Water-Quality Monitoring for a Pilot Piling-Removal Field Evaluation, Coal Creek Slough, Washington, 2008–09

By Elena B. Nilsen and David Alvarez

Prepared in cooperation with the U.S. Army Corps of Engineers

Open-File Report 2011–1233

U.S. Department of the Interior
U.S. Geological Survey

Cover: Piling fields are common to the Lower Columbia River and Estuary. These pilings were removed in a study of the possible effects of treated wood pilings on sediment and water quality. (Photograph by Elena Nilsen, U.S. Geological Survey, August 6, 2008.)

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KEN SALAZAR, Secretary

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Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

Suggested citation:
Nilsen, E.B., and Alvarez, David, 2011, Water-quality monitoring for a pilot piling removal field evaluation, Coal Creek Slough, Washington, 2008–09: U.S. Geological Survey Open-File Report 2011-1233, 26 p.

Contents

Figures

Tables

Conversion Factors and Datums

Multiply	cm	To obtain
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L), micrograms per liter (µg/L), or nanograms per liter (ng/L), which are approximately equivalent to parts per million, parts per billion, and parts per trillion, respectively. Concentrations of chemical constituents in solids are given in micrograms per kilogram (µg/kg), equivalent to parts per billion.

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).
Elevation, as used in this report, refers to distance above the vertical datum.

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Significant Findings

Water and sediment quality monitoring was conducted before and after the removal of a piling field located in Coal Creek Slough near Longview, Washington. Passive chemical samplers and continuous water-quality monitoring instruments were deployed at the piling removal site, Coal Creek Slough Site 1 (CCS1), and at a comparison site, Coal Creek Slough Site 2 (CCS2), before (2008) and after (2009) piling removal. Surface and subsurface (core) sediment samples were collected before and after piling removal and were analyzed for grain size, organic carbon content, and chemicals of concern. Significant findings from this study include:

- Phenanthrene was the only compound detected in wood piling samples analyzed for a large suite of semivolatile organic compounds and polycyclic aromatic hydrocarbons (PAHs). Metals potentially associated with wood treatment were detected in the wood piling samples at low concentrations.
- Organic carbon was slightly lower in core samples from CCS1 in pre-removal (2008) and post-removal (2009) samples than in surface samples from both sites in both years.
- Grain-size class distributions were relatively uniform between sites and years.
- Thirty-four out of 110 chemicals of concern were detected in sediments. Eight of those detected were anthropogenic waste indicator (AWI) compounds, 18 were PAHs, 4 were sterols, and 4 were metals potentially associated with wood treatment.
- Nearly all reported concentrations of chemicals of concern in sediments are qualified as estimates, primarily due to interferences in extracts resulting from complex sample matrices. Indole, perylene, and fluoranthene are reported without qualification for some of the samples, and the metals are reported without qualification for all samples.
- The highest frequency of detection of chemicals of concern was seen in the pre-removal surface samples at both sites.
- AWI compounds were detected less frequently and at lower concentrations during the post-removal sampling compared to the pre-removal sampling.
- Several PAHs were detected at relatively high concentrations in core samples, likely indicating historical sources.
- Most commonly detected PAHs in sediments were 2,6-dimethylnaphthalene, fluoranthene, perylene, and pyrene.
- Most commonly detected AWIs in sediments were 3-methyl-1h-indole (skatol), acetophenone, indole, phenol, and para-cresol.
- Sedimentary concentrations of perylene exceeded available sediment quality guidelines. Perylene is widespread in the environment and has large potential natural sources in addition to its anthropogenic sources.

- Concentrations of metals did not exceed sediment quality guidelines.
- Multiple organochlorine pesticides, both banned and currently used, were detected at each site using passive samplers.
- Commonly detected pesticides included hexachlorobenzene, pentachloroanisole (a degradation product of pentachlorophenol), diazinon, cis-chlordane, endosulfan, DDD, and endosulfan sulfate..
- PBDE concentrations detected in passive sampler extracts were less than the method detection limit at all sites with the exception of PBDE-99, detected at a concentration less than the reporting limit.
- The fragrance galaxolide was detected at a concentration greater than the method detection limit.
- Common PAHs, such as phenanthrene, fluoranthene, and pyrene, were detected in every passive sampler.
- Dissolved oxygen concentration was slightly higher at site CCS1 compared to site CCS2 in both years.
- Overall, there was no systematic increase in chemicals of concern at the restoration site during post-removal monitoring compared to conditions during pre-removal monitoring. Any immediate, short-duration effects of piling removal on water quality could not be determined because monitoring was not conducted during the removal.

Introduction

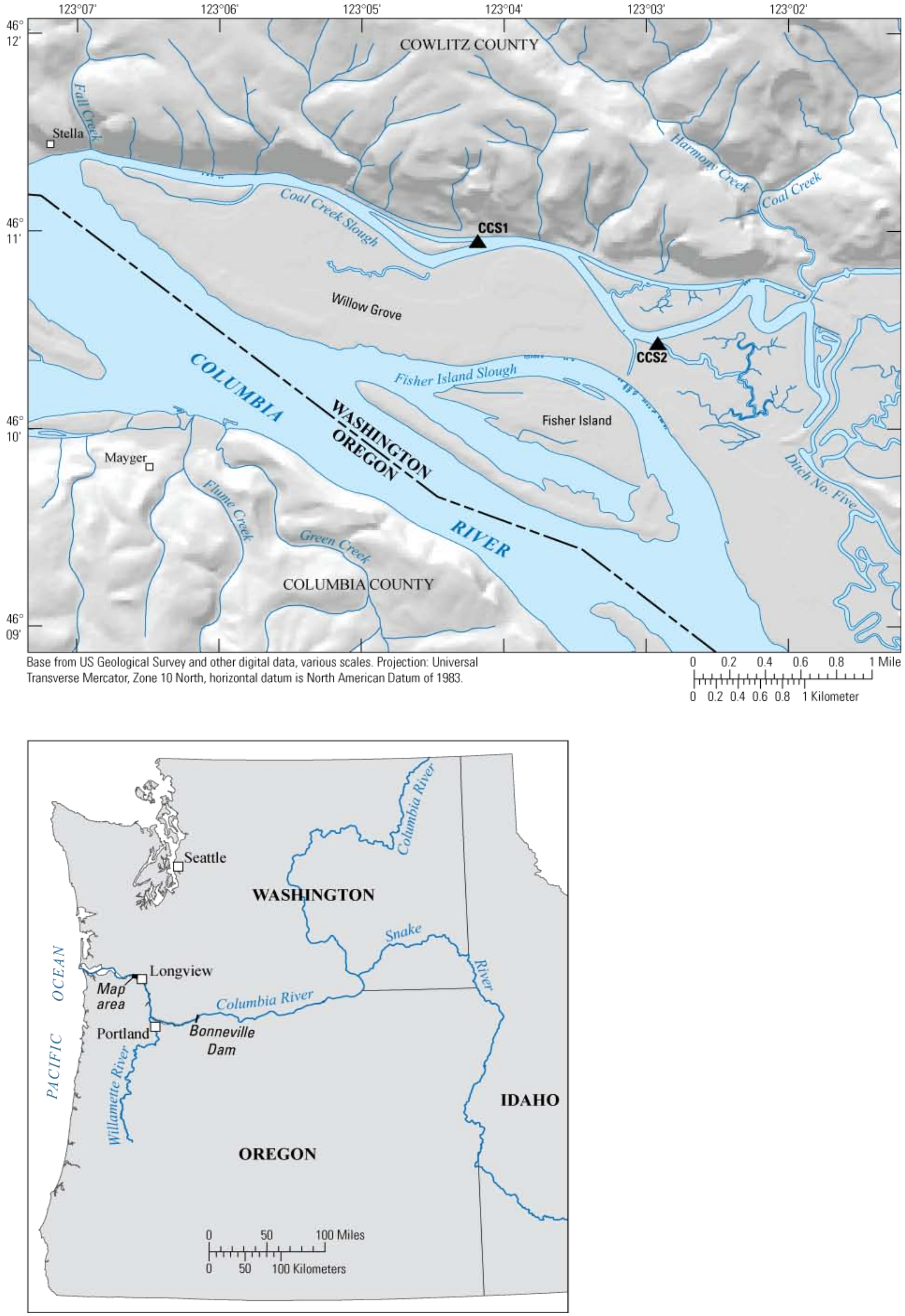
Background

Water- and sediment-quality monitoring was conducted before and after the removal of a piling field from Coal Creek Slough near Longview, Washington (fig. 1). This effort was in support of the U.S. Army Corps of Engineers Lower Columbia River Ecosystem Restoration General Investigation Study. Piling fields are common to the Lower Columbia River and Estuary and their removal may improve salmonid access to off-channel habitat, reduce habitat for predators of salmonids, and restore natural sediment dynamics. However, many of the pilings have been chemically treated with wood preservatives (containing contaminants such as polycyclic aromatic hydrocarbons [PAHs]), and disturbance of the bed material during piling removal could mobilize these plus any other contaminants that may have been transported and accumulated in the sediments over time.

Pilings were removed from Coal Creek Slough in February 2009 as part of a pilot restoration project designed by the Lower Columbia River Estuary Partnership with the goal of improving habitat for salmonids without causing additional impairment, such as to water quality. The monitoring described here was conducted before piling removal to establish baseline conditions, and repeated after removal for comparison.

Study Area

Coal Creek Slough separates Willow Grove from mainland Washington State (fig. 1). The slough enters the Columbia River at river mile (RM) 56.5, near the town of Stella. Two sites were selected for monitoring: site CCS1 (USGS station number 461057123041100) was a rectangular field of pilings at the mouth of a small, off-channel waterway.



Base from US Geological Survey and other digital data, various scales. Projection: Universal Transverse Mercator, Zone 10 North, horizontal datum is North American Datum of 1983.

Figure 1. Sediment sample collection sites in Coal Creek Slough, Washington.

The Lower Columbia River Estuary Partnership selected site CCS1 because it was thought that the piling field might limit salmonid access and/or affect water quality in the off-channel waterway. The piling field was removed in February 2009. Site CCS2 (461026123025500) is a small pile field upstream of site CCS1 at the mouth of another small off-channel waterway. Site CCS2 did not undergo restoration and was selected to serve as a comparison because its water and sediment quality would not have been affected by piling removal.

Objectives

This study is a pilot monitoring effort designed to provide information on water and sediment quality before and after piling field removal. The intent of the study is to provide information that will support objectives of the U.S. Army Corps of Engineers Lower Columbia River Ecosystem Restoration General Investigation Study: (1) provide information for future piling field restoration projects, (2) increase success of planned restoration efforts, (3) facilitate avoidance of additional impacts, and (4) identify actions and recommendations beneficial to future projects aimed at augmenting salmonid habitat. Specific information sought in this study includes the following: Which contaminants are associated with bed sediments in proximity to the pilings? Are the contaminants present in the near-surface sediments and/or in subsurface sediments? Are contaminants present in ambient waters? The study does not address how far downstream contaminants may be transported; that question is beyond the scope of this monitoring.

Approach

Reconnaissance

Prior to the start of monitoring, a day of onsite reconnaissance was conducted. Monitoring locations were observed and strategies for how to representatively sample the sites were determined. Locations and appropriate installation methods for deployment of passive samplers and continuous water-quality instrumentation were determined. The pilings were sampled for chemical analysis to determine whether the pilings were treated with wood preservatives.

Passive Samplers

Semipermeable Membrane Devices (SPMDs) and Polar Organic Chemical Integrative Samplers (POCIS) were deployed at each site for periods of approximately 1 month during August 2008 and September 2009 (table 1). At site CCS1, a sample canister and replicate sample canister each containing three SPMD and two POCIS were deployed. At site CCS2, a single canister containing three SPMD and two POCIS was deployed. A second set of samplers was deployed at both sites 1 year after the initial deployment, during the same flow season as for the pre-removal monitoring, to capture water-quality conditions after piling removal. Field blanks also were exposed at both sites in both years. These passive samplers were an important component of the monitoring strategy because they simulate uptake of contaminants by fish through respiration and therefore represent the possible uptake of contaminants by juvenile salmonids and other fish. Results of the sampling provide information about water quality near piling fields located in Coal Creek Slough.

Table 1. Deployment dates for passive samplers in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal.

[NA, not applicable]

Year	Station Name	Deployment dates	Days deployed
2008	CCS1	8/6/08–9/3/08	28
2008	CCS1 replicate	8/6/08–9/3/08	28
2008	CCS2 (lost in field)	NA	NA
2009	CCS1	9/3/09–9/30/09	27
2009	CCS1 replicate	9/3/09–9/30/09	27
2009	CCS2	9/3/09–9/30/09	27

Dissolved Oxygen

Dissolved oxygen concentration was monitored at sites CCS1 and CCS2 near the passive samplers using Yellow Springs Instruments (YSI) continuous water-quality monitors at each site to capture natural variability. Dissolved oxygen is an important determinant of habitat quality for fish. The monitoring provided information on whether sediment disturbance caused by piling removal had an effect on dissolved oxygen concentrations in the water column. Subsurface sediments may be anoxic, and their exposure as a result of piling removal has the potential to draw down oxygen from overlying waters. The monitoring provided a comparison of dissolved oxygen concentrations in the water column before and after piling removal.

Sediment Sample Collection

Surficial bed sediments represent a large potential sink of contaminants that could be resuspended during piling removal. One hundred ten (110) chemicals of concern were targeted, including semivolatile organic compounds such as PAHs and pentachlorophenol/pentachloroanisole; anthropogenic waste indicators such as surfactants and phthalates; and wood treatment metals. Surficial bed sediments were collected at regular intervals among the field of pilings at sites CCS1 and CCS2. Collection of multiple samples was necessary to adequately represent each site, but to contain analytical costs the samples were composited into one sample for each site.

At each site, 10 surface sediment samples were collected using a hand-held clamshell dredge and the top approximately 3 cm were homogenized. In addition, sediment cores were collected from each site to determine presence of contaminants beneath the surface sediments. Using a hand auger corer with extension handle, three cores were retrieved from each site and material was composited from the interval 15–30 cm. Each homogenized sediment sample was transferred to a certified organic free clean glass I-Chem® jar and then frozen until shipment to the laboratory. A split of each sediment sample was stored separately for grain size and organic carbon analysis to provide insight into factors controlling contaminant accumulation at the sites: these types of compounds are often associated with fine-grained sediments and organic matter.

Composite piling shaving samples were collected from pilings using a hand drill with augur bit. Each sample comprised shavings from two boreholes from two pilings (four bore holes total, homogenized). Bore holes were approximately 3 cm in diameter and 7 cm deep. The chemicals of concern analyzed were PAHs, pentachlorophenol/pentachloroanisole compounds, and wood treatment metals.

Analytical Methods

Wood and Sediment Chemistry

Wood and sediment samples were analyzed for the appropriate contaminant classes at the USGS National Water Quality Laboratory (NWQL). Wood sample preparation and analysis correspond to that described in Zaugg and others (2006). Briefly, a split of each wood sample underwent solvent extraction and concentration. The extract was analyzed by gas chromatography–mass spectrometry (GC–MS) for semiquantitation of the organic compound classes. This provides quantitation, but does not include a multistep clean up; therefore the values are relative in nature as opposed to the rigorous quantitation that is applied to the sediment samples using standardized, published methods. A second split of the sample underwent acid digestion, clean up, concentration and analysis by inductively coupled plasma-mass spectrometry (ICP–MS) for the metals of interest (Cu, As, Zn, and Cr).

For analysis of organic contaminants in sediments, the general laboratory procedure was solvent extraction, clean up, and concentration followed by quantification by GC-MS. Specific procedures differ by compound suite as follows:

PAHs (Zaugg and others, 2006) and AWI compounds (Burkhardt and others, 2006). The qualitative identification of compounds detected by mass spectrometer can be verified, although not necessarily reliably quantified, at concentrations less than the method quantitation limit. Any such detection is reported as an estimated concentration only. For the metals, sediments underwent acid digestion, cleanup, concentration, and analysis by ICP–MS. Values reported are total, recoverable metal concentrations.

Passive Samplers

The SPMDs and POCIS were created at Columbia Environmental Research Center (CERC), shipped to the Oregon Water Science Center for deployment and retrieval, and then returned to CERC for processing and analysis. Chemicals targeted in the SPMDs include PBDE congeners 28, 47, 99, 100, and 153; organochlorine pesticides (OCs); total polychlorinated biphenyls (PCBs); PAHs; and a screen for potential endocrine disrupting chemicals (EDCs) likely originating from wastewater treatment plant effluents (Alvarez and others, 2008). POCIS extracts were analyzed for the same suite of EDCs and were screened by the yeast estrogen screen (YES) assay to test for estrogens or estrogen-mimicking compounds. Average water concentrations were calculated using models that have been reported elsewhere (Alvarez, 2010).

Continuous Water-Quality Monitors

YSI model 6920 V2 continuous water-quality monitors (“sondes”) with YSI Rox 6150 optical dissolved oxygen and YSI 6036 turbidity probes were placed vertically at each site using a float system. The sondes recorded dissolved oxygen concentration, pH, specific conductance, and temperature at the beginning of every hour during the deployment period of approximately 30 days coincident with the passive sampler deployment.

Sondes were cleaned and checked to ensure proper function during a field site visit mid-way through the deployment period. Separate field measurements of dissolved oxygen concentration, pH, specific conductance, and temperature at the depth of the station sonde were made as an additional check of sonde performance and data quality. Calibration of each parameter was checked in the laboratory after sonde retrieval to measure calibration drift. The raw data were then uploaded to the USGS automated data-processing system (ADAPS).

Bulk Sediment

Sediments were analyzed for loss on ignition and grain size at the USGS Cascades Volcano Observatory in Vancouver, Washington. Loss on ignition was determined following the method of Fishman and Friedman (1989). A portion of homogenized sediment was dried at 105º C and compared to a portion that was weighed and ignited at 550º C. The loss of weight on ignition represents the volatile solids present in the sample, which provides an estimate of organic carbon in the sample.

Two methods were used for the full grain-size classification. For material with particles larger than 0.0625 mm, the wet or dry sieve method was used (Knott and others, 1993; American Society for Testing and Materials, 1998). For particles finer than 0.0635 mm, the Micromeritics SediGraph 5120 was used (see, for example, Meyer and Fisher, 1997). Briefly, the fraction of a sediment sample finer than 0.0635 mm was placed in suspension in dispersant solution. The SediGraph uses a collimated beam of X-rays to determine the concentration of sediments settling in a suspension through time and then determines the size distribution of the settling particles. The resulting data define a cumulative-mass percent distribution in terms of equivalent particle diameter.

Quality Assurance

Sedimentary chemical analyses were carried out at the NWQL following established USGS Quality Control (QC) and Quality Assurance (QA) protocols (U.S. Geological Survey, 2009;

2011). Reporting limits, precision, and other quality control criteria are explained in detail in published method reports (Burkhardt and others, 2006; Zaugg and others, 2006), and are defined in general for all organics analyses performed at the NWQL in Pirkey and Glodt (1998). As part of the laboratory method, each set of analyzed samples included a laboratory blank sample and a spiked blank sample. Spike recoveries for detected compounds ranged from 29 to 149 percent and fell within acceptable spike recovery limits as determined by the NWQL (table 2). However, these sediment samples had a complex chemical matrix with interfering constituents that could not be completely separated from target analytes during clean up and concentration procedures. Interfering matrix effects resulted in decreased signal-to-noise ratios and high method detection limits (MDL) relative to environmental concentrations. In addition, the ubiquitous presence of some of these compounds as low-level laboratory contamination resulted in blank detections. Despite rerunning many of the extracts, most detections are reported as estimated concentrations.

Quality control measures used in conjunction with the passive samplers included field blanks at each site to monitor airborne contamination of the samples, laboratory blanks, matrix and procedural recovery spikes, and continuous instrument calibration checks (Alvarez, 2010). Recovery of the chemicals of interest and levels of background contamination in the blanks were within acceptable ranges. Each sample screened by the YES was run concurrently with a series of positive and negative controls to ensure the quality of the data (Alvarez and others, 2008).

Quality of continuous water-quality monitor data was assured by field information collected during the midpoint field visit, including separate field measurements of dissolved oxygen concentration, pH, specific conductance, and temperature. Corrections to data made necessary by biological fouling and drift as determined during the post-deployment calibration check were entered into ADAPS, which calculated the corrected values.

Results

Wood Pilings

Wood samples collected from pilings were analyzed for a large suite of semivolatile organic compounds and PAHs (appendix A). Out of the 80 compounds analyzed for, only phenanthrene was detected, and at low concentrations (approximately 200 µg/kg). Method detection limits were high on these analyses relative to those common in this type of analysis. Metals potentially associated with wood treatment also were detected at low concentrations (<20 µg/kg).

Grains Size and Organic Carbon in Sediments

Sedimentary organic carbon content and grain-size class distributions are reported in table 3. Grain-size class distributions were similar between the two sites and for both years (fig. 2). Organic carbon was slightly lower in the core samples from site CCS1 in both years than the surface samples from both sites in both years (fig. 3).

Table 2. Results of quality control analyses for sediment samples collected at sites in Coal Creek Slough, Washington, 2008 and 2009.

[µg/kg, microgram per kilogram; E, concentration is an estimate; NA, not applicable; ND, not determined]

Parameter	Range of spike recovery, this study (percent)	Low spike limit (percent)	High spike limit (percent)	Blank value (µg/kg)	Comments	Lab Code
2,6-dimethylnaphthalene	45–76	41	102	<25	Reported concentrations are estimates.	15506
3–beta–coprostanol	68–71	41	114	<500	Reported concentrations are estimates.	15433
3–methyl–1h–indole (skatol)	74–89	35	109	<50	Reported concentrations are estimates.	15433
4,5–methylenephenanthrene	43–97	44	124	<25	Reported concentration is an estimate.	15506
acetophenone	91–104	0	113	<150	Reported concentrations are estimates.	15433
anthraquinone	49–70	0	107	<50	Reported concentration is an estimate.	15433
benz[a]anthracene	44–90	27	153	<25	Reported concentrations are estimates.	15506
benzo[a]pyrene	86–89	24	115	<50	Reported concentrations are estimates.	15433
benzo[b]fluoranthene	49–110	38	145	E1.30	Reported concentrations are estimates.	15506
benzo[e]pyrene	48–105	34	147	E1.06	Reported concentrations are estimates.	15506
benzo[g,h,i]perylene	47–78	32	149	E1.01	Reported concentrations are estimates.	15506
benzo[k]fluoranthene	46–95	36	144	E1.71	Reported concentrations are estimates.	15506
beta–sitosterol	41–66	9	136	E171	Reported concentrations are estimates.	15433
beta–stigmastanol	39–65	19	130	<500	Reported concentrations are estimates.	15433
cholesterol	48–65	27	137	E188	Blank problems. Reported concentrations are estimates.	15433
chrysene	43–89	42	143	E1.04	Blank problems. Reported concentrations are estimates.	15506
fluoranthene	90	44	119	<50	Some reported concentrations are estimates.	15433
indeno[1,2,3–cd]pyrene	47–84	38	141	E1.50	Blank problems. Reported concentrations are estimates.	15506
indole	55–94	7	143	<100	Some reported concentrations are estimates.	15433
isophorone	67–68	0	85	<50	Reported concentrations are estimates.	15433
naphthalene	42–77	37	88	E2.68	Blank problems. Reported concentrations are estimates.	15506

Table 2. Results of quality control analyses for sediment samples collected at sites in Coal Creek Slough, Washington, 2008 and 2009—continued

[µg/kg, microgram per kilogram; E, concentration is an estimate; NA, not applicable; ND, not determined]

Parameter	Range of spike recovery, this study (percent)	Low spike limit (percent)	High spike limit (percent)	Blank value (µg/kg)	Comments	Lab Code
para–cresol	68–98	21	119	<250	Some reported concentrations are estimates.	15433
para–nonylphenol (total)	77–91	26	129	E28.1	Blank problems. Reported concentrations are estimates.	15433
perylene	39–71	27	144	E0.880	Some reported concentrations are estimates.	15506
phenol	92–106	2	104	E17.6	Blank problems. Reported concentrations are estimates.	15433
pyrene	87–90	33	121	<50	Reported concentrations are estimates.	15433
c1–alkylated benzopyrene/perylene	NA	ND[1]	ND	<25	Reported concentrations are estimates.	15507
c1–alkylated fluoranthene/pyrene	NA	ND	ND	<25	Reported concentrations are estimates.	15507
c1–alkylated naphthalene	NA	ND	ND	<25	Reported concentrations are estimates.	15507
c2–alkylated naphthalene	NA	ND	ND	<25	Reported concentration is an estimate.	15507
arsenic	NA	ND	ND	<25	Concentrations reported without qualification.	
chromium	NA	ND	ND	<25	Concentrations reported without qualification.	
copper	NA	ND	ND	<25	Concentrations reported without qualification.	
zinc	NA	ND	ND	<25	Concentrations reported without qualification.	
1–methylnaphthalene	67–80	24	98	<50	No detections.	15433
1–methylphenanthrene	43–96	38	136	<25	No detections.	15506
1–methylpyrene	44–101	45	134	<25	No detections.	15506
1,2–dimethylnaphthalene	46–85	56	97	<25	No detections.	15506
1,2,4–trichlorobenzene	72–129	19	89	<25	No detections. Some high spike recoveries.	15506
1,4–dichlorobenzene	65–66	14	81	<50	No detections.	15433
1,6–dimethylnaphthalene	46–76	47	100	<25	No detections.	15506
2–ethylnaphthalene	45–75	38	99	<25	No detections.	15506
2–methylanthracene	43–87	43	128	<25	No detections.	15506
2–methylnaphthalene	66–83	24	104	<50	No detections.	15433
2,3,6–trimethylnaphthalene	45–78	41	124	<25	No detections.	15506
3–tert–butyl–4–hydroxyanisole (bha)	10–63	0	97	<150	No detections.	15433
4–cumylphenol	86–106	37	113	<50	No detections.	15433

Table 2. Results of quality control analyses for sediment samples collected at sites in Coal Creek Slough, Washington, 2008 and 2009—continued

[µg/kg, microgram per kilogram; E, concentration is an estimate; NA, not applicable; ND, not determined]

Parameter	Range of spike recovery, this study (percent)	Low spike limit (percent)	High spike limit (percent)	Blank value (µg/kg)	Comments	Lab Code
4–n–octylphenol	59–86	31	109	<50	No detections.	15433
4–nonylphenol monoethoxylate, total (np1eo)	79	36	162	<500	No detections.	15433
4–octylphenol diethoxylate–(opeo2)	91–95	25	197	<50	No detections.	15433
4–octylphenol monoethoxylate–(opeo1)	119–149	36	148	<250	No detections.	15433
4–tert–octylphenol	82–87	31	122	<50	No detections.	15433
acenaphthene	43–89	33	116	<25	No detections.	15506
acetyl–hexamethyl–tetrahydronaphthalene (ahtn)	92–107	37	128	<50	No detections.	15433
anthracene	42–89	24	140	E0.548	No detections.	15506
atrazine	80–86	27	120	<100	No detections.	15433
benzophenone	91–99	39	114	E2.94	No detections.	15433
bis(2–ethylhexyl) phthalate	50–98	33	142	E28.3	No detections.	15506
bisphenol a	19–21	0	97	<50	No detections.	15433
bromacil	89–90	ND	ND	<500	No detections.	15433
camphor	79–103	25	114	<50	No detections.	15433
carbazole	83–85	44	109	<50	No detections.	15433
chlorpyrifos	58–68	ND	ND	<50	No detections.	15433
d–limonene	57–67	24	86	<50	No detections.	15433
diazinon	75–106	ND	ND	<50	No detections.	15433
dibenz[a,h]anthracene	48–77	52	126	E1.78	No detections. Blank problems.	15506
dibenzothiophene	42–94	55	112	<25	No detections. Blank problems.	15506
diethyl phthalate	65–76	0	123	E5.96	No detections. Blank problems.	15433
diethylhexyl phthalate	89–99	16	132	E21	No detections. Blank problems.	15433
hexachlorobenzene	39–73	54	96	<25	No detections.	15506
hexahydrohexamethyl–cyclo–pentabenzopyran (hhcb)	92–104	36	123	<50	No detections.	15433
isoborneol	82–102	0	124	<50	No detections.	15433
isopropylbenzene (cumene)	54–67	7	78	<100	No detections.	15433
isoquinoline	50–77	4	106	<100	No detections.	15433
menthol	76–88	0	123	<50	No detections.	15433
metolachlor	74–96	ND	ND	<50	No detections.	15433
n,n–diethyl–meta–toluamide (deet)	93–104	27	114	<100	No detections.	15433
nonylphenol, diethoxy–(total, npeo2)	68–81	17	162	<1,000	No detections.	15433

Table 2. Results of quality control analyses for sediment samples collected at sites in Coal Creek Slough, Washington, 2008 and 2009—continued

[µg/kg, microgram per kilogram; E, concentration is an estimate; NA, not applicable; ND, not determined]

Parameter	Range of spike recovery, this study (percent)	Low spike limit (percent)	High spike limit (percent)	Blank value (µg/kg)	Comments	Lab Code
pentachloroanisole	42–82	55	98	<25	No detections.	15506
pentachloronitrobenzene	33–46	24	96	<25	No detections.	15506
phenanthrene	80–85	36	114	<50	No detections.	15433
phenanthridine	44–100	46	136	<25	No detections.	15506
prometon	75–103	ND	ND	<50	No detections.	15433
tetrabromodiphenyl ether	28–122	0	215	<50	No detections.	15433
tri(2–butoxyethyl) phosphate	60–81	0	137	<150	No detections.	15433
tri(dichloroisopropyl) phosphate	29–43	0	76	<100	No detections.	15433
tributyl phosphate	97–119	38	137	<50	No detections.	15433
triclosan	93–131	23	146	<50	No detections.	15433
triphenyl phosphate	31–49	0	82	<50	No detections.	15433
c1–alkylated benz[a]anthracene/chrysene	NA	ND	ND	<25	No detections.	15507
c1–alkylated phenanthrene/anthracene	NA	ND	ND	<25	No detections.	15507
c2–alkylated benz[a]anthracene/chrysene	NA	ND	ND	<25	No detections.	15507
c2–alkylated benzopyrene/perylene	NA	ND	ND	<25	No detections.	15507
c2–alkylated fluoranthene/pyrene	NA	ND	ND	<25	No detections.	15507
c2–alkylated phenanthrene/anthracene	NA	ND	ND	<25	No detections.	15507
c3–alkylated benz[a]anthracene/chrysene	NA	ND	ND	<25	No detections.	15507
c3–alkylated benzopyrene/perylene	NA	ND	ND	<25	No detections.	15507
c3–alkylated fluoranthene/pyrene	NA	ND	ND	<25	No detections.	15507
c3–alkylated naphthalene	NA	ND	ND	<25	No detections.	15507
c3–alkylated phenanthrene/anthracene	NA	ND	ND	<25	No detections.	15507
c4–alkylated benz[a]anthracene/chrysene	NA	ND	ND	<25	No detections.	15507
c4–alkylated benzopyrene/perylene	NA	ND	ND	<25	No detections.	15507
c4–alkylated fluoranthene/pyrene	NA	ND	ND	<25	No detections.	15507
c4–alkylated naphthalene	NA	ND	ND	<25	No detections.	15507

Table 2. Results of quality control analyses for sediment samples collected at sites in Coal Creek Slough, Washington, 2008 and 2009—continued

[µg/kg, microgram per kilogram; E, concentration is an estimate; NA, not applicable; ND, not determined]

Parameter	Range of spike recovery, this study (percent)	Low spike limit (percent)	High spike limit (percent)	Blank value (µg/kg)	Comments	Lab Code
c4–alkylated phenanthrene/anthracene	NA	ND	ND	<25	No detections.	15507
c5–alkylated benz[a]anthracene/chrysene	NA	ND	ND	<25	No detections.	15507
c5–alkylated benzopyrene/perylene	NA	ND	ND	<25	No detections.	15507
c5–alkylated fluoranthene/pyrene	NA	ND	ND	<25	No detections.	15507
c5–alkylated naphthalene	NA	ND	ND	<25	No detections.	15507
c5–alkylated phenanthrene/anthracene	NA	ND	ND	<25	No detections.	15507

[1] The alkylated PAH homolog groups lack reference standards and are considered semiquantitative

Table 3. Sedimentary organic carbon content and grain-size classification of samples from at sites in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal.

	Sample					
	CCS1 08 surface	CCS1 09 surface	CCS1 08 core	CCS1 09 core	CCS2 08 surface	CCS2 09 surface
Grain size	Percentage of sediment particles in grain-size class					
< 4.0 mm	100	100	100	100	100	100
< 2.0 mm	100	100	100	100	100	100
< 1.0 mm	100	99	100	100	98	100
< 0.50 mm	100	98	100	100	97	99
< 0.25 mm	99	97	99	100	89	98
< 0.125 mm	95	91	96	97	76	89
< 0.063 mm	85	83	86	85	60	67
< 0.031 mm	71	75	71	71	52	59
< 0.016 mm	51	58	52	49	41	47
< 0.008 mm	36	44	37	34	31	38
< 0.004 mm	26	33	27	25	23	31
< 0.002 mm	20	26	21	19	17	25
< 0.001 mm	15	21	17	14	13	22
	Organic carbon content of sample, in percent					
	6.3	7.6	5.5	5.2	10.4	8.6

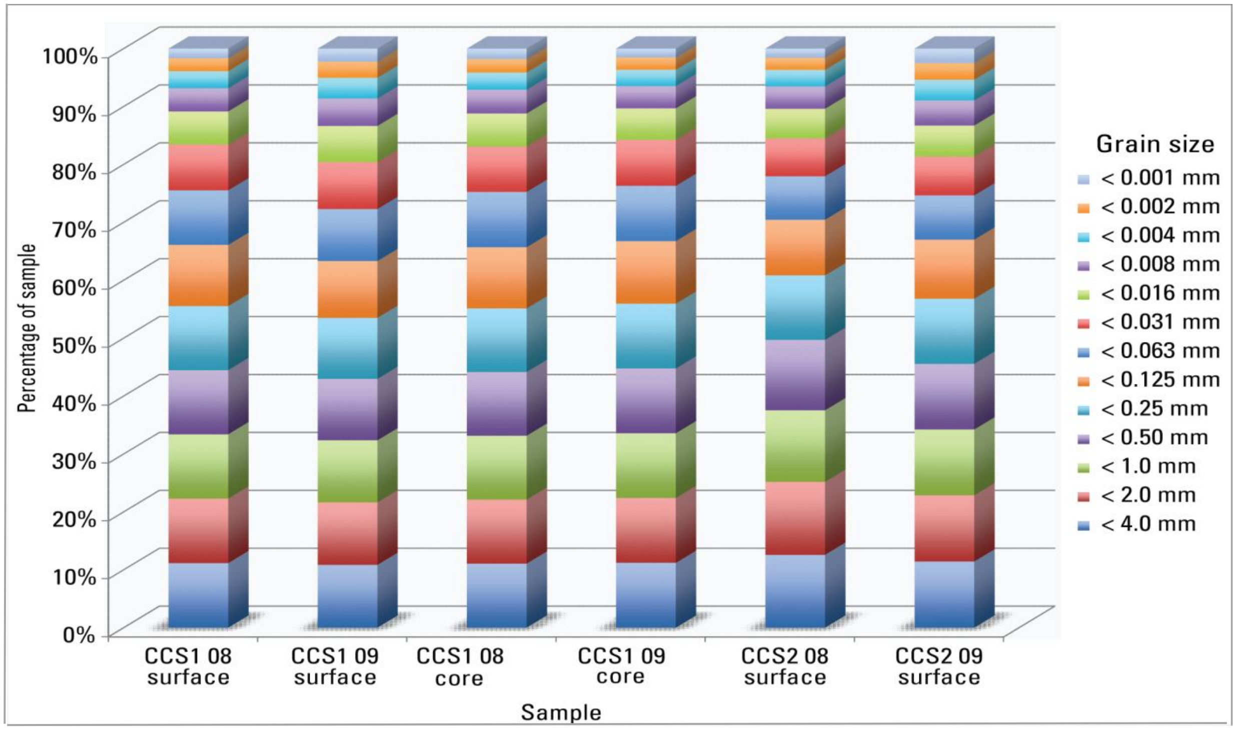


Figure 2. Sediment grain-size distribution of samples collected at sites in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal.

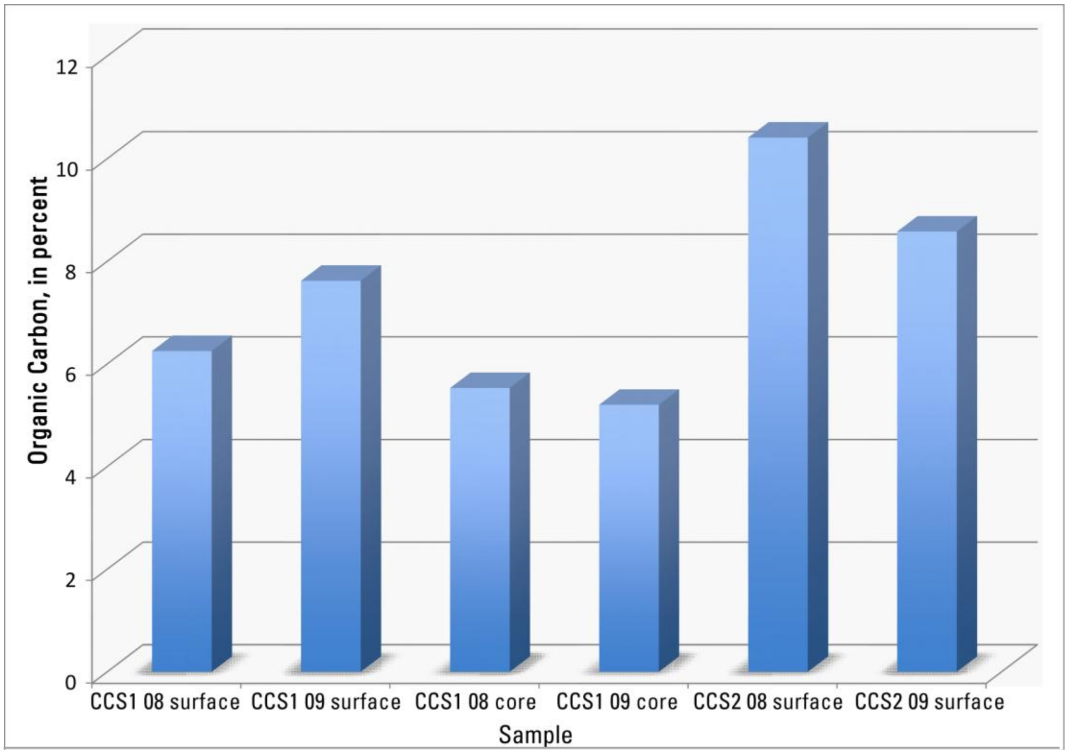


Figure 3. Organic carbon content of sediment samples collected at sites in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal.

Contaminants in Sediments

Of the 110 compounds analyzed for, 34 were detected in sediments during this study (table 4). Of the 34 compounds detected, 8 were anthropogenic waste indicator (AWI) compounds, 18 were PAHs, 4 were sterols, and 4 were metals that can be associated with wood treatment compounds. Nearly all reported concentrations are qualified as estimates due to interferences in sample extracts resulting from complex sample matrices. Indole, fluoranthene, and perylene are reported without qualification for some of the samples, and the metals are reported without qualification for all samples. Twelve compounds had blank detections due to low-level laboratory contamination. Estimated concentrations were reported for those compounds if sample concentrations were greater than five times the blank concentrations.

Table 4. Concentrations of chemical contaminants in sediment samples collected at sites in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal.

[Concentrations are in micrograms per kilogram; MDL, method detection limit; E, concentration is an estimate; —, not detected; AWI, anthropogenic waste indicator; WT, wood treatment compound; PAH, polycyclic aromatic hydrocarbon; NS, natural sources; TM, metals used in some wood treatments; detected, concentration not reported because less than 5 times the blank value]

			Sample						
Compound class	**Compound**	**Initial MDL**	**CCS1 surface 2008**	**CCS1 surface 2009**	**CCS1 core 2008**	**CCS1 core 2009**	**CCS2 surface 2008**	**CCS2 surface 2009**	**Blank**
AWI	3-methyl-1h-indole (skatol)	30.9	E26.3	E37.8	E8.34	E5.20	E40	E35.9	—
AWI	acetophenone	101	E212	E60.7	E185	—	E300	—	—
AWI	anthraquinone	24.3	E21.2	—	—	—	E19.9	—	—
AWI	indole	45.5	126	188	E61.7	E52.1	E118	E264	—
AWI	isophorone	43.4	E35.5	E4.14	—	—	E37.5	—	—
AWI	para-nonylphenol (total)	499	—	E181	—	—	—	E481	E 28.1
AWI	phenol	38.2	E707	—	E213	—	E1480	—	E17.6
AWI/WT	para-cresol	161	E164	—	E49.8	—	1180	E76.4	—
PAH	2,6-dimethylnaphthalene	8.5	E28.1	E19.6	E4.35	E5.05	E15.8	E36.3	—
PAH	4,5-methylenephenanthrene	12.5	—	—	—	—	E12.4	—	—
PAH	benz[a]anthracene	13.4	E9.63	—	E3.79	—	E10.3	—	—
PAH	benzo[a]pyrene	24.6	E6.58	E6.44	—	—	E8.29	—	—
PAH	benzo[b]fluoranthene	13.3	E20.7	—	—	—	E28.2	—	E1.30
PAH	benzo[e]pyrene	12	E13.9	—	—	—	E17.6	—	E1.06
PAH	benzo[g,h,i]perylene	13.5	E8.48	—	—	—	E7.77	—	E1.01
PAH	benzo[k]fluoranthene	11.6	E8.96	—	—	—	E10.1	—	E1.71
PAH	c1-alkylated benzopyrene/perylene	NA	E17.2	—	E41.2	—	E18.4	—	—
PAH	c1-alkylated fluoranthene/pyrene	NA	E15.1	—	E6.1	—	E28.6	—	—
PAH	c1-alkylated naphthalene	NA	E16.4	—	—	—	E17.8	—	—
PAH	c2-alkylated naphthalene	NA	E93.2	—	—	—	—	—	—
PAH	chrysene	13.5	E15.2	—	—	—	E17	—	E1.04
PAH	fluoranthene	23.2	E30.6	E12.8	—	—	43.1	E32.4	—

Table 4. Concentrations of chemical contaminants in sediment samples collected at sites in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal—continued.

[Concentrations are in micrograms per kilogram; MDL, method detection limit; E, concentration is an estimate; —, not detected; AWI, anthropogenic waste indicator; WT, wood treatment compound; PAH, polycyclic aromatic hydrocarbon; NS, natural sources; TM, metals used in some wood treatments; detected, concentration not reported because less than 5 times the blank value]

			Sample						
Compound class	**Compound**	**Initial MDL**	**CCS1 surface 2008**	**CCS1 surface 2009**	**CCS1 core 2008**	**CCS1 core 2009**	**CCS2 surface 2008**	**CCS2 surface 2009**	**Blank**
PAH	indeno[1,2,3-cd]pyrene	12.9	detected	—	—	—	E7.78	—	E1.50
PAH	naphthalene	7.7	E17.6	—	—	—	E18.9	—	E2.68
PAH	pyrene	20.6	E26.5	E11.5	E8.42	—	E34.3	E27.4	—
sterol	3-beta-coprostanol	360	—	E291	—	—	—	E288	—
sterol	beta-sitosterol	363	detected	E3,320	detected	E983	E1,080	E8,460	E171
sterol	beta-stigmastanol	367	—	E1,040	—	E437	E493	E3,710	—
sterol	cholesterol	168	detected	E1,460	—	—	detected	—	E188
PAH/NS	perylene	9.8	310	E165	982	405	E376	E224	E0.880
TM	arsenic	100	6,100	8,900	3,800	1,800	8,500	6,600	—
TM	chromium	100	15,000	32,200	21,100	11,700	24,400	25,500	—
TM	copper	100	22,900	34,800	22,300	18,300	29,600	25,900	—
TM	zinc	100	75,500	86,300	54,200	54,700	95,100	73,200	—

The frequency of detection of compounds was higher in the pre-removal (2008) surface sediment samples from both sites CCS1 and CCS2 than in the pre-removal core sample and all post-removal (2009) samples (fig. 4*A*). A few PAHs were found at relatively higher concentrations in the core samples than in the surface samples, indicating historical sources. AWI compounds were detected less frequently and at lower concentrations in the post-removal samples than in the pre-removal samples. One exception is para-nonylphenol, which was detected in 2009 but not in 2008. Para-cresol and phenol were detected at the highest concentrations in the site CCS2 surface sample (fig. 4*B*), which also had the highest organic carbon value. The sterol concentrations were highest in the 2009 samples.

Only concentrations of perylene, fluoranthene, and the metals that were reported without qualification are compared herein to existing sediment quality guidelines. Sediment quality guidelines are not available for indole, the other compound reported without qualification.

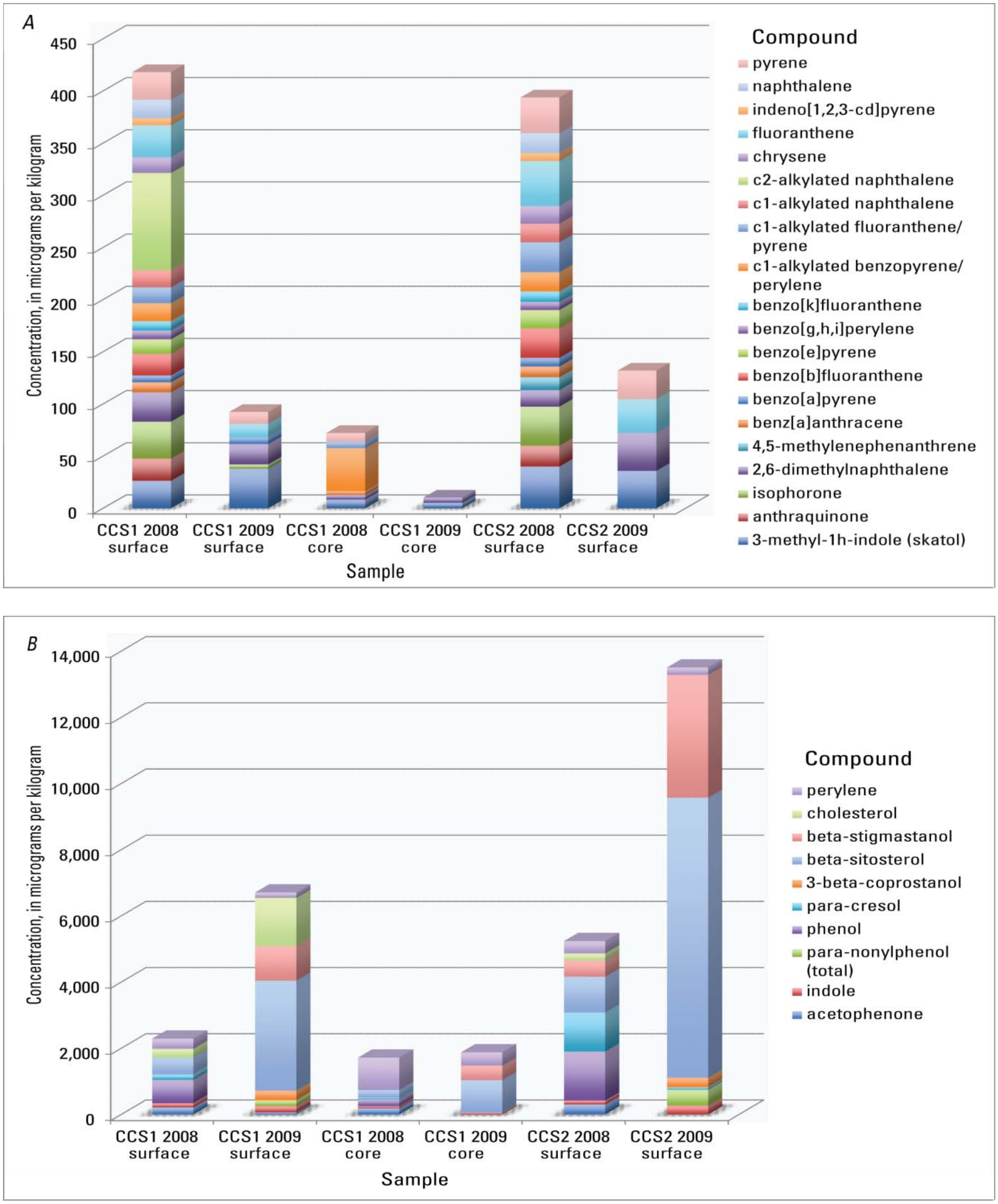


Figure 4. Sediment concentrations of chemical contaminants detected at sites in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal. *A*, Compounds detected at low concentrations; *B*, Compounds detected at high concentrations. Data are presented separately because of large differences in scale.

Perylene was detected in all six sediment samples (table 4). Estimated and unqualified concentrations of most samples exceeded both the USEPA sediment quality guideline of 160 µg/kg (U.S. Environmental Protection Agency, 2004) and the Oregon Department of Environmental Quality guideline of 300 µg/kg (Oregon Department of Environmental Quality, 1998). The highest concentrations were detected in the core samples, suggesting historical natural or anthropogenic sources. Perylene is widespread in the environment and has several potential natural sources, including including forest fires in catchment or redox processes since perylene is more stable in anoxic settings. Fluoranthene concentrations did not exceed the USEPA sediment quality guideline of 290 µg/kg (U.S. Environmental Protection Agency, 2004).

All four metals had concentrations less than the sediment quality guidelines (U.S. Environmental Protection Agency, 2004) and less than Regional Sediment Evaluation Framework screening level 1 (RSEF SL1 [Regional Sediment Evaluation Team, 2006]) at all sites in both years. Metal concentrations in surface samples were slightly higher in 2009 than in 2008. Concentrations in core samples were slightly lower at CCS1 in 2009 than in 2008 (table 4).

Contaminant Results from Passive Samplers

In general, all replicates from each sampling period were within a factor of two or less, which is reasonable considering that the replicate samples were from different deployment canisters. Although these canisters were deployed close to each other, they potentially experienced differences in flow and a buildup of a biofilm that can affect the amount of chemicals accumulated. Because equipment at the 2008 site CCS2 was lost due to vandalism, only the 2009 dataset was available to compare conditions between sites. With so few samples, statistical differences were not determined; however, differences in results between the two sites do not indicate that the pilings were a major source of chemicals into the water.

PBDE/PCB/Pesticide Screen

In addition to the five targeted PBDE congeners, a suite of OC pesticides and total PCBs were included in the analysis (table 5). PBDEs were below the method detection limit at all sites with the exception of PBDE-99, which was detected at a concentration equal to the MDL in the 2008 sample from site CCS1. Numerous organochlorine pesticides, both banned and currently used, were detected at each site. Commonly detected pesticides included: hexachlorobenzene, pentachloroanisole (a degradation product of pentachlorophenol), diazinon, cis-chlordane, endosulfan, DDD, and endosulfan sulfate.

EDC Screen

SPMD and POCIS samples from the 2009 sampling were screened for a suite of EDCs. The only notable chemical that was detected greater than the method detection limit was the fragrance galaxolide. Concentrations in the SPMDs for galaxolide were 190, 66, and <10 ng/SPMD for site CCS1, site CCS1 replicate, and site CCS2, respectively. Multiple interferences from unidentified chemicals sampled from the sites prevented the identification and quantitation of most chemicals in the POCIS.

Table 5. Estimated concentrations in water of selected polybrominated diphenyl ethers, organochlorine pesticides, and total polychlorinated biphenyls (PCBs) measured by semipermeable membrane devices in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal

[PDBE, polybrominated diphenyl ethers, PCB, polychlorinated biphenyls; concentrations are in picograms per liter; MDL, method detection limit; E, concentration is an estimate; —, not detected; data from CCS2 in 2008 lost due to vandalism]

		Deployment dates				
		August 6–September 3, 2008 (before piling removal)		September 3–September 30, 2009 (after piling removal)		
Compound	MDL	CCS1	CCS1 Replicate	CCS1	CCS1 Replicate	CCS2 (comparison site)
PBDEs						
congener 28	38	—	—	—	—	—
congener 47	73	—	—	—	—	—
congener 99	37	—	E37	—	—	—
congener 100	12	—	—	—	—	—
congener 153	170	—	—	—	—	—
Organochlorine pesticides and total PCBs						
Trifluralin	38	—	—	53	—	—
Hexachlorobenzene (HCB)	3.5	19	22	50	22	E17
Pentachloroanisole (PCA)	3.4	37	48	140	69	68
Tefluthrin	1,100	—	—	2,000	—	—
alpha-Benzenehexachloride (α-BHC)	120	—	—	—	—	—
Diazanon	1,000	4,200	3,500	2,300	3,700	1,700
Lindane	180	—	—	E190	—	—
beta-Benzenehexachloride (β-BHC)	160	—	—	1,200	720	690
Heptachlor	3.4	—	—	—	—	—
delta-Benzenehexachloride (δ-BHC)	64	—	—	150	79	80
Dacthal	7.4	E8.5	E11	11	—	—
Chlorpyrifos	2.4	9.0	10	14	10	E4.6
Oxychlordane	3.4	—	—	E3.8	E4.9	—
Heptachlor epoxide	21	—	—	35	—	—
trans-Chlordane	5.7	—	—	26	E9.1	E10
trans-Nonachlor	4.4	E4.9	E6.8	E13	—	E4.5
o,p'-DDE	34	—	—	—	—	—
cis-Chlordane	3.4	E4.9	E6.5	28	E11	E13
Endosulfan	23	E100	120	E37	E35	E27
p,p'-DDE	190	—	—	—	—	—
Dieldrin	36	—	—	81	45	37
o,p'-DDD	3.9	E17	E19	130	61	60
Endrin	81	—	—	—	—	—
cis-Nonachlor	32	—	—	—	—	—
o,p'-DDT	48	—	—	—	—	—

Table 5. Estimated concentrations in water of selected polybrominated diphenyl ethers, organochlorine pesticides, and total polychlorinated biphenyls (PCBs) measured by semipermeable membrane devices in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal—continued

[PDBE, polybrominated diphenyl ethers, PCB, polychlorinated biphenyls; concentrations are in picograms per liter; MDL, method detection limit; E, concentration is an estimate; —, not detected; data from CCS2 in 2008 lost due to vandalism]

		Deployment dates				
		August 6–September 3, 2008 (before piling removal)		September 3–September 30, 2009 (after piling removal)		
Compound	**MDL**	**CCS1**	**CCS1 Replicate**	**CCS1**	**CCS1 Replicate**	**CCS2 (comparison site)**
Organochlorine pesticides and total PCBs (continued)						
p,p'-DDD	31	—	—	140	65	47
Endosulfan-II	46	E58	—	—	—	—
p,p'-DDT	120	—	—	150	—	—
Endosulfan Sulfate	86	360	300	250	170	210
p,p'-Methoxychlor	40	—	—	E63	—	—
Mirex	5.9	—	—	—	—	—
cis-Permethrin	130	—	—	—	—	—
trans-Permethrin	13	—	—	E23	—	—
Total PCBs	890	—	—	—	—	—

Estrogenicity Screen

Data from the YES is reported as estradiol equivalent factors (EEQ), which provides a measure of the amount of 17β-estradiol, a natural hormone, which would be required to give a response equivalent to that of the complex mixture of chemicals sampled at each site. These data can be a useful tool in ranking sites on the basis of a normalized scale of total estrogenic potential of estrogens and estrogen-mimicking chemicals present at the site.

Only POCIS extracts from the 2009 deployment were screened by the YES. No estrogenicity was measured greater than the negative controls of the test that is equivalent to approximately 3.2 pg/L of 17β-estradiol.

PAH Screen

Results from the PAH screen are given in table 6. Common PAHs such as phenanthrene, fluoranthene, and pyrene were measured in every deployed sample.

Table 6. Estimated concentrations in water of select polycyclic aromatic hydrocarbons measured by semi-permeable membrane devices in Coal Creek Slough, Washington, before (2008) and after (2009) piling removal.

[Concentrations are in micrograms per liter; MDL, method detection limit; —, not detected; E, concentration is an estimate; data from CCS2 in 2008 were lost to vandalism.]

		Deployment dates				
		August 6–September 3, 2008 (before piling removal)		September 3–September 30, 2009 (after piling removal)		
Compound	MDL	CCS1	CCS1 Replicate	CCS1	CCS1 Replicate	CCS2 (comparison site)
Naphthalene	820	—	—	—	—	—
Acenaphthylene	61	—	—	—	—	—
Acenaphthene	53	E120	E130	—	—	—
Fluorene	46	E91	E110	E170	—	—
Phenanthrene	190	490	670	720	E270	E210
Anthracene	76	—	E88	E160	—	—
Fluoranthene	140	860	1,200	2,700	970	600
Pyrene	320	600	830	2,200	940	730
Benz[a]anthracene	37	—	—	—	—	—
Chrysene	34	140	300	650	170	250
Benzo[b]fluoranthene	36	—	—	260	E98	E160
Benzo[k]fluoranthene	41	—	—	320	—	—
Benzo[a]pyrene	44	—	—	—	—	—
Indeno[i,2,3-c,d]pyrene	210	—	—	—	—	—
Dibenz[a,h]anthracene	48	—	—	—	—	—
Benzo[g,h,i]perylene	180	—	—	—	—	—
Benzo[b]thiophene	550	—	—	—	—	—
2-methylnaphthalene	220	E240	E250	E300	—	—
1-methylnaphthalene	180	E240	E250	E230	—	—
Biphenyl	77	—	—	—	—	—
1-ethylnaphthalene	46	—	—	—	—	—
1,2-dimethylnaphthalene	51	—	—	—	—	—
4-methylbiphenyl	49	—	—	—	—	—
2,3,5-trimethylnaphthalene	95	—	—	—	—	E110
1-methylfluorene	73	—	—	E100	—	—
Dibenzothiophene	46	—	—	—	—	—
2-methylphenanthrene	36	E55	140	—	—	—
9-methylanthracene	34	—	—	—	—	—
3,6-dimethylphenanthrene	34	—	—	E130	—	—
2-methylfluoranthene	65	—	—	E160	—	—
Benzo[b]naphtho[2,1-d]thiophene	34	—	—	E67	—	—
Benzo[e]pyrene	218	—	—	E296	—	—
Perylene	40	300	400	—	E150	E190
3-methylcholanthrene	69	—	—	—	—	—

Dissolved Oxygen

Dissolved oxygen concentration was slightly higher at site CCS1 than at site CCS2 over the two monitoring intervals (fig. 5). All of the values were less than the Washington State Standard Aquatic Life Dissolved Oxygen Criterion in Fresh Water (1-day minimum of 9.5 mg/L) for Summer Salmonid Habitat (Washington Department of Ecology, 2003). There was not a marked difference in dissolved oxygen concentrations between the pre-removal monitoring in 2008 and the post-removal monitoring in 2009 at site CCS1 except during monitor deployment days 16–24 (fig. 5*A*). The cause for the divergent trends on those days is unknown, but likely was not related to piling removal. The 2009 record for site CCS2 (fig. 5*B*) extends only to the time of the midpoint check. Subsequent to that date, the YSI sonde was vandalized and presumably stolen along with the passive samplers; therefore the remainder of the record was lost.

Monitors were not in place during piling removal, so no direct, short-duration effects of piling removal on dissolved oxygen concentrations could be determined. All dissolved oxygen data are available in appendixes B–E

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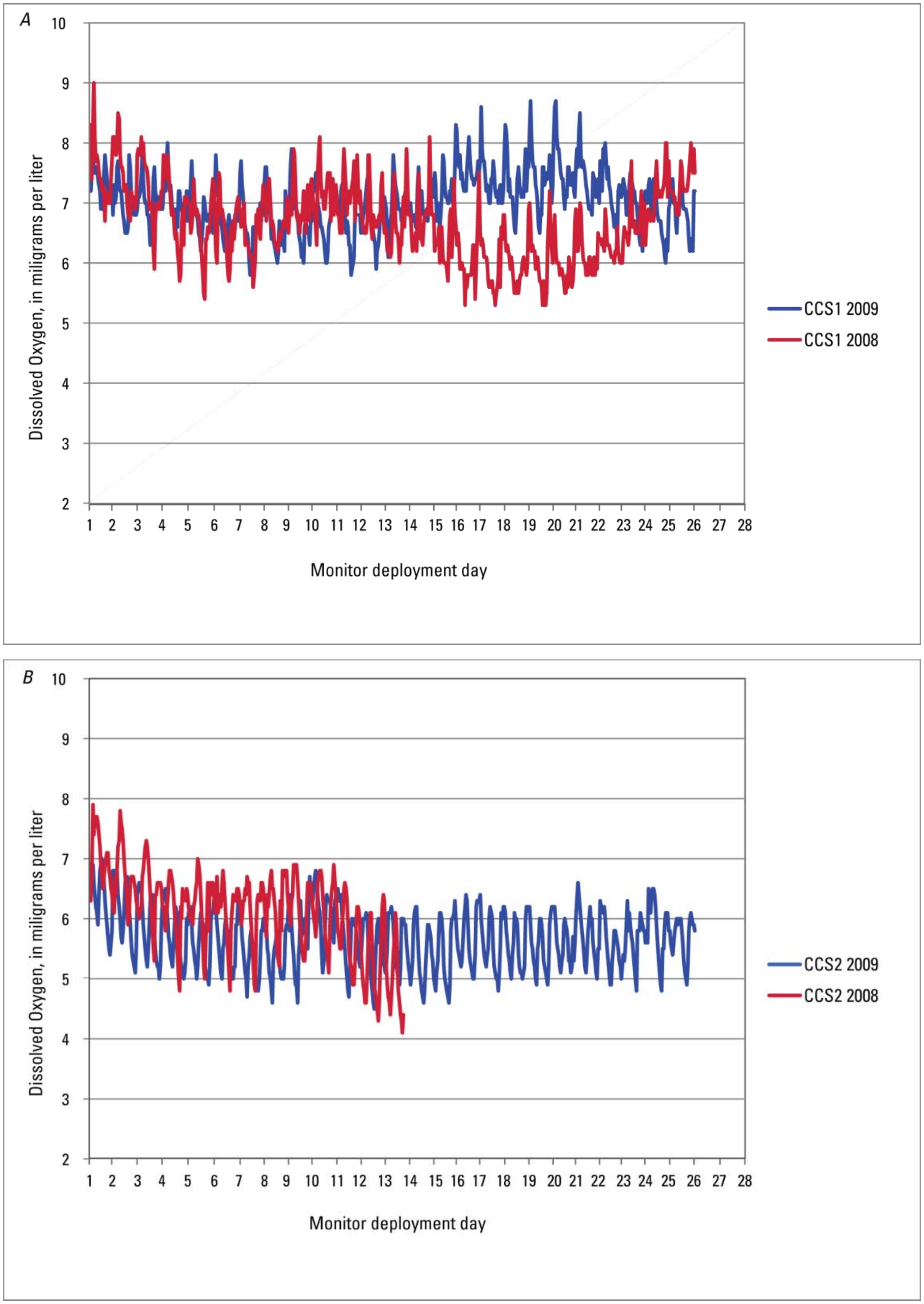

Figure 5. Dissolved oxygen concentrations at sites CCS1 and CCS2 during 2008 and 2009 in Coal Creek Slough, Washington. *A*, Dissolved oxygen concentration at site CCS1. *B,* Dissolved oxygen concentration at site CCS2.

Acknowledgments

We would like to thank the Lower Columbia River Estuary Partnership for help with sample design and implementation. We thank Pacific Northwest National Laboratory (PNNL) for help with reconnaissance. In particular we thank John Vavrinec at PNNL for help in searching for our lost equipment.

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The following data tables are in an Excel workbook that can be accessed by clicking on this link.

Appendix A. Chemical Results of ReconnaissanceTesting of Wood Pilings

Appendix B. Continuous Water-Quality Monitoring data from CCS1 for the Monitoring Period during 2008

Appendix C. Continuous Water-Quality Monitoring Data from CCS1 for the Monitoring Period during 2009

Appendix D. Continuous Water-Quality Monitoring Data from CCS2 for the Monitoring Period during 2008 to the Midpoint Check

Appendix E. Continuous Water-Quality Monitoring Data from CCS2 for the Monitoring Period during 2009

Nilsen and Alvarez— **Water-Quality Monitoring for a Pilot Piling-Removal Field Evaluation, Coal Creek Slough, Washington**—Open-File Report 2011–1233