LMS/MNT/S07361

Monticello Mill Tailings Site Operable Unit III Biomonitoring Program Status and Analytical Update

March 2011

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Abbreviations

BTAG	Biological Technical Assistance Group
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
mg/kg	milligrams per kilogram
µg/L	micrograms per liter
MMTS	Monticello Mill Tailings Site
ORNL	Oak Ridge National Laboratory
OU	Operable Unit
ROD	Record of Decision
Se	selenium
UDEQ	Utah Department of Environmental Quality
UMC	Upper Montezuma Creek
VSP	Visual Sampling Plan

Statistical Abbreviations

ANOVA	Analysis of Variance
p	p-value
N (or n)	number of samples in data set or subgroup
SE	standard error

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1.0 Introduction

1.1 Overview

Biomonitoring at Operable Unit (OU) III of the Monticello Mill Tailings Site (MMTS) began in 2004 in accordance with the OU III Record of Decision (ROD), May 2004 (DOE 2004a). The MMTS is a Comprehensive Environmental Response, Compensation, and Liability Act, National Priorities List site located in and near the city of Monticello, Utah. Biomonitoring focuses on the potential risk to ecological receptors from selenium accumulation in wetlands habitat following remediation of OU I (former mill site) and OU II (properties surrounding the former mill site). Under OU I and OU II, removal of contaminated soil, sediment, and debris associated with the former uranium- and vanadium-ore mill, and placement of these materials in a permanent disposal cell, was completed by the U.S. Department of Energy (DOE) by 1999. OU III addresses residual surface water and groundwater contamination derived from the former mill tailings. Figure 1 shows the OU III study area and plots the most recent selenium results for relevant sampling locations.

After remediation of OU I and OU II was completed, concentrations of most site-related contaminants began to decrease in surface water (Montezuma Creek) and the affected shallow alluvial aquifer; however, an increase in selenium was observed in surface water (in particular, mill site seeps) and groundwater. The source of elevated selenium is the weathering of two bedrock units—Mancos Shale and Dakota Sandstone—which contain naturally high concentrations of selenium. These units were freshly exposed during OU I and OU II remedial actions on the former mill site when the overlying alluvial sediments were removed to bedrock. The alluvial aquifer was then reconstructed to directly overlie the fresh bedrock surface. Bedrock units from off-site locations also contribute selenium to OU III surface water and groundwater. Supporting information regarding the source of selenium contamination at OU III is provided in recent annual groundwater evaluation reports (e.g., see DOE 2010).

The OU III ROD describes the selected remedy for surface water and groundwater contamination (monitored natural attenuation with institutional controls) and includes biomonitoring as a remedy component. Biomonitoring was implemented in response to increases in selenium in surface water and groundwater observed at that time. Concentrations of selenium in surface water and groundwater have since decreased. The objective of biomonitoring is to determine if selenium is present in environmental media at levels that could have adverse effects on ecological receptors. Ecological receptors were identified in the OU III baseline risk assessment (DOE 1998); however, new wetlands constructed at and downstream of the former mill site (Wetlands 1–3 and the sediment retention pond [Sediment Pond]) after OU I and OU II remedial actions represent new habitat that would support potentially different ecological receptors from those identified in 1998. The update to the baseline risk assessment (DOE 2004b) identified that the primary ecological receptors of concern associated with the new habitat are birds that frequent the wetlands to feed on aquatic organisms. Updated wildlife surveys were conducted as a part of the biomonitoring effort to identify avian species using the area.

To date, biomonitoring has consisted of surface water, sediment, and macroinvertebrate sampling. Section 3.0 of the OU III ROD states that if concentrations of selenium in macroinvertebrate tissue for any stratum exceed 7 milligrams per kilogram (mg/kg), the need for sampling of avian eggs will be evaluated. The threshold of 7 mg/kg of selenium in invertebrates

was adopted from ecological risk guidelines used by the Sacramento Fish and Wildlife Office[1] for evaluating the effects of selenium residues in the San Joaquin Valley. According to these guidelines, levels below 3 mg/kg (dry weight) in the animal food chain (invertebrates) should have no adverse effect on birds. Invertebrate concentrations between 3 and 7 mg/kg represent a "level of concern," and 7 mg/kg is established as the toxicity threshold above which adverse effects (i.e., reproductive impairment) are expected. These guidelines are population based and are therefore intended for comparison to mean concentrations rather than individual measurements. Because selenium concentrations in macroinvertebrate samples collected in reference (background) areas historically exceed the aforementioned levels of concern, this analysis focuses only on the 7 mg/kg toxicity threshold in accordance with the OU III ROD (DOE 2004a).

1.2 Objectives and Scope

The catalyst for this evaluation is established in the OU III ROD and subsequent program directives, which stipulate that:

(1) Selenium concentrations in macroinvertebrate tissue for any stratum must not exceed 7 mg/kg (if selenium concentrations exceed this threshold, bird egg sampling may be necessary); and

(2) If no consistent increases in selenium are observed in biota, and if biota concentrations remain below threshold levels for 3 consecutive years, in the context of benthic macroinvertebrates, biomonitoring can be discontinued or significantly reduced in scope.

In September 2010, during the semiannual Federal Facility Agreement meeting, DOE, in concurrence with the U.S. Environmental Protection Agency (EPA) and the Utah Department of Environmental Quality (UDEQ), agreed to prepare a data summary and analysis for all surface water, sediment, and macroinvertebrate samples, including reference (background) data, relevant to OU III biomonitoring. The content of this report fulfills that commitment and is intended to provide MMTS risk managers with the necessary information to determine if current and projected ecological risks are acceptable and to define the scope of future near- and long-term biomonitoring at OU III.

This report presents a statistical analysis of OU III biomonitoring data and other relevant OU III data collected during the pre-ROD ecological risk assessment (DOE 1998). The statistical analysis compares selenium trending in environmental media (sediment, surface water, and benthic macroinvertebrates) in Wetland 3 and the Sediment Pond to ROD-specific criteria that define acceptable risk to avian receptors and the stated conditions by which biomonitoring may be discontinued.

The statistical analysis also compares selenium concentrations in these media to concentrations in similar media collected from reference locations on Montezuma Creek upstream of the former mill site and from Verdure Creek, located approximately 5 miles south of the OU III study area (Figure 1). Sampling locations as close as possible to Wetland 3 and the Sediment Pond were identified (areas with slow-moving water and emergent or shoreline vegetation). Verdure Creek was used as a reference area in the OU III risk assessment because it represents the waterway in

[1] www.fws.gov/sacramento/ec/GBP/Table1.htm, accessed February 8, 2011.

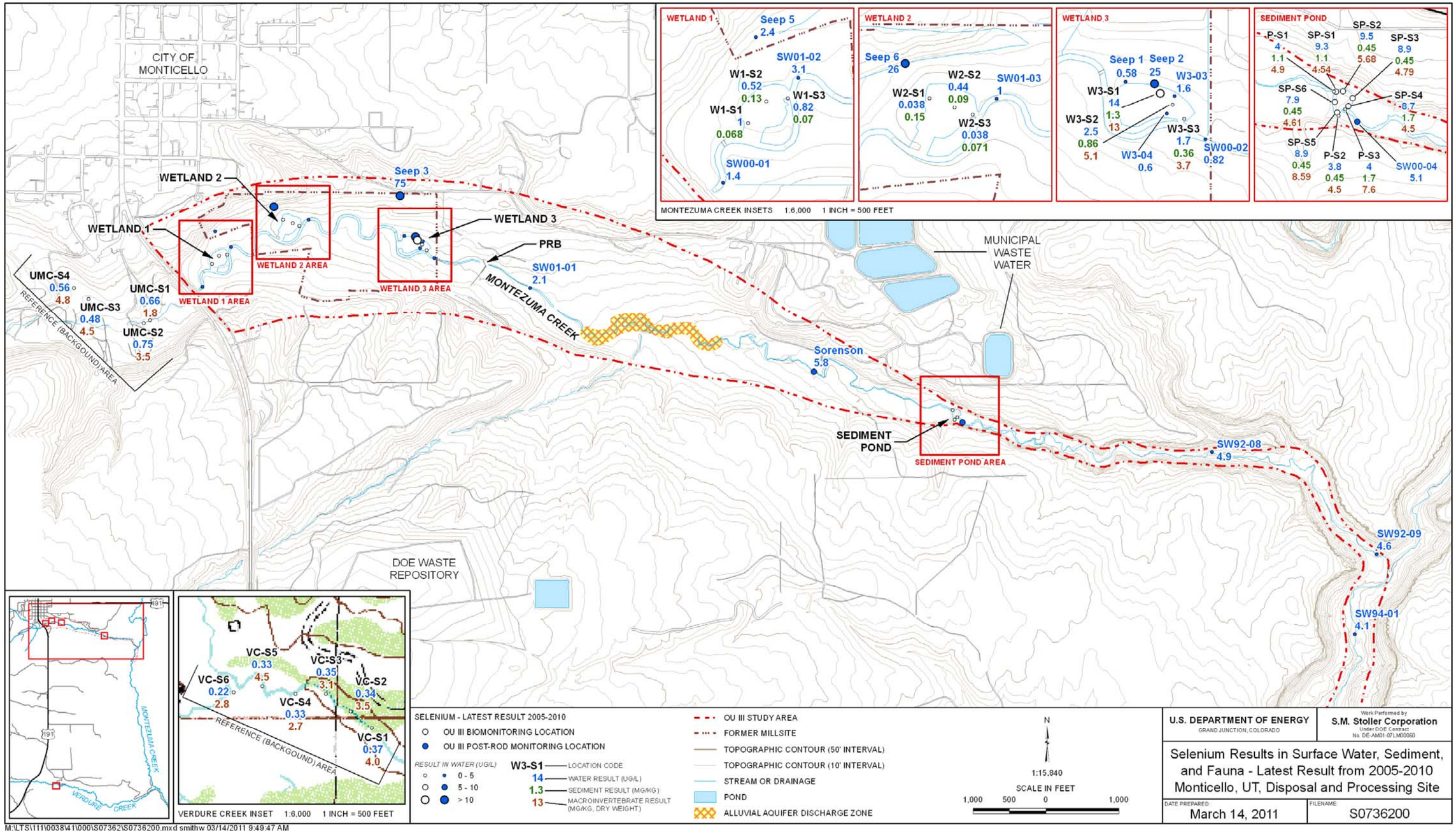

Figure 1. Biomonitoring Study Areas and Sample Location Map Showing Most Recent Selenium Results

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the region that is most similar to Montezuma Creek. However, its use as an analog in this evaluation is conservative because it does not contain ponded areas with associated wetlands similar to those of the OU III biomonitoring focus, where selenium levels would be expected to be higher. Outside of other former mill site wetlands, there are no true analogs to Wetland 3. Although they represent a greater flow-through environment, several of the reference areas upstream from the mill site (UMC-S3 and UMC-S4) are reasonable analogs for the Sediment Pond.

This report focuses on the Sediment Pond and Wetland 3. Biomonitoring was discontinued at Wetlands 1 and 2 in 2007 because benchmark levels were never exceeded, and monitoring did not indicate any apparent trending. Statistical analysis of selenium data for Wetlands 1 and 2 is therefore not addressed in this report. However, selenium data for these wetlands are included in the overall assessment of population exposure within all of OU III. Surface water samples are collected semiannually as part of the post-ROD surface water monitoring program (DOE 2010); except for those locations in the vicinity of the areas of focus, these data are also not addressed.

1.3 Report Organization

Section 2 summarizes the biomonitoring approach and the media-specific thresholds. Section 3 provides an overview of the analytical and statistical approaches used herein. Sections 4 and 5 document the historical results reported for analysis of sediment/surface water and macroinvertebrate sampling, respectively. To facilitate interpretation of the statistical analysis in light of the broader ecological (exposure) context, Section 6 summarizes results of the avian surveys conducted in 2005–2006 and 2008. Section 7 summarizes the findings and conclusions of this report. References, including a summary of all OU III biomonitoring program directives, are provided in Section 8. Section 9 provides a brief glossary of statistical terms used in many of the graphical plots.

To facilitate review, the bulk of the information in this report is provided in the figures and tables. The text is generally limited to a discussion of key assumptions and salient findings. Appendix A presents the detailed analytical data used in this evaluation.[2] Appendix B presents summary statistics for selenium in macroinvertebrate tissue samples. Appendix C summarizes in tabular format the results of the avian surveys.

2.0 Biomonitoring Approach

The biomonitoring approach was developed in consultation with the multi-agency Biological Technical Assistance Group (BTAG), which continues to guide the effort. The BTAG comprises representatives of DOE, EPA, UDEQ, and the U.S. Fish and Wildlife Service having expertise in biology, ecology, hydrogeology, and ecotoxicity. The results of biomonitoring are reported annually to EPA and UDEQ and are regularly discussed with the BTAG to assess ecological risk and to determine the future scope of biomonitoring. Components of the biomonitoring task identified in the OU III ROD are:

- Conducting an updated avian survey to identify species using the area, including threatened, endangered, and State-sensitive species.

[2] These data are also available in electronic or disk format upon request.

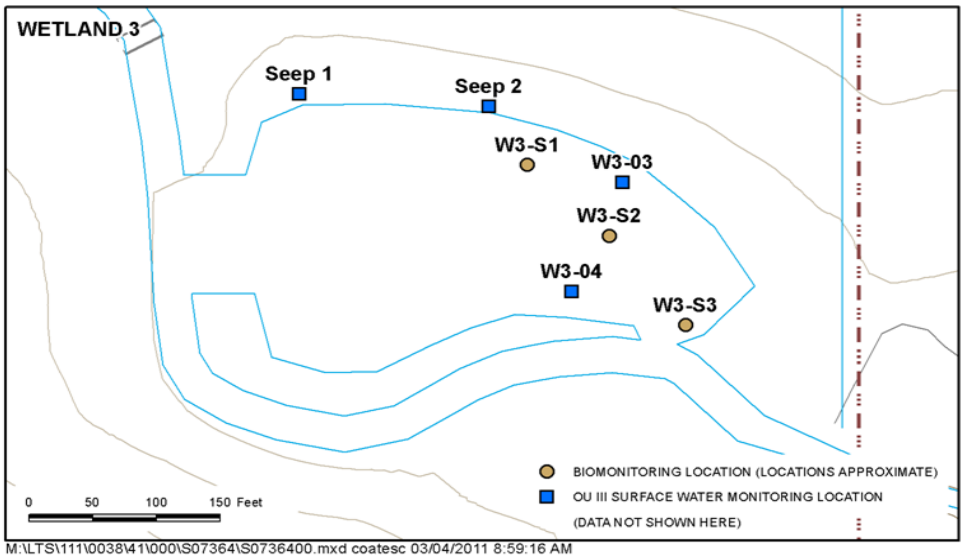
- Using a multilevel sampling approach, beginning with surface water and sediment, followed by macroinvertebrates, followed by bird eggs.
- Establishing threshold levels that determine if the next level should be sampled. Threshold levels are:
  - — 5 micrograms per liter (µg/L) selenium in any surface water stratum[3] or 4 mg/kg selenium in any sediment stratum. Macroinvertebrate sampling is needed if either level is exceeded.
  - — 7 mg/kg selenium in macroinvertebrate tissue for any stratum. If directed by BTAG, bird egg sampling is necessary if the threshold is exceeded.
- If no consistent increases in selenium are observed in water or sediment, and if biota concentrations remain below threshold levels for 3 consecutive years, biomonitoring can be discontinued.

Avian surveys were completed in 2005, 2006, and 2008. Whereas surveys conducted in 2005 and 2006 included all wetlands (Wetlands 1–3) and the Sediment Pond, the survey conducted in 2008 focused on Wetland 3 and the Sediment Pond only. The surveys were designed to determine the primary avian species using the wetlands and to determine if those species included federally listed threatened or endangered species, State-listed, or other sensitive species. In addition to routine OU III semiannual surface water sampling, which includes points in and near Wetland 3 and the Sediment Pond, co-located surface water and sediment sampling was conducted at all wetlands from 2004 to 2008 and in 2010 in Wetland 3 and the Sediment Pond. Benthic macroinvertebrate sampling was completed between 2005 and 2008 and in 2010. As stated in Section 1.2, biomonitoring was discontinued in 2007 at Wetlands 1 and 2.

Sediment, surface water, and benthic macroinvertebrate sampling locations were selected on the basis of dividing Wetlands 1, 2, and 3 into three zones: the inlet area, the middle portion of the wetland, and the outlet area. For these wetlands, the inlet corresponds to the area nearest the point where groundwater is discharged to the wetland at its upstream end. Because a primary source of selenium to the wetlands, particularly at Wetland 3, was considered to be from discharging groundwater, this criterion for the inlet location was intentionally selected to evaluate the likely highest levels of selenium in the sample media. The sampling location strategy for the Sediment Pond was selected to characterize selenium accumulation at the inlet and outlet areas and at a slack-water shore location agreed upon by the BTAG. Figures 2 and 3, which document results for Wetland 3 and the Sediment Pond, respectively, provide a more detailed view of the study area shown in Figure 1. In 2010, the sampling strategy was expanded to include additional locations in Wetland 3 and the Sediment Pond as conditions allowed.

In accordance with the OU III ROD, all samples of environmental media were analyzed for selenium. Sediment, surface water, and macroinvertebrate samples were collected in accordance with Sampling and Analysis Plans reviewed and approved by BTAG. These concurred upon sampling and analysis plans are attached to the Program Directives for the Monticello project, referenced at the end of Section 8.0. Macroinvertebrate samples collected in 2005–2010 were analyzed by Battelle Marine Sciences Laboratory in Sequim, Washington.

[3] A stratum is defined in the OU III ROD as a distinct established sampling region within the wetland (e.g., inlet, shore, outlet).



Wetland 3 Selenium Results: Inlet (W3-S1)

Date	Sediment (mg/kg Se)	Surface Water (µg/L Se)	Macroinvertebrates Date	Macroinvertebrates Se (mg/kg)
10/6/2004	1.3	14	--	--
4/5/2005	0.64	3	5/24/2005	6.2
10/11/2005	0.32	0.54	--	--
4/19/2006	6.9	3.5	5/17/2006	6.5
10/4/2006	1.7	4.2	--	--
4/9/2007	8.8	22	5/24/2007	--
4/8/2008	1.3	14	6/10/2008	13.0
6/24/2010	--	1.9	6/24/2010	4.7**
Additonal June 23, 2010 samples, generally colocated with W3-S1:				
W3-S4	--	1.9	--	--
W3-S5	--	3.1	--	--

Notes:

- Although W3-S1, W3-S2, and W3-S3 were intended to represent inlet, middle, and outlet strata, actual locations varied yearly depending on water and vegetation conditions. Two additional samples, W3-S4 and W3-S5, were collected in June 2010 near previous W3-S1 locations.
- All surface water results are non-filtered.
- Macroinvertebrate results are dry weight concentrations.
- Values in red exceed the corresponding criterion:
  Sediments: 4 mg/kg Se
  Surface water: 5 µg/L Se
  Macroinvertebrates: 7 mg/kg Se

-- Not sampled

**Although intended as an inlet sample, in June 2010, macroinvertebrate sample W3-S1 (the only location sampled) was collected near the interior of the wetland because of low stagnant water. Because of these conditions (there were only a few open pools in the middle of the wetland), it was not possible to sample macroinvertebrates at any other location in 2010.

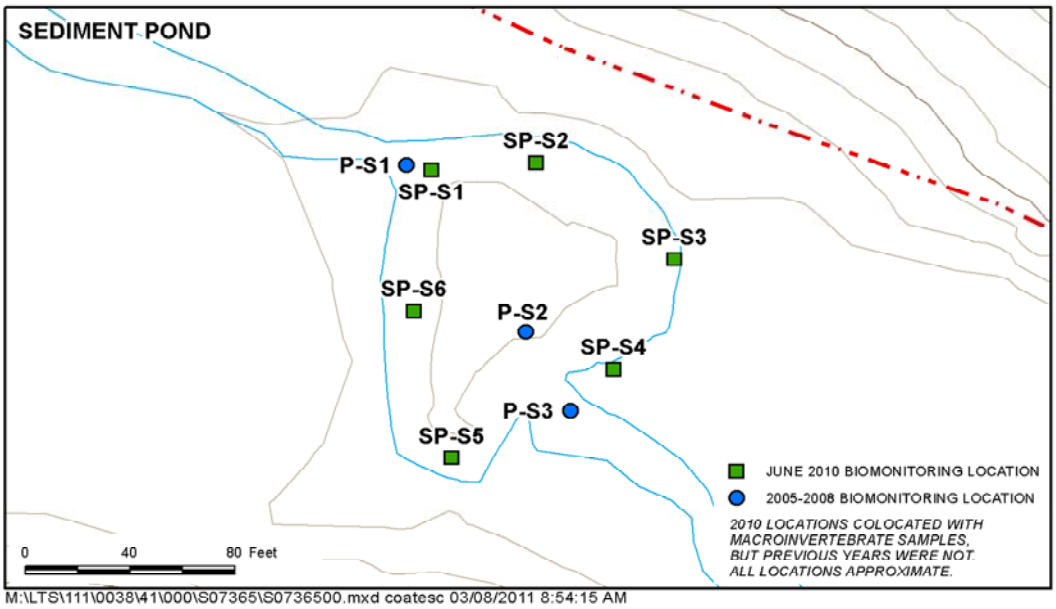
Wetland 3 Selenium Results: Middle (W3-S2)

Date	Sediment (mg/kg Se)	Surface Water (µg/L Se)	Macroinvertebrates Date	Macroinvertebrates Se (mg/kg)
10/6/2004	0.63	1.1	--	--
4/5/2005	0.88	2.1	5/24/2005	10.3
10/11/2005	0.37	0.4	--	--
4/19/2006	1.0	0.56	5/17/2006	3.7
10/4/2006	0.84	1.6	--	--
4/9/2007	< 0.069	0.74	5/24/2007	6.8
--	--	--	5/24/2007	9.5
4/8/2008	0.86	2.5	6/10/2008	5.1
6/24/2010	--	--	6/24/2010	--

Wetland 3 Selenium Results: Outlet (W3-S3)

Date	Sediment (mg/kg Se)	Surface Water (µg/L Se)	Macroinvertebrates Date	Macroinvertebrates Se (mg/kg)
10/6/2004	0.43	1.5	--	--
4/5/2005	0.2	2.6	5/24/2005	5.2
10/11/2005	0.27	0.21	--	--
4/19/2006	0.45	1.4/3*	5/17/2006	5.9
10/4/2006	0.32	< 0.025	--	--
4/9/2007	< 0.06	0.52	5/24/2007	3.9
4/8/2008	0.36	1.7	6/10/2008	3.7
6/24/2010	--	--	6/24/2010	--

Figure 2. Wetland 3 Sampling Locations and Historical Biomonitoring Analytical Results



Pond Inlet Selenium Results:
P-S1 (2004-2008) and SP-S1 (2010)

Date	Sediment (mg/kg Se)	Surface Water (µg/L Se)	Macroinvertebrates Date	Macroinvertebrates Se (mg/kg)
10/6/2004	3.3	3.7	--	--
4/5/2005	1.3	2.9	5/24/2005	4.3
10/11/2005	1.9	3	--	4.2/3.09*
4/19/2006	0.56	3.6	5/17/2006	3.6
10/4/2006	0.58	4.1	--	--
4/9/2007	4.3	4.5	5/23/2007	5.1/6.5*
4/8/2008	1.1	4	6/11/2008	4.9
6/23/2010	--	9.3	6/23/2010	4.5

Notes:

- As noted for Wetland 3, Sediment Pond samples also varied yearly depending on water and vegetation conditions.
- All surface water results are non-filtered.
- Macroinvertebrate results are dry weight concentrations.
- * denotes replicate results.
- Values in red exceed the corresponding criterion:
  - sediments: 4 mg/kg Se
  - surface water: 5 mg/L Se
  - macroinvertebrates: 7 mg/kg Se

-- Not sampled

Pond Middle Selenium Results:
P-S2 (2004-2008), SP-S2, SP-S3, SP-S5, & SP-S6

Date	Sediment (mg/kg Se)	Surface Water (µg/L Se)	Macroinvertebrates Date	Macroinvertebrates Se (mg/kg)
10/6/2004	3.0	1.6	--	--
4/5/2005	0.86	2.8	5/24/2005	3.15
10/11/2005	0.51	3.2	--	--
4/19/2006	0.55	3.4	5/17/2006	5.15 3.95/2.4/4.6*
10/4/2006	0.74	4.5	--	--
4/9/2007	< 0.069	3.9	5/23/2007	8.02/8.8*
4/8/2008	0.45	3.8	6/10/2008	4.5/4.3*
June 23, 2010 samples, not colocated with previous:				
SP-S2:	--	9.5	6/23/2010	5.7
SP-S3:	--	8.9	" "	4.8
SP-S5:	--	8.9	6/23/2010	8.6
SP-S6:	--	7.9	" "	4.6/4.0*

Pond Outlet Selenium Results:
P-S3 (2004-2008) and SP-S4 (2010)

Date	Sediment (mg/kg Se)	Surface Water (µg/L Se)	Macroinvertebrates Date	Macroinvertebrates Se (mg/kg)
10/6/2004	2.2	2	--	--
4/5/2005	3.4	3	5/24/2005	3.84
10/11/2005	4.1	3.1	--	--
4/19/2006	1.4	3.4	5/17/2006	4.7/4.8*
10/4/2006	0.78	4	--	--
4/9/2007	< 0.069	3.9	5/23/2007	3.55
4/8/2008	1.7	4.0	6/11/2008	7.64
6/23/2010	--	8.7	6/23/2010	4.5

Figure 3. Sediment Pond Biomonitoring Locations and Historical Analytical Results

A description of analytical methods, complete results, QA/QC narratives, and chain-of-custody forms are available in biomonitoring reports previously submitted to BTAG (DOE 2005b, Battelle 2007, Battelle 2008, DOE 2008b). Macroinvertebrates were collected and analyzed from reference areas in 1995 and 1996 by Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, according to procedures outlined in ORNL 1996 and ORNL 1997.

3.0 General Technical Approach

In analyzing the data, for each medium—sediments, surface water, and macroinvertebrates—essentially we are asking the following questions:

- What are the general patterns in space and time (spatial and temporal variation) and are trends apparent?
- What are concentrations relative to the corresponding threshold established in the ROD?
- What are the concentrations relative to background?

To address these questions, the following evaluation relies heavily upon exploratory data analysis techniques and associated graphical output. To express the central tendency and variability in the sample data, the data are plotted showing means plus or minus 1 standard error (SE) by grouping variable (e.g., area or year). In most of these graphs, raw data (i.e., individual measurements) are also plotted to better reflect the underlying distribution, including outlier and extreme observations (defined in the glossary in Section 9). As part of the preliminary exploratory analysis conducted for this evaluation, in addition to the plots of means and errors, plots were also generated where the vertical error bars represented 95 percent confidence intervals around the mean.[4] [5] Although the latter plots capture more of the variability about the mean, we have been consistent with previous studies (Peterson et al 2002; Battelle 2007; Battelle 2008; and DOE 2008b) in plotting the standard errors. (Figure 17 demonstrates the differences in these two measures of variability for pooled study area data.)

In another respect, we have not been consistent. Although previous biomonitoring reports (e.g., Battelle 2007, 2008) used the geometric means as the measure of central tendency, this report uses arithmetic means. This approach was adopted because it was considered to yield a more conservative analysis. Use of a geometric mean can yield a biased estimate of central tendency, and this bias is usually low (less conservative). Furthermore, as shown in Appendix B for macroinvertebrate tissue selenium results, in most cases, there was little difference between arithmetic and geometric means.

Statistical evaluations of data focused primarily on the macroinvertebrate monitoring results because, as demonstrated in the following section, selenium concentrations in the majority of sediment and surface water samples have been below corresponding toxicity thresholds.

[4] In general (except for very small sample sizes), assuming an underlying normal distribution, when vertical bars are standard errors of the mean, confidence intervals are about double the range of the standard errors.

[5] Initial exploratory data analysis also involved generation of standard non-parametric box and whisker plots—i.e., plotting the median, lower and upper quartiles, outliers, and extremes. Although often helpful and illustrative for larger data sets, this visualization tool was not helpful for this study because most of the small group sample sizes.

Additionally, previous studies have found no correlation between selenium in these media with macroinvertebrate results.

Statistical tests were performed and graphics were generated using Statistica (Version 10, StatSoft); this software was also used to perform Analysis of Variance (ANOVA) and t-tests. XLSTAT (Addinsoft, Version 2010.4.02) was used to generate the summary statistics provided in Appendix B and, as a corroborative measure (when sample sizes allowed), trending was also evaluated using the Mann-Kendall test Visual Sampling Plan (VSP) software developed by Battelle (http://vsp.pnl.gov/). This report was written assuming a general familiarity with statistical terms and methods.

4.0 Sediment and Surface Water Biomonitoring Results

Surface water and sediment were the initial environmental media addressed as part of the tiered biomonitoring approach presented in the OU III ROD. Toxicity thresholds for surface water or sediment were exceeded at one or more locations in 2004, prompting DOE to expand the biomonitoring scope to include the collection and analysis of benthic macroinvertebrates in subsequent years. This section presents a brief evaluation that includes historical distribution of selenium at OU III biomonitoring locations for sediment and surface water and a temporal analysis for Wetland 3 and the Sediment Pond.

The focus of the evaluation presented in this section is on Wetland 3 and the Sediment Pond, although historical information regarding Wetlands 1 and 2 is briefly addressed. Sediments in Wetlands 1 and 2 were sampled for selenium between October 2004 and April 2007. Because levels were consistently below the no-effects level, and no upward trending was apparent, BTAG approved discontinuing monitoring in these areas. Additional results and discussion for Wetlands 1 and 2 biomonitoring are provided in each of the annual OU III biomonitoring reports (for example, see DOE 2008b).

The evaluation of historical distributions and temporal trending of selenium in sediment and surface water presented in this section is brief compared to the evaluations presented in Section 5.0, which addresses selenium distribution and temporal trending in benthic macroinvertebrates. This is because sediment and surface water criteria were initially established as triggers for the collection and analysis of benthic macroinvertebrates. The BTAG determined that sediment and surface water selenium distributions were much less informative in assessing risk to avian receptors than selenium distributions in benthic macroinvertebrates, the primary food source of those receptors.

4.1 Sediments

The BTAG concurred in DOE's proposal to discontinue collection of sediment samples for OU III biomonitoring in 2010 because sediment concentrations were low and because selenium distribution in sediment was considered to be of minor importance in assessing risk to the avian receptors at OU III. Figure 4, which plots the mean selenium concentrations in sediments by study area (2004–2008), shows that the majority of results are below the 4 mg/kg toxicity threshold.

The few extreme observations at Wetland 3—all at the W3-S1 inlet location, 6.6−8.8 mg/kg—likely reflect the biased sampling strategy (applied between 2006 and 2008) by which samples were collected at points closest to the source of selenium to the wetland (Seep 2).[6] This explanation does not apply to the two extreme observations at the Sediment Pond (4.1–4.3 mg/kg); however, these two values only marginally exceed the toxicity threshold.

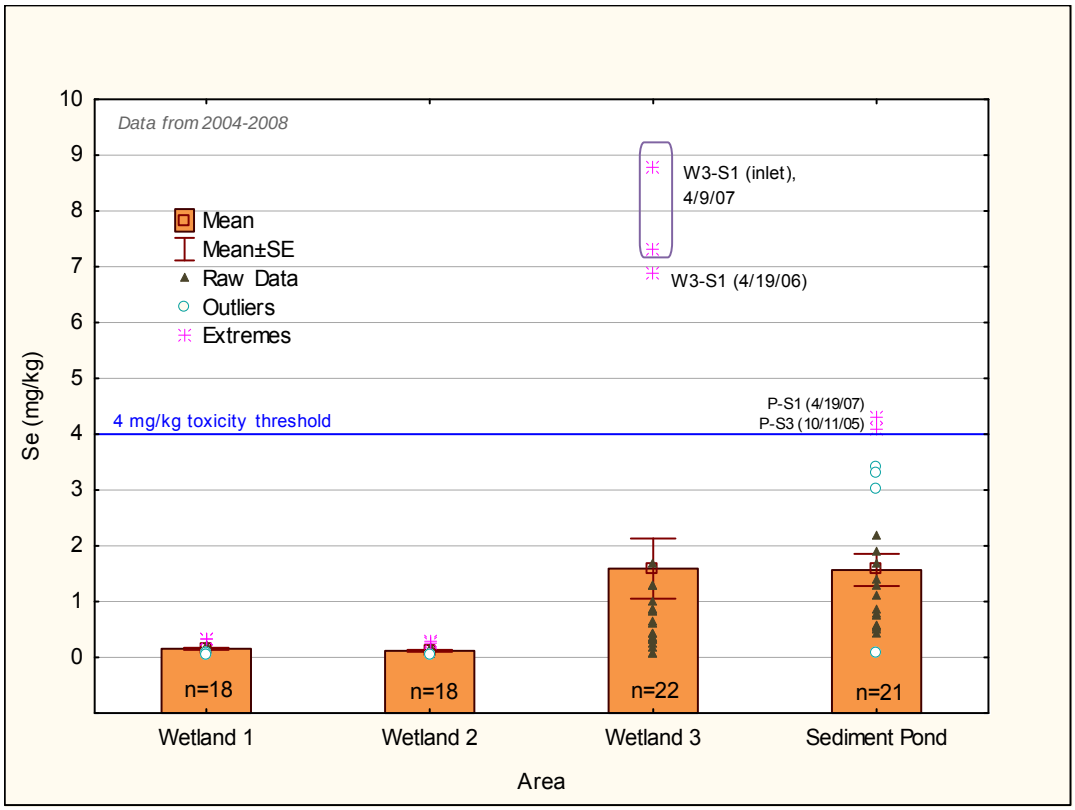


Figure 4. Historical Distribution of Selenium in Sediments at Biomonitoring Locations

Temporal trends of selenium in sediment at Wetland 3 and the Sediment Pond are shown in Figures 5 and 6. Variability of sample results is high in the inflow area of Wetland 3, located below the discharge point of Seep 2; a correlation to seasonal effects is not apparent. Linear regression analysis of the mean selenium concentration in Wetland 3 sediment indicates no temporal increase in selenium concentrations (Figure 5; linear fit of arithmetic mean). Figure 6 indicates no temporal increase in selenium in sediment at the Sediment Pond; instead, the mean concentration may be decreasing (linear fit of arithmetic mean; note that in Figures 5 and 6 individual mean values are not shown). These findings were also presented in the most recent biomonitoring report (DOE 2008b) and corroborate the recent decision to terminate the sediment sampling component of the biomonitoring program.

[6] Refer to the glossary in Section 9 for a definition of outliers and extremes.

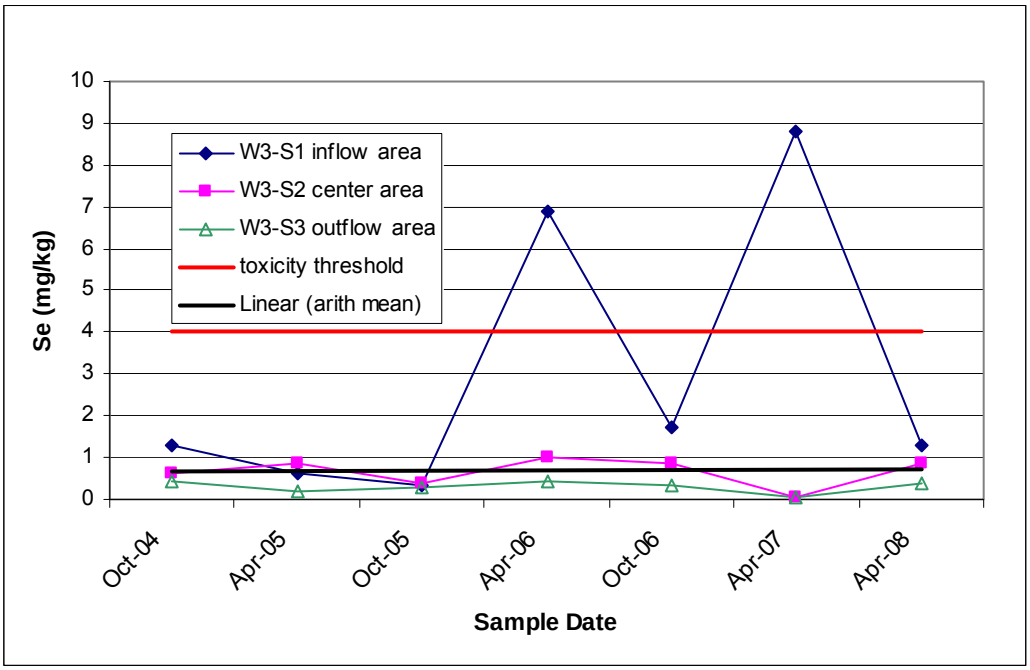


Figure 5. Temporal Variation of Selenium in Sediment at Wetland 3

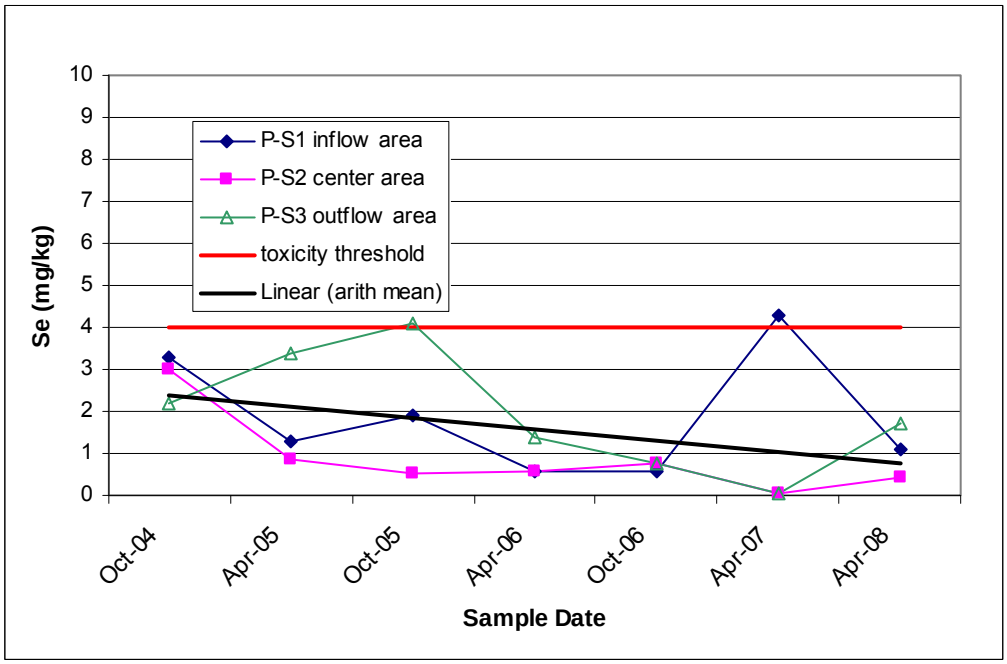


Figure 6. Temporal Variation of Selenium in Sediment at Sediment Pond

4.2 Surface Water

Surface water sampling at Wetland 3 and the Sediment Pond continued through 2010. As noted previously, biomonitoring at Wetlands 1 and 2 was discontinued in 2007. Figure 7 plots historical results for selenium in surface water (non-filtered results) by spatial group. Temporal trends for Wetland 3 and the Sediment Pond are plotted in Figures 8 and 9, respectively.

Figure 7 shows that the majority of all results are below the 5 µg/L toxicity threshold. The few extreme observations at Wetland 3 are the effect of a biased sampling strategy by which biomonitoring samples were collected nearest the source of selenium to the wetland (Seep 2). Temporal trends of selenium in surface water at Wetland 3 (Figure 8) show that variability of sample results is highest in the inflow area, located below the discharge point of Seep 2. Natural variation in the flow conditions in the wetland and sample location variation (e.g., proximity to Seep 2 inflow) may generally account for sample result variability over time.

Linear regression analysis of the mean selenium concentration in Wetland 3 surface water indicates no temporal increase (Figure 8; linear fit of arithmetic mean) and that the mean remains below the toxicity threshold. Figure 9 indicates a temporal increase in surface water selenium concentration at the Sediment Pond through June 2010 (note that in Figures 8 and 9, individual means are not shown). Selenium in surface water in the reach of Montezuma Creek downstream of the former mill site has been attributed to the discharge of remnant contamination in the alluvial aquifer to the creek (see hatched portion of Figure 1). Variability in selenium concentrations in OU III surface water may be attributable to a number of factors, including the natural variation in surface water and groundwater flow conditions (e.g., the movement of the groundwater contaminant plume) and biological processes in the pond that affect solubility.

The BTAG has determined that selenium concentration in surface water is less informative than concentrations in benthic macroinvertebrates for assessing ecological risk at OU III. The temporal trend implied in Figure 9 may therefore be inconsequential to an ecological risk management decision at OU III, given the analysis of selenium distribution in benthic macroinvertebrates presented in Section 5.0. Temporal trending of selenium in surface water (and groundwater) remains relevant to OU III because of established federal and state water quality restoration goals for OU III that are independent of the biomonitoring task. The ongoing task of water quality monitoring and data analysis that evaluates the progress in meeting these restoration goals (including selenium) is performed separately from the biomonitoring task.

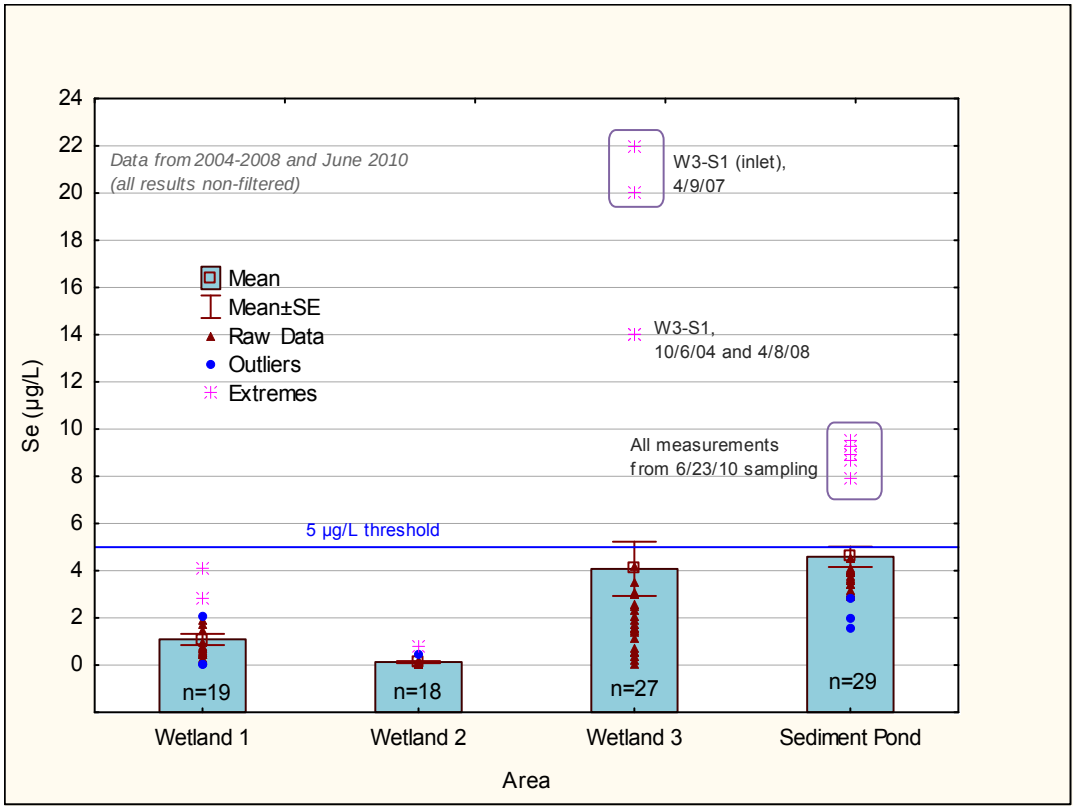


Figure 7. Historical Distribution of Selenium in Surface Water at Biomonitoring Locations

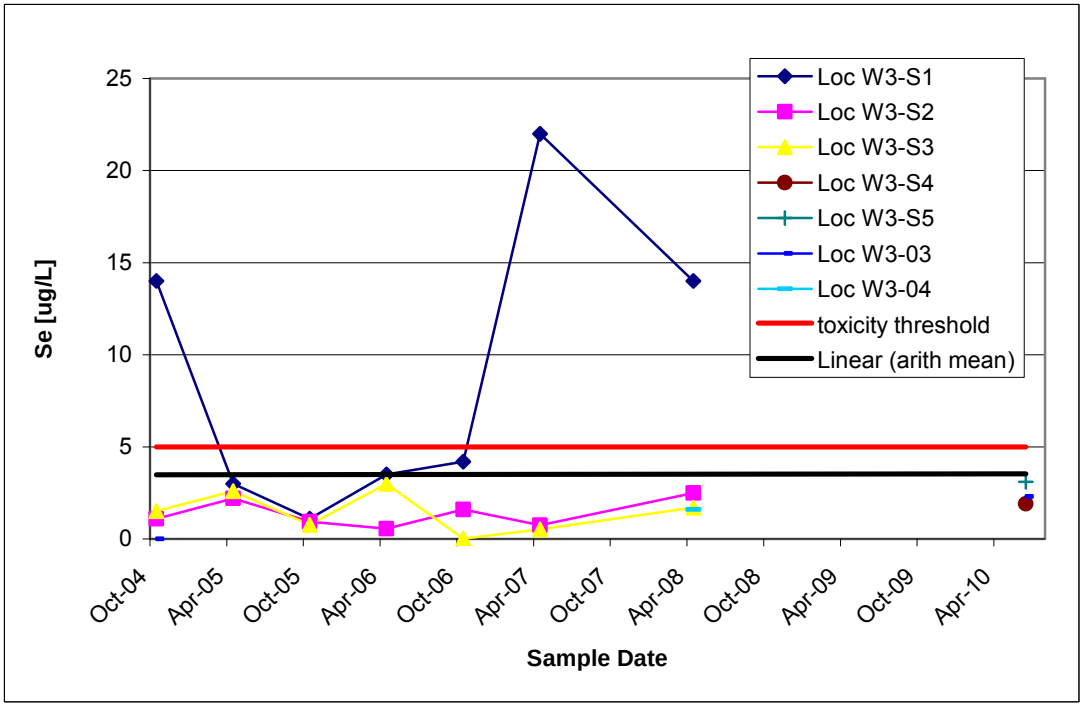


Figure 8. Temporal Variation of Selenium in Surface Water at Wetland 3

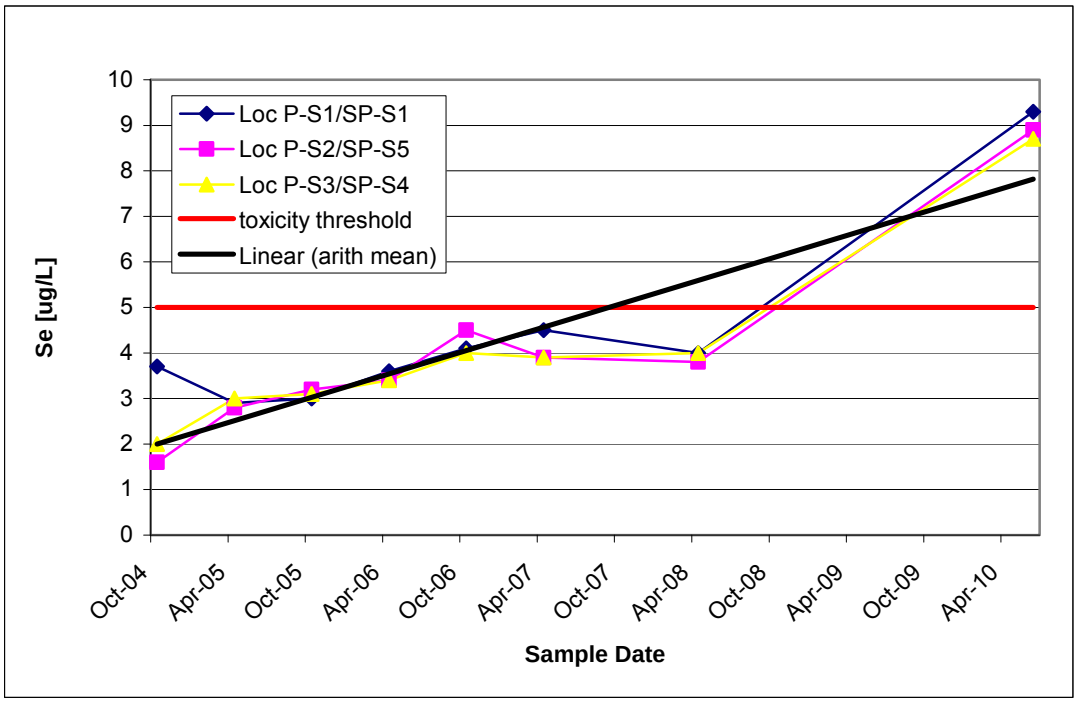


Figure 9. Temporal Variation of Selenium in Surface Water at the Sediment Pond

5.0 Macroinvertebrate Biomonitoring Results

This section provides an analysis of the results of all historical macroinvertebrate sampling efforts conducted for the Monticello project.

5.1 Sampling Summary and Overview

In compliance with the OU III ROD and in concurrence with the BTAG, macroinvertebrate sampling was initiated in 2005 and has been conducted annually, with the exception of 2009, since that time. Macroinvertebrate data were also collected by ORNL in 1995 and 1996 (ORNL 1996, ORNL 1997; see also Peterson et al. 2002) and are included as reference data. Table 1 summarizes all historical macroinvertebrate field sampling efforts conducted to date; resulting data are analyzed in the remainder of this section.

Sample collection procedures are described in detail in previous reports (see references provided in Table 1). Original field procedures included kick net, artificial substrate (Hester-Dendy type), and light trap sampling at Wetlands 1–3 and the Sediment Pond. The field procedures and sampling scopes changed each year in response to BTAG decisions after the previous year's data were collected and analyzed. The analysis presented in this section includes only data from kick net sampling. Results of Hester-Dendy samples, collected in 2005–2007 at the Sediment Pond, were excluded from this analysis for two reasons. First, this technique never produced sufficient biomass to yield any reliable conclusions about the set of organisms sampled. Second, this technique wasn't consistently employed across locations.

Table 1. Summary of Historical Macroinvertebrate Field Sampling Efforts

Year (Program Directive) [a]	Sampler and Dates	Areas and Locations Sampled (Number of Samples)[b]	Comments[c]
1995	ORNL August 17, 1995 (ORNL 1996; Peterson et. al 2002)	Background Verdure Creek (VD1-A/B; *n* = 2) Composite samples collected downstream of mill site: MZ2-A/B/C (*n* = 3) MZ3-A/B/C (*n* = 3) MZ5-A (*n* = 3) MZ9-A/B (*n* = 2)	Composite samples of similar macroinvertebrate taxa and functional feeding groups were collected from each site. This year was considered representative of normal precipitation conditions.
1996	ORNL August 14–15, 1996 (ORNL 1997)	Same as above, but expanded to include upper Montezuma Creek reference area (*n* = 18 total; see Figure 10 summary)	This year was considered to represent dry-year conditions. Selenium results at all locations, including the Verdure Creek and Montezuma Creek reference areas, were significantly higher than in the previous year.
2005 (MSG-05-03)	Battelle Memorial Institute (Battelle) May 24, 2005 (DOE 2005b)	Wetland 1 (*n* = 3); Wetland 2 (*n* = 4); Wetland 3 (*n* = 3); Sediment Pond (*n* = 4)	No background sampling conducted. Hester-Dendy samples collected but not evaluated herein for the reasons discussed in Section 5.1.
2006 (MSG-06-03)	Battelle May 17, 2006 (Battelle 2007)	Wetland 3 (*n* = 4) Sediment Pond (*n* = 4)	No exceptional conditions associated with this event.
2007 (MSG-06-03, extended)	S.M. Stoller Corporation (Stoller) May 23–24, 2007 (Battelle 2008)	Wetland 3 (*n* = 3) Sediment Pond (*n* = 4)	Biased sampling approach implemented at Wetland 3 (intentional collection in areas of highest known selenium).
2008 (MNT-08-03)	Stoller June 10–11, 2008 (DOE 2008b)	Wetland 3 (*n* = 3) Sediment Pond (*n* = 3)	Biased sampling approach continued at Wetland 3.
2010 (MNT-2010-03)	Stoller June 23, 2010	Wetland 3 (*n* = 1) Sediment Pond (*n* = 6) Reference areas Verdure Creek (*n* = 6) and Upper Montezuma Creek (*n* = 4)	Sampling scope expanded where conditions allowed. Sampling of Verdure Creek and Upper Montezuma Creek resumed. Only one sample could be collected in Wetland 3 because water was low and stagnant.

[a] OU III program directives are provided at the conclusion of Section 8.0 (References).

[b] The numbers cited above reflect the total number of samples used in the data analysis. For example, replicate composite samples collected by ORNL in 1995 (MZ2-A, MZ2-B, and MZ2-C) were treated as discrete data points and used to calculate the arithmetic mean. Alternatively, in the case of laboratory split samples and/or field duplicates with similar species composition, results were averaged consistent with previous investigators (ORNL 1995–1996, Battelle 2007–2008). Total numbers of samples are also provided in the tabular inset in Figure 10 by group and year.

[c] Detailed results, including taxa composition, are provided in Appendix A, Table A–1. This table also documents the results of Hester-Dendy samples collected in the Sediment Pond in 2005, 2006, and 2007.

Figure 10 plots all historical selenium results by area (grouping variable) and year (categorization variable); the intent of this figure is to show temporal variations for each spatial region. Seven plots are shown, representing Verdure Creek (Plot 1), ORNL pre-remediation data for selected areas downstream of the mill site (Plot 2), the upper Montezuma Creek reference area (Plot 3), Wetlands 1 and 2 (sampled in 2005 only; Plots 4 and 5, respectively), and—the primary focus of this evaluation—Wetland 3 and the Sediment Pond (Plots 6 and 7, respectively). To depict spatial variation within a given year, Figure 11 plots the same results but

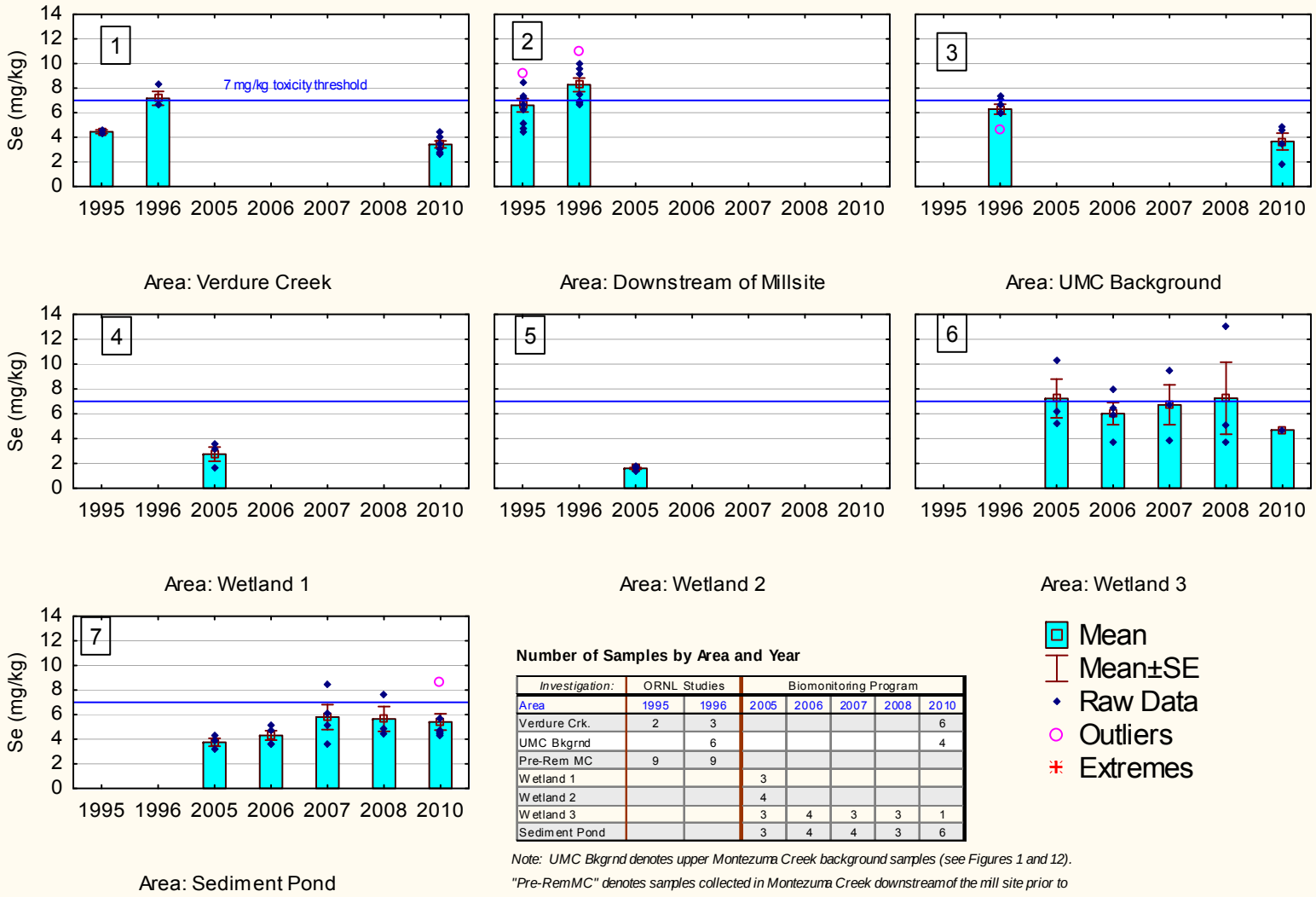
in an alternate fashion (grouping by year [2005–2010 only], then area) for Wetland 3, the Sediment Pond, and the reference areas. These and subsequent graphs plot the group mean selenium concentrations (in milligrams per kilogram dry weight) and standards errors; raw data are also plotted to facilitate review. In these and all subsequent plots, horizontal lines denote the 7 mg/kg toxicity threshold.

Several trends are apparent in Figure 10, including the temporal variation in selenium concentrations at both the Verdure Creek and Montezuma Creek reference areas (Plots 1 and 3); and (2) the apparent stable temporal trend in Wetland 3 and the Sediment Pond (Plots 6 and 7). Results for Wetlands 1 and 2 (with means of 2.8 and 1.7 mg/kg selenium, respectively) are well below the 7 mg/kg toxicity threshold. Although slight increases in mean selenium concentrations in the sediment pond are indicated between 2005 and 2007, all means (and most individual observations) are below the threshold. As both Figure 10 and Figure 11 are intended as preliminary snapshots, these findings (and supporting statistical analyses) are discussed further in the following pages.

5.2 Initial (Pre-Remediation) ORNL Findings: 1995–1996

This section provides some elaboration of ORNL results, which included selenium data for samples collected at the two reference areas, Verdure Creek (1995 and 1996) and upper Montezuma Creek (1996 only; see westernmost UMC- locations in Figure 1). Since these reference areas were not sampled as part of the biomonitoring program until 2010, the historical data provide useful information regarding temporal variation in these areas. This evaluation also provides a context for comparing current results relative to pre-remediation spatial and temporal patterns of selenium contamination. Figure 12 shows the 1995–1996 ORNL sampling locations; corresponding selenium results for macroinvertebrate tissue samples are plotted in Figure 13. As indicated previously, Verdure Creek is a free-flowing system, and it is not an ideal analog for a background comparison to the backwater wetlands (Wetland 3 and the Sediment Pond) found in Montezuma Creek.

Composite samples of similar macroinvertebrate taxa and functional feeding groups were collected from each site over a 2-year period. In both years, mean selenium concentrations were significantly higher (a factor of 2–4; $p < 0.05$) in macroinvertebrates collected from the two Montezuma Creek sites immediately downstream of the site (MZ-2 and MZ-3 in Figure 12) in comparison to concentrations from reference locations.



Number of Samples by Area and Year

Investigation:	ORNL Studies		Biomonitoring Program				
Area	1995	1996	2005	2006	2007	2008	2010
Verdure Crk.	2	3					6
UMC Bkgrnd		6					4
Pre-Rem MC	9	9					
Wetland 1			3				
Wetland 2			4				
Wetland 3			3	4	3	3	1
Sediment Pond			3	4	4	3	6

Note: UMC Bkgrnd denotes upper Montezuma Creek background samples (see Figures 1 and 12). "Pre-RemMC" denotes samples collected in Montezuma Creek downstream of the mill site prior to remediation during the ORNL studies (Figures 12-13).

Figure 10. Selenium Results for Macroinvertebrate Samples by Area and Year: 1995–1996, 2005–2010

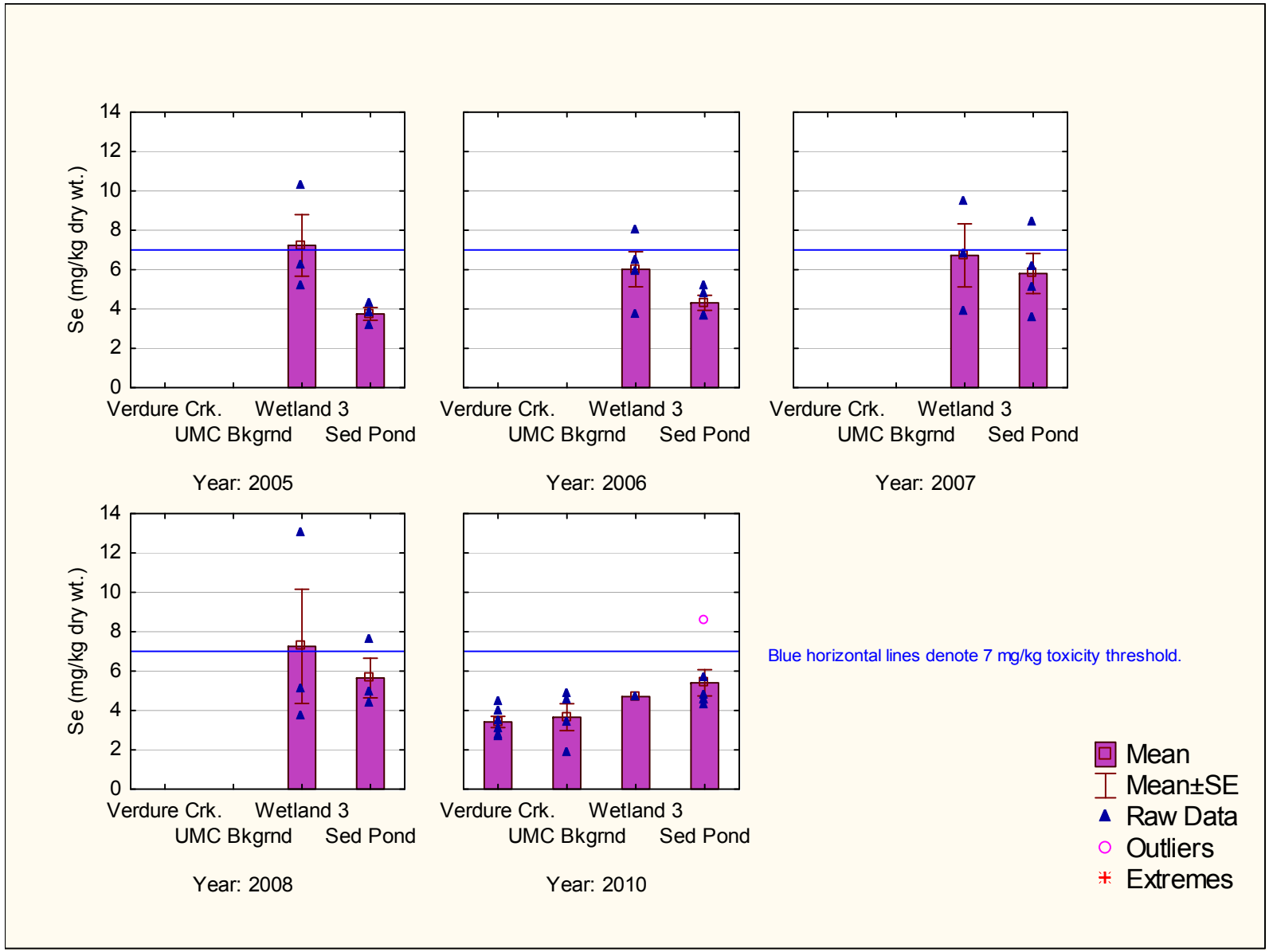


Figure 11. Categorized Plot of Selenium in Macroinvertebrates by Year, Location

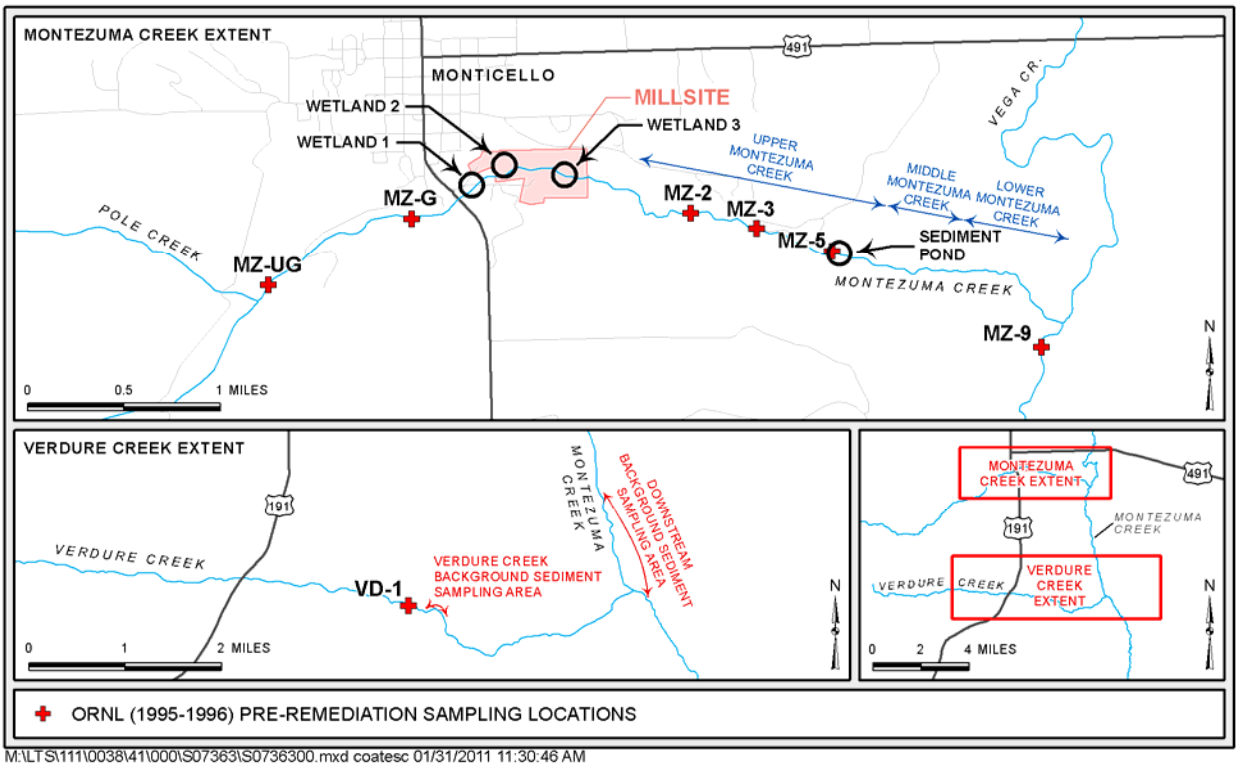


Figure 12. ORNL Sampling Sites on Montezuma Creek and Verdure Creek: 1995–1996

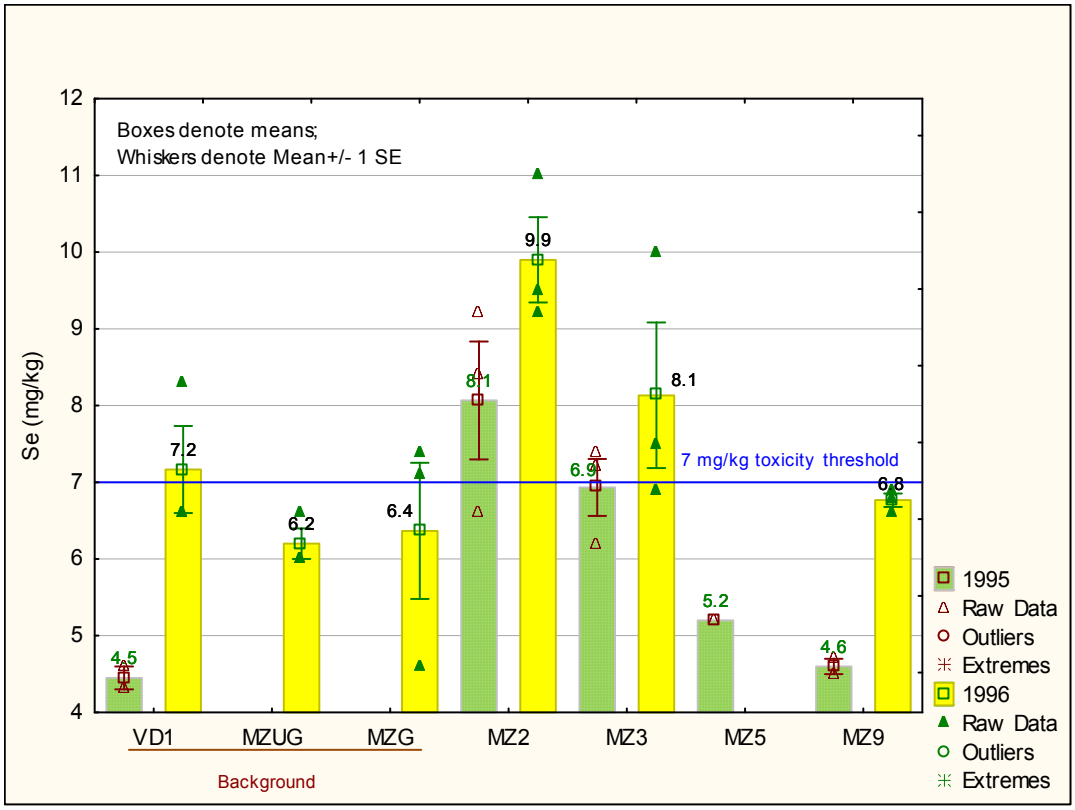


Figure 13. 1995–1996 ORNL (Pre-Remediation) Macroinvertebrate Sampling Results

Selenium concentrations were also significantly higher in the second year of the study. At Verdure Creek, the mean selenium concentration increased from 4.5 mg/kg in 1995 (essentially equivalent to the recent June 2010 mean, 4.5 mg/kg; see Plot 1 in Figure 10) to 7.2 mg/kg in 1996. The authors suggested that regional precipitation differences between years—for example, the drought in the second year of the study (1996)—may have accounted for these increases.[7] The upper Montezuma Creek reference area—MZ-UG and MZ-G in Figures 12 and 13—was not sampled in 1995, but in 1996, mean selenium concentrations were 6.2 and 6.4 mg/kg, respectively.

As discussed early in Section 1.1, and as identified in previous reports (Battelle 2007–2008; DOE 2008b), in addition to the 7 mg/kg toxicity threshold, the recommended ecological risk guidelines for selenium in macroinvertebrates also include a threshold for no effect (3 mg/kg) and a level of concern range (3–7 mg/kg). However, mean selenium concentrations in both Verdure Creek and upper Montezuma Creek reference areas significantly exceeded the 3 mg/kg lower threshold in 1996 (and in fact approached or exceeded the 7 mg/kg toxicity threshold). Recent (June 2010) background means (3.4–3.7 mg/kg) also exceed the no effects level. Given these findings), all comparisons in the remainder of this section are based on the 7 mg/kg toxicity threshold.

5.3 Macroinvertebrate Biomonitoring Results for Wetland 3 and the Sediment Pond

This section documents the historical results of macroinvertebrate sampling conducted at Wetland 3 and the Sediment Pond, assessing both spatial and temporal trends. As discussed in Section 2, the catalyst for this evaluation is established in the OU III ROD, which stipulates that:

- Selenium concentrations in macroinvertebrate tissue for any stratum must not exceed 7 mg/kg; and
- If no consistent increases in selenium are observed in biota, and if biota concentrations remain below 7 mg/kg for 3 consecutive years, in the context of benthic macroinvertebrates, biomonitoring can be discontinued or significantly reduced in scope.

The objective of this section is to evaluate the benthic biomonitoring results in light of those conditions. As discussed in Section 3, because most of the comparisons were of means between two independent groups (e.g., mean selenium concentrations in Wetland 3 vs. selenium in reference areas), or comparison of means with the toxicity threshold, t-tests were employed in all comparisons.[8] These tests were supplemented by ANOVA for comparisons of more than two independent groups (e.g., concentrations in Sediment Pond vs. selenium in both Verdure Creek and upper Montezuma Creek reference areas). As a corroborative measure, trending was also evaluated using the Mann-Kendall test and the VSP software. The reader is referred to Section 3 for additional information, to Appendix A (Table A–1) for the raw data and corresponding field observations, and to Appendix B for supporting statistical documentation.

[7] In elaborating on this point, Peterson et al. (2002) also suggested that low surface water flows would mean less dilution of groundwater sources and greater silt deposition in the remaining pools. This may have been especially important in upstream reaches of the creeks, particularly Verdure Creek, where the stream was reduced to a series of isolated pools with little water in riffle areas.

[8] Underwood (1997) provides a useful discussion of these approaches in the context of ecological experimental design.

Before proceeding with this evaluation, we should mention some necessary caveats. First, raw data are provided only to facilitate understanding of the underlying data. The population mean (as estimated by the sample mean) is the relevant basis for assessing ecological risks, so although individual exceedances may be of interest, they carry less weight in the analysis. Second, the constraints imposed by both small and uneven sample sizes must be acknowledged—in most cases, within groups, the number of samples (*n*) was less than 4 (see Figure 10; the only exceptions were for the early ORNL studies and the most recent June 2010 sampling in the Sediment Pond and reference areas). These constraints were unavoidable because many populations of macroinvertebrates in the area are not abundant (for example, it was only possible to collect one sample from Wetland 3 in 2010).

Figures 14 and 15 plot the means, standard errors, and raw data for selenium concentrations in Wetland 3 and the Sediment Pond, respectively, for the 2005–2010 biomonitoring period. These plots essentially duplicate the individual plots shown in Figure 8 (Plots 6 and 7), but they are provided on a larger scale and annotated to facilitate this discussion. In these figures, expanded captions are provided to facilitate review.

Figure 16 duplicates the plot in Figure 11, showing spatial distributions of selenium for the most recent (June 2010) snapshot. Essentially, this figure compares selenium distributions in the background areas with those in Wetland 3 and the Sediment Pond. This figure is annotated to document results of ANOVA tests, which test the hypothesis of comparability of group means. Conclusions based on these analyses are summarized in Table 2. Additional recommendations and summaries are provided in Section 7. Figure 17 presents a global summary plot reflecting all historical macroinvertebrate sampling results (data pooled over time); this figure also demonstrates the differences in expressions of variability, comparing data plotted using standard error bars (the approach taken herein) and confidence intervals.

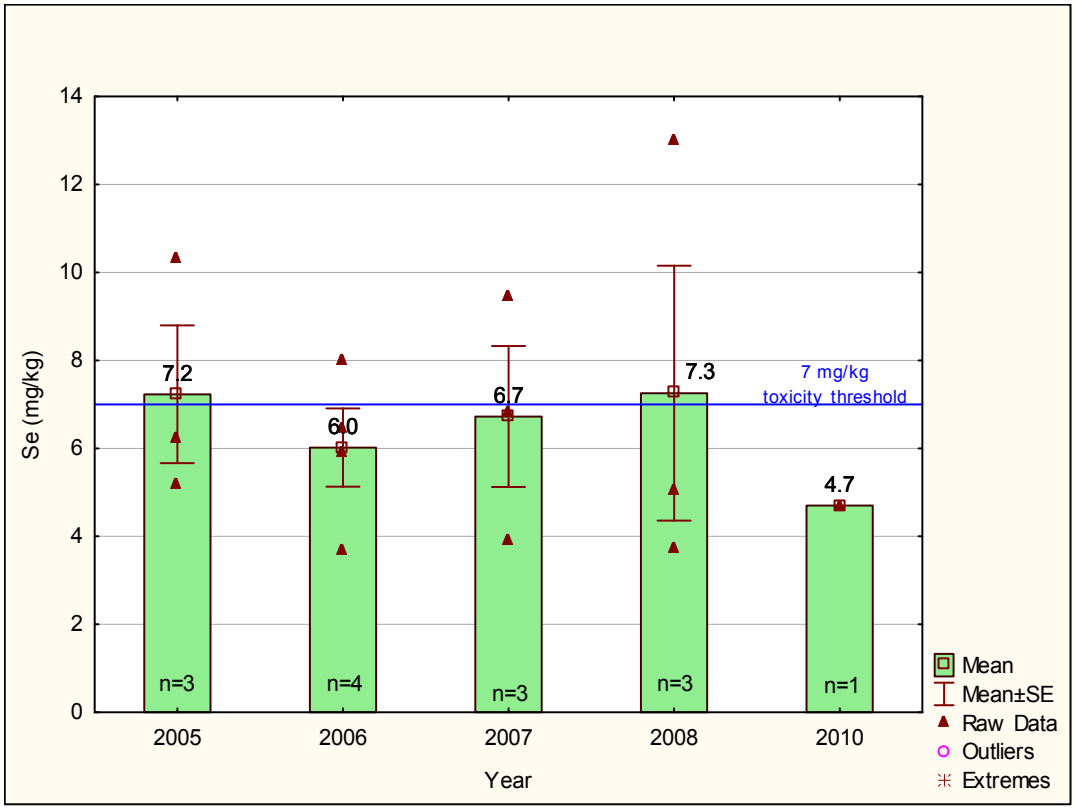


Figure 14. Selenium Concentrations in Macroinvertebrate Tissues in Wetland 3 Samples: 2005–2010

Test results: No significant temporal trend (ANOVA: Selenium by Year; $F(4, 9 = 1.875$, $p = 0.94)$; latter corroborated by Mann-Kendall ($S = -2$). Comparison to toxicity mg/kg threshold: Cannot accept null hypothesis that mean selenium concentrations are less than or greater than 7 mg/kg.

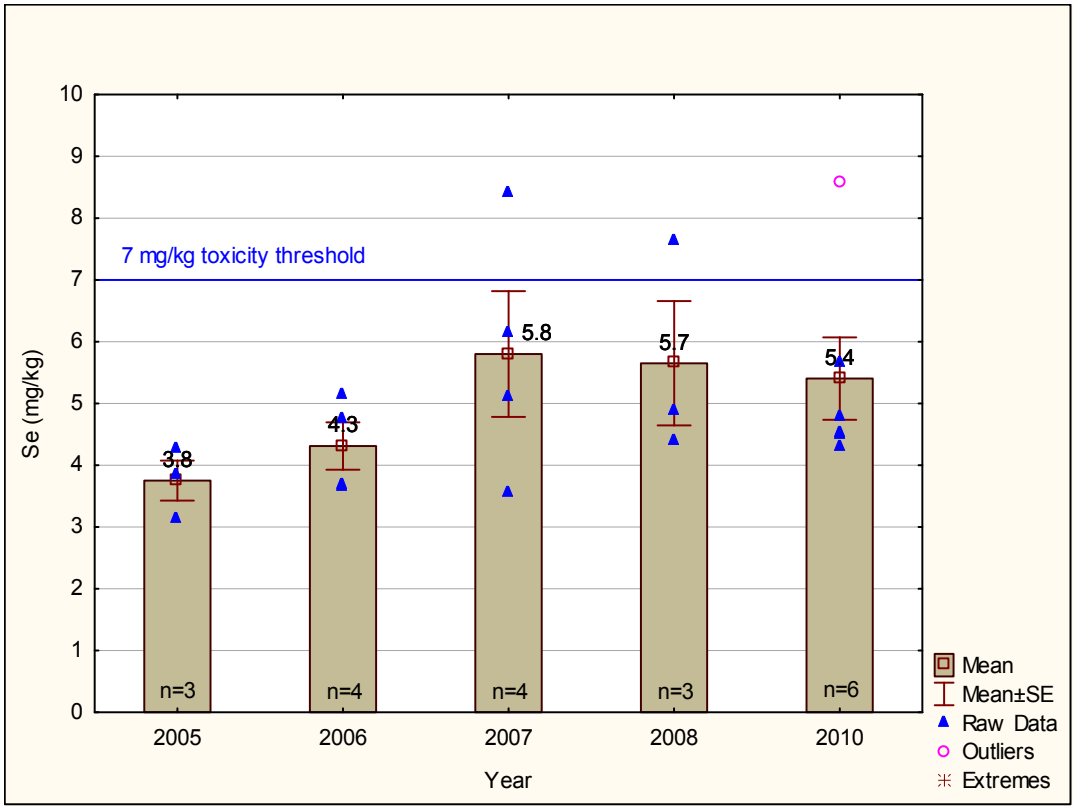


Figure 15. Selenium Concentrations in Macroinvertebrate Tissues in Sediment Pond Samples: 2005–2010

Test results: No significant temporal trend (ANOVA: Selenium by Year; $F(4, 15 = 1.24, p = 0.335)$; latter corroborated by Mann-Kendall ($S = 4$). Comparison to toxicity mg/kg threshold: Cannot accept null hypothesis that mean selenium concentrations are less than or greater than 7 mg/kg.

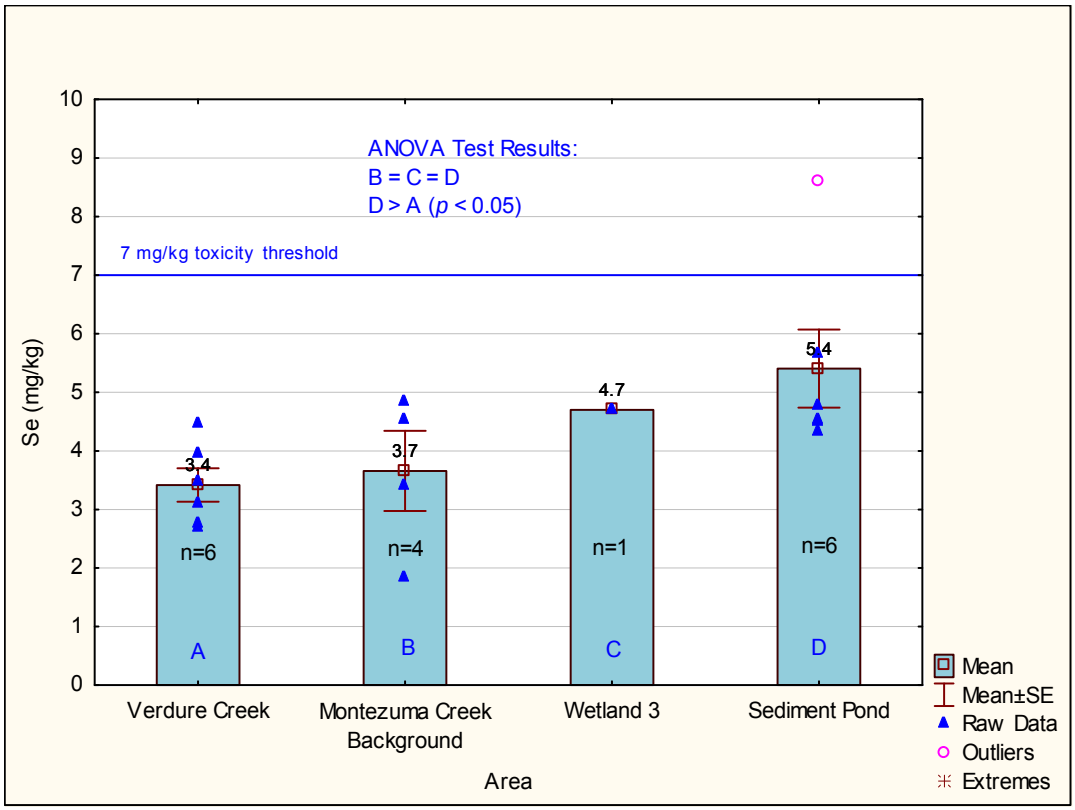
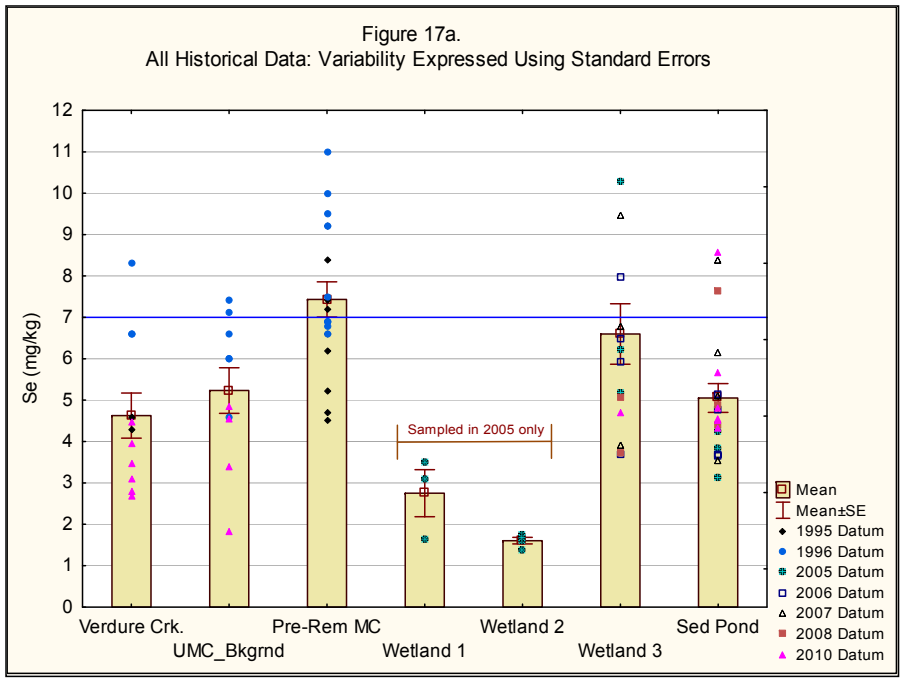
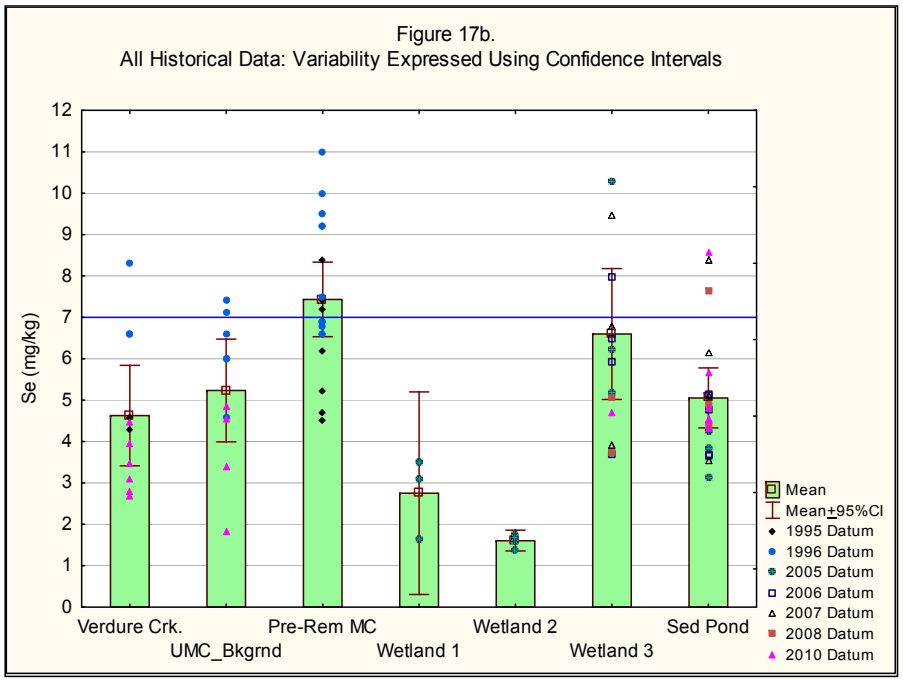


Figure 16. Selenium Concentrations in Macroinvertebrate Tissue by Area in June 2010 and Corresponding ANOVA Results

Annotations in the upper left portion of the figure indicate the results based on an ANOVA comparison of group means. Although based on visual observation, one might hastily conclude that selenium concentrations in both Wetland 3 and the Sediment Pond exceed concentrations in Verdure and Montezuma Creek (upgradient of mill site) reference areas, the only significant difference is yielded for Verdure Creek (A) vs. Sediment Pond (D). Given sample numbers and corresponding variability, all other areas are not significantly different from one another.





Plot Abbreviations

Bkgrnd	Background
Crk	Creek
MC	Montezuma Creek
Pre-Rem	Pre-remediation (conditions)
Sed	Sediment
UMC	Upper Montezuma Creek

Number of Samples by Area and Year:

Investigation:	ORNL Studies		Biomonitoring Program					
Area	1995	1996	2005	2006	2007	2008	2010	Sum
Verdure Crk.	2	3					6	11
UMC_Bkgrnd		6					4	10
Pre-Rem MC	9	9						18
Wetland 1			3					3
Wetland 2			4					4
Wetland 3			3	4	3	3	1	14
Sediment Pond			3	4	4	3	6	20

Figure 17. Global Summary Plot Showing All Historical Macroinvertebrate Results by Area: Variability Expressed Using Both Standard Errors and Confidence Intervals

Table 2. Summary of Conclusions Drawn for Wetland 3 and Sediment Pond Based on Historical Biomonitoring Results

Endpoint Evaluated	Wetland 3	Sediment Pond
Means and distributions	Means ranged from 4.7 mg/kg Se (most recent based on a single sample) to 7.2 mg/kg Se.	Means ranged from 3.8 mg/kg Se (2005) to 5.8 mg/kg Se (2007).
Temporal trend evident?	No No upward or downward monotonic trend detected with 5% alpha. From 2005 through 2008, mean Se concentrations essentially equaled, but did not significantly exceed, the 7 mg/kg toxicity threshold (see below). Although Figures 10 and 14 suggest that Se concentrations are downward trending based on the most recent (June 2010) result, this apparent trend is not significant because only one sample could be collected. Results suggest that Se concentrations in the pond may have reached equilibrium.	No No upward or downward monotonic trend detected ($p > 0.05$). Although an increase is apparent between 2005 and 2007 (means increased from 3.8 to 5.8 mg/kg), concentrations have stabilized in the last 3 years. Unlike Wetland 3 (where interpretation is constrained because only one sample could be collected), the most recent mean for the Sediment Pond was calculated based on six discrete samples, most of which were below 5 mg/kg.
Do mean Se concentrations exceed the 7 mg/kg toxicity threshold?	No For all years, and across years, mean Se concentrations in Wetland 3 have not significantly exceeded the toxicity threshold. At the same time, the alternate hypothesis—i.e., that Se < 7 mg/kg—cannot be accepted.	No For all years, and across years, mean Se concentrations in the Sediment Pond have not significantly exceeded the toxicity threshold.
Comparison to reference areas (Comparison limited to 1995–1996 and 2010)	No conclusions can be drawn based on the most recent (June 2010) sampling effort because, due to field and environmental conditions, only one sample could be collected in Wetland 3.	The only significant difference is yielded for Verdure Creek vs. Sediment Pond. Given sample numbers and corresponding variability, all other areas are not significantly different from one another ($p > 0.05$).

6.0 Summary of Avian Surveys

Because post-remediation wetlands represent different types of habitat than pre-remediation wetlands at the former mill site and Sediment Pond, the OU III ROD specified an updated wildlife survey to identify avian species using the area, including any threatened, endangered, or State-listed sensitive species. The updated survey results may be used to interpret the data presented in the previous sections in the broader context of ecological risk.

In 2005, 2006, and 2008, a total of 43 avian surveys and 3 nest surveys were conducted at the former mill site wetlands and the Sediment Pond (DOE 2005a, DOE 2006, DOE 2008a). Surveys were conducted at regular intervals between April and August each year. The focus differed each year, yielding a comprehensive view of avian species in the wetlands. Both the 2005 and 2008 surveys focused on identifying all avian species in the area, but 2008 surveys also included specific techniques for identifying threatened and endangered species. In 2006, surveys focused primarily on waterfowl.

The most common species at Wetland 3 is the red-winged blackbird (*Agelaius phoeniceus*). This species was observed during 100 percent of the surveys, and individuals occurred with the greatest abundance (up to 50 or more birds per survey). Three species observed during

50 percent or more of the surveys occurred in low numbers at Wetland 3. Of these, only the sora (*Porzana carolina*) typically utilizes wetlands. Nests, nesting behavior, or young were observed for several additional species known to consume aquatic invertebrates, including killdeer (*Charadrius vociferus*), mallard (*Anas platyrhynchos*), and song sparrow (*Melospiza melodia*). However, these species were observed infrequently with low abundance.

The most common species at the Sediment Pond is the cliff swallow (*Petrochelidon pyrrhonota*), which was observed during 84 percent of the surveys. It occurred in the greatest numbers and nested in the area. Several other species of swallows flocked with the cliff swallows and were observed in low to moderate numbers. Five species were observed during 50 percent or more of the surveys but occurred in low numbers at the Sediment Pond. Of these, three species—the song sparrow, mallard, and red-winged blackbird—typically utilize wetlands and were suspected to be breeding in the area. In 2008, black phoebes (*Sayornis nigricans*), which also feed on aquatic macroinvertebrates, were also observed.

No federally protected, State of Utah listed, or other avian species of concern were nesting in or near the MMTS wetlands, and no suitable nesting habitat currently exists. Several of these species were infrequently observed but determined to be seasonal transients. A detailed list of avian species observed during the surveys is provided in Appendix C.

7.0 Summary and Conclusions

The purpose of biomonitoring at MMTS has been to determine if selenium concentrations in the environment exceed levels that might impact avian receptors that use the wetland and Sediment Pond. The ecological risk guidelines agreed upon by the BTAG for selenium in macroinvertebrates, water, and sediment include a threshold concentration that is considered toxic to avian receptors identified at OU III. This analysis focused on observed concentrations relative to established toxicity thresholds, because measurements in background areas indicated that, with the exception of sediments, attempts to achieve levels below those thresholds may not be feasible.

At times, selenium concentrations in Wetland 3 and the Sediment Pond macroinvertebrates have significantly exceeded those in Verdure Creek, one of the two designated reference areas. However, as discussed previously, both Verdure Creek and upper Montezuma Creek are considered to be conservative analogs for statistical comparisons.

Table 3 summarizes the major conclusions of this evaluation.

Table 3. Summary of Findings

Matrix	Toxicity Threshold	Wetland 3	Sediment Pond	Global Trends and Findings
Sediment	>4 mg/kg	A regression analysis of the mean indicates a stable (neither increasing, nor decreasing) trend since 2004 that is below the 4 mg/kg threshold.	A regression analysis of the mean indicates a decreasing trend; all means are well below the threshold.	No further sampling recommended. The bulk of Se results have been well below the toxicity threshold (most less than 2 mg/kg).
Surface Water	>5 µg/L	A regression analysis of the mean indicates a stable (neither increasing, nor decreasing) trend since 2004 that is below the 5 µg/L threshold	A regression analysis of the mean indicates that historical results (including June 2010) show an upward trend that now exceeds the threshold. Prior to June 2010, a slight upward trend was indicated, but the threshold was not exceeded.	Surface water is sampled routinely as part of the post-ROD monitoring program. Overall results for the biomonitoring areas must be interpreted in the broader context of ecological risk.
Invertebrates	>7 mg/kg	No significant trending and no indication of exceedance of the toxicity threshold. Since biomonitoring began, Se concentrations have remained stable at or near the 7 mg/kg threshold but have never exceeded it.	No significant trending and no indication of exceedance of the toxicity threshold. Mean Se concentrations have remained stable at about 5–6 mg/kg.	Results suggest that Se concentrations in both Wetland 3 and the Sediment Pond have stabilized after reaching levels at or near, but not significantly exceeding, the toxicity threshold.

The following conclusions are offered as a catalyst for further discussion among the BTAG to determine the scope of future biomonitoring. This analysis focused primarily on benthic macroinvertebrates because of recent indications by BTAG that, from a risk perspective, sediment and surface water trends are less informative for the receptors identified at OU III. The statistical analysis documented in this report confirms the conclusions drawn in the three preceding biomonitoring reports (Battelle 2007, Battelle 2008, DOE 2008b) that selenium concentrations in macroinvertebrate tissue are not significantly trending and that macroinvertebrate sample results do not significantly exceed the established toxicity threshold. Additionally, while weather and water conditions have varied each year, mean tissue concentrations have not significantly varied over time within the Wetland 3 and Sediment Pond study areas. Therefore, it appears that OU III ROD criteria are being met, which would justify discontinuing or reducing the scope of biomonitoring, assuming BTAG consensus.

Extrapolating these findings to the broader context of risk, DOE maintains that the benefit of the wetlands in providing wildlife habitat exceeds the minor risk to individual receptors potentially posed by the current selenium distributions. DOE also recognizes that entire avian populations are not likely impacted given their home range and the presence of other similar habitat in and near OU III. Furthermore, avian surveys did not identify any federally protected, Utah-listed, or other avian species of concern nesting in or near the MMTS wetlands.

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See following page for a listing of relevant program directives.

Program Directives Related to Biomonitoring at OU III

Directive No.	Effective Date	Expiration Date	Directive Subject
MSG-04-01	October 1, 2004	September 30, 2005	Sediment and surface water sampling and analysis
MSG-05-01	January 15, 2005	September 30, 2005	Wildlife surveys – avian wetland species
MSG-05-03	April 4, 2005	September 30, 2005	Aquatic macroinvertebrate sampling and analysis
MSG-06-01*	April 14, 2006	September 30, 2006	Sediment and surface water sampling and analysis
MSG-06-02*	April 14, 2006	September 30, 2006	Wildlife surveys – avian waterfowl species
MSG-06-03*	April 14, 2006	September 30, 2006	Aquatic macroinvertebrate sampling and analysis
MNT-08-01	March 21, 2008	September 30, 2008	Sediment and surface water sampling and analysis
MNT-08-02	March 21, 2008	September 30, 2008	Wildlife surveys—avian species, including sensitive species
MNT-08-03	March 21, 2008	September 30, 2008	Aquatic macroinvertebrate sampling and analysis
MNT-2010-03	June 1, 2010	September 30, 2010	Aquatic macroinvertebrate sampling and analysis, including reference (background) locations

* Note: MSG-06-01, MSG-06-02 and MSG-06-03 were extended to 2007 by memorandum.

9.0 Glossary of Statistical Terms

The preceding statistical evaluation relies heavily on the supporting graphics, the majority of which consist of mean and standard error plots. In many of these plots, raw data are also plotted to facilitate review, and outlier and extreme values—i.e., values that are far from the middle of the distribution—are identified. Although all plots (means, error bars, non-outlier raw data, and outliers and extremes) are identified in the figure legends, assumptions underlying the definition of outliers and extremes are not explained. These terms are described below in greater detail.

Outliers. A data point is deemed to be an outlier if the following conditions hold:

data point value > UBV + (o.c.)(UBV – LBV)

or

data point value < LBV – (o.c.)(UBV – LBV)

where:

UBV is the upper value of the box in the box plot (i.e., the mean + standard error).

LBV is the lower value of the box in the box plot (e.g., the mean – standard error).

o.c. default outlier coefficient, 1.5

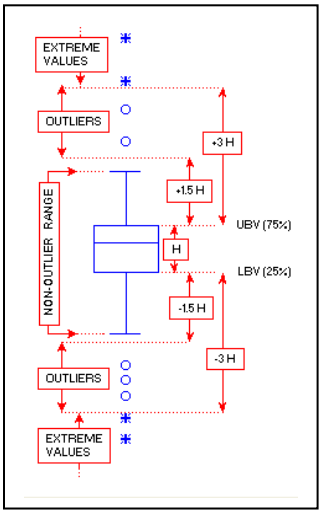
Extremes. A data point is deemed to be an extreme value if the following conditions hold:

data point value > UBV + 2 × o.c. × (UBV – LBV)

or

data point value < LBV – 2 × o.c. × (UBV – LBV)

The following diagram illustrates the ranges of outliers and extremes in a classic box and whisker plot where the upper box value (UBV) is the 75th percentile, the lower box value (LBV) is the 25th percentile, and the outlier coefficient is equal to 1.5 (Statistica; Version 10, StatSoft).



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Appendix A

Analytical Results for Post-ROD Biomonitoring Baseline Surface Water, Sediment, and Benthic Macroinvertebrate Samples

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Table A–1. Detailed Macroinvertebrate Monitoring Results

Sampler	Sample ID	Area (Categorization Variable)	Year	Date(s)	Datum Used?	Investigation Phase	Collection Method	Selenium (mg/kg), dry weight	Selenium (mg/kg), wet weight	Wet weight (g)	% Moisture	Comment	Sample composition by macroinvertebrate feeding group
ORNL	VD1-A	Verdure Creek	1995	8/17/1995	Yes	Pre-remediation	Kick Net	<4.3	<1.02		76.3		12% filter feeders, 57% collector-gatherers/detritivores, 31% predators
ORNL	VD1-B	Verdure Creek	1995	8/17/1995	Yes	Pre-remediation	Kick Net	<4.6	<1.1		76.1		
ORNL	MZ2-A	ORNL Other	1995	8/17/1995	Yes	Pre-remediation	Kick Net	9.2	1.65		82.1	CV for MZ2 set is 17% (ORNL 1996, Table A–1).	6% filter feeders, 73% collector-gatherers/detritivores, 21% predators
ORNL	MZ2-B	ORNL Other	1995	8/17/1995	Yes	Pre-remediation	Kick Net	8.4	1.47		82.5	CV for MZ2 set is 17% (ORNL 1996, Table A–1).	
ORNL	MZ2-C	ORNL Other	1995	8/17/1995	Yes	Pre-remediation	Kick Net	6.6	1.11		83.1	CV for MZ2 set is 17% (ORNL 1996, Table A–1).	
ORNL	MZ3-A	ORNL Other	1995	8/17/1995	Yes	Pre-remediation	Kick Net	6.2	0.98		84.1	CV for MZ3 set is 9% (ORNL 1996, Table A–1).	1% filter feeders, 82% collector-gatherers/detritivores, 18% predators
ORNL	MZ3-B	ORNL Other	1995	8/17/1995	Yes	Pre-remediation	Kick Net	7.2	1.15		84.0	CV for MZ3 set is 9% (ORNL 1996, Table A–1).	
ORNL	MZ3-C	ORNL Other	1995	8/17/1995	Yes	Pre-remediation	Kick Net	7.4	1.13		84.7	CV for MZ3 set is 9% (ORNL 1996, Table A–1).	
ORNL	MZ5-A	Sediment Pond	1995	8/17/1995	Yes	Pre-remediation	Kick Net	5.2	0.94		81.9	Coincides generally with current Sediment Pond location.	9% filter feeders, 72% collector-gatherers/detritivores, 19% predators
ORNL	MZ9-A	ORNL Other	1995	8/17/1995	Yes	Pre-remediation	Kick Net	<4.5	<1.11		75.4		9% filter feeders, 65% collector-gatherers/detritivores, 26% predators
ORNL	MZ9-B	ORNL Other	1995	8/17/1995	Yes	Pre-remediation	Kick Net	<4.7	<1.09		76.8		
ORNL	VD1-1	Verdure Creek	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6.6	1.48		77.6		81% collector-gatherers/detritivores, 19% predators
ORNL	VD1-2	Verdure Creek	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	8.3	1.78		78.6		
ORNL	VD1-3	Verdure Creek	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6.6	1.54		76.7		
ORNL	MZUG-A	UMC Background	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6.6	1.11		83.2		89% collector-gatherers/detritivores, 11% predators
ORNL	MZUG-B	UMC Background	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6	1.03		82.8		
ORNL	MZUG-C	UMC Background	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6	1.06		82.3		
ORNL	MZG-A	UMC Background	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	4.6	<0.78		83.0	QA data were provided for only wet wt values in 1996.	2% filter feeders, 91% collector-gatherers/detritivores, 7% predators
ORNL	MZG-B	UMC Background	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	7.4	1.11		84.9		
ORNL	MZG-C	UMC Background	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	7.1	1.08		84.8		
ORNL	MZ2-A	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	9.2	1.39		84.9		2% filter feeders, 79% collector-gatherers/detritivores, 19% predators
ORNL	MZ2-B	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	9.5	1.6		83.2		
ORNL	MZ2-C	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	11	1.72		84.4		
ORNL	MZ3-A	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6.9	1.16		83.1		3% filter feeders, 81% collector-gatherers/detritivores, 16% predators
ORNL	MZ3-B	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	10	1.48		85.2		
ORNL	MZ3-C	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	7.5	1.13		85.0		
ORNL	MZ9-A	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6.9	0.99		85.7		5% filter feeders, 82% collector-gatherers/detritivores, 13% predators
ORNL	MZ9-B	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6.6	1.06		84.0		
ORNL	MZ9-C	Mill site Area	1996	8/14-15, 1996	Yes	Pre-remediation	Kick Net	6.8	1.05		84.5		
Battelle	SP-S1	Sediment Pond	2005	5/24/2005	Yes	Post-remediation	Kick Net	4.26		4.80			3% filter feeders, 57% collector-gatherers/detritivores, 40% predators
Battelle	SP-S2	Sediment Pond	2005	5/24/2005	Yes	Post-remediation	Kick Net	3.15		5.00			15% collector-gatherers/detritivores, 85% predators
Battelle	SP-S3	Sediment Pond	2005	5/24/2005	Yes	Post-remediation	Kick Net	3.84		3.60			50% collector-gatherers/detritivores, 50% predators
Battelle	W1-S1	Wetland 1	2005	5/23/2005	Yes	Post-remediation	Kick Net	1.64		7.00			40% collector-gatherers/detritivores, 60% predators
Battelle	W1-S2	Wetland 1	2005	5/23/2005	Yes	Post-remediation	Kick Net	3.11		9.50			5% filter feeders, 30% collector-gatherers/detritivores, 60% predators
Battelle	W1-S3	Wetland 1	2005	5/23/2005	Yes	Post-remediation	Kick Net	3.51		5.30			10% filter feeders, 10% collector-gatherers/detritivores, 80% predators
Battelle	W2-S1	Wetland 2	2005	5/24/2005	Yes	Post-remediation	Kick Net	1.76		5.50			5% filter feeders, 45% collector-gatherers/detritivores, 50% predators
Battelle	W2-S2	Wetland 2	2005	5/24/2005	Yes	Post-remediation	Kick Net	1.6		7.50			5% filter feeders, 30% collector-gatherers/detritivores, 65% predators
Battelle	W2-S3	Wetland 2	2005	5/24/2005	Yes	Post-remediation	Kick Net	1.39		5.40			3% filter feeders, 48% collector-gatherers/detritivores, 50% predators

Table A–1 (continued). Detailed Macroinvertebrate Monitoring Results

Sampler	Sample ID	Area (Categorization Variable)	Year	Date(s)	Datum Used?	Investigation Phase	Collection Method	Selenium (mg/kg), dry weight	Selenium (mg/kg), wet weight	Wet weight (g)	% Moisture	Comment	Sample composition by macroinvertebrate feeding group
Battelle	W2-S4 (A)	Wetland 2	2005	5/24/2005	Yes	Post-remediation	Kick Net	1.69		7.50		Used average of split sample 1.68 (mg/kg).	100% predators
Battelle	W2-S4 (B)	Wetland 2	2005	5/24/2005		Post-remediation	Kick Net	1.66		7.50			
Battelle	W3-S1	Wetland 3	2005	5/24/2005	Yes	Post-remediation	Kick Net	6.21		6.20			2% filter feeders, 4% collector-gatherers/detritivores, 90% predators
Battelle	W3-S2	Wetland 3	2005	5/24/2005	Yes	Post-remediation	Kick Net	10.3		6.10			10% collector-gatherers/detritivores, 90% predators
Battelle	W3-S3	Wetland 3	2005	5/24/2005	Yes	Post-remediation	Kick Net	5.18		12.50			10% filter feeders, 45% collector-gatherers/detritivores, 45% predators
Battelle	SP-S1-HD	Sediment Pond	2005	6/22/2005	No	Post-remediation	Hester-Dendy	3.52		0.83			50% collector-gatherers/detritivores, 50% predators
Battelle	SP-S2-HD	Sediment Pond	2005	6/22/2005	No	Post-remediation	Hester-Dendy	4.35		0.46			2% filter feeders, 57% collector-gatherers/detritivores, 34% predators
Battelle	SP-S3-HD	Sediment Pond	2005	6/22/2005	No	Post-remediation	Hester-Dendy			0.12			
Battelle	SP-S1	Sediment Pond	2006	5/17/2006	Yes	Post-remediation	Kick Net	4.2		3.46	77.7	Used average of split sample 3.65 (mg/kg). SP-S1-R is replicate redigest of SP-S1.	65% collector-gatherers/detritivores, 35% predators
Battelle	SP-S1-R	Sediment Pond	2006	5/17/2006		Post-remediation	Kick Net	3.09		3.46	77.7		
Battelle	SP-S2	Sediment Pond	2006	5/17/2006	Yes	Post-remediation	Kick Net	5.15		3.94	71.4		5% filter feeders, 75% collector-gatherers/detritivores, 20% predators
Battelle	SP-S3	Sediment Pond	2006	5/17/2006	Yes	Post-remediation	Kick Net	4.74		3.24	73.5	Used average of split sample 4.77 (mg/kg). SP-S3-R is replicate redigest of SP-S3.	40% collector-gatherers/detritivores, 60% predators
Battelle	SP-S3-R	Sediment Pond	2006	5/17/2006		Post-remediation	Kick Net	4.8		3.24	73.5		
Battelle	SP-S4	Sediment Pond	2006	5/17/2006	Yes	Post-remediation	Kick Net	3.95		10.25	74.5	Used average of split sample 3.68 (mg/kg). SP-S4-R1 and -R2 replicate redigests of SP-S4.	3% filter feeders, 18% collector-gatherers/detritivores, 80% predators
Battelle	SP-S4-R1	Sediment Pond	2006	5/17/2006		Post-remediation	Kick Net	2.44		10.25	74.5		
Battelle	SP-S4-R2	Sediment Pond	2006	5/17/2006		Post-remediation	Kick Net	4.64		10.25	74.5		
Battelle	SP-S1-HD	Sediment Pond	2006	6/13/2006	No	Post-remediation	Hester-Dendy	12.65	0.31	0.31	89.3		70% filter feeders, 30% collector-gatherers/detritivores
Battelle	SP-S2-HD	Sediment Pond	2006	6/13/2006	No	Post-remediation	Hester-Dendy	10.93	0.78	0.78	77.7		95% filter feeders, 5% collector-gatherers/detritivores
Battelle	SP-S3-HD	Sediment Pond	2006	6/13/2006	No	Post-remediation	Hester-Dendy	5.97	1.09	1.09	76.7		8% filter feeders, 42% collector-gatherers/detritivores, 50% predators
Battelle	W3-S1	Wetland 3	2006	5/17/2006	Yes	Post-remediation	Kick Net	6.47		3.44	84.5		30% collector-gatherers/detritivores, 70% predators
Battelle	W3-S2	Wetland 3	2006	5/17/2006	Yes	Post-remediation	Kick Net	3.69		3.50	79.1		20% collector-gatherers/detritivores, 80% predators
Battelle	W3-S3	Wetland 3	2006	5/17/2006	Yes	Post-remediation	Kick Net	5.93		3.34	77.1		38% collector-gatherers/detritivores, 62% predators
Battelle	W3-S4	Wetland 3	2006	5/17/2006	Yes	Post-remediation	Kick Net	7.98		3.71	74.3	Split sample (unknown which stratum)	50% collector-gatherers/detritivores, 50% predators
Stoller	SP-S1-1	Sediment Pond	2007	5/23/2007	Yes	Post-remediation	Kick Net	5.1		0.52	71.8		50% collector-gatherers/detritivores, 50% predators
Stoller	SP-S1-2	Sediment Pond	2007	5/23/2007	Yes	Post-remediation	Kick Net	6.15		7.04	82.4		55% collector-gatherers/detritivores, 50% predators
Stoller	SP-HD	Sediment Pond	2007	6/26/2007	No	Post-remediation	Hester-Dendy	5.82		1.75	86.1	Result is comparable to other pond inlet samples.	70% filter feeders, 15% collector-gatherers/detritivores, 15% predators
Stoller	SP-S2-1	Sediment Pond	2007	5/23/2007	Yes	Post-remediation	Kick Net	8.02		4.16	83.8	Used average of replicates 8.4 (mg/kg).	20% collector-gatherers/detritivores, 80% predators
Stoller	SP-S2-2	Sediment Pond	2007	5/23/2007		Post-remediation	Kick Net	8.78		4.68	82.3		
Stoller	SP-S3	Sediment Pond	2007	5/23/2007	Yes	Post-remediation	Kick Net	3.55		10.74	81.2		20% collector-gatherers/detritivores, 80% predators
Stoller	W3-S2-1	Wetland 3	2007	5/24/2007	Yes	Post-remediation	Kick Net	9.46		1.75	83.5	Used average of replicates 8.13 (mg/kg).	60% collector-gatherers/detritivores, 40% predators
Stoller	W3-S2-2	Wetland 3	2007	5/24/2007		Post-remediation	Kick Net	6.8		2.21	70.2		100% collector-gatherers/detritivores
Stoller	W3-S3	Wetland 3	2007	5/24/2007	Yes	Post-remediation	Kick Net	3.91		3.0	80.8		80% collector-gatherers/detritivores, 20% predators
Stoller	SP-S1	Sediment Pond	2008	6/11/2008	Yes	Post-remediation	Kick Net	4.9		12.20	77.4		39% collector-gatherers/detritivores, 60% predators
Stoller	SP-S2-1	Sediment Pond	2008	6/11/2008	Yes	Post-remediation	Kick Net	4.5		8.30	75.6	Used average of split sample 4.41 (mg/kg).	62% collector-gatherers/detritivores, 38% predators
Stoller	SP-S2-2	Sediment Pond	2008	6/11/2008		Post-remediation	Kick Net	4.32		10.80	75.0		51% collector-gatherers/detritivores, 49% predators
Stoller	SP-S3	Sediment Pond	2008	6/11/2008	Yes	Post-remediation	Kick Net	7.64		14.90	79.3		68% collector-gatherers/detritivores, 33% predators
Stoller	W3-S1	Wetland 3	2008	6/10/2008	Yes	Post-remediation	Kick Net	13		7.90	80.6		1% filter feeders, 80% collector-gatherers/detritivores, 18% predators
Stoller	W3-S2	Wetland 3	2008	6/10/2008	Yes	Post-remediation	Kick Net	5.06		4.90	79.7		1% filter feeders, 23% collector-gatherers/detritivores, 77% predators
Stoller	W3-S3	Wetland 3	2008	6/10/2008	Yes	Post-remediation	Kick Net	3.71		8.20	78.2		1% filter feeders, 68% collector-gatherers/detritivores, 30% predators
Stoller	SP-S1	Sediment Pond	2010	6/23/2010	Yes	Post-remediation	Kick Net	4.54		20.40	82.1	Co-located with surface water samples.	3% filter feeders, 62% collector-gatherers/detritivores,

Table A–1 (continued). Detailed Macroinvertebrate Monitoring Results

Sampler	Sample ID	Area (Categorization Variable)	Year	Date(s)	Datum Used?	Investigation Phase	Collection Method	Selenium (mg/kg), dry weight	Selenium (mg/kg), wet weight	Wet weight (g)	% Moisture	Comment	Sample composition by macroinvertebrate feeding group
													35% predators
Stoller	SP-S2	Sediment Pond	2010	6/23/2010	Yes	Post-remediation	Kick Net	5.68		38.30	79.6	Co-located with surface water samples.	64% collector-gatherers/detritivores, 36% predators
Stoller	SP-S3	Sediment Pond	2010	6/23/2010	Yes	Post-remediation	Kick Net	4.79		23.60	79.5	Co-located with surface water samples.	70% collector-gatherers/detritivores, 30% predators
Stoller	SP-S4	Sediment Pond	2010	6/23/2010	Yes	Post-remediation	Kick Net	4.5		12.30	80.9	Co-located with surface water samples.	58% collector-gatherers/detritivores, 42% predators
Stoller	SP-S5	Sediment Pond	2010	6/23/2010	Yes	Post-remediation	Kick Net	8.59		16.10	78.2	Co-located with surface water samples.	44% collector-gatherers/detritivores, 56% predators
Stoller	SP-S6	Sediment Pond	2010	6/23/2010	Yes	Post-remediation	Kick Net	4.61		8.00	78.9	Co-located with surface water samples. Used average of replicates 4.32 (mg/kg).	68% collector-gatherers/detritivores, 32% predators
Stoller	2966	Sediment Pond	2010	6/23/2010		Post-remediation	Kick Net	4.03		9.40	79.8		77% collector-gatherers/detritivores, 23% predators
Stoller	UMC-S1	UMC Background	2010	6/25/2010	Yes	Post-remediation	Kick Net	1.83		5.10	77.4	Co-located with surface water samples.	2% filter feeders, 68% collector-gatherers/detritivores, 30% predators
Stoller	UMC-S2	UMC Background	2010	6/25/2010	Yes	Post-remediation	Kick Net	3.41		0.60	74.0	Co-located with surface water samples.	50% filter feeders, 8% collector-gatherers/detritivores, 42% predators
Stoller	UMC-S3	UMC Background	2010	6/25/2010	Yes	Post-remediation	Kick Net	4.54		2.60	80.8	Co-located with surface water samples.	4% filter feeders, 12% collector-gatherers/detritivores, 84% predators
Stoller	UMC-S4	UMC Background	2010	6/25/2010	Yes	Post-remediation	Kick Net	4.85		3.70	84.0	Co-located with surface water samples.	22% collector-gatherers/detritivores, 77% predators
Stoller	VC-S1	Verdure Creek	2010	6/24/2010	Yes	Post-remediation	Kick Net	3.96		1.30	85.1	Co-located with surface water samples.	45% collector-gatherers/detritivores, 55% predators
Stoller	VC-S2	Verdure Creek	2010	6/24/2010	Yes	Post-remediation	Kick Net	3.48		2.10	80.9	Co-located with surface water samples.	100% collector-gatherers/detritivores
Stoller	VC-S3	Verdure Creek	2010	6/24/2010	Yes	Post-remediation	Kick Net	3.11		3.00	79.0	Co-located with surface water samples.	9% filter feeders, 91% collector-gatherers/detritivores
Stoller	VC-S4	Verdure Creek	2010	6/24/2010	Yes	Post-remediation	Kick Net	2.7		5.90	81.9	Co-located with surface water samples.	7% filter feeders, 90% collector-gatherers/detritivores, 2% predators
Stoller	VC-S5	Verdure Creek	2010	6/24/2010	Yes	Post-remediation	Kick Net	4.48		1.80	84.8	Co-located with surface water samples.	88% collector-gatherers/detritivores, 12% predators
Stoller	VC-S6	Verdure Creek	2010	6/24/2010	Yes	Post-remediation	Kick Net	2.78		1.80	88.7	Co-located with surface water samples.	100% collector-gatherers/detritivores
Stoller	W3-S1	Wetland 3	2010	6/24/2010	Yes	Post-remediation	Kick Net	4.7		5.70	79.6	Co-located with surface water samples W3-S4 and W3-S5. Macro sampling region included both surface water points.	2% filter feeders, 95% collector-gatherers/detritivores, 4% predators

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Table A–2. Surface Water and Sediment Biomonitoring Results

Sample ID	Area	Date Sampled	Sediment	Surface Water								Comment
			Selenium (mg/kg)	Selenium (µg/L)	Selenium[a] (µg/L)	Alkalinity (mg/L)	Conductivity (µmhos/cm)	ORP (mV)	pH (s.u.)	Temperature (ºC)	Turbidity (NTU)	
P-S1	Sediment Pond	10/6/2004	3.3	3.7	3	273	1481	-	8.1	14.5	-	surface water duplicate; maximum value used (3.7 µg/L)
		10/6/2004	-	3.6	2.9	-	-	-	-	-	-	
P-S2	Sediment Pond	10/6/2004	3	1.6	1.2	292	1500	-	7.72	13.3	53.5	
P-S3	Sediment Pond	10/6/2004	2.2	2	1.6	306	1523	-	7.72	12.2	50.7	
W1-S1	Wetland 1	10/6/2004	0.18	2.8	2.3	328	1830	-	6.6	9.9	1.91	
W1-S2	Wetland 1	10/6/2004	0.17	1.5	1	-	1861	-	7.15	7.6	12.5	
W1-S3	Wetland 1	10/6/2004	0.32	1.7	1.3	308	1786	-	7.26	7.8	152	
W2-S1	Wetland 2	10/6/2004	0.082	0.045	< 0.029	336	1463	-	7.52	12.7	196	
W2-S2	Wetland 2	10/6/2004	0.12	0.03	0.041	341	1400	-	7.65	9.2	33.4	
W2-S3	Wetland 2	10/6/2004	0.13	0.093	0.068	215	1496	-	7.81	10	8.8	
W3-S1	Wetland 3	10/6/2004	1.3	14	10	338	1645	-	7.27	12.5	43.2	
W3-S2	Wetland 3	10/6/2004	0.63	1.1	0.8	236	1304	-	7.52	13.1	43.5	
W3-S3	Wetland 3	10/6/2004	0.43	1.5	1	205	1240	-	7.79	11.1	71.4	
P-S1	Sediment Pond	4/5/2005	1.3	2.9	2.2	170	810	-	7.92	12.08	38.5	
P-S2	Sediment Pond	4/5/2005	0.86	2.8	2.4	171	785	-	7.99	13.1	37.4	
P-S3	Sediment Pond	4/5/2005	3.4	3	2.5	176	803	-	8.04	13.92	33.6	
W1-S1	Wetland 1	4/5/2005	0.14[b]	4.1	3.8	323	1606	-	6.84	10.89	1.57	
W1-S2	Wetland 1	4/5/2005	0.15[b]	2.1	1.9	280	1324	-	7.25	12.78	35.6	
W1-S3	Wetland 1	4/5/2005	0.2[b]	1.9	1.6	281	1255	-	7.45	12.96	12.5	
W2-S1	Wetland 2	4/5/2005	< 0.099	< 0.068	< 0.068	294	1478	-	7.54	14.81	12.6	
W2-S2	Wetland 2	4/5/2005	0.17[b]	< 0.068	< 0.068	332	1533	-	7.29	15.82	3.54	
W2-S3	Wetland 2	4/5/2005	0.18[b]	0.78	0.99	233	1364	-	7.39	14.89	9.53	
W3-S1	Wetland 3	4/5/2005	0.64	3	2.4	193	1152	-	7.58	14.6	8.78	
W3-S2	Wetland 3	4/5/2005	0.88	2.1	2.2	191	1054	-	7.47	13.78	10.4	
W3-S3	Wetland 3	4/5/2005	0.2[b]	2.6	2	199	1248	-	7.38	14.62	11.4	

Table A–2 (continued). Surface Water and Sediment Biomonitoring Results

Sample ID	Area	Date Sampled	Sediment	Surface Water								Comment
			Selenium (mg/kg)	Selenium (µg/L)	Selenium[a] (µg/L)	Alkalinity (mg/L)	Conductivity (µmhos/cm)	ORP (mV)	pH (s.u.)	Temperature (ºC)	Turbidity (NTU)	
P-S1	Sediment Pond	10/11/2005	1.9	3	2.8	-	-	-	-	-	-	
P-S2	Sediment Pond	10/11/2005	0.51	3.2[b]	2.8	-	-	-	-	-	-	
P-S3	Sediment Pond	10/11/2005	4.1	3.1	2.6	-	-	-	-	-	-	
W1-S1	Wetland 1	10/11/2005	< 0.033	0.67	0.75	-	-	-	-	-	-	
W1-S2	Wetland 1	10/11/2005	< 0.034	0.44[b]	0.73	-	-	-	-	-	-	
W1-S3	Wetland 1	10/11/2005	< 0.035	0.29[b]	0.33	-	-	-	-	-	-	
W2-S1	Wetland 2	10/11/2005	< 0.034	< 0.023	0.59	-	-	-	-	-	-	
W2-S2	Wetland 2	10/11/2005	< 0.045	0.11[b]	0.64	-	-	-	-	-	-	
W2-S3	Wetland 2	10/11/2005	< 0.04	0.1[b]	0.58	-	-	-	-	-	-	
W3-S1	Wetland 3	10/11/2005	0.32	0.54	1.1	-	-	-	-	-	-	
W3-S2	Wetland 3	10/11/2005	0.37	0.4[b]	0.93	-	-	-	-	-	-	
W3-S3	Wetland 3	10/11/2005	0.27	0.21[b]	0.77	-	-	-	-	-	-	
P-S1	Sediment Pond	4/19/2006	0.56	3.6[b]	-	-	-	-	-	-	-	
P-S2	Sediment Pond	4/19/2006	0.55	3.4[b]	-	-	-	-	-	-	-	
P-S3	Sediment Pond	4/19/2006	1.4	3.4[b]	-	-	-	-	-	-	-	
W1-S1	Wetland 1	4/19/2006	0.13	0.56[b]	-	-	-	-	-	-	-	
W1-S2	Wetland 1	4/19/2006	0.21	0.49[b]	-	-	-	-	-	-	-	
W1-S3	Wetland 1	4/19/2006	0.19	0.43[b]	-	-	-	-	-	-	-	
W2-S1	Wetland 2	4/19/2006	0.13	< 0.02	-	-	-	-	-	-	-	
W2-S2	Wetland 2	4/19/2006	0.11	0.2[b]	-	-	-	-	-	-	-	
W2-S3	Wetland 2	4/19/2006	0.29	0.13[b]	-	-	-	-	-	-	-	
W3-S1	Wetland 3	4/19/2006	6.9	3.5[b]	-	-	-	-	-	-	-	
W3-S2	Wetland 3	4/19/2006	1	0.56[b]	-	-	-	-	-	-	-	
W3-S3	Wetland 3	4/19/2006	0.45	1.4[b]	-	-	-	-	-	-	-	surface water duplicate; maximum value used (3 µg/L)
		4/19/2006	-	3[b]	-	-	-	-	-	-	-	
P-S1	Sediment Pond	10/4/2006	0.58	4.1[b]		-	-	-	-	-	-	
P-S2	Sediment Pond	10/4/2006	0.74	4.5	-	-	-	-	-	-	-	
P-S3	Sediment Pond	10/4/2006	0.78	4	-	-	-	-	-	-	-	

Table A–2 (continued). Surface Water and Sediment Biomonitoring Results

Sample ID	Area	Date Sampled	Sediment	Surface Water								Comment
			Selenium (mg/kg)	Selenium (µg/L)	Selenium[a] (µg/L)	Alkalinity (mg/L)	Conductivity (µmhos/cm)	ORP (mV)	pH (s.u.)	Temperature (ºC)	Turbidity (NTU)	
W1-S1	Wetland 1	10/4/2006	0.16	0.71	-	-	-	-	-	-	-	
W1-S2	Wetland 1	10/4/2006	0.31	0.6	-	-	-	-	-	-	-	
W1-S3	Wetland 1	10/4/2006	0.23	< 0.025	-	-	-	-	-	-	-	surface water duplicate
		10/4/2006	-	< 0.025	-	-	-	-	-	-	-	
W2-S1	Wetland 2	10/4/2006	< 0.044	< 0.025	-	-	-	-	-	-	-	
W2-S2	Wetland 2	10/4/2006	< 0.035	< 0.025	-	-	-	-	-	-	-	
W2-S3	Wetland 2	10/4/2006	0.27	< 0.025	-	-	-	-	-	-	-	
W3-S1	Wetland 3	10/4/2006	1.7	4.2	-	-	-	-	-	-	-	
W3-S2	Wetland 3	10/4/2006	0.84	1.6	-	-	-	-	-	-	-	
W3-S3	Wetland 3	10/4/2006	0.32	< 0.025	-	-	-	-	-	-	-	
P-S1	Sediment Pond	4/9/2007	4.3	4.5	-	-	-	-	-	-	-	
P-S2	Sediment Pond	4/9/2007	< 0.069	3.9	-	-	-	-	-	-	-	
P-S3	Sediment Pond	4/9/2007	< 0.069	3.9	-	-	-	-	-	-	-	
W1-S1	Wetland 1	4/9/2007	< 0.068	1	-	-	-	-	-	-	-	
W1-S2	Wetland 1	4/9/2007	< 0.13	0.52	-	-	-	-	-	-	-	
W1-S3	Wetland 1	4/9/2007	< 0.07	0.82	-	-	-	-	-	-	-	
W2-S1	Wetland 2	4/9/2007	< 0.15	< 0.038	-	-	-	-	-	-	-	
W2-S2	Wetland 2	4/9/2007	< 0.09	0.44	-	-	-	-	-	-	-	
W2-S3	Wetland 2	4/9/2007	< 0.071	< 0.038	-	-	-	-	-	-	-	
W3-S1	Wetland 3	4/9/2007	8.8	22	-	-	-	-	-	-	-	surface water duplicate; maximum value used (22 µg/L)
		4/9/2007	7.3	20	-	-	-	-	-	-	-	
W3-S2	Wetland 3	4/9/2007	< 0.069	0.74	-	-	-	-	-	-	-	
W3-S3	Wetland 3	4/9/2007	< 0.06	0.52	-	-	-	-	-	-	-	
P-S1	Sediment Pond	4/8/2008	1.1	4	-	-	858	82	7.32	8.6	-	surface water duplicate; maximum value used (4 µg/L)
		4/8/2008	-	3.9	-	-	-	-	-	-	-	
P-S2	Sediment Pond	4/8/2008	0.45	3.8	-	-	845	90	7.3	9.1	-	
P-S3	Sediment Pond	4/8/2008	1.7	4	-	-	805	90	7.35	8.1	-	

Table A–2 (continued). Surface Water and Sediment Biomonitoring Results

Sample ID	Area	Date Sampled	Sediment	Surface Water								Comment
			Selenium (mg/kg)	Selenium (µg/L)	Selenium[a] (µg/L)	Alkalinity (mg/L)	Conductivity (µmhos/cm)	ORP (mV)	pH (s.u.)	Temperature (ºC)	Turbidity (NTU)	
W3-S1	Wetland 3	4/8/2008	1.3	14	-	-	756	125	5.87	5.3	-	
W3-S2	Wetland 3	4/8/2008	0.86	2.5	-	-	890	82	6.1	4.5	-	
W3-S3	Wetland 3	4/8/2008	0.36	1.7	-	-	673	69	7.01	6.4	-	
SP-S1	Sediment Pond	6/23/2010	-	9.3	-	260	2024	156.1	7.1	20.76	20.6	surface water duplicate
		6/23/2010	-	9.3	-	-	-	-	-	-	-	
SP-S2	Sediment Pond	6/23/2010	-	9.5	-	244	1606	83.2	8.21	20.88	11.3	
SP-S3	Sediment Pond	6/23/2010	-	8.9	-	234	1584	64.5	8.17	21.01	9.99	
SP-S4	Sediment Pond	6/23/2010	-	8.7	-	238	1597	71.9	8.3	21.56	10.9	
SP-S5	Sediment Pond	6/23/2010	-	8.9	-	240	1621	91	8.28	22.29	12	
SP-S6	Sediment Pond	6/23/2010	-	7.9	-	246	1554	92.3	8.12	22.44	6.7	
VC-S1	Verdure Crk.	6/24/2010	-	0.37	-	182	555	157.9	6.34	14.23	15.6	
VC-S2	Verdure Crk.	6/24/2010	-	0.34	-	184	435	110.2	8.22	13.24	12.6	
VC-S3	Verdure Crk.	6/24/2010	-	0.35	-	175	432	105.6	8.21	14.03	12.1	
VC-S4	Verdure Crk.	6/24/2010	-	0.33	-	162	427	115.1	7.75	15.24	12.3	
VC-S5	Verdure Crk.	6/24/2010	-	0.33	-	190	426	113.7	8.15	16.17	11.6	
VC-S6	Verdure Crk.	6/24/2010	-	0.22	-	170	411	121.7	8.18	16.88	12.9	
W3-S4	Wetland 3	6/24/2010	-	1.9	-	391	1551	224.8	7.01	25.43	68.9	
W3-S5	Wetland 3	6/24/2010	-	3.1	-	270	1858	221.8	7.58	23.12	17.2	
UMC-S1	UMC_Bkgrnd	6/25/2010	-	0.66	-	218	906	71	7.25	13.29	12.8	
UMC-S2	UMC_Bkgrnd	6/25/2010	-	0.75	-	230	894	71.9	8.21	14.95	9.42	
UMC-S3	UMC_Bkgrnd	6/25/2010	-	0.48	-	206	677	187.7	6.36	15.17	10.1	
UMC-S4	UMC_Bkgrnd	6/25/2010	-	0.56	-	201	646	191.4	6.76	19.43	10.1	

[a] Sample was filtered in the field.
[b] Estimated quantity.

Appendix B

Summary Statistics

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Summary Statistics for Selenium in Macroinvertebrate Tissue Samples: Pooled Group Summary Statistics

Descriptive statistics (Quantitative data): **Sediment Pond**

Sample	N	Minimum	Maximum	Median	Mean	Geometric mean	Variance (n)	Std. Dev. (n-1)	Std. Error of mean	Mean +/- Std. Error
All Results	**20**	**3.15**	**9**	**4.7**	**5.1**	**4.86**	**2.28**	**1.55**	**0.35**	**5.0**
2005	3	3.2	4.3	3.8	3.8	3.7	0.2	0.6	0.3	4.2
2006	4	3.6	5.2	4.2	4.3	4.3	0.4	0.8	0.4	4.6
2007	4	3.6	8.4	5.6	5.8	5.5	3.1	2.0	1.0	6.6
2008	3	4.4	7.6	4.9	5.7	5.5	2.0	1.7	1.0	5.9
2010	6	4.3	8.6	4.7	5.4	5.2	2.2	1.6	0.7	5.3

Synopsis: In 2005 and 2006, and all years combined, means are significantly less than the toxicity threshold.
Although this is not the case in the last 3 years, t-values are negative, indicating no signficant exceedance of the threshold.

Descriptive statistics (Quantitative data): **Wetland 3**

Sample	N	Minimum	Maximum	Median	Mean	Geometric mean	Variance (n)	Std. Dev. (n-1)	Std. Error of mean	Mean +/- Std. Error
All Results	**14**	**3.69**	**13.0**	**6.07**	**6.60**	**6.1**	**6.96**	**2.74**	**0.73**	**6.8**
2005	3	5.2	10.3	6.2	7.2	6.9	4.9	2.7	1.6	7.8
2006	4	3.7	8.0	6.2	6.0	5.8	2.4	1.8	0.9	7.1
2007	3	3.9	9.5	6.8	6.7	6.3	5.1	2.8	1.6	8.4
2008	3	3.7	13.0	5.1	7.3	6.2	16.8	5.0	2.9	8.0
2010	1	4.7	4.7	4.7	4.7	4.7	-			4.7

Descriptive statistics (Quantitative data): **Upper Montezuma Creek Background**

Sample	N	Minimum	Maximum	Median	Mean	Geometric mean	Variance (n)	Std. Dev. (n-1)	Std. Error of mean	Mean +/- Std. Error
All Results	**10**	**1.83**	**7.40**	**5.43**	**5.23**	**4.89**	**2.72**	**1.74**	**0.55**	**6.0**
1996	6	4.6	7.4	6.3	6.3	6.2	0.8	1.0	0.4	6.7
2010	4	1.8	4.9	4.0	3.7	3.4	1.4	1.4	0.7	4.7

Descriptive statistics (Quantitative data): **Verdure Creek**

Sample	N	Minimum	Maximum	Median	Mean	Geometric mean	Variance (n)	Std. Dev. (n-1)	Std. Error of mean	Mean +/- Std. Error
All Results	**11**	**2.70**	**8.30**	**4.30**	**4.63**	**4.34**	**2.96**	**1.81**	**0.54**	**4.8**
1995	2	4.3	4.6	4.5	4.5	4.4	0.0	0.2	0.2	4.6
1996	3	6.6	8.3	6.6	7.2	7.1	0.6	1.0	0.6	7.2
2010	6	2.7	4.5	3.3	3.4	3.4	0.4	0.7	0.3	3.6

Notes:
Values in red exceed the 7 mg/kg toxicity threshold.

Pooled Group Summary Statistics

	Valid N	Mean	Mean+SE	Confidence, -95%	Confidence 95%	Geometric Mean	Median	Minimum	Maximum
Verdure Creek	11	4.6	5.2	3.4	5.8	4.3	4.3	2.7	8.3
UMC Background	10	5.2	5.8	4.0	6.5	4.9	5.4	1.8	7.4
Pre-Remediation MC	18	7.4	7.9	6.5	8.3	7.2	7.1	4.5	11.0
Wetland 1	3	2.8	3.3	0.3	5.2	2.6	3.1	1.6	3.5
Wetland 2	4	1.6	1.7	1.4	1.9	1.6	1.6	1.4	1.8
Wetland 3	14	6.6	7.3	5.0	8.2	6.1	6.1	3.7	13.0
Sediment Pond	20	5.1	5.4	4.3	5.8	4.9	4.7	3.2	8.6

	Variance	Std.Dev.	Std. Error	Coef.Var.	Skewness	Kurtosis
Verdure Creek	3.3	1.8	0.5	39.0	1.0	0.1
UMC Background	3.0	1.7	0.5	33.2	(0.7)	0.1
Pre-Remediation MC	3.3	1.8	0.4	24.4	0.3	(0.5)
Wetland 1	1.0	1.0	0.6	35.8	(1.4)	
Wetland 2	0.0	0.2	0.1	9.9	(1.0)	1.2
Wetland 3	7.5	2.7	0.7	41.5	1.1	0.8
Sediment Pond	2.4	1.5	0.3	30.6	1.3	0.9

T-test results: Comparisons Against Reference Constant (7 mg/kg Toxicity Threshold)

Results in red are significant at p=0.05 level

Variable	All Groups Test of means against reference constant (value)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Se (dw)	5.564833	2.362052	80	0.264085	7.000000	-5.43448	79	0.000001

Variable	Area 2=Verdure Crk. Test of means against reference constant (value)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Se (dw)	4.628182	1.805330	11	0.544327	7.000000	-4.35734	10	0.001427

Variable	Area 2=UMC_Bkgrnd Test of means against reference constant (value)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Se (dw)	5.233000	1.737118	10	0.549325	7.000000	-3.21668	9	0.010545

Variable	Area 2=Pre-Rem MC Test of means against reference constant (value)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Se (dw)	7.433333	1.811077	18	0.426875	7.000000	1.015129	17	0.324275

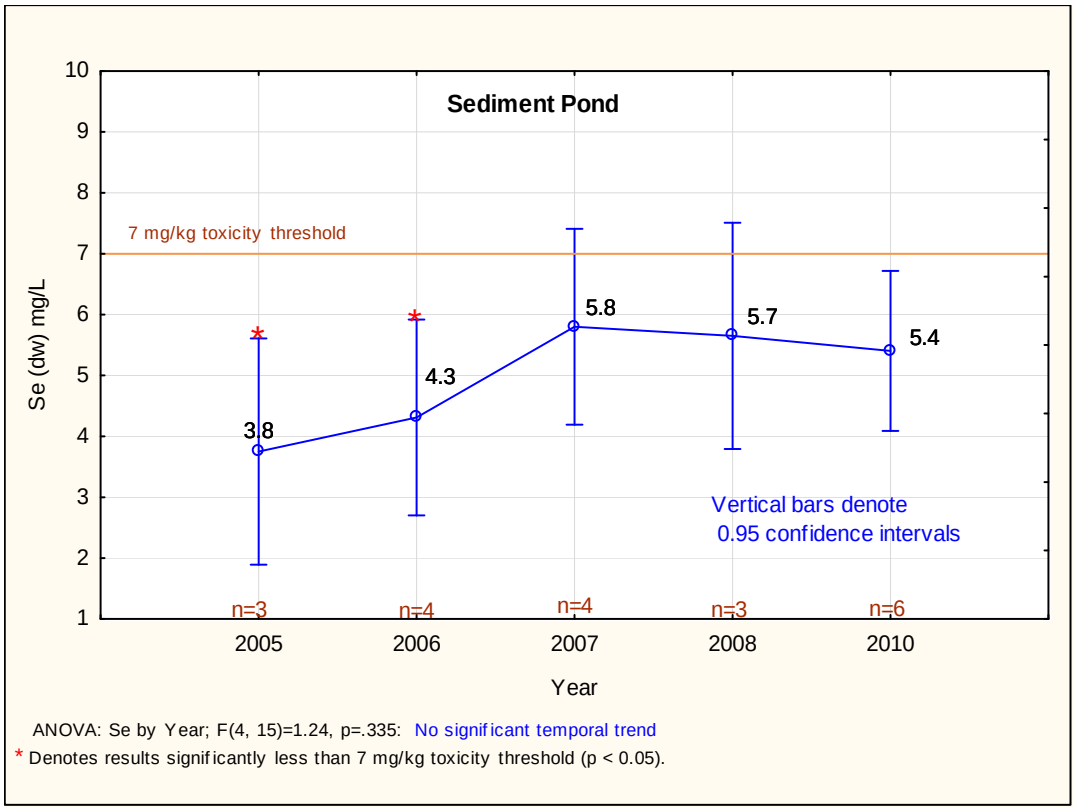
Variable	Area 2=Wetland 1 Test of means against reference constant (value)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Se (dw)	2.753333	0.984700	3	0.568517	7.000000	-7.46973	2	0.017454

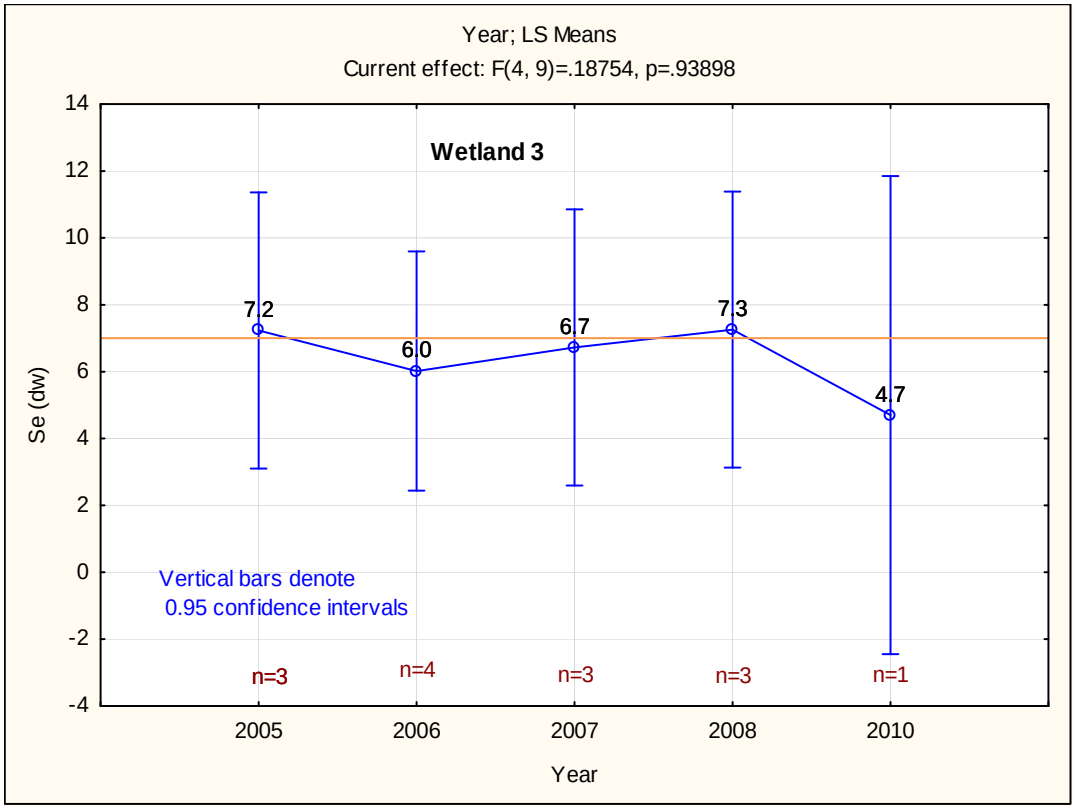
Variable	Area 2=Wetland 2 Test of means against reference constant (value)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Se (dw)	1.606250	0.158292	4	0.079146	7.000000	-68.1495	3	0.000007

Variable	Area 2=Wetland 3 Test of means against reference constant (value)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Se (dw)	6.600000	2.737857	14	0.731723	7.000000	-0.546655	13	0.593875

Variable	Area 2=Sed Pond Test of means against reference constant (value)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Se (dw)	5.053083	1.548569	20	0.346271	7.000000	-5.62253	19	0.000020

Analysis of Variance (ANOVA) Results:





Appendix C

Avian Survey Results

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Table C–1. Avian Survey Results—Wetland 3

Common Name	Scientific Name	Frequency[a]	Abundance[b]	Comments
Red-winged blackbird	*Agelaius phoeniceus*	100	High	Nests and breeds at Wetland 3; consumes aquatic and terrestrial insects and seeds. Harding[c] found high selenium tolerance and a nonlinear uptake curve in this species where selenium concentrations in prey fed to chicks was up to 37 mg/kg dry wt.
Western meadowlark	*Sturnella neglecta*	58	Low	Observed frequently in grasslands at former mill site; not observed using wetlands; species nests in grasslands; consumes insects (primarily terrestrial), seeds, and grain.
Sora	*Porzana carolina*	56	Few	Identified in wetland mainly by call; nesting/breeding in wetland; consumes seeds and aquatic invertebrates.
Common raven	*Corvus corax*	51	Few	Observed in surrounding area, not in wetland; omnivorous terrestrial species.
Mallard	*Anas platyrhynchos*	47	Low	Observed using wetland during five surveys (11%); young observed in 2005; one nest identified in 2008; species uses multiple wetlands in area and is most abundant at nearby sewage lagoons (DOE 2006).
Song sparrow	*Melospiza melodia*	47	Low	Nests in willows bordering Montezuma Creek; observed once foraging in Wetland 3; species consumes mainly seeds and fruit, supplemented by terrestrial and aquatic insects.
Violet-green swallow	*Tachycineta thalassina*	47	Low	Mainly in flocks of mixed species of swallow flying over grasslands and wetland; consumes flying insects.
Barn swallow	*Hirundo rustica*	40	Low	Mainly in flocks of mixed species of swallow flying over grasslands and wetland; consumes flying insects.
Turkey vulture	*Cathartes aura*	37	Low	Observed in surrounding area; not observed in wetland; omnivorous, terrestrial scavenger.
Northern harrier	*Circus cyaneus*	28	Few	Bird of conservation concern; 1 pair nested in Wetland 3 in 2008; fledged three young; carnivore—terrestrial hunter.
Cinnamon teal	*Anas cyanoptera*	26	Low	Small flocks observed using wetland during three surveys (7%); consumes seeds, aquatic vegetation, aquatic and semiterrestrial insects, snails, and zooplankton.
Mourning dove	*Zenaida macroura*	23	Low	Observed in small numbers in the surrounding area; consume almost entirely seeds and grain.
Killdeer	*Charadrius vociferus*	21	Few	Observed in small numbers between Wetland 3 and Montezuma Creek; suspected to nest and breed in area; consumes primarily aquatic and terrestrial invertebrates.
Cliff swallow	*Petrochelidon pyrrhonota*	19	Low	Mainly in flocks of mixed species of swallow flying over grasslands and wetland; consumes flying insects.
Brewer's blackbird	*Euphagus cyanocephalus*	16	Moderate	Observed among flocks of red-winged blackbirds; consumes primarily seeds and grains, supplemented with insects (primarily terrestrial).
Northern rough-winged swallow	*Stelgidopteryx serripennis*	16	Few	Mainly in flocks of mixed species of swallow flying over grasslands and wetland; consumes flying insects.

Table C–1 (continued). Avian Survey Results—Wetland 3

Common Name	Scientific Name	Frequency[a]	Abundance[b]	Comments
Lesser goldfinch	*Carduelis psaltria*	14	Low	Observed in the area once in 2005 and throughout the summer in 2008; terrestrial species; consumes primarily seeds.
White-faced ibis	*Plegadis chihi*	14	Few	Transient; observed in May all 3 years; on water in Wetland 3 during one survey only.
Black-chinned hummingbird	*Archilochus alexandri*	12	Few	Observed in area but not in wetland; consumes nectar and small insects and spiders.
Blue grosbeak	*Passerina caerulea*	12	Few	Observed during 2008 surveys; consumes insects, other invertebrates, and seeds.
Canada goose	*Branta canadensis*	12	Few	Observed infrequently at wetland, primarily flying over; consumes vegetation.
Great-tailed grackle	*Quiscalus mexicanus*	12	Few	Observed infrequently in area; omnivorous; diet may include aquatic insects.
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	12	Low	Observed in wetland but nesting/breeding behavior not observed; consumes aquatic insects, grain, and seeds.
Brown-headed cowbird	*Molothrus ater*	9	Low	Infrequently observed; parasitic species; consumes mainly grains and seeds; insects make up about 25% of diet.
Common yellowthroat	*Geothlypis trichas*	9	Few	Infrequently observed in summer of 2008; insectivorous.
Great blue heron	*Ardea herodias*	9	Few	Infrequently observed; consumes mainly fish, occasionally mammals, reptiles, and other birds.
Tree swallow	*Tachycineta bicolor*	9	Low	Mainly in flocks of mixed species of swallow flying over grasslands and wetland; consumes flying insects.
American crow	*Corvus brachyrhynchos*	7	Few	Rarely observed; terrestrial omnivore.
Bank swallow	*Riparia riparia*	7	Low	Rarely observed; May and June 2006 and 2008.
Common snipe	*Gallinago gallinago*	7	Few	Rarely observed; May and August 2005; also at Wetlands 1 and 2.
European starling	*Sturnus vulgaris*	7	Moderate	Flocks observed in the area in May–June 2008.
Vesper sparrow	*Pooecetes gramineus*	7	Low	Rarely observed; August 2005 and 2008.
American kestrel	*Falco sparverius*	5	Few	Rarely observed; August 2005 and June 2008; in Wetlands 1 and 2 in April 2005.
Common nighthawk	*Chordeiles minor*	5	Few	Rarely observed; July 2005 and June 2008.
Black-billed magpie	*Pica pica*	2	Few	Observed once in May 2008; at Wetlands 1 and 2 in 2005.
Bobolink	*Dolichonyx oryzivorus*	2	Few	State-listed species; observed once May 2008; probable transient.
Chipping sparrow	*Spizella passerina*	2	Moderate	Small flock observed once in August 2005.
Eurasian collared dove	*Streptopelia decaocto*	2	Few	Observed once in May 2008; probable transient.
Great horned owl	*Bubo virginianus*	2	Few	Observed once in July 2008.
Lark sparrow	*Chondestes grammacus*	2	Few	Observed once in August 2008.

Table C–1 (continued). Avian Survey Results—Wetland 3

Common Name	Scientific Name	Frequency[a]	Abundance[b]	Comments
Lazuli bunting	*Passerina amoena*	2	Few	Observed August 2008; at Wetlands 1 and 2 in July 2005.
Mountain bluebird	*Sialia currucoides*	2	Few	Observed once in June 2005.
Say's phoebe	*Sayornis saya*	2	Few	Observed once in April 2005; at Wetlands 1 and 2 in 2005.
Spotted sandpiper	*Actitis macularia*	2	Few	Observed once in May 2005; probable transient.
Western kingbird	*Tyrannus verticalis*	2	Few	Observed once in July 2008.
Western wood-pewee	*Contopus sordidulus*	2	Few	Observed once in May 2008; probable transient.
Yellow warbler	*Dendroica petechia*	2	Few	Observed once in May 2008; probable transient.

[a] Frequency represents the percentage of total surveys (2005, 2006, and 2008) during which this species was observed.
[b] Abundance represents, when a species was observed, the relative number of individuals observed. Few = 1-5; Low = 6-20; Moderate = 21-50; High = 50 or more.
[c] Harding, Lee E., 2007. *Non-linear uptake and hormesis effects of selenium in red-winged blackbirds (Agelaius phoeniceus)*, Science of the Total Environment 389 (2008), 350–366.

Table C–2. Avian Survey Results—Sediment Pond

Common Name	Scientific Name	Frequency	Abundance	Comments
Cliff swallow	*Petrochelidon pyrrhonota*	84	High	Occurs in mixed flocks with other swallows; consumes flying insects; this species nests in the area.
Song sparrow	*Melospiza melodia*	79	Low	Nests and breeds in willows around the pond; observed foraging in pond on two occasions; species consumes mainly seeds and fruit, supplemented by terrestrial and aquatic insects.
Mallard	*Anas platyrhynchos*	72	Low	Observed using wetland in 13 surveys (30%); young seen in 2006 and 2008 on pond.
Black-billed magpie	*Pica pica*	63	Few	Frequently observed in small numbers in area; not observed at pond; terrestrial omnivore.
Great horned owl	*Bubo virginianus*	58	Few	Observed frequently in small numbers in area; not observed at pond; nesting/breeding in canyon downstream from pond; terrestrial carnivore.
Red-winged blackbird	*Agelaius phoeniceus*	58	Few	Frequently observed in small numbers in emergent vegetation upstream from pond; consumes aquatic and terrestrial insects and seeds; selenium tolerant (see Table C-1).
Common raven	*Corvus corax*	49	Low	Observed frequently in surrounding area, not in wetland; terrestrial omnivore.
American robin	*Turdus migratorius*	47	Few	Observed frequently in surrounding area, not in wetland; consumes invertebrates and fruit; terrestrial species.
Violet-green swallow	*Tachycineta thalassina*	44	Low	Mainly in flocks of mixed species of swallow flying over pond and forest; consumes flying insects.
Mourning dove	*Zenaida macroura*	37	Few	Observed in small numbers in the surrounding area; consume almost entirely seeds and grain.
Yellow warbler	*Dendroica petechia*	37	Low	Observed in small numbers in the surrounding area; nest suspected in the area in 2008; consumes insects.
Canada goose	*Branta canadensis*	35	Low	Observed using wetland during 5 surveys (12%); young observed; nesting on canyon walls downstream from pond; consumes vegetation.
Black phoebe	*Sayornis nigricans*	33	Few	Observed rarely in 2005 but frequently in 2008; observed foraging in wetland; consumes insects and some berries.
Blue grosbeak	*Passerina caerulea*	26	Few	Observed in small numbers in area; not observed in wetland; consumes insects, other invertebrates, and seeds.
Spotted towhee	*Pipilo maculatus*	21	Few	Observed in small numbers in area; not observed in wetland; consumes terrestrial insects, fruits, and grains.
Yellow-breasted chat	*Icteria virens*	21	Few	Observed in small numbers in area; not observed in wetland; consumes small invertebrates and fruits.
Northern (red-shafted) flicker	*Colaptes aurantus*	19	Few	Observed in small numbers in area; not observed in wetland; consumes terrestrial insects and seeds.
Red-tailed hawk	*Buteo jamaicensis*	19	Few	Not observed in wetland; terrestrial carnivore.
Brown-headed cowbird	*Molothrus ater*	14	Few	Observed infrequently; parasitic species; consumes mainly grains and seeds with insects making up about 25% of diet.

Table C–2 (continued). Avian Survey Results—Sediment Pond

Common Name	Scientific Name	Frequency	Abundance	Comments
Scrub jay	*Aphelocoma coerulescens*	14	Low	Observed infrequently; terrestrial omnivore.
Turkey vulture	*Cathartes aura*	14	Few	Observed infrequently; terrestrial scavenger.
American goldfinch	*Carduelis tristis*	12	Few	Observed infrequently.
Bank swallow	*Riparia riparia*	9	moderate	Mainly in flocks of mixed species of swallow flying over pond and forest; consumes flying insects.
Bushtit	*Psaltiparus minimis*	9	Few	Observed infrequently; terrestrial insectivore.
Canyon wren	*Catherpes mexicanus*	9	Few	Observed infrequently; insectivore.
Cinnamon teal	*Anas cyanoptera*	9	Low	Observed infrequently; consumes seeds, aquatic vegetation, aquatic and semiterrestrial insects, snails, and zooplankton.
Common nighthawk	*Chordeiles minor*	9	Few	Observed infrequently; consumes flying insects.
Gadwall	*Anas streptera*	9	Few	Observed infrequently; young observed on pond once in 2005; consumes vegetation.
Great blue heron	*Ardea herodias*	9	Few	Observed infrequently; consumes mainly fish, occasionally mammals, reptiles, and other birds.
Western wood-pewee	*Contopus sordidulus*	9	Few	Observed infrequently; consumes flying insects; terrestrial.
Wilson's warbler	*Wilsonia pusilla*	9	Few	Observed infrequently; consumes insects and occasional berries.
Ash-throated flycatcher	*Myiarchus cinerascens*	7	Few	Observed rarely; terrestrial insectivore; occasionally eats fruits.
Black-chinned hummingbird	*Archilochus alexandri*	7	Few	Observed rarely; consumes nectar and small insects and spiders.
Black-throated gray warbler	*Dendroica nigrescens*	7	Few	Bird of conservation concern; observed rarely; terrestrial insectivore.
Bullock's oriole	*Icterus bullockii*	7	Few	Observed rarely; terrestrial omnivore.
Common yellowthroat	*Geothlypis trichas*	7	Few	Observed rarely; insectivorous.
Lazuli bunting	*Passerina amoena*	7	Few	Observed rarely; terrestrial; consumes seeds, fruits, and insects.
Northern rough-winged swallow	*Stelgidopteryx serripennis*	7	moderate	Mainly in flocks of mixed species of swallow flying over pond and forest; consumes flying insects.
Sora	*Porzana carolina*	7	Few	Observed rarely; not breeding at pond; consumes seeds and aquatic invertebrates.
Western tanager	*Piranga ludoviciana*	7	Few	Observed rarely; terrestrial insectivore; eats some fruit.
Wild turkey	*Meleagris gallopavo*	7	Few	Observed rarely; terrestrial omnivore.
American crow	*Corvus brachyrhynchos*	5	Low	Observed in June and August 2008.
Black-headed grosbeak	*Pheucticus melanocephalus*	5	Few	Observed in May and July 2005.
Blue-grey gnatcatcher	*Polioptila caerulea*	5	Few	Observed in August 2008; probable transient.

Table C–2 (continued). Avian Survey Results—Sediment Pond

Common Name	Scientific Name	Frequency	Abundance	Comments
Killdeer	*Charadrius vociferus*	5	Few	Observed in June 2005 and August 2008.
Lesser goldfinch	*Carduelis psaltria*	5	Few	Observed in June and August 2008.
Rock wren	*Salpinctes obsoletus*	5	Few	Observed in July and August 2008.
Say's phoebe	*Sayornis saya*	5	Few	Observed in May 2005 and 2008; probable transient.
Warbling vireo	*Viero gilvus*	5	Few	Observed in June and July 2008.
Yellow-rumped warbler	*Dendroica coronata*	5	Few	Observed in August 2005 and 2008; probable transient.
Barn swallow	*Hirundo rustica*	2	Few	Mainly in flocks of mixed species of swallow flying over pond and forest; consumes flying insects
Bewick's wren	*Thyromanes bewickii*	2	Few	Observed once in August 2005.
Black-capped chickadee	*Poecile atricapilla*	2	Few	Observed once in May 2008.
Blue-winged teal	*Anas discors*	2	Few	Observed once in May 2008.
Dark-eyed junco	*Junco hyemalis*	2	Few	Observed once in May 2008.
Grey flycatcher	*Empidonax wrightii*	2	Few	Observed once in July 2008.
House wren	*Troglodytes aedon*	2	Few	Observed once in May 2008.
Lark sparrow	*Chondestes grammacus*	2	Few	Observed once in August 2005.
MacGillivray's warbler	*Oporonis tolmiei*	2	Few	Observed once in August 2005.
Olive-sided flycatcher	*Contopus borealis*	2	Few	Observed once in August 2005.
Ruby-crowned kinglet	*Regulus calendula*	2	Few	Observed once in May 2008.
Tree swallow	*Tachycineta bicolor*	2	Low	Observed once with other species of swallow.
Virginia's warbler	*Vermivora virginiae*	2	Few	Observed once in August 2008.
Western meadowlark	*Sturnella neglecta*	2	Few	Observed once in June 2006.
White-breasted nuthatch	*Sitta carolinensis*	2	Few	Observed once in June 2005.
White-faced ibis	*Plegadis chihi*	2	Few	Observed once in May 2006 flying over wetland.
Willow flycatcher	*Empidonax traillii*	2	Few	Although the subspecies could not be identified, the bird may have been a threatened species (southwestern willow flycatcher). Observed once in May 2008; probable transient.