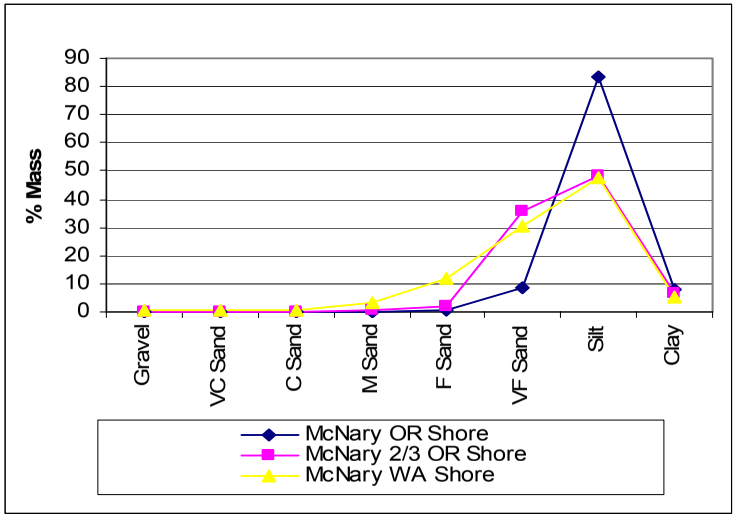
Sediment samples from all locations were analyzed for sediment grain size distributions and the results are provided in Appendix B, Table B.6. Sediment size fractions were evaluated for gravel (>2.0 mm), very coarse sand (1.0 – 2.0 mm), coarse sand (0.5 – 1.0 mm), medium sand (0.25 – 0.5 mm), fine sand (0.125–0.25 mm), very fine sand (0.0625 - 0.125 mm), silt (0.002 – 0.0625 mm), and clay (<0.002 mm).

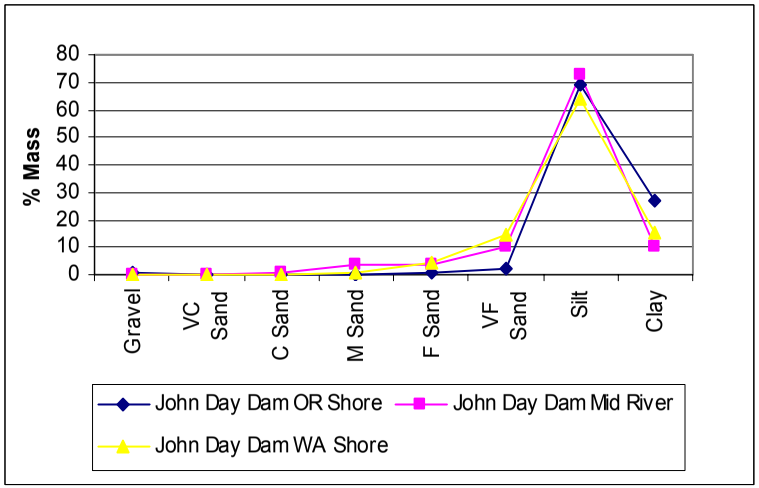
River sediment samples were similar at most locations with the majority of the mass composed of silt, with some contribution from very fine sand and clay (Figure 11). The notable exception was The Dalles Dam sediment collected on the Washington side of the river, which was composed primarily of medium, fine, and very fine sand. John Day Dam had a very uniform distribution of sediment size for all river sediment locations. River sediment from McNary Dam and The Dalles Dam revealed a shift in the sediment distribution to coarser sediment size for the samples collected on the Washington side of the river. Sediment grain size distributions for this study were similar to previously reported values at McNary Dam (Blanton et al. 1995; Patton and Crecelius 2001).

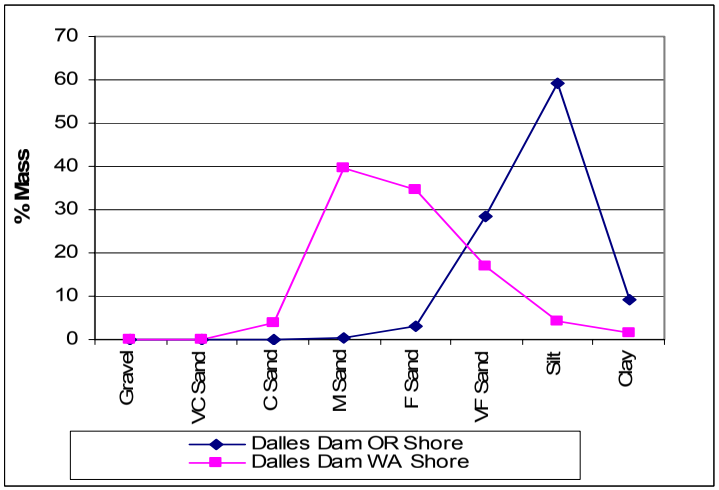
For locations where shoreline beach sediment samples were collected (McNary Dam and Bonneville Dam), the majority of the sediment mass was composed of medium and coarse sand (Figure 12).

4.1.2.5 Total Organic Carbon Content

The total organic carbon (TOC) content of Columbia River sediment samples are shown in Figure13 and presented in Appendix B, Table B.7. For most river sediment locations, the TOC content ranged from 5,460 to 16,200 mg/kg; however, the sample collected on the Washington side of The Dalles Dam had a low TOC value of 1,490 mg/kg. TOC content showed considerable variation within each reservoir, with McNary Dam and The Dalles Dam having lower values for the samples collected on the Washington side of the river. TOC values at John Day Dam were highest at mid-river (maximum TOC value for the entire study) with concentrations decreasing slightly for the samples collected on the Washington and Oregon sides of the river. The TOC concentrations of Columbia River beach sediment were low for all samples collected, with values ranging from 214 to 1,110 mg/kg. In general, the locations with higher TOC contents typically were composed of finer grain sediment.







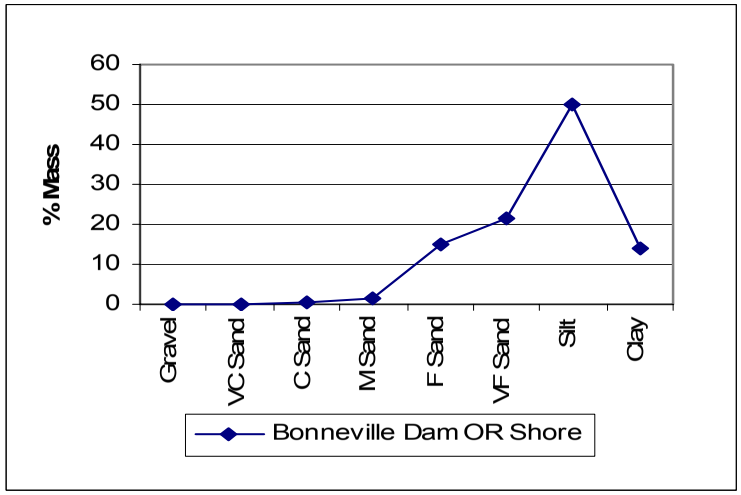
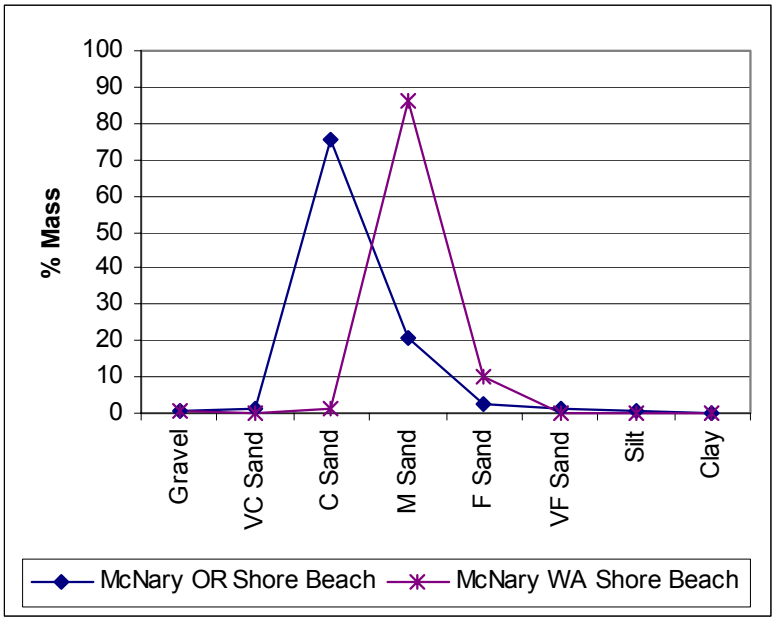


Figure 11. Sediment Grain Size Distribution for Columbia River Sediment.



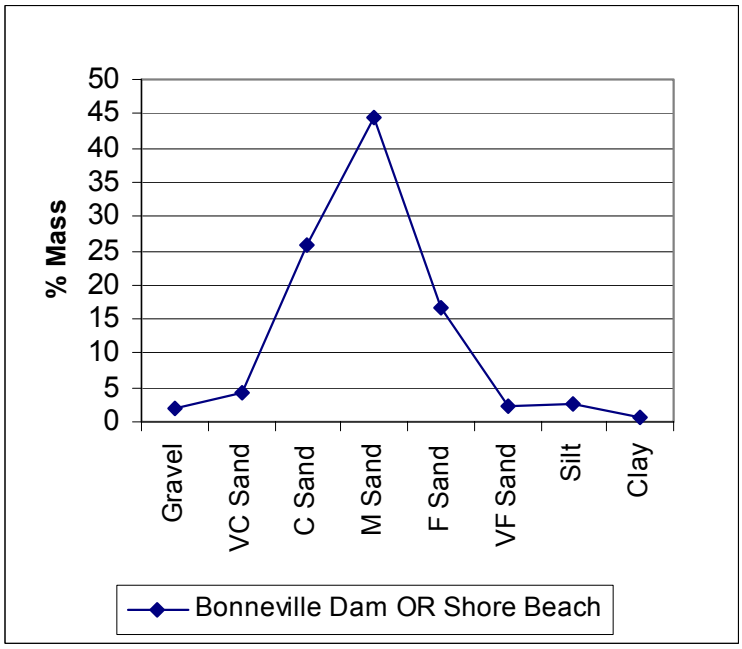


Figure 12. Sediment Grain Size Distribution for Columbia River Beach Sediment Upriver from McNary and Bonneville Dams.

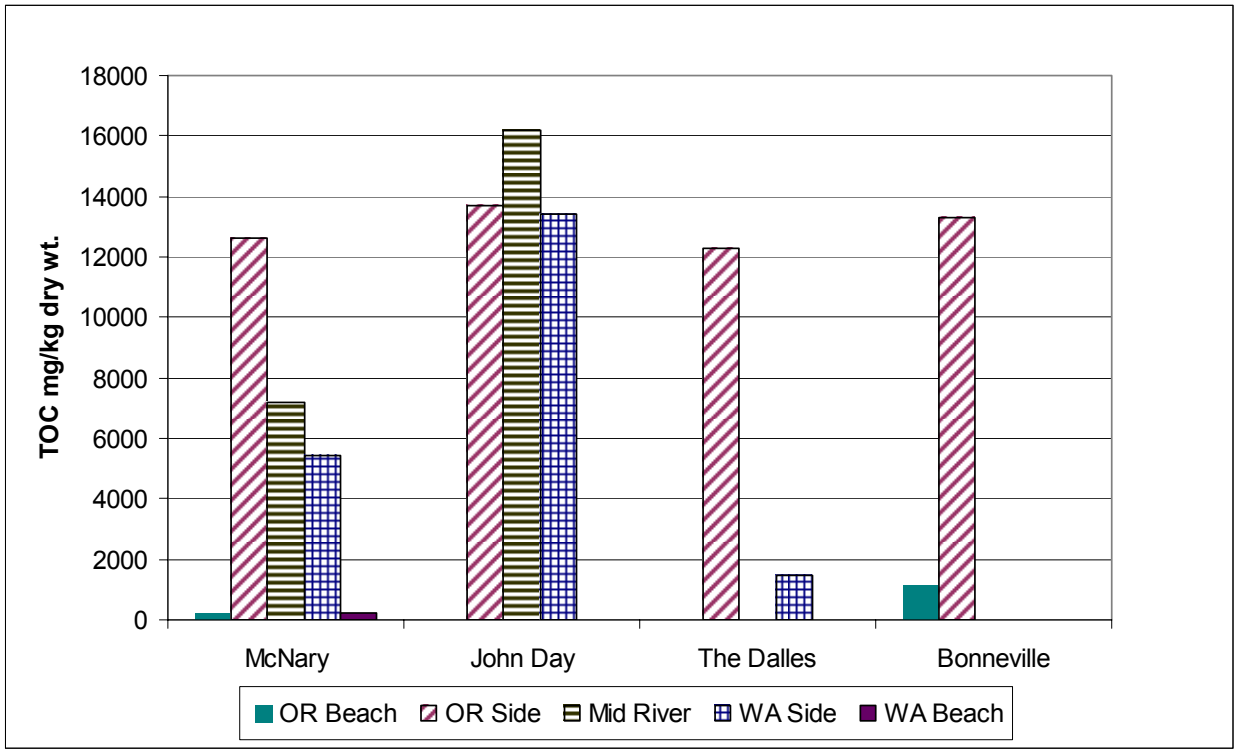


Figure 13. Total Organic Carbon Content (mg/kg dry wt.) for Columbia River and Beach Sediment.

4.1.3 Bioassays (Microtox® and *Daphnia* IQ Tests)

Microtox® and *Daphnia* IQ toxicity tests are rapid screening assays that have shown good prediction with more standard acute toxicity bioassays (Hayes et al. 1993; Toussaint et al. 1995; Burton et al. 2001). Evaluation of porewater toxicity can be informative because sediments integrate contaminant fluctuations over time (Nipper et al. 2003).

Microtox® has been evaluated by the Washington State Department of Ecology for use as a screening test for sediments (Bennet and Cubbage 1992). It is most appropriately used in a battery of tests where sediment is evaluated based on the results of several different bioassays. The *Daphnia* IQ test measures inhibition of galactosidase, reducing in vivo cleavage of a fluorometric substrate, methylumbelliferyl (MUF) galactoside (Hayes et al. 1993). The test employs the freshwater cladoceran, *Daphnia magna*, a common aquatic invertebrate used in toxicity testing. Those organisms that feed normally and retain functional galactosidase are able to cleave the MUF marker from the substrate. The fluorescent marker is then freed to the hemolymph of the organism and is readily observed. Janssen and Persoone (1993) found the *Daphnia* Magna IQ test to be substantially more sensitive than the Microtox® assay for copper (170x), cadmium (1,216x), zinc (110x), and chromium (3,417x), and similarly sensitive for mercury.

The EC_{50} is the sample concentration that causes 50% of the exposed bacteria to exhibit a predetermined adverse response at a specific time. High EC_{50} indicates low toxicity, while low values indicate high

toxicity. For example, an EC_{50} of 80% is less toxic than an EC_{50} of 25%. The EC_{50} data in Table 3 indicate that the *Daphnia* IQ test was more sensitive than the Microtox® test.

Table 3. Effective Dose (EC_{50}) for Microtox® (n=1) and *Daphnia* IQ Toxicity Tests (n=3)

Dam Sediment	Microtox® EC_{50} (%)				*Daphnia* IQ EC_{50} (CL) (%)[a]
	0.2 µm Filtered		Non-Filtered		Non-Filtered
Porewater	5 min	15 min	5 min	15 min	75 min
McNary	>100[b]	>100[b]	>100[b]	>100[b]	78.3 (56.0 - 143)
John Day	>100[b]	>100[b]	>100[b]	>100[b]	22.4 (15.8 - 31.1)
Dalles	>100[b]	>100[b]	>100[b]	>100[b]	51.8 (42.2 - 63.9)
Bonneville	>100[b]	>100[b]	>100[b]	>100[b]	33.2 (27.1 - 40.7)

(a) 95% Confidence Limit.
(b) Extrapolated value.

The Microtox® evaluations of sediment porewater demonstrated no observed toxicity with all results reported as being greater than 100%.

The *Daphnia* IQ test exhibited some measurable toxicity, relative to controls. Toxicity of sediment porewater was greatest for sediment porewater from John Day Dam and least for sediment porewater from McNary Dam. The sediment porewater toxicity was inversely related to the amount of acid volatile sulfide measured for the sediment sampling locations (Figure 14). The sediment with high acid volatile sulfide loadings come from a reducing environment (low oxygen content) and this may have influenced the toxicity results. There were no other readily apparent trends between toxicity and contaminant levels at the sampling locations.

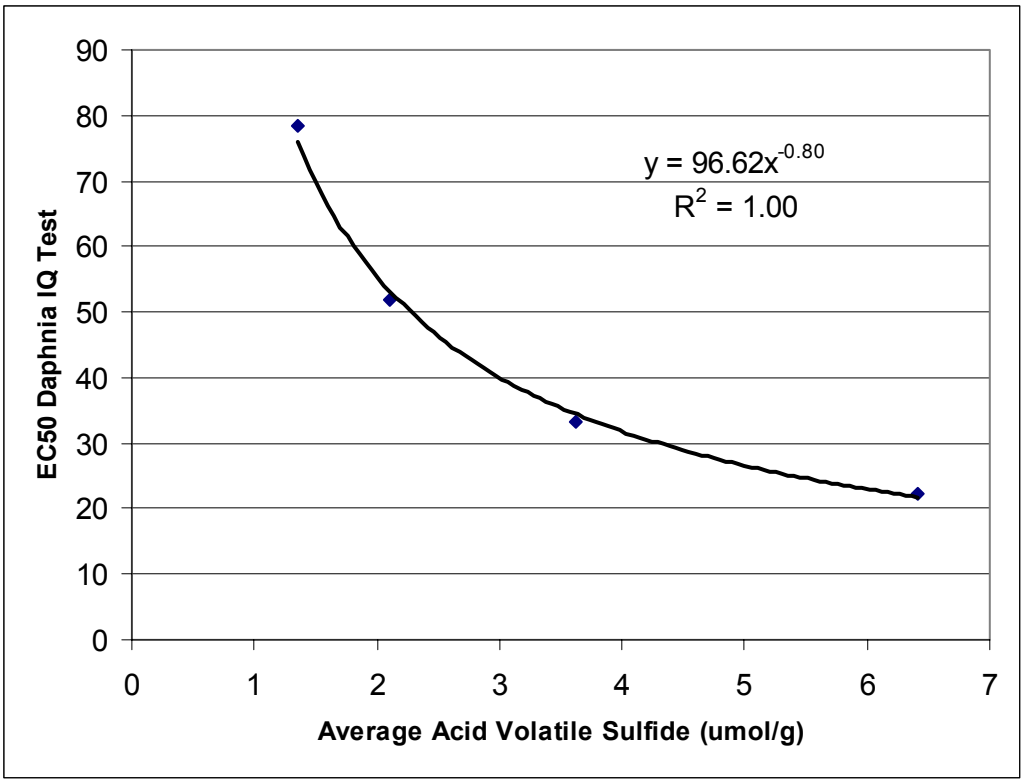


Figure 14. Relationship Between *Dapnia* IQ Test Results (EC50) for Sediment Porewater and Average Acid Volatile Sulfide Concentrations in Associated Sediments.

4.2 Radionuclides in Columbia River Water

River water samples were collected at McNary Dam reservoir at the same locations as the river sediment samples. The mid-river (McNary 2/3 OR Shore) location was analyzed for gamma-emitting radionuclides, strontium-90, isotopic uranium, and isotopic plutonium. The water samples from the Washington and Oregon sides of the river at McNary Dam were only analyzed for strontium-90. The results for the water samples analyzed for radionuclides are presented inAppendix B, Table B.8. In general the water concentrations at McNary Dam were similar to levels reported by the Hanford Site Surface Environmental Surveillance Project for the Richland Pumphouse and Priest Rapids Dam (Poston et al. 2003). Strontium-90 was detected in all water samples with values ranging from 0.12 to 0.15 pCi/L, which were well below the Washington State ambient water quality criteria of 8 pCi/L. The concentration of total uranium in water at McNary Dam (0.45 ± 0.051 pCi/L) was well below the EPA drinking water standard of 30 µg/L (~27 pCi/L) (40 CFR 141; WAC 246-290; EPA 822-R-96-001). Gamma-emitting radionuclides, uranium-235, and isotopic plutonium were below the detection limits.

5.0 Conclusions

In 2003, sediment samples were collected in the impoundments upriver from McNary, John Day, The Dalles, and Bonneville Dams and at beaches along the shores of the impoundments (where available). The upper layer sediment was readily available upriver from McNary, John Day, and The Dalles Dams. Sediment was limited (as determined by unsuccessful attempts to collect samples) upriver of the Bonneville Dam and was only successfully collected in close proximity to the dam structure. Beach sediment sampling locations were limited to above McNary Dam and at the mouth of Eagle Creek on the Oregon side of the Bonneville Dam impoundment. In general, the river sediment samples were composed primarily of very fine sand, silt, and clay; whereas the beach sediment was composed primarily of coarse and medium sand. At McNary Dam and The Dalles Dam, there was a trend for coarse grained sediment on the Washington side of the river. Total organic content of the river sediment was fairly consistent, with most locations having concentrations above 10,000 mg/kg, and the locations with higher organic content generally had finer grain sediment. Samples from the Washington side of the McNary Dam and The Dalles Dam had lower total organic content.

Sediment samples submitted for radionuclide analysis had detectable levels of potassium-40, cobalt-60, strontium-90, cesium-137, europium-152, isotopic uranium, and isotopic plutonium. In general, the values were similar to previously reported concentrations at Priest Rapids Dam (Wells 1994; OHD 1994; Poston et al. 2003). Cesium-137 and europium-152 concentrations were somewhat elevated at the lower Columbia River pools compared to sediment from the Priest Rapids pool; this provides an indication of a potential Hanford source; however, additional sampling and evaluation would be required to confirm this information.

Metals were detected in most river and beach sediment samples, with the levels reported for this study similar to previously reported values (Patton and Crecelius 2001; Poston et al. 2003). Median concentrations of cadmium, arsenic, nickel, copper, lead, chromium, and zinc were highest for sediment collected at the Priest Rapids Dan pool. Compared to Priest Rapid Dam sediment, the median concentrations of mercury, silver, selenium, antimony, and thallium were generally higher for the downriver pools. Median sediment concentrations for antimony, cadmium, silver (John Day Dam only), and zinc were all above the proposed Washington State sediment quality criteria (Michelsen 2003). Samples submitted for hexavalent chromium analysis were all below the detection limit. There was no indication of a unique Hanford Site contribution for metals in Columbia River sediment.

Sediment samples analyzed for organic compounds (e.g., PAHs, PCBs, pesticides, and semi-volatile organics) were all below the analytical detections limits. The analytical detection limits were below the proposed Washington State sediment quality criteria (Michelsen 2003).

Sediment porewater toxicity was not observed with the MicroTox® test for any of the sediment sampling locations. The *Daphnia* IQ test exhibited some measurable toxicity for sediment porewater, relative to controls. Toxicity of sediment porewater was greatest for sediment porewater from John Day Dam and least for sediment porewater from McNary Dam. The sediment porewater toxicity was inversely related

to the amount of AVS measured for the sediment sampling locations. There were no other readily apparent trends between toxicity and contaminant levels at the sampling locations.

The water concentrations at McNary Dam were similar to levels reported by the Hanford Site Surface Environmental Surveillance Project for the Richland Pumphouse and Priest Rapids Dam (Poston et al. 2003). Strontium-90 was detected in all water samples with values ranging from 0.12 to 0.15 pCi/L, which were well below the Washington State ambient water quality criteria of 8 pCi/L. The concentration of total uranium concentration in water at McNary Dam (0.45 ± 0.051 pCi/L) was below the EPA drinking water standard of 30 µg/L (~27 pCi/L) (40 CFR 141; WAC 246-290; EPA 822-R-96-001). Gamma-emitting radionuclides, uranium-235, and isotopic plutonium were below the detection limits.

In summary, low concentrations of radionuclides were observed in upper layer sediment samples from the lower Columbia River. The concentrations of most radionuclides in the lower Columbia River sediment were similar to background values measured upstream from the Hanford Site. Cesium-137 and Europium-152 values were slightly elevated at McNary Dam and may indicate some Hanford Site contribution; however, additional sampling and evaluation would be required to confirm this information. Sediment concentrations for antimony, cadmium, silver (John Day Dam only), and zinc were all above the proposed Washington State sediment quality criteria. Samples submitted for hexavalent chromium analysis were all below the detection limit. There was no indication of a unique Hanford Site contribution for metals in Columbia River sediment. Sediment samples analyzed for organic compounds (e.g., PAHs, PCBs, pesticides, and semi-volatile organics) were all below the analytical detection limits. Sediment porewater toxicity was not observed with the MicroTox® test for any of the sediment sampling locations. The *Daphnia* IQ test exhibited some measurable toxicity, relative to controls.

6.0 References

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Appendix A

Quality Assurance

Appendix A

Quality Assurance

A.1 Washington State Department of Ecology Quality Assurance/Quality Control

The quality of the data produced and used by WDOE is assured in many ways. WDOE has specific responsibilities and requirements pertaining to data quality for contract analytical laboratories. Analysis and receipt of samples must be conducted in licensed facilities. The laboratory must participate in the organic and inorganic U.S. Environmental Protection Agency Intercomparison Studies Programs. The laboratory must be Washington State accredited for water and wastewater analysis. A chemical hygiene plan which implements the safety requirements of the Occupational Safety Health Administration must be readily available in the laboratory facility. Analytical and standard operating procedures shall meet the requirements of all applicable regulations and reflect the actual operating conditions during analysis of the WDOE samples. A quality assurance plan must be implemented and updated as needed. Personnel training includes continued training to ensure job proficiency. WDOE performs audits as necessary on facilities, equipment, files, documents, laboratory information systems, and records. All standards must be made from National Institute of Science and Technology traceable materials. Data packages are defensible documentation with deliverables that include the following items as applicable for the analysis reported:

- sample results
- blank results
- MS/MSD or MS and duplicate results, recoveries, and relative percent differences
- surrogate results and recoveries
- initial and continuing calibration results and recoveries
- control standards results and recoveries
- detection limit determinations
- all raw data

A.2 Pacific Northwest National Laboratory Quality Assurance/Quality Control

Procedures for field sampling were consistent with the PNNL Ecological Monitoring Project and the Hanford Site Surface Environmental Surveillance Project. Procedures for sample collections (including sample handling and chain-of-custody) were consistent with the *Surface Environmental Surveillance Procedures Manual* (PNNL 2003) and the *Quality Assurance Project Plan for the Hanford Site Surface Environmental Surveillance Project (SESP)* and *the Drinking Water Monitoring Project (DWMP)* (PNNL 2002).

A.3 Washington State Department of Health Quality Assurance/Quality Control

The Washington State Department of Health samples were analyzed for radionuclides at the DOH Radiation Laboratory in Shoreline, Washington. Analytical techniques are based on laboratory standard operating procedures (DOH 2002). The quality assurance program is documented in the laboratory's quality assurance manual (DOH 2002b).

A.4 Oregon Department of Energy Quality Assurance/Quality Control

Samples collected by the ODOE were analyzed by Oregon State University according to their quality assurance/quality control procedures. The maintenance of quality assurance and control with the Oregon State University Radiological Laboratory, located in Corvallis, Oregon, is achieved through the application of common protocols which are consistent with the radiological analysis industry. Key quality program tasks conducted for this analysis group were the establishment of initial and final counting efficiencies, along with counter calibration; use of traceable radioactivity standards; and determination of a project-specific counting background.

For example, each sample was counted for ~11 hours in order to achieve reasonable counting statistics. As mentioned, a background count was obtained for a blank sample container under identical conditions. This background count was removed from each sample's measured gamma spectrum and the resulting net spectrum was analyzed for isotopic signatures. The detector was calibrated with a multi-nuclide standard source. The calibration standard is encapsulated in a 500 mL Marinelli beaker and has the same geometry as the unknown and blank samples. It contains the following radionuclides: Cd-109, Co-57, Te-123m, Cr-51, Sn-113, Sr-85, Cs-137, Y-88, and Co-60. The activity of the standards was 187.3 kBq on April 15, 2002.

The counting equipment at the Oregon State University Radiation Center is calibrated quarterly using the above described source. The quality assurance and quality control database is updated during these times.

A.5 References

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Appendix B

Results for Columbia River Sediment, Beach Sediment, and Water Samples

Table B.1. Concentrations of Radionuclides in Columbia River Sediment

Site	Analyte	Result	Error[a]	LLD[b]	MDA[c]	Agency
Bonneville Dam OR Shore	Be-7	0.0547	0.29		0.52	PNNL
Dalles Dam OR Shore	Be-7	-0.044	0.29		0.495	PNNL
John Day Dam Mid-River	Be-7	0.273	0.27		0.497	PNNL
McNary 2/3 OR Shore	Be-7	-0.016	0.23		0.385	PNNL
McNary 2/3 OR Shore	Be-7	0.0551	0.28		0.493	PNNL
Priest Rapids Dam Grant Co. Side	Be-7	0.0658	0.12		0.208	PNNL
Priest Rapids Dam Yakima Co. Side	Be-7	0.0976	0.11		0.199	PNNL
Bonneville Beach (OR)	Co-60	0.012	0.009			ODOE
Bonneville Beach (OR)	Co-60	0.003	0.006	0.01	0.01	DOH
Bonneville Dam OR Shore	Co-60	0.0224	0.032		0.0619	PNNL
Bonneville Dam OR Shore	Co-60	0	0.004	0.01	0.006	DOH
Bonneville Dam OR Shore	Co-60	ND				ODOE
Dalles Dam WA Shore	Co-60	0.015	0.012			ODOE
Dalles Dam OR Shore	Co-60	0.0046	0.028		0.0527	PNNL
Dalles Dam OR Shore	Co-60	0.01	0.006	0.01	0.01	DOH
Dalles Dam WA Shore	Co-60	0.014	0.004	0.01	0.008	DOH
Dalles Dam OR Shore	Co-60	0.025	0.019			ODOE
John Day Dam WA Shore	Co-60	0.029	0.018			ODOE
John Day Dam Mid-River	Co-60	0.0373	0.035		0.0664	PNNL
John Day Dam Mid-River	Co-60	ND				ODOE
John Day Dam Mid-River	Co-60	0.012	0.007	0.01	0.0124	DOH
John Day Dam OR Shore	Co-60	0.049	0.012	0.01		DOH
John Day Dam WA Shore	Co-60	0.022	0.011	0.01		DOH
John Day Dam OR Shore	Co-60	0.076	0.028			ODOE
McNary 2/3 OR Shore	Co-60	0.08	0.04			ODOE
McNary 2/3 OR Shore	Co-60	0.067	0.022			ODOE
McNary 2/3 OR Shore	Co-60	0.037	0.007	0.01		DOH
McNary 2/3 OR Shore	Co-60	0.045	0.013	0.01		DOH
McNary 2/3 OR Shore	Co-60	0.0597	0.034		0.0684	PNNL
McNary 2/3 OR Shore	Co-60	0.0619	0.028		0.0559	PNNL
McNary OR Beach	Co-60	0.015	0.013			ODOE
McNary WA Beach	Co-60	ND				ODOE
McNary OR Beach	Co-60	0.005	0.004	0.01	0.0063	DOH
McNary OR Shore	Co-60	0.02	0.01	0.01	0.0188	DOH
McNary OR Shore	Co-60	ND				ODOE
McNary WA Beach	Co-60	0	0.006	0.01	0.0105	DOH

Table B.1. (contd)

Site	Analyte	Result	Error[a]	LLD[b]	MDA[c]	Agency
McNary WA Shore	Co-60	0.042	0.017			ODOE
McNary WA Shore	Co-60	0.008	0.006	0.01	0.0097	DOH
Priest Rapids Dam Grant Co. Side	Co-60	-0.0003	0.012		0.0209	PNNL
Priest Rapids Dam Yakima Co. Side	Co-60	0.004	0.011		0.0203	PNNL
Bonneville Dam OR Shore	Cs-134	0.0508	0.06		0.0777	PNNL
Dalles Dam OR Shore	Cs-134	0.0325	0.036		0.0663	PNNL
John Day Dam Mid-River	Cs-134	0.0765	0.036		0.0682	PNNL
McNary 2/3 OR Shore	Cs-134	0.0456	0.035		0.0648	PNNL
McNary 2/3 OR Shore	Cs-134	0.0645	0.029		0.0545	PNNL
Priest Rapids Dam Grant Co. Side	Cs-134	0.0456	0.018		0.0264	PNNL
Priest Rapids Dam Yakima Co. Side	Cs-134	0.0347	0.016		0.0237	PNNL
Bonneville Beach (OR)	Cs-137	0.101	0.017			ODOE
Bonneville Beach (OR)	Cs-137	0.14	0.02	0.01		DOH
Bonneville Dam OR Shore	Cs-137	0.146	0.05		0.0569	PNNL
Bonneville Dam OR Shore	Cs-137	0.094	0.009	0.01		DOH
Bonneville Dam OR Shore	Cs-137	0.173	0.031			ODOE
Dalles Dam WA Shore	Cs-137	0.107	0.019			ODOE
Dalles Dam OR Shore	Cs-137	0.155	0.058		0.0565	PNNL
Dalles Dam OR Shore	Cs-137	0.15	0.01	0.01		DOH
Dalles Dam WA Shore	Cs-137	0.098	0.014	0.01		DOH
Dalles Dam OR Shore	Cs-137	0.192	0.031			ODOE
John Day Dam WA Shore	Cs-137	0.327	0.04			ODOE
John Day Dam Mid-River	Cs-137	0.333	0.07		0.0524	PNNL
John Day Dam Mid-River	Cs-137	0.315	0.04			ODOE
John Day Dam Mid-River	Cs-137	0.25	0.02	0.01		DOH
John Day Dam OR Shore	Cs-137	0.43	0.03	0.01		DOH
John Day Dam WA Shore	Cs-137	0.22	0.02	0.01		DOH
John Day OR Shore	Cs-137	0.627	0.052			ODOE
McNary 2/3 OR Shore	Cs-137	0.513	0.046			ODOE
McNary 2/3 OR Shore	Cs-137	0.47	0.039			ODOE
McNary 2/3 OR Shore	Cs-137	0.4	0.03	0.01		DOH
McNary 2/3 OR Shore	Cs-137	0.45	0.02	0.01		DOH
McNary 2/3 OR Shore	Cs-137	0.378	0.081		0.0388	PNNL
McNary 2/3 OR Shore	Cs-137	0.425	0.083		0.0591	PNNL
McNary OR Beach	Cs-137	0.042	0.012			ODOE
McNary WA Beach	Cs-137	0.01	0.009			ODOE

Table B.1. (contd)

Site	Analyte	Result	Error[a]	LLD[b]	MDA[c]	Agency
McNary OR Beach	Cs-137	0.042	0.007	0.01		DOH
McNary OR Shore	Cs-137	0.23	0.02	0.01		DOH
McNary OR Shore	Cs-137	0.313	0.041			ODOE
McNary WA Beach	Cs-137	-0.001	0.006	0.01		DOH
McNary WA Shore	Cs-137	0.424	0.036			ODOE
McNary WA Shore	Cs-137	0.41	0.02	0.01		DOH
Priest Rapids Dam Grant Co. Side	Cs-137	0.324	0.048		0.023	PNNL
Priest Rapids Dam Yakima Co. Side	Cs-137	0.285	0.041		0.0218	PNNL
Bonneville Dam OR Shore	Eu-152	-0.0564	0.083		0.138	PNNL
Dalles Dam OR Shore	Eu-152	0.0667	0.088		0.15	PNNL
John Day Dam Mid-River	Eu-152	0.0162	0.077		0.133	PNNL
John Day Dam OR Shore	Eu-152	0.24	0.04	0.05		DOH
John Day Dam WA Shore	Eu-152	0.071	0.023	0.05		DOH
McNary 2/3 OR Shore	Eu-152	0.22	0.02	0.05		DOH
McNary 2/3 OR Shore	Eu-152	0.26	0.03	0.05		DOH
McNary 2/3 OR Shore	Eu-152	0.217	0.12		0.166	PNNL
McNary 2/3 OR Shore	Eu-152	0.286	0.11		0.136	PNNL
McNary OR Shore	Eu-152	0.054	0.023	0.05		DOH
McNary WA Shore	Eu-152	0.18	0.02	0.05		DOH
Priest Rapids Dam Grant Co. Side	Eu-152	0.0256	0.032		0.0527	PNNL
Priest Rapids Dam Yakima Co. Side	Eu-152	0.00947	0.027		0.0459	PNNL
Bonneville Dam OR Shore	Eu-154	0.0713	0.1		0.197	PNNL
Dalles Dam OR Shore	Eu-154	0.00353	0.093		0.168	PNNL
John Day Dam Mid-River	Eu-154	0.0379	0.1		0.187	PNNL
McNary 2/3 OR Shore	Eu-154	0.0026	0.091		0.162	PNNL
McNary 2/3 OR Shore	Eu-154	0.02	0.072		0.13	PNNL
Priest Rapids Dam Grant Co. Side	Eu-154	0.011	0.036		0.0641	PNNL
Priest Rapids Dam Yakima Co. Side	Eu-154	0.00043	0.035		0.061	PNNL
Bonneville Dam OR Shore	Eu-155	0.0214	0.086		0.151	PNNL
Dalles Dam OR Shore	Eu-155	0.0474	0.077		0.136	PNNL
John Day Dam Mid-River	Eu-155	0.0761	0.07		0.121	PNNL
McNary 2/3 OR Shore	Eu-155	0.0854	0.062		0.109	PNNL
McNary 2/3 OR Shore	Eu-155	0.113	0.074		0.127	PNNL
Priest Rapids Dam Grant Co. Side	Eu-155	0.0471	0.034		0.0562	PNNL
Priest Rapids Dam Yakima Co. Side	Eu-155	0.0455	0.033		0.0559	PNNL
Bonneville Beach (OR)	K-40	8	0.476			ODOE

Table B.1. (contd)

Site	Analyte	Result	Error[a]	LLD[b]	MDA[c]	Agency
Bonneville Beach (OR)	K-40	13.4	0.5	0.22		DOH
Bonneville Dam OR Shore	K-40	13.1	2.1		0.491	PNNL
Bonneville Dam OR Shore	K-40	8.2	1.8	0.22		DOH
Bonneville Dam OR Shore	K-40	16.9	1.009			ODOE
Dalles Dam WA Shore	K-40	16	0.684			ODOE
Dalles Dam OR Shore	K-40	12	1.8		0.469	PNNL
Dalles Dam OR Shore	K-40	13.3	0.3	0.22		DOH
Dalles Dam WA Shore	K-40	15.5	0.6	0.22		DOH
Dalles Dam OR Shore	K-40	14.8	0.92			ODOE
John Day Dam WA Shore	K-40	16.8	0.977			ODOE
John Day Dam Mid-River	K-40	14.2	2.1		0.417	PNNL
John Day Dam Mid-River	K-40	16.5	0.994			ODOE
John Day Dam Mid-River	K-40	14.7	0.3	0.22		DOH
John Day Dam OR Shore	K-40	14.1	0.6	0.22		DOH
John Day Dam WA Shore	K-40	13.4	0.6	0.22		DOH
John Day Dam OR Shore	K-40	18.7	1.029			ODOE
McNary 2/3 OR Shore	K-40	18	16.5			ODOE
McNary 2/3 OR Shore	K-40	16.5	0.816			ODOE
McNary 2/3 OR Shore	K-40	15.1	0.6	0.22		DOH
McNary 2/3 OR Shore	K-40	16.3	0.3	0.22		DOH
McNary 2/3 OR Shore	K-40	14	2		0.46	PNNL
McNary 2/3 OR Shore	K-40	14.8	2		0.293	PNNL
McNary OR Beach	K-40	12.9	0.545			ODOE
McNary WA Beach	K-40	12.9	0.559			ODOE
McNary OR Beach	K-40	13.6	0.2	0.22		DOH
McNary OR Shore	K-40	13.7	0.6	0.22		DOH
McNary OR Shore	K-40	18.3	1.037			ODOE
McNary WA Beach	K-40	12.6	0.5	0.22		DOH
McNary WA Shore	K-40	16.2	0.769			ODOE
McNary WA Shore	K-40	16.2	0.3	0.22		DOH
Priest Rapids Dam Grant Co. Side	K-40	12.3	1.6		0.183	PNNL
Priest Rapids Dam Yakima Co. Side	K-40	12.2	1.6		0.134	PNNL
Bonneville Beach (OR)	Pu-238	0.003	0.003	0.03	0.004	DOH
Bonneville Dam OR Shore	Pu-238	0.00021	0.00044		0.0008	PNNL
Bonneville Dam OR Shore	Pu-238	0.003	0.003	0.03	0.004	DOH
Dalles Dam OR Shore	Pu-238	0.00035	0.00019		0.0002	PNNL

Table B.1. (contd)

Site	Analyte	Result	Error[a]	LLD[b]	MDA[c]	Agency
Dalles Dam OR Shore	Pu-238	0	0.003	0.03	0.006	DOH
Dalles Dam WA Shore	Pu-238	0.02	0.005	0.03	0.003	DOH
John Day Dam Mid-River	Pu-238	0.00027	0.00025		0.0002	PNNL
John Day Dam Mid-River	Pu-238	0	0.003	0.03	0.005	DOH
John Day Dam OR Shore	Pu-238	0	0.001	0.03	0.003	DOH
John Day Dam WA Shore	Pu-238	0	0.002	0.03	0.0043	DOH
McNary 2/3 OR Shore	Pu-238	0	0.002	0.03	0.005	DOH
McNary 2/3 OR Shore	Pu-238	0	0.002	0.03	0.005	DOH
McNary 2/3 OR Shore	Pu-238	0.0002	0.00018		0.0002	PNNL
McNary 2/3 OR Shore	Pu-238	0.00053	0.00033		0.0003	PNNL
McNary OR Beach	Pu-238	0	0.002	0.03	0.005	DOH
McNary OR Shore	Pu-238	0.004	0.003	0.03	0.004	DOH
McNary WA Beach	Pu-238	0	0.003	0.03	0.006	DOH
McNary WA Shore	Pu-238	0	0.003	0.03	0.006	DOH
Priest Rapids Dam Grant Co. Side	Pu-238	0.00064	0.00038		0.0001	PNNL
Priest Rapids Dam Yakima Co. Side	Pu-238	0.00022	0.00026		0.0002	PNNL
Bonneville Beach (OR)	Pu-239/240	0.001	0.003	0.006	0.005	DOH
Bonneville Dam OR Shore	Pu-239/240	0.00451	0.0016		0.0003	PNNL
Bonneville Dam OR Shore	Pu-239/240	0.014	0.004	0.006	0.002	DOH
Dalles Dam OR Shore	Pu-239/240	0.00598	0.0011		6E-05	PNNL
Dalles Dam OR Shore	Pu-239/240	0.007	0.003	0.006	0.003	DOH
Dalles Dam WA Shore	Pu-239/240	0.049	0.008	0.006	0.002	DOH
John Day Dam Mid-River	Pu-239/240	0.00963	0.0021		0.0002	PNNL
John Day Dam Mid-River	Pu-239/240	0.008	0.003	0.006		DOH
John Day Dam OR Shore	Pu-239/240	0.001	0.001	0.006	0.001	DOH
John Day Dam WA Shore	Pu-239/240	0.006	0.003	0.006		DOH
McNary 2/3 OR Shore	Pu-239/240	0.009	0.004	0.006		DOH
McNary 2/3 OR Shore	Pu-239/240	0.013	0.004	0.006		DOH
McNary 2/3 OR Shore	Pu-239/240	0.00954	0.0019		0.0001	PNNL
McNary 2/3 OR Shore	Pu-239/240	0.0104	0.0018		0.0002	PNNL
McNary OR Beach	Pu-239/240	0.002	0.002	0.006	0.002	DOH
McNary OR Shore	Pu-239/240	0.008	0.004	0.006	0.005	DOH
McNary WA Beach	Pu-239/240	0.002	0.002	0.006	0.003	DOH
McNary WA Shore	Pu-239/240	0.01	0.004	0.006		DOH
Priest Rapids Dam Grant Co. Side	Pu-239/240	0.0116	0.0023		0.0001	PNNL
Priest Rapids Dam Yakima Co. Side	Pu-239/240	0.00956	0.0023		0.0006	PNNL

Table B.1. (contd)

Site	Analyte	Result	Error[a]	LLD[b]	MDA[c]	Agency
Bonneville Dam OR Shore	Ru-106	0.246	0.3		0.542	PNNL
Dalles Dam OR Shore	Ru-106	-0.219	0.26		0.421	PNNL
John Day Dam Mid-River	Ru-106	-0.266	0.26		0.417	PNNL
McNary 2/3 OR Shore	Ru-106	-0.0878	0.19		0.326	PNNL
McNary 2/3 OR Shore	Ru-106	0.0634	0.25		0.45	PNNL
Priest Rapids Dam Grant Co. Side	Ru-106	0.00343	0.1		0.18	PNNL
Priest Rapids Dam Yakima Co. Side	Ru-106	0.015	0.083		0.145	PNNL
Bonneville Dam OR Shore	Sb-125	0.034	0.081		0.142	PNNL
Dalles Dam OR Shore	Sb-125	-0.0255	0.074		0.126	PNNL
John Day Dam Mid-River	Sb-125	0.0322	0.072		0.125	PNNL
McNary 2/3 OR Shore	Sb-125	0.0109	0.074		0.128	PNNL
McNary 2/3 OR Shore	Sb-125	0.0233	0.059		0.103	PNNL
Priest Rapids Dam Grant Co. Side	Sb-125	0.0165	0.03		0.0522	PNNL
Priest Rapids Dam Yakima Co. Side	Sb-125	0.0044	0.026		0.0448	PNNL
Bonneville Beach (OR)	Sr-90	0.011	0.004	0.003	0.007	DOH
Bonneville Beach (OR)	Sr-90	0.022	0.020		0.0328	PNNL
Bonneville Dam OR Shore	Sr-90	0.0045	0.018		0.0334	PNNL
Bonneville Dam OR Shore	Sr-90	0.011	0.004	0.003	0.007	DOH
Dalles Dam OR Shore	Sr-90	0.0341	0.022		0.0353	PNNL
Dalles Dam OR Shore	Sr-90	0.011	0.004	0.003	0.006	DOH
Dalles Dam WA Shore	Sr-90	0.0122	0.020		0.0357	PNNL
Dalles Dam WA Shore	Sr-90	0.006	0.003	0.003	0.005	DOH
John Day Dam Mid-River	Sr-90	0.0061	0.022		0.0412	PNNL
John Day Dam Mid-River	Sr-90	0.018	0.006	0.003	0.008	DOH
John Day Dam OR Shore	Sr-90	0.0298	0.018		0.0282	PNNL
John Day Dam OR Shore	Sr-90	0.032	0.007	0.003	0.009	DOH
John Day Dam WA Shore	Sr-90	0.0258	0.023		0.0398	PNNL
John Day Dam WA Shore	Sr-90	0.019	0.004	0.003	0.005	DOH
McNary 2/3 OR Shore	Sr-90	0.013	0.003	0.003	0.004	DOH
McNary 2/3 OR Shore	Sr-90	0.015	0.004	0.003	0.005	DOH
McNary 2/3 OR Shore	Sr-90	0.0162	0.024		0.0427	PNNL
McNary 2/3 OR Shore	Sr-90	0.0124	0.022		0.0397	PNNL
McNary OR Beach	Sr-90	0.001	0.002	0.003	0.005	DOH
McNary OR Beach	Sr-90	-0.007	0.021		0.0396	PNNL
McNary OR Shore	Sr-90	0.017	0.004	0.003	0.006	DOH
McNary OR Shore	Sr-90	-0.0061	0.018		0.0339	PNNL

Table B.1. (contd)

Site	Analyte	Result	Error[a]	LLD[b]	MDA[c]	Agency
McNary WA Beach	Sr-90	0.002	0.002	0.003	0.005	DOH
McNary WA Beach	Sr-90	-0.0069	0.019		0.0361	PNNL
McNary WA Shore	Sr-90	0.01	0.003	0.003	0.004	DOH
Priest Rapids Dam Grant Co Side	Sr-90	0.0104	0.024		0.0435	PNNL
Priest Rapids Dam Yakima Co Side	Sr-90	0.0033	0.021		0.0384	PNNL
Bonneville Beach (OR)	Total U	2.29	0.15	0.09	0.04	DOH
Bonneville Dam OR Shore	Total U	0.9	0.09	0.09	0.04	DOH
Dalles Dam OR Shore	Total U	2.21	0.15	0.09	0.04	DOH
Dalles Dam WA Shore	Total U	3.56	0.19	0.09	0.04	DOH
John Day Dam Mid-River	Total U	2.8	0.2	0.09		DOH
John Day Dam OR Shore	Total U	2.3	0.2	0.09		DOH
John Day Dam WA Shore	Total U	2.7	0.2	0.09		DOH
McNary 2/3 OR Shore	Total U	3	0.2	0.09		DOH
McNary 2/3 OR Shore	Total U	3	0.2	0.09		DOH
McNary OR Beach	Total U	0.92	0.11	0.09		DOH
McNary OR Shore	Total U	3	0.2	0.09		DOH
McNary WA Beach	Total U	0.76	0.1	0.09		DOH
McNary WA Shore	Total U	2.1	0.2	0.09	0.053	DOH
Bonneville Beach (OR)	U-234	1.21	0.11	0.063	0.03	DOH
Bonneville Dam OR Shore	U-234	0.697	0.12		0.0135	PNNL
Bonneville Dam OR Shore	U-234	0.5	0.07	0.063	0.03	DOH
Dalles Dam OR Shore	U-234	0.674	0.11		0.0116	PNNL
Dalles Dam OR Shore	U-234	1.2	0.11	0.063	0.03	DOH
Dalles Dam WA Shore	U-234	1.74	0.14	0.063	0.04	DOH
John Day Dam Mid-River	U-234	0.946	0.16		0.0239	PNNL
John Day Dam Mid-River	U-234	1.4	0.1	0.063		DOH
John Day Dam OR Shore	U-234	1.2	0.1	0.063		DOH
John Day Dam WA Shore	U-234	1.4	0.1	0.063		DOH
McNary 2/3 OR Shore	U-234	1.4	0.1	0.063		DOH
McNary 2/3 OR Shore	U-234	1.5	0.1	0.063		DOH
McNary 2/3 OR Shore	U-234	0.677	0.12		0.0053	PNNL
McNary 2/3 OR Shore	U-234	0.732	0.13		0.0027	PNNL
McNary OR Beach	U-234	0.45	0.07	0.063		DOH
McNary OR Shore	U-234	1.6	0.2	0.063		DOH
McNary WA Beach	U-234	0.39	0.07	0.063		DOH

Table B.1. (contd)

Site	Analyte	Result	Error[a]	LLD[b]	MDA[c]	Agency
McNary WA Shore	U-234	1.1	0.1	0.063	0.035	DOH
Priest Rapids Dam Grant Co. Side	U-234	0.727	0.12		0.0066	PNNL
Priest Rapids Dam Yakima Co. Side	U-234	0.669	0.12		0.0019	PNNL
Bonneville Beach (OR)	U-235	0.051	0.022	0.01	0.007	DOH
Bonneville Dam OR Shore	U-235	0.0201	0.0099		0.0093	PNNL
Bonneville Dam OR Shore	U-235	0.017	0.013	0.01	0.007	DOH
Dalles Dam OR Shore	U-235	0.0103	0.0072		0.0084	PNNL
Dalles Dam OR Shore	U-235	0.046	0.021	0.01	0.007	DOH
Dalles Dam WA Shore	U-235	0.062	0.025	0.01	0.007	DOH
John Day Dam Mid-River	U-235	0.0242	0.014		0.0158	PNNL
John Day Dam Mid-River	U-235	0.041	0.026	0.01		DOH
John Day Dam OR Shore	U-235	0.027	0.024	0.01		DOH
John Day Dam WA Shore	U-235	0.037	0.026	0.01		DOH
McNary 2/3 OR Shore	U-235	0.03	0.027	0.01		DOH
McNary 2/3 OR Shore	U-235	0.03	0.027	0.01		DOH
McNary 2/3 OR Shore	U-235	0.0225	0.011		0.0027	PNNL
McNary 2/3 OR Shore	U-235	0.0257	0.0098		0.002	PNNL
McNary OR Beach	U-235	0.015	0.022	0.01		DOH
McNary OR Shore	U-235	0.027	0.032	0.01		DOH
McNary WA Beach	U-235	0.011	0.021	0.01		DOH
McNary WA Shore	U-235	0.042	0.023	0.01	0.025	DOH
Priest Rapids Dam Grant Co. Side	U-235	0.0217	0.0091		0.0052	PNNL
Priest Rapids Dam Yakima Co. Side	U-235	0.0155	0.0077		0.0052	PNNL
Bonneville Beach (OR)	U-238	0.97	0.1	0.054	0.03	DOH
Bonneville Dam OR Shore	U-238	0.562	0.098		0.0093	PNNL
Bonneville Dam OR Shore	U-238	0.38	0.06	0.054	0.03	DOH
Dalles Dam OR Shore	U-238	0.516	0.09		0.0091	PNNL
Dalles Dam OR Shore	U-238	0.94	0.09	0.054	0.03	DOH
Dalles Dam WA Shore	U-238	1.73	0.13	0.054	0.02	DOH
John Day Dam Mid-River	U-238	0.699	0.12		0.0211	PNNL
John Day Dam Mid-River	U-238	1.2	0.1	0.054		DOH
John Day Dam OR Shore	U-238	1.1	0.1	0.054		DOH
John Day Dam WA Shore	U-238	1.2	0.1	0.054		DOH
McNary 2/3 OR Shore	U-238	1.4	0.1	0.054		DOH
McNary 2/3 OR Shore	U-238	1.4	0.1	0.054		DOH
McNary 2/3 OR Shore	U-238	0.58	0.1		0.002	PNNL
McNary 2/3 OR Shore	U-238	0.593	0.11		0.0027	PNNL

Table B.1. (contd)

Site	Analyte	Result	Error[(a)]	LLD[(b)]	MDA[(c)]	Agency
McNary OR Beach	U-238	0.42	0.07	0.054		DOH
McNary OR Shore	U-238	1.3	0.2	0.054		DOH
McNary WA Beach	U-238	0.35	0.07	0.054		DOH
McNary WA Shore	U-238	0.96	0.1	0.054	0.035	DOH
Priest Rapids Dam Grant Co. Side	U-238	0.659	0.11		0.0066	PNNL
Priest Rapids Dam Yakima Co. Side	U-238	0.576	0.1		0.0066	PNNL

(a) DOH and PNNL errors are reported as 2-sigma; ODOE errors are reported as 3-sigma.
(b) LLD = Lower limit of detection.
(c) MDA = Minimal detectable activity.
Co = County.
ODOE = Oregon Department of Energy.
PNNL = Pacific Northwest National Laboratory.
DOH = Washington State Department of Health.

Table B.2. Concentrations of Metals in Columbia River Sediment (µg/g dry wt.)

WDOE Proposed Standards														
			Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb
Proposed WA Sediment Quality Standard[(a)]			--	0.4	20	--	--	0.6	--	95	80	--	--	335
Proposed WA Sediment Cleanup Screening Level[(a)]			--	0.6	51	--	--	1.0	--	100	830	--	--	430
WDOE Results														
Sample No.	Location	Date	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb
B17BB8	Bonneville OR Shore	08/07/03	11,000	4.3	4.8	120	1.1	1.1	4,400	16	12	23	24,000	13
B17BB5	Bonneville OR Beach	08/07/03	11,000	3	1.5	79	0.74	1.5	4,500	15	21	16	42,000	4
B17B93	Dallas Dam OR Shore	08/07/03	12,000	4.5	4.6	120	1.1	1.4	4,800	18	13	23	27,000	14
B17B99	Dallas Dam WA Shore	08/08/03	5,500	2.6	3.3	72	0.65	0.65	3,100	9.4	10	7.5	22,000	7.3
B17B84	John Day WA Shore	08/08/03	18,000	5.5	7.4	170	1.4	2.4	5,900	25	19	34	37,000	22
B17B81	John Day Mid River	08/08/03	19,000	6.1	8.6	170	1.5	2.3	6,100	27	18	35	37,000	23
B17B78	John Day Dam OR Shore	08/08/03	22,000	5.9	9.5	210	1.5	2.5	6,800	30	22	46	44,000	27
B17B60	McNary Dam OR Shore	08/08/03	17,000	5.1	7.6	150	1.3	1.9	5,800	26	17	31	34,000	20
B17B57	McNary Dam OR Beach	08/08/03	2,900	2.4	2.1	53	0.6	1.2	3,500	3.7	12	7.1	24,000	2.1
B17B65	McNary 2/3 OR Shore	08/08/03	11,000	3.7	5.8	110	0.93	1.4	4,700	21	13	19	27,000	18
B17B66 (dup)	McNary 2/3 OR Shore	08/08/03	11,000	3.5	5.9	110	0.88	1.4	4,500	20	13	19	26,000	18
B17B72	McNary Dam WA Beach	08/08/03	3,800	2.5	1.8	68	0.62	1.2	3,700	5.7	13	8.2	27,000	2.5
B17B67	McNary Dam WA Shore	08/08/03	9,100	3.4	4.3	92	0.84	1.0	4,000	16	11	15	24,000	14
PNNL Results														
B17BK5	Bonneville Dam OR Shore	08/07/03	NA	0.84	5.96	NA	1.60	0.88	NA	57.3	NA	32.1	NA	18.7
B17BK5 (dup)	Bonneville Dam OR Shore	08/07/03	NA	0.86	6.09	NA	1.55	0.89	NA	59.0	NA	32.3	NA	18.4
B17BK1	Dalles Dam Mid. River	08/07/03	NA	0.6	5.57	NA	1.60	1.21	NA	57.2	NA	30.8	NA	17.6
B17BJ7	John Day Dam Mid. River	08/08/03	NA	0.82	9.90	NA	1.89	2.02	NA	69.3	NA	40.2	NA	25.6
B17BJ3	McNary 2/3 OR Shore	08/08/03	NA	0.7	7.55	NA	1.79	1.48	NA	73.2	NA	26.7	NA	24.7
SESP Results														
B17704	PRD-Grant Co. Side	07/14/03	NA	0.91	9.73	NA	1.56	8.93	NA	86.9	NA	50.0	NA	49.6
B17704 (dup)	PRD-Grant Co. Side	07/14/03	NA	0.9	9.50	NA	1.47	9.02	NA	86.9	NA	49.8	NA	50.2
B17702	PRD-Yakima Co. Side	07/14/03	NA	0.9	9.20	NA	1.50	5.99	NA	92.1	NA	45.9	NA	54.2

Table B.2. (contd)

			Mg	Mn	Ni	K	Se	Ag	Na	Tl	V	Zn	Hg
WDOE Proposed Standards													
Proposed WA Sediment Quality Standard[(a)]			--	--	60	--	--	2.0	--	--	--	140	0.50
Proposed WA Sediment Cleanup Screening Level[(a)]			--	--	70	--	--	2.5	--	--	--	160	0.75
WDOE Results													
Sample No.	Location	Date	Mg	Mn	Ni	K	Se	Ag	Na	Tl	V	Zn	Hg
B17BB8	Bonneville OR Shore	08/07/03	4,200	510	16	1,400	1.3	2.1	340	2.1	58	140	0.21
B17BB5	Bonneville OR Beach	08/07/03	7,000	450	30	450	1.5	1.5	390	3	120	64	0.15
B17B93	Dallas Dam OR Shore	08/07/03	4,100	400	16	1,500	1.1	2.2	330	2.2	62	160	0.22
B17B99	Dallas Dam WA Shore	08/08/03	3,100	370	9.7	830	0.96	1.3	170	1.3	62	84	0.13
B17B84	John Day WA Shore	08/08/03	6,400	680	24	2,500	1.6	2.8	320	2.8	73	240	0.28
B17B81	John Day Mid River	08/08/03	6,700	770	25	2,500	1.5	3	320	3	71	250	0.3
B17B78	John Day Dam OR Shore	08/08/03	7,500	840	29	3,000	1.5	2.9	370	2.9	87	270	0.29
B17B60	McNary Dam OR Shore	08/08/03	6,700	640	25	2,300	1.3	2.5	280	2.5	64	220	0.25
B17B57	McNary Dam OR Beach	08/08/03	3,200	280	6.1	490	1.2	1.2	130	2.4	72	53	0.18
B17B65	McNary 2/3 OR Shore	08/08/03	5,500	630	20	1,700	0.93	1.9	220	1.9	50	240	0.19
B17B66 (dup)	McNary 2/3 OR Shore	08/08/03	5,300	600	19	1,700	0.88	1.8	220	1.8	48	230	0.12
B17B72	McNary Dam WA Beach	08/08/03	4,200	450	15	1,400	0.84	1.7	210	1.7	47	160	NA
B17B67	McNary Dam WA Shore	08/08/03	3,900	410	7.9	660	1.2	1.2	140	2.5	77	46	NA
PNNL Results													
B17BK5	Bonneville Dam OR Shore	08/07/03	NA	NA	25	NA	**0.477**	0.314	NA	0.445	NA	175	0.512
B17BK5 (dup)	Bonneville Dam OR Shore	08/07/03	NA	NA	27	NA	**0.477**	0.319	NA	0.462	NA	180	0.168
B17BK1	Dalles Dam Mid. River	08/07/03	NA	NA	24.0	NA	**0.477**	0.337	NA	0.535	NA	179	0.0533
B17BJ7	John Day Dam Mid. River	08/08/03	NA	NA	32	NA	**0.477**	0.433	NA	0.694	NA	261	0.105
B17BJ3	McNary 2/3 OR Shore	08/08/03	NA	NA	30	NA	**0.477**	0.438	NA	0.729	NA	276	0.0927
SESP Results													
B17704	PRD-Grant Co. Side	07/14/03	NA	NA	42	NA	**0.477**	0.484	NA	1.72	NA	591	0.167
B17704 (dup)	PRD-Grant Co. Side	07/14/03	NA	NA	42	NA	**0.477**	0.469	NA	1.74	NA	594	0.171
B17702	PRD-Yakima Co. Side	07/14/03	NA	NA	47	NA	**0.477**	0.447	NA	1.15	NA	495	0.187

(a) Michelsen (2003).
Bold values are below the listed detection limit.
Co = County; dup = Duplicate; NA = Not analyzed; PNNL = Pacific Northwest National Laboratory; PRD = Priest Rapids Dam; SESP = Surface Environmental Surveillance Project; WDOH = Washington State Department of Health.

Table B.3. Simultaneously Extracted Metal/Acid Volatile Sulfide (SEM/AVS) Concentrations (µmol/g dry wt.) for Columbia River Sediment

Sample No.	Location	Date	% Dry Weight	AVS	SEM Cd	SEM Cu	SEM Hg	SEM Ni	SEM Pb	SEM Zn
B17BK3	Bonneville Dam OR Shore	8/7/2003	49.0	3.631	0.0053	0.195	0.000009	0.103	0.054	1.487
B17BJ9	Dalles Dam OR. Shore	8/7/2003	48.9	4.166	0.0083	0.205	0.000016	0.097	0.059	1.791
B17BJ9 (dup)	Dalles Dam OR. Shore	8/7/2003	48.9	3.420	0.0080	0.198	0.000014	0.094	0.057	1.703
B17BK2	Dalles Dam WA Shore	8/7/2003	73.8	**0.051**	0.0033	0.068	0.000029	0.046	0.033	0.752
B17BJ5	John Day Dam OR Shore	8/8/2003	36.7	3.292	0.0143	0.419	0.000013	0.174	0.105	2.735
B17BJ6	John Day Dam Mid. River	8/8/2003	38.5	7.575	0.0143	0.286	0.000014	0.142	0.093	2.835
B17BJ8	John Day Dam WA Shore	8/8/2003	51.8	8.385	0.0161	0.274	0.000007	0.158	0.087	2.434
B17BJ1	McNary OR Shore	8/8/2003	39.3	4.900	0.0129	0.261	0.000019	0.155	0.083	2.388
B17BJ2	McNary 2/3 OR Shore	8/8/2003	57.7	**0.118**	0.0104	0.181	0.000161	0.098	0.074	2.224
B17BJ4	McNary WA Shore	8/8/2003	59.9	**0.069**	0.0090	0.145	0.000115	0.081	0.061	1.717
B17BJ4 (dup)	McNary WA Shore	8/8/2003	59.9	**0.075**	0.0087	0.142	0.000120	0.068	0.060	1.704
Detection Limit (mean DL used for AVS)				0.123	0.0001	0.0001	0.0000003	0.0001	0.00002	0.0009
B17703	Priest Rapids Grant Co. Side	7/14/2003	47.2	7.47	0.0770	0.3509	0.0000065	0.157	0.189	8.379
B17703 (dup)	Priest Rapids Grant Co. Side	7/14/2003	45.2	7.09	0.0743	0.38327	0.0000201	0.178	0.185	8.193
B17701	Priest Rapids Yakima Co. Side	7/14/2003	51.1	3.83	0.0442	0.46107	0.0000083	0.210	0.184	6.014
B17701(dup)	Priest Rapids Yakima Co. Side	7/14/2003	51.1	3.61	0.0430	0.46193	0.0000107	0.210	0.179	5.950
Bold = Value was below detection limit.				0.086	0.00006	0.00008	0.0000002	0.00005	0.00002	0.001
Co = County; dup = Duplicate. DL = Detection limit.										

Table B.4. Analytical Detection Limits (µg/kg dry wt.) for Pesticides, PCBs, and Semivolatile Organic Compounds in Columbia River Sediment

Organochlorine Pesticides	MDL µg/kg	Semi-Volatile Organics	MDL µg/kg	Semivolatile Organics	MDL µg/kg
Alpha-BHC	1.7	Pyridine	330	2,6-Dinitrotoluene	330
Lindane (Gamma-BHC)	1.7	N-Nitrosodimethytlamine	330	Acenaphthalene	330
Beta-BHC	1.7	Aniline	830	3-Nitroaniline	1,700
Delta-BHC	1.7	Phenol	330	Acenaphthene	330
Hepatachlor	1.7	Bis(2-chloroethyl)ether	330	2,4-Dinitrophenol	1,700
Aldrin	1.7	2-Chlorophenol	330	4-Nitrophenol	1,700
Hepatachlor epoxide	1.7	1,3-Dichlorobenzene	330	Dibenzofuran	330
Gamma-chlordane	1.7	1,4-Dichlorobenzene	330	2,4-Dinitrotoluene	330
Alpha-chlordane	1.7	1,2-Dichlorobenzene	330	Diethylphthalate	330
4,4- DDE	1.7	Benzyl alcohol	330	Fluorene	330
Endosulfan I	1.7	Bis(2-chloroisopropyl)ether	330	4-Chlorophenyl phenyl ether	330
Dieldrin	1.7	2-Methylphenol	330	4-Nitroaniline	1,700
Endrin	1.7	N-Nitroso-di-n-propylamine	330	Azobenzene	330
4,4-DDD	1.7	4-Methylphenol	330	4,6-Dinitro-2-methylphenol	1,700
Endosulfan II	1.7	Hexachloroethane	330	N-nitrosodiphenylamine	330
4,4-DDT	1.7	Nitrobenzene	330	4-Bromophenyl phenyl ether	330
Endrin aldehyde	1.7	Isophorone	330	Hexachlorobenzene	330
Methoxychlor	8.3	2-Nitrophenol	330	2,3,4,6-Tetrachlorophenol	1,700
Endosulfan sulfate	1.7	2,4-Dimethylphenol	330	Pentachlorophenol	1,700
Endrin ketone	1.7	Bis(2-chloroethoxy)methane	330	Phenanthrene	330
Toxaphene	83	2,4-Dichlorophenol	330	Anthracene	330
		Benzoic Acid	1700	Carbazole	330
PCBs		1,2,4,-Trichlorobenzene	330	Di-n-butyl phthalate	330
Aroclor-1016	33	Naphthalene	330	Fluoranthene	330
Aroclor-1221	67	4-Chloroaniline	330	Pyrene	330
Aroclor-1232	33	Hexachlorobutadiene	330	Butyl benzyl phthalate	330

Table B.4. (contd)

PCBs	MDL µg/kg	Semi-Volatile Organics	MDL µg/kg	Semivolatile Organics	MDL µg/kg
Aroclor-1242	33	4-Chloro-3-methylphenol	330	Benzo(a)anthracenene	330
Aroclor-1248	33	2-Methylnaphthalene	330	3,3-Dichlorobenzidine	1,700
Aroclor-1254	33	Hexachlorocyclopentadiene	330	Chrysene	330
Aroclor-1260	33	2,4,6-Trichlorophenol	330	Bis(2-ethylhexyl)phthalate	330
		2,4,5-Trichlorophenol	330	Di-n-octylphthalate	330
		2-Chloronaphthalene	330	Benzo(b)fluoranthene	330
		2-Nitroaniline	1700	Benzo(k)fluoranthene	330
		Dimethylphthalate	330	Benzo(a)pyrene	330
				Indeno(1,2,3-cd)pyrene	330
				Dibenzo(a,h)anthracene	330
				Benzo(g,h)perylene	330

MDL = Method detection limit.
PCB = Polychlorinated biphenyl.

Table B.5. Semivolatile Organic Compounds in Columbia River Sediment (all values in µg/kg dry wt.). All results were below the detection limits listed in Table B.4.

Analyte	Proposed WA Sediment Quality Standard (a)	Proposed WA Cleanup Screening Level (a)	Columbia River Sediment Concentration						
			Bonneville OR SH	Dalles OR SH	Dalles WA SH	McNary 2/3 OR SH	Bonneville OR Beach	John Day WA SH	John Day Mid-River
2-Methylnaphthalene	470	560	330	330	330	330	330	330	330
Acenaphthene	1,060	1,320	330	330	330	330	330	330	330
Acenaphtheylene	470	640	330	330	330	330	330	330	330
Anthracene	1,200	1,580	330	330	330	330	330	330	330
Benzanthracene	4,260	5,800	330	330	330	330	330	330	330
Benzopyrene	3,300	4,810	330	330	330	330	330	330	330
Benzofluoranthenes	11,000	14,000	330	330	330	330	330	330	330
Benzoperylene	3,300	4,810	330	330	330	330	330	330	330
Chrysene	5,940	6,400	330	330	330	330	330	330	330
Dibenzanthracene	800	840	330	330	330	330	330	330	330
Fluoranthene	11,000	15,000	330	330	330	330	330	330	330
Fluorene	1,000	3,000	330	330	330	330	330	330	330
Indenopyrene	4,120	5,300	330	330	330	330	330	330	330
Napthalene	500	1,310	330	330	330	330	330	330	330
Phenanthrene	6,100	7,600	330	330	330	330	330	330	330
Pyrene	8,800	16,000	330	330	330	330	330	330	330
LPAH's	6,600	9,200	--	--	--	--	--	--	--
HPAH's	3,100	54,800	--	--	--	--	--	--	--
Bis(2-ethylhexyl)phthalate	230	320	330	330	330	330	330	330	330
Butylbenzylphthalate	260	370	330	330	330	330	330	330	330
Dimethylphthalate	46	440	330	330	330	330	330	330	330
Di-n-octyl phthalate	26	45	330	330	330	330	330	330	330
Dibenzofuran	400	440	330	330	330	330	330	330	330

Table B.5. (contd)

Analyte	Proposed WA Sediment Quality Standard (a)	Proposed WA Cleanup Screening Level (a)	Columbia River Sediment Concentration					
			McNary 2/3 OR SH dup	John Day OR SH	McNary WA SH	McNary WA Beach	McNary OR Beach	McNary Dam OR SH
2Methylnaphthalene	470	560	330	330	330	330	330	330
Acenaphthene	1,060	1,320	330	330	330	330	330	330
Acenaphtheylene	470	640	330	330	330	330	330	330
Anthracene	1,200	1,580	330	330	330	330	330	330
Benzanthracene	4,260	5,800	330	330	330	330	330	330
Benzopyrene	3,300	4,810	330	330	330	330	330	330
Benzofluoranthenes	11,000	14,000	330	330	330	330	330	330
Benzoperylene	3,300	4,810	330	330	330	330	330	330
Chrysene	5,940	6,400	330	330	330	330	330	330
Dibenzanthracene	800	840	330	330	330	330	330	330
Fluoranthene	11,000	15,000	330	330	330	330	330	330
Fluorene	1,000	3,000	330	330	330	330	330	330
Indenopyrene	4,120	5,300	330	330	330	330	330	330
Napthalene	500	1,310	330	330	330	330	330	330
Phenanthrene	6,100	7,600	330	330	330	330	330	330
Pyrene	8,800	16,000	330	330	330	330	330	330
LPAH's	6,600	9,200	-	-	-	-	-	-
HPAH's	3,100	54,800	-	-	-	-	-	-
Bis(2-ethylhexyl)phthalate	230	320	330	330	330	330	330	330
Butylbenzylphthalate	260	370	330	330	330	330	330	330
Dimethylphthalate	46	440	330	330	330	330	330	330
Di-n-octyl phthalate	26	45	330	330	330	330	330	330
Dibenzofuran	400	440	330	330	330	330	330	330

a) Michelsen, 2003. SH = Shore.

Table B.6. Sediment Grain Size Distributions for Columbia River Sediment

Sponsor ID	Sample Description	Date	Total Solids (%)	Grain Size (Percent of Total Weight Recovered)				
				Gravel (2.0 mm)	Sand, Very Coarse (1.0 mm)	Sand, Coarse (0.5 mm)	Sand, Medium (0.25 mm)	Sand, Fine (0.125 mm)
B17BM3	Bonneville Dam OR Shore Beach	08/07/2003	70.6	1.81	4.36	25.7	44.3	16.6
B17BM3 (Dup)	Bonneville Dam OR Shore Beach	08/07/2003	70.4	1.74	4.26	27.5	45.4	15.0
B17BM3 (Tri)	Bonneville Dam OR Shore Beach	08/07/2003	--	2.02	4.75	25.9	45.0	16.5
B17BM5	Bonneville Dam OR Shore	08/07/2003	53.2	0.02	0.16	0.39	1.33	15.0
B17BL9	Dalles Dam OR Shore	08/07/2003	50.7	0.04	0.10	0.19	0.47	3.23
B17BM1	Dalles Dam WA Shore	08/07/2003	72.3	0.11	0.13	4.02	39.6	34.6
B17BL4	Johns Dam OR. Shore	08/08/2003	39.3	0.42	0.03	0.16	0.24	0.38
B17BL5	Johns Dam Mid-River	08/08/2003	29.8	0.00	0.08	0.51	3.54	3.95
B17BL6	Johns Dam WA Shore	08/08/2003	43.0	0.00	0.05	0.16	0.79	4.56
B17BK7	McNary OR Shore Beach	08/08/2003	75.5	0.40	1.53	75.6	20.6	2.71
B17BK8	McNary OR Shore	08/08/2003	37.6	0.00	0.00	0.09	0.29	0.56
B17BK9	McNary 2/3 OR Shore	08/08/2003	54.6	0.00	0.00	0.04	0.46	1.82
B17BK9	McNary 2/3 OR Shore	08/08/2003	54.5	--	--	--	--	--
B17BL0 (Dup)	McNary 2/3 OR Shore,	08/08/2003	58.1	0.00	0.01	0.05	0.44	2.22
B17BL1	McNary WA Shore	08/08/2003	55.6	0.99	0.41	0.59	3.53	11.6
B17BL2	McNary WA Shore Beach	08/08/2003	81.3	0.43	0.11	1.19	86.2	10.1

Table B.6. (contd)

Sponsor ID	Sample Description	Date	Total Solids (%)	Grain Size (Percent of Total Weight Recovered)			
				Sand, Very Fine (0.0625 mm)	Silt	Clay	Check (Total % Recovered)
B17BM3	Bonneville Dam OR Shore Beach	08/07/2003	70.6	2.15	2.64	0.71	98.3
B17BM3 (Dup)	Bonneville Dam OR Shore Beach	08/07/2003	70.4	2.16	2.59	0.67	99.3
B17BM3 (Tri)	Bonneville Dam OR Shore Beach	08/07/2003	--	2.05	2.57	0.66	99.5
B17BM5	Bonneville Dam OR Shore	08/07/2003	53.2	21.50	50.2	14.1	103
B17BL9	Dalles Dam OR Shore	08/07/2003	50.7	28.30	59.4	9.35	101
B17BM1	Dalles Dam WA Shore	08/07/2003	72.3	17.10	4.23	1.70	101
B17BL4	Johns Dam OR. Shore	08/08/2003	39.3	2.36	69.4	27.1	100
B17BL5	Johns Dam Mid-River	08/08/2003	29.8	10.10	73.0	10.5	102
B17BL6	Johns Dam WA Shore	08/08/2003	43.0	14.70	64.3	15.2	99.8
B17BK7	McNary OR Shore Beach	08/08/2003	75.5	0.99	0.35	0.09	102
B17BK8	McNary OR Shore	08/08/2003	37.6	8.75	83.5	7.69	101
B17BK9	McNary 2/3 OR Shore	08/08/2003	54.6	35.7	48.3	6.38	92.7
B17BK9 (Dup)	McNary 2/3 OR Shore	08/08/2003	54.5	--	--	--	--
B17BL0	McNary 2/3 OR Shore	08/08/2003	58.1	39.60	51.3	7.67	101
B17BL1	McNary WA Shore	08/08/2003	55.6	30.6	47.9	5.54	101
B17BL2	McNary WA Shore Beach	08/08/2003	81.3	0.28	0.20	0.13	98.6

-- = No analysis/not applicable. Dup = Duplicate. Tri = Triplicate.
RPD = Relative percent difference.
RSD = Relative standard deviation.

Table B.7. Total Organic Carbon Content (TOC) of Columbia River Sediment and Beach Sediment

Sample No.	Date	Location	TOC (mg/kg dry wt.)
B17BR8	07-Aug-03	Bonneville Dam OR Shore	13,300
B17BR7	07-Aug-03	Bonneville Dam OR Shore Beach	1,110
B17BR3	07-Aug-03	Dalles Dam OR Shore	12,300
B17BR5	07-Aug-03	Dalles Dam WA Shore	1,490
B17BP9	08-Aug-03	John Day Dam Mid-River	16,200
B17BP8	08-Aug-03	John Day Dam OR Shore	13,700
B17BR0	08-Aug-03	John Day Dam WA Shore	13,400
B17BP3	08-Aug-03	McNary-2/3 OR Shore	7,190
B17BP4	08-Aug-03	McNary-2/3 OR Shore	7,280
B17BP1	08-Aug-03	McNary-OR Shore Beach	216
B17BP2	08-Aug-03	McNary-Oregon Shore	12,600
B17BP6	08-Aug-03	McNary-WA Shore Beach	214
B17BP5	08-Aug-03	McNary-Wash. Shore	5,460

Table B.8. Radiological Results for Columbia River Water Samples Collected at McNary Dam

Date	Location	Analyte	Result	Unit	Counting Error	Total Analytical Error	Detection Limit	Qualifier
PNNL Results								
08-Aug-03	McNary-Oregon Shore	Sr-90	0.152	pCi/L	0.022	0.032	0.0252	
08-Aug-03	McNary-2/3 OR Shore	Be-7	-0.959	pCi/L	23	23	40.4	U
08-Aug-03	McNary-2/3 OR Shore	Co-60	4.42	pCi/L	3.1	3.1	7.18	U
08-Aug-03	McNary-2/3 OR Shore	Cs-134	0.699	pCi/L	3.3	3.3	6.18	U
08-Aug-03	McNary-2/3 OR Shore	Cs-137	-3.15	pCi/L	2.6	2.6	3.77	U
08-Aug-03	McNary-2/3 OR Shore	Eu-152	-4.22	pCi/L	6.8	6.8	11.6	U
08-Aug-03	McNary-2/3 OR Shore	Eu-154	-1.08	pCi/L	7.9	7.9	14.9	U
08-Aug-03	McNary-2/3 OR Shore	Eu-155	-1.13	pCi/L	5.7	5.7	10.2	U
08-Aug-03	McNary-2/3 OR Shore	K-40	-41.5	pCi/L	66	66	145	U
08-Aug-03	McNary-2/3 OR Shore	Pu-238	-0.0000285	pCi/L	0.0033	0.0033	0.00849	U
08-Aug-03	McNary-2/3 OR Shore	Pu-239/240	0.00177	pCi/L	0.0033	0.0033	0.00313	U
08-Aug-03	McNary-2/3 OR Shore	Ru-106	4.27	pCi/L	21	21	39.7	U
08-Aug-03	McNary-2/3 OR Shore	Sb-125	0.131	pCi/L	6.1	6.1	11	U
08-Aug-03	McNary-2/3 OR Shore	Sr-90	0.115	pCi/L	0.022	0.029	0.029	
08-Aug-03	McNary-2/3 OR Shore	U-234	0.253	pCi/L	0.038	0.055	0.01	
08-Aug-03	McNary-2/3 OR Shore	U-235	0.00349	pCi/L	0.0061	0.0064	0.0037	U
08-Aug-03	McNary-2/3 OR Shore	U-238	0.188	pCi/L	0.033	0.044	0.0127	
08-Aug-03	McNary-WA Shore	Sr-90	0.123	pCi/L	0.023	0.03	0.0296	
ODOE Results								
08-Aug-03	McNary-2/3 OR Shore	Co-60	0.005	pCi/L	0.003			
08-Aug-03	McNary-2/3 OR Shore	Co-60	0.009	pCi/L	0.005			
08-Aug-03	McNary-2/3 OR Shore	Cs-137	ND	pCi/L				
08-Aug-03	McNary-2/3 OR Shore	Cs-137	ND	pCi/L				
08-Aug-03	McNary-2/3 OR Shore	K-40	0.2	pCi/L	0.111			
08-Aug-03	McNar-2/3 OR Shore	K-40	0.3	pCi/L	0.12			

ODOE = Oregon Department of Energy.
PNNL = Pacific Northwest National Laboratory.

B.9 References

Michelsen TM. 2003. *Development of Freshwater Sediment Quality Values for Use in Washington State. Phase II Report: Development and Recommendations for SQVs for Freshwater Sediment in Washington State.* Pub. No. 03-09-088. Avocet Consulting (Kenmore, Washington) under contract to Science Applications International Corporation (Bothell, Washington).