Shorty's Island (Kootenai River)
Sediment Core Analysis Report:
PCBs, Organochlorine Pesticides and Metals Analysis

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Abstract

Habitat alteration to the Kootenai River aquatic ecosystem, including historic environmental contamination, has been cited as a key factor in the loss of aquatic species, including the white sturgeon. Sediments comprise an important component of aquatic ecosystems, providing habitat for a wide range of benthic and epibenthic organisms. Sturgeon, a long-lived, benthic species, is highly susceptible to exposure and bioaccumulation of sediment-associated contaminants during all life stages. Attempts to restore Kootenai River white sturgeon spawning and rearing habitat include a proposal to increase channel capacity in the Shorty's Island reach of the Kootenai River by removing material from the high flow channel (back channel) that parallels the main channel. Results of this study indicated exceedances of two sediment quality guidelines for metals. A significant correlation between depth, pH and TOC for some metals was also apparent. Of the compounds tested (metals, organochlorine pesticides and PCBs), cadmium, lead and zinc are considered metals of concern. Effects concentrations calculations (PEQs, TEQs, SQGQs) indicated that sediments from back channel core samples contained contaminants that would more likely affect aquatic organisms than sediment-associated contaminants found in main channel core samples.

Acknowledgements

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Introduction

Habitat alteration to the Kootenai River aquatic ecosystem has been cited as a key factor in the loss of aquatic species including the white sturgeon (KTOI and MWFP 2004). Several forms of habitat alteration to the Kootenai River are being addressed, including the potential loss of spawning habitat and effects of environmental contaminants. Contaminants in the form of mining waste, agricultural chemicals, dam operations and other activities such as transportation, recreation and timber processing have all potentially added to the degradation of the Kootenai River ecosystem.

Because sediments comprise an important componenet of aquatic ecosystems, providing habitat for a wide range of benthic and epibenthic organisms, exposure to certain substance in sediments represents a potentially significant hazard to the health of these organisms (Government Canada 2005). Sturgeon, a long-lived, bottom-dwelling species, is highly susceptible to exposure and bioaccumulation of contaminants at all life stages.

Attempts to restore spawning habitat for Kootenai River white sturgeon include a proposal to increase channel capacity in the Shorty's Island reach of the Kootenai River by removing material from the high flow channel (back channel) that parallels the main channel. Removal of channel sediments would require disturbance of river-bottom sediments within the back channel area to a substantial depth. Therefore, it was apparent that contaminant concentrations in river-bed sediments be analyzed to determine potential effects of disturbance and redistribution of deep sediment-related contaminants within the back main channels.

Methods

Sediment Coring

A 7.3-m pontoon coring boat was employed for taking vibracores of sediment beneath the riverbed. Six cores of riverbed sediment were collected from the Kootenai River minor channel that flows around Shorty's Island (3 samples) and from the main river channel (3 samples) between river kilometer 229.7 to 231.9. The core sites were referenced spatially using a mapping grade GPS with positioning accuracy of less than 1-meter. The vibracoring system was equipped with a 0.08-m-diameter aluminum core barrel, 3.66 m in length and capable of recovering clay, silt, sand, gravel, and some cobble. In order to prevent metals and other substances on the aluminum coring tube from contaminating the sediment samples, a contaminant free polycarbonate liner was installed inside the coring tube. Penetration of the vibracore barrel into the riverbed was reduced because the polycarbonate liner dampened the vibration of the core barrel. Immediately upon retrieval of each core, the core length was cut using a pipe cutter to just greater than the length of sediment recovery, and then the top and bottom of the core was capped. Additional information on the vibracoring technology used in this study can be obtained from Pete VanMetre, U.S. Geological Survey, Austin, Texas, and found in Barton (2004).

Each sediment core was split in half by (1) using a power saw to cut the aluminum and polycarbonate core liner, the blade depth was set equal to the thickness of the skin of the aluminum and polycarbonate core barrel, and then (2) a contaminant free Teflon spatula was used to slice the sediment in the core into halves. Sediment samples were collected from the core using a contaminant free Teflon spatula, any sediment in direct contact with the polycarbonate core barrel was not sampled.

The six vibracores collected in the minor channel at Shorty's Island penetrated 0.9 to 2.9-meters of river bottom sediment. The maximum length of core recovered during was 2.16-m and the average recovery was 1.31-m. However, the vibrating action caused compaction of sand and organic debris (no effect on clay-silt layers) in the core barrel. Compaction of sand in vibracores has been observed in other settings (Keith Ludwig, U.S. Geological Survey, personal communication, 2000; Barton, 2004). Thickness of sand and organic layers in vibracores was adjusted for compaction by multiplying measured thickness by a correction factor. The thickness correction factor was determined from depth penetrated by the vibracore divided by the thickness of sediment recovered in the core barrel. Calculations were adjusted to account for any clay-silt layer(s) recovered in the core because clay and silt do not measurably compact in vibracores. The average compaction correction factor was about 1.31.

Contaminant and Data Analysis

Sediment core samples were collected at different depths within each core for both metals and organochlorine (pesticide and PCB) analysis. Laboratory analyses for the sediment samples were as follows: Metals concentrations were determined by CCME regulatory analysis in soils and sediments, organochlorine pesticides concentrations were determined by GC/Low resolution analysis, Aroclor PCBs and 209 congeners were analyzed by GC/High resolution.

Mean and average concentrations of compounds were calculated for each site with non-detects being entered as a zero. Data did not display homogeneity of variances so the nonparametric Spearman Rank correlation analysis was conducted to test for relationships between PCBs or organochlorine pesticides and sediment total organic carbon. Spearman Rank correlation analysis was also conducted to identify significant ($P < 0.05$) relationships between sediment metal concentrations, sample site, soil depth, pH, total organic carbon and soil type. The nonparametric Kruskall-Wallace test was applied to test the hypothesis that TOC or metals concentrations were not significantly different ($P < 0.05$) between Sites #1, 2, 3 (backchannel) and Sites #4, 5, 6 (main channel).

Concentrations were compared with Sediment Quality Guidelines (SQGs) and known effects concentrations. In order to quantify the degree to which substances in samples exceeded guidelines the Mean Probable Effects Level Quotients (PEQs) were calculated for each site using the following calculation:

$$\text{Mean PEQ} = \sum [\text{MC}/\text{PEL}] \div \text{N}$$

Where:
MC = mean measured concentration of a given compound at the sample site
PEL = Probable Effects Level for given compound
N = number of compounds for which both measured concentrations and PELs are available

Mean Toxic Effects Quotients (TEQs) were also calculated as a means of comparing site toxicity. Mean TEQs were calculated by multiplying the actual concentration of each dioxin-like PCB compound by its corresponding WHO TEF and then summing the results.

A third measure of toxicity, the Sediment Quality Guideline Quotient (SQGQs) was also used to predict acute toxicity of sediment to ampipods (Fairey et al. 2001). Although several SQGQs are available, the formula for SQGQ1 was used as follows:

$$\text{SQGQ1} = ((\sum ([\text{cadmium}]/4.21)([\text{copper}]/270)([\text{lead}]/112.18)([\text{silver}]/1.77)([\text{zinc}]/410)([\text{total chlordane}]/6)([\text{dieldrin}]/8)([\text{total PAH}_{\text{oc}}]/1{,}800)([\text{total PCB}]/400))/9)$$

Compounds that were below detection limits or not tested for were excluded from the calculation.

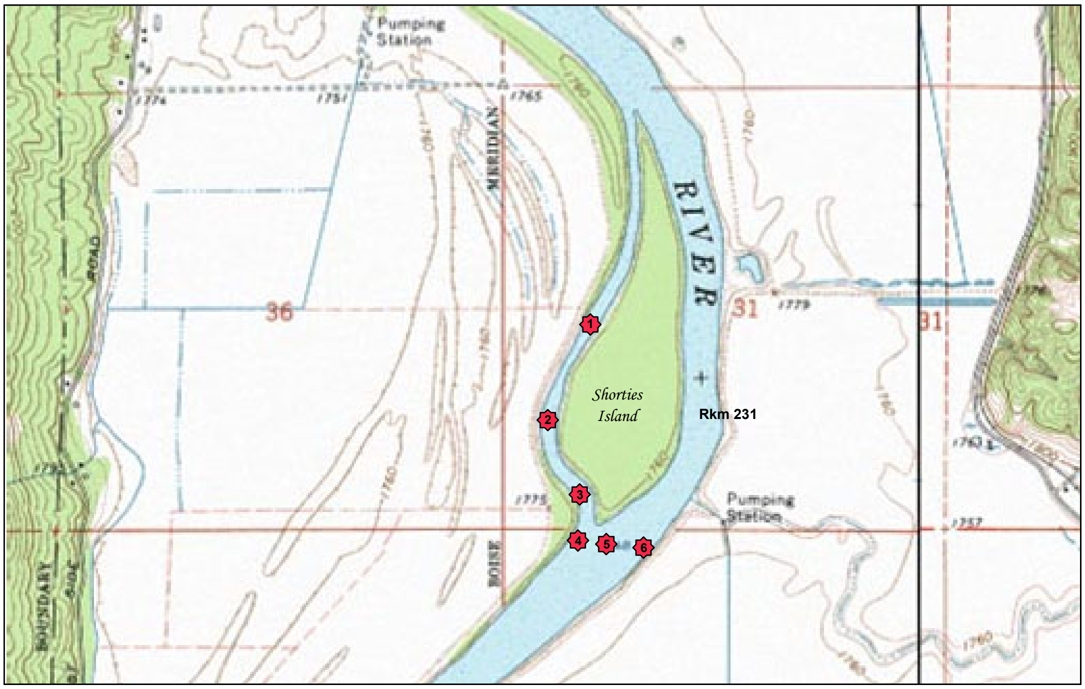

Figure 1. Site location map for 2004 sediment core sampling at Shorties Island, Kootenai River, Boundary County, Idaho.

Results

PCBs and Organochlorine Pesticides

Concentrations of Aroclor PCBs and Organochlorine Pesticides were highest at site #2 and lowest at site #5 (Tables 1 & 2). With the exception of site #5 (where Aroclor 1254 was the dominant PCB), Aroclor 1260 was the most frequently detected Aroclor PCB compound (Figure 2). The three dominant congeners for sites #1-4 and 6 included Penta-, Hexa- and Heptachloro Biphenyls (Figure 3). The three dominant congeners for site #5 were Penta-, Hexa- and Dichloro Biphenyls.

Table 1. Average and range concentrations (pg/g; ppt) of total PCB congeners detected in sediment samples collected from the Shorty's Island area of the Kootenai River, Boundary County, Idaho, 2004.

Sample Site #	**Number of individual sub-samples collected**	**Sum of PCBs in all subsamples (range)**	**Average of PCBs in all subsamples**
1	4	1463.306 (11.30-774.46)	365.827
2	3	4761.514 (6.90-3452.19)	1587.171
3	3	1752.522 21.67-1055.81)	584.174
4	3	1389.094 (53.58-923.25)	463.031
5	1	219.053	219.053
6	3	1452.831 (120.25-735.65)	484.277

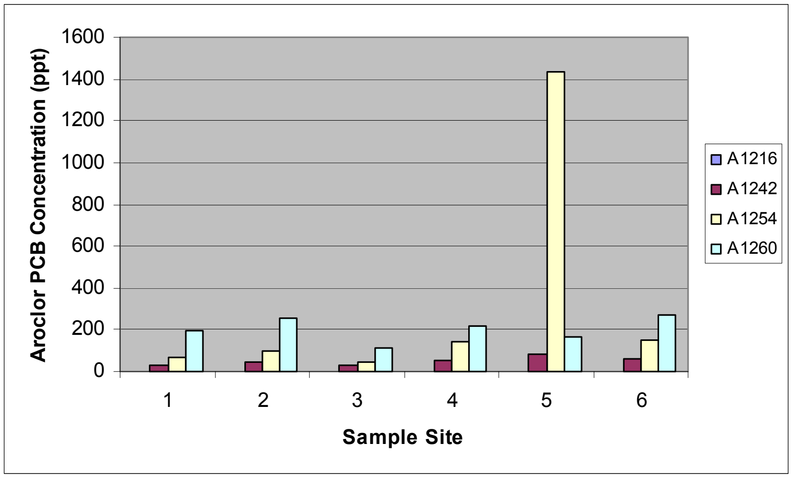

Figure 2. Mean concentrations of Aroclor PCBs in sediment core samples collected from the Shorty's Island area, Kootenai River, Boundary County Idaho, 2004. A1216=Aroclor 1216, A1242= Aroclor 1242, A1254=Aroclor 1254, A1260=Aroclor 1260.

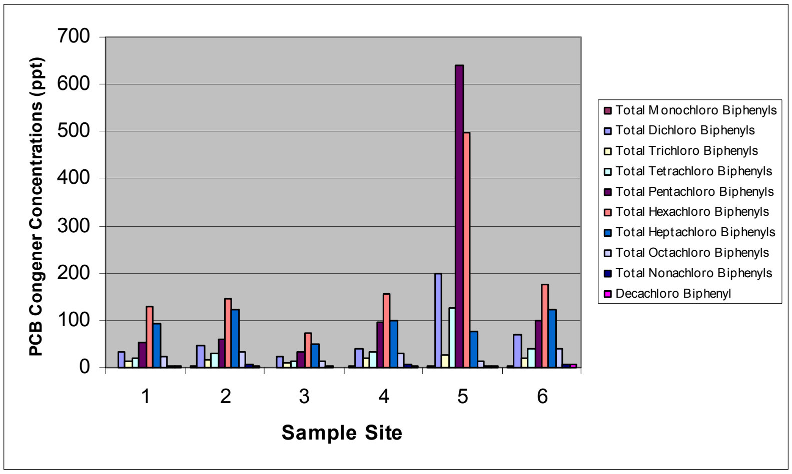

Figure 3. Mean concentrations of PCB congeners in sediment core samples collected from the Shorty's Island area, Kootenai River, Boundary County Idaho, 2004.

Table 2. Average and range concentrations (ng/g; ppb) of total OC Pesticides detected in sediment samples collected from the Shorty's Island area of the Kootenai River, Boundary County, Idaho, 2004.

Sample Site #	**Number of individual sub-samples collected**	**Sum of OC Pesticides in all sub-samples (range)**	**Average of OC Pesticides in all sub-samples**
1	4	0.510 (0.039-0.244)	0.128
2	3	0.604 (0.091-0.416)	0.201
3	3	0.571 (0.061-0.273)	0.190
4	3	0.570 (0.007-0.294)	0.190
5	1	0.079	0.079
6	3	0.551 (0.035-0.283)	0.184

The hypothesis that organochlorine or PCB concentrations were not significantly different between sample sites was rejected. The hypothesis that PCB or organochlorine pesticide concentrations and sediment total organic carbon concentrations were significantly correlated was also rejected ($P < 0.05$).

Metals

Several of the metals concentrations exceeded sediment quality standards. Arsenic, cadmium and copper exceeded New York Department of Environmental Conservation criteria (New York Department of Environmental Conservation 1999) for lowest effects levels in samples #1-5, 1-6 and 6, respectively. Mean arsenic and cadmium concentrations at all sample sites exceeded ISOG (Canadian Interim Quality

Sediment Guidelines; Environment Canada 2003) standards. Other exceedences in ISOG standards included lead in sediment from sample sites number 1, 2, 4 and 5 as well as zinc at sample site #5.

Arsenic and zinc at sample sites #2 and #5 exceeded the Ontario Ministry of the Environment guidelines for open lake disposal of sediments (Dredging Subcomittee 1986). Cadmium in sediment from sample site #5 exceeded the 1986 Wisconsin criteria, the Wisconsin DNR Sediment Quality Guidelines (SQGs; Wisconsin Department of Natural Resources 2003) and the Ontario Ministry of the Environment guildelines for open lake disposal of sediments (Dredging Subcomittee 1986). In comparison to the Great Lakes Harbor Sediment Criteria, sediment from the collected sample sites can be classified as follows: moderate arsenic pollution, excessive barium pollution, moderate lead pollution at sites #2 and 6, and moderate pollution for zinc at sites 1, 2, 4 and 5 (USEPA 1977).

Significant correlations were identified between several factors. Chromium concentrations significantly decreased with depth. All metals concentrations increased with decreasing pH of sediment samples. Concentrations of beryllium were significantly higher in samples containing coarser sediments. No other significant relationships appeared between coarseness of sediment and concentrations of metals. Sites #1-3 (backchannel sites) appeared to contain higher concentrations of TOC and barium than Sites #4-6 (mainstem sites). Cadmium concentrations appeared to increase with depth.

The hypothesis that TOC or metals concentrations were not significantly different ($P < 0.05$) between Sites #1, 2, 3 (backchannel) and Sites #4, 5, 6 (main channel) was only rejected for zinc. Therefore, zinc concentrations were significantly ($P = 0.028$) higher in the main channel sites (4, 5, and 6) than in the back channel sites (1, 2 and 3). Concentrations of all other metals and TOC were not significantly different between the back channel and main channel sites.

Probable Effects

Concentrations of metals did not exceed Probable Effects Levels (PELs; Table 4), Severe Effects Levels (SELs), Toxic Effects Thresholds (TETs), 28-day probable effects level for *Hyalella azteca (*PEL-HA28), or Consensus-based Probable Effects Concentrations (Ingersoll et al. 2000). However, arsenic exceeded NOAA ERL criteria at sites #2 and 5, cadmium exceeded TECs (Toxic Effects Concentrations) at site #5, lead exceeded TECs at sites #1, 2 and 5 as well as ERLs at site #5, and zinc exceeded TECs at site #5 (Table 3; Long and Morgan 1991; MacDonald et al. 2000).

None of the samples contained concentrations of PCBs or Organochlorine pesticides that exceeded known effects levels (Table 5; PEL – probable effects level; SEL – severe effects level; TET – toxic effects level; PEL-HA28 – 28-day probable effects level for *Hyalella azteca*; Consensus-based PEC – probable effects concentrations; Ingersoll et al. 2000).

Table 3. Average and range concentrations (mg/kg; ppm) of metals detected in sediment samples collected from the Shorty's Island area of the Kootenai River, Boundary County, Idaho, 2004. Concentrations exceeding existing state and/or federal sediment contaminant criteria are footnoted.

	Sample Site Average (range)					
Parameter	**1 (n=7)**	**2 (n=6)**	**3 (n=10)**	**4 (n=5)**	**5 (n=16)**	**6 (n=9)**
pH	8.30 (8.09-8.63)	8.24 (7.73-8.6)	8.36 (7.96-8.62)	8.26 (7.94-8.59)	8.27 (7.82-8.52)	8.34 (8.21-8.7)
TOC (%)	<0.10	10.58 (0.14-35.1)	10.71 (4.72-16.7)	0.80 (0.32-1.89)	2.71 (0.15-7.42)	<0.10
Sb	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
As	6.95[b,c] (5.1-8.3)	9.18[a,b,c,d] (5.3-16.8)	6.46 [b,c] (5.0-8.6)	6.77 [b,c] (5.1-9.3)	8.33[a,b,c,d] (5.1-15.2)	5.95[c] (5.2-6.7)
Ba	89.70 (38.1-122)	84.53 (33.7-212)	71.96 (40.6-123)	58.70 (29.9-107)	71.66 (40.7-148)	89.10 (56.2-123)
Be	<0.50	0.54 (0.51-0.57)	<0.50	<0.50	0.52 (ND-0.52)	<0.50
Cd	0.65 [b,c, f] (0.54-0.77)	0.92 [b,c, f] (0.52-1.54)	0.68 [b,c, f] (0.58-0.77)	0.66 [b, c, f] (0.5-0.82)	1.06 [b,c,d,e, f] (0.57-2.22)	0.68 [b,c, f] (ND-0.68)
Cr	17.39 (7.5-26.8)	21.04 (7.3-24.7)	12.48 (7.4-17.4)	12.15 (8.5-17.1)	25.02 (9.1-81.6)	12.62 (9.3-15.5)
Co	6.20 (4.4-7.5)	6.83 (4.3-15.7)	5.44 (3.9-6.7)	5.57 (4.6-7.0)	6.43 (4.9-12.5)	5.24 (3.9-6.4)
Cu	15.23 (5.3-33.7)	14.43 (4.5-34.3)	11.62 (4.5-16.2)	10.73 (5.6-19.5)	13.48 (7.1-31.1)	17.90 [b] (5.9-31.2)
Pb	37.00[c,e] (ND-37)	48.80 [a,c,e] (31-65)	32.67 (31-34)	35.50[c] (31-40)	47.75 [a,c,e] (37-58)	<30.0
Hg	0.020 0.16-0.03)	0.017 (0.10-0.03)	0.014 (0.01-0.02)	0.018 0.09-0.29)	0.017 (0.01-0.02)	0.018 (0.01-0.03)
Mo	<4	<4	<4	<4	<4	<4
Ni	12.53 (8.0-15.6)	12.68 (7.7-30.4)	10.03 (7.7-12.9)	10.45 (7.9-14.3)	12.80 (9.2-24.6)	11.90 (9.4-14.8)
Se	<2	<2	<2	<2	<2	<2
Ag	<2	<2	<2	<2	<2	<2
Tl	<1	<1	<1	<1	<1	<1
V	9.93 (7.7-12.4)	9.66 (5.5-16.3)	8.46 (6.8-10.3)	9.92 (7.9-12.8)	10.75 (7.7-14.6)	10.70 (7.8-12.5)
Zn	98.87 (71.5-120)	102.83[d] (41.8-228)	88.87 (77.3-767)	93.77 (71.3-120)	165.57[c,d,e] (81.1-493)	68.14 (35.4-111)

[a] Exceeds NOAA ERL (Lowest Effects Level) criteria

[b] Exceeds New York Department of Environmental Conservation criteria

[c] Exceeds Canadian Interim Quality Sediment Guidelines (ISQGs)

[d] Exceeds Ontario Ministry of the Environment guidelines for open lake disposal of sediments

[e] Exceeds Wisconsin DNR Sediment Quality Criteria TEC (Toxic Effects Concentrations)

[f] Exceeds British Columbia Working Sediment Quality Guidelines TEL (Threshold Effects Level)

Table 4. Mean concentrations of metals in sediment core samples for which Probable Effects Levels (PELs) were available. Samples collected from the Shorty's Island area of the Kootenai River, Boundary County, Idaho, 2004.

Parameter	PEL	Mean Concentration					
		Site #1	**Site #2**	**Site #3**	**Site #4**	**Site #5**	**Site #6**
Metals (ppm)							
As	17.0	6.95	9.18	6.46	6.77	8.38	5.95
Cd	3.5	0.65	0.92	0.68	0.66	1.06	0.68
Cr	90.0	17.39	21.04	12.48	12.15	25.02	12.62
Cu	197.0	15.23	14.43	11.62	10.73	13.48	17.9
Pb	91.3	37.00	48.80	32.67	35.50	47.75	<30.0
Hg	0.486	0.02	0.02	0.01	0.02	0.02	0.02
Zn	315.0	98.87	102.83	170.44	93.77	165.57	68.14

Table 5. Mean concentrations of organochlorine compounds in sediment core samples for which Probable Effects Levels (PELs; Based on 1% TOC) were available. Adjusted PELs are based on actual mean %TOC at each sample site. Samples collected from the Shorty's Island area of the Kootenai River, Boundary County, Idaho, 2004. BDL = Below detection limit.

Parameter	PEL	Mean Organochlorine Concentration (Adjusted PEL)					
		Site #1	**Site #2**	**Site #3**	**Site #4**	**Site #5**	**Site #6**
Organochlorine Pesticides; ppb;ug/kg							
Chlordane	8.87	0.007 (0.444)	0.011 (93.85)	0.006 (95.00)	0.012 (7.10)	BDL (24.03)	0.010 (0.444)
DDD	8.51	0.068 (0.426)	0.166 (90.04)	0.64 (91.14)	0.096 (6.81)	0.025 (23.06)	0.071 (0.426)
DDE	6.75	0.029 (0.338)	0.116 (71.42)	0.061 (72.29)	0.079 (5.400)	0.026 (18.29)	0.066 (0.338)
DDT	4.77	0.014 (0.239)	0.06 (50.47)	0.026 (51.09)	0.045 (3.816)	0.013 (12.93)	0.050 (0.239)
Lindane	1.38	BDL (1.900)	0.061 (14.60)	0.012 (14.78)	0.019 (1.104)	BDL (3.740)	0.035 (1.900)
Polychlorinated Biphenyls (ppb;ug/kg)							
Total PCBs[1]	277	1.463 (13.85)	4.762 (2931)	1.753 (2967)	1.389 (221.6)	0.0219 (750.7)	1.453 (13.85)
Aroclor 1254	340	0.0672 (17.00)	1.438 (3597)	0.0147 (3641)	0.0976 (272.0)	0.0444 (921.4)	0.0141 (17.00)

[1] Total PCBs are based on totals of all congeners, not Aroclors

Probable Effects Level Quotients (PEQs) for organochlorine pesticides, PCBs and metals ranged between 0.084 (Site #6) and 0.187 (Site #5; Table 6). The mean Toxic Equivalency Quotients (TEQs) ranged between 0.001 (Site #5) and 0.020 (Site #2) for all sites (Table 7). Mean Sediment Quality Guideline Quotients (SQGQs) ranged between 0.060 (Site #1) and 0.126 (Site #5; Table 8).

Table 6. Mean Probable Effects Level Quotients (PEQ) by site for sediment core samples collected from the Shorty's Island area of the Kootenai River, Boundary County, Idaho, 2004.

Site #	**Mean PEQ**
1	0.127
2	0.171
3	0.124
4	0.111
5	0.187
6	0.084

Table 7. Mean Toxic Equivalency Quotients (TEQ) by site for sediment core samples collected from the Shorty's Island area of the Kootenai River, Boundary County, Idaho, 2004.

Site #	**Mean TEQ**
1	0.002
2	0.020
3	0.004
4	0.002
5	0.001
6	0.003

Table 8. Mean Sediment Quality Guideline Quotients (SQGQs) by site for sediment core samples collected from the Shorty's Island area of the Kootenai River, Boundary County, Idaho, 2004.

Site #	**Mean SQGQ**
1	0.060
2	0.106
3	0.101
4	0.082
5	0.126
6	0.044

Summary

The main objective of this study was to assess concentrations of metals, organochlorine pesticides and PCBs in sediments around Shorty's Island, Kootenai River (rkm 231-231.5), for potential effects due to proposed dredging activities.

There is slight concern about redistribution of cadmium, lead and zinc from sediments if dredging is to be undertaken within the study area. Toxic effects (significant reduction in survival or a sublethal endpoint such as growth) to aquatic organisms have been documented after exposure to sediments containing similar concentrations of cadmium, lead and zinc found in samples from sites #1, 2 and 5 (MacDonald et al. 2000).

Probable Effects Quotients (PEQs) were calculated for metals, organochlorine pesticides and PCBs at each sample site in order to quantify the degree to which substances exceed guidelines (Environment Canada 2005). The PEQs calculated for sites #1-5 correspond with quotients for sites that the Canadian government would classify as 'Medium-low priority sites' for concern with a 25% probability of toxicity in amphipod tests (Environment Canada 2005). Site #6 would be classified as a 'low priority site' with a 10.4% probability of toxicity in amphipod tests under the same ranking system. Sites 1-3 were in the back channel behind Shorty's Island and sites 4-6 were located in the main channel of the Kootenai River.

Although concentrations of organochlorine pesticides and PCBs were below known effects concentrations, Toxic Equivalency Quotients (TEQs) were calculated anyway. Toxic Equivalency Quotients are used to account for how various compounds in a sample vary in toxicity and are expressed in grams of TEQ. Resulting TEQs indicated that if any toxic response were to occur, Site #2 (back channel) was the most likely to elicit a response and Site #5 (main channel) was the least likely to elicit a response. These results would follow the common sense approach since Site #2 possessed the highest PCB concentrations and Site #5 possessed the lowest PCB concentrations.

The calculated SQGQ values indicted incidence and magnitude of acute toxicity of sediment samples to amphipods would be ranked from highest to lowest as follows: Site 5, Site 2, Site 3, Site 4, Site 1, Site 6. In other words, Site #5 (main channel site) would be the most likely to illicit an acutely toxic response to aquatic organisms.

Data used in calculation of PEQs and SQGQs includes information about various chemical types. Calculations for TEQs only consider use of dioxin-like substances. Therefore, use of PEQs and SQGQs appears to be the best choice for determining toxicity of these sediment samples. Both PEQa and SQGQs indicate that the least toxic site was #6, which was located in the thalweg of the main channel, suggesting lower deposition and retention of chemicals in the thalweg zone.

Although uptake of contaminants occurs through several routes of exposure, dermal uptake and bioaccumulation of contaminants by adult sturgeon and embryos exposed to freshly disturbed sediments is a potential concern. Kruse and Scarnecchia (2002a) found that metal and PCB concentrations were significantly higher in Kootenai River white sturgeon embryos that were deadheased with river-bottom sediment than those deadheased with Fullers Earth or suspended solids from the Kootenai River. These results indicate the potential for significant embryonic uptake through sediment exposure. Kruse (2000) also showed significant correlations between both Copper and PCB concentrations and embryo mortality. Efficiency of PCB uptake through dermal tissue is generally higher with lower sediment organic carbon concentration (Mayes et al. 2002). Mayes et al. showed a 4.3% uptake after 24 hours from soil with 6% organic carbon and a 14% uptake from soil with 0.09% organic carbon. Therefore, disturbance of sediments at the sample sites could potentially redistribute sediment-associated PCBs, making them bioavailable for an approximate 3% or greater membrane uptake and potentially increasing mortality or developmental deformities in embryonic and larval sturgeon.

This study did not analyze all potentially harmful compounds (i.e. deposition of tremolite from the Rainy Creek mine blowout in the early 1990's) that could be associated with deposited sediments and therefore, is not conclusive of the effects that dredging and redistribution of river-bottom sediments may have on fish and other aquatic organisms. Further sampling to assess chemicals such as PAHs, PBDEs and tremolite should be undertaken prior to disturbing soil with dredging activities.

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