# FINAL REPORT

# BUNKER HILL FACILITY NON-POPULATED AREAS OPERABLE UNIT 2 BIOLOGICAL MONITORING, 2007

**U.S. Fish and Wildlife Service**
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## 1.0 Background and Objectives

This report summarizes activities and results of U.S. Fish and Wildlife Service (USFWS) 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 2007. USFWS 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, 2006).

Phase I of the Comprehensive Cleanup Plan for OU-2 includes the evaluation of remedial actions on ecological conditions at the site. Biological resources monitoring under the EMP were designed to aid in this evaluation and relate the effectiveness of the overall Phase I remedy for OU-2 based on 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, 2006). Information will provide data 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.

U.S. Fish and Wildlife Service (USFWS) biological monitoring activities conducted at the Bunker Hill Facility Non-Populated Areas operable unit (OU-2) and the South Fork Coeur d'Alene River (SFCDR) in 2007 have been supported through an Interagency Agreement with USEPA. Consistent with the requirements outlined in the Record of Decision (ROD) for OU-2 (USEPA, 1992) and as stated in the recommendations and required actions outlined by USEPA (2000), these monitoring activities were designed to evaluate the status of biological resources and their habitat at the site, thereby monitoring the effectiveness of remedial actions related to those resources.

As identified in the Environmental Monitoring Plan for OU-2 (USEPA, 2006), USFWS conducted studies in 2007 designed to evaluate two components of remedy with respect to biological resources. The first component investigated the status of aquatic and terrestrial wildlife populations and habitat quality in remediated areas. These studies included the evaluation of waterfowl wetland use within OU-2. The second component evaluated exposure of biological resources to contaminants of concern, including arsenic (As), cadmium (Cd), lead (Pb), and zinc (Zn). These studies included the evaluation of riparian songbird exposure to lead in soils at Smelterville Flats and large mammal exposure to lead in soils at Smelterville Flats, the Central Impoundment Area (CIA) and Deadwood Gulch. 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, a review of relevant literature, previous studies conducted on site, and sampling site accessibility. Reference locations were not evaluated as part of 2007 studies.

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

The following sections discuss the available results from the biological monitoring activities conducted within OU-2 during 2007. Analytical results from benthic macroinvertebrate diversity and abundance surveys conducted in 2006 within the SFCDR had not been received by the date of publication of the 2006 annual report. Those results are also included here.

## 2.0 Page Ponds Wetland Complex and Smelterville Flats Waterfowl Surveys

Thousands of waterfowl utilize lower Coeur d'Alene Basin (Basin) wetland habitats during spring migration (Audet et al., 1999; USFWS, 2006). However, waterfowl habitat in the upper Basin is primarily limited to the Page Ponds and Smelterville Flats wetland complexes. Assessment of use and exposure to mining-related metals of concern at these sites is critical in evaluating OU-2 Phase I remedial activities as they pertain to the protection of the environment.

The Page Ponds wetland complex is comprised of two wetlands (East Swamp and West Swamp) occurring on the east and west sides of the Page tailings impoundment. The tailings impoundment consists of inactive flotation tailings produced by the Page Mill (USEPA, 1992). Located on top of the tailings impoundment is the Page Ponds Waste Water Treatment Plant (WTP), consisting of four aeration lagoons and a stabilization pond. As of 2007, the East and West swamps and the four aeration lagoons contained open water. The stabilization pond was dewatered in 2003.

The Smelterville Flats area is located in the west end of OU-2 within the floodplain of the South Fork Coeur d'Alene River. Uncontrolled discharges of jig and flotation tailings into the river, as well as the construction of a plank and pile dam to retain tailings within the floodplain, lead to heavy metal contamination of soil, sediments and surface waters (USEPA, 2005). Water inputs to the floodplain include the river, effluent from the Page Ponds and Smelterville wastewater treatment plants, and groundwater. These water inputs, combined with tailings removal activities, have lead to the development of several ponds and wetlands in the Smelterville Flats area.

The OU-2 Environmental Monitoring Program (EMP) identifies ecological risks to plants and animals associated with mining-related hazardous substances in OU-2 within four habitat types including riverine, palustrine, riparian, and upland habitats. Focusing on the goals for the OU-2 remedy identified in the 1992 Record of Decision (ROD), the EMP recognizes waterfowl in palustrine environments as key indicators of change (USEPA, 2006). Exposure pathways of waterfowl to contaminants of concern within OU-2 include ingestion of soil-sediment, surface water, and food resources. We conducted waterfowl surveys at the Page Ponds and Smelterville flats sites within OU-2 to quantify continued waterfowl use and types of use (i.e., feeding, loafing, and resting), and provide a measure of relative waterfowl abundance within OU-2 during the spring migration. Information will be used in conjunction with other monitoring activities (i.e., waterfowl blood lead concentrations) to help evaluate Phase I remedial actions.

## 2.1 Methods

We conducted 12 waterfowl surveys, one/week for 12 weeks, at the Page Ponds Wastewater Treatment Plant (WTP) and associated wetlands (wetland complex) and Smelterville Flats area from February to May 2007. Surveys at the Page Ponds wetland complex included observations at the 4 active WTP aeration lagoons, the lower sewage ponds north of the Trail of the Coeur d'Alenes, and the 2 wetlands occurring on the east and west side of the WTP (East and West Swamps). Survey locations at Smelterville Flats included Emerald Pond at the east end of Smelterville Flats, and 4 observation points adjacent to ponds and wetlands located north and west of the Shoshone County Airport (Figure 2-1). We conducted all surveys following UCFWO 1020.1013 (Waterfowl Survey in the Coeur d'Alene River Basin). Data collected included species identification, numbers of individual species and waterfowl behavior (i.e., feeding, loafing, and resting).

## 2.2 Results

We observed 2,753 individual waterfowl and 18 species using the Page Ponds wetland complex (Table 2-1). Individual waterfowl averaged 229 per survey. The most common species included common goldeneye (*Bucephala clangula*), mallard (*Anas platyrynchos*) and Barrow's goldeneye (*Bucephala islandica*).

We observed 81 individual waterfowl and 6 species at Smelterville Flats. Individual waterfowl averaged 6.8 per survey (Table 2-2). The most common species included mallard and Canada goose (*Branta canadensis*).

Waterfowl densities were highest in mid-March and early April at the Page Ponds wetland complex and highest at Smelterville Flats in mid-March (Figures 2-2 and 2-3).

## 2.3 Discussion

Our data demonstrate that waterfowl continue to use the Page Ponds complex as well as Smelterville Flats wetlands. We recorded an average number per survey of 229 at the Page Ponds complex. In comparison, average number of waterfowl observed using the complex per survey was 147.7, 129.5, and 162.2 in 2003, 2005 and 2006, respectively (USFWS, 2005).

Because the establishment of ponds and wetlands in the Smelterville Flats area has been fairly recent (i.e., Phase I remedial actions were completed in 2001 (USEPA, 2005), data on waterfowl use of that area were limited. However, our data show that these wetland areas continue to be used by migratory waterfowl. In addition, while the total number of waterfowl using the Smelterville Flats area appears to be relatively low, a female brooding green-winged teal was observed during another on-site assessment in 2006, suggesting increased use (i.e., waterfowl nesting and brooding) and potential exposure to mining-related metals. Data on exposure to metals of concern in soils and potential effects at the Smelterville Flats site are lacking. A waterfowl blood lead evaluation and sediment monitoring planned under in the OU2 EMP in 2008 should provide useful on contaminant exposure at this location.

Waterfowl continue to use wetlands within OU-2, including those newly developed at Smelterville Flats. Lead poisoning has been identified as the cause of death in waterfowl ingesting lead-contaminated sediment during normal feeding behavior in lower Coeur d'Alene Basin habitats (Beyer et al., 2000; USEPA, 2002). Previous authors examined waterfowl exposure to lead and associated injury in the wetland complex (McCulley et al., 1994; Mullins and Burch, 1993; Burch et al., 1996). Mean blood lead concentrations in mallards collected from the East swamp 1993-2003 (Mullins and Burch, 1993; Burch et al., 1996; Audet et al., 1999; USFWS, 2005) were all within those suggesting clinical and severe clinical poisoning in waterfowl (>0.2 mg/kg) (Pain, 1996). No downward trends have been apparent. Given this lack of apparent trend, reductions in blood lead concentrations at the Page Ponds complex may not improve without further remedial or management actions. Continued monitoring will provide valuable information regarding the continued use of the Page Pond and Smelterville wetland complexes and trends in ecological receptor exposure to mining-related metals within OU-2.

Table 2-1. Species and number of waterfowl and other notable bird species observed using Page Ponds wetland complex, Coeur d'Alene Basin, Idaho, 2005, 2006, and 2007.

| 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|
| **Species** | **Number** | **Species** | **Number** | **Species** | **Number** |
| American coot | 43 | American coot | 30 | American coot | 36 |
| American wigeon | 50 | American wigeon | 39 | American wigeon | 40 |
| Barrow's goldeneye | 107 | Barrow's goldeneye | 192 | Barrow's goldeneye | 260 |
| Blue-wing teal | 3 | Bufflehead | 32 | Bufflehead | 14 |
| Bufflehead | 6 | Canada goose | 44 | Canada goose | 30 |
| Canada goose | 51 | Common goldeneye | 1087 | Common goldeneye | 1650 |
| Canvasback | 2 | Common merganser | 6 | Common merganser | 4 |
| Cinnamon teal | 2 | Crow | 11 | Gadwall | 10 |
| Common goldeneye | 708 | Eurasian wigeon | 1 | Great blue heron | 2 |
| Common merganser | 52 | Gadwall | 6 | Green-wing teal | 138 |
| Gadwall | 15 | Green-wing teal | 64 | Killdeer | 2 |
| Great blue heron | 3 | Lesser scaup | 34 | Lesser scaup | 8 |
| Green-wing teal | 48 | Mallard | 247 | Mallard | 335 |
| Hooded merganser | 1 | Northern shoveler | 34 | Northern shoveler | 39 |
| Lesser scaup | 45 | Redhead | 52 | Redhead | 74 |
| Mallard | 182 | Ring-necked duck | 41 | Ring-necked duck | 37 |
| Northern shoveler | 60 | Ruddy duck | 1 | Ruddy duck | 1 |
| Pied-billed grebe | 1 | Wood duck | 23 | Wood duck | 73 |
| Redhead | 112 | | | | |
| Ring-neck duck | 35 | | | | |
| Ruddy duck | 1 | | | | |
| Tundra swan | 1 | | | | |
| Wood duck | 20 | | | | |

Table 2-2. Species and number of waterfowl and other notable bird species observed using Smelterville Flats ponds and wetlands, Coeur d'Alene Basin, Idaho, 2006 and 2007.

| 2006 | | 2007 | |
|---|---|---|---|
| **Species** | **Number** | **Species** | **Number** |
| American coot | 2 | Barrow's goldeneye | 2 |
| American wigeon | 1 | Canada goose | 11 |
| Barrow's goldeneye | 5 | Common merganser | 5 |
| Bufflehead | 4 | Mallard | 52 |
| Canada goose | 21 | Northern pintail | 1 |
| Common goldeneye | 2 | Redhead duck | 6 |
| Common merganser | 7 | Wood duck | 2 |
| Great blue heron | 3 | | |
| Green-wing teal | 24 | | |
| Hooded merganser | 2 | | |
| Mallard | 52 | | |
| Northern pintail | 6 | | |
| Redhead duck | 4 | | |

Figure 2-1. Waterfowl survey points and adjacent wetland habitats, Coeur d'Alene Basin Operable Unit 2, Idaho, 2007.

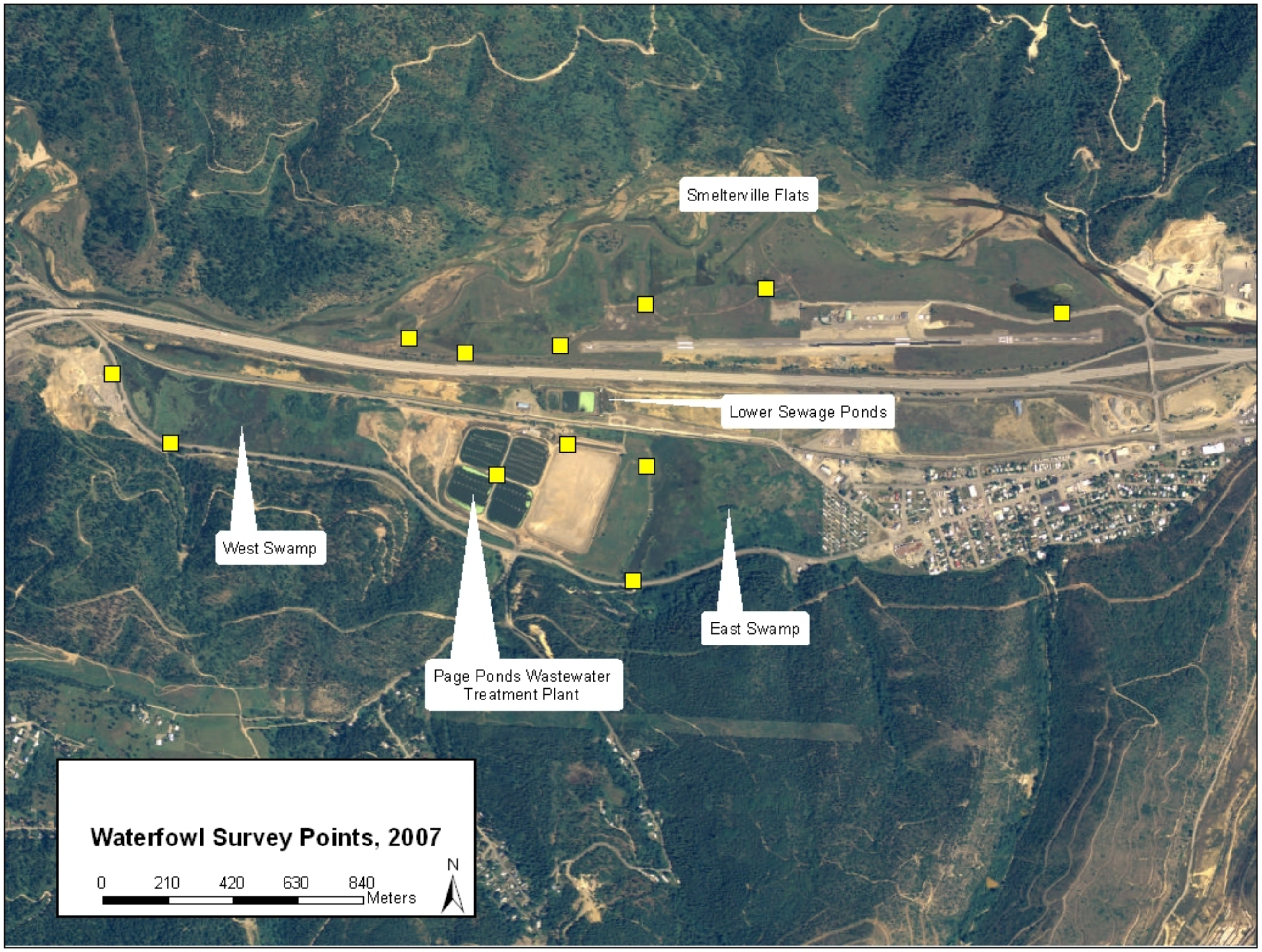


Figure 2-2. Number of waterfowl observed per survey at Page Ponds wetland complex, Coeur d'Alene Basin, Idaho, 2005, 2006, and 2007.

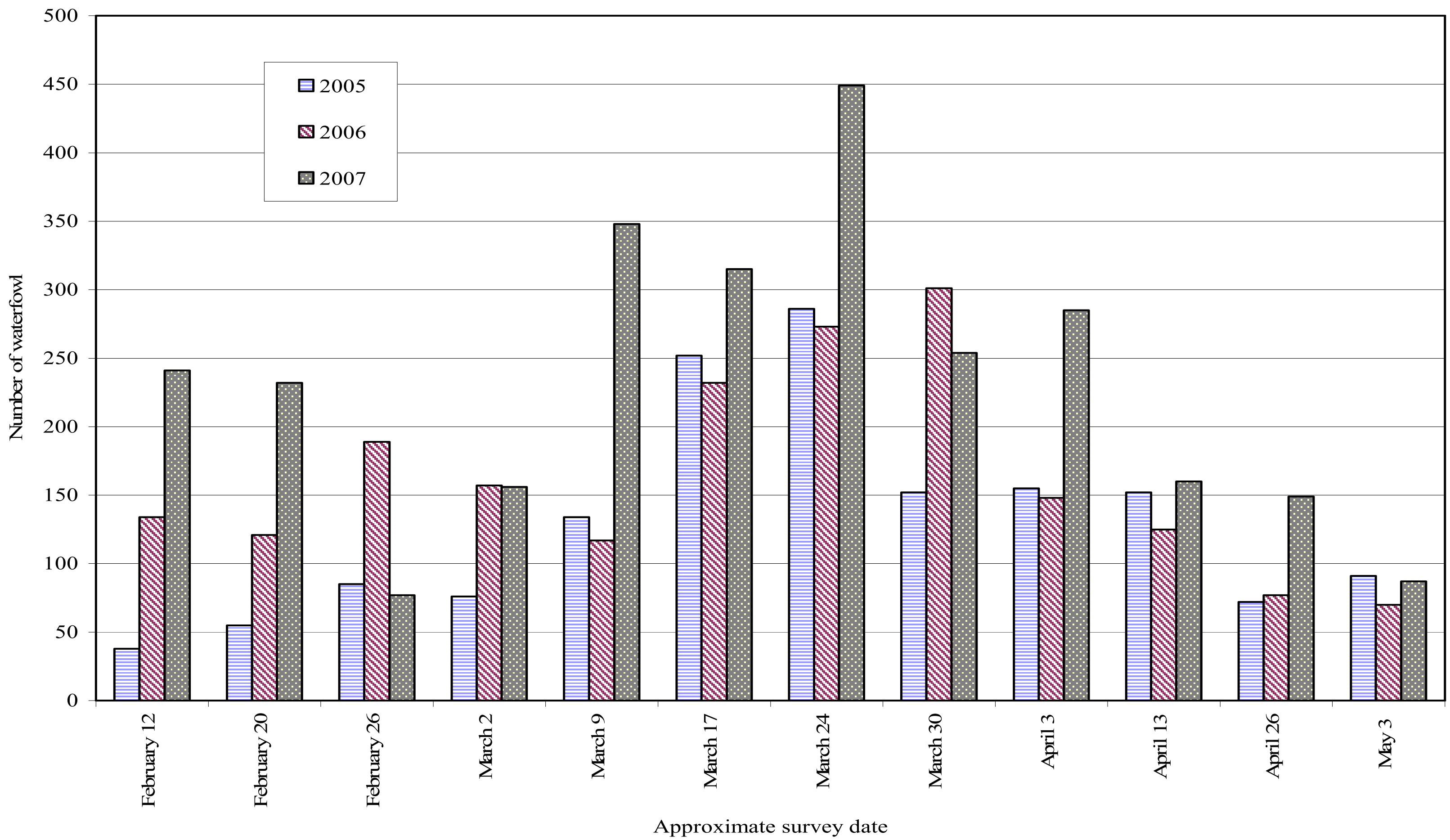
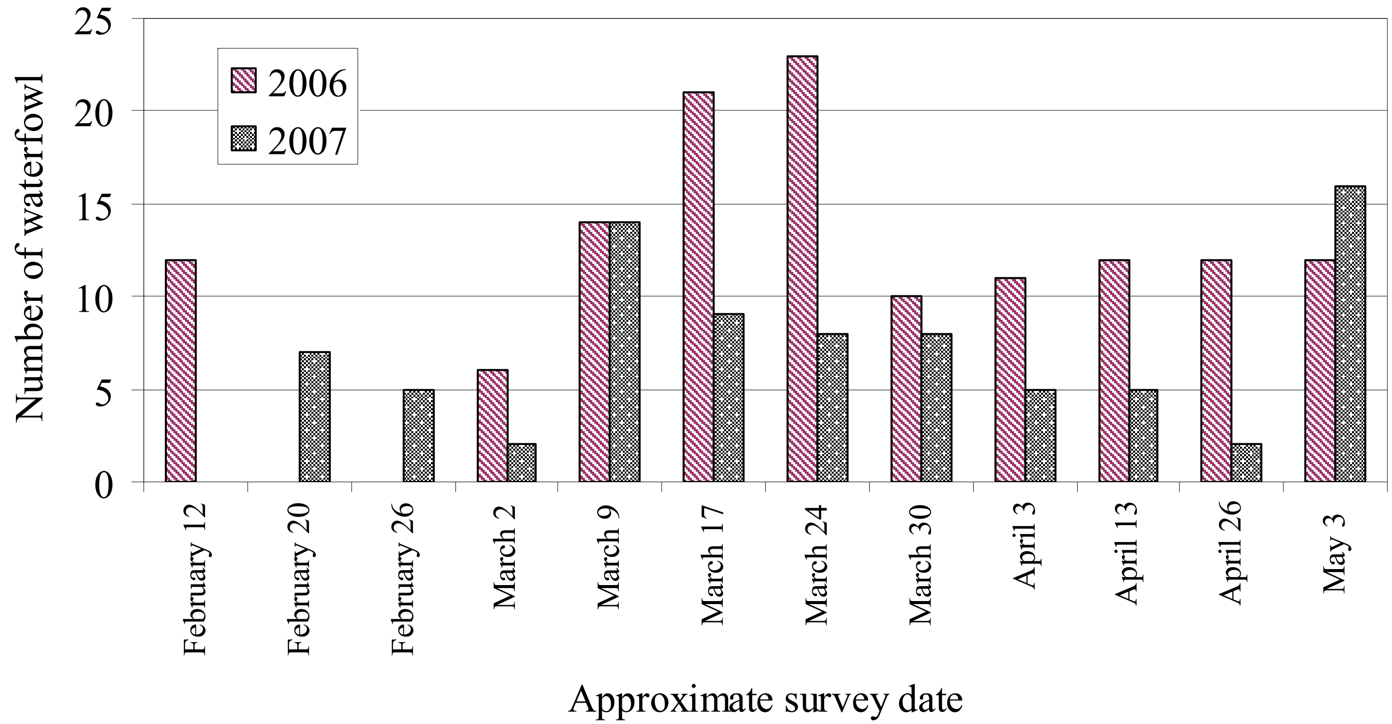


Figure 2-3. Number of waterfowl observed per survey at Smelterville flats, Coeur d'Alene Basin, Idaho, 2007.



## 3.0 Riparian Songbird Blood Lead

The Coeur d'Alene Basin contains elevated lead (Pb) and other metal concentrations in soil, sediment, and water from historic mining, milling, and smelting operations (USEPA, 2001a; USEPA, 2001b; USEPA, 2002). Elevated Pb within the Basin continues to cause toxicity in a number of migratory birds in several Basin habitats (Blus et al., 1995; Audet et al., 1999; Johnson et al., 1999; Beyer et al., 2000; Hansen, 2007). Ingestion of Pb-contaminated soil and sediment has been shown to be the primary pathway of exposure (Sileo et al., 2001; Hansen, 2007).

Remedial activities within OU-2 have addressed surface soil contamination in a number of areas, including Smelterville Flats. Smelterville Flats is located adjacent to the SFCDR within the floodplain at the west end of OU-2. Soil and sediments at the site were 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). TerraGraphics and Ralston (2006) estimated that this area included more than 1,488,000 cubic yards of tailings. Target remedial goals for soil and sediment at the site were 3,000 mg/kg Pb and 3,000 mg/kg zinc north of I-90 (USEPA, 2005). Several phases of remedial activities occurred at Smelterville Flats beginning in 1997 (TerraGraphics and Ralston, 2006). Excavation of contaminated material typically reached depths of 4-6 feet, with up to 16 feet of vertical material removed. The final quantity of excavated material transported to the Central Impoundment Area repository was 1,208,448 cubic yards. 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).

Riparian songbirds were selected as representative receptors within the EMP to aid in the evaluation of success in reducing ecological exposure to metals of concern at Smelterville Flats. Riparian songbird blood Pb concentrations were examined in 2007 to evaluate ongoing exposure to Pb in soils. Survey methods followed those used by Hansen (2007) for songbird blood Pb surveys for the overall Coeur d'Alene Basin. Results can thus be compared to those in evaluating riparian songbird exposure to Pb at this partially remediated location in relation to those at other locations. Blood Pb and relationships between soil Pb and blood enzyme (delta-aminolevulinic acid dehydratase, ALAD) activity developed by Hansen (2007) can also be used to determine potential songbird risk at this location.

Previous surveys evaluated blood Pb in birds from the Coeur d’Alene Basin (Hansen, 2007). Those surveys serve as the baseline condition. This was the first songbird blood Pb survey conducted under the EMP (USEPA, 2006). Information gathered as part of this effort will aid in the evaluation of cumulative effects of Phase I remedial actions in OU-2 with respect to ecological conditions (USEPA, 2006) and provide an index trend of riparian health as it pertains to the success of remedial activities in protecting ecological receptors from exposure to metals of concern. Subsequent surveys are scheduled to take place every 5 years beginning 2012.

## 3.1 Methods

Song sparrows (*Melospiza melodia*), American robin (*Turdus migratorius*) and Swainson's thrush (*Catharus ustulatus*) were targeted for blood collection. These species were selected because of their relative abundance in the Basin, because the Coeur d'Alene Basin Risk Assessment concluded these three species were at relatively high risk in the basin (USEPA, 2001b), and based on previous research (Blus et al., 1995; Audet, 1997; Johnson et al., 1999; Hansen, 2007). Birds were captured using 12m by 3m mist nets placed at 23 sites concentrated along the bank of the SFCDR within forested riparian corridor habitat (Figure 3-1).

Individuals from target species were removed from nets, placed into cloth bags and transported to the on-site processing station. Birds of other species were removed from nets and released on site. Each bird collected was aged, sexed and identified to species. Blood sampling followed UCFWO SOP #1019.3765 (*Collection and preservation of blood from small birds for laboratory analysis*). A new set of powder-free gloves were worn by the sampler for each bird to avoid cross contamination. Blood was sampled from the jugular vein of each bird using a 1-ml syringe equipped with a 26-gauge needle. Needles/syringes were prepared with an internal rinse of heparin to help avoid blood clotting in the syringe. The sampling area was wiped with a cotton ball dipped in alcohol, and a target of at least 200 µl of blood drawn. A Kimwipe was pressed against the puncture site following blood collection until the bleeding was determined to have stopped (typically 30 seconds to 2 minutes). Samplers clipped the outer tail feather of each bird sampled to identify sampled birds should they be caught again (recaptured birds were released at the net site and not resampled). Each bird was offered a sugar water solution for energy replacement and released or placed back into a cloth bag to recover and then released when the bird appeared alert and in good condition. The needle was removed from the syringe and blood placed into labeled, chemically cleaned laboratory vial. Blood mass was recorded to 0.001g. Vials were placed in a cooler on dry ice and transported to the UCFWO for storage in a -20º C freezer until being shipped on dry ice to USEPA's contract laboratory.

Laboratory results were reported as wet weight. We used the songbird blood percent moisture value provided by Hansen (2007) (81.4%) to convert results to dry weight. Blood Pb is reported as mg/kg dry weight (mean $\pm$ standard deviation). Analysis of variance was used to examine blood Pb differences between species at Smelterville Flats and between birds sampled at Smelterville Flats and those of the same species sampled by Hansen (2007) at a reference location along the North Fork of the Coeur d'Alene River. Kolmogorov-Smirnov (K-S) tests were used to evaluate normality of distributions within species. Leven's test was used to evaluate homogeneity of variances. Nonparametric Kruskal-Wallis tests were used to examine differences between sexes and ages for song sparrows due to small sample sizes. Statistical significance in all tests was determined at $\alpha = 0.05$.

In order to aid in blood Pb interpretations, soil samples were also collected at net locations where target birds were captured. A composite of five grab samples was collected at each net (grabs consisted of surface scoops taken from each of the two net pole locations, the center of the net, and from either side of the net ~5 m from the center in a direction perpendicular to the net). Grab samples were mixed in the field with stainless steel bowls and spoons, transported to the UCFWO, bench dried and analyzed with a portable X-ray florescence analyzer (Innov-X Systems, Inc., Woburn, MA). Analysis of variance and Pierson product moment correlations were used to evaluate correlations between blood Pb and soil Pb at capture nets. Net locations were also divided into four groups based on their geographical location (nets 1-10, nets 11, 12 and 24, nets 13-20, and nets 21-23) (Figure 3-1). Pierson product moment correlations and analysis of variance were then also used to evaluate soil Pb concentrations in each net group and compare blood Pb correlations with soil concentrations at each net.

## 3.2 Results

Forty-four American robins and song sparrows were captured and processed: one juvenile, eight adult male and two adult female robins, and 15 juvenile, 10 adult male and seven adult female song sparrows and one song sparrow that escaped prior to ageing, sexing or weighing (only blood Pb data from this bird was included in analysis). Sample numbers, weight and blood Pb statistics are provided in Table 3-1.

Robin blood Pb ranged from 1.77-4.42 mg/kg (3.37 $\pm$ 0.69). Song sparrow blood Pb ranged from 0.47-2.84 mg/kg (1.69 $\pm$ 0.58). Blood Pb was normally distributed in both robins (K-S $d$ = 0.15) and song sparrows (K-S $d$ = 0.07) and variances were homogeneous ($F_{1,42}$ <0.01; $P$ = 0.98). Mean blood Pb was higher in robins than song sparrows ($F_{1,42}$ = 63; $P$ <0.01) (Figure 3-2). Robin sample sizes precluded blood Pb comparisons between age and sex. Mean song sparrow blood Pb did not differ between juveniles and adults ($H$ = 0.63; $P$ = 0.43), but was higher in adult females (2.02 $\pm$ 0.54) than adult males (1.34 $\pm$ 0.58) ($H$ = 5.04; $P$ = 0.02). Mean blood Pb was were higher than those from Hansen's (2007) reference location for both robin (0.24 $\pm$ 0.210) ($F_{1,15}$ = 112; $P$ <0.01) and song sparrow (<0.19 $\pm$ 0.10) ($F_{1,54}$ = 182; $P$ <0.01) (Figure 3-2).

Soil Pb concentrations at net sites ranged from 2,411-10,930 mg/kg (4,027 $\pm$ 1,608) (Table 3-2). Mean soil Pb did not differ among net groupings ($F_{3,39}$ = 1.19; $P$ = 0.32). Blood Pb did not correlate well with net soil Pb for robin ($r^2$ = 0.08) or song sparrows ($r^2$ <0.01).

## 3.3 Discussion

Hansen (2007) demonstrated that riparian songbirds using the Coeur d'Alene Basin accumulated Pb above suggested toxicological levels. Despite previous remedial activities at Smelterville Flats, results of this study demonstrate that representative songbirds using the area continue to be exposed to and accumulate Pb at concentrations observed to cause toxicity.

When using Hansen's (2007) songbird blood moisture content, Pain's (1996) suggested blood Pb toxicity threshold concentrations for waterfowl result in thresholds of <1 mg/kg dw as background, 1-2.5 as subclinical poisoning, 2.5-5 as clinical poisoning and >5 as severe clinical poisoning. All robins sampled had blood Pb concentrations above those suggested to be background levels, and 90% (10/11) had concentrations in the range suggested to be clinical poisoning. Likewise, 88% (29/33) of song sparrows sampled had concentrations above suggested background levels, 79% (26/33) had concentrations in the range suggested to be subclinical poisoning, and 9% (3/33) had concentrations in the range suggested to be clinical poisoning. Robin and song sparrow home ranges (<1 acre to a couple acres) (Howell, 1942; Young, 1951; Halliburton and Mewaldt, 1976; Pitts, 1984) and the exposure pathway analysis and blood Pb concentrations in birds sampled from the Coeur d'Alene Basin reference area provided by Hansen (2007) suggest that soils in the Smelterville Flats area were the primary source of exposure.

Reduced ALAD activity is a clinical biochemical indicator of Pb exposure (Hoffman et al., 1981). Data on ALAD from other studies suggest that exposure to Pb in soils at Smelterville Flats is resulting in adverse effects to songbirds. Hansen (2007) observed that most birds with blood Pb concentrations >1 mg/kg dw (the suggested range above background levels) in the Coeur d'Alene Basin had ALAD reductions of >50%. All robins and 88% (29/33) of song sparrows sampled at Smelterville Flats in this study had blood Pb concentrations >1 mg/kg dw. Furthermore, Hansen (2007) developed a regression model for expected ALAD reduction based on soil Pb concentration. Using this regression, Pb contamination at our net sites would result in 71-100% ALAD reduction. In another study, Beyer et al. (1988) exposed red-winged blackbirds (*Agelaius phoeniceus*), brown-headed cowbirds (*Molothrus ater*) and common grackles (*Quiscalus quiscula*) to gradually increasing doses of Pb until 50% of individuals from each species died. Surviving birds of each group were then euthanized and their blood Pb concentration and ALAD activity measured. Average time to 50% deaths ranged from 61-73 days. Median ALAD reduction in euthanized birds ranged 81%-95%. These data would suggest that chronic ALAD reductions in this range would approximate a LC50 for some passerines (50% of birds with concentrations within this range would die). Given these data and the regressions developed by Hansen (2007), blood Pb concentrations in soil and blood from song sparrows and robins at Smelterville Flats would suggest that songbird exposure to Pb in this area is resulting in adverse effects, including potential mortality.

Hansen (2007) provided a correlation between average Pb concentrations in soil and songbird blood at different locations. We did not observe such a correlation for soil at each net site within the Smelterville Flats location. This was likely due to the variability in soil Pb concentrations among net sites (range from 2,411 to 10,930 mg Pb/kg) and the fact that song sparrow and robin home ranges (~0.5 to several acres) (Howell, 1942; Young, 1951; Halliburton and Mewaldt, 1976; Pitts, 1984) likely encompassed more than one net site. Individuals were likely exposed to a wide range of soil Pb concentrations from more than one net area, thus reducing the correlation between soil Pb at a particular net site and blood Pb in an individual bird. Even though the high variability of soil Pb at Smelterville Flats prevents a correlation of blood Pb to soil Pb, blood Pb in songbirds was less variable than soil Pb. The mean soil Pb from all nets where birds were collected was 4,971 mg/kg with a standard deviation (sd) of 2,510 and relative variance[1] of 50%. In contrast, song sparrows had a mean blood Pb of 1.69 mg/kg and sd of 0.58, and American robin had a mean blood Pb of 3.37 mg/kg and sd of 0.69 (Table 3-1). The relative variance of blood Pb data was 35% and 21%, respectively. Since relative variance is a way to express data variance relative to the magnitude of the mean, songbird blood Pb has much lower relative variance compared to soil Pb. The data show that songbirds are integrating their exposure to Pb in soil by effectively averaging their exposure over a wider area that contains more variable soil Pb concentrations. Biological sampling of songbird blood Pb may be a better monitoring tool than soil sampling because of its lower relative variance.

Remedial actions were conducted on a large portion of Smelterville Flats (TerraGraphics and Ralston, 2006). Remedial boundaries were based on descriptions and hand drawn maps (depicted by TerraGraphics and Ralston, 2006). Songbird sampling locations for this study appear to fall outside of these boundaries. However, it is unclear whether the Pb contamination at the site above remedial action cleanup goals (3,000 mg/kg; USEPA, 2005) is a remnant of a lack of remedial action in songbird sampling areas or subsequent contamination through deposition from upstream sources. Regardless, this contamination appears to be negatively affecting riparian songbirds. These data will inform any potential future remedial action scope and goals in protecting migratory songbirds.

[1] The sd (or variance) of the sample measures has a magnitude that is dependent on the magnitude of the data. Relative variance is a calculation that expresses the variance of the sample measures relative to the magnitude of the mean, and is calculated as the sd divided by the mean, expressed as percent.

Table 3-1. Riparian songbirds captured and processed for blood lead analysis, Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2007.

| **Species** | **N** | **Mean weight (g)** | **Mean blood lead (mg/kg dw)** | **Standard Deviation** |
|---|---|---|---|---|
| **American Robin** | | | | |
| Juvenile | 1 | 54.7 | 3.65 | - |
| Adult male | 8 | 78.7 | 3.35 | 0.82 |
| Adult female | 2 | 77.85 | 3.32 | 0.11 |
| All American robin | 11 | | 3.37 | 0.69 |
| **Song sparrow** | | | | |
| Juvenile | 15 | 19.86 | 1.79 | 0.51 |
| Adult male | 10 | 23.59 | 1.34 | 0.58 |
| Adult female | 7 | 21.74 | 2.02 | 0.54 |
| Unknown | 1 | - | 1.23 | - |
| All song sparrow | 33 | - | 1.69 | 0.58 |

Table 3-2. Soil lead concentrations (mg/kg dw) at song bird net sites, Smelterville Flats, OU-2, Coeur d'Alene Basin, Idaho, 2007.

| **Net Number** | **Soil Concentration** |
|---|---|
| 1 | 2411 |
| 3 | 4374 |
| 4 | 2953 |
| 5 | 3987 |
| 7 | 4338 |
| 8 | 10930 |
| 12 | 3577 |
| 14 | 9448 |
| 15 | 5687 |
| 18 | 5973 |
| 19 | 2477 |
| 21 | 5921 |
| 22 | 4238 |
| 24 | 3280 |
| | |
| Mean | 4971 |
| Standard deviation | 2510 |

Figure 3-1. Riparian songbird mist net locations, Smelterville Flats, Operable Unit 2, Coeur d'Alene Basin, Idaho, 2007.

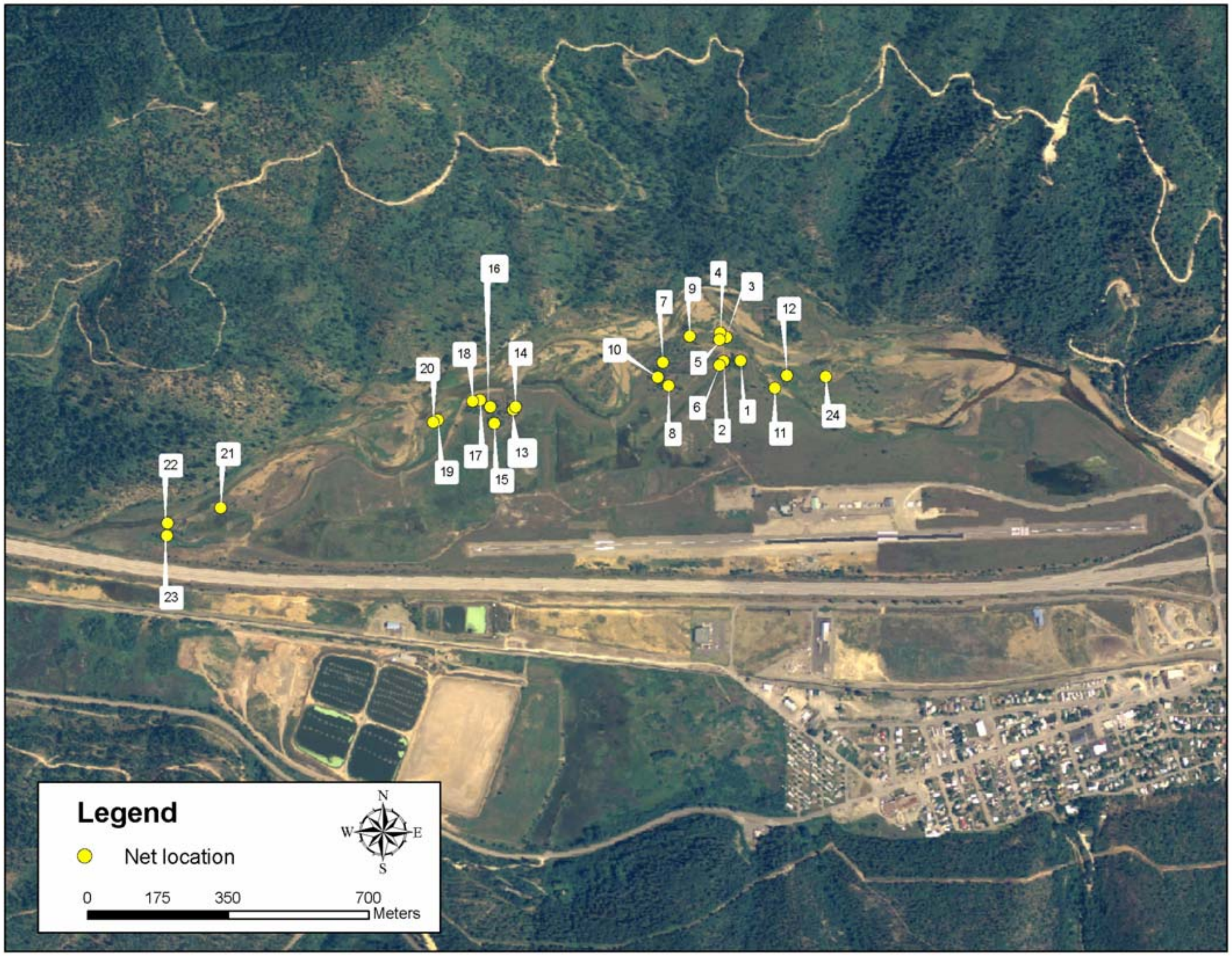
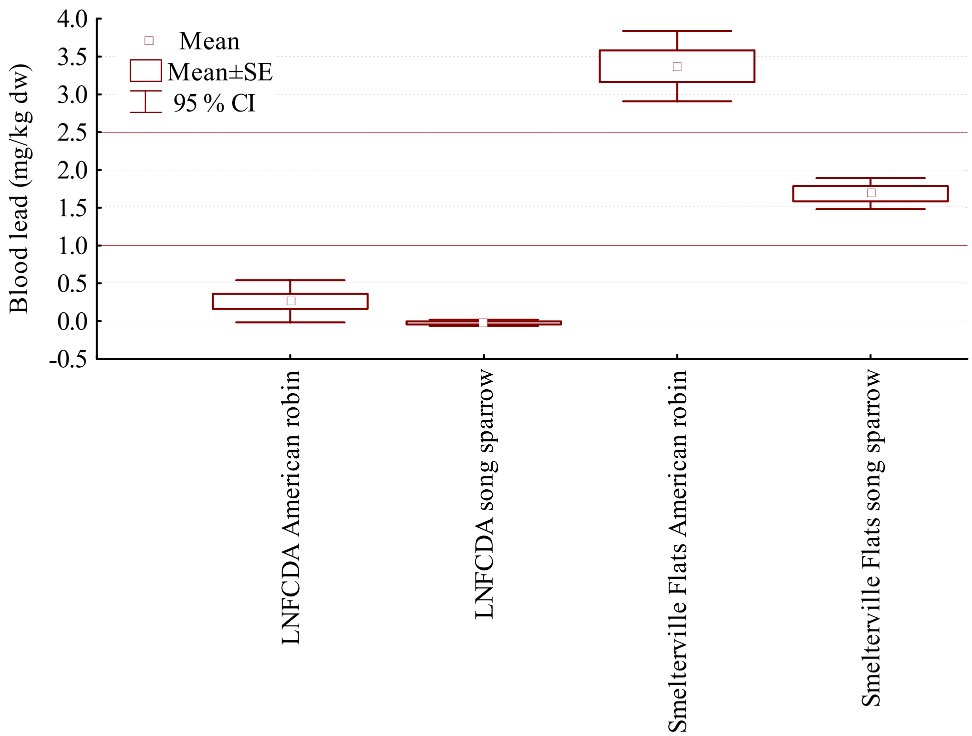


Figure 3-2. Blood lead concentrations (mg/kg dw) in American robins and song sparrows, Smelterville Flats and a reference area (Little North Fork Coeur d'Alene River; Hansen, 2007), Coeur d'Alene Basin, 2008[a].




[a]Blood lead concentrations <1.0, 1-2.5 mg/kg dw and >2.5 mg/kg dw correspond to suggested background levels, subclinical, and clinical poisoning thresholds, respectively (Hansen, 2007).

## 4.0 Wildlife Fecal Soil Ingestion and Metals Evaluation

Wildlife ingest soil or sediment while foraging (Beyer et al., 1994). Ingested soil supplies necessary nutrients such as sodium or calcium, but can also expose animals to parasites and pathogens (Hui, 2004). Soil ingestion can also be a principle route of exposure of wildlife to contaminants of concern, such as mining-related metals prevalent in the Coeur d'Alene Basin environment. Analysis of feces is one way to evaluate species-specific soil ingestion rates and exposure to metals via the soil ingestion pathway (Beyer et. al., 1994). Beyer et al. (1998) used this technique to establish a direct correlation between lead toxicosis in waterfowl and the ingestion of lead-contaminated sediment in the Coeur d'Alene Basin.

Percent acid-insoluble ash (%AIA) and soil ingestion rates (%Soil) are metrics developed to determine soil ingestion. Percent acid-insoluble ash is an estimate of the soil content of feces. The soil ingestion rate is calculated using the dry weight of the sample, the weight of the %AIA in the sample, and the estimated digestibility of each species' diet (Beyer et al., 1994; Beyer et al., 1998).

Biological resource monitoring under the EMP was designed to provide information needed to evaluate cumulative effects of Phase I remedy in terms of improving ecological conditions at the site (USEPA, 2000). Monitoring includes analyses of large mammal fecal samples to evaluate exposure to metals of concern through soil ingestion (USEPA, 2005). We collected large mammal fecal samples from OU-2 remediated areas in 2007 to assess soil ingestion and metals exposure in terms of the effectiveness of remedial actions related to those resources.

## 4.1 Methods

Fecal sample collection followed UCFWO SOP #1019.3736 (*Fecal sample collection for contaminant and sediment ingestion analysis*). We conducted opportunistic collection of deer (*Odocoileus spp.*), elk (*Cervus elaphus*), coyote (*Canis latrans*) and black bear (*Ursus americanus*) feces within OU-2 in 2007 at Smelterville Flats, Deadwood Gulch and the Central Impoundment Area (CIA). Samples were not collected from Government Gulch or Magnet Gulch due to private development activities within those sites. We used nitrile gloves to collect fecal samples that appeared fresh, intact and relatively free from soil and debris. Samples were placed in certified pre-cleaned jars. Each sample was transported on wet ice to the UCFWO and stored at -20º C. Each sample was then split. Samples were shipped overnight on dry ice to USEPA's Manchester Environmental Laboratory (Port Orchard, WA) for analysis of aluminum (Al), cadmium (Cd), lead (Pb) and zinc (Zn). Splits were shipped overnight on dry ice to the USGS Patuxent Wildlife Research Center (Beltsville, MD) for %AIA analysis. We calculated %Soil from the %AIA content of the feces and the estimated digestibility of the diet using Beyer et al. (1994). Aluminum is an element common in soil but highly indigestible in an animal's gut (Cherney et al., 1983; Beyer et al., 2007). Aluminum concentrations were therefore used independently to estimate relative soil ingestion (Beyer et al., 2007) and help corroborate acid-insoluble ash content.

We did not collect fecal samples from reference locations in 2007. However, fecal samples from Little North Fork Coeur d'Alene River (LNF CdA) reference locations had been collected for OU-2 monitoring activities conducted in 2002, 2003, and 2005 (USFWS, 2003; USFWS, 2005). We used these values for comparison with 2007 OU-2 results. All reference values used herein are taken from previous evaluations (USFWS, 2003; USFWS, 2005).

All metal concentrations are reported as mg/kg dry weight (dw). Fecal metal concentrations, %AIA, and %Soil were not normally distributed (Anderson-Darling, normality test; $P < 0.05$). Kruskal-Wallis H multiple comparisons and two-sample Mann-Whitney with confidence interval tests were therefore used to evaluate differences among and within species and locations and between years. Statistical differences were evaluated at $\alpha = 0.05$.

## 4.2 Results

We collected a total of 12 deer and 22 elk fecal samples from Deadwood Gulch and Smelterville Flats (Table 4-1). We did not collect elk or deer samples from the CIA due to the lack of fresh droppings. We also collected one coyote sample from the CIA and three black bear samples from Deadwood gulch.

### 4.2.1 Fecal Sediment Content

The mean %Soil from the coyote and bear samples was less than 2%. Mean %Soil for deer was 3.04 at Deadwood Gulch and less than 2% at Smelterville Flats. Mean %Soil for elk was 5.55 at Deadwood Gulch and less than 2% at Smelterville Flats.

No difference existed in %Soil in deer samples between Smelterville Flats and Deadwood Gulch ($W = 36.0$; $P = 0.626$). Deer samples from reference areas had higher %Soil than those from Deadwood Gulch ($W = 42.0$; $P = 0.03$) and Smelterville Flats ($W = 81.0$; $P = 0.08$). Elk samples from Deadwood Gulch had higher %Soil than those from Smelterville Flats ($W = 185.0$; $P = 0.002$) and reference areas ($W = 368.0$; $P = 0.001$). No differences existed for %Soil in elk samples between Smelterville Flats and reference areas ($W = 142.0$; $P = 0.06$).

No differences existed in %Soil between deer and elk samples from Deadwood Gulch ($W = 30.0$; $P = 0.126$) or Smelterville Flats ($W = 53.0$; $P = 0.353$). Percent soil in pooled area deer samples were less than reference area samples ($W = 158.0$; $P = 0.013$). There were no differences in %Soil between pooled OU-2 assessment areas and reference areas for elk.

### 4.2.2 Fecal Metal Concentrations

The small coyote and bear sample sizes precluded statistical analysis for metals. However, the mean Cd concentration from the coyote sample (0.40 mg/kg dw) was slightly lower than the reference mean (0.59; USFWS, 2003; USFWS, 2005). Means for Pb (8.13) and Zn (0.127), however, were 1.5 and 1.3 times higher, respectively. Mean bear fecal Cd (1.87), Pb (14.47), and Zn (374) were 1.4, 13.7, and 4.1 times higher, respectively, than mean reference concentrations (1.63, 1.06 and 0.93, respectively).

Statistics for deer and elk metals are provided in Table 4-2. No differences existed in Cd, Pb or Zn concentrations in deer and elk samples between Deadwood Gulch and Smelterville Flats. Deer and elk Cd, Pb and Zn concentrations were higher in OU-2 than reference locations. Aluminum concentrations in deer and elk samples from OU-2 were lower or the same as reference (Table 4-2; Figures 4-1 through 4-12).

### 4.3 Discussion

Soil ingestion can be a major pathway of wildlife exposure to environmental contaminants (Beyer et al., 1998; Beyer et al., 2007; USFWS, 2007). Monitoring soil uptake is an important component in evaluating remedial success in reducing wildlife exposure to contaminants in soil. On the whole, Al concentrations and percent soil in large mammal fecal samples from OU-2 suggest that these receptors are consuming similar amounts of soil as those in reference areas. However, Cd, Pb and Zn in OU-2 samples continued to be elevated relative to reference. These data suggest that the soil large mammals are being exposed to and consuming within OU-2 contain metals concentrations above those of reference areas.

Reducing soil ingestion can help reduce wildlife exposure to contaminants in soil. Reducing wildlife exposure to soil through increasing vegetation and other ground cover may be one way to do this. Aggressive activities have been undertaken to revegetate areas within OU-2, including the CIA, Deadwood Gulch and Smelterville Flats area. These activities have been relatively successful (TerraGraphics and Ralston, 2006; USEPA, 2005) and may have helped manage large mammal soil ingestion at background levels. Fecal data suggest that elk consume more soil at Deadwood Gulch than both Smelterville Flats and reference areas. This may be an indication of a continued relative lack of ground cover in the Deadwood Gulch area (USFWS, 2005). However, identifying the source of ingested soil can be complicated by wildlife movement and home ranges.

Estimated average seasonal home ranges for white-tailed deer and elk are 2.6 $km^2$ and 45.1 $km^2$, respectively (Edge et al., 1985; Beyer et al., 2007). The mean retention time of food in the digestive system of white-tailed deer and elk are approximately 23 and 25 hours, respectively (Westra and Hudsen, 1981; Beyer et al., 2007). Both species have been known to forage approximately one half the distance of their home ranges within a 24 hour period (Edge et al., 1985; Beyer et al., 2007). Because of home range size, the close proximity of Smelterville Flats and Deadwood Gulch (3.2 km; TerraGraphics, 2006) and potential food retention times, it is difficult to ascertain the exact location of soil ingestion (ingested soil may be a composite of both sites and/or other nearby areas). Elevated metal concentrations in OU-2 samples, however, suggest that OU-2 is a primary source of soil exposure.

Our 2007 results are similar to previous evaluations comparing wildlife fecal metal concentrations within OU-2 remediated areas to reference locations (USFWS, 2005). Mean overall OU-2 Cd, Pb and Zn concentrations from deer and elk in 2001, 2002, 2003 and 2007 show increased metals exposure within OU-2 remediated areas (Figures 4-5 through 4-12). Furthermore, no downward trend exists within OU-2 for any of these metals among years ($P > 0.05$).

Large mammals in upland environments are identified as key indicators of change under the EMP (USEPA, 2006). Monitoring wildlife fecal metal concentrations is intended to evaluate the effectiveness of the overall remedy with respect to ecological conditions. A downward trend in wildlife fecal metal concentrations would thus indicate less exposure over time. These results have not yet been demonstrated.

Table 4-1. Sample collection location, species, sample size (*N*), mean, standard deviation (SD), and range of metal concentration, percent soil and percent soil ingestion in wildlife fecal samples, Bunker Hill Operable Unit-2, Coeur d'Alene Basin, Idaho, 2007.

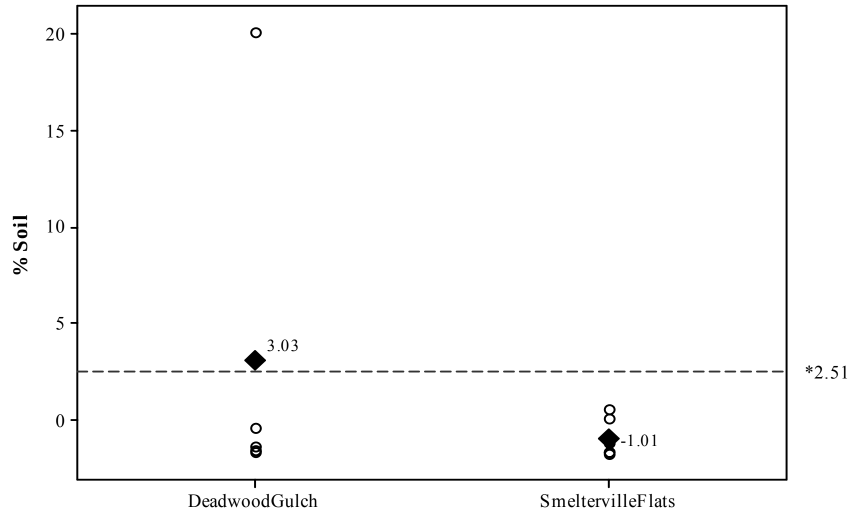
| **Location** | **Species** | | **Cd mg/kg dw** | **Pb mg/kg dw** | **Zn mg/kg dw** | **Al mg/kg dw** | ***N*** | **% soil content** | **% soil ingestion**[a] |
|---|---|---|---|---|---|---|---|---|---|
| Deadwood Gulch | Deer | Mean | 12.0 | 46.5 | 871 | 1610 | 5 | 9.75 | 3.04 |
| | | SD | 2.19 | 32 | 231 | 2481 | | 16.5 | 9.60 |
| | | Range | (9.42-14.7) | (12.7-85.8) | (615-1220) | (389-6040) | | (1.48-39.1) | (-1.65-20.2) |
| | Elk | Mean | 9.02 | 47.6 | 633 | 1659 | 12 | 11.1 | 5.55 |
| | | SD | 1.75 | 29.2 | 166 | 4030 | | 16.2 | 13.9 |
| | | Range | (5.51-11.1) | (19.4-99.1) | (340-835) | (115-14400) | | (0.85-60.6) | (-1.8-49.0) |
| Smelterville Flats | Deer | Mean | 13.1 | 44.1 | 531 | 387 | 7 | 2.96 | -1.01 |
| | | SD | 4.02 | 64.1 | 199 | 247 | | 2.15 | 0.95 |
| | | Range | (8.66-21.0) | (3-187) | (273-901) | (130-760) | | (1.08-6.49) | (-1.82-0.55) |
| | Elk | Mean | 10.2 | 24.2 | 442 | 513 | 10 | 2.77 | -0.71 |
| | | SD | 3.13 | 21.3 | 176 | 359 | | 1.51 | 0.87 |
| | | Range | (4.63-14.5) | (2.40-57.5) | (271-800) | (160-1300) | | (1.01-5.18) | (-1.71-0.69) |
| OU-2, 2007 Pooled Data | Deer | Mean | 12.6 | 45.1 | 672 | 898 | 12 | 5.79 | 0.68 |
| | | SD | 3.30 | 51.1 | 268 | 1633 | | 10.6 | 6.19 |
| | | Range | (8.60-21.0) | (3-187) | (273-1220) | (130-6040) | | (1.08-39.1) | (-1.82-20.2) |
| | Elk | Mean | 9.54 | 36.9 | 547 | 1138 | 22 | 7.31 | 2.71 |
| | | SD | 2.48 | 28 | 193 | 2984 | | 12.5 | 10.6 |
| | | Range | (4.63-14.5) | (2.40-99) | (271-835) | (115-14400) | | (0.85-60.6) | (-1.84-8.99) |
| Pooled Reference Data (LNF CdA; USFWS, 2005) | Deer | Mean | 2.28 | 4.14 | 165 | 1585 | 27 | 7.64 | 2.51 |
| | | SD | 1.96 | 2.64 | 83 | 1068 | | 7.74 | 4.69 |
| | | Range | (0.42-8.71) | (0.75-14.3) | (41.2-367) | (356-5950) | | (2.48-43.3) | (-0.07-24.9) |
| | Elk | Mean | 3.05 | 3.54 | 186 | 927 | 29 | 0.05 | 4.05 |
| | | SD | 1.51 | 2.71 | 90 | 769 | | 1.28 | 2.14 |
| | | Range | (0.52-5.07) | (0.66-9.66) | (60.6-386) | (394-3380) | | (-1.14-3.84) | (2.02-10.4) |

[a]Assumptions are made regarding acid insoluble ash contents in wildlife diets in %Soil calculations (Beyer et al., 1994). Due to these constraints, the equation can result in negative %Soil values. This merely indicates that the actual %AIA in a species' diet is below 2%.

Table 4-2. Two-sample Mann-Whitney test results (α = 0.05), Bunker Hill Operable Unit-2, Coeur d'Alene Basin, Idaho, 2007.

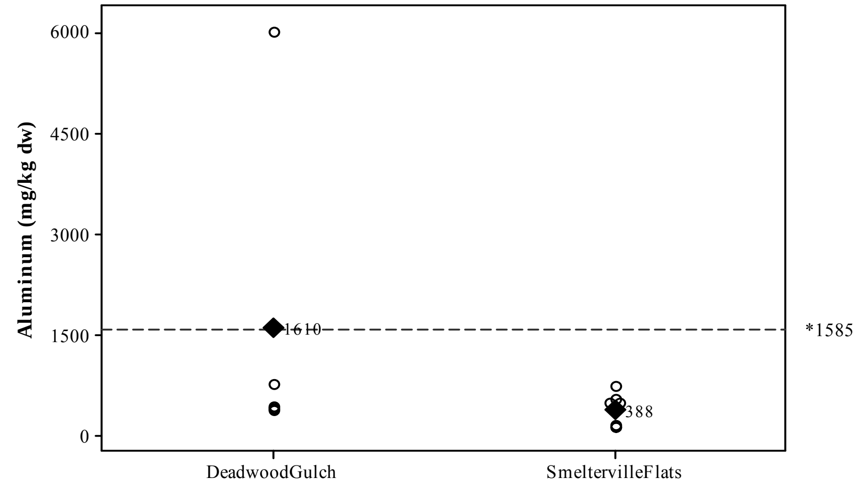
| | Deadwood Gulch | | | Smelterville Flats | | | | |
|---|---|---|---|---|---|---|---|---|
| **Deer** | ***N*** | **Mean** | **SD** | ***N*** | **Mean** | **SD** | ***W*** | ***P*** |
| % AIA | 5 | 9.75 | 16.5 | 7 | 2.96 | 2.15 | 36.0 | 0.63 |
| % Soil | 5 | 3.04 | 9.6 | 7 | -1.01 | 0.96 | 36.0 | 0.63 |
| Cd | 5 | 12.0 | 2.19 | 7 | 10.2 | 3.13 | 240 | 0.06 |
| Pb | 5 | 46.5 | 32 | 7 | 24.2 | 21.3 | 314 | 0.87 |
| Zn | 5 | 871 | 231 | 7 | 442 | 176 | 506 | 0.87 |
| **Elk** | | | | | | | | |
| % AIA | 12 | 11.1 | 16.2 | 10 | 2.77 | 1.51 | 185 | **<0.01** |
| % Soil | 12 | 5.55 | 13.9 | 10 | -0.71 | 0.87 | 185 | **<0.01** |
| Cd | 12 | 9.02 | 1.75 | 10 | 10.2 | 3.13 | 510 | 0.38 |
| Pb | 12 | 47.6 | 29.2 | 10 | 24.2 | 21.3 | 533 | 0.17 |
| Zn | 12 | 633 | 165 | 10 | 442 | 176 | 565 | **0.04** |
| | **Deadwood Gulch** | | | **LNF CdA River (reference)** | | | | |
| **Deer** | ***N*** | **Mean** | **SD** | ***N*** | **Mean** | **SD** | ***W*** | ***P*** |
| % AIA | 5 | 9.75 | 16.5 | 27 | 7.64 | 7.74 | 51.0 | 0.11 |
| % Soil | 5 | 3.04 | 9.6 | 27 | 2.51 | 4.69 | 42.0 | **0.04** |
| Cd | 5 | 12.0 | 2.19 | 27 | 2.28 | 1.96 | 150 | **<0.01** |
| Pb | 5 | 46.5 | 32 | 27 | 4.14 | 2.64 | 149 | **<0.01** |
| Zn | 5 | 871 | 231 | 27 | 165 | 83 | 150 | **<0.01** |
| **Elk** | | | | | | | | |
| % AIA | 12 | 11.1 | 16.2 | 29 | 0.05 | 1.28 | 358 | **<0.01** |
| % Soil | 12 | 5.55 | 13.9 | 29 | 4.05 | 2.14 | 368 | **<0.01** |
| Cd | 12 | 9.02 | 1.75 | 29 | 3.05 | 1.51 | 426 | **<0.01** |
| Pb | 12 | 47.6 | 29.2 | 29 | 3.54 | 2.71 | 426 | **<0.01** |
| Zn | 12 | 633 | 165 | 29 | 186 | 90 | 423 | **<0.01** |
| | **Smelterville Flats** | | | **LNF CdA River (reference)** | | | | |
| **Deer** | ***N*** | **Mean** | **SD** | ***N*** | **Mean** | **SD** | ***W*** | ***P*** |
| % AIA | 7 | 2.96 | 2.15 | 27 | 7.64 | 7.74 | 56.0 | **<0.01** |
| % Soil | 7 | -1.01 | 0.96 | 27 | 2.51 | 4.69 | 81.0 | 0.08 |
| Cd | 7 | 10.2 | 3.13 | 27 | 2.28 | 1.96 | 216 | **<0.01** |
| Pb | 7 | 24.2 | 21.3 | 27 | 4.14 | 2.64 | 196 | **<0.01** |
| Zn | 7 | 442 | 176 | 27 | 165 | 83 | 213 | **<0.01** |
| **Elk** | | | | | | | | |
| % AIA | 10 | 2.77 | 1.51 | 29 | 0.05 | 1.28 | 146 | 0.09 |
| % Soil | 10 | -0.71 | 0.87 | 29 | 4.05 | 2.14 | 142 | 0.06 |
| Cd | 10 | 10.2 | 3.13 | 29 | 3.05 | 1.51 | 340 | **<0.01** |
| Pb | 10 | 24.2 | 21.3 | 29 | 3.54 | 2.71 | 309 | **<0.01** |
| Zn | 10 | 442 | 176 | 29 | 186 | 90 | 326 | **<0.01** |

Figure 4-1. Deer fecal % Soil, Bunker Hill Operable Unit-2, 2007, Coeur d'Alene Basin, ID.



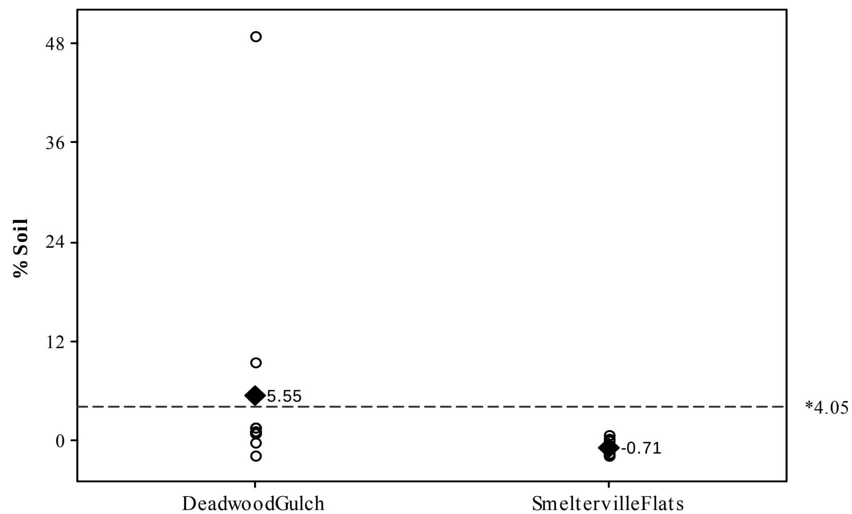

* Reference deer % Soil, Little North Fork CDAR (USFWS, 2003; USFWS, 2005).

Figure 4-2. Deer fecal aluminum concentrations, Bunker Hill Operable Unit-2, 2007, Coeur d'Alene Basin, ID.



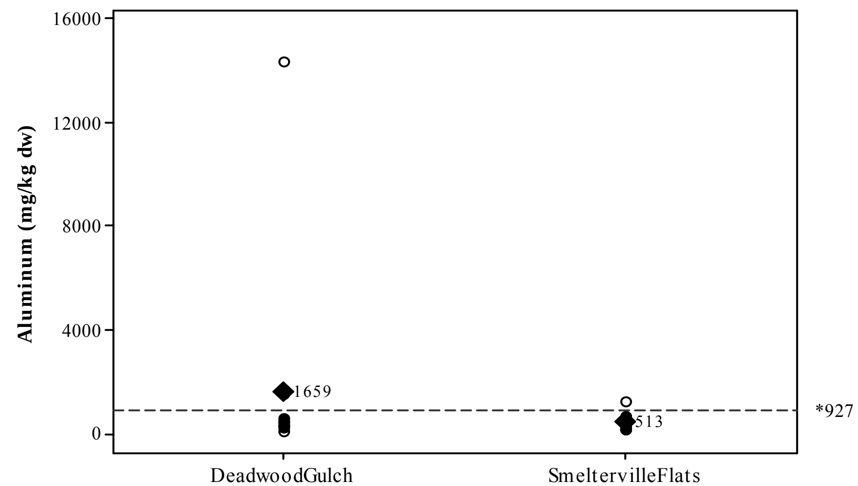

* Reference deer mean aluminum concentrations, Little North Fork CDAR (USFWS, 2003; USFWS, 2005).

Figure 4-3. Elk fecal % Soil, Bunker Hill Operable Unit-2, 2007, Coeur d'Alene Basin, ID.



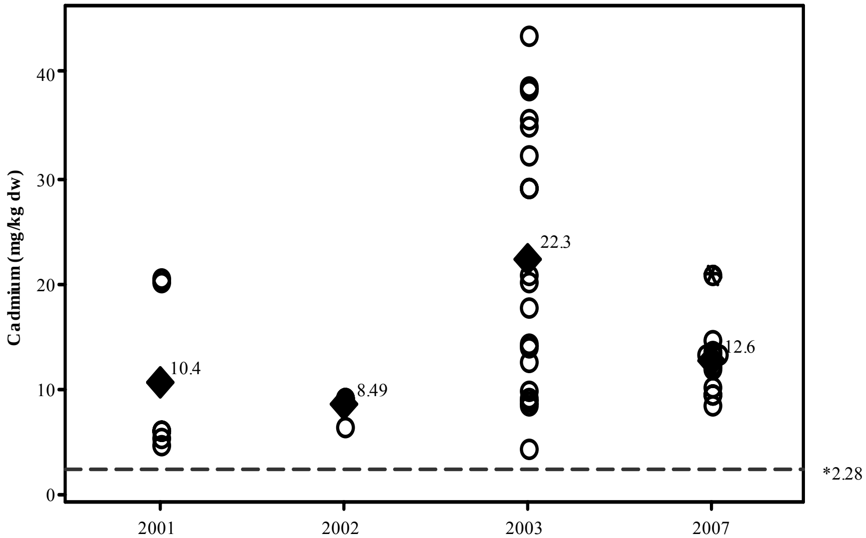

* Reference elk %Soil, Little North Fork CDAR (USFWS, 2003; USFWS, 2005)

Figure 4-4. Elk fecal aluminum concentrations, Bunker Hill Operable Unit-2, 2007, Coeur d'Alene Basin, ID.



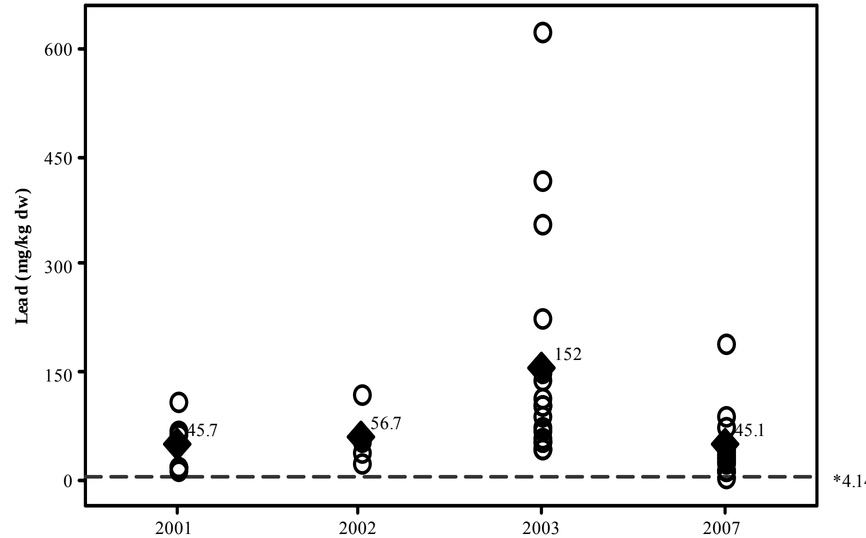

* Reference elk mean aluminum concentrations, Little North Fork CDAR (USFWS, 2003; USFWS, 2005).

Figure 4-5. Deer fecal mean cadmium concentrations, Smelterville Flats and Deadwood Gulch, Bunker Hill Operable Unit 2, 2001, 2002, 2003, and 2007, Coeur d'Alene Basin, ID.



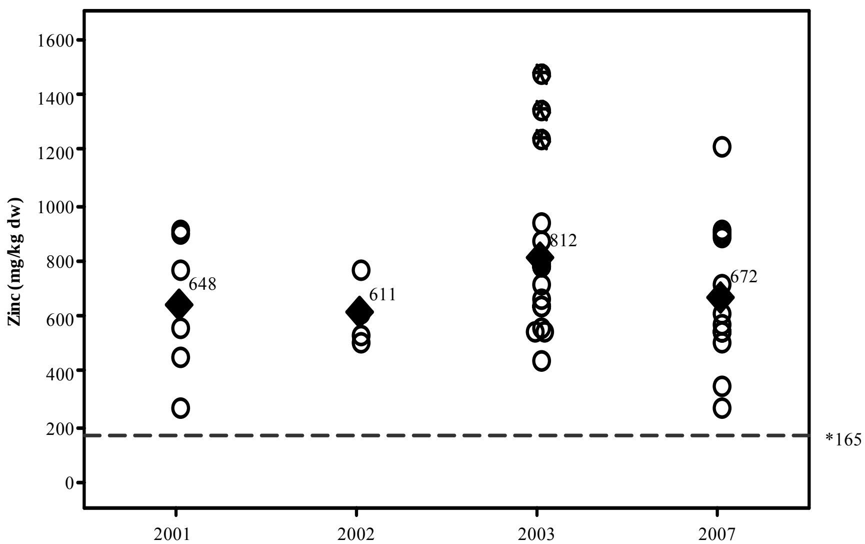

*Reference deer mean cadmium concenrations, Little North Fork CdA River (USFWS, 2005).

Figure 4-6. Deer fecal mean lead concentrations, Smelterville Flats and Deadwood Gulch, Bunker Hill Operable Unit 2, 2001, 2002, 2003, and 2007, Coeur d'Alene Basin, ID.



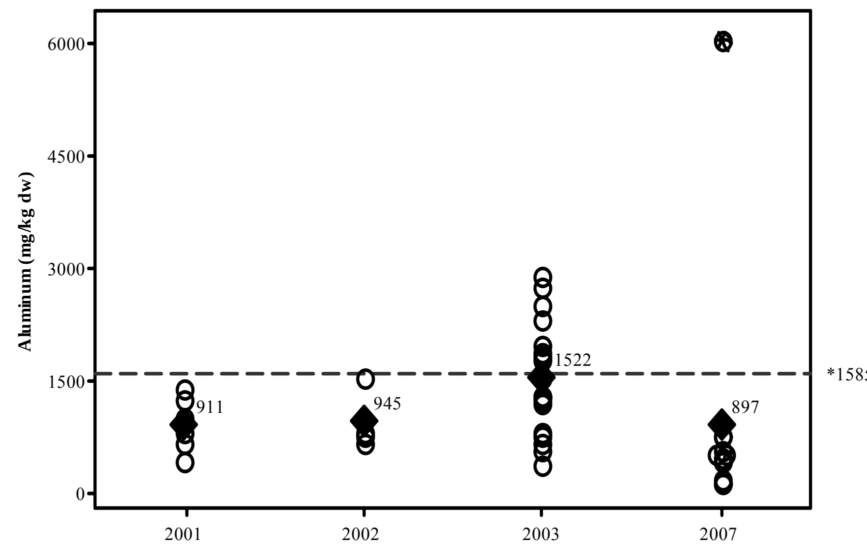

*Reference deer mean lead concentrations, Little North Fork CdA River (USFWS, 2005).

Figure 4-7. Deer fecal mean zinc concentrations, Smelterville Flats and Deadwood Gulch, Bunker Hill Operable Unit 2, 2001, 2002, 2003, and 2007, Coeur d'Alene Basin, ID.



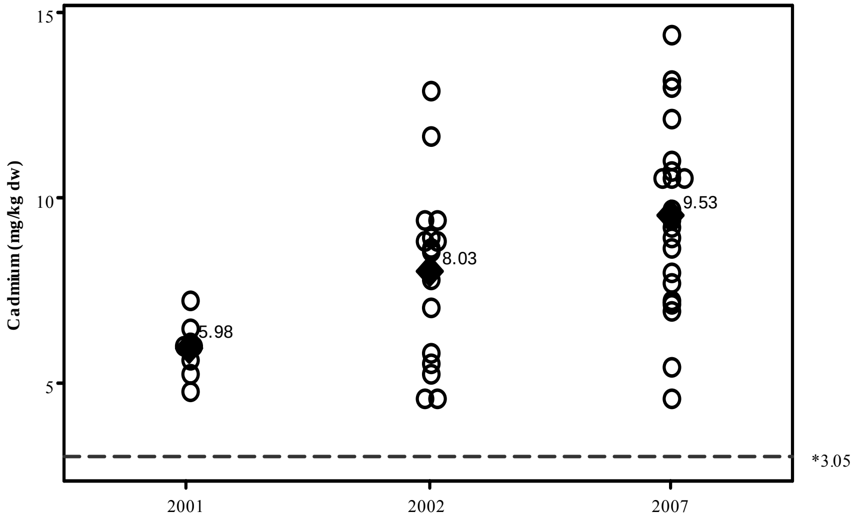

* Reference deer mean zinc concentrations, Little North Fork CdA River (USFWS, 2005).

Figure 4-8. Deer fecal mean aluminum concentrations, Smelterville Flats and Deadwood Gulch, Bunker Hill Operable Unit 2, 2001, 2002, 2003, and 2007, Coeur d'Alene Basin, ID.



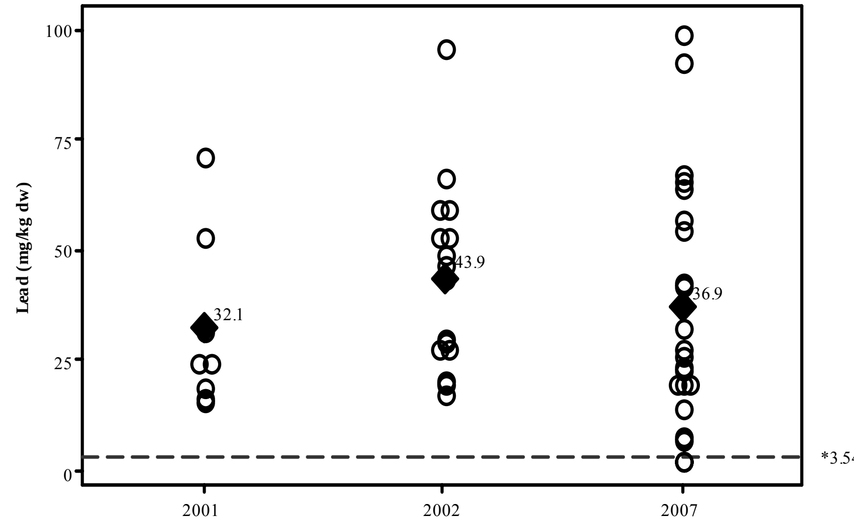

*Reference deer mean aluminum concentrations, Little North Fork CdA River (USFWS, 2005).

Figure 4-9. Elk fecal mean cadmium concentrations, Smelterville Flats and Deadwood Gulch, Bunker Hill Operable Unit 2, 2001, 2002, and 2007, Coeur d'Alene Basin, ID.



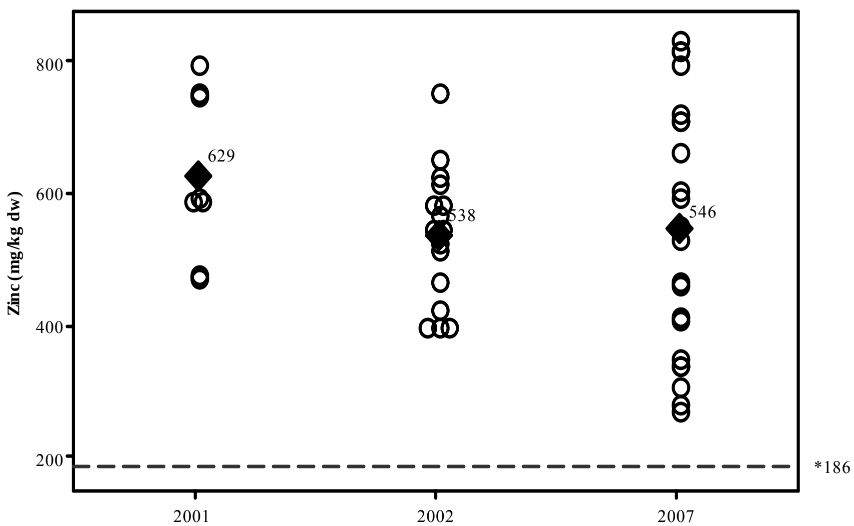

* Reference elk mean cadmium concentrations, Little North Fork CdA River (USFWS, 2005).

Figure 4-10. Elk fecal mean lead concentrations, Smelterville Flats and Deadwood Gulch, Bunker Hill Operable Unit 2, 2001, 2002, and 2007, Coeur d'Alene Basin, ID.



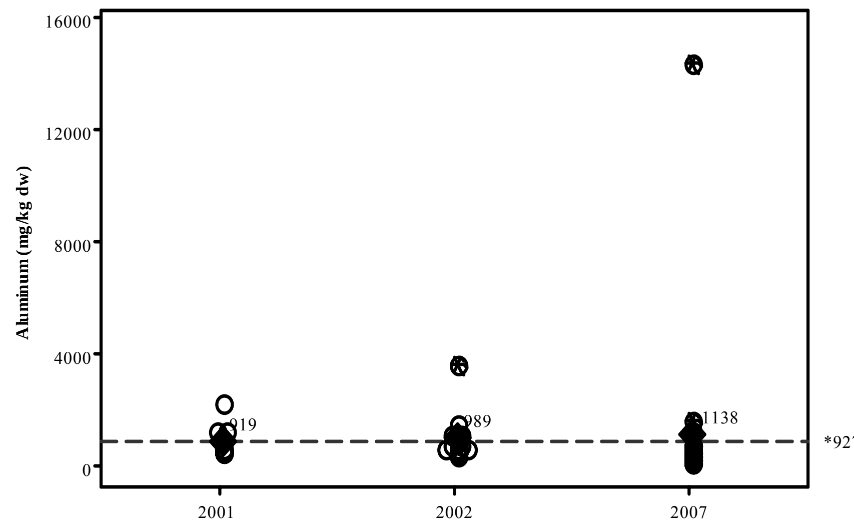

* Reference elk mean lead concentrations, Little North Fork CdA River (USFWS, 2005).

Figure 4-11. Elk fecal mean zinc concentrations, Smelterville Flats and Deadwood Gulch, Bunker Hill Operable Unit 2, 2001, 2002, and 2007, Coeur d'Alene Basin, ID.




*Reference elk mean zinc concentrations, Little North Fork CdA River (USFWS, 2005).

Figure 4-12. Elk fecal mean aluminum concentrations, Smelterville Flats and Deadwood Gulch, Bunker Hill Operable Unit 2, 2001, 2002, and 2007, Coeur d'Alene Basin, ID.




*Reference elk mean aluminum concentrations, Little North Fork CdA River (USFWS, 2005).

## 5.0 2006 Benthic Macroinvertebrate Diversity and Abundance

Healthy streams support diverse assemblages of common benthic macroinvertebrates. These organisms provide energy pathways from primary producers (algae) and organic material to consumers (fish) (McGuire, 2001). The community structure (assemblage) of benthic macroinvertebrates is commonly used as an indicator of local aquatic habitat quality (Barbour et al., 1999; Plotnikoff and Wiseman, 2001). As integral components of the aquatic ecosystem, macroinvertebrate assemblages reflect cumulative impacts of all pollutants (toxic substances, organic pollution, sedimentation) producing characteristic changes in the aquatic community (McGuire, 2001). Benthic macroinvertebrates assemblages were evaluated in the South Fork Coeur d'Alene River (SFCDR) within OU-2 in 2006 as part of biological monitoring activities identified in the EMP. Data provides a line of evidence evaluating the health of the OU-2 SFCDR habitat and the exposure of ecological receptors to metals of concern.

This was the first year of benthic macroinvertebrate sampling to evaluate diversity and abundance within OU-2 under the EMP. The objective of macroinvertebrate assemblage monitoring is to determine if there is an improvement to the aquatic environment over time (i.e., trends) with relation to cleanup activities in the SFCDR Basin (USEPA, 2005). This report presents macroinvertebrate assemblage data in the form of metrics and indices useful for evaluation of this objective. This monitoring effort provides baseline data that can later be used for trend analysis to determine if biological conditions in the SFCDR Basin are improving.

### 5.1 Methods

Methods for sampling, evaluating, and interpretation of benthic macroinvertebrate diversity and abundance are fully explained in USFWS (2007).

#### 5.1.1 Sample Locations

Benthic macroinvertebrate samples were collected at four locations (SFR-1, SFR-2, SFR-3, SFR-4) within OU-2 along randomly selected transect lines (Table 5-1; Figure 5-1). In 2006, benthic macroinvertebrates were also collected from these locations for metals residue analysis. Results from the metals evaluation were presented by USFWS (2007). These sample locations also correspond with the same locations where fish diversity and abundance and metals residue assessments were previously conducted in OU-2.

#### 5.1.2 Field Sampling

In July 2006, macroinvertebrate samples were collected using kick nets from downstream to upstream at three randomly selected transects (sites) within riffle zones at each of the four locations (n=12). The streambed substrate was "kicked" thoroughly and rocks were lifted and rubbed to remove any attached particles. Macroinvertebrates were collected into kick nets along transects across the river. The entire contents of the kick net was transferred into 3.75 L polypropylene containers and fixed in a 95% ethanol solution. Coordinates of sample collection locations were recorded with a hand-held GPS unit.

### 5.1.3 Sample Sorting and Identification

All benthic macroinvertebrate samples were submitted to Rhithron Associates, Inc. (Missoula, Montana) for organism identification to lowest possible taxonomic level. Once received by the laboratory, samples were sorted and taxonomic determinations were made. If samples contained less than 500 organisms, all individuals in the sample were identified. Subsamples of a minimum of 500 organisms were otherwise obtained following the protocols described in Plotnikoff and Wiseman (2001). Organisms were identified to the lowest practical level, typically to genus or species. Midges (Diptera: Chironomidae) were morphotyped, slide-mounted and identified using a compound microscope. Organism identifications were recorded on data sheets along with numbers of organisms. Quality assurance procedures were consistent with Plotnikoff and Wiseman (2001); however, Rhithron standard laboratory quality assurance procedures were additionally applied (Bollman, 2007).

### 5.1.4 Sample Analysis

Taxonomic data were entered into Rhithron's electronic database system (RIALIS). Data were compiled by Rhithron Associates, Inc. in a project report for EPA (Bollman, 2007). RIALIS provided database-calculated results for all metrics specified in Barbour et al. (1999).

### 5.1.5 Data Analysis and Interpretation

Benthic macroinvertebrate assemblage evaluation followed USFWS (2007) for OU-3 and the Spokane River. The metrics and multimetric indices evaluated in this assessment include: total taxa; EPT [Ephemeroptera (mayflies), Plecoptera (stoneflies), Tricoptera (caddisflies)] and sediment tolerant species richness; percent of dominant taxa, Ephemeroptera, Plecoptera, Tricoptera, Diptera, metals sensitive and sediment tolerant species; and five multimetric indices [Simpson's Diversity Index (SDI), Hilsenhoff's Biotic Index (HBI), metals tolerance index (MTI), benthic macroinvertebrate index of biotic integrity (B-IBI), and the river macroinvertebrate index (RMI)]. Definitions, formulas, and rankings for each of these metrics and indices are described by USFWS (2007).

Significant differences between locations were determined using the nonparametric Kruskal-Wallis multiple comparison test (Minitab® Statistical Software version 15) Significance was based on $\alpha = 0.05$.

## 5.2 Results

Benthic macroinvertebrates identified per sample site ranged from 388 to 582 individuals. Four of the 12 samples consisted of fewer than 500 organisms; therefore, all individuals in those four samples were identified. Other samples with greater than 500 individuals were subsampled to a minimum of 500 individuals counted (Table 5-1).

There were no significant differences between locations for several of the metrics and indices. Those where no statistical differences were found included taxa richness, percent dominant taxon, EPT richness, percent Tricoptera, percent Diptera, SDI, MTI, percent metals sensitive species, percent sediment tolerant, and sediment tolerant richness (Table 5-2).

*SFR-1*

The SFR-1 samples had the highest mean percent Dipteran taxa (41%), although not significantly different from the other locations sampled. The SFR-1 samples had the lowest mean percent EPT taxa (43%) dominated by *Lepidostoma sp.* (mean of 21%) (Appendix A). This location also had the lowest mean percent Ephemeroptera (11%) (Figure 5-2). The SFR-1 percent EPT taxa was significantly lower than the SFR-2 and SFR-4 samples, and the percent Ephemeroptera was significantly lower than SFR-2 and SFR-3 samples. This location had a significantly higher HBI (mean of 4.2) than SFR-2 and SFR-4 samples (Table 5-2). The SFR-1 samples had the highest B-IBI score (32) of the four locations (Table 5-3).

*SFR-2*

Of the four locations sampled, SFR-2 had the highest mean percent of dominant taxa (33%), although not significantly different from the other locations sampled. This location had the second highest mean percent EPT (74%) with the highest mean percent Ephemeroptera (36%) (Figure 5-2). The percent Ephemeroptera at SFR-2 was significantly higher than the SFR-1 samples, with *E. longimanus* the most dominant taxa in the SFR-2 samples (Appendix A). The mean HBI value was significantly lower than the SFR-1 location (Table 5-2).

*SFR-3*

The SFR-3 location had the highest mean number of total richness (38) and EPT richness (15), although neither were significantly different from other locations (Table 5-2). These samples had the highest mean percent Plecoptera (8%) (Figure 5-2) that was significantly higher than the SFR-1 and SFR-4 samples and dominated by *Malenki sp.* (7%) (Appendix A).

*SFR-4*

The SFR-4 samples had the highest mean percent EPT (77%) of all four locations and the percent EPT was significantly higher than the SFR-1 samples (Figure 5-2). This location had the lowest number of EPT richness (11.7) and was dominated by *Epeorus longimanus* (26%), *Brachycentrus americanus* (25%), and Hydropsychidae (15%) (Appendix A). The SFR-4 samples had the lowest mean percent Diptera (19%) of the four locations. This location also had the lowest mean taxa richness (28) (Table 5-2) and the lowest mean B-IBI score of 26 of all locations (Table 5-3).

## 5.3 Discussion

Benthic macroinvertebrate diversity and abundance data collected from the four SFCDR locations identified in this report represent the first data set specifically from Bunker Hill OU-2. The indices and metrics we used to evaluate the health of benthic macroinvertebrate communities in OU-2 provide information for assessing potential changes in sensitive habitats due to management actions and environmental changes over time. These preliminary data indicate the overall health of the South Fork River within Bunker Hill OU-2 is in fair ecological condition, at least with respect to the benthic macroinvertebrate community.

Data collected for the present monitoring effort are comparable to data collected under the Basin Environmental Monitoring Plan for OU-3 (USFWS, 2007). However, fewer samples per sample location were collected for the OU-2 (n=3) effort compared to that collected for OU-3 (n=6). The relatively low sample size for OU-2 monitoring efforts likely represent a low statistical power to determine differences between sample locations. The apparent low statistical power may reduce our ability to determine trends between this sampling effort and future sampling efforts. The low power is apparent in the lack of significant differences between locations for most of our selected metrics and indices (Table 5-2).

The three most upstream locations (SFR-2, SFR-3, and SFR-4) in OU-2 were relatively similar based on several metrics and indices, whereas the most downstream location (SFR-1) was notably different. The percent EPT from SFR-1 was significantly lower than at SFR-2 and SFR-4, and the percent Ephemeroptera from SFR-1 was significantly lower than at SFR-2 and SFR-3. These differences were most attributable to the much lower numbers of the Ephemeropteran *E. longimanus* (Heptageniidae family) in SFR-1. This mayfly (*E. longimanus*), as well as other Heptageniid mayflies are reliable indicators of the health of an aquatic environment because they may be more sensitive to elevated metal concentrations than other mayflies (Voshell, 2002; Kiffney and Clements, 1994; Mize and Deacon, 2002). Percent Plecoptera at SFR-1 was also significantly lower than at SFR-3, thus also contributing to the lower percent EPT. Finally, the HBI at SFR-1 was significantly higher than at SFR-2 and SFR-4. This higher HBI indicates higher organic pollution, which could indicate nutrient enrichment, high sediment loads, low dissolved oxygen, thermal impacts, and other organic pollution (Hilsenhoff, 1987). The relatively high abundance of Chironomidae species in the SFR-1 samples could be an indication of elevated trace element concentrations and/or fine sediment deposition (MacCoy, 2004; Mize and Deacon, 2002).

This initial year of benthic macroinvertebrate diversity and abundance monitoring within OU-2 provides baseline data to be used for trend analysis to determine if biological conditions in OU-2 are improving over time, potentially as a result of remedial actions. Changes in the benthic macroinvertebrate community will provide useful information in evaluating habitat quality (including water quality and sedimentation trends) within the SFCDR. Further monitoring of benthic macroinvertebrate diversity and abundance, particularly if a higher number of samples per location are sampled, may provide valuable monitoring data to determine the health of the aquatic environment, and may provide trends of aquatic health improvement over time.

## 5.4 Recommendations

- Benthic macroinvertebrate diversity and abundance monitoring will continued to provide valuable trend indices in evaluating OU-2 aquatic habitat quality, as well as help provide information Basin-wide when evaluated in light of benthic macroinvertebrate monitoring being conducted in OU-3. The sample size per location should be increased (n=6) to give increased strength to the statistical power of the interpretation.

- Both diversity and abundance and metals residue monitoring for macroinvertebrates should be conducted concurrently during the same time of year, since each component is important to overall data interpretation.

- Monitoring diversity and abundance for both OU-2 and OU-3 should occur in the same year to facilitate Basin-wide comparisons.

- FWS will work with Rhithron Associates to obtain the full list of species and calculations that Rhithron Associates used to calculate each of the metrics and indices identified in their report. Should Rhithron Associates not be available for future taxonomic evaluations, this information would be necessary to be able to duplicate the metric and index calculations using the same species as used for the present study for trend analysis to be valid.

Table 5-1. Sample reach, benthic macroinvertebrate sample number, number of invertebrates identified per sample, average number of invertebrates identified per reach, and geographical location of samples collected in 2006 within the South Fork Coeur d'Alene River, Idaho.

| Reach | Sample # | Invert Count/ Sample | Geographical Location |
|---|---|---|---|
| SFR-1 | BH06I01 | 491 | Within the historic Pinehurst Narrows, west of Smelterville Flats and down gradient of the Page Ponds Wetland complex and the Central Impoundment Area (CIA). |
| | BH06I02 | 552 | |
| | BH06I03 | 516 | |
| | Average/Reach | 520 | |
| SFR-2 | BH06I04 | 506 | West of Smelterville Flats and down gradient of the CIA |
| | BH06I05 | 500 | |
| | BH06I06 | 507 | |
| | Average/Reach | 504 | |
| SFR-3 | BH06I010 | 582 | East of Theater Bridge and down gradient of Bunker Creek and the CIA |
| | BH06I011 | 509 | |
| | BH06I012 | 388 | |
| | Average/Reach | 493 | |
| SFR-4 | BH06I07 | 485 | East end of OU-2 and is up gradient of the CIA |
| | BH06I08 | 500 | |
| | BH06I09 | 401 | |
| | Average/Reach | 462 | |

Table 5-2. Mean (standard deviation in parentheses) of selected metrics and indices at each of the South Fork Coeur d'Alene Basin locations sampled in 2006. Different letters indicate significant differences (α = 0.05).

| ***2006*** | SFR-1 | SFR-2 | SFR-3 | SFR-4 |
|---|---|---|---|---|
| Taxa Richness (↓) | 37 (6.8)a | 33 (4.6)a | 38 (2.9)a | 28 (5.5)a |
| % Dominant Taxon (↑) | 25% (6%)a | 33% (2%)a | 22% (7%)a | 29% (2%)a |
| % EPT[1] (↓) | 43% (14%)a | 74% (9%)b | 63% (11%)ab | 77% (2%)b |
| EPT Richness (↓) | 14.0 (1.0)a | 14.0 (2.6)a | 15.3 (2.1)a | 11.7 (2.9)a |
| % Ephemeroptera (↓) | 11% (2%)a | 36% (7%)b | 35% (7%)b | 27% (5%)a |
| % Tricoptera (↓) | 31% (14%)a | 35% (11%)a | 21% (4%)a | 49% (7%)a |
| % Plecoptera (↓) | 1% (0%)ac | 3% (1%)bc | 8% (6%)b | 0% (0%)a |
| % Diptera (↑) | 41% (30%)a | 22% (7%)a | 32% (11%)a | 19% (2%)a |
| SDI[2] (↓) | 0.87 (0.10)a | 0.79 (0.10)a | 0.89 (0.10)a | 0.81 (0.10)a |
| HBI[3] (↑) | 4.2 (1.1)b | 2.5 (0.4)a | 3.6 (0.5)ab | 2.7 (0.2)a |
| MTI[4] (↑) | 4.2 (0.5)a | 2.9 (0.3)a | 3.2 (0.5)a | 3.0 (0.3)a |
| % Metals Sensitive[5] Species (↓) | 35% (13%)a | 36% (8%)a | 33% (11%)a | 31% (6%)a |
| % Sediment Tolerant (↑) | 1.0% (0)a | 1.0% (0)a | 0.0% (0)a | 1.0% (2%)a |
| Sediment Tolerant Richness (↑) | 1.0 (0.0)a | 1.0 (0.0)a | 1.0 (0.0)a | 0.7 (0.6)a |

[1]Ephemeroptera, Plecoptera, Tricoptera taxa, [2]Simpons's Diversity Index, [3]Hilsenhoff Biotic Index, [4]Metals Tolerance Index,[5] Metals Sensitive Species as determined by McGuire (2001) with values ≤2, ↓= metric or index value is predicted to decrease in response to perturbation,↑= metric or index value is predicted to increase in response to perturbation.

Table 5-3. Mean macroinvertebrate multimetric index values for each of the Coeur d'Alene River sample reaches in 2006.

| | RMI[a] | B-IBI[b] |
|---|---|---|
| SFR-1 | 15 | 32 |
| SFR-2 | 16 | 28 |
| SFR-3 | 16 | 30 |
| SFR-4 | 14 | 26 |

[a]RMI Ratings: >16 = good condition, 14-15 = intermediate condition, <14 = poor condition.
[b]B-IBI Ratings:13-65 possible points (locations rated relative to each other).

Figure 5-1. Benthic macroinvertebrate diversity and abundance sample locations, South Fork of the Coeur d'Alene River, Operable Unit 2, Coeur d'Alene Basin, Idaho, 2006.

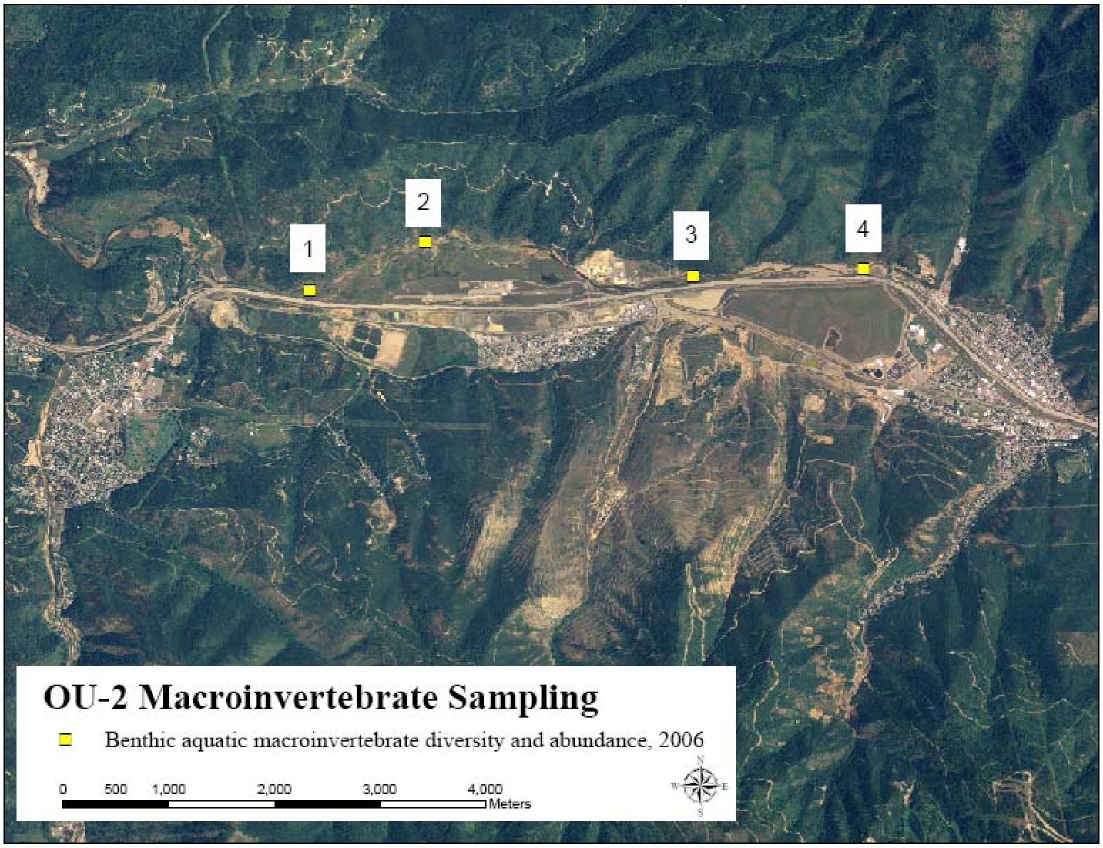
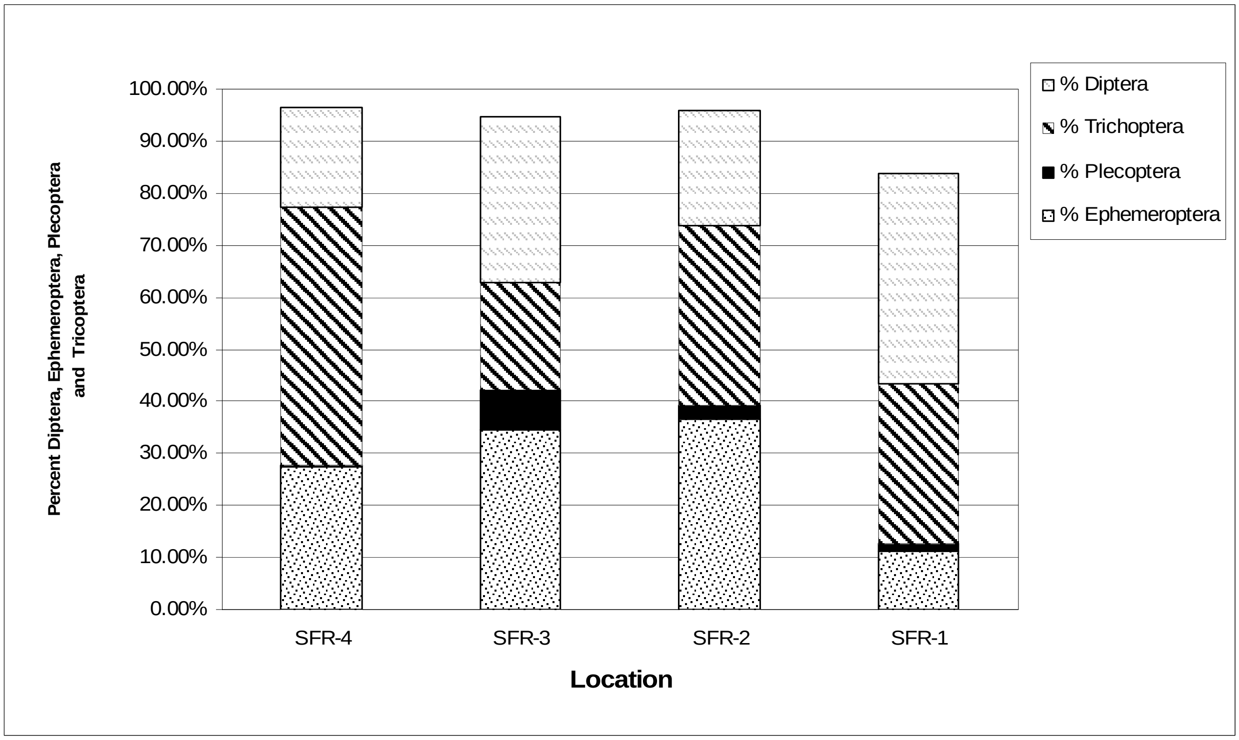


Figure 5-2. Mean percent Diptera, Ephemeroptera, Plecoptera, and Tricoptera at each location in 2006.



## 6.0 References

Audet, D.J. 1997. Coeur d'Alene basin natural resource damage assessment biological reconnaissance investigation. Final Draft.

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.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Scribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water, Washington, D.C.

Beyer, W.N., J.W. Spann, L. Sileo, and J.C. Franson. 1988. Lead poisoning in six captive avian species. Archives of Environmental Contamination and Toxicology 17:121-130.

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

Beyer, W.N., D.J. Audet, A. Morton, J.K. Campbell, and L. LeCaptain. 1998. Lead exposure of waterfowl ingesting Coeur d'Alene River Basin sediments. Journal of Environmental Quality 27:1533-1538.

Beyer, W.N., D.J. Audet, G.H. Heinz, D.J. Hoffman, and D. Day. 2000. Relation of waterfowl poisoning to sediment lead concentrations in the Coeur d'Alene River Basin. Ecotoxicology 9:207-218.

Beyer, W.N., G. Gaston, R. Brazzle, A.F. O'Connell, Jr., and D.J. Audet. 2007. Deer exposed to exceptionally high concentrations of lead near the Continental Mine in Idaho, USA. Environmental Toxicology and Chemistry 26:1040-1046.

Blus, L.J., C.J. Henny, D.J. Hoffman, and R.A. Grove. 1995. Accumulation in and effects of lead and cadmium on waterfowl and passerines in Northern Idaho. *Environmental Pollution*. 89:311-318.

Bollman, W. 2007. Analysis of biological samples: Technical Summary. Rhithron Assoc., Inc., Missoula, Montana, for CH2MHill.

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.

Cherney, J.H., D.L. Robinson, L.C. Kappel, F.G. Hembry, and R.H. Ingraham. 1983. Soil contamination and elemental concentrations of forages in relation to grass tetany. Agronomy Journal 75:447-451.

Edge, W.D., C.L. Marcum, and S.L. Olson. 1985. Effects of logging activities on home range fidelity of elk. The Journal of Wildlife Management 49:741-744.

Halliburton, R., and L.R. Mewaldt. 1976. Survival and mobility in a population of Pacific coast song sparrows (*Melospiza melodia gouldii*). The Condor 78:499-504.

Hansen, J.A. 2007. Songbird exposure to lead-contaminated soils in the Coeur d'Alene River Basin. U.S. Fish and Wildlife Service. Prepared for U.S. Environmental Protection Agency. Upper Columbia Fish and Wildlife Service, Spokane, Washington.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist 20:31-39.

Hoffman, D.J., O.H. Patee, S.N. Wiemeyer, and B. Mulhern. 1981. Effects of lead shot ingestion on delta-aminolevulinic acid dehydratase activity, hemoglovin concentration, and serum chemistry in bald eagles. Journal of Wildlife Diseases 17:423-431.

Howell, J.C. 1942. Notes on the nesting habits of the American robin (Turdus migratorius L.). American Midland Naturalist 28:529-603.

Hui, C. 2004. Geophagy and potential contaminant exposure for terrestrial vertebrates. Review of Environmentla Contaminants and Toxicology 183:115-134.

Johnson, G.D., D.J. Audet, J.W. Kern, L.J. LeCaptain, M.D. Strickland, D.J. Hoffman, and L.L. McDonald. 1999. Lead exposure in passerines inhabiting lead-contaminated floodplains in the Coeur d'Alene River Basin, Idaho, USA. Environmental Toxicology and Chemistry 18:1190-1194.

Kiffney, P.M., and W.H. Clements. 1994. Effects of heavy metals on a macroinvertebrate assemblage from a rocky mountain stream in experimental microcosms. Journal of the North American Benthological Society 13:511-523.

MacCoy, D.E. 2004. Water Quality and Biological Conditions in the Lower Boise River, Ada and Canyon Counties, Idaho, 1994-2002. U.S. Geological Survey Scientific Investigation Report 2004-5128, 80 p.

McGuire D. 2001. Clark Fork River Macroinvertebrate Community Biointegrity: 2000 Assessments. Prepared for Montana Department of Environmental Quality Planning, Prevention, and Assistance Division.

Mize, S.V., and J.R. Deacon. 2002. Relations of Benthic Macroinvertebrates to Concentrations of Trace Elements in Water, Streambed Sediments, and Transplanted

Bryophytes and Stream Habitat Conditions in Nonmining and Mining Areas of the Upper Colorado River Basin, Colorado, 1995–98.Denver, Colorado. U.S. Geological Survey. Water-Resources Investigations Report 02–4139.

McCulley, Frick, and Gilman, Inc. 1994. Bunker Hill Superfund Site draft Page Pond remedial design report. Prepared for ASARCO Incorporated, Hecla Mining Company, and Sunshine Mining Company.

Morrison Knudsen Corporation. 1999. Smelterville Flats construction activities report of the Bunker Hill remedial action project report, volume XX.

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.

Pain, D.J. 1996. Lead in waterfowl. Chapter 10 in Environmental contaminants in wildlife: interpreting tissue concentrations. W.N. Beyer, G.H. Heinz and A.W. Redmon-Norwood, eds. CRC Press LLC, Boca Raton, Florida.

Plotnikoff, R.W., and C. Wiseman. 2001. Revision. Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams. Department of Environmental Quality; Olympia, WA. Publication No. 01-03-028.

Pitts, T.D. 1984. Description of American robin territories in northwest Tennessee. Migrant 55:1-6.

Sileo, L., L.H. Creekmore, D.J. Audet, M.R. Snyder, C.U. Meteyer, J.C. Franson, L.N. Locke, M.R. Smith, and D.L. Finley. 2001. Lead poisoning of waterfowl by contaminated sediment in the Coeur d'Alene River. Archives of Environmental Contamination and Toxicology 41:364-368.

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. 1996a. Amendment to the Record of Decision for the Bunker Hill Mining and Metallurgical Complex (Non-Populated Areas) Superfund Site. U.S. Environmental Protection Agency, Seattle, Washington.

USEPA. 1996b. Explanation of significant differences for revised remedial actions at the Bunker Hill Superfund Site OU2, Shoshone County, Idaho. U.S. Environmental Protection Agency, Seattle, Washington.

USEPA. 1998. Explanation of significant differences for revised remedial actions at the Bunker Hill Superfund Site OU2, Shoshone County, Idaho. EPA/ESD/R10-98/037. U.S. Environmental Protection Agency, Seattle, Washington.

USEPA. 2000. First 5-Year Review of the Non-Populated Area Operable Unit, Bunker Hill Mining and Metallurgical Complex, Shoshone County, Idaho. U.S. Environmental Protection Agency Report.

USEPA. 2001a. Amendment to Record of Decision, Bunker Hill Mining and Metallurgical Complex OU2, Shoshone County, Idaho. ROD EPA/541/R-02/105. U.S. Environmental Protection Agency, Seattle, Washington.

USEPA. 2001b. Final Ecological Risk Assessment. Coeur d'Alene Basin Remedial Investigation/Feasibility Study. Prepared by CH2M Hill and URS Corporation for Region 10 EPA, Seattle, WA. May 18.

USEPA. 2002. Record of Decision, Bunker Hill Mining and Metallurgical Complex Operable Unit 3. U.S. Environmental Protection Agency Report.

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

USFWS. 2001. Bunker Hill Facility Biological Monitoring Investigations, Quality Assurance Plan. USFWS, Spokane, Washington.

USFWS. 2003. Bunker Hill Facility Non-Populated Areas Operable Unit (OU-2), biological monitoring 2002, 2$^{nd}$ 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. USFWS, Spokane, Washington.

USFWS. 2006. Annual report: 2005 Biological resource monitoring, Coeur d'Alene Basin Operable Unit 3. Final Report. USFWS, Spokane, Washington.

USFWS. 2007. Annual report: 2006 biological resource monitoring, Coeur d'Alene Basin Operable Unit 3. Final Report. USFWS, Spokane, Washington.

Voshell, R. J. 2002. A Guide to Common Freshwater Invertebrates of North America. The McDonald and Woodward Publishing Company. Blacksburg, Virginia. 442 p.

Westra R and R.T. Hudson. 1981. Digestive function of wapiti calves. The Journal of Wildlife Management 45:148-155.

Young, H. 1951. Territorial behavior in the eastern robin. Proceedings of the Linnaean Society 58-62:1-37.

# Appendix A

# Benthic Aquatic Invertebrate Diversity and Abundance Data[2]

[2] Taxon rows with no individuals identified in any site sample were removed for brevity.

| SFR-1 | Site | BH06I01 | BH06I02 | BH06I03 | Mean | SD |
|---|---|---|---|---|---|---|
| | Sample date | 7/17/2006 | 7/17/2006 | 7/17/2006 | | |
| | | SFR-1 | SFR-1 | SFR-1 | | |
| | Proportion of sample used | 66.67% | 20.00% | 16.67% | | |
| | Total Count | 491 | 552 | 516 | 520 | 31 |
| | **Taxon/Metric** | | | | | |
| Non-insect taxa | Nematoda | 1% | 1% | 0% | 1% | 0% |
| Ephemeroptera | Baetidae - early instar | 0% | 1% | 0% | 0% | 1% |
| | *Baetis tricaudatus* | 3% | 7% | 9% | 6% | 3% |
| | *Epeorus* - damaged | 0% | 1% | 0% | 0% | 1% |
| | *Epeorus longimanus* | 6% | 1% | 4% | 4% | 2% |
| Plecoptera | *Suwallia* | 2% | 0% | 0% | 1% | 1% |
| | *Malenka* | 0% | 1% | 0% | 0% | 0% |
| | *Sigara* | 1% | 0% | 0% | 0% | 0% |
| Trichoptera | *Brachycentrus americanus* | 5% | 3% | 4% | 4% | 1% |
| | *Micrasema* | 1% | 1% | 0% | 1% | 0% |
| | *Arctopsyche grandis* | 1% | 1% | 0% | 1% | 0% |
| | *Hydropsyche* | 1% | 0% | 1% | 1% | 1% |
| | Hydropsychidae - early instar or pupa | 1% | 1% | 0% | 1% | 0% |
| | *Hydroptila* | 0% | 1% | 1% | 1% | 1% |
| | *Lepidostoma* | 32% | 10% | 21% | 21% | 11% |
| | Rhyacophila Angelita Gr. | 1% | 1% | 1% | 1% | 0% |
| | *Neophylax rickeri* | 2% | 0% | 0% | 1% | 1% |
| Coleoptera | Dytiscidae - larva | 1% | 1% | 1% | 1% | 0% |
| | *Oreodytes* | 26% | 1% | 6% | 11% | 13% |
| | *Stictotarsus* | 2% | 0% | 1% | 1% | 1% |
| | *Brychius* | 0% | 0% | 1% | 0% | 0% |
| | *Haliplus* | 4% | 0% | 0% | 1% | 2% |
| Diptera | Ceratopogoninae | 0% | 1% | 0% | 0% | 1% |
| | *Chelifera* | 0% | 1% | 0% | 0% | 0% |
| | Empididae - early instar, pupa or damaged | 1% | 1% | 3% | 2% | 1% |
| | Simuliidae - pupa | 0% | 1% | 1% | 1% | 0% |
| | *Simulium* | 2% | 3% | 3% | 3% | 1% |
| | *Tipula* | 1% | 0% | 1% | 1% | 0% |
| Chironomidae | *Cricotopus bicinctus* | 0% | 2% | 2% | 1% | 1% |
| | *Eukiefferiella* - early instar | 0% | 1% | 0% | 0% | 1% |
| | Eukiefferiella Brehmi Gr. | 0% | 1% | 0% | 0% | 0% |
| | Eukiefferiella Claripennis Gr. | 0% | 5% | 0% | 2% | 3% |
| | Eukiefferiella Devonica Gr. | 2% | 22% | 10% | 11% | 10% |
| | Orthocladiinae - early instar | 0% | 6% | 2% | 2% | 3% |
| | *Orthocladius* | 1% | 10% | 11% | 7% | 5% |
| | *Pagastia* | 1% | 1% | 1% | 1% | 0% |
| | *Phaenopsectra* | 0% | 0% | 2% | 1% | 1% |
| | *Polypedilum* | 0% | 3% | 4% | 3% | 2% |
| | *Psectrocladius* | 0% | 1% | 0% | 0% | 0% |
| | *Tanytarsus* | 0% | 0% | 1% | 0% | 0% |
| | Tvetenia Bavarica Gr. | 0% | 3% | 3% | 2% | 2% |

| SFR-1 (Cont.) | Taxon/Metric | BH06I01 | BH06I02 | BH06I03 | Mean | SD |
|---|---|---|---|---|---|---|
| | *Tvetenia vitracies* | 0% | 3% | 0% | 1% | 2% |
| **METRICS** | | | | | | |
| | Taxa Richness | 29.0 | 39.0 | 42.0 | 36.7 | 6.8 |
| | EPT Richness | 13.0 | 14.0 | 15.0 | 14.0 | 1.0 |
| | E Richness | 3.0 | 3.0 | 2.0 | 2.7 | 0.6 |
| | P Richness | 1.0 | 4.0 | 3.0 | 2.7 | 1.5 |
| | T Richness | 9.0 | 7.0 | 10.0 | 8.7 | 1.5 |
| | EPT Percent | 57.03% | 29.17% | 43.80% | 43% | 14% |
| | E Percent | 9.78% | 10.69% | 13.18% | 11% | 2% |
| | Pollution Sensitive Richness | 1.0 | 2.0 | 3.0 | 2.0 | 1.0 |
| | Pollution Tolerant Percent | 5.09% | 2.72% | 3.49% | 4% | 1% |
| | Dominant Taxon Percent | 31.77% | 22.28% | 20.74% | 25% | 6% |
| | Dominant Taxa (2) Percent | 57.43% | 32.07% | 32.17% | 41% | 15% |
| | Dominant Taxa (3) Percent | 63.54% | 41.67% | 42.05% | 49% | 13% |
| | Filterer Percent | 9.57% | 8.33% | 9.69% | 9% | 1% |
| | Grazers + Scrapers Percent | 9.16% | 2.54% | 6.98% | 6% | 3% |
| | Clinger Richness | 14.0 | 15.0 | 18.0 | 15.7 | 2.1 |
| | Clinger Percent | 22.81% | 21.20% | 26.55% | 24% | 3% |
| | *Pteronarcys* Richness | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Diptera Richness | 3.0 | 4.0 | 6.0 | 4.3 | 1.5 |
| | Chironomidae Richness | 5.0 | 16.0 | 16.0 | 12.3 | 6.4 |
| | Plecoptera Percent | 1.63% | 1.45% | 1.16% | 1% | 0% |
| | Trichoptera Percent | 45.62% | 17.03% | 29.46% | 31% | 14% |
| | Diptera Percent | 4.07% | 8.33% | 7.95% | 7% | 2% |
| | Chironomidae Percent | 4.07% | 58.51% | 38.37% | 34% | 28% |
| | Tanytarsini Tribe Percent | 0.00% | 0.36% | 1.36% | 1% | 1% |
| | Other Diptera and non-insects Percent | 4.89% | 9.24% | 8.33% | 7% | 2% |
| | *Corbicula* Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Oligochaeta Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Intolerant Snail and Mussel Richness | 0 | 0 | 0 | 0% | 0% |
| | Sediment Tolerant Percent | 0.81% | 0.54% | 0.97% | 1% | 0% |
| | Hilsenhoff Biotic Index | 3.0 | 5.3 | 4.2 | 4.2 | 1.1 |
| | Hydropsychidae/Trichoptera | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| | Omnivore and Scavenger Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Gatherer and Filterer Percent | 17.72% | 70.11% | 47.48% | 45% | 26% |
| | Gatherer Percent | 8.15% | 61.78% | 37.79% | 36% | 27% |
| | Predator Percent | 34.01% | 7.61% | 14.34% | 19% | 14% |
| | Shredder Percent | 33.60% | 18.12% | 29.65% | 27% | 8% |
| | Multivoltine Percent | 8.35% | 67.93% | 49.03% | 42% | 30% |
| | Univoltine Percent | 51.73% | 25.18% | 36.63% | 38% | 13% |
| | | | | | | |
| **ADDITIONAL METRICS** | Air Breather Percent | 29.74% | 2.90% | 9.69% | 14% | 14% |
| | Air Breather Richness | 4.0 | 3.0 | 4.0 | 3.7 | 0.6 |
| | Baetidae/Ephemeroptera | 0.35 | 0.73 | 0.69 | 59% | 21% |
| | Burrower Percent | 1.02% | 1.99% | 1.74% | 2% | 1% |
| | Burrower Richness | 2.0 | 3.0 | 5.0 | 3.3 | 1.5 |

| SFR-1 (Cont.) | Taxon/Metric | BH06I01 | BH06I02 | BH06I03 | Mean | SD |
|---|---|---|---|---|---|---|
| | Cold Stenotherm Percent | 0.20% | 0.18% | 0.39% | 0% | 0% |
| | Cold Stenotherm Richness | 1.0 | 1.0 | 2.0 | 1.3 | 0.6 |
| | Collector Percent | 17.72% | 70.11% | 47.48% | 45% | 26% |
| | CTQa | 64.09 | 70.07 | 75.28 | 6982% | 560% |
| | Dominant Taxa (10) Percent | 84.11% | 71.74% | 75.78% | 77% | 6% |
| | Evenness | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| | Filterer Richness | 3.0 | 2.0 | 4.0 | 3.0 | 1.0 |
| | Hemoglobin Bearer Percent | 0.20% | 3.62% | 6.01% | 3% | 3% |
| | Hemoglobin Bearer Richness | 1 | 2 | 2 | 167% | 58% |
| | Intolerant Percent | 49.90% | 21.74% | 32.56% | 35% | 14% |
| | Margalef D | 4.5 | 6.2 | 6.6 | 5.8 | 1.1 |
| | Metals Tolerance Index | 3.7 | 4.7 | 4.0 | 4.2 | 0.5 |
| | Non-Insect Percent | 0.81% | 0.91% | 0.39% | 1% | 0% |
| | Predator Richness | 7.0 | 8.0 | 12.0 | 9.0 | 2.6 |
| | Scraper/Filterer | 1.0 | 0.3 | 0.7 | 0.7 | 0.3 |
| | Scraper/Scraper+Filterer | 0.5 | 0.2 | 0.4 | 0.4 | 0.1 |
| | Scraper+Shredder Percent | 42.77% | 20.65% | 36.63% | 33% | 11% |
| | Sediment Sensitive Percent | 1.63% | 0.72% | 0.39% | 1% | 1% |
| | Sediment Sensitive Richness | 2.0 | 2.0 | 1.0 | 1.7 | 0.6 |
| | Sediment Tolerant Richness | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| | Semivoltine Richness | 8 | 7 | 8 | 767% | 58% |
| | Shannon H (log2) | 3.19 | 3.98 | 3.98 | 3.72 | 0.46 |
| | Shannon H (loge) | 2.21 | 2.76 | 2.76 | 2.58 | 0.32 |
| | Simpson D | 0.19 | 0.11 | 0.10 | 0.13 | 0.05 |
| | Simpson D (1-D) | 0.81 | 0.89 | 0.90 | 0.87 | 0.95 |
| | Supertolerant Percent | 1.83% | 29.89% | 10.85% | 14% | 14% |
| | Swimmer Percent | 36.25% | 7.97% | 16.28% | 20% | 15% |
| | Swimmer Richness | 6.0 | 3.0 | 3.0 | 4.0 | 1.7 |
| | Univoltine Richness | 14.0 | 13.0 | 15.0 | 14.0 | 1.0 |
| | Elmidae Percent | 0.41% | 0.36% | 0.19% | 0.32% | 0.11% |
| | Scraper Richness | 5.00 | 6.00 | 6.00 | 5.7 | 0.6 |
| | % Metals Sensitive Species | 46% | 21% | 36% | 35% | 13% |
| | RMI | 17 | 15 | 15 | 15.7 | 1.2 |
| | B-IBI | 30 | 30 | 36 | 32 | |

| SFR-2 | | | | | | |
|---|---|---|---|---|---|---|
| | **Site** | **BH06I04** | **BH06I05** | **BH06I06** | **Mean** | **SD** |
| | **Sample date** | 7/17/2006 | 7/17/2006 | 7/17/2006 | | |
| | | **SFR-2** | **SFR-2** | **SFR-2** | | |
| | Proportion of sample used | 80.00% | 73.33% | 40.00% | | |
| | Total Count | 506 | 500 | 507 | 504 | 4 |
| | **Taxon/Metric** | | | | | |
| Non-insect taxa | Turbellaria | 1% | 0% | 0% | 0% | 0% |
| | Nematoda | 2% | 1% | 1% | 1% | 0% |
| Ephemeroptera | *Baetis tricaudatus* | 9% | 4% | 5% | 6% | 3% |
| | *Epeorus longimanus* | 31% | 35% | 24% | 30% | 6% |
| Plecoptera | *Suwallia* | 3% | 3% | 2% | 3% | 1% |
| Trichoptera | Brachycentridae - pupa | 2% | 0% | 0% | 1% | 1% |
| | *Brachycentrus americanus* | 7% | 33% | 32% | 24% | 15% |
| | *Micrasema* | 1% | 0% | 0% | 0% | 0% |
| | *Arctopsyche grandis* | 1% | 1% | 0% | 1% | 0% |
| | *Hydropsyche* | 1% | 2% | 1% | 1% | 1% |
| | Hydropsychidae - early instar or pupa | 0% | 1% | 1% | 1% | 1% |
| | *Hydroptila* | 0% | 0% | 2% | 1% | 1% |
| | *Lepidostoma* | 8% | 2% | 1% | 4% | 4% |
| | Rhyacophila Angelita Gr. | 1% | 1% | 2% | 2% | 1% |
| Coleoptera | Dytiscidae - larva | 1% | 0% | 0% | 0% | 0% |
| | *Oreodytes* | 1% | 0% | 0% | 0% | 0% |
| | *Narpus* | 1% | 0% | 1% | 1% | 1% |
| | *Brychius* | 1% | 0% | 0% | 0% | 1% |
| Diptera | *Chelifera* | 1% | 0% | 0% | 0% | 0% |
| | Empididae - early instar, pupa or damaged | 9% | 1% | 3% | 4% | 4% |
| | Simuliidae - pupa | 2% | 3% | 3% | 3% | 0% |
| | *Simulium* | 4% | 4% | 8% | 6% | 2% |
| | *Tipula* | 1% | 1% | 1% | 1% | 0% |
| Chironomidae | Eukiefferiella Claripennis Gr. | 1% | 0% | 1% | 1% | 0% |
| | Eukiefferiella Devonica Gr. | 3% | 2% | 4% | 3% | 1% |
| | *Micropsectra* | 1% | 1% | 0% | 0% | 0% |
| | Orthocladiinae - early instar | 0% | 0% | 1% | 0% | 0% |
| | *Orthocladius* | 2% | 0% | 1% | 1% | 1% |
| | *Pagastia* | 1% | 0% | 0% | 1% | 1% |
| | *Polypedilum* | 1% | 1% | 1% | 1% | 0% |
| | Tvetenia Bavarica Gr. | 1% | 0% | 2% | 1% | 1% |
| **METRICS** | | | | | | |
| | Taxa Richness | 38.0 | 29.0 | 32.0 | 33.0 | 4.6 |
| | EPT Richness | 17.0 | 12.0 | 13.0 | 14.0 | 2.6 |
| | E Richness | 3.0 | 3.0 | 2.0 | 2.7 | 0.6 |
| | P Richness | 3.0 | 1.0 | 2.0 | 2.0 | 1.0 |
| | T Richness | 11.0 | 8.0 | 9.0 | 9.3 | 1.5 |
| | EPT Percent | 66.40% | 83.20% | 71.40% | 74% | 9% |
| | E Percent | 40.71% | 39.80% | 28.80% | 36% | 7% |
| | Pollution Sensitive Richness | 2.0 | 0.0 | 0.0 | 0.7 | 1.2 |
| | Pollution Tolerant Percent | 2.96% | 1.00% | 1.97% | 2% | 1% |

| SFR-2 (Cont.) | Taxon/Metric | BH06I04 | BH06I05 | BH06I06 | Mean | SD |
|---|---|---|---|---|---|---|
| | Dominant Taxon Percent | 31.23% | 35.40% | 32.15% | 33% | 2% |
| | Dominant Taxa (2) Percent | 40.32% | 68.40% | 56.02% | 55% | 14% |
| | Dominant Taxa (3) Percent | 49.21% | 72.80% | 64.10% | 62% | 12% |
| | Filterer Percent | 15.61% | 43.40% | 45.56% | 35% | 17% |
| | Grazers + Scrapers Percent | 32.81% | 36.20% | 24.46% | 31% | 6% |
| | Clinger Richness | 17.0 | 13.0 | 15.0 | 15.0 | 2.0 |
| | Clinger Percent | 55.73% | 83.00% | 76.73% | 72% | 14% |
| | *Pteronarcys* Richness | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Diptera Richness | 6.0 | 4.0 | 5.0 | 5.0 | 1.0 |
| | Chironomidae Richness | 8.0 | 7.0 | 9.0 | 8.0 | 1.0 |
| | Plecoptera Percent | 3.36% | 2.80% | 1.97% | 3% | 1% |
| | Trichoptera Percent | 22.33% | 40.60% | 40.63% | 35% | 11% |
| | Diptera Percent | 18.18% | 10.40% | 15.38% | 15% | 4% |
| | Chironomidae Percent | 8.30% | 4.00% | 10.26% | 8% | 3% |
| | Tanytarsini Tribe Percent | 0.59% | 0.60% | 0.20% | 0% | 0% |
| | Other Diptera and non-insects Percent | 20.55% | 11.40% | 16.77% | 16% | 5% |
| | *Corbicula* Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Oligochaeta Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Intolerant Snail and Mussel Richness | 0 | 0 | 0 | 0% | 0% |
| | Sediment Tolerant Percent | 0.99% | 1.40% | 0.99% | 1% | 0% |
| | Hilsenhoff Biotic Index | 2.9 | 2.0 | 2.7 | 2.5 | 0.4 |
| | Hydropsychidae/Trichoptera | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| | Omnivore and Scavenger Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Gatherer and Filterer Percent | 35.57% | 51.00% | 59.57% | 49% | 12% |
| | Gatherer Percent | 19.96% | 7.60% | 14.00% | 14% | 6% |
| | Predator Percent | 19.17% | 7.40% | 8.88% | 12% | 6% |
| | Shredder Percent | 10.67% | 4.00% | 4.14% | 6% | 4% |
| | Multivoltine Percent | 19.76% | 9.60% | 18.34% | 16% | 6% |
| | Univoltine Percent | 67.00% | 55.20% | 47.53% | 57% | 10% |
| | | | | | | |
| **ADDITIONAL METRICS** | Air Breather Percent | 3.56% | 2.40% | 1.97% | 3% | 1% |
| | Air Breather Richness | 4.0 | 4.0 | 3.0 | 3.7 | 0.6 |
| | Baetidae/Ephemeroptera | 0.22 | 0.11 | 0.17 | 17% | 6% |
| | Burrower Percent | 1.78% | 1.80% | 1.58% | 2% | 0% |
| | Burrower Richness | 3.0 | 3.0 | 4.0 | 3.3 | 0.6 |
| | Cold Stenotherm Percent | 0.40% | 0.00% | 0.00% | 0% | 0% |
| | Cold Stenotherm Richness | 2.0 | 0.0 | 0.0 | 0.7 | 1.2 |
| | Collector Percent | 35.57% | 51.00% | 59.57% | 49% | 12% |
| | CTQa | 66.00 | 71.59 | 73.88 | 7049% | 405% |
| | Dominant Taxa (10) Percent | 78.46% | 89.60% | 84.81% | 84% | 6% |
| | Evenness | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| | Filterer Richness | 3.0 | 3.0 | 4.0 | 3.3 | 0.6 |
| | Hemoglobin Bearer Percent | 0.59% | 0.60% | 0.99% | 1% | 0% |
| | Hemoglobin Bearer Richness | 1 | 1 | 1 | 100% | 0% |
| | Intolerant Percent | 57.71% | 76.00% | 63.12% | 66% | 9% |
| | Margalef D | 6.1 | 4.5 | 5.0 | 5.2 | 0.8 |
| | Metals Tolerance Index | 2.8 | 2.6 | 3.2 | 2.9 | 0.3 |

| **SFR-2** (Cont.) | **Taxon/Metric** | **BH06I04** | **BH06I05** | **BH06I06** | **Mean** | **SD** |
|---|---|---|---|---|---|---|
| | Non-Insect Percent | 2.37% | 1.00% | 1.38% | 2% | 1% |
| | Predator Richness | 14.0 | 8.0 | 9.0 | 10.3 | 3.2 |
| | Scraper/Filterer | 2.1 | 0.8 | 0.5 | 1.2 | 0.8 |
| | Scraper/Scraper+Filterer | 0.7 | 0.5 | 0.3 | 0.5 | 0.2 |
| | Scraper+Shredder Percent | 43.48% | 40.20% | 28.60% | 37% | 8% |
| | Sediment Sensitive Percent | 0.59% | 0.80% | 0.79% | 1% | 0% |
| | Sediment Sensitive Richness | 1.0 | 2.0 | 2.0 | 1.7 | 0.6 |
| | Sediment Tolerant Richness | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| | Semivoltine Richness | 8 | 8 | 5 | 700% | 173% |
| | Shannon H (log2) | 3.60 | 2.68 | 3.12 | 3.13 | 0.46 |
| | Shannon H (loge) | 2.49 | 1.86 | 2.16 | 2.17 | 0.32 |
| | Simpson D | 0.17 | 0.27 | 0.20 | 0.21 | 0.05 |
| | Simpson D (1-D) | 0.83 | 0.73 | 0.80 | 0.79 | 0.95 |
| | Supertolerant Percent | 3.95% | 2.00% | 4.93% | 4% | 1% |
| | Swimmer Percent | 10.28% | 5.00% | 5.72% | 7% | 3% |
| | Swimmer Richness | 3.0 | 4.0 | 3.0 | 3.3 | 0.6 |
| | Univoltine Richness | 19.0 | 11.0 | 14.0 | 14.7 | 4.0 |
| | Elmidae Percent | 1.38% | 0.20% | 0.59% | 0.73% | 0.60% |
| | Scraper Richness | 4.00 | 5.00 | 3.00 | 4.0 | 1.0 |
| | % Metals Sensitive Species | 42% | 39% | 27% | 36% | 8% |
| | RMI | 15 | 17 | 15 | 15.7 | 1.2 |
| | B-IBI | 32 | 26 | 26 | 28 | |

## SFR-3

| | | BH06I10 | BH06I11 | BH06I12 | Mean | SD |
|---|---|---|---|---|---|---|
| | **Site** | **BH06I10** | **BH06I11** | **BH06I12** | **Mean** | **SD** |
| | **Sample date** | 7/19/2006 | 7/19/2006 | 7/19/2006 | | |
| | | **SFR-3** | **SFR-3** | **SFR-3** | | |
| | Proportion of sample used | 13.33% | 40.00% | 100.00% | | |
| | Total Count | 582 | 509 | 388 | 493 | 98 |
| | **Taxon/Metric** | | | | | |
| Non-insect taxa | *Polycelis coronata* | 1% | 3% | 2% | 2% | 1% |
| | Nematoda | 3% | 1% | 0% | 1% | 2% |
| Ephemeroptera | *Baetis tricaudatus* | 16% | 12% | 12% | 13% | 2% |
| | *Epeorus longimanus* | 12% | 21% | 29% | 21% | 8% |
| Plecoptera | *Suwallia* | 1% | 1% | 0% | 1% | 0% |
| | *Malenka* | 3% | 13% | 5% | 7% | 6% |
| | *Doroneuria* | 0% | | | | |
| Trichoptera | *Brachycentrus americanus* | 6% | 2% | 7% | 5% | 3% |
| | *Micrasema* | 2% | 1% | 0% | 1% | 1% |
| | *Arctopsyche grandis* | 1% | 0% | 1% | 1% | 1% |
| | *Hydropsyche* | 4% | 6% | 12% | 7% | 4% |
| | Hydropsychidae - early instar or pupa | 1% | 1% | 1% | 1% | 0% |
| | *Hydroptila* | 1% | 3% | 1% | 1% | 1% |
| | *Lepidostoma* | 0% | 2% | 1% | 1% | 1% |
| | *Dicosmoecus atripes* | 1% | 1% | 2% | 1% | 1% |
| | *Onocosmoecus unicolor* | 0% | 0% | 1% | 0% | 0% |
| | Rhyacophila Angelita Gr. | 2% | 2% | 2% | 2% | 0% |
| Coleoptera | *Oreodytes* | 0% | 3% | 1% | 1% | 1% |
| | *Stictotarsus* | 0% | 0% | 1% | 0% | 0% |
| Diptera | Empididae - early instar, pupa or damaged | 1% | 2% | 2% | 1% | 1% |
| | *Neoplasta* | 1% | 0% | 0% | 0% | 0% |
| | Muscidae | 0% | 1% | 0% | 0% | 0% |
| | Simuliidae - pupa | 2% | 1% | 2% | 2% | 1% |
| | *Simulium* | 13% | 10% | 5% | 9% | 4% |
| | *Tipula* | 0% | 3% | 1% | 1% | 2% |
| Chironomidae | *Cardiocladius* | 0% | 0% | 1% | 0% | 0% |
| | *Cricotopus (Cricotopus)* | 0% | 0% | 1% | 0% | 0% |
| | *Cricotopus bicinctus* | 3% | 1% | 1% | 2% | 1% |
| | *Eukiefferiella* - early instar | 0% | 0% | 1% | 0% | 0% |
| | Eukiefferiella Claripennis Gr. | 1% | 1% | 2% | 1% | 1% |
| | Eukiefferiella Devonica Gr. | 3% | 1% | 0% | 1% | 1% |
| | Eukiefferiella Pseudomontana Gr. | 1% | 0% | 0% | 0% | 0% |
| | *Orthocladius* | 8% | 3% | 2% | 4% | 3% |
| | *Pagastia* | 1% | 0% | 0% | 0% | 0% |
| | *Phaenopsectra* | 0% | 0% | 1% | 0% | 1% |
| | *Polypedilum* | 6% | 3% | 4% | 4% | 2% |
| | Tvetenia Bavarica Gr. | 3% | 1% | 1% | 2% | 1% |
| **METRICS** | | | | | | |
| | Taxa Richness | 40.0 | 40.0 | 35.0 | 38.3 | 2.9 |

| | Taxon/Metric | BH06I10 | BH06I11 | BH06I12 | Mean | SD |
|---|---|---|---|---|---|---|
| | EPT Richness | 16.0 | 17.0 | 13.0 | 15.3 | 2.1 |
| **SFR-3** (Cont.) | **Taxon/Metric** | **BH06I10** | **BH06I11** | **BH06I12** | **Mean** | **SD** |
| | E Richness | 3.0 | 4.0 | 2.0 | 3.0 | 1.0 |
| | P Richness | 3.0 | 3.0 | 2.0 | 2.7 | 0.6 |
| | T Richness | 10.0 | 10.0 | 9.0 | 9.7 | 0.6 |
| | EPT Percent | 50.69% | 65.62% | 72.16% | 63% | 11% |
| | E Percent | 28.18% | 33.99% | 41.49% | 35% | 7% |
| | Pollution Sensitive Richness | 3.0 | 2.0 | 1.0 | 2.0 | 1.0 |
| | Pollution Tolerant Percent | 1.89% | 3.54% | 1.29% | 2% | 1% |
| | Dominant Taxon Percent | 15.64% | 21.22% | 29.12% | 22% | 7% |
| | Dominant Taxa (2) Percent | 28.87% | 34.58% | 41.49% | 35% | 6% |
| | Dominant Taxa (3) Percent | 41.24% | 46.95% | 53.87% | 47% | 6% |
| | | | | | | |
| | Filterer Percent | 26.63% | 20.04% | 26.55% | 24% | 4% |
| | Grazers + Scrapers Percent | 12.54% | 21.81% | 30.93% | 22% | 9% |
| | Clinger Richness | 14.0 | 18.0 | 13.0 | 15.0 | 265% |
| | Clinger Percent | 55.84% | 52.65% | 65.72% | 58% | 7% |
| | *Pteronarcys* Richness | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Diptera Richness | 4.0 | 7.0 | 4.0 | 5.0 | 1.7 |
| | Chironomidae Richness | 15.0 | 10.0 | 13.0 | 12.7 | 2.5 |
| | Plecoptera Percent | 3.78% | 14.15% | 5.15% | 8% | 6% |
| | Trichoptera Percent | 18.73% | 17.49% | 25.52% | 21% | 4% |
| | Diptera Percent | 17.35% | 17.49% | 9.28% | 15% | 5% |
| | Chironomidae Percent | 26.98% | 10.02% | 14.18% | 17% | 9% |
| | Tanytarsini Tribe Percent | 0.17% | 0.00% | 0.26% | 0% | 0% |
| | Other Diptera and non-insects Percent | 21.65% | 21.02% | 11.08% | 18% | 6% |
| | *Corbicula* Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Oligochaeta Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Intolerant Snail and Mussel Richness | 0 | 0 | 0 | 0% | 0% |
| | Sediment Tolerant Percent | 0.34% | 3.14% | 0.52% | 1% | 2% |
| | Hilsenhoff Biotic Index | 4.1 | 3.3 | 3.2 | 3.6 | 0.5 |
| | Hydropsychidae/Trichoptera | 0.3 | 0.4 | 0.5 | 0.4 | 0.1 |
| | Omnivore and Scavenger Percent | 0.69% | 2.55% | 1.80% | 2% | 1% |
| | Gatherer and Filterer Percent | 59.97% | 39.10% | 45.36% | 48% | 11% |
| | Gatherer Percent | 33.33% | 19.06% | 18.81% | 24% | 8% |
| | Predator Percent | 7.39% | 10.22% | 8.76% | 9% | 1% |
| | Shredder Percent | 14.78% | 22.79% | 12.63% | 17% | 5% |
| | Multivoltine Percent | 48.11% | 28.49% | 28.87% | 35% | 11% |
| | Univoltine Percent | 43.13% | 65.23% | 59.79% | 56% | 12% |
| | | | | | | |
| **ADDITIONAL METRICS** | Air Breather Percent | 0.86% | 5.70% | 2.84% | 3% | 2% |
| | Air Breather Richness | 3.0 | 2.0 | 4.0 | 3.0 | 1.0 |
| | Baetidae/Ephemeroptera | 0.55 | 0.36 | 0.30 | 41% | 13% |
| | Burrower Percent | 0.69% | 4.32% | 1.03% | 2% | 2% |
| | Burrower Richness | 2.0 | 5.0 | 2.0 | 3.0 | 1.7 |
| | Cold Stenotherm Percent | 0.69% | 0.98% | 1.55% | 1% | 0% |
| | Cold Stenotherm Richness | 2.0 | 2.0 | 1.0 | 167% | 58% |
| | Collector Percent | 59.97% | 39.10% | 45.36% | 48% | 11% |

| | Taxon/Metric | | | | | |
|---|---|---|---|---|---|---|
| | CTQa | 70.13 | 72.73 | 71.09 | 7132% | 131% |
| | Dominant Taxa (10) Percent | 75.09% | 77.01% | 80.15% | 77% | 3% |
| **SFR-3** (Cont.) | **Taxon/Metric** | **BH06I10** | **BH06I11** | **BH06I12** | **Mean** | **SD** |
| | Evenness | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| | Filterer Richness | 4.0 | 3.0 | 3.0 | 3.3 | 0.6 |
| | Hemoglobin Bearer Percent | 6.19% | 3.14% | 5.41% | 5% | 2% |
| | Hemoglobin Bearer Richness | 1 | 1 | 2 | 133% | 58% |
| | Intolerant Percent | 30.58% | 45.78% | 47.94% | 41% | 9% |
| | Margalef D | 6.2 | 6.3 | 5.7 | 6.1 | 0.3 |
| | Metals Tolerance Index | 3.8 | 3.0 | 2.9 | 3.2 | 0.5 |
| | Non-Insect Percent | 4.30% | 3.54% | 1.80% | 3% | 1% |
| | Predator Richness | 10.0 | 12.0 | 11.0 | 11.0 | 1.0 |
| | Scraper/Filterer | 0.5 | 1.1 | 1.2 | 0.9 | 0.4 |
| | Scraper/Scraper+Filterer | 0.3 | 0.5 | 0.5 | 0.5 | 0.1 |
| | Scraper+Shredder Percent | 27.32% | 44.60% | 43.56% | 38% | 10% |
| | Sediment Sensitive Percent | 1.37% | 0.39% | 0.52% | 1% | 1% |
| | Sediment Sensitive Richness | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| | Sediment Tolerant Richness | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| | Semivoltine Richness | 5 | 8 | 7 | 667% | 153% |
| | Shannon H (log2) | 4.06 | 3.96 | 3.69 | 3.90 | 0.19 |
| | Shannon H (loge) | 2.82 | 2.74 | 2.56 | 2.71 | 0.13 |
| | Simpson D | 0.09 | 0.10 | 0.14 | 0.11 | 0.03 |
| | Simpson D (1-D) | 0.91 | 0.90 | 0.86 | 0.89 | 0.97 |
| | Supertolerant Percent | 4.81% | 2.36% | 3.09% | 3% | 1% |
| | Swimmer Percent | 15.81% | 14.93% | 14.43% | 15% | 1% |
| | Swimmer Richness | 2.0 | 2.0 | 4.0 | 2.7 | 1.2 |
| | Univoltine Richness | 15.0 | 18.0 | 12.0 | 15.0 | 3.0 |
| | Elmidae Percent | 0.34% | 0.59% | 0.26% | 0.40% | 0.17% |
| | Scraper Richness | 2.00 | 4.00 | 4.00 | 3.3 | 1.2 |
| | % Metals Sensitive Species | 20% | 39% | 39% | 33% | 11% |
| | RMI | 13 | 15 | 15 | 14.3 | 1.2 |
| | B-IBI | 32 | 32 | 26 | 30 | |

| SFR-4 | Site | BH06I07 | BH06I08 | BH06I09 | Mean | SD |
|---|---|---|---|---|---|---|
| | Sample date | 7/18/2006 | 7/18/2006 | 7/18/2006 | | |
| | | SFR-4 | SFR-4 | SFR-4 | | |
| | Proportion of sample used | 100.00% | 90.00% | 100.00% | | |
| | Total Count | 485 | 500 | 401 | 462 | 53 |
| | **Taxon/Metric** | | | | | |
| Ephemeroptera | *Baetis tricaudatus* | 1% | 0% | 2% | 1% | 1% |
| | *Drunella flavilinea* | 0% | 0% | 1% | 0% | 0% |
| | *Epeorus longimanus* | 21% | 26% | 30% | 26% | 5% |
| Trichoptera | *Brachycentrus americanus* | 26% | 30% | 20% | 25% | 5% |
| | *Hydropsyche* | 23% | 11% | 13% | 15% | 6% |
| | Hydropsychidae - early instar or pupa | 3% | 3% | 1% | 2% | 1% |
| | *Lepidostoma* | 0% | 0% | 1% | 1% | 1% |
| | Rhyacophila Angelita Gr. | 3% | 4% | 5% | 4% | 1% |
| | *Neophylax rickeri* | 1% | 1% | 0% | 1% | 0% |
| Coleoptera | *Oreodytes* | 0% | 0% | 3% | 1% | 1% |
| | *Lara avara* | 0% | 0% | 1% | 0% | 0% |
| | *Narpus* | 1% | 1% | 1% | 1% | 0% |
| Diptera | Simuliidae - pupa | 2% | 3% | 1% | 2% | 1% |
| | *Simulium* | 11% | 9% | 2% | 7% | 5% |
| Chironomidae | *Cardiocladius* | 1% | 0% | 0% | 0% | 0% |
| | *Cricotopus (Cricotopus)* | 0% | 0% | 1% | 0% | 0% |
| | Eukiefferiella Claripennis Gr. | 0% | 0% | 1% | 1% | 0% |
| | Eukiefferiella Devonica Gr. | 0% | 1% | 0% | 0% | 0% |
| | *Orthocladius* | 2% | 0% | 4% | 2% | 2% |
| | *Pagastia* | 0% | 0% | 1% | 0% | 0% |
| | *Polypedilum* | 1% | 3% | 5% | 3% | 2% |
| | Tvetenia Bavarica Gr. | 1% | 2% | 1% | 1% | 0% |
| METRICS | | | | | | |
| | Taxa Richness | 22.0 | 32.0 | 31.0 | 28.3 | 5.5 |
| | EPT Richness | 10.0 | 10.0 | 15.0 | 11.7 | 2.9 |
| | E Richness | 2.0 | 4.0 | 5.0 | 3.7 | 1.5 |
| | P Richness | 3.0 | 0.0 | 1.0 | 1.3 | 1.5 |
| | T Richness | 5.0 | 6.0 | 9.0 | 6.7 | 2.1 |
| | EPT Percent | 79.79% | 75.60% | 76.06% | 77% | 2% |
| | E Percent | 22.27% | 27.00% | 33.17% | 27% | 5% |
| | Pollution Sensitive Richness | 1.0 | 0.0 | 1.0 | 0.7 | 0.6 |
| | Pollution Tolerant Percent | 0.21% | 0.20% | 0.50% | 0% | 0% |
| | Dominant Taxon Percent | 26.39% | 29.60% | 30.17% | 29% | 2% |
| | Dominant Taxa (2) Percent | 49.07% | 55.80% | 50.37% | 52% | 4% |
| | Dominant Taxa (3) Percent | 69.90% | 66.40% | 63.59% | 67% | 3% |
| | Filterer Percent | 64.95% | 55.40% | 37.41% | 53% | 14% |
| | Grazers + Scrapers Percent | 21.44% | 27.20% | 31.67% | 27% | 5% |
| | Clinger Richness | 10.0 | 15.0 | 14.0 | 13.0 | 2.6 |
| | Clinger Percent | 92.78% | 92.80% | 82.79% | 89% | 6% |
| | *Pteronarcys* Richness | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Diptera Richness | 1.0 | 4.0 | 2.0 | 2.3 | 1.5 |

| SFR-4 (Cont.) | Taxon/Metric | BH06I07 | BH06I08 | BH06I09 | Mean | SD |
|---|---|---|---|---|---|---|
| | Chironomidae Richness | 8.0 | 12.0 | 7.0 | 9.0 | 2.6 |
| | Plecoptera Percent | 0.82% | 0.00% | 0.25% | 0% | 0% |
| | Trichoptera Percent | 56.70% | 48.60% | 42.64% | 49% | 7% |
| | Diptera Percent | 12.58% | 13.20% | 3.49% | 10% | 5% |
| | Chironomidae Percent | 6.19% | 8.60% | 13.97% | 10% | 4% |
| | Tanytarsini Tribe Percent | 0.00% | 0.20% | 0.00% | 0% | 0% |
| | Other Diptera and non-insects Percent | 12.58% | 13.80% | 4.99% | 10% | 5% |
| | *Corbicula* Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Oligochaeta Percent | 0.00% | 0.00% | 0.00% | 0% | 0% |
| | Intolerant Snail and Mussel Richness | 0 | 0 | 0 | 0% | 0% |
| | Sediment Tolerant Percent | 0.00% | 0.20% | 0.25% | 0% | 0% |
| | Hilsenhoff Biotic Index | 3.0 | 2.6 | 2.6 | 2.7 | 0.2 |
| | Hydropsychidae/Trichoptera | 0.5 | 0.3 | 0.3 | 0.4 | 0.1 |
| | Omnivore and Scavenger Percent | 0.00% | 0.20% | 0.50% | 0% | 0% |
| | Gatherer and Filterer Percent | 71.55% | 60.80% | 48.63% | 60% | 11% |
| | Gatherer Percent | 6.60% | 5.40% | 11.22% | 8% | 3% |
| | Predator Percent | 5.36% | 6.40% | 9.48% | 7% | 2% |
| | Shredder Percent | 1.65% | 5.00% | 9.23% | 5% | 4% |
| | Multivoltine Percent | 7.63% | 9.60% | 16.96% | 11% | 5% |
| | Univoltine Percent | 64.12% | 58.40% | 57.36% | 60% | 4% |
| ADDITIONAL METRICS | Air Breather Percent | 0.21% | 0.60% | 2.99% | 1% | 2% |
| | Air Breather Richness | 1.0 | 2.0 | 1.0 | 1.3 | 0.6 |
| | Baetidae/Ephemeroptera | 0.06 | 0.01 | 0.05 | 4% | 3% |
| | Burrower Percent | 0.62% | 1.60% | 0.25% | 1% | 1% |
| | Burrower Richness | 1.0 | 5.0 | 1.0 | 2.3 | 2.3 |
| | Cold Stenotherm Percent | 0.00% | 0.00% | 0.75% | 0% | 0% |
| | Cold Stenotherm Richness | 0.0 | 0.0 | 2.0 | 0.7 | 1.2 |
| | Collector Percent | 71.55% | 60.80% | 48.63% | 60% | 11% |
| | CTQa | 72.06 | 80.04 | 69.65 | 7392% | 544% |
| | Dominant Taxa (10) Percent | 93.81% | 92.20% | 85.54% | 91% | 4% |
| | Evenness | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| | Filterer Richness | 3.0 | 3.0 | 4.0 | 3.3 | 0.6 |
| | Hemoglobin Bearer Percent | 1.44% | 3.40% | 5.74% | 4% | 2% |
| | Hemoglobin Bearer Richness | 1 | 1 | 2 | 133% | 58% |
| | Intolerant Percent | 53.20% | 62.60% | 62.59% | 59% | 5% |
| | Margalef D | 3.4 | 5.0 | 5.0 | 4.5 | 0.9 |
| | Metals Tolerance Index | 3.4 | 2.9 | 2.7 | 3.0 | 0.3 |
| | Non-Insect Percent | 0.00% | 0.60% | 1.50% | 1% | 1% |
| | Predator Richness | 7.0 | 7.0 | 6.0 | 6.7 | 0.6 |
| | Scraper/Filterer | 0.3 | 0.5 | 0.8 | 0.6 | 0.3 |
| | Scraper/Scraper+Filterer | 0.2 | 0.3 | 0.5 | 0.3 | 0.1 |
| | Scraper+Shredder Percent | 23.09% | 32.20% | 40.90% | 32% | 9% |
| | Sediment Sensitive Percent | 0.41% | 0.40% | 0.25% | 0% | 0% |
| | Sediment Sensitive Richness | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| | Sediment Tolerant Richness | 0.0 | 1.0 | 1.0 | 0.7 | 0.6 |
| | Semivoltine Richness | 5 | 6 | 6 | 567% | 58% |

| SFR-4 (Cont.) | Taxon/Metric | BH06I07 | BH06I08 | BH06I09 | Mean | SD |
|---|---|---|---|---|---|---|
| | Shannon H (log2) | 2.77 | 2.94 | 3.32 | 3.01 | 0.28 |
| | Shannon H (loge) | 1.92 | 2.04 | 2.30 | 2.09 | 0.19 |
| | Simpson D | 0.20 | 0.20 | 0.17 | 0.19 | 0.02 |
| | Simpson D (1-D) | 0.80 | 0.80 | 0.83 | 0.81 | 0.98 |
| | Supertolerant Percent | 0.62% | 1.00% | 1.25% | 1% | 0% |
| | Swimmer Percent | 1.44% | 0.80% | 4.74% | 2% | 2% |
| | Swimmer Richness | 1.0 | 2.0 | 3.0 | 2.0 | 1.0 |
| | Univoltine Richness | 8.0 | 11.0 | 14.0 | 11.0 | 3.0 |
| | Elmidae Percent | 1.24% | 1.60% | 2.00% | 1.61% | 0.38% |
| | Scraper Richness | 2.00 | 4.00 | 4.00 | 3.3 | 1.2 |
| | % Metals Sensitive Species | 25% | 31% | 38% | 31% | 6% |
| | RMI | 15 | 15 | 15 | 15 | 0.0 |
| | B-IBI | 24 | 26 | 28 | 26 | |