FINAL REPORT

BUNKER HILL FACILITY NON-POPULATED AREAS OPERABLE UNIT 2 BIOLOGICAL MONITORING, 2008

U.S. Fish and Wildlife Service
Kate Healy, Tim Kiser and Brian Spears
Upper Columbia Fish and Wildlife Office
Spokane, Washington

October 2009

Table of Contents

List of Tables

List of Figures

1.0 Background and Objectives

This report summarizes activities and results of U.S. Fish and Wildlife Service (Service) Upper Columbia Fish and Wildlife Office (UCFWO) biological resource monitoring conducted at the Bunker Hill Mining and Metallurgical Complex Operable Unit 2 (OU-2) during 2008. The Service is responsible for conducting biological resource monitoring to assist USEPA in evaluating the progress of remedial actions in terms of improving ecological conditions. This work was supported through an Interagency Agreement with the U.S. Environmental Protection Agency (USEPA) and follows the framework of the Environmental Monitoring Plan (EMP) (USEPA, 2006a).

Phase I of the Comprehensive Cleanup Plan for OU-2 includes the evaluation of effects of remedial actions on ecological conditions at the site. Biological resource monitoring under the EMP was designed to aid in this evaluation, relating the effectiveness of the overall Phase I remedy for OU-2 to goals and objectives identified in the OU-2 Record of Decision (USEPA, 1992) and subsequent amendments (USEPA, 1996a; USEPA, 2001a) and explanations of significant differences (USEPA, 1996b; USEPA, 1998) (USEPA, 2006a). Data will provide information for the required Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) five-year reviews and be used to guide Phase II of the remedy within OU-2.

As identified in the Environmental Monitoring Plan for OU-2 (USEPA, 2006a), the Service conducted studies in 2008 designed to evaluate two components of remedy with respect to biological resources: the status of aquatic and terrestrial wildlife populations and habitat quality in remediated areas, and exposure of biological resources to contaminants of concern, including arsenic (As), cadmium (Cd), lead (Pb), and zinc (Zn). Biological resource monitoring projects completed in 2008 included:

- small mammal populations at Smelterville Flats and the Central Impoundment Area (CIA),
- analyses of soil, sediment, water from Smelterville Flats, within the South Fork of the Coeur d'Alene River (SFCDR), within Page Ponds wetlands and on the CIA for arsenic (As), cadmium (Cd), lead (Pb) and zinc (Zn),
- waterfowl blood and fecal samples from Smelterville Flats[1], and
- As, Cd, Pb and Zn tissue concentrations in small mammals collected from Smelterville Flats and the CIA.

The selection of study areas within OU-2 was dependent upon a review of past remedial actions (USEPA, 2000), reconnaissance investigations of current habitat conditions, review of relevant literature, previous studies conducted on site, and sampling site accessibility. Reference locations were not evaluated as part of 2008 studies. Brief descriptions of study areas follow.

[1] Service personnel attempted to collect waterfowl fecal samples from Smelterville Flats. However, no samples appropriate for analyses were found.

SFCDR

The SFCDR flows from near the Idaho-Montana border through OU-2 to the confluence with the North Fork of the Coeur d'Alene River near Cataldo. The SFCDR within OU-2 is contaminated with mining-related metals from upstream sources and tailings placed on site. Remedial actions were conducted within this stretch from 1999 to 2004 and included excavation and removal of contaminated material, channel reconstruction, bank stabilization and revegetation (TerraGraphics and Ralston, 2006). Sources of mining-related metals remain upstream of this stretch of river, which may continue to contribute to metal contamination at the site as their material erodes and moves downstream.

Smelterville Flats

Smelterville Flats is located adjacent to the South Fork Coeur d'Alene River within the floodplain at the west end of OU-2. Soil and sediments at the site have been impacted by a century of uncontrolled discharges of jig and flotation tailings related to Coeur d'Alene Basin mining (USEPA, 2005; TerraGraphics and Ralston, 2006). Estimates of mining wastes in the area include approximately 1,488,000 cubic yards of tailings (TerraGraphics and Ralston, 2006). Several phases of remedial activities occurred at Smelterville Flats beginning in 1997 (TerraGraphics and Ralston, 2006). Target remedial goals for soil and sediment at the site were 1,000 mg/kg lead south of I-90 and 3,000 mg/kg lead and 3,000 mg/kg zinc north of I-90 (USEPA, 2005). Approximately 1,208,448 cubic yards of tailings were removed and capped with backfill and topsoil (TerraGraphics and Ralston, 2006). Backfill and cap consisted of 526,870 cubic yards of borrow pit and topsoil material (Morrison Knudsen Corporation, 1999, as cited by TerraGraphics and Ralston, 2006). Approximately 400,000 cubic yards of contaminated material greater than 1,000 mg/kg Pb is estimated to remain within the top 8 feet of material at Smelterville Flats north of I-90 (TerraGraphics and Ralston, 2006). As of the date of this study, this floodplain area received water from the South Fork of the Coeur d'Alene River, the Page Ponds and Smelterville wastewater treatment plants, and groundwater. Elevated metals loadings had been identified for each of these sources at the site (USEPA, 2006b). Water inputs, combined with topography resulting from tailings removal activities, have lead to the development of several ponds and wetlands in the Smelterville Flats area.

Page Ponds Wetland Complex

The Page Waste Water Treatment Plant (WTP) is located at the west end of Smelterville within OU-2. The WTP includes 4 aeration lagoons and a stabilization pond located on top of a tailings impoundment consisting of inactive floatation tailings produced by the Page Mill (USEPA, 1992). The wetland complex is comprised of two wetlands (East Swamp and West Swamp) occurring on the east and west sides of the Page tailings impoundment.

CIA

The area on which the CIA rests was originally part of the SFCDR floodplain. The CIA was originally constructed in 1928 as a tailings impoundment for the Bunker Hill Mine to hold smelter slag and slimes (TerraGraphics and Ralston, 2006). Remedial actions implemented as part of the OU-2 remedy included the placement of a cap for dust control and the prevention of direct contact with contaminated material, collection of upper zone groundwater for wetland treatment, and the construction of a repository for consolidating extensive contamination from various areas of the site (USEPA, 2005). This repository became the CIA.

The CIA is bordered by I-90 on the north, Bunker Creek on the South, and located at the east end of OU-2. The CIA currently holds approximately 2,599,250 cubic yards of material excavated from around OU-2. Mine wastes impounded within the CIA included granulated slag from the lead smelter, gypsum by-products and flotation tailings. This material was capped with a geomembrane cover and soil and seeded (TerraGraphics and Ralston, 2006) to prevent direct contact with contaminated material and prevent infiltration of precipitation to allow the contaminated soil to dry and reduce movement of dissolved metals (USEPA, 1992). Reduced infiltration appears to have been effective based on reduced groundwater levels in the CIA's proximity and consistently dry sampling wells within the CIA (CH2M Hill, 2007). TerraGraphics and Ralston (2006) estimate approximately 2.6 million cubic yards of waste material was added to the CIA during remedial activities on site. The top of the CIA is approximately 265 acres with embankment heights ranging from 30 to 70 feet (TerraGraphics and Ralston, 2006).

Biological resource monitoring was conducted in accordance with UCFWO Standard Operating Procedures (SOPs) and the EMP (USEPA, 2006a), both designed for data continuity and comparability with existing studies. Upper Columbia Fish and Wildlife SOPs were developed and implemented for all studies conducted and a Quality Assurance Plan completed for the control of chemical analysis (USFWS, 2001). Project methods and results are presented below.

2.0 Soil, sediment and water metal concentrations

The OU-2 Environmental Monitoring Program (EMP) (USEPA, 2006a) identifies ecological risks to plants and animals associated with mining-related hazardous substances in OU-2 within four habitat types: riverine, palustrine, riparian, and upland. Exposure pathways to contaminants of concern within OU-2 include ingestion of soil and sediment, surface water, and food resources.

Phase I of the Comprehensive Cleanup Plan for OU-2 includes the evaluation of remedial actions on ecological conditions at the site. Monitoring components under the EMP investigate the status of aquatic and terrestrial wildlife populations and habitat quality in remediated areas, as well as exposure of biological resources to contaminants of concern, including As, Cd), Pb, and Zn. Data gaps in metal concentrations in soil, sediment and water existed at biological monitoring locations in OU-2, making evaluations of Phase I remedial action success in addressing ecological exposure difficult. To address these gaps, the Service and USEPA developed a media sampling evaluation in these locations.

Past biological monitoring locations within OU-2 included hillsides and gulches to the south and above Smelterville and Kellogg, the SFCRD, Smelterville Flats, the Page Ponds wetland complex and the CIA. Land ownership changes and development within the hillsides and gulches limited recent monitoring activities and were expected to limit future activities. Media sampling, therefore, was limited to the SFCDR, Smelterville Flats, the Page Ponds wetland complex and the CIA.

The Page Ponds aerial lagoons and wetland complex and Smelterville Flats area are used by ecological receptors, including small mammals, waterfowl and amphibians (USFWS, 2004; USFWS, 2007; USFWS, 2008a). The CIA is used by small mammals, large mammals and songbirds (USFWS, 2008a; USFWS, personal observation). Previous sampling demonstrated that the Page Ponds wetland complex and Smelterville Flats area contained surface sediment lead concentrations above 530 mg/kg, the level determined to be protective of waterfowl (USEPA, 2002a), and that receptors using OU-2 areas have elevated exposure to metals of concern (Mullins and Burch, 1993; Burch et al., 1996). This was not unexpected given the remedial action goals used for Smelterville Flats and the fact that the Page Ponds East Swamp has not been remediated.

Service personnel collected soil, sediment and water samples from Smelterville Flats, Page Ponds wetlands, CIA and the SFCDR to help evaluate recontamination issues, the integrity of remedial caps, and help provide data on ecological receptor exposure and help interpret tissue concentrations and continued exposure to residual metal concentrations at these sites. Ecological exposure to soils and surface water, especially where the primary exposure is through the ingestion of contaminated media, generally occurs within the top 6” of depth. Soil and sediment sampling therefore included only 0-6” below ground surface.

2.1 Methods

Soil, sediment and water collection was conducted in August, 2008 in accordance with UCFWO SOPs, the EMP QAPP (USEPA, 2006a) and the project Field Sampling Plan (USFWS, 2008b). Geographic information system programs and habitat delineations were used determine sample sites with the appropriate number of samples within each habitat type.

Soil/sediment samples were conducted by hand coring locations from land or small boat. Water samples were collected with acid rinsed and filter-equipped syringes and placed in 125 ml acid-rinsed polypropylene bottles. Twenty soil samples were collected from the CIA. Ten sites were randomly selected across the location ≥100 m apart, and 10 were digitized along the edge of the location to evaluate cap integrity. Sampling at the Page Ponds complex was limited to 20 soil/sediment samples from within the East Swamp. One hundred ten soil/sediment and 45 water samples were collected from Smelterville Flats: 20 soil samples from riparian habitats and 90 soil/sediment and 45 water samples from wetland habitats. Twenty four sediment samples were collected within the South Fork Coeur d’Alene River, 6 from each of 4 100-m reaches previously used in EPM sampling. A random number generator was used to determine locations of 6 cross-river transects within each reach. A grab sample was taken at ~2 m intervals along each transect. These samples were composited into a single sample for each transect.

Samples were transported from the field to the UCFWO. Water samples were refrigerated and soil/sediment samples were stored at -20 degrees C in a locked facility until being shipped to a USEPA Contract Lab CLP for total antimony, As, Cd, calcium, copper, Pb, magnesium, mercury and Zn analyses. Soil and sediment concentrations are reported as mg/kg dry weight. Water concentrations are reported as ug/L.

2.2 Results

Soil and sediment sample information and results are provided in tables 2-1 to 2-6 and figures 2-1 and 2-2. Pierson's Product Moment correlations for metals in soil/sediment are provided in tables 2-7 to 2-10. Water sample information and results are provided in tables 2-2 and 2-11 and figure 2-3. Mercury was not detected above the lab reporting limit in any sample.

2.3 Discussion

Soil and sediment results appear to suggest mixed results in the effectiveness of previous remedial actions within OU-2. Target remedial goals for soil and sediment in the Smelterville Flats area north of I-90 were 3,000 mg/kg lead and 3,000 mg/kg zinc (USEPA, 2005). Lead results from SFCDR samples generally ranged from 1,000-3,000 mg/kg, but ranged well above that. However, ninety-two percent (24/26) of samples contained zinc concentrations below the remedial goal. Likewise, lead and zinc concentrations in the majority of other samples collected at the site were below target remedial goals: 54% (12/22) and 82% (18/22) for lead and zinc, respectively, from the Smelterville Flats riparian area, and 83% (80/96) and 81% (79/96), respectively, from Smelterville Flats wetland areas. These data suggest some success in the long-term integrity of remedial activities.

Riparian area samples may or may not have been remediated previously. Regardless, the Smelterville Flats area sampled was within the immediate SFCDR flood plain, and it is likely that it has been inundated with SFCDR water and affected by mining-related metals from upstream sources high in metals concentrations. It was therefore not entirely unexpected that elevated metals concentrations appeared in the riparian area. Wetland area samples, however, were well within the area remediated from 1999-2004 (Terragraphics and Ralston, 2005; figure 2-1). Several wetland samples contained concentrations well above target remedial goals. Using lead, for example, 17% (15/90) were above the remedial goal, 1% (9/90) above 5,000 mg/kg, 5 above 10,000 mg/kg, and one at a concentration of 32,100 mg/kg (table 2-1; figure 2-1). River flood channels were designed as part of the Smelterville Flats remediation to limit recontamination of the area by flooding (Anne Dailey, USEPA, Seattle, WA, personal communication). It is unclear whether the elevated concentrations in samples from wetland areas are the result of surface recontamination from flooding (and thus an indication of how well these flood channels performed), input from other potential sources (e.g., Page Ponds and Smelterville wastewater treatment plants or groundwater), or the erosion or lack of soil cap designed to cover contaminated material left in place.

Metals concentrations in blood, tissues and fecal samples collected from small mammals (Section 5.0), large mammals, riparian songbirds, fish, and benthic aquatic invertebrates at Smelterville Flats and the SFCDR in OU-2 have suggested continued elevated exposure to mining-related metals (USFWS, 2007; USFWS, 2008a; USFWS, 2008c). Certain ecological receptors (e.g., large mammals) may be exposed to the variation in metal concentrations across Smelterville Flats wetlands indicated by samples from this study. Other ecological receptors, however (e.g., riparian songbirds) concentrate in the riparian zone within Smelterville Flats due to the habitat characteristics and resources it provides. Soil sampling from this and previous study of ecological exposure demonstrate consistently elevated metals concentrations within the riparian zone (USFWS, 2008a), which appear to be causing ecological exposure to levels of injury to wildlife. For example, USFWS (2008a) reported that blood and liver lead concentrations in riparian songbirds using Smelterville Flats were above those shown to cause toxicity. During the 2008 small mammal sampling effort (see Sections 4.0 and 5.0), a Spotted Towhee (*Pipilo maculates*), a ground nesting/feeding songbird, was incidentally captured. The liver from this individual was later removed for analysis. The liver lead concentration was 6.29 mg/kg dry weight, which exceeds the subclinical toxicity threshold suggested for riparian songbirds (5.7 mg/kg dw; Hansen, 2007). This result reflects a continuing contaminant exposure to songbirds at this site. Providing riparian corridors with metals concentrations below those shown to negatively affect ecological receptors needs to be considered as remedial planning moves forward

While a paucity of data exists on exposure information for receptors using the CIA, tissue concentrations from ecological receptors using the CIA may provide further information on cap integrity and effectiveness. Small mammal tissue residues, which most likely demonstrate site-specific exposure, suggest elevated exposure at the site (see Section 5.0). In addition, lead and Zn in a coyote fecal sample (8.13 mg/kg and 0.127 mg/kg, respectively) collected from the CIA in 2007 were 1.5 and 1.3 times higher than those from a reference area (USFWS, 2007)[2]. Finally, three Savannah sparrows (*Passerculus sandwichensis)*, a ground nesting/feeding species commonly observed on the CIA, were incidentally captured during small mammal trapping on the CIA in 2008 (see Section 5.0). Liver lead concentrations from these individuals were 0.28 mg/kg, 0.34 mg/kg and 4.2 mg/kg. While two of three of these individuals appeared to mirror exposure expected at background, the 4.2 mg/kg result was well above those observed for songbirds in reference areas (0.26-0.37 mg/kg; Hansen, 2007). Together, these data suggest that metals exposure in the CIA area may not be protective of ecological receptors. However, results from soil sampling conducted on the CIA suggest that the soil cap is mostly intact and protecting receptors from the Superfund material below[3]. The apparent discrepancy between soil concentrations and elevated receptor exposure at the CIA constitutes a data gap regarding what the exposure source is. This is discussed more in Section 5.3 of this report.

The East Swamp of the Page Ponds wetland complex has not been remediated. Previous studies documented that ecological receptors using the East Swamp incur elevated metals exposure to levels potentially causing injury (Mullins and Burch, 1993; Burch et al., 1996; Audet et al., 1999; USFWS, 2005). Consistently high metals concentrations in samples from this study, including lead concentrations up to 73,200 mg/kg, suggest that exposure to these levels are probably continuing at this site.

Dissolved concentrations of metals of concern in Smelterville Flats wetlands water samples were mixed in terms of protection of aquatic resources. Mercury was not detected in any samples.

---

[2]Because of home range size and the close proximity of nearby contaminated areas, it is difficult to ascertain whether contaminated material within the CIA was the primary source of coyote exposure to metals.

[3] A fabric membrane was visible in several locations of the cap during sampling (Service personnel, personal observation), suggesting that the soil cap had eroded in these areas. This membrane appeared to be a turf reinforcement mat designed to reduce erosion and support plant growth, not the geomembrane cover described by USEPA (2005). A "slag drainage layer" would be exposed directly below this growth medium support mat (USEPA, 2005). It is possible that available metals within the slag drainage layer may contribute to ecological exposure.

Concentrations in neither arsenic nor copper were above chronic or acute water quality criteria guidelines (USEPA, 2009). However, cadmium, lead and zinc concentrations were above chronic criteria and lead and zinc were above acute criteria in a number of samples (table 4-11). Cadmium and zinc are notable metals of concern at the site. Both metals had dissolved concentration means above acute water quality guidelines, and maximum levels of more than 12 and 58 times that of acute water quality guidelines, respectively. Dissolved metals concentrations within Smelterville flats wetlands may be limiting use and reproduction at the site by aquatic receptors such as fish and amphibians (Birge et al., 2000). The source of these concentrations may be a combination of leaching of metals from the underlying material, wastewater treatment plant inputs and/or groundwater influences.

Table 2-1. Soil and sediment metals concentrations, OU-2, Coeur d'Alene Basin, Idaho, 2008.

Collection Date	Collection Time	Location	Sample #	Easting	Northing	Matrix	As mg/kg dw	Cd mg/kg	Pb mg/kg	Zn mg/kg dw	Comments
8/11/2008	10:55	CIA	BH08S001	563527	5266320	Soil	11.15	0.805	175	1245	
8/11/2008	11:15	CIA	BH08S002	563654	5266261	Soil	6.1	0.18	11.3	58.6	
8/11/2008	11:45	CIA	BH08S003	563511	5266123	Soil	6.4	0.19	11.2	47.1	
8/11/2008	11:58	CIA	BH08S004	563762	5266136	Soil	7.4	0.24	13.9	328	
8/11/2008	12:04	CIA	BH08S005	563881	5265969	Soil	7.1	0.25	25.4	88.5	
8/11/2008	12:18	CIA	BH08S006	564237	5265815	Soil	7.1	1.2	32.6	988	
8/11/2008	12:21	CIA	BH08S007	564410	5266024	Soil	6.5	0.26	24.1	195	
8/11/2008	12:30	CIA	BH08S008	564512	5266023	Soil	9.6	0.37	57.2	127	
8/11/2008	12:40	CIA	BH08S009	564571	5265666	Soil	11	0.48	12	47.9	
8/11/2008	1:02	CIA	BH08S010	564825	5265817	Soil	7.2	0.26	37	70	
8/11/2008	1:08	CIA	BH08S011	564725	5265972	Soil	8.6	0.38	49.9	111	
8/11/2008	1:20	CIA	BH08S012	564998	5265893	Soil	9.8	0.46	74	212	
8/11/2008	1:21	CIA	BH08S013	564998	5265893	Soil	9.2	0.45	73.3	233	Field dupe of BH08S012
8/11/2008	1:22	CIA	BH08S014	564782	5266211	Soil	7.4	0.41	49.6	130	
8/11/2008	1:33	CIA	BH08S015	564882	5266285	Soil	6.5	0.32	51.7	81	
8/11/2008	1:35	CIA	BH08S016	564499	5266247	Soil	7	0.34	54.8	110	
8/11/2008	1:48	CIA	BH08S017	564539	5266341	Soil	6.5	0.34	56.1	95.3	
8/11/2008	1:56	CIA	BH08S018	564296	5266172	Soil	7.1	0.3	40.1	215	
8/11/2008	2:03	CIA	BH08S019	564236	526336	Soil	7.6	0.38	53.7	162	
8/11/2008	2:08	CIA	BH08S020	564089	2566259	Soil	6.5	0.29	45.7	104	
8/11/2008	2:15	CIA	BH08S021	563853	5266322	Soil	7.35	0.495	78.45	276.5	
8/21/2008	9:21	Page East Swamp	BH08SE143	560405	5265401	Sed	6.5	1.8	310	134	
8/21/2008	9:36	Page East Swamp	BH08SE144	560412	5265606	Sed	26.1	16.8	1120	2250	
8/21/2008	9:37	Page East Swamp	BH08SE145	560481	5265579	Sed	44.9	24.5	2370	1500	
8/21/2008	10:01	Page East Swamp	BH08SE146	560533	5265593	Sed	19.25	8.95	1270	363.5	
8/21/2008	10:27	Page East Swamp	BH08SE147	560683	5265668	Sed	37.9	6.6	790	444	
8/21/2008	10:27	Page East Swamp	BH08SE148	560654	5265710	Sed	100	15.4	4670	981	
8/21/2008	11:11	Page East Swamp	BH08SE149	560478	5265902	Sed	57.2	28.3	36300	3570	
8/21/2008	11:12	Page East Swamp	BH08SE150	560463	5265915	Sed	64.5	30.5	4360	2620	
8/21/2008	11:51	Page East Swamp	BH08SE151	560511	5265940	Sed	103	14.5	72300	3470	
8/21/2008	11:51	Page East Swamp	BH08SE152	560511	5265940	Sed	94.1	15.3	57600	3050	Field dupe of BH08SE151
8/21/2008	11:55	Page East Swamp	BH08SE153	560521	5265947	Sed	41.5	16.2	8870	1580	
8/21/2008	12:22	Page East Swamp	BH08SE154	560486	5265803	Sed	40	47	1780	2420	
8/21/2008	12:23	Page East Swamp	BH08SE155	560563	5265800	Sed	62.6	12.8	2130	1240	
8/21/2008	12:46	Page East Swamp	BH08SE156	560729	5265634	Sed	44.4	6.2	799	447	On dike
8/21/2008	12:46	Page East Swamp	BH08SE157	560720	5265662	Sed	43.4	5.1	1130	343	
8/21/2008	1:08	Page East Swamp	BH08SE158	560806	5265656	Sed	52	13.5	825	2180	In creek
8/21/2008	1:08	Page East Swamp	BH08SE159	560863	5265672	Sed	69.1	5.5	1550	525	On dike
8/21/2008	1:32	Page East Swamp	BH08SE160	560645	5265898	Sed	41.9	39.7	3870	908	
8/21/2008	1:32	Page East Swamp	BH08SE161	560643	5264882	Sed	9.9	29.3	2410	855	
8/21/2008	1:47	Page East Swamp	BH08SE162	560658	5265916	Sed	23.7	16.9	1950	673	
8/21/2008	1:48	Page East Swamp	BH08SE163	560692	5265854	Sed	112	13.6	10700	1410	
8/19/2008	9:44	River reach-1	BH08SE117	559512	5266353	Sed	28.4	4.6	4840	1010	
8/19/2008	10:00	River reach-1	BH08SE118	559469	5266340	Sed	17.7	2.9	1780	1040	
8/19/2008	10:22	River reach-1	BH08SE119	559472	5266340	Sed	85	5.2	1640	1010	

Collection Date	Collection Time	Location	Sample #	Easting	Northing	Matrix	As mg/kg dw	Cd mg/kg	Pb mg/kg	Zn mg/kg dw	Comments
8/19/2008	10:30	River reach-1	BH08SE120	559484	5266342	Sed	31.2	18.3	1480	2130	
8/19/2008	10:48	River reach-1	BH08SE121	559509	5266356	Sed	42.7	8.4	2420	1660	
8/19/2008	11:03	River reach-1	BH08SE122	559511	5266352	Sed	16.5	8.6	1040	2030	
8/20/2008	9:05	River reach-2	BH08SE123	560513	5266800	Sed	9.5	3.3	455	893	
8/20/2008	9:15	River reach-2	BH08SE124	560519	5266799	Sed	21.3	7	1030	1140	
8/20/2008	9:21	River reach-2	BH08SE125	560533	5266790	Sed	25.5	5.5	1100	1330	
8/20/2008	9:30	River reach-2	BH08SE126	560550	5266784	Sed	17	6.15	1615	1250	
8/20/2008	9:42	River reach-2	BH08SE127	560555	5266780	Sed	24.8	23.4	2060	3820	
8/20/2008	9:50	River reach-2	BH08SE128	560580	5266753	Sed	42	8.2	1330	1370	
8/20/2008	10:08	River reach-3	BH08SE129	564701	5266543	Sed	19.2	7.1	5660	1470	
8/20/2008	10:19	River reach-3	BH08SE130	564712	5266542	Sed	19.7	5.7	1550	1310	
8/20/2008	10:27	River reach-3	BH08SE131	564711	5266543	Sed	24	6.8	1910	1430	
8/20/2008	10:48	River reach-3	BH08SE132	564719	5266454	Sed	33.3	8.6	1960	1800	
8/20/2008	11:00	River reach-3	BH08SE133	564723	5266547	Sed	21.9	5.3	1200	1190	
8/20/2008	11:19	River reach-3	BH08SE134	564773	5266566	Sed	38.4	8.1	2080	1740	
8/20/2008	12:54	River reach-4	BH08SE135	563032	5266448	Sed	31.5	6.8	1760	1370	
8/20/2008	12:58	River reach-4	BH08SE136	563036	5266447	Sed	27.1	6	1610	1180	
8/20/2008	1:10	River reach-4	BH08SE137	563049	5266452	Sed	35.6	7.9	2010	1620	
8/20/2008	1:15	River reach-4	BH08SE138	563052	5266454	Sed	68.5	13.2	3110	2120	
8/20/2008	1:20	River reach-4	BH08SE139	563095	5266448	Sed	38.4	9.5	3370	1940	
8/20/2008	1:21	River reach-4	BH08SE140	563109	5266450	Sed	40	65.3	1610	2120	
8/20/2008	12:59	River reach-4	BH08SE141	563036	5266442	Sed	30.7	7.4	1720	1310	Field dupe of BH08SE136
8/20/2008	1:21	River reach-4	BH08SE142	563095	5266448	Sed	47.3	24.6	28700	5420	Field dupe of BH08SE139
8/15/2008	9:51	Smelterville Riparian	BH08SE060	562000	5266454	Sed	175	29.2	10900	5210	
8/15/2008	10:24	Smelterville Riparian	BH08SE061	561855	5266512	Sed	56.7	16.9	2860	2080	
8/15/2008	10:26	Smelterville Riparian	BH08SE062	561761	5266584	Sed	73.1	34.4	2850	3290	UTM change from QAPP
8/15/2008	10:37	Smelterville Riparian	BH08SE063	561761	5266584	Sed	54.8	32.8	2320	2810	Field dupe of BH08SE62
8/18/2008	10:41	Smelterville Riparian	BH08SE099	560677	5266724	Soil	218	23.5	2945	2475	
8/18/2008	10:43	Smelterville Riparian	BH08SE100	560768	5266803	Soil	75.8	18.8	3620	2360	
8/18/2008	11:00	Smelterville Riparian	BH08SE101	560546	5266700	Soil	61.6	13.6	2110	2500	
8/18/2008	11:01	Smelterville Riparian	BH08SE102	560396	5266743	Sed	69.1	55.1	3190	4130	
8/18/2008	11:30	Smelterville Riparian	BH08SE103	560986	5266730	Sed	57.5	23.4	2750	2500	
8/18/2008	11:33	Smelterville Riparian	BH08SE104	560102	5266715	Sed	53.7	8	1680	1430	
8/18/2008	11:33	Smelterville Riparian	BH08SE105	560102	5266715	Sed	72	25.8	3780	2880	Field dupe of BH08SE104
8/18/2008	12:10	Smelterville Riparian	BH08SE106	561275	5266617	Sed	36.75	14.1	3240	3150	
8/18/2008	12:15	Smelterville Riparian	BH08SE107	561204	5266696	Sed	61.5	12.5	3120	1930	
8/18/2008	12:30	Smelterville Riparian	BH08SE108	561506	5266682	Soil	64.2	17	3720	2570	
8/18/2008	12:35	Smelterville Riparian	BH08SE109	561382	5266691	Soil	40.5	9.1	2330	1950	
8/18/2008	12:57	Smelterville Riparian	BH08SE110	560241	5266649	Soil	7.2	0.46	47.7	90	
8/18/2008	1:02	Smelterville Riparian	BH08SE111	560125	5266555	Sed	54.2	16.6	2160	2410	
8/18/2008	1:10	Smelterville Riparian	BH08SE112	559943	5266520	Soil	54.2	12.5	2270	1840	
8/18/2008	1:22	Smelterville Riparian	BH08SE113	559811	5266508	Soil	34.3	9.4	2590	1470	
8/18/2008	1:30	Smelterville Riparian	BH08SE114	559712	5266463	Soil	75.2	17.4	4690	2670	
8/18/2008	1:40	Smelterville Riparian	BH08SE115	559593	5266418	Soil	116	18.7	5280	2780	
8/18/2008	1:44	Smelterville Riparian	BH08SE116	559399	5266350	Soil	109	15.2	3570	2330	
8/13/2008	10:19	Smelterville Wetlands	BH08SE001	559632	5266316	Sed	8.8	4.7	195	571	
8/13/2008	10:28	Smelterville Wetlands	BH08SE002	559539	5266305	Sed	94.4	7	5960	2220	

Collection Date	Collection Time	Location	Sample #	Easting	Northing	Matrix	As mg/kg dw	Cd mg/kg	Pb mg/kg	Zn mg/kg dw	Comments
8/13/2008	10:30	Smelterville Wetlands	BH08SE003	559464	5266311	Sed	110	16.3	4690	2490	
8/13/2008	10:42	Smelterville Wetlands	BH08SE004	559624	5266378	Sed	8	4.7	376	722	
8/13/2008	10:45	Smelterville Wetlands	BH08SE005	559541	5266335	Sed	18.1	3.1	526	635	
8/13/2008	12:05	Smelterville Wetlands	BH08SE006	559828	5266367	Sed	7.5	27.8	87.3	2650	
8/13/2008	12:09	Smelterville Wetlands	BH08SE007	559847	5266374	Sed	6.6	47.1	630	4100	
8/13/2008	12:21	Smelterville Wetlands	BH08SE008	559717	5266284	Sed	44.3	153	10200	6900	
8/13/2008	12:23	Smelterville Wetlands	BH08SE009	559807	5266337	Sed	28.6	51.3	9330	6810	
8/13/2008	12:50	Smelterville Wetlands	BH08SE010	559849	5266404	Sed	10.6	9.8	1240	1860	
8/13/2008	1:04	Smelterville Wetlands	BH08SE011	559848	5266355	Sed	12.2	17.5	1890	1840	
8/13/2008	1:15	Smelterville Wetlands	BH08SE012	559801	5266319	Sed	26.8	40.9	6370	5130	
8/13/2008	1:16	Smelterville Wetlands	BH08SE013	559863	5266339	Sed	15.3	26.4	3970	4410	
8/13/2008	1:39	Smelterville Wetlands	BH08SE014	559895	5266336	Sed	52.9	229	32100	25300	
8/13/2008	1:31	Smelterville Wetlands	BH08SE015	559901	5266350	Sed	6.7	8.4	531	922	
8/13/2008	1:32	Smelterville Wetlands	BH08SE016	559909	5266312	Sed	11.5	8.6	320	1570	
8/14/2008	9:05	Smelterville Wetlands	BH08SE017	559920	5266276	Soil	6.7	0.34	20.6	466	
8/14/2008	9:10	Smelterville Wetlands	BH08SE018	559942	5266281	Soil	6.1	0.25	15.9	53.1	
8/14/2008	9:30	Smelterville Wetlands	BH08SE019	559949	5266270	Soil	6.8	6	764	1060	
8/14/2008	9:34	Smelterville Wetlands	BH08SE020	560084	5266278	Sed	7.4	12.4	41.1	1970	
8/14/2008	9:50	Smelterville Wetlands	BH08SE021	560062	5266273	Sed	7.9	0.3	18.4	66.9	
8/14/2008	10:00	Smelterville Wetlands	BH08SE022	560109	5266295	Soil	4.3	0.46	12.6	80.5	
8/14/2008	10:05	Smelterville Wetlands	BH08SE023	560084	5266299	Soil	6.3	0.26	22.8	67.8	
8/14/2008	10:10	Smelterville Wetlands	BH08SE024	560038	5266302	Soil	13.5	1.3	52.8	281	
8/14/2008	10:25	Smelterville Wetlands	BH08SE025	560024	5266324	Sed	6.8	3.6	33.3	613	
8/14/2008	10:30	Smelterville Wetlands	BH08SE026	560020	5266343	Sed	5.4	32.3	193	814	
8/14/2008	10:56	Smelterville Wetlands	BH08SE027	560047	5266354	Sed	9	86.5	2810	4860	
8/14/2008	10:57	Smelterville Wetlands	BH08SE028	560088	5266334	Sed	6.8	40	879	3170	
8/14/2008	11:08	Smelterville Wetlands	BH08SE029	560086	5266373	Sed	6.7	0.4	24.4	166	
8/14/2008	11:10	Smelterville Wetlands	BH08SE030	560208	5266340	Soil	7.4	0.26	16.2	57.1	
8/14/2008	11:25	Smelterville Wetlands	BH08SE031	560180	5266342	Soil	7	3.1	247	1480	
8/14/2008	11:30	Smelterville Wetlands	BH08SE032	560111	5266409	Soil	6.4	0.54	48.8	98.7	
8/14/2008	11:31	Smelterville Wetlands	BH08SE033	560213	5266397	Sed	23	19.7	2390	1980	
8/14/2008	11:37	Smelterville Wetlands	BH08SE034	560266	5266453	Soil	10.2	13.6	2110	1330	
8/14/2008	11:40	Smelterville Wetlands	BH08SE035	560245	5266460	Sed	5.6	0.32	20.1	67	
8/14/2008	11:50	Smelterville Wetlands	BH08SE036	560244	5266429	Sed	7.4	0.3	19.8	65	
8/14/2008	11:55	Smelterville Wetlands	BH08SE037	560215	5266435	Sed	7.1	0.67	49.6	129	
8/14/2008	12:15	Smelterville Wetlands	BH08SE038	560208	5266480	Sed	7	3.5	15.7	844	
8/14/2008	12:18	Smelterville Wetlands	BH08SE039	560169	5266484	Sed	5.4	5.8	207.5	750.5	
8/14/2008	1:04	Smelterville Wetlands	BH08SE040	560261	5266511	Sed	10	7.85	922	1305	
8/14/2008	1:05	Smelterville Wetlands	BH08SE041	560193	5266510	Sed	5.5	1.3	211	363	
8/14/2008	1:20	Smelterville Wetlands	BH08SE042	560255	5266552	Soil	7.8	0.43	35.7	70.2	
8/14/2008	1:20	Smelterville Wetlands	BH08SE043	560255	5266552	Soil	6.6	0.37	37.7	63.5	Field dupe of BH08SE42
8/14/2008	1:22	Smelterville Wetlands	BH08SE044	560211	5266851	Sed	7.2	6.7	496	750	
8/14/2008	1:22	Smelterville Wetlands	BH08SE045	560211	5266851	Sed	8.8	5.3	503	686	Field dupe of BH08SE44
8/14/2008	1:40	Smelterville Wetlands	BH08SE046	560366	5266572	Sed	22	35.5	4700	2620	
8/14/2008	1:41	Smelterville Wetlands	BH08SE047	560336	5266500	Sed	36.4	39.2	9430	4350	
8/14/2008	1:55	Smelterville Wetlands	BH08SE048	560395	5266586	Soil	6.9	0.23	17.4	47	
8/14/2008	1:56	Smelterville Wetlands	BH08SE049	560401	5266563	Soil	5.6	0.39	30.3	59.9	

Collection Date	Collection Time	Location	Sample #	Easting	Northing	Matrix	As mg/kg dw	Cd mg/kg	Pb mg/kg	Zn mg/kg dw	Comments
8/15/2008	8:50	Smelterville Wetlands	BH08SE050	561584	5266514	Soil	12.9	4.4	575	456	
8/15/2008	8:50	Smelterville Wetlands	BH08SE051	561554	5266491	Soil	6.3	0.23	11.8	47.5	
8/15/2008	8:50	Smelterville Wetlands	BH08SE052	561584	5266514	Soil	11.9	3.9	475	392	Field dupe of BH08SE50
8/15/2008	9:05	Smelterville Wetlands	BH08SE053	561554	5266491	Soil	8.1	0.22	13.1	45.3	Field dupe of BH08SE51
8/15/2008	9:05	Smelterville Wetlands	BH08SE054	561714	5266490	Sed	12.9	5.9	1020	691	
8/15/2008	9:05	Smelterville Wetlands	BH08SE055	561714	5266490	Sed	19.4	6.9	1850	998	Field dupe of BH08SE54
8/15/2008	9:05	Smelterville Wetlands	BH08SE056	561771	5266452	Sed	4.7	152	235	4140	
8/15/2008	9:15	Smelterville Wetlands	BH08SE057	561485	5266482	Soil	7.3	0.3	18	42.2	UTM change from QAPP
8/15/2008	9:15	Smelterville Wetlands	BH08SE058	561481	5266520	Soil	7.3	1.8	51.7	428	
8/15/2008	9:37	Smelterville Wetlands	BH08SE059	561625	5266466	Sed	28.6	3.5	1600	1380	
8/15/2008	9:37	Smelterville Wetlands	BH08SE59-A	561654	5266429	Sed	47.2	15.95	4720	3060	
8/15/2008	10:37	Smelterville Wetlands	BH08SE064	560799	5266476	Soil	9	3.4	418	395	UTM change from QAPP
8/15/2008	11:15	Smelterville Wetlands	BH08SE065	560768	5266463	Soil	5	0.36	22.8	63.5	UTM change from QAPP
8/15/2008	11:15	Smelterville Wetlands	BH08SE066	560694	5266439	Soil	6.1	36.2	16.3	1850	
8/15/2008	11:20	Smelterville Wetlands	BH08SE067	560686	5266497	Soil	5.4	0.37	25	61.9	
8/15/2008	11:20	Smelterville Wetlands	BH08SE068	560629	5266476	Sed	7.2	0.49	65.9	82.2	
8/15/2008	11:50	Smelterville Wetlands	BH08SE069	560551	5266398	Sed	4.4	1.9	51.3	251	
8/15/2008	11:50	Smelterville Wetlands	BH08SE070	560667	5266540	Sed	7.2	1.6	175	591	
8/15/2008	11:52	Smelterville Wetlands	BH08SE071	560641	5266539	Sed	142	31.1	11100	5890	
8/15/2008	12:35	Smelterville Wetlands	BH08SE072	560641	5266562	Sed	8.5	0.5	165	114	
8/15/2008	12:36	Smelterville Wetlands	BH08SE073	560471	5266579	Sed	49.5	10.2	10200	1620	
8/15/2008	12:45	Smelterville Wetlands	BH08SE074	560511	5266448	Soil	10.1	47.6	765	2210	
8/15/2008	12:55	Smelterville Wetlands	BH08SE075	560526	5266443	Soil	5.9	0.22	13.8	42.4	
8/15/2008	12:55	Smelterville Wetlands	BH08SE076	560552	5266433	Soil	8.5	0.3	16.6	59	
8/15/2008	1:00	Smelterville Wetlands	BH08SE077	560555	5266448	Soil	5.7	3.6	308	259	
8/15/2008	1:00	Smelterville Wetlands	BH08SE078	560484	5266398	Soil	29	17.1	398	2120	
8/15/2008	1:05	Smelterville Wetlands	BH08SE079	560482	5266417	Soil	12.45	27.7	129.5	2710	
8/15/2008	1:05	Smelterville Wetlands	BH08SE080	560459	5266416	Soil	9.4	0.35	20.5	66.5	
8/15/2008	1:09	Smelterville Wetlands	BH08SE081	560439	5266448	Soil	12.2	6.5	462	792	
8/15/2008	1:09	Smelterville Wetlands	BH08SE082	560408	5266429	Sed	6.9	0.61	21.6	96.8	
8/15/2008	1:15	Smelterville Wetlands	BH08SE083	560455	5266430	Sed	7.5	2.1	113	479	UTM change from QAPP
8/15/2008	1:15	Smelterville Wetlands	BH08SE084	560409	5266479	Soil	5.4	0.75	83.5	105	
8/15/2008	1:23	Smelterville Wetlands	BH08SE085	560381	5266491	Soil	7.2	1.8	72	231	
8/15/2008	1:35	Smelterville Wetlands	BH08SE086	560390	5266585	Soil	8.8	0.54	42.2	91.5	
8/15/2008	1:35	Smelterville Wetlands	BH08SE087	560336	5266500	Soil	47.6	37	10300	5120	Very fine sediment
8/15/2008	1:48	Smelterville Wetlands	BH08SE088	560525	5266463	Sed	13.1	48.9	3460	3130	
8/15/2008	1:58	Smelterville Wetlands	BH08SE089	560530	5266474	Sed	4.7	0.52	41.2	143	
8/15/2008	1:58	Smelterville Wetlands	BH08SE090	560516	5266470	Sed	3.7	53.2	180	1880	
8/15/2008	2:07	Smelterville Wetlands	BH08SE091	560525	5266497	Sed	7.4	29.8	442	3220	
8/18/2008	9:35	Smelterville Wetlands	BH08SE092	560866	5266725	Sed	5.2	5.4	85.7	470	UTM change from QAPP
8/18/2008	9:35	Smelterville Wetlands	BH08SE093	560539	5266528	Soil	7	0.38	29.4	75.9	
8/18/2008	9:50	Smelterville Wetlands	BH08SE094	560498	5266527	Sed	8.4	12	583	3180	
8/18/2008	9:50	Smelterville Wetlands	BH08SE095	560463	5266525	Sed	6.3	2.3	155	522	
8/18/2008	10:20	Smelterville Wetlands	BH08SE096	560445	5266546	Sed	20.4	13	4780	2430	
8/18/2008	10:20	Smelterville Wetlands	BH08SE097	560460	5266482	Sed	11.5	22.4	1670	4600	
8/18/2008	10:40	Smelterville Wetlands	BH08SE098	560454	5266501	Sed	4.3	26.2	313	1220	

Table 2-2. Filtered water metals concentrations, Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2008.

Collection Date	Collection Time	Sample #	Easting	Northing	Matrix	Ca ug/l	Mg ug/l	Hg ug/l	Cd ug/l	As ug/l	Pb ug/l	Cu ug/l	Sb ug/l	Zn ug/l	Comments
8/13/2008	9:52	BH08W001	559568	5266302	Water			0.20 R[1]	1.0 U[2]	0.95 J[3]	3.5	5.0	2.0 U	89.4	
8/13/2008	10:05	BH08W002	559527	5266362	Water			0.20 R	0.84 J	1.0 U	0.66 J	2.1	2.0 U	771	
8/13/2008	10:11	BH08W003	559653	5266363	Water			0.20 R	1.0 U	8.0	1.9	7.2	1.5 J	234	
8/13/2008	11:13	BH08W004	559739	5266320	Water			0.20 R	1.2	1.0 U	1.3	0.77 J	2.0 U	1920	
8/13/2008	11:20	BH08W005	559836	5266405	Water			0.20 R	1.0 U	4.0	0.81 J	1.2 J	2.0 U	1650	
8/13/2008	11:26	BH08W006	559828	5266375	Water			0.20 R	1.1	9.6	2.2	6.4	1.1 J	1310	
8/13/2008	11:36	BH08W007	559810	5266290	Water			0.20 R	0.99 J	11.2	3.2	8.9	1.4 J	1390	
8/13/2008	11:52	BH08W008	559867	5266274	Water			0.20 R	1.0 U	8.7	1.0	1.2 J	2.0 U	119	
8/13/2008	11:53	BH08W009	559868	5266263	Water			0.20 R	1.0 U	8.9	0.81 J	1.4 J	2.0 U	96.5	
8/14/2008	9:40	BH08W010	560102	5266325	Water			0.20 R	18.3	7.7	4.7	1.2 J	2.0 U	6770	
8/14/2008	9:45	BH08W011	560043	5266326	Water			0.20 R	1.0 U	1.5	4.7	2.7	2.0 U	224	
8/14/2008	10:12	BH08W012	560066	5266326	Water			0.20 R	25.3	3.8	14.5	0.74 J	2.0 U	5450	
8/14/2008	10:15	BH08W013	560056	5266313	Water			0.20 R	8.3	0.67 J	14.6	1.2 J	2.0 U	7000	
8/14/2008	10:20	BH08W014	560077	5266322	Water			0.20 R	13.6	7.9	8.9	0.72 J	1.1 J	5620	
8/14/2008	10:25	BH08W015	560195	5266397	Water			0.20 R	1.0 U	7.2	1.1	1.3 J	2.0 U	96.2	
8/14/2008	10:55	BH08W016	560151	5266390	Water			0.20 R	1.0 U	5.2	1.4	1.0 J	2.0 U	69.4	
8/14/2008	11:20	BH08W017	560243	5266485	Water			0.20 R	1.0 U	2.0	2.2	2.0 U	2.0 U	70.9	
8/14/2008	11:31	BH08W018	560369	5266423	Water			0.20 R	0.90 J	4.2	8.0	2.0 U	20.9	261	
8/14/2008	11:35	BH08W019	560319	5266415	Water			0.20 R	0.51 J	3.2	1.1	2.0 U	0.76 J	1310	
8/14/2008	11:56	BH08W020	560352	5266547	Water			0.20 R	1.0 U	4.2	17.8	1.6 J	0.87 J	166	
8/14/2008	12:00	BH08W021	560320	5266545	Water	15000	5550	0.20 R	0.50 J	3.1	4.3	1.9 J	1.2 J	236	
8/14/2008	12:10	BH08W022	560325	5266564	Water	15000	5480	0.20 R	0.56 J	0.69 J	5.8	2.0 U	1.2 J	278	
8/14/2008	12:20	BH08W023	560313	5266504	Water	15200	5630		1.0 U	3.9	4.7	2.0 U	1.4 J	200	
8/14/2008	1:00	BH08W024	560434	5266465	Water	14200	5290	0.20 R	0.92 J	2.9	2.2	2.0 U	1.1 J	446	
8/14/2008	1:00	BH08W025	560434	5266465	Water	15000	5570	0.20 R	1.2	0.50 J	3.4	1.4 J	1.1 J	464	Field dupe of 24
8/14/2008	1:02	BH08W026	560433	5266449	Water	15200	5600	0.20 U	1.0	3.3	3.5	1.2 J	1.2 J	438	
8/15/2008	9:00	BH08W027	561639	5266442	Water	20700	7140	0.20 R	0.92 J	4.6	5.1	0.53	3.6	513	
8/15/2008	9:00	BH08W028	561708	5266464	Water	20500	7140	0.20 R	1.0	10.8	4.5	0.54	3.5	548	
8/15/2008	9:05	BH08W029	561639	5266442	Water	20900	7260	0.20 R	1.0	0.92 J	5.1	2.0 U	3.6	528	Field dupe of 27
8/15/2008	9:05	BH08W030	561708	5266464	Water	21000	7180	0.20 U	1.1	4.2	4.9	2.0 U	3.5	567	Field dupe of 28
8/15/2008	9:20	BH08W031	561715	5266490	Water	21200 R	7040	0.20	3.4 J	3.8 U	0.67	2.0	2.9	788	
8/15/2008	9:20	BH08W032	561668	5266442	Water	20700 R	7140	0.20 J	1.0	0.76 U	5.5	2.0	3.6	537	
8/15/2008	9:55	BH08W033	561715	5266490	Water	19900 R	6610	0.20	3.0 J	4.4 U	0.50	2.0	2.4	671	Field dupe of 31
8/15/2008	9:55	BH08W034	561776	5266430	Water	17500 R	6210 U	0.20	1.0	4.4 J	2.2	0.88	3.3	132	
8/15/2008	10:10	BH08W035	561731	5266415	Water	20200 R	7100 J	0.20 J	0.86	0.79 U	6.4	2.0	3.6	552	UTM change from QAPP
8/15/2008	10:10	BH08W036	561702	5266483	Water	20800 R	7190	0.20	1.2	3.8 U	5.4	2.0	3.4	530	UTM change from QAPP
8/15/2008	10:25	BH08W037	561773	5266446	Water	19400 R	6960 J	0.20 J	0.54	0.86	5.2	0.59	3.0 U	338 J	
8/15/2008	10:25	BH08W038	561718	5266435	Water	13000	4530 J	0.20 J	0.69	4.1	3.7	1.3	2.3	347	
8/15/2008	10:35	BH08W039	561752	5266422	Water	18400 R	6450 J	0.20	0.82	4.2 J	4.2	0.98	2.9	522	
8/15/2008	10:35	BH08W040	561661	5266435	Water	20400 R	7010 J	0.20	0.89	3.8 J	5.2	0.83	3.5	468	
8/15/2008	11:15	BH08W041	561607	5266440	Water	19700 R	6810 J	0.20	0.79	4.4 U	4.7	2.0	3.4	399 J	
8/15/2008	11:15	BH08W042	560780	5266482	Water	10000 R	4600	0.20 U	4.7 J	1.0 J	0.54 U	0.71	2.0	1020	UTM change from QAPP
8/15/2008	11:30	BH08W043	560775	526660	Water	20300 R	6970	0.20	7.0	2.4	2.6 UJ	0.64	1.9 U	861 J	UTM change from QAPP

Collection Date	Collection Time	Sample #	Easting	Northing	Matrix	Ca ug/l	Mg ug/l	Hg ug/l	Cd ug/l	As ug/l	Pb ug/l	Cu ug/l	Sb ug/l	Zn ug/l	Comments
8/15/2008	11:48	BH08W044	560808	5266495		14700 U	5500	0.20 U	6.2 U	3.8	1.0	2.0	0.98 U	729 J	Potential gw influence
8/15/2008	11:48	BH08W045	560652	5266604	Water	17200	6150	0.20	1.0	4.2 J	32.0 J	0.57	3.6 U	51.0	
8/15/2008	11:52	BH08W046	560685	5266560	Water	19400	6520	0.20	5.2	3.9	1.6 U	0.53 U	1.6 U	686 U	

[1]"R" is a qualifier placed on the result by the laboratory signifying that no usable result was acquired for the analyte.
[2]"U" is a qualifier placed on the result by the laboratory signifying that the analyte was not detected above the reported value.
[3]"J" is a qualifier placed on the result by the laboratory signifying that the reported value is an estimate.

Table 2-3. Number of samples and metals concentrations in sediment samples collected from Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2008.

	N[a]	Mean	Minimum	Maximum	Standard deviation
Arsenic	117	26.1	3.7	218	35.8
Cadmium	117	17.5	0.22	229	31.1
Lead	117	2,001	11.8	32,100	3,859
Zinc	117	1,808	42.2	25,300	2,718

[a]Includes field duplicate samples.

Table 2-4. Number of samples and metals concentrations in sediment samples collected from the South Fork Coeur d'Alene River, OU-2, Coeur d'Alene Basin, Idaho, 2008.

	N[a]	Mean	Minimum	Maximum	Standard deviation
Arsenic	26	32.2	9.5	85.0	16.3
Cadmium	26	10.9	2.9	65.3	12.3
Lead	26	3,040	455	28,700	5,355
Zinc	26	1,719	893	5,420	957

[a]Includes field duplicate samples.

Table 2-5. Number of samples and metals concentrations in sediment samples collected from the Central Impoundment Area, OU-2, Coeur d'Alene Basin, Idaho, 2008.

	N[a]	Mean	Minimum	Maximum	Standard deviation
Arsenic	21	7.8	6.1	11.2	1.5
Cadmium	21	0.40	0.18	1.2	0.23
Lead	21	48.9	11.2	175	35.5
Zinc	21	234	47.1	1,245	305

[a]Includes field duplicate samples.

Table 2-6. Number of samples and metals concentrations in sediment samples collected from the east swamp, OU-2, Coeur d'Alene Basin, Idaho, 2008.

	N[a]	Mean	Minimum	Maximum	Standard deviation
Arsenic	21	52.09	6.5	112	30.0
Cadmium	21	17.6	1.8	47	11.8
Lead	21	10,338	310	72,300	19,873
Zinc	21	1,474	134	3,570	1,076

[a]Includes field duplicate samples.

Table 2-7. Pierson's Product Moment Correlations (r^2) for metals in sediment samples collected from Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2008. Values in bold identify significant correlations (P <0.05).

	Arsenic	**Cadmium**	**Lead**	**Zinc**
Arsenic		**0.18**	**0.49**	**0.34**
Cadmium	**0.18**		**0.69**	**0.85**
Lead	**0.49**	**0.69**		**0.90**
Zinc	**0.34**	**0.85**	**0.90**	

Table 2-8. Pierson's Product Moment Correlations (r^2) for metals in sediment samples collected from the South Fork Coeur d'Alene River, OU-2, Coeur d'Alene Basin, Idaho, 2008. Values in bold identify significant correlations (P <0.05).

	Arsenic	**Cadmium**	**Lead**	**Zinc**
Arsenic		0.19	0.21	0.20
Cadmium	0.19		0.21	**0.48**
Lead	0.21	0.21		**0.78**
Zinc	0.20	**0.48**	**0.78**	

Table 2-9. Pierson's Product Moment Correlations (r^2) for metals in soil samples collected from the Central Impoundment Area cap, OU-2, Coeur d'Alene Basin, Idaho, 2008. Values in bold identify significant correlations (P <0.05).

	Arsenic	**Cadmium**	**Lead**	**Zinc**
Arsenic		0.39	**0.54**	0.37
Cadmium	0.39		**0.44**	**0.83**
Lead	**0.54**	**0.44**		**0.63**
Zinc	0.37	**0.83**	**0.63**	

Table 2-10. Pierson's Product Moment Correlations (r^2) for metals in soil samples collected from the east swamp, Page wetland complex, OU-2, Coeur d'Alene Basin, Idaho, 2008. Values in bold identify significant correlations (P <0.05).

	Arsenic	**Cadmium**	**Lead**	**Zinc**
Arsenic		-0.05	**0.57**	**0.46**
Cadmium	-0.05		0.03	**0.45**
Lead	**0.57**	0.03		**0.71**
Zinc	**0.46**	**0.45**	**0.71**	

Table 2-11. Number of samples and metals concentrations (ug/L) in filtered water samples collected from Smelterville Flats wetlands, OU-2, Coeur d'Alene Basin, Idaho, 2008.

	N	Mean	Minimum	Maximum	Standard deviation
Mercury[a]	41				
Cadmium	42	2.79	0.50	25.3	4.85
Arsenic	42	4.05	0.50	11.2	2.83
Lead	42	4.77	0.50	32	5.53
Copper	42	1.90	0.53	8.9	1.71
Antimony	42	2.60	0.76	20.9	2.90
Zinc	42	1032	51	7000	1682

[a]Not detected.

Table 2-12. Acute (AWQC) and chronic (CWQC) water quality criteria (ug/L) (USEPA, 2009) compared to dissolved metals concentrations in samples collected from Smelterville Flats wetlands, OU-2, Coeur d'Alene Basin, Idaho, 2008.

	AWQC (ug/L)	CWQC (ug/L)	Percent samples above AWQC	Percent samples above CWQC
Arsenic	340	150	0	0
Cadmium	2.0	0.25	24	100
Copper	13	9.0	0	0
Lead	65	2.5	0	67
Zinc	120	120	93	93

Figure 2-1. Smelterville Flats, South Fork Coeur d'Alene River and Page east swamp 0-6” soil and sediment lead concentrations (mg/kg), Coeur d'Alene Basin, Idaho, 2008. Outline of the Smelterville Flats remediation area hand-drawn from TerraGraphics and Ralston (2005).

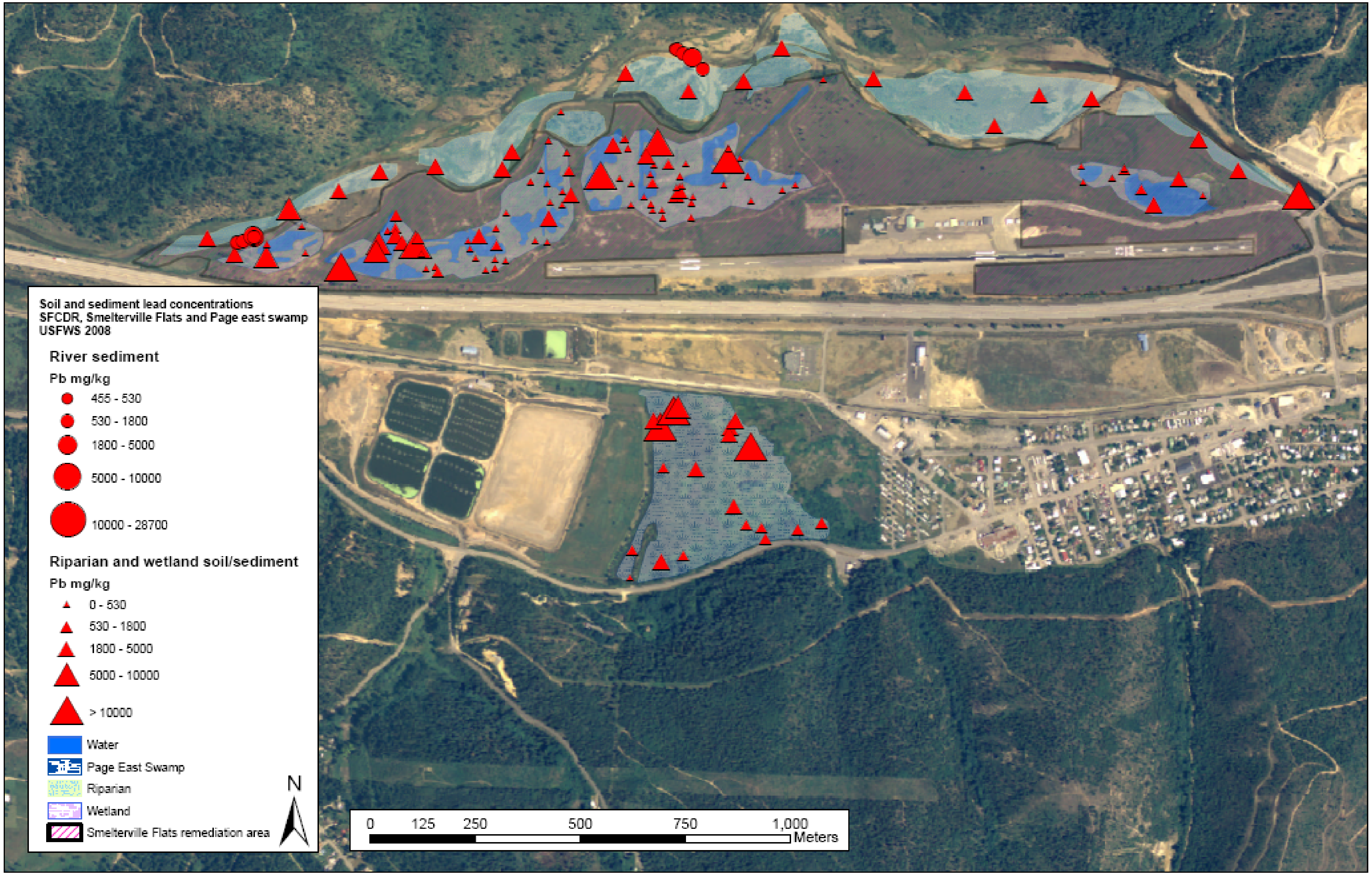


Figure 2-2. Central Impoundment Area and South Fork Coeur d'Alene River 0-6” soil and sediment lead concentrations (mg/kg), Coeur d'Alene Basin, Idaho, 2008.

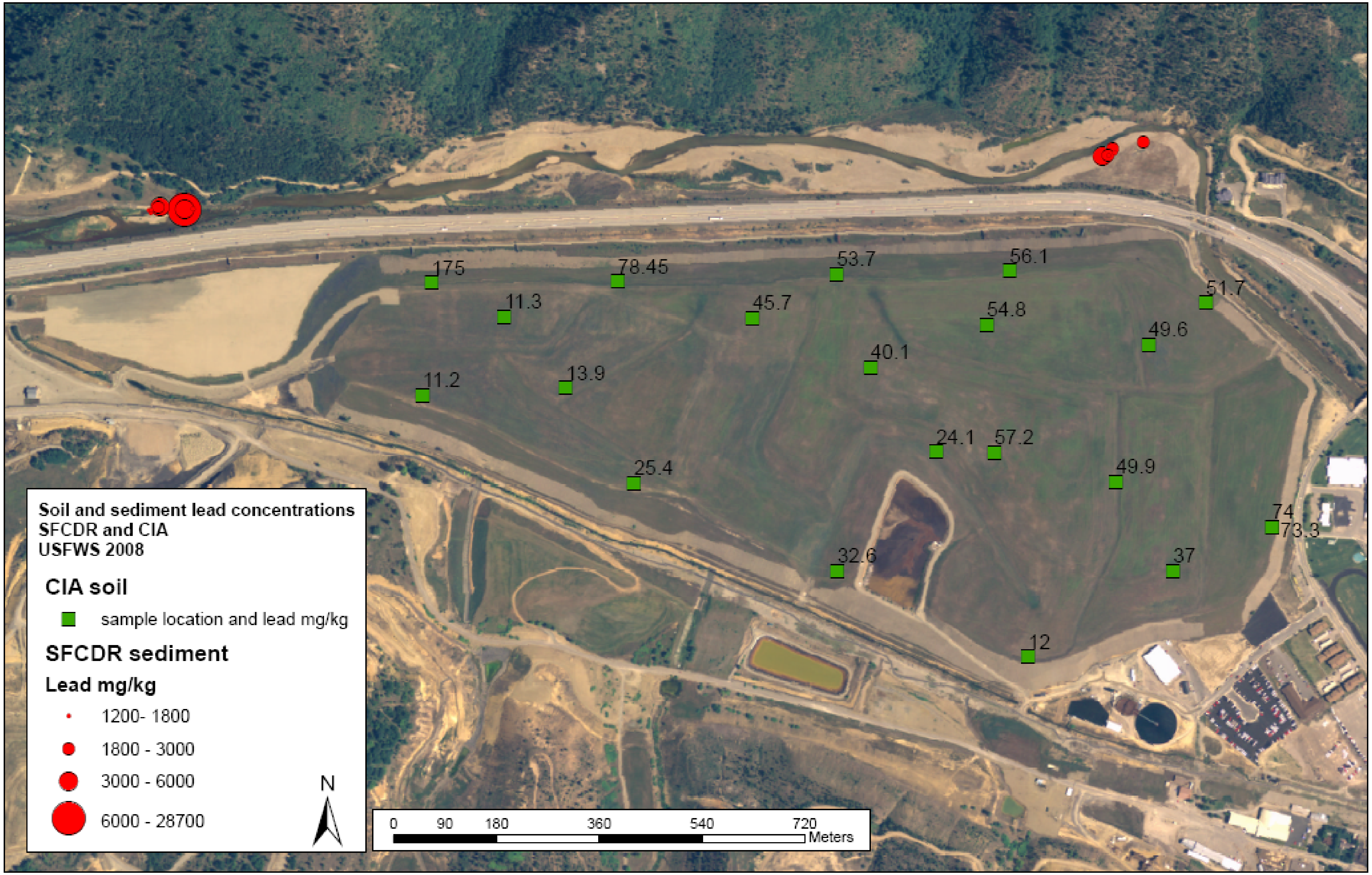
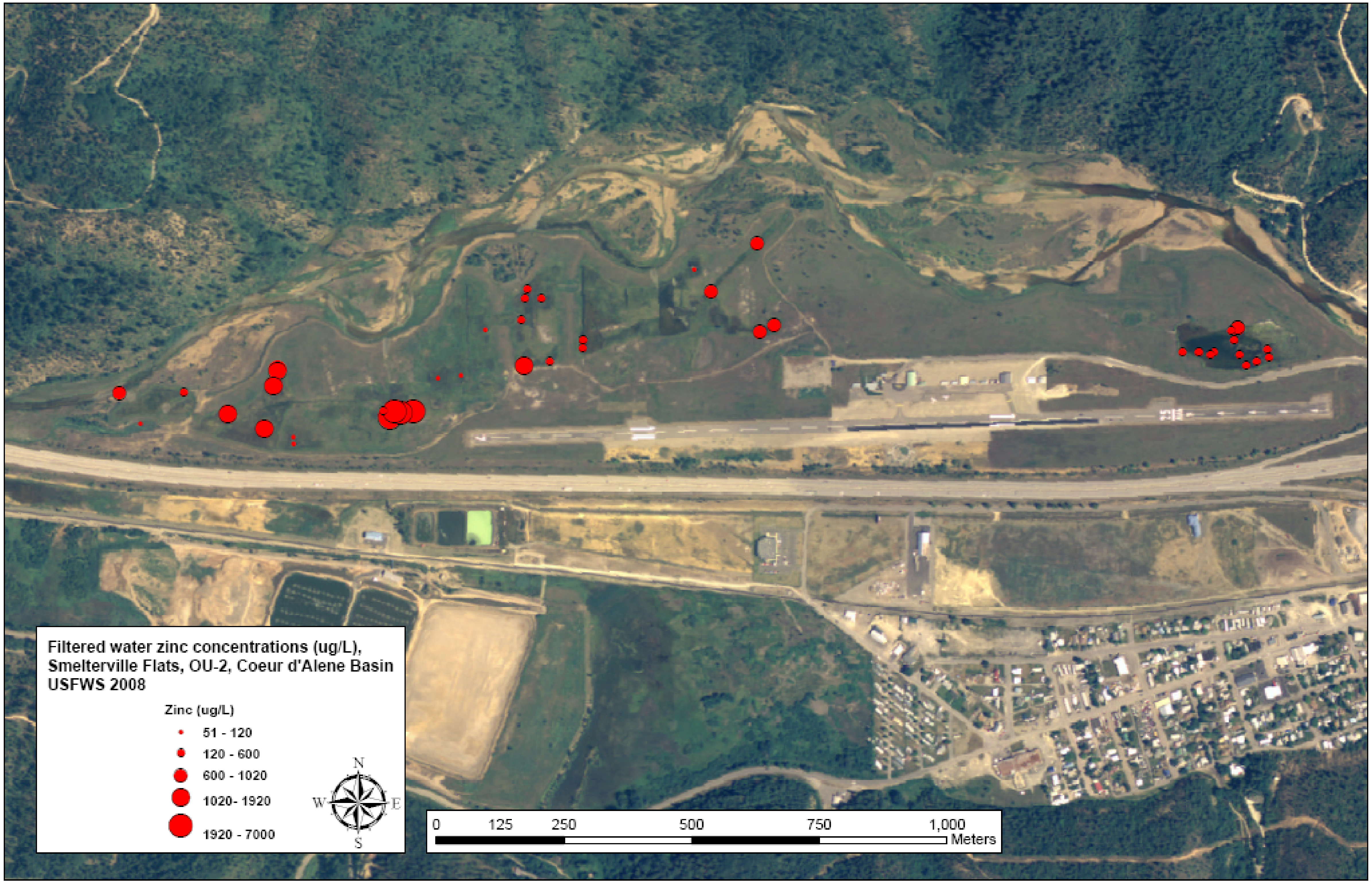


Figure 2-3. Smelterville Flats, dissolved zinc concentrations (ug/L), Coeur d'Alene Basin, Idaho, 2008.



3.0 Waterfowl blood analyses

The Coeur d'Alene Basin is contaminated with elevated lead and other toxic metals from historic mining activities. Smelterville Flats is located within the flood plain of the SFCDR in the west end of OU-2 (figure 3-1). Since remediation of the Smelterville Flats area, a succession of flora has occurred, as well as the formation of small wetland habitats. This area is now being used by various wildlife, including ungulates, small mammals, waterfowl, songbirds, reptiles, and amphibians.

Phase I of the Comprehensive Cleanup Plan for OU-2 includes the evaluation of remedial actions on ecological conditions at the site. Biological resource monitoring under the EMP was designed to aid in this evaluation and relate the effectiveness of the overall Phase I remedy for OU-2 to goals and objectives identified in the OU-2 Record of Decision (USEPA, 1992). The ROD for OU-2 recognizes waterfowl in palustrine environments as key indicators of change (USEPA 2006). Waterfowl were selected for three purposes: 1) palustrine habitats supporting waterfowl use have developed within Smelterville Flats since remedial actions, 2) data exists on waterfowl exposure at other sites in the Basin for comparison, and 3) waterfowl data can be compared to known threshold effect levels that can be easily interpreted and provide a reliable comparison to future studies (Pain, 1996).

Previous studies evaluated waterfowl exposure to metals of concern within OU-3 and the Page Ponds complex within OU-2 (Mullins and Burch, 1993; Burch et al., 1996; Audet et al., 1999; USFWS, 2005). This project constituted the first evaluation of waterfowl exposure to metals within the remediated flooplain area of OU-2 (Smelterville Flats). We use blood lead concentrations in waterfowl using Smelterville Flats wetlands as an indicator of exposure and compare the success of remedial activities conducted at Smelterville Flats with exposure at remediated and unremediated areas within OU-3 (Thompson Marsh, Campbell Marsh and Schlepp conservation easement area[4]). This evaluation also helps establish a post-remediation baseline for analyzing temporal trends in exposure within OU-2.

3.1 Methods

Service personnel trapped waterfowl at three locations at Smelterville Flats in June and July, 2008 (figure 3-1). Mallards were targeted due to their prevalence within the Basin and for comparisons with previous results. Blood samples and physical data were also collected from incidentally captured wood ducks.

Ducks were captured in baited walk-in traps following methods described in UCFWO SOP #1019.3742. Blood samples were collected as described in UCFWO SOP #1020.1009. Additional data collected from captured waterfowl followed UCFWO SOP #1019.3741. Waterfowl were fitted with aluminum toe tags for future identification.

Samples were labeled and handled following UCFWO SOP #1019.3701 and immediately placed on wet or blue ice. Samples were transported to the UCFWO and stored in a locked facility at -20º Celsius until being shipped on dry ice to USEPA's Manchester Laboratory (Port Orchard,

[4] Complete results from OU-3 samples are provided by USFWS, 2009.

WA) for lead analysis. All results are reported as µg/g on a wet weight (ww) basis. Data were analyzed for differences among Basin sites using nonparametric Kruskall-Wallis tests. Tests were considered statistically significant at $\alpha \leq 0.05$.

3.2 Results

Five individual ducks were captured and bled at Smelterville Flats, including 4 wood ducks and one mallard. Mean blood lead concentrations in Smelterville Flats were 0.695 ug/g for wood duck and 1.86 µg/g for mallard. Because of the small sample size, results were combined between species for comparison with OU-3 sites. Blood lead concentrations in samples exceeded suggested toxicity thresholds for waterfowl (table 3-1).

3.3 Discussion

Ingestion of lead-contaminated sediment has been shown to be the cause of the majority of waterfowl mortality within the Basin (Beyer et al., 2000; Stratus, 2000; USEPA, 2002). No remedial action goal for the protection of wildlife was associated with remediation of the Smelterville Flats area. However, 34% (31/90) of sediment samples collected from Smelterville Flats wetlands in 2008 exceeded the ecological remedial action goal of 530 mg/kg for OU-3, which is the suggested toxicity threshold for the protection of tundra swans (Beyer et al., 2000)[5]. Furthermore, sediment lead concentrations in several samples were above remediation goals. For example, 17% (15/90) were above the remedial goal for lead (3,000 mg/kg), 1% (9/90) above 5,000 mg/kg, 5 above 10,000 mg/kg, and one at a concentration of 32,100 mg/kg (see Section 2.0). It is unclear if these elevated sediment concentrations are remnants from source material onsite or from ongoing impacts (e.g., elevated metals concentrations from upstream surface sources or groundwater). Regardless, these sediment concentrations, in conjunction with blood lead data collected during this evaluation, suggest that waterfowl utilizing wetlands within the remediated area of Smelterville Flats continue to be at risk from exposure to lead-contaminated sediments.

The mean waterfowl blood lead concentration at Smelterville Flats was not statistically different from those at OU-3 unremediated and remediated sites ($p = 0.2520$). However, the mean of blood lead concentrations from Smelterville Flats samples was lower than that from samples collected from the OU-3 unremediated area (Thompson Marsh). This suggests success in reducing waterfowl exposure to lead-contaminated soil in the Basin. However, the mean was higher than that from the OU-3 remediated area (Schlepp conservation easement), which included the remedial action goal of 530 mg/kg for lead for the protection of waterfowl, and above the toxicity threshold suggested to cause severe clinical poisoning in waterfowl (figure 3-2). The remedial action goal for the site, remedial design, integrity of the remedial action (e.g., integrity of the cap) or recontamination of the site may all be factors affecting ongoing waterfowl exposure to lead. All of these potential factors should be evaluated in determining the effectiveness of the action and evaluating future actions. Future waterfowl blood-lead monitoring at the site will help evaluate long-term trends in exposure and help quantify success of any additional remedial activities conducted in this portion of OU-2.

---

[5] The OU-3 remedial action goal of 530 mg/kg was established after the Phase I remedial action at Smelterville Flats was completed.

Since remediation at Smelterville Flats, habitat structure of the area has increased, along with the formation of several wetlands, creating an attractive area for wildlife. Given that metals within the remediated area appear to continue to be bioavailable at levels shown to cause injury to wildlife, improvements in habitat may be increasing wildlife injury due to increased use. This should be taken into account when evaluating the need for future remedial actions within OU-2.

Table 3-1. Blood lead concentrations and associated data from ducks captured at Smelterville Flats, Coeur d'Alene Basin, OU-2 2008.

Date	Location	Sample ID	Species	Age	Sex	Weight (g)	Blood Pb (mg/kg ww)	Toe Tag #	Comments
7/2/2008	Smelterville Flats	BM08B022	wood duck	adult	M	700	0.24[1]	2925	
7/2/2008	Smelterville Flats	BM08B023	wood duck	adult	M	500	0.45[1]	1358	
7/3/2008	Smelterville Flats	BM08B024	wood duck	adult	F	500	1.86[2]	1172	
7/3/2008	Smelterville Flats	BM08B025	mallard	adult	F	800	1.56[2]	1173	
7/3/2008	Smelterville Flats	BM08B026	mallard	adult	F	800	1.48[2]		field dupe of BM08B025
7/9/2008	Smelterville Flats	BM08B028	wood duck	adult	M	550	0.23[1]	2719	
							0.24[1]		lab dupe of BH08B028

Species	Sex	N	Weight (g)	Mean Blood Pb (mg/kg ww)
wood duck	**M**	**3**	**583**	**0.307**[1]
wood duck	**F**	**1**	**500**	**1.86**[2]
mallard	**F**	**1**	**800**	**1.52**[2]

[1]Above suggested threshold of subclinical lead poisoning (Pain, 1996).
[2]Above suggested threshold of severe clinical poisoning (Pain, 1996).

Figure 3-1. Waterfowl trapping sites, Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2008.

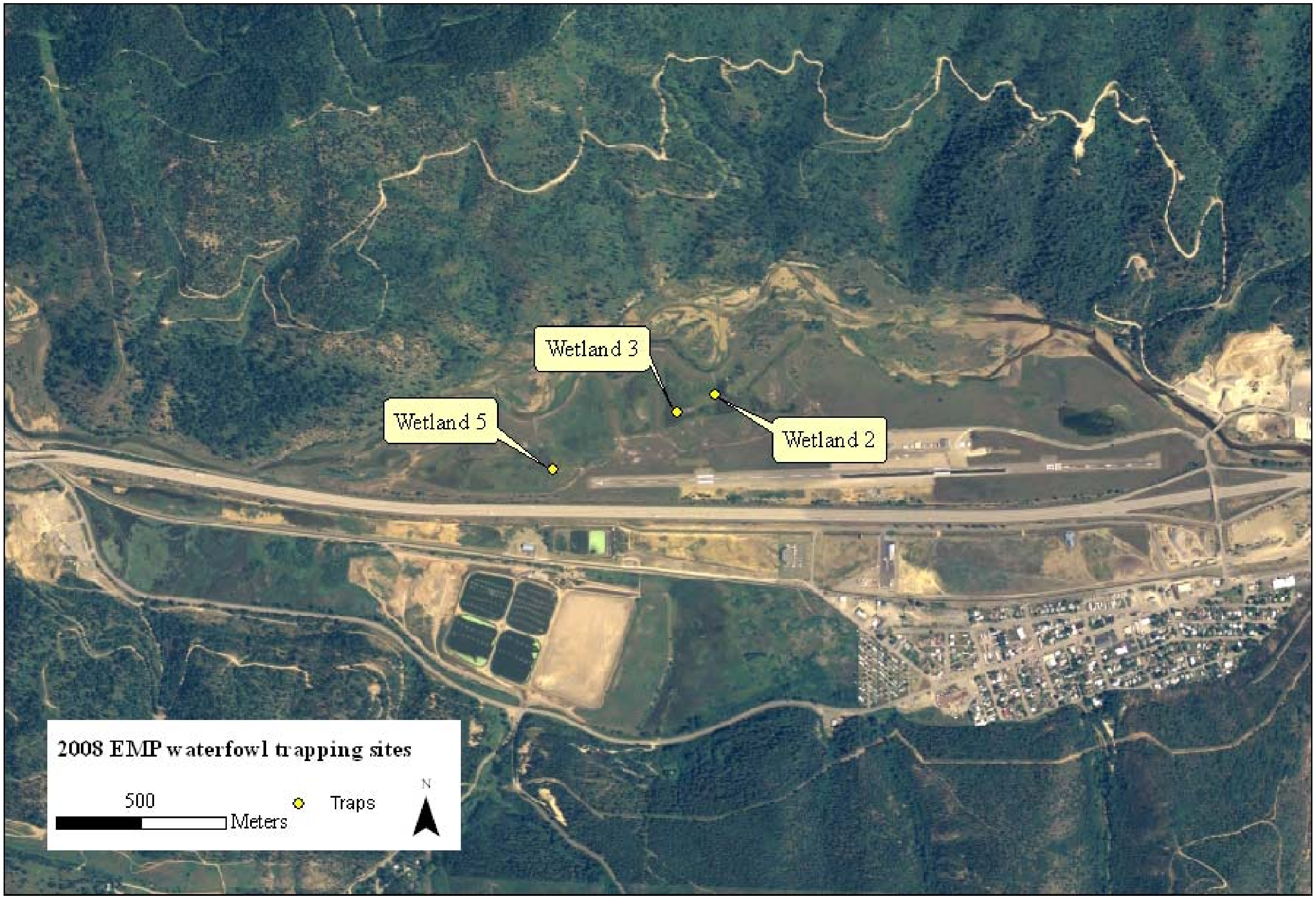
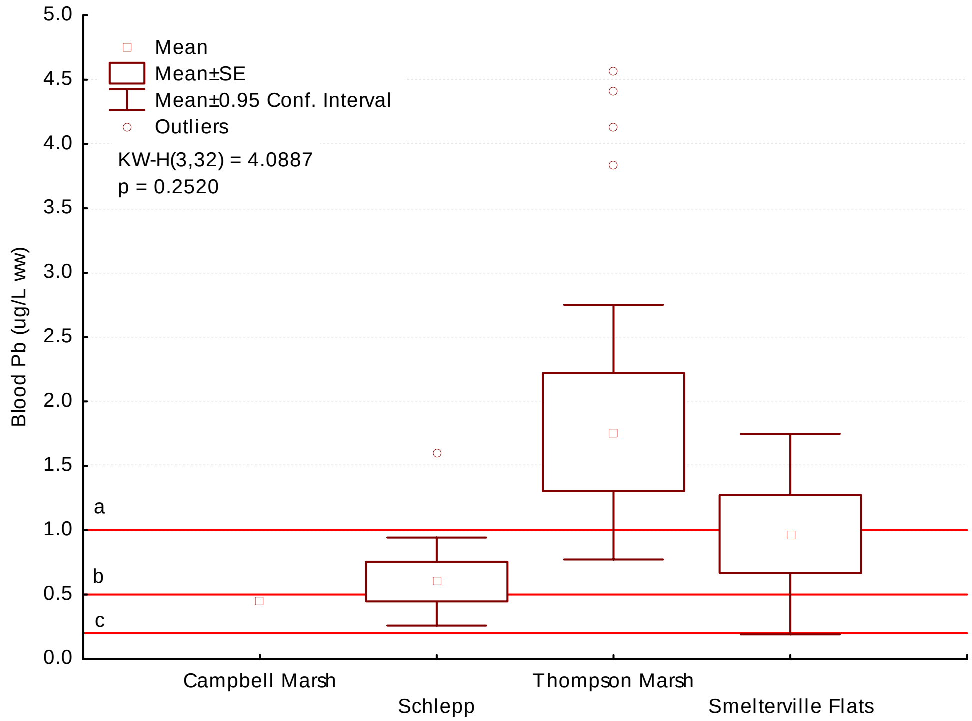


Figure 3-2. Waterfowl blood lead concentrations, OU-2 and OU-3, Coeur d'Alene Basin, Idaho, 2008.



[a]Suggested severe clinical toxicity for waterfowl (Pain, 1996).
[b]Suggested clinical toxicity threshold for waterfowl (Pain, 1996).
[c]Suggested subclinical toxicity threshold for waterfowl (Pain, 1996).

4.0 Small Mammal Diversity and Abundance

Small mammal species are found in abundance within a variety of habitats and are routinely used as sentinels of environmental contamination (Talmage and Walton, 1991; Smith et al., 2002; Reynolds et al., 2006). Their ubiquitous distribution, large populations, and small home range make them relatively easy to capture and study at the population and community level (Smith et al., 2002; Reynolds et al., 2006; Schwarz, 2003). Short life spans, high reproductive rates and close association with the soil makes small mammals ideal receptors of interest with which to evaluate bioavailability of contaminants of concern: each new generation reflects current amounts of contaminant in the environment (Talmage and Walton, 1991).

Previous studies demonstrated elevated exposure to metals and related effects in small mammals using OU-2 habitats (Herman, 1975; USFWS, 2002; USFWS, 2005). Remedial activities within OU-2 addressed soil contamination in a number of these areas, including Smelterville Flats and the Central Impoundment Area (CIA). The OU-2 Record of Decision (ROD) recognizes the assessment of wildlife exposure and effects to mining-related contaminants of concern essential in evaluating the success of OU-2 Phase I remedial activities as they pertain to the protection of the environment (USEPA, 1992). For the purpose of monitoring and evaluating Phase 1 remedy with respect to meeting ROD goals, the Environmental Monitoring Program for OU-2 (EMP) identified small mammals as representative receptors of continued ecological exposure to contaminants of concern in terrestrial habitats.

Exposure pathways of small mammals to contaminants of concern within OU-2 include ingestion of contaminated food items and the inadvertent ingestion of soil while foraging, digging, or grooming (Talmage and Walton, 1991; Reynolds et al., 2006; Smith et al., 2002). Small mammals living in areas of high metal concentrations in soil typically contain elevated levels of metals in body tissues (Ma et al., 1991; Ma, 1994; Clark et al., 1992; Reynolds et al., 2006; Schwarz, 2003). Elevated small mammal metal exposure has been linked to depressed hematocrit and hemoglobin (Siewicki et al., 1983), jaw defects, cleft palates, club feet, pulmonary hyperplasia (Cook and Johnson, 1996), and severe testicular and renal injury (Ma, 1996; Swiergosz et al., 1998). Small mammal population level effects due to metals exposure include reduced reproduction and juvenile survival (Shore and Douben, 1994), and decreased population density and species diversity (Herman 1975; Read et al., 1993; Dmowski et al., 1998).

Service personnel sampled small mammal populations at Smelterville Flats and the CIA in 2008 as part of the EMP in an ongoing effort to evaluate the success of remedial actions in reducing the bioavailability of metals in soils within OU-2. Evaluations included measurements of relative abundance and species diversity, as well as metal residue analyses in individual small mammals. Sampling on the CIA was specifically intended to help determine wildlife use of available habitat at the site and potential exposure to contaminants of concern given the design of the repository. We present results of the relative abundance and species diversity here. Metal residue analyses are discussed in Section 5.

4.1 Methods

Victor snap-traps (Woodstream Corp., Lititz, PA) were used to conduct small mammals on Smelterville Flats and the CIA. Sampling followed UCFWO SOP #1019.3761. Surveys on Smelterville Flats consisted of placing 100 snap-traps at 10-meter intervals in one 100 x 100-meter grid array within upland habitat, and 50 snap-traps at 10-meter intervals along a 500-meter transect within a riparian edge of the South Fork Coeur d'Alene River (SFCDR) (Figure 4-1). The sampling locations for Smelterville Flats were used in previous studies conducted within OU-2 (USFWS, 2001). Traps were baited with a mixture of rolled oats and peanut butter, and were checked and re-baited daily. Data collected included location (e.g., upland or riparian), species, weight, sex, age, and reproductive status. Surveys were initially conducted on Smelterville Flats from May 19 to May 23. However, only one small mammal was captured during that period. To obtain a better estimate of small mammal abundance at the site, trapping was extended for another twelve days. This 12-day trapping effort utilized 29 snap-traps within the upland grid array and 28 along the riparian edge.

Trapping on the CIA was conducted using 50 snap-traps at 10-meter intervals in three 100 x 50-meter grid arrays. Arrays were distributed equidistance apart for maximum coverage of the CIA (Figure 4-1). Surveys were conducted from May 19 to May 23. Survey protocols and data collected followed those used at Smelterville Flats.

Relative small mammal abundance was calculated as the total number of individuals captured per 100 trap nights (tn) (e.g., (individuals captured)/(number of traps x number of trap nights) x 100) (Lancia et al., 1994). We used the Shannon-Weiner index to evaluate species diversity differences between sites and for comparisons with previous study results.

4.2 Results

The trapping effort at Smelterville Flats resulted in a total of 1,434 trap nights. Nine deer mice (*Peromyscus maniculatus*) and 17 shrews (*Sorex* spp.) were collected from Smelterville Flats, representing 2 species in 2 genera. Total relative abundance was 1.8/100tn. Fifty percent of the adult population was female. Thirty-eight percent of the female population was reproductively active (pregnant and/or lactating). Juveniles comprised 15% of all small mammals captured from Smelterville Flats (table 4-1). Table 4-2 includes historic site data for reference comparisons.

The trapping effort on the CIA resulted in a total of 750 trap nights. Six deer mice and 5 voles (*Microtus* spp.) were collected from the CIA, representing 2 species in 2 genera. Total relative abundance was 1.4/100tn. Twenty-seven percent of the adult population was female. Thirty-three percent of the female population was reproductively active. Juveniles represented 27% of the total small mammal population captured from the CIA (table 4-1).

The Shannon-Weiner species diversity index was higher at the CIA (H_1 = 0.994) than Smelterville Flats (H_1 = 0.931). The CIA was nearer equiprobability (D_1 = 0.006) and had a higher community species evenness index (99.4) than Smelterville Flats (D_1 = 0.069; 93.05) (table 4-3).

4.3 Discussion

Small mammals are utilizing available habitat on the CIA and within Smelterville Flats. Population densities appeared lower and species diversity higher in 2008 compared to 2001 (USFWS, 2002). Fluctuations in small mammal population relative abundance, as well as species composition, have been well documented (Krebs, 1996; Getz et al., 2001; Getz et al., 2005; Gillespie et al., 2008). Decreased population abundance or diversity has been correlated with metal contamination in soil (Dmowski et al., 1995; Read et al., 1993; Herman, 1975), and small mammals appear to be incurring elevated exposures to metals of concern in OU-2 (USFWS, 2005; USFWS, 2002; Herman, 1975; see Section 5.0). However, complex interactions between a number of factors including weather, plant production, food supply, vegetative cover, predation, and competition (Gillespie et al., 2008) all have the potential to influence small mammal communities occupying OU-2 habitats. Some or all of these factors may be regulating fluctuations we observed, making correlations with metals exposure difficult.

The relative small mammal density at Smelterville Flats in 2008 was 6 times lower than observed in 2001 (11/100tn; table 4-2). Conversely, species diversity and community evenness were higher in 2008 relative to 2001 (table 4-3). Differences observed in the small mammal community on Smelterville Flats between 2008 and 2001 can be attributed to the composition of species observed in the community. In 2001, deer mice represented 67% of the total small mammals captured from Smelterville Flats (table 4-2) and only 35% of the small mammals captured in 2008 (table 4-1). The result is that, even though species richness (number of different species present in a population) in 2001 was slightly higher than in 2008, the predominance of deer mice in the population in 2001 lead to a decrease in the community diversity and evenness (relative abundance of the different species within the community) indices (Getz et al., 2005). Small mammal populations can fluctuate with variations in environmental conditions (Krebs, 1996; Getz et al., 2001; Getz et al., 2005; Gillespie et al., 2008). However, species with different life histories will exhibit different patterns of population growth under similar environmental conditions (Wilson et al., 2004). As a result, fluctuations in the population structure of the individual species will affect the community structure. This was evidenced by the decrease in deer mice population numbers on Smelterville Flats in 2008.

The low small mammal relative abundance observed on Smelterville Flats in 2008 could be attributed to weather conditions at the time of sampling. A flood event occurred during small mammal collection in 2008, covering a large portion of the grid array with approximately 3 to 6 inches of water, potentially reducing small mammal movement and our corresponding ability to trap them. Flooding and weather patterns may have also contributed to a delay in vegetative growth observed on site, affecting the quality and quantity of available food and protective ground cover during a time of year when small mammals are actively breeding and raising young (Foresman, 2001; O'Connell, 2006). These events both have the potential to negatively affect estimations of small mammal population densities (Krebs, 1996; Getz et al., 2001).

Two species in 2 genera were captured on the CIA in 2008. Because of the equal distribution of both species in the community, species diversity and community evenness were high relative to Smelterville Flats. The presence of small mammals on the CIA was not unanticipated given the vegetative composition of the habitat available. As herbivores, voles characteristically prefer arid grasslands, mountain meadows, and grassy sagebrush habitats (O'Connell, 2006). Habitat characteristics of deer mice include dry grasslands to mountain and subalpine forests. Both species of small mammals are widely distributed throughout northern Idaho ecosystems (Foresman, 2001), and positive correlations exist been between vegetative ground cover and small mammal population densities (Getz et al., 2005; Johnston and Anthony, 2006). The vegetative ground cover on the CIA is relatively continuous and composed primarily of several grass and legume species (Service, personal observation), providing protective cover from predators and high quality small mammal food sources.

Periodic fluctuations in small mammal communities are not unusual, but potential causes, such as local metals contamination, continue to be poorly understood (Oli and Dobson, 2000). Dmowski et al. (1995) documented reductions in population densities in all small mammal species observed using a site polluted with Cd and Pb, even though species richness remained high. Read et al. (1993) found small mammal communities at a Pb and Zn smelter had the lowest abundance and species richness in areas with the greatest soil concentrations of Cd, Copper (Cu), Pb and Zn. Within OU-2, deer mice abundance did not appear to be affected by smelter activities. However, small mammal species diversity correspondingly increased with increasing distance from the smelter (Herman, 1975). Conversely, conclusions from other studies appear to confound these findings. For example, Hooper et al. (2002) and Schwarz (2003) conducted a two-year study on small mammals inhabiting areas with varying levels of contaminants of concern (i.e., As, Cd, Cu, Pb, and Zn) in surface soils at the Anaconda Smelter Superfund, Deer Lodge County, Montana. Results indicated that, while small mammals were exposed to contaminants of concern at levels sufficient to affect physiological homeostasis and tissue metal residues corresponded to soil metal concentrations, small mammal populations did not exhibit decreased abundance, survival, or reproduction. Similarly, populations of white-footed mice (*Peromyscus leucopus*) inhabiting a heavy metals-contaminated wetland (Levengood and Heske, 2008) and short-tailed shrews (*Blarina brevicauda*) occupying palustrine habitat contaminated with varying levels of polychlorinated biphenyls (Boonstra and Bowman, 2003) showed no detectible change in abundance, demographics, or reproductive activity that would indicate population-levels effects of contaminant exposure.

Considerable local variations have been observed in small mammal population fluctuations among species and among populations of the same species (Gillespie et al., 2008). Site-specific (habitat), temporal, and geographic differences have also been observed. Krebbs (1996) found that within a species, populations occupying different habitats in the same region may display erratic, annual, or multiannual fluctuations. Species with similar habitat requirements may display different cyclic events and species with different requirements may display similar cycles in the same site (Getz et al., 2001). Such variations make simple explanations of population fluctuations in small mammal communities difficult. Whether the variability observed within OU-2 between 2001 and 2008 is due to the presence of contaminants of concern or related to the dynamic relationship between small mammal populations and a host of environmental factors remains unclear.

The monitoring program outlined in the EMP (USEPA, 2006a) is designed to use parameters and sampling frequencies intended to be sensitive and responsive to the potential rate of environmental change in OU-2 habitats over time, including the bioavailability of metals of concern. The preliminary evaluation of the dynamics of small mammal populations within OU-2 with 2001 and 2008 data suggest that small mammal population diversity and abundance sampling may be scheduled at a rate in which a degree of variability in demographic parameters may make interpretation difficult. Limited sampling may lead to missing OU-2 small mammal peak densities among years or sites during the same year (Getz et al., 2005; Gillespie et al., 2008), or make analysis of the role of changes in survival, reproduction, sex ratio, and other demographic traits in annual or multiannual population cycles difficult. Demographic events during other seasons that may provide explanations of cyclic phenomena may also be missed. The frequency and duration of a sampling regime needs to take these factors into account to adequately monitor changes in site-specific small mammal communities, especially with respect to a single potential cause. Further study would be needed to investigate the effects of chronic exposure to contaminants of concern at the population and community level. Due to variations in small mammal population dynamics within OU-2, a higher frequency of monitoring and the inclusion of reference sampling may aid in evaluating the effects of metals exposure on the health of this representative receptor within OU-2.

While a more definitive examination of small mammal population-level effects to contaminants of concern would require a more detailed study of population densities, productivity, and survival, small mammals are well known for their utility in monitoring exposure to local contaminants, including metals (Siewicki et al., 1983; Talmage and Walton, 1991; Ma et al., 1991; Clark et al., 1992; Ma, 1994; Ma, 1996; Cook and Johnson, 1996; Swiergosz et al., 1998; Smith et al., 2002; Schwarz, 2003; Reynolds et al., 2006). Species of small mammals known to inhabit areas of OU-2 (e.g., deer mice, voles, shrews) are ubiquitously distributed, abundant, and are relatively easy to trap. Tissue metal residues in these species have been effectively used to assess contaminant bioavailability at both impacted and reference sites, and help evaluate effects to individuals from exposure (Reynolds et al., 2006; USFWS, 2003; Hooper, 2002; Shore and Douben, 1994; Ma, 1996; Ma, 1994; Ma et al., 1991). Small mammal exposure to mining related metals of concern should continue to be evaluated as an index of remedial success in protecting ecological receptors (see Section 5.0).

Table 4-1. Location, species, number, relative abundance, male to female ratio, percent reproductive, and percent juvenile small mammals captured during small mammal population surveys, Smelterville Flats and CIA, OU-2, Coeur d'Alene Basin, Idaho, 2008.

Location/Species	**Number of individuals collected**	**Relative abundance / 100 trap nights**	**% Male**[c]	**% Reproductive Male**[d]	**% Female**[c]	**% Reproductive Female**[e]	**% Juvenile**[c]
Smelterville Flats[a]							
Shrew species *(Sorex spp)*	17	1.2					
Deer mouse *(Peromyscus maniculatus)*	9	0.6					
Total small mammals	26	1.8	50	46	50	38	15
CIA[b]							
Vole species (*Microtus spp.)*	5	0.6					
Deer mouse (*Peromyscus maniculatus)*	6	0.8					
Total small mammals	11	1.4	72	62	27	33	27

[a]Relative abundance calculated at 1434 trap nights.
[b]Relative abundance calculated at 750 trap nights.
[c]Percent of total population.
[d]Percent of male population.
[e]Percent of female population

Table 4-2. Species, number, relative abundance, ratio of male to female, percent reproductive, and percent juveniles of small mammals captured during population surveys, Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2001.

Species	**Number of individuals collected**	**Relative abundance / 100 trap nights**	**% Male[a]**	**% Reproductive Male[b]**	**% Female[a]**	**% Reproductive Female[c]**	**% Juvenile[a]**
Deer mouse (*Peromyscus maniculatus)*	67	7.4					
Meadow vole (*Microtus pennsylvanicus)*	31	3.4					
Masked shrew (*Sorex cinerius)*	1	0.1					
Total small mammals	99	11.0	44	43	55	22	60

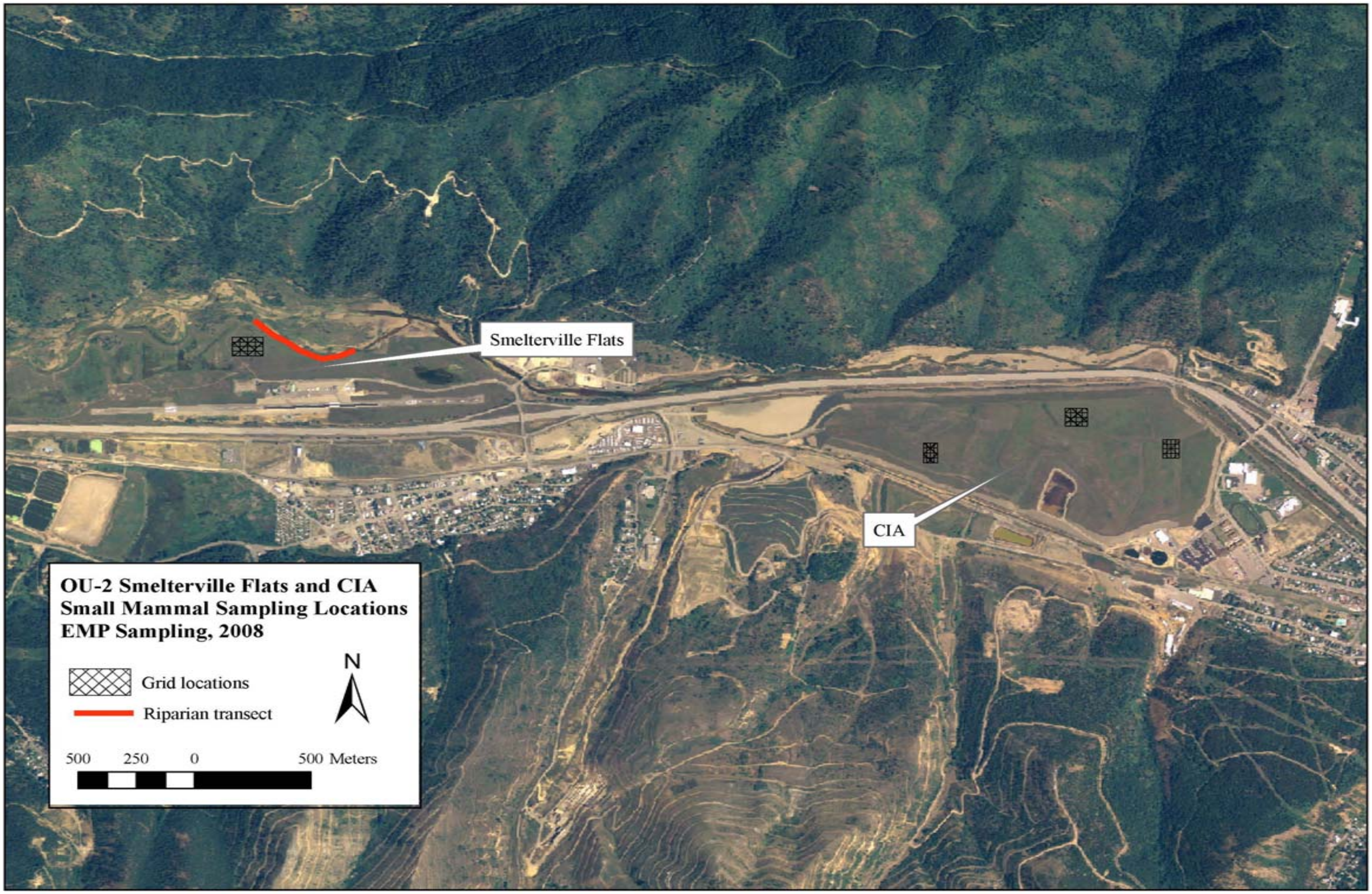
[a] Percent of total population.
[b] Percent of male population.
[c] Percent of female population

Table 4-3. Small mammal Shannon-Weiner diversity index, CIA and Smelterville Flats (SF), OU-2, Coeur d'Alene Basin, Idaho, 2001 and 2008.

Measure	**CIA**	**SF 2001**	**SF 2008**
Species	2	3	2
Individuals	11	99	26
H_1	0.994	0.972	0.931
H_1Max	1	1.584	1
D_1	0.006	0.612	0.069
D_1 pct	0.596	38.6	6.94
Evenness	99.4	61.4	93.1

H_1 = community species diversity index.
H_1 Max = maximum diversity, dependant on total number of species; all species are represented in equal proportions.
$D_1 = H_1$ Max - H_1 (divergence from equiprobability).
D_1 pct = D_1 / H_1 Max.
Evenness = percent relative abundance with which each species is represented in an area (H_1/H_1Max).
Source:http://math.hws.edu/javamath/ryan/Diversity Test.html.

Figure 4-1. Small mammal survey locations, OU-2, Coeur d'Alene Basin, Idaho, 2008.



5.0 Small mammal tissue metal concentrations

Small mammals have been used extensively as sentinels of terrestrial metals contamination (Ma et al., 1991; Ma, 1994; Cooke and Johnson, 1996; Talmage and Walton, 1991; Hooper et al., 2002; Reynolds et al., 2006). Their close association with the soil, large populations, small home ranges, and position within the food web make them good biomonitors of contaminant exposure and effects (Talmage and Walton, 1991; Shore and Douben, 1994a). Small mammal life history traits vary from strict insectivores to omnivores and herbivores, which directly and indirectly influences contaminant exposure through dietary intake (Talmage and Walton, 1991). Short life spans and high reproductive rate allows for the assessment of immediate effects: each new generation reflects current amounts of contaminant in the environment and long term effects occur over several generations (Talmage and Walton, 1991). Small mammals living in areas of high soil metal concentrations typically contain elevated levels of metals in body tissues (Ma, 1994; Shore and Douben, 1994b; Ma, 1996; Cooke and Johnson, 1996), with concentrations in tissues correlating with those in soils (Clark et al., 1992; Hooper et al., 2002; Schwarz, 2003; Reynolds et al., 2006). Elevated small mammal metal exposure has been linked to a decrease in red blood cell aminolevulinic acid dehydratase (ALAD) enzyme activity (Kucharczak et al., 1999), fibrosis of the liver and renal intranuclear inclusion bodies (Damek-Poprawa et al., 2003), pulmonary hyperplasia (Cooke and Johnson, 1996), and sever testicular and renal injury (Ma, 1996; Swiergosz et al., 1998).

The OU-2 Record of Decision (ROD) recognizes the assessment of wildlife exposure and effects to mining-related contaminants of concern as essential in evaluating the success of OU-2 Phase I remedial activities as they pertain to the protection of the environment (USEPA, 1992). For the purpose of monitoring and evaluating Phase 1 remedy with respect to meeting ROD goals, the Environmental Monitoring Program for OU-2 (EMP) identified small mammals in riparian and upland habitats as representative receptors of continued ecological exposure to contaminants of concern in terrestrial habitats (USEPA, 2006a). Exposure pathways of small mammals to contaminants of concern within OU-2 include ingestion of contaminated food items and the inadvertent ingestion of soil while foraging, digging, or grooming (Talmage and Walton, 1991; Smith et al., 2002; Reynolds et al., 2006). Previous studies demonstrated elevated exposure to metals and related effects in small mammals using OU-2 habitats (Herman, 1975; USFWS, 2002; USFWS, 2005). Remedial activities within OU-2 addressed soil contamination in a number of these areas, including Smelterville Flats and the Central Impoundment Area (CIA).

We collected small mammal carcass, liver and kidney tissue at Smelterville Flats and the CIA in 2008 as part of the EMP and analyzed them for OU-2 metals of concern in an ongoing effort to evaluate the success of remedial actions in reducing the bioavailability of metals in soils within OU-2. We then compared results with toxicological reference values and results from previous work in the Coeur d'Alene Basin to evaluate the success of remedial actions in protecting these receptors.

5.1 Methods

We collected small mammals for tissue metal residue analysis on Smelterville Flats and the CIA concurrently with small mammal population surveys (See Section 4.1). Surveys were conducted on Smelterville Flats and the CIA from May 19 to May 23, with an additional 12 day trapping effort conducted on Smelterville Flats following the scheduled trapping period[6]. On Smelterville Flats, 100 Victor snap-traps (Woodstream Corp., Lititz, PA) were placed at 10-meter intervals in one 100 x 100 meter grid array within upland habitat, and 50 snap-traps at 10-meter intervals along a 500-meter transect within a riparian edge of the SFCDR (Figure 5-1). On the CIA, 50 snap-traps were placed at 10-meter intervals in three 100 x 50-meter grid arrays. Arrays were distributed equidistance apart for maximum coverage of the CIA area (Figure 5-1). Traps were baited with a mixture of rolled oats and peanut butter, and were checked and re-baited daily. Data collected on captured individuals included location (e.g., upland or riparian), species, weight, sex, age, and reproductive status.

Small mammal specimens were placed in individual zip-lock bags, labeled and immediately placed in coolers on wet or blue ice. Specimens were transported to the UCFWO and stored in a locked facility at -20º Celsius until dissection. Removal of small mammal kidney and liver tissue followed UCFWO SOP #1020.1014. In short, carcasses were opened with a stainless steel scalpel and livers and kidneys removed. Carcass, liver, and kidney samples were placed in laboratory-prepped glass containers and shipped on dry ice to USEPA's Manchester Laboratory (Port Orchard, WA) for arsenic (As), cadmium (Cd), lead (Pb), and zinc (Zn) analysis. All results were reported as µg/g dry weight (dw).

Exposure to metals in soil among mice, voles and shrews may differ, depending on species-specific behavioral (e.g., use of habitat) and feeding (e.g., insectivore vs. herbivore) characteristics. All results were therefore grouped by species prior to analyses. Data were analyzed using Kruskal-Wallis nonparametric tests with Dunn's multiple comparison test, and/or Mann-Whitney nonparametric tests with 95% confidence interval. Carcass, liver and kidney results were compared between sex, age (adult vs. juvenile) and habitat (upland vs. riparian) within sample locations. Carcass, liver and kidney results were also compared between sample locations (e.g., Smelterville Flats and the CIA), and to results from samples collected at Smelterville Flats in 2001 (USFWS, 2002) and the previously sampled Latour Creek reference area (USFWS, 2003) where applicable.

5.2 Results

A total of 37 small mammals were captured during the collection period. The trapping effort on Smelterville Flats resulted in the collection of carcass, liver and kidney samples from 9 deer mice and 17 shrews. The trapping effort on the CIA resulted in the collection of carcass, liver, and kidney samples from six deer mice and 5 voles. Arsenic, Cd, Pb, and Zn concentrations were not significantly different between male/female, adult/juvenile, or riparian/upland small mammals. Therefore, data were pooled by species prior to further statistical analysis

5.2.1 Carcass concentrations

Metal concentrations in deer mice, shrew and vole carcass samples collected from Smelterville Flats and the CIA in 2008 are summarized in Table 5-1. Shrew carcass cadmium and Pb concentrations were significantly higher (P=0.01 and P=0.05, respectively) than deer mice and vole species in 2008 samples (Table 5-1). No significant differences existed among deer mice, shrew, and vole species for As and Zn carcass concentration levels.

[6] Additional trapping days were added due to poor trapping success during the originally planned period.

Metal concentrations in deer mice carcasses were not different between Smelterville Flats and the CIA ($P \geq 0.05$). Mean cadmium and Zn concentrations in deer mice carcass samples from Smelterville Flats in 2008 were significantly higher than those collected on site in 2001 (P = 0.001) (Figure 5-2).

No differences existed in shrew carcasses metal concentrations between Smelterville Flats 2008 and 2001 (USFWS, 2002) samples (P= 0.21-0.87). Mean Smelterville Flats 2008 carcass Pb and Zn concentrations were significantly higher than those from Latour Creek (P=0.002 and 0.006, respectively) (Figure 5-3).

Vole carcass metal concentrations collected from the CIA in 2008 and Smelterville Flats in 2001 (USFWS, 2002) were not significantly different (P= 0.08-0.57). Cadmium, Pb, and Zn concentrations were significantly higher at the CIA in 2008 than from Latour Creek ($P \leq 0.05$) (Figure 5-4).

5.2.2 Liver concentrations

Metal concentrations in deer mice, shrew and vole liver samples collected from Smelterville Flats and the CIA in 2008 are summarized in Table 5-2. Liver As, Cd, Pb, and Zn concentration levels were significantly higher (P= 0.01-0.03) in shrew species collected in 2008 than deer mice and vole species (Table 5-2).

Deer mice liver metals concentrations were not significantly different between 2008 Smelterville Flats and CIA samples (P=0.15-0.55). Arsenic, Cd, and Pb concentrations in samples from Smelterville Flats in 2008 were significantly higher than those from Latour Creek (P=0.08, P=0.05, and P=0.01, respectively). Likewise, As and Pb concentrations in samples collected from the CIA in 2008 were significantly higher than those from Latour Creek (P=0.01 and P=0.01, respectively). Arsenic and Pb concentrations in samples collected from Smelterville Flats in 2008 were significantly higher than those collected from Smelterville Flats in 2001 (P=0.03 and P=0.04, respectively) (Figure 5-5). Neither shrew nor vole liver data were available from Smelterville Flats in 2001 or Latour Creek with which to compare with 2008 samples. Figures 5-6 and 5-7 display graphical representations of 2008 shrew and vole liver data, respectively.

5.2.3 Kidney metal concentrations

Metal concentrations in deer mice, shrew and vole kidney samples collected from Smelterville Flats and the CIA in 2008 are summarized in Table 5-3 and figures 5-8 to 5-10. Kidney arsenic, Cd, Pb, and Zn concentrations were significantly higher in shrews collected in 2008 than deer mice and voles (P= 0.01-0.02) No differences existed in kidney arsenic, Cd, Pb, and Zn concentrations in deer mice collected from Smelterville Flats and the CIA. Small mammal kidney data were not available from Smelterville Flats in 2001 or Latour Creek with which to compare with 2008 samples.

5.3 Discussion

Data collected in 2008 indicate that small mammals utilizing habitat on the CIA and within Smelterville Flats are exposed to soil metals concentrations above those from reference areas and, in some instances, above levels shown to be associated with adverse effects to small mammals (Ma, 1996; Cooke and Johnson, 1996). Furthermore, while exposure appears to vary among individuals and species within OU-2, data also suggest that small mammal exposure to contaminants of concern within OU-2 has not decreased since 2001.

Individual and interspecific variations in small mammal exposure to metals in soil is not uncommon, and can be driven by a number of factors, including diet, behavior and habitat use. However, ingestion of contaminated soil and food constitutes the primary exposure pathway for small mammals to contaminants in soil (Ma et al., 1991; Efroymson et al., 2001). The composition of small mammal diets, therefore, has the greatest impact on exposure, bioavailability and accumulation of contaminants (Shore and Douben, 1994a; Ma, 1996; Cooke and Johnson, 1996). Because deer mice, voles and shrews utilize different feeding strategies, exposure can be expected to differ. Deer mice and voles incorporate relatively similar ecological life histories, although differences in foraging strategies exist (Foresman, 2001). Deer mice tend toward omnivory, feeding opportunistically on soil invertebrates. In contrast, voles are more strict herbivores, feeding preferentially on the green stems and leaves of grasses (Hunter et al. 1987). Shrews are strict insectivores, opportunistically feeding on invertebrates active at the ground surface and supplemented by soil macrofauna caught while burrowing in the surface soil (Ma, 1994; Ma and Talmage, 2001). The dietary life-history traits of shrews put them at greater risk of metal exposure, due to the fact that invertebrate prey items contain high levels of contaminants when compared with vegetation (Ma, 1991). Results from small mammal sampling in 2008 are consistent with the consumption of soil invertebrates constituting a major exposure factor: mean carcass, liver and kidney metals concentrations were highest in shrew species, followed by deer mice and then voles.

Target remedial goals for soil and sediment in the Smelterville Flats area north of I-90 were 3,000 mg/kg lead and 3,000 mg/kg zinc (USEPA, 2005). Ninety-two percent (24/26) of samples collected in 2008 contained zinc concentrations below this remedial goal. Likewise, lead and zinc concentrations in the majority of other samples collected at the site were below target remedial goals: 54% (12/22) and 82% (18/22) for lead and zinc, respectively, from the Smelterville Flats riparian area, and 83% (80/96) and 81% (79/96), respectively, from Smelterville Flats wetland areas (see Section 2). These data suggest some success in the long-term integrity of remedial activities. However, despite remedial actions results, data from 2008 indicate that small mammal exposure to metals of concern at the site continues to be elevated above reference areas. Metals in carcasses and livers were above those observed at Latour Creek, and metals in carcasses, livers and kidneys above reference values suggested by other studies (Talmage and Walton, 1991; Cooke and Johnson, 1996; Ma, 1996) (figures 5-1 to 5-9). More troubling, however, is that there does not appear to be a decrease in small mammal exposure to metals of concern over time at the site. For example, deer mice carcass Cd and Pb concentrations from Smelterville Flats in 2008 were 1.6 and 3 times higher, respectively, than samples collected at the site in 2001. Furthermore, no differences existed in metal concentrations in shrew carcasses collected from Smelterville Flats in 2008 and 2001 (Figure 5-2). Trends in liver concentrations were similar to those of carcasses: deer mice liver Cd and Pb concentrations were 4.5 and 1.4 times higher, respectively, in 2008 than 2001. At the time of small mammal sampling on Smelterville Flats, composite soil samples were collected from 10 locations within the upland grid array and riparian transect, composited, analyzed for metals using an X-ray fluorescence spectrometry analyzer (XRF; Innov-X Systems, Inc Woburn, MA 01801). Mean lead concentrations in upland and riparian soils were 2,190 and 25 mg/kg dw, respectively. Given these concentrations, the elevated small mammal tissue concentrations were not unexpected. The vegetative structure on Smelterville Flats has improved significantly since remediation, creating habitat characteristics attractive to wildlife. However, small mammal tissue metals concentrations reflect a deficit in remedy effectiveness in protecting ecological receptors. Furthermore, given soil concentrations reported in Section 2.0, site recontamination appears to be a factor affecting ongoing small mammal exposure to contaminants of concern.

Small mammal sampling on top of the CIA was intended to help determine wildlife use of the cap, as well as to help evaluate cap integrity as it pertained to the protection of ecological resources. Soil sampling from this area (see Section 3.0) suggests that surface soil metals concentrations are protective of wildlife. Small mammal data, however, 2008 suggest that metal concentrations in deer mice and voles inhabiting the CIA are elevated above reference area samples, and are comparable to metal concentrations in small mammals from Smelterville Flats where there are known elevations in surface soil metals concentrations (USFWS, 2008a; Section 3.0). Mean Cd and Pb concentrations in deer mice carcasses from the CIA were 1.2 and 65 times higher than those from the Latour Creek reference area, and 50% (3/6) were above toxicological reference values for Pb (Ma, 1996). Likewise, the mean Pb concentration in vole carcasses was 6.6 times higher than Latour Creek area samples.

Concentrations of metals in small mammals inhabiting Smelterville Flats and the CIA were above levels previously shown to be associated with adverse effects in small mammals (Talmage and Walton, 1991; Cooke and Johnson, 1996; Ma, 1996). The majority of data linking harmful effects to concentrations of Pb and Cd in the liver and kidney is derived from histological analyses, and demonstrate that relatively low concentrations of Pb and Cd can cause damage to small mammal tissues (Ma et al., 1991; Ma, 1996; McGivern et al., 1991; Kucharczak et al., 1999). Analyses of 2008 OU-2 samples did not include histological examination. However, metals residues in samples suggest that small mammals inhabiting Smelterville Flats and the CIA may be incurring a number of harmful health effects from exposure to metals. Forty percent of deer mice and 58% of shrews collected from Smelterville Flats and the CIA had liver Pb concentrations at or above concentrations known to be associated with clinical and/or acute lead poisoning in mammalian wildlife (e.g., 5-30mg/kg dw; Ma, 1996). Likewise, 33% of deer mice and 76% of shrews had kidney Pb concentrations associated with body weight loss, renal intranuclear inclusion bodies, and altered kidney to body weight ratios (Ma, 1996; Damek-Poprawa and Sawacka-Kapusta, 2003). Kucharczak et al. (1999) associated kidney Pb concentrations of 5.25 mg/kg dw to decreased ALAD activity. According to this threshold, 80% (4/5) of deer mice collected from the CIA had decreased ALAD, as did 77% (6/9) of deer mice collected from Smelterville Flats and 100% (17/17) of shrews collected. Other potential histological effects OU-2 small mammals may be incurring include fibrosis of the liver, damage to hepatic blood vessels (Damek-Poprawa and Sawicka-Kapusta 2003), depression of renal iron concentrations (Cooke and Johnson, 1996), proximal tubule degeneration (Swiergosz and Kowalska 2000), and glomeruli swelling (Damek-Poprawa and Sawicka-Kapusta 2003). All of these diagnoses carry the potential to disrupt the normal structure and function of the liver and kidney and thus health of the animal.

The apparent discrepancy between soil concentrations and elevated small mammal exposure data at the CIA constitutes a data gap regarding what the exposure source is. The small mean home ranges of deer mice and voles (0.04 to 1.6 ha; O'Connell, 2006) suggests that organic and inorganic components of the CIA cap constitute 100% of the potential exposure source. Beyer et al. (1994) suggests a dietary soil ingestion rate of 2% for mice. Given this small percentage, unless small mammals using the CIA are exposed to significantly elevated soil concentrations, incidental ingestion of soil would not appear to be a major exposure pathway. As omnivores and herbivores, vegetation constitutes the primary dietary component for deer mice and voles. Elemental uptake by vegetation tends to occur from the soil at the root level and from the atmosphere by leaves. Certain plants are well known for their ability to uptake metals (e.g., Carbonell et al., 1998; Dahmani-Muller et al., 2000; Wongkongkatep et al., 2003), and high accumulation of Pb and Cd by vegetation has been observed due to atmospheric deposition (Voutsa et al., 1996). Both subsurface and above ground uptake of metals of concern by plants could contribute to an elevated exposure pathway for herbivorous and omnivorous small mammals. Atmospheric deposition of metals of concern onto the CIA could be occurring through blowing dust from source areas, which has been observed to be significant within OU-2 at times (USEPA and Idaho Department of Environmental Quality personnel, personal communication). From subsurface to surface, the CIA cap consists of a slag cushion layer, a geomembrane, a slag drainage layer, growth media (soil), and vegetation at the surface (Terragraphics and Ralston, 2006). A paucity of data exists on whether vegetation planted and/or otherwise growing in the cap is uptaking metals of concern that may be present in the slag layers, or even reaching and uptaking metals in the remediated soils below. Because it appears to be a potential significant source of exposure to metals of concern for ecological receptors which may be affected by cap design, vegetation uptake of metals of concern as an exposure source should be evaluated.

The purpose of biological monitoring under the EMP is to evaluate the success of remedial actions in protecting ecological receptors. Data collected can help guide future remedial actions on site, and suggest successes and/or improvements for future actions in other areas. Remedial activities conducted at Smelterville Flats under the OU-2 ROD (USEPA, 1992) did not include ecological remedial action goals. Regardless, the CIA and much of the Smelterville Flats area were capped with soil with metals concentrations below those known to cause negative physiological effects in wildlife (e.g., 100 mg/kg Pb). Sampling conducted since the completion of Phase I remedial activities at Smelterville Flats demonstrated that elevated metals concentrations remain onsite (USFWS, 2008; Section 3.0). It is therefore not entirely surprising that ecological receptors such as small mammals are still incurring elevated exposure. Monitoring small mammal exposure at the site should be continued to assure the long-term success of meeting goals of protection of the environment at the site. The source of small mammal metals exposure at the CIA appears significant, and is a data gap that should be further evaluated to inform future repository designs.

Table 5-1. Species, number, and metals concentrations in small mammal carcass samples collected from the Central Impoundment Area and Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2008.

Species/Site	*N*		As mg/kg dw	Cd mg/kg dw	Pb mg/kg dw	Zn mg/kg dw
Deer mouse		Mean	0.40	0.64	29.60	120.3
CIA	6	SD	0.27	0.92	19.40	10.60
		Min	0.25	0.10	2.53	106
		Max	0.90	2.51	50.80	134
Smelterville Flats		Mean	1.17	1.05	96.40	154.4
	9	SD	1.57	0.63	115.8	64.20
		Min	0.25	0.27	17.80	106
		Max	5.16	1.90	372	275
Shrew spp		Mean	0.62	4.38	54.30	142.7
Smelterville Flats	17	SD	0.66	4.29	42.90	41.20
		Min	0.24	0.34	13.00	101
		Max	2.40	12.90	177	260
Vole spp		Mean	0.34	0.21	2.25	116.4
CIA	5	SD	0.21	0.09	1.51	9.94
		Min	0.24	0.11	0.73	107
		Max	0.72	0.31	4.02	131

Table 5-2. Species, number, and metals concentrations in small mammal liver samples collected from the Central Impoundment Area and Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2008.

Species/Site	*N*		As mg/kg dw	Cd mg/kg dw	Pb mg/kg dw	Zn mg/kg dw
Deer mouse/ CIA	6	Mean	0.36	1.54	2.29	87.50
		SD	0.12	2.76	1.68	5.35
		Min	0.28	0.11	0.13	81.60
		Max	0.57	7.15	4.83	95.60
Smelterville Flats	9	Mean	0.49	0.82	4.52	82.48
		SD	0.17	0.55	4.25	11.69
		Min	0.26	0.28	0.37	69.80
		Max	0.80	1.90	11.30	103
Shrew spp / Smelterville Flats	17	Mean	1.40	39.50	4.49	106.4
		SD	0.42	48.60	2.99	20.15
		Min	0.81	0.70	1.40	79.50
		Max	2.40	135	14.70	145
Vole spp / CIA	5	Mean	0.57	0.37	0.20	96.70
		SD	0.43	0.22	0.11	4.32
		Min	0.24	0.23	0.06	92
		Max	1.30	0.76	0.34	102

Table 5-3. Species, number, and metals concentrations in small mammal kidney samples collected from the Central Impoundment Area and Smelterville Flats, OU-2, Coeur d'Alene Basin Idaho, 2008.

Species/Site	*N*		As mg/kg dw	Cd mg/kg dw	Pb mg/kg dw	Zn mg/kg dw
Deer mouse		Mean	1.40	3.07	7.85	84.32
CIA	6	SD	0.46	3.50	5.87	3.19
		Min	1.10	0.37	0.38	81.20
		Max	2.30	9.90	15.70	89.30
Smelterville Flats		Mean	1.51	2.80	16.72	82.21
	9	SD	0.24	3.24	16.58	6.08
		Min	1.20	0.44	3.00	74.30
		Max	2.00	11.00	48.10	92.80
Shrew spp		Mean	5.38	34.00	35.57	106
Smelterville Flats	17	SD	1.05	41.80	25.68	22.70
		Min	3.50	1.30	8.30	70.90
		Max	6.90	126	102	149
Vole spp		Mean	1.86	2.28	1.13	81.56
CIA	5	SD	1.06	2.48	0.53	5.47
		Min	1.00	0.56	0.53	77.20
		Max	3.30	6.50	1.90	89.90

Figure 5-1. Small mammal collection locations, OU-2, Coeur d'Alene Basin, Idaho, 2008.

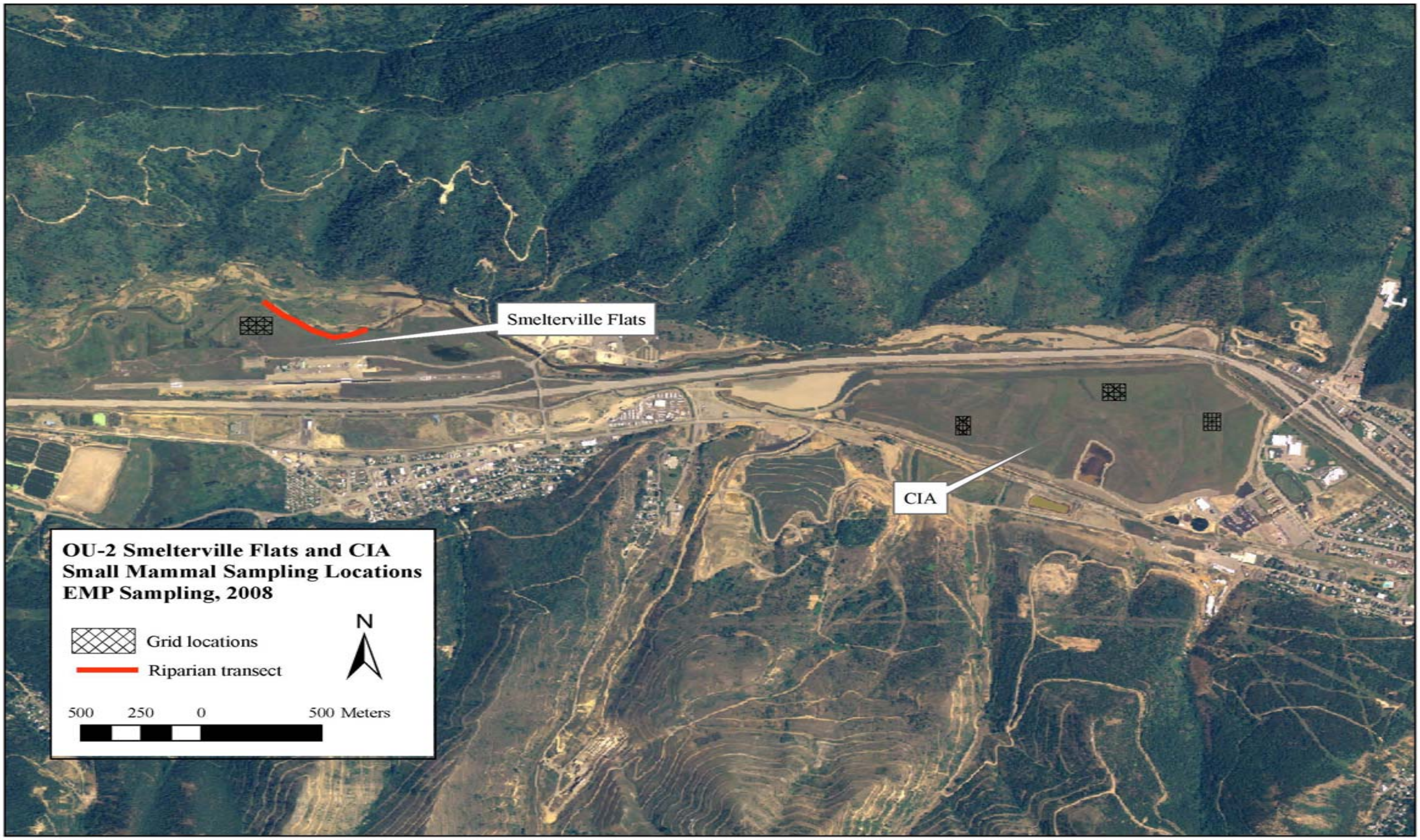
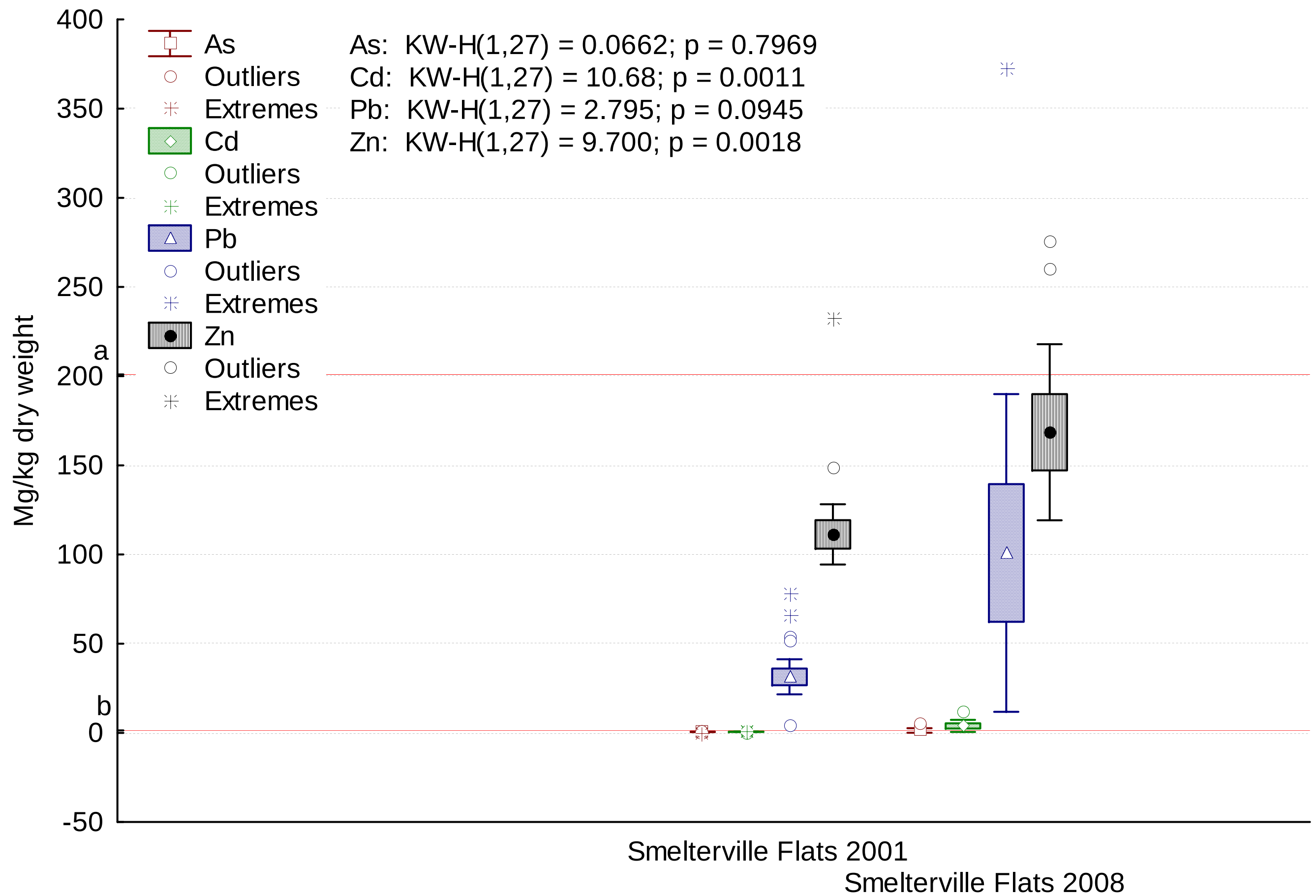
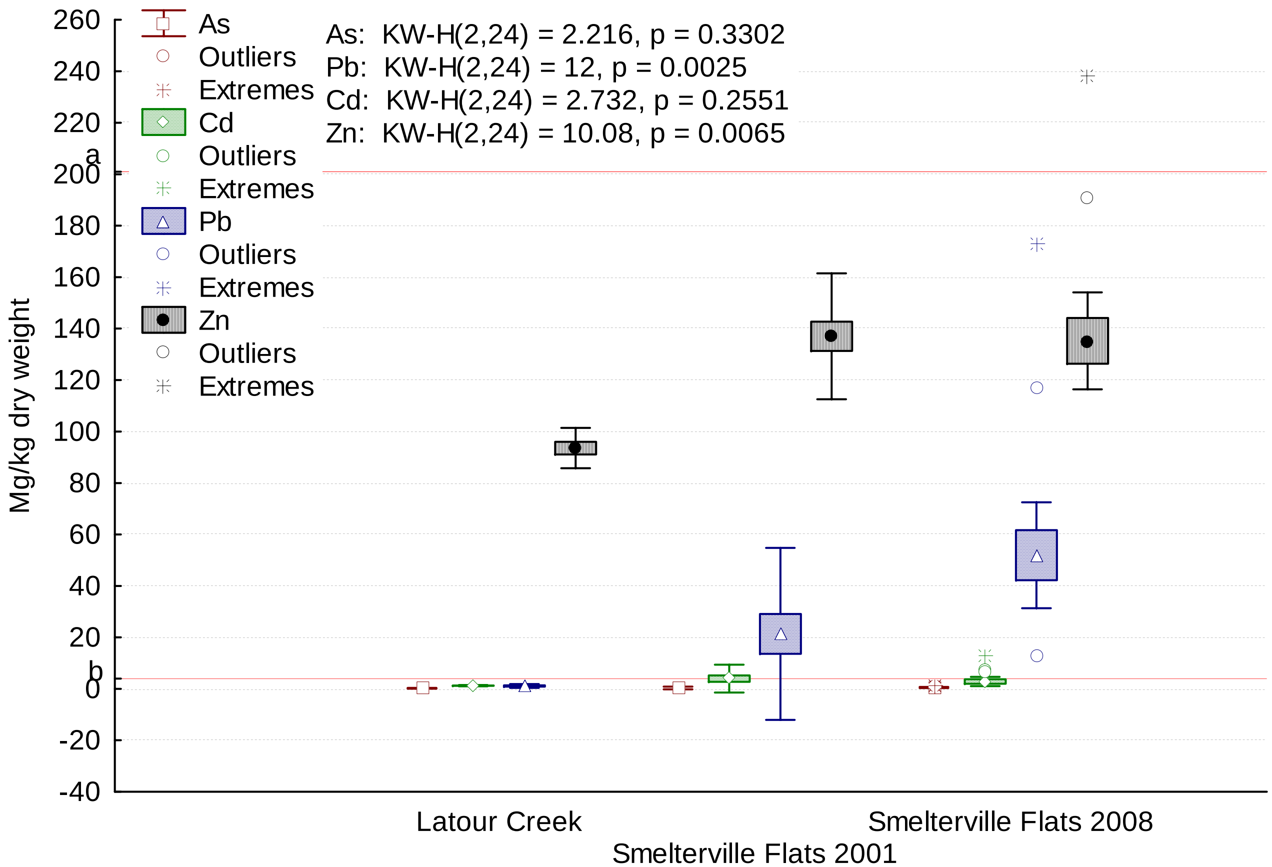


Figure 5-2. Deer mice carcass metals concentrations, Smelterville Flats, Operable Unit 2, Coeur d'Alene Basin, Idaho, 2001 (USFWS, 2002) and 2008.



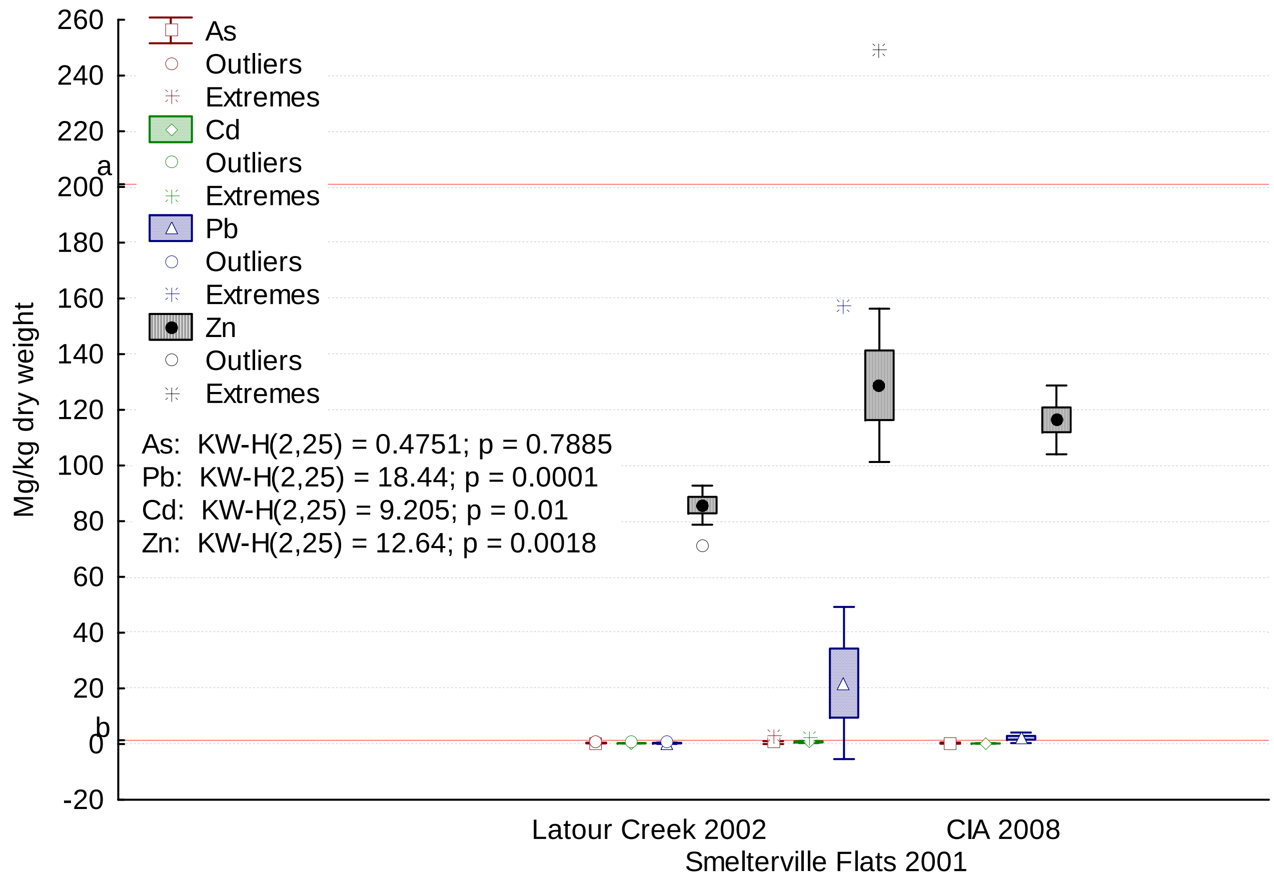
[a] Suggested carcass zinc reference value (Talmage and Walton, 1991).
[b] Suggested carcass cadmium reference value (Cooke and Johnson, 1996).

Figure 5-3. Shrew carcass metals concentrations, Smelterville Flat 2001 (USFWS, 2002) and 2008, and a previously evaluated reference location (Latour Creek; USFWS, 2003), Coeur d'Alene Basin, Idaho.



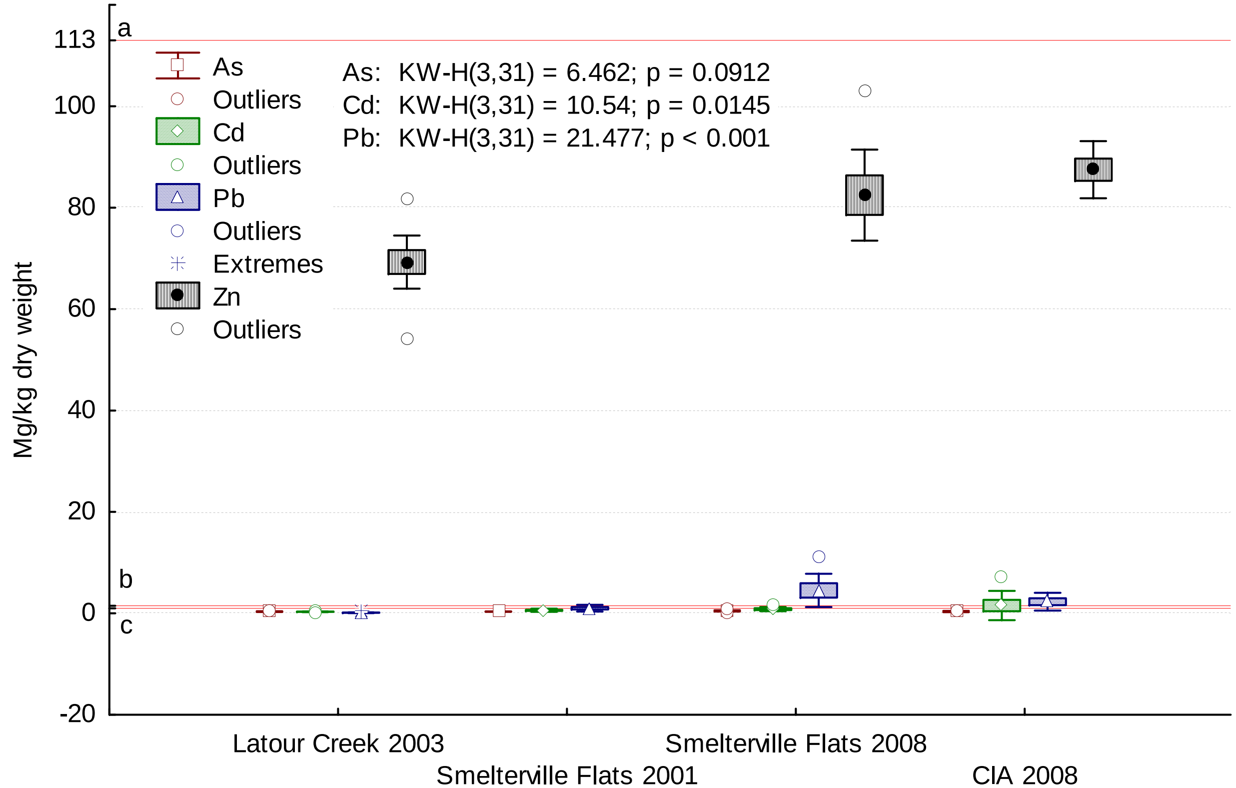
a Suggested shrew carcass zinc reference value (Hunter et al. 1989).
b Suggested shrew carcass cadmium reference value (Hunter et al. 1989).

Figure 5-4. Vole carcass metals concentrations, Central Impoundment Area (CIA 2008), and previous sampling locations (Smelterville Flats and Latour Creek; USFWS, 2002; USFWS, 2003), Coeur d'Alene Basin, Idaho.



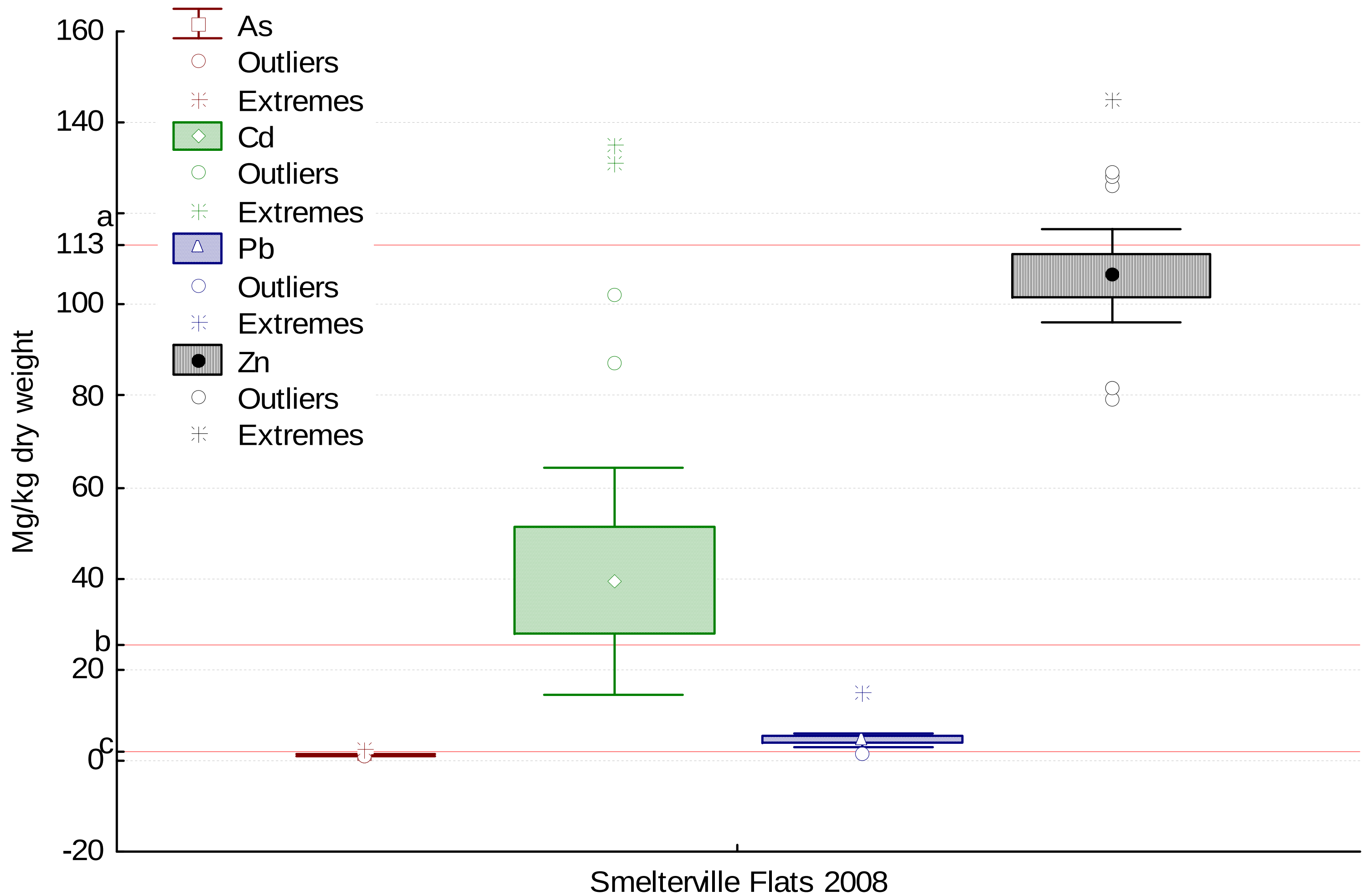
[a] Suggested carcass zinc reference value (Talmage and Walton, 1991).
[b] Suggested carcass cadmium reference value (Hunter et al., 1986).

Figure 5-5. Deer mice liver metals concentrations from samples collected at Smelterville Flats and the Central Impoundment Area (CIA) in 2008, Smelterville Flats in 2001 (USFWS, 2002), and the Latour Creek reference area in 2003 (USFWS, 2003), Coeur d'Alene Basin, Idaho.



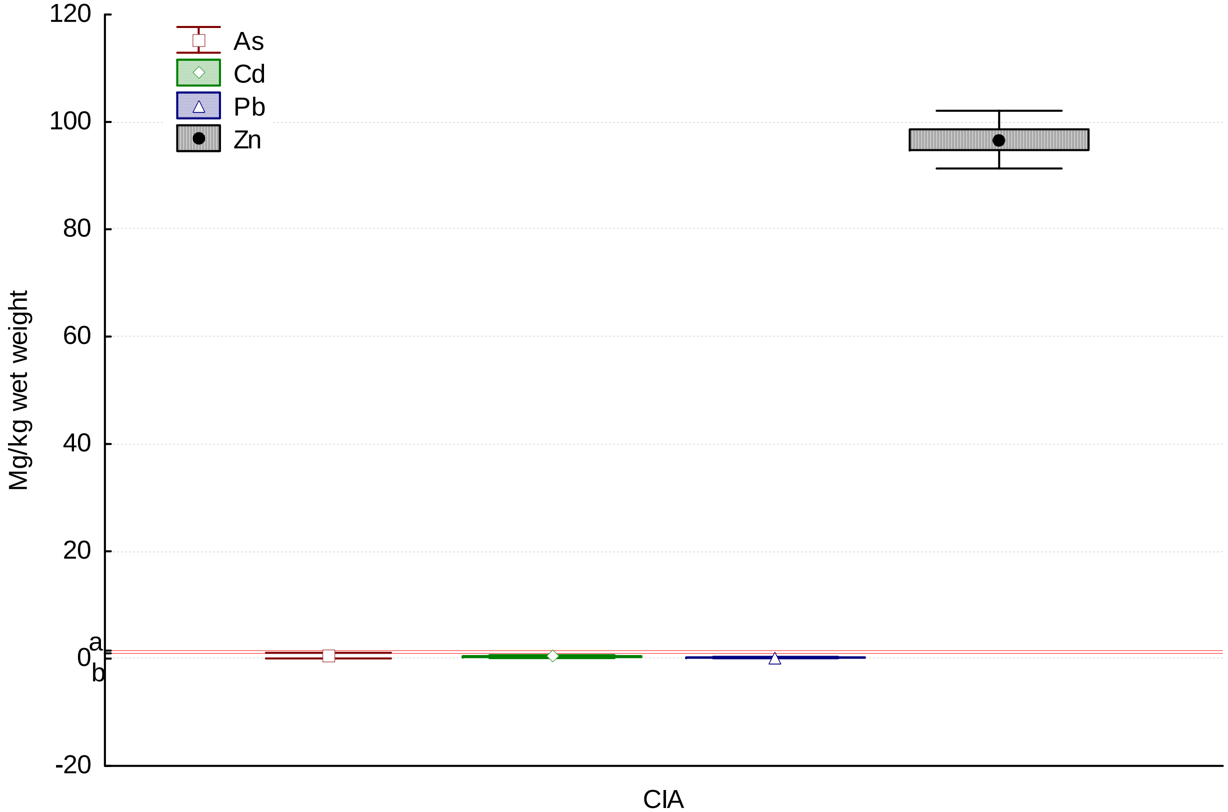
[a] Suggested deer mouse liver zinc reference concentration (Talmage and Walton, 1991).
[b] Suggested deer mouse liver cadmium reference concentration (Cooke and Johnson, 1996).
[c] Suggested deer mouse liver lead reference concentration (Ma, 1996).

Figure 5-6. Shrew liver metals concentrations, Smelterville Flats, Operable Unit 2, Coeur d'Alene Basin, Idaho, 2008.



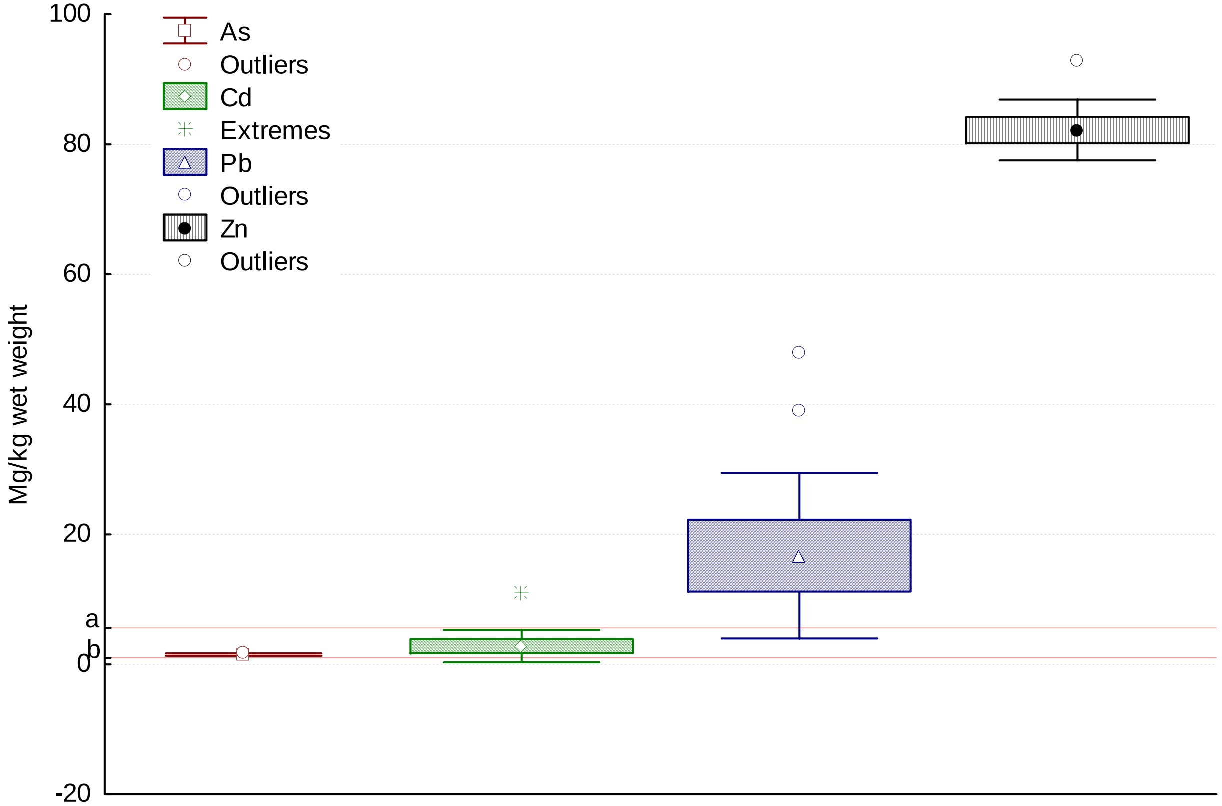
[a]Suggested shrew liver zinc reference value (Talmage and Walton, 1991).
[b]Suggested shrew liver cadmium reference value (Cooke and Johnson, 1996)
[c]Suggested shrew liver lead reference value (Ma, 1996).

Figure 5-7. Vole liver metals concentrations, Central Impoundment Area, Operable Unit 2, Coeur d'Alene Basin, Idaho, 2008.



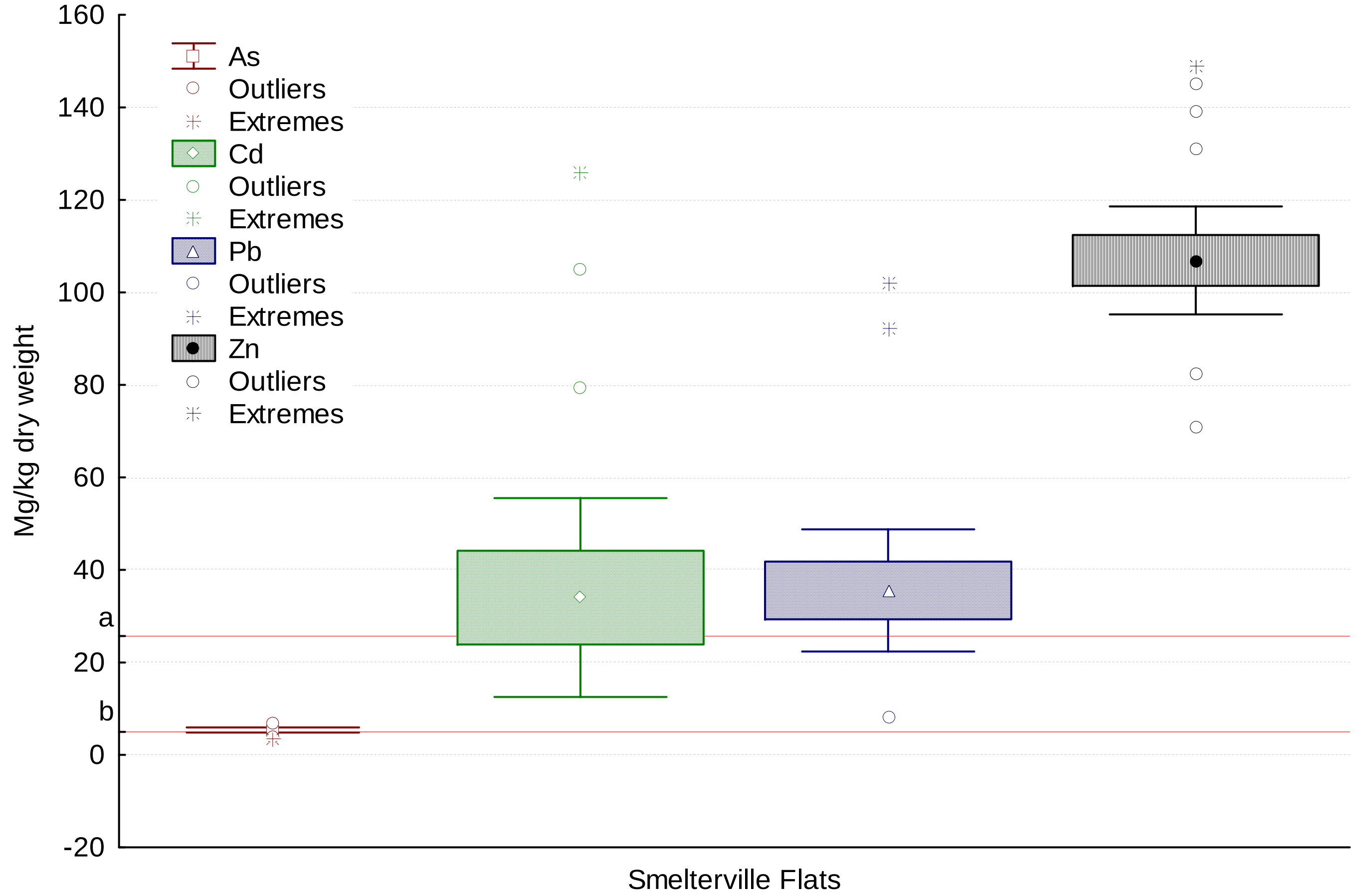
[a]Suggested liver cadmium reference concentration (Cooke and Johnson, 1996).
[b]Suggested liver lead reference concentration (Ma, 1996).

Figure 5-8. Deer mice kidney metals concentrations, Smelterville Flats, Operable Unit 2, Coeur d'Alene Basin, Idaho, 2008.



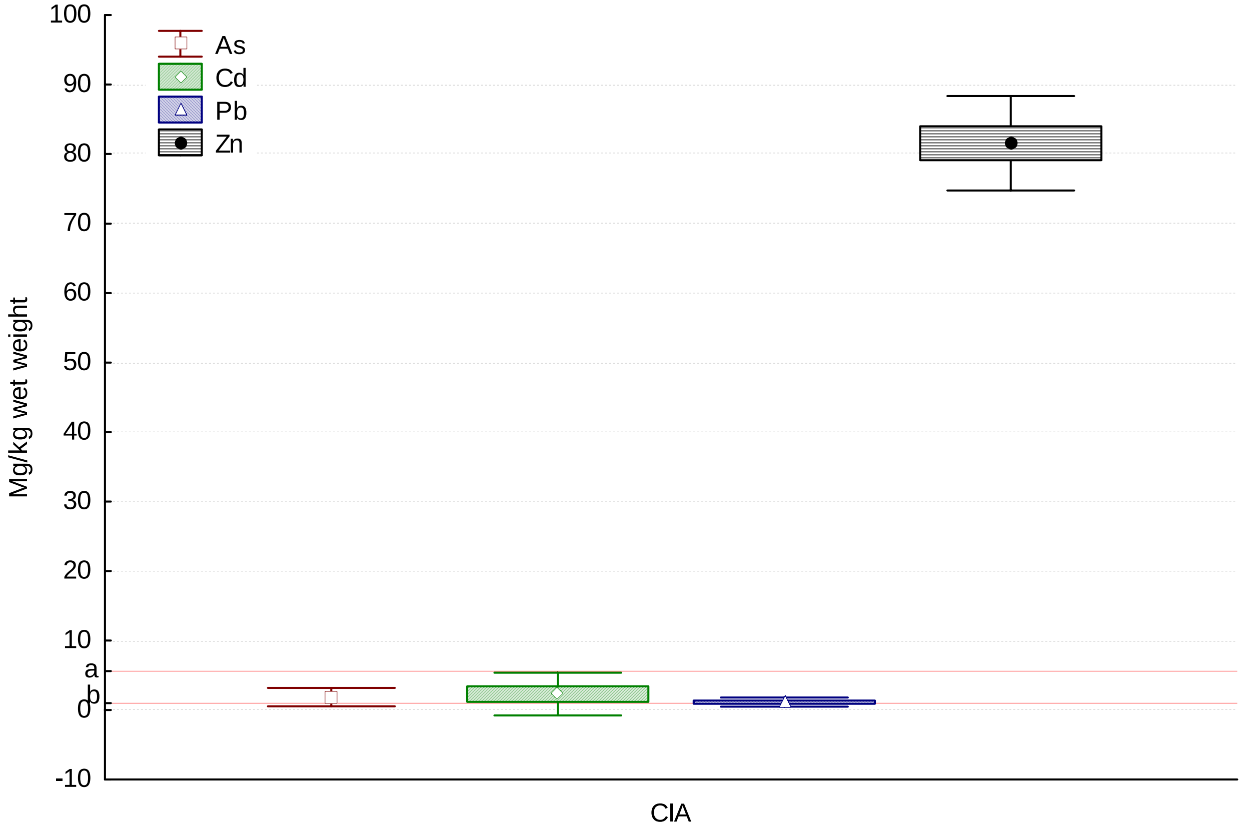
[a] Suggested kidney cadmium reference value (Cooke and Johnson, 1996).
[b] Suggested kidney lead reference value (Ma, 1996).

Figure 5-9. Shrew kidney metals concentrations, Smelterville Flats, Operable Unit 2, Coeur d'Alene Basin, Idaho, 2008.



[a] Suggested kidney cadmium reference concentration (Cooke and Johnson, 1996).
[b] Suggested kidney lead reference concentration (Ma, 1996).

Figure 5-10. Vole kidney metals concentrations, Central Impoundment Area, Operable Unit 2, Coeur d'Alene Basin, Idaho, 2008.



[a] Suggested kidney cadmium reference value (Cooke and Johnson, 1996).
[b] Suggested kidney lead reference value (Ma, 1996).

6.0 References

Audet, D.J., M.R. Snyder, and J.K. Campbell. 1999. Biological monitoring at the Page Pond Wastewater Treatment Plant ponds and wetlands on the Bunker Hill Superfund Site, Idaho, 1997. U.S. Fish and Wildlife Service. Prepared for Environmental Protection Agency, IAG no. DW 14957137-01-0.

Beyer, W.N., E.E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. Journal of Wildlife Management 58:375-382.

Birge, W.J., A.G. Westerman, and J.A. Spromberg. 2000. Comparative toxicology and risk assessment of amphibians. Chapter 14a in Ecotoxicology of amphibians and reptiles. D.W. Sparling, G. Linder and C.A. Bishop, eds. Society of Environmental Toxicology and Chemistry, Pensacola, Florida.

Boonstra R. and L. Bowman. 2003. Demography of short-tailed shrew populations living on polychlorinated biphenyl-contaminated sites. Environmental Toxicology and Chemistry 22:1394-1403.

Burch, S., D. Audet, M. Snyder, and L. LeCaptain. 1996. Evaluation of metals accumulation in aquatic biota and mallard ducks from the Page Pond wetlands and sewage ponds on the Bunker Hill Superfund Site, Idaho. U.S. Fish and Wildlife Service. Prepared for the Environmental Protection Agency, IAG no. DW 14957137-01-0.

Carbonell, A.A., M.A. Aarabi, R.D. DeLaune, R.P. Gambrell, W.H. Patrick, Jr. 1998. Arsenic in wetland vegetation: availability, phytotoxicity, uptake and effects on plant growth and nutrition. The Science of the Total Environment 217:189-199.

CH2M Hill. 2007. Phase I remedial action assessment report, Operable Unit 2, Bunker Hill Mining and Metallurgical Superfund Site. Prepared for U.S. Environmental Protection Agency Region 10.

Clark Jr. D., K.S. Forester, C.M. Marn, R.L. Hothem. 1992. Uptake of environmental contaminants by small mammals in pickleweed habitats at San Francisco Bay, California. Archives of Environmental Contamination and Toxicology 22:389-396

Cooke J.A. and M.S. Johnson. 1996. Cadmium in small mammals. In Environmental Contaminants in Wildlife. W.N. Beyer, G.H. Heinz and A.W. Redmond-Norwood, eds. Lewis Publishers, Boca Raton. pp 377-388.

Dahmani_Muller, H., F. van Oort, B. Geilie, and M. Balabane. 2000. Strategies of heavy metal uptake by three plant species growing near a metal smelter. Environmental Pollution 109:231-238.

Damek-Poprawa, M and K. Sawacka-Kapusta. 2003. Damage to the liver, kidney, and testis with reference to burden of heavy metals in yellow-necked mice from areas around steelworks and zinc smelters in Poland. Toxicology 186:1-10.

Dmowski K., M. Kozakiewicz and A. Kozakiewicz. 1995. Ecological effects of heavy metal pollution (Pb, Cd, Zn) on small mammal population and communities. Bull Polish Academy of Sciences Biological Sciences 43(1):1-10.

Dmowski K., A. Kozakiewicz and M. Kozakiewicz. 1998. Small mammal population and community under conditions of extremely high thallium contamination in the environment. Exotoxicology and Environmental Safety 41:2-7.

Efroymson, R.A., B.E. Sample, and G.W. Sutter II. 2001. Uptake of inorganic shemicals from soil by plant leaves: regressions of field data. Environmental Toxicology and Chemistry 20:2561-2571.

Foresman, K.R. 2001. The wild mammals of Montana. Special Publication No. 12. American Society of Mammalogists. Allen Press., Inc. Lawrence, KS.

Getz L. L., J.E. Hofmann, B. McGuire, and T.W. Dolan III. 2001. Twenty-five years of population fluctuations in *Microtus ochrogaster* and *Microtus pennsylvanicus* in three habitats in east-central Illinois. Journal of Mammalogy 82:22-34

Getz, L. L., M.K. Oli, J.E. Hofmann, and B. McGuire. 2005. Habitat specific demography of sympatric vole populations over 25 years. Journal of Mammalogy 86:561-568

Gillespie, S.C., D.H. Van Vuren, D.A. Kelt, J.E. Eadie, and D.W. Anderson. 2008. Dynamics of rodent populations in semiarid habitats in Lassen County, California. Western North American Naturalist 68:76-82

Herman, S.G. 1975. Lead and cadmium in soils, vegetation and small mammals near Kellogg, Idaho. Evergreen State College. 81 pp.

Hooper, M.J., G.P. Cobb, and S.T. McMurry. 2002. Final report – wildlife biomonitoring at the Anaconda Smelter Site, Deer Lodge County, Montana. Submitted to USEPA Region 8 and USFWS. 713 pp.

Hunter, B.A., M.S. Johnson, and D.T. Thompson. 1987. Ecotoxicology of copper and cadmium in a contaminated grassland ecosystem. III. Small mammals. The Journal of Applied Ecology. 24:601-614.

Hooper, M.J., G.P. Cobb, and S.T. McMurry. 2002. Wildlife biomonitoring at the Anaconda Smelter Site, Deer Lodge County, Montana. Final Report. Prepared for U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency by The Institute of Environmental and Human Health, Texas Tech University, Lubbock, Texas.

Johnson, M.S., R.D. Roberts, M. Hutton, M.J. Inslip. 1978. Distribution of lead, zinc, and cadmium in small mammals from polluted environments. Oikos 30:153-159.

Johnston, A.N., and R.G. Anthony. 2006. Small-mammal microhabitat associations and response to grazing in Oregon. Journal of Wildlife Management 72:1736-1746.

Kucharczak, E., Z. Jopek, S. Klimentowski, and J. Monkievicz. 1999. Environmental exposure to lead, zinc and copper versus ALAD activity in the blood of wild rats. Polish Journal of Environmental Studies 8:209-213.

Krebs, C.J. 1996. Population cycles revisited. Journal of Mammalogy 77:8-24.

Kucharczak, E., Z.Jopek, S.Klimentowski, and J. Monkiewicz. 1999. Environmental exposure to lead, zinc, and copper versus ALAD activity in the blood of wild rats. Polish Journal of Environmental Studies 8:209-213.

Lancia, R.A., J.D. Nichols, and K.H. Pollock. 1994. Estimating the number of animals in wildlife populations. In Research and Management Techniques for Wildlife and Habitats. T.A. Bookout, ed. Fifth ed. The Wildlife Society, Bethesda, MD pp. 216-253.

Levengood J.M. and E.J. Heske. 2008. Heavy metal exposure, reproductive activity, and demographic patterns in white-footed mice *(Peromyscus leucopus*) inhabiting a contaminated floodplain wetland. 2008. Science of the Total Environment 389:320-328.

Ma, W.C. 1989. Effect of soil pollution with metallic lead pellets on lead bioaccumulation and organ/body weight alterations in small mammals. Archives of Environmental Contamination and Toxicology 18:617-622.

Ma, W.C., W. Denneman, and J. Faber. 1991. Hazardous exposure of ground-living small mammals to cadmium in contaminated terrestrial ecosystems. Archives of Environmental Contaminants and Toxicology 20:266-270.

Ma, W.C. 1994. Methodological principles of using small mammals for ecological hazard assessment of chemical soil pollution, with examples on cadmium and lead. In Ecotoxicology of Soil Organisms. M. H. Donker, H. Eijsackers and F. Heimbach, eds. CRC Press, Inc. pp 357-370.

Ma, W.C. 1996. Lead in mammals. In Environmental Contaminants in Wildlife. W.N. Beyer, G.H. Heinz and A.W. Redmond-Norwood, eds. Lewis Publishers, Boca Raton. pp. 281-296.

Ma, W.C., and S. Talmage. 2001. Insectivora. In Ecotoxicology of Wild Mammals. R.F. Shore and B.A. Rattner, eds. John Wiley & Sons Ltd. Chichester, England. pp 123-158.

McGivem, R. F., R. Z. Sokol, and N. G. Berman. 1991. Prenatal lead exposure in the rat during the third week of gestation: long-term behavioral, physiological, anatomical effects associated with reproduction. Toxicology and AppliedPharmacology. 110:206-215.

Mullins W.H., and S. A. Burch. 1993. Evaluation of lead in sediment and biota east and west page swamps, Bunker Hill Superfund Site, Idaho. U.S. Fish and Wildlife Service. Prepared for Environmental Protection Agency, IAG no. DW 14957070-01-01.

O'Connell, M. A., 2006. Guide to the small mammals of the Columbia Basin region of Washington state. Published by the Bureau of Land Management in association with Eastern Washington University.

Read H.J., M.H. Martin 1993. The effect of heavy metals on populations of small mammals from woodlands in Avon (England): with particular emphasis on metal concentrations in *Sorex Araneus L.* and *Sorex Minutus L.* Chemosphere 27:2197-2211.

Reynolds, K.D. 2004. Heavy metal and arsenic bioaccumulation in small mammals inhabiting the anaconda smelter superfund site, Montana. Unpublished doctoral dissertation, Texas Tech University, Lubbock. Retrieved: December 2, 2008. http//:etd.lib.ttu.edu/thesis/available/edt-

Reynolds, K.D., M.S. Schwarz, C.A. McFarland, T. McBride, B. Adair, R.E. Strauss, G.P. Cobb, M.J. Hooper, and S.T. McMurry. 2006. Northern pocket gophers (*Thomomys talpoides*) as biomonitors of environmental metal contamination. Environmental Toxicology and Chemistry 25:458-469.

Schwarz, M.S. 2003. Deer mouse and meadow vole population and community dynamics in metal and arsenic contaminated areas at the anaconda smelter site, Deer Lodge County, Montana. Unpublished master's thesis, Texas Tech University, Lubbock. Retrieved: December 2, 2008. http//:etd.lib.ttu.edu/thesis/available/etd-.

Sheffield, S.R., K. Sawicka-Kapusta, J.B. Cohen and B.A. Rattner. 2001. Rodentia and lagomorpha. In Ecotoxicology of Wild Mammals. R.F. Shore and B.A. Rattner, eds. John Wiley & Sons Ltd. Chichester, England. pp 215-314.

Shore R.F. and P.T. Douben. 1994a. Predicting ecotoxicological impacts of environmental contaminants on terrestrial small mammals. Reviews of Environmental Contamination and Toxicology 134:49-88

Shore R.F. and P.T. Douben. 1994b. The ecotoxicological significance of cadmium intake and residues in terrestrial small mammals. Ecotoxicology and Environmental Safety 29:101-112.

Smith, P.N., G.P. Cobb, F.M. Harper, B.M. Adair, and S.T. McMurry. 2002. Comparison of white-footed mice and rice rats as biomonitors of polychlorinated biphenyl and metal contamination. Environmental Pollution 119:261-268.

Swiergosz, R., M. Zakrzewska, K. Sawicka-Kapusta, K. Bacia, and I. Janowska. 1998. Accumulation of cadmium in and its effect on bank vole tissues after chronic exposure. Ecotoxicology and Environmental Safety 41:130-136.

Swiergosz, R., and A. Kowalska. 2000. Cadmium accumulation and its effects in growing pheasants Phasianus colchicus. Environmental Toxicology and Chemistry 19:2742-2750.

Talmage, S.S., and B.T. Walton. 1991. Small mammals as monitors of environmental contaminants. Reviews of Environmental Contamination and Toxicology 119:47-145.

TerraGraphics Environmental Engineering, Inc. and Ralston Hydrologic Services (TerraGraphics and Ralston). 2006. Phase I remedial action characterization report for the Bunker Hill Mining and Metallurgical Complex Operable Unit 2. Prepared for the Idaho Department of Environmental Quality, Kellogg, Idaho.

USEPA. 1992. The Bunker Hill Mining and Metallurgical Complex Operable Unit 2 Record of Decision. U.S. Environmental Protection Agency, Seattle, Washington.

USEPA. 2005. Second five-year review for the Bunker Hill Mining and Metallurgical Complex Superfund Site, Operable Units 1, 2, and 3, Idaho and Washington. EPA 910-R-05-006. U.S. Environmental Protection Agency, Seattle, Washington.

USEPA. 2006a. Environmental monitoring plan, Operable Unit 2, Bunker Hill Mining and Metallurgical Complex Superfund Site. CH2MHill contract no. 68-S7-04-01. USEPA, Seattle, Washington.

USEPA. 2006b. Statistical analysis of post-phase I remedial action water quality data 2000-2004, Operable Unit 2, Bunker Hill Mining and Metallurgical Complex Superfund Site. CH2MHill contract no. 68-S7-04-01. USEPA, Seattle, Washington.

USEPA. 2009. Water quality critera: current national recommended water quality criteria. http://www.epa.gov/waterscience/criteria/wqctable/.

USFWS. 2002. Bunker Hill Non-Populated Areas Operable Unit, Biological Monitoring-2001, Annual Report of Preliminary Data. USFWS, Spokane, Washington.

USFWS. 2003. Bunker Hill Non-Populated Areas Operable Unit, Biological Monitoring-2002, 2nd Annual Report of Preliminary Data. USFWS, Spokane, Washington.

USFWS. 2005. Bunker Hill Facility Non-Populated Areas Operable Unit 2 Biological Monitoring, 2001-2004. Final report. U.S. Fish and Wildlife Service, Spokane, Washington.

USFWS. 2008a. Bunker Hill Facility Non-Populated Areas Operable Unit 2 biological monitoring, 2007. Final report. U.S. Fish and Wildlife Service, Spokane, Washington.

USFWS. 2008b. Field sampling plan, Bunker Hill Facility Non-Populated Areas Operable Unit 2 biological monitoring, soil and water sampling, 2008. U.S. Fish and Wildlife Service, Spokane, Washington.

USFWS. 2008c. Bunker Hill Facility Non-Populated Areas Operable Unit 2 biological monitoring, 2001-2004. Final report amendment. U.S. Fish and Wildlife Service, Spokane, Washington.

USFWS. 2009. Annual report, 2008 biological resource monitoring, Coeur d'Alene Basin Operable Unit 3. Final Draft. U.S. Fish and Wildlife Service, Spokane, Washington.

Vousta, D., A. Gimmanis, and C. Samara. 1996. Trace elements in vegetables grown in an industrial area in relation to soil and air particulate matter. Environmental Pollution 94:325-335.

Wilson, J.A., R.L. Lochmiller, and D.M. Janz. 2004. Dynamics of rodent assemblages inhabiting abandoned petroleum landfarms in Oaklahoma. Ecological Applications 14:1016-1027.

Wongkongkatep, J., K. Fukushi, P. Parkpian, R.D. DeLaune, and A. Jugsujinda. 2003. Arsenic uptake by native fern species in Thailand: effect of chelating agents on hyperaccumulation of arsenic by Pityrogramma calomelanos. Journal of Environmental Science and Health A38:2773-2784.