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Final Report: Assessment of Trace-Metal Exposures to Aquatic Biota from Historical Mine Sites in the Western Great Basin

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1.0 INTRODUCTION

1.1 Background

Mining activities since the mid-1800s have greatly accelerated metal cycling in aquatic systems. Although naturally enriched ore bodies can contribute relatively minor loadings to these systems, anthropogenic activities such as the extraction and processing of metals can introduce highly enriched material to surrounding water bodies (Luoma and Carter, 1991; Axtmann and Luoma, 1991). Although many metals are biologically essential in trace amounts (for example, chromium, copper, and zinc), excessive quantities can interfere with physiological processes. Non-essential metals such as cadmium, lead, mercury, and silver also can accumulate in the tissues of aquatic organisms and cause adverse biological impacts in aquatic organisms (Lau et al., 1998).

Current and historical mining operations represent significant threats to aquatic systems in Nevada and elsewhere in the western United States (National Research Council, 1999). For example, Moore et al. (1991) found that arsenic, cadmium, copper, and zinc remained elevated in sediment up to 25 km down stream of the contaminant source even though metal concentrations in solution decreased within a few kilometers down stream of the mine drainage input. Locally, metals mobilized from an abandoned mine site in the Santa Rosa Mountains in Humboldt County, Nevada, have contaminated sediments at least 3 km downstream of the mine site and may extend as much as 8 km downstream of the site (Earth Technology Corporation, 1991). Data collected in the Humboldt River watershed by the U.S. Environmental Protection Agency's Regional Environmental Monitoring and Assessment Program (REMAP) in 1998 revealed concentrations in sediment, at sites associated with mining activities, that exceeded adverse effect levels suggested by Long and Morgan (1991) for several metals, including arsenic, cadmium, chromium, copper, lead, nickel, silver, and zinc (Higgins and Hall, in prep). In addition, many historical mine sites had milling operations that used mercury in amalgamation processes to extract precious metals from ores. Large losses of mercury occurred in these processes and from mercury mining itself, releasing mercury into the environment through discarded mill tailings and effluents. Adverse effects of mercury in aquatic systems are well established (Zilloux et al., 1993). Similarly, adverse impacts of mercury-contaminated drainages from historical milling operations have been well documented. Sampling of stream sediments down-gradient of mill tailings at Castle Peak Mine located in Storey County, Nevada, revealed total mercury concentrations of up to 8,400 ng/g (ppb) dry weight (Nevada Bureau of Mines and Geology, unpubl. data). These concentrations exceed the potential for adverse biological effects suggested by Long and Morgan (1991).

Metals in drainage emanating from historical mine sites in the western Great Basin are likely impacting aquatic biota, including the threatened Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*) (LCT) and the candidate species Columbia spotted frog (*Rana luteiventris*) (CSF). Degradation of water quality has been identified as a principal threat to the LCT throughout its range (U.S. Fish and Wildlife Service, 1995). However, degradation of water quality and habitats receiving historical mining drainage has never been adequately assessed or addressed in recovery planning efforts. There are several historic mining operations that are in existing LCT streams. However, the impact of these historical mine drainages on LCT populations is unknown.

1.2 Purpose and Scope

The purpose of this investigation is to identify and characterize the nature and extent of sediment and food chain contamination, and to determine the potential for adverse effects to aquatic life, from metals in drainage emanating from current and historical mine sites. To achieve this purpose, this investigation accomplished the following tasks: 1) determination of metals and trace elements in water, sediment, aquatic benthic invertebrates, and fish tissues; 2) aquatic invertebrate community assessment; 3) fish community assessment; and 4) fish health assessment.

The scope of the investigation includes aquatic habitats that support or have the potential to support trust resources of the U.S. Fish and Wildlife Service (Service), primarily habitat for the threatened LCT. Data collected by this investigation were compared to threshold values determined in other investigations on toxicity of water, sediment, and diet to fish and invertebrates.

2.0 Description of Study Areas

In March 1999, the Bureau of Land Management (BLM) initiated the formation of the Nevada Abandoned Mine Land Environmental Task Force (NAMLET) to begin the remediation of environmental problems associated with abandoned and inactive mines in Nevada. The task force is comprised of 13 federal and state agencies in order to foster regulatory cooperation, identify priority sites for cleanup, and provide administrative oversight for funded projects. Thirty-three mines sites were identified by the NAMLET as potentially impacting ground or surface water and needing some type of reclamation action in the near future (NAMLET 1999).

Using information from NAMLET and the U.S. Forest Service (USFS), the Service selected five locations with known or suspected contaminant concerns within a watershed identified for recovery of LCT or likely to affect other Service trust resources and their habitat (Table 1 and Figure 1). One control site without any known mining influences was also included for comparison to an "un-impacted" or background watershed area. Brief descriptions of the historical mining activities conducted at the various selected mine sites along with locations are provided in the following sections.

Table 1. Selected study locations for data collection with known contamination and U.S. Fish and Wildlife Service Trust Resources.

Study Area ID #	Study Area	Stream	County and State	Trust Resources[a]	Known Contaminant Concerns	Reference(s)
1	American Beauty Mine Complex	Long Canyon	Elko Co., NV	LCT, CSF	antimony, cadmium, mercury, lead, silver, pH	Higgins and Hall, in prep.
2	Aurora-Bodie Historic Mining Area	Bodie Creek	Mineral Co., NV; Mono Co., CA	LCT	antimony, arsenic, cadmium, copper, mercury, lead, pH, silver, zinc	Science Applications International Corporation, 2001.
3	Birch Creek District – Austin Gold Venture Mine	Birch Creek	Lander Co., NV	LCT, CSF	copper, iron, manganese, nickel, pH, selenium, sulfate, total suspended solids	Resource Concepts, Inc., 1996.
4	CONTROL	Hunter Creek	Washoe Co., NV	LCT	None	None
5	McCormick Group & Buckskin National Mines	N. Fork Little Humboldt River	Humboldt Co., NV	LCT	arsenic, cyanide, selenium, lead, iron, mercury, pH	Earth Technology Corporation, 1991; Higgins and Hall, in prep.
6	Washington District	San Juan Creek	Nye Co., NV	LCT	copper, iron, pH , zinc	Service correspondence, April 2000.

[a] Trust Resources: CSF = Columbia spotted frog (*Rana lutieventris*); LCT = Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*)

Figure 1. General locations of study areas for the collection of sediment, water, invertebrate, and fish samples from stream sites potentially affected by historical mine sites in the western Great Basin.

2.1 American Beauty Mine Complex – Long Canyon

The American Beauty Mine (ABM) Complex is a group of five former lead-zinc mines within the Long Canyon Creek watershed located in the west-central Ruby Mountains of eastern Nevada. The Knob Hill Mine and American Beauty Mine are the major contributors of the ABM Complex located in the upper reaches of Long Canyon at approximately 8,300 - 8,500 feet elevation respectively. The other contributors of the ABM Complex include Galena King Mine, Hargrove Mine, and an un-named adit which are located in Segunda Creek, a major tributary to Long Canyon , at approximately 8,000 - 8,700 feet in elevation. Ore containing lead, silver, zinc, and copper was shipped from the site in 1871 and again from 1915 to 1919 (LaPointe et al., 1991). Much of this early production was derived from the American Beauty Mine (LaPointe et al., 1991). The district produced additional ore from 1921 until 1929, in 1934, and again from 1949 until 1958 (LaPointe et al., 1991). Most of the ore mined during the latter period came from the Knob Hill Mine (LaPointe et al., 1991). Approximately 1,400 tons of lead-silver ore, lesser amounts of copper and zinc, and minor gold were produced from the district. With the drop in lead and zinc prices production from the deposits ceased in 1959 (LaPointe, et al., 1991).

2.2 Aurora/Bodie Mining Area – Bodie Creek

The Aurora-Bodie Historical Mining Area is located east of the Sierra Nevada range within the Bodie Creek watershed near the California-Nevada border in Mono County, California and Mineral County, Nevada. A small group of prospectors first discovered gold in Bodie Valley in 1859. Additional discoveries were also found the following year 12 miles north in Aurora, Nevada. Through the 1860s and 1870s, several individuals and small companies continued to explore claims and process ores in the Bodie area using crude amalgamation techniques. Meanwhile, the Aurora area reached its peak mining production in 1864 with 14 active steam-driven stamp mills that crushed the ore and allowed the removal of the precious metal, for a combined total of 120 stamps (Mono County Historical Society, 2003). Aurora's prime lasted about 10 years, during which the mining district produced approximately $30 million in bullion, mostly silver.

The Bodie Creek watershed contains both Bodie Creek and Aurora Creek. Bodie Creek flows for approximately 17.4 miles in a northeasterly direction starting upstream of Bodie State Park (SHP) and flows downstream approximately 5 miles to its confluence with Aurora Creek where it continues to its terminus at Rough Creek in Nevada.

Within California, Bodie Creek occurs on lands managed by the BLM and the State of California. Multiple mining features can be found within the Bodie area that affect approximately 3.5 miles of Bodie Creek, which flows through BLM-administered lands, private property (800 acres), and the Bodie SHP property (495 acres). Other mining features in the Bodie area include a former ore milling operation (known as the Syndicate Mill), a large tailings impoundment, and numerous prospects, shafts, adits, and tailings piles (Dynamac, 2002) .

Within Nevada, the Aurora Creek watershed contains remnants of historic structures previously described. The portions of Bodie and Aurora Creek watersheds in Nevada are managed by the Humboldt-Toiyabe National Forest (HTNF). Overall, Bodie Creek has a rocky streambed and several pools and deep holes. Bodie Creek currently supports a population LCT hybridized with rainbow trout (*Oncorhynchus mykiss*) (USFS, 2006).

2.3 Birch Creek District/Austin Gold Venture Mine – Birch Creek

The Birch Creek District is located on the eastern slope of the Toiyabe Range about 10 miles southeast of Austin, Nevada and contains the Birch Creek watershed for which it is named. Discovery of precious metals in this watershed dates back to 1863 when the Charles C. Breyfogle party found silver ores near the mouth of Birch Creek in Big Smoky Valley (Tingley and Smith, 1982). A 20-stamp mill was constructed near the mouth of Birch Creek Canyon in 1866, but it operated for only a short time and by 1867 the camp was deserted (Tingley and Smith, 1982). There was a short period of activity between 1910 and 1912, again in 1916-1919, and minor production was reported from several old mines during the 1940s and 1950s. Tungsten was discovered about 1942, uranium in 1955, and small production resulted from both (Tingley and Smith, 1982). Beryl was found in the area in 1960, but the deposits proved too small for development (Tingley and Smith, 1982).

Beginning in 1985, Inspiration Resources, Inc., began production of the Austin Gold Venture (AGV) Mine in the headwaters of the watershed. The AGV Mine had a life expectancy of 5 years and by the early 1990s began closing operations. The mine was an open pit operation containing two pits and eleven dumps located within the Birch Creek drainage. One dump in an area called Dump Gulch was deposited on a spring with an annual average flow of 0.3 cubic feet per second. The engineered components consisting of three rock check dams, and three sediment basins were constructed to prevent flow from the spring from directly entering Birch Creek. However, the sedimentation basins have since been combined into one structure. The sedimentation basin holds water year-round and infiltrates and/or evaporates drainage water from Dump Gulch.

Monitoring data from the spring discharge site AGV-7 has shown elevated levels of selenium with a mean concentration of 0.014 mg/L (ppm) from 1989 to 1995. Water-borne concentrations of selenium as low as 0.002 mg/L (ppm) can affect the health and long-term survival of fish and birds (Lemly 1996). Potential bioaccumulation of selenium in the sediment basin could present a hazard to migratory birds and seepage of selenium-contaminated water from the sediment basins into Birch Creek could impact resident fish populations.

Anecdotal information indicates that Birch Creek contained LCT in the past. Recent fish surveys have shown that Birch Creek does not support any LCT (J. Elliott, Nevada Department of Wildlife, pers. comm. 2007). However, Birch Creek is considered valuable for having potential to support an out-of-basin population that could be used in future conservation and recovery efforts.

2.4 Control Site – Thomas Creek

Thomas Creek is located about 8 miles southwest of Reno, Nevada and originates from the east side of the Carson Range at approximately 9,000 feet. At 6,000 feet, the creek leaves the Carson Range and flows onto the upper slopes of the Truckee Meadows and ultimately empties into Steamboat Creek, a tributary to the Truckee River. The only mining activity conducted within this watershed includes some geothermal activity in the Steamboat Hills area which is located immediately to the south.

2.5 McCormick Group and Buckskin National Mines – North Fork Little Humboldt River

The McCormick Group and Buckskin National mines are located in northern Humboldt County, Nevada. The general physical location of the Site is on Buckskin Mountain, Santa Rosa Mountains, in the North Fork of the Little Humboldt River drainage. The McCormick Group Mine, near the top of Buckskin Mountain, was in operation the first half of the 20th century, for an unknown period. Between 1922 and 1928, while prospecting for gold and silver, Chalmers McCormick located 18 unpatented claims covering a mercury "quicksilver" deposit. Mercury production totaled approximately 130 flasks. In 1932, mercury was recovered with a pan retort. A 64-foot rotary furnace was installed and produced 70 flasks of mercury before it was dismantled and removed from the property in 1941. The McCormick Group also had a rock crusher, and three waste dumps remain. The soils surrounding the retort, in the dump's surface and several feet below were found to contained elevated levels of mercury (Brooks, 2002).

The Buckskin National mining claims were first located in 1906 by W.J. Bell and G.B. Ward. The Buckskin National property was mined intermittently from 1906 to 1941 with total production of 24,000 ounces of gold and 300,000 ounces of silver. The site consists of extensive workings covering 20 acres, including a tailings pile and dam, waste rock dumps, six adits, eroding structures, and abandoned process residuals. Between one and 53 gallons per minute of acidic, metal-laden water flows from the main Hatch adit (Brooks, 2002).

2.6 Washington District - San Juan Creek

The Washington District lies on the west slope of the Toiyabe Range near the boundary between Lander and Nye Counties, 35 miles south-southwest of Austin, Nevada. It was organized in 1863, and for several years thereafter a number of mines and prospects were located and actively worked in San Pedro, Cottonwood, and San Juan Canyons; but with the decline of silver mining in the Toiyabe Range, the district became inactive and remained almost forgotten for many years.

A total of seven mine sites operated in the San Juan Creek drainage (Table 2). Most of the sites have shafts or adits in close proximity to the creek that could be potentially contributing discharge from groundwater. Descriptions of the ore and workings for several sites indicate much of it has oxidized. However, it is not known if previous analytical data have been collected for this drainage.

Table 2. Historical mine sites in the San Juan Creek drainage, northern Nye County, Nevada (taken from U.S. Geological Survey's Mineral Resource Data System).

Mine Site	Product
Bi-metallic Group	lead, zinc, silver, gold, arsenic, copper, manganese, bismuth
Bi-metallic Prospect #3	lead, gold, silver
Jim Dandy Prospect	lead, silver, gold
St. Elena Patent	lead, silver
Grandview Group	lead, silver, copper

3.0 METHODS OF SAMPLE COLLECTION AND ANALYSES

3.1 Selection of Stream Sites

All sampling for this investigation occurred from July to August 2004. Samples of water, sediment, aquatic invertebrates, and fish tissue were collected from three stream sites at each of the six identified study areas (Figure 1; Table 1). Locations of the three stream sites for each study area are provided in Table 3 and were selected using the following general guidelines: a) Lower portion - an area not to exceed 5 km downstream of significant tailings influence; b) Middle portion - an area not to exceed 1.5 m downstream of significant tailings influence; and c) Upper portion - immediately downstream of significant tailings influence.

Biotic samples collected in these stream sites are fairly restricted due to limited water availability, therefore limiting migration and contaminant uptake from other sampling sites. The collection period was during early summer when access was available to high elevation sites, water availability was most likely, and biological activity was at a maximum. Locations of stream sites for each study area were obtained and recorded using global positioning system methodology and are provided in Table 3.

Table 3. Geographic coordinates of stream sites among each study area where water, sediment, aquatic invertebrate, and fish data were collected, July - August 2004. (Coordinates in Universal Transverse Mercator (UTM) units; Zone 11; NAD83.)

Study Area – Stream Name (Study Area ID #; fig. 1)	Stream Sites	Site ID #	Date (2004)	UTM EAST	UTM NORTH	Elev. (ft)
American Beauty Mine Complex – Long Canyon (1)	lower portion	1a	8/25	624,951	4,490,472	6,300
	middle portion	1b	8/24	627,782	4,489,726	6,721
	upper portion	1c	8/24	631,423	4,487,252	7,838
Aurora/Bodie Mining Area – Bodie Creek (2)	lower portion	2a	8/2	332,168	4,243,585	6,334
	middle portion	2b	8/2	331,336	4,238,772	7,141
	upper portion	2c	8/2	330,236	4,237,340	7,378
Birch Creek District/Austin Gold Venture Mine – Birch Creek (3)	lower portion	3a	8/9	497,471	4,359,827	6,770
	middle portion	3b	8/9	496,775	4,360,915	7,038
	upper portion	3c	-	-	-	-
Control Area – Thomas Creek (4)	lower portion	4a	7/22	255,664	4,363,909	5,950
	middle portion	4b	7/27	253,701	4,364,111	6,391
	upper portion	4c	7/27	253,180	4,364,476	6,550
McCormick Group & National Buckskin Mines – N. Fork Little Humboldt River (5)	lower portion	5a	8/31	467,989	4,624,219	5,972
	middle portion	5b	8/31	464,670	4,625,033	6,136
	upper portion	5c	8/30	456,011	4,626,870	7,148
Washington District – San Juan Creek (6)	lower portion	6a	8/9	476,236	4,330,156	7,308
	middle portion	6b	8/17	478,222	4,329,392	7,750
	upper portion	6c	8/17	479,391	4,328,433	8,288

3.2 Water Chemistry

Water quality parameters were measured at each stream site, including the following: temperature, dissolved oxygen, pH, total dissolved solids (TDS), salinity, and turbidity. All water quality parameters were measured using a Hydrolab DataSonde 4a multiprobe unit, calibrated before each use.

To evaluate water chemistry in identified aquatic habitats, one grab sample was collected from each of three stream sites among the six study areas (Table 3). However, no water quality measurements or grab samples were collected from site 3c because of the lack of surface water. Method of collection followed NAWQA Program guidelines for sampling water using parts per billion (ppb) detection limits (Shelton, 1994). Water samples were analyzed for 19 filtered (total) trace-metals, including mercury. Trace-metal concentrations determined in these surface water samples were compared to environmental concentrations for surface water provided by the National Oceanic and Atmospheric Administration's Screening Quick Reference Tables (SQuiRT). The SQuiRT guidelines used by this investigation for assessing chronic (Criteria Continuous Concentration) and acute (Criteria Maximum Concentration) exposures for non-hardness-based constituents of aluminum, arsenic, barium, iron, manganese, mercury, and selenium are provided in Table 4.

The acute and chronic values used in the SQuiRT are based upon information from the Ambient Water Quality Criteria (AWQC) developed by the Environmental Protection Agency (EPA) for aquatic organisms. The SQuiRTs are intended for preliminary screening purposes only and do not represent any criteria or clean-up levels. However, EPA's AWQC are rules developed to provide protection for aquatic organisms and are used by the States to develop water-quality standards (U.S. Environmental Protection Agency, 1999). Concentrations that exceed the

Table 4. National Oceanic and Atmospheric Administration's Screening Quick Reference Table (SQuiRT) values used for screening non-hardness-based trace-metal concentrations in water samples (mg/L or parts per million- filtered) collected from historical mine sites in the western Great Basin.

Trace-Metal	Chronic Value (Criteria Continuous Concentration)	Acute Value (Criteria Maximum Concentration)
Aluminum	0.087	0.75
Arsenic	0.15	0.34
Barium	0.004	0.11
Iron	-	1.0
Manganese	0.12	23
Mercury	0.00077	0.0014
Selenium	0.002*	-

* based on recommendation by Hamilton and Lemly (1999).

AWQC provided in the SQuiRT could be in violation of State water-quality standards and pose a threat to the health of aquatic organisms.

Significant concern and debate have occurred over the effect that differences in water quality characteristics (e.g., sulfate, hardness, pH, etc.) and hydrogeology (e.g., lentic vs. lotic habitats) have on selenium toxicity in aquatic ecosystems (Canton and Van Derveer, 1997; Van Derveer and Canton, 1997; EPA, 1998; Skorupa, 1998; Chapman, 1999; and Hamilton and Lemly, 1999). For purposes of screening for potential risks to aquatic biota in light of this controversy, this investigation used a conservative value of 0.002 mg/L (parts per million or ppm) for comparison among sites recommended by Hamilton and Lemly (1999) in place of the SQuiRT value of 0.005 ppm which is based on EPA's national criterion.

3.3 Streambed Sediment

Using methods described in Dodge et al. (2000), 10 grab samples were collected from the surface of depositional areas at three stream sites for each of the six study areas. Samples were wet-sieved to 63 microns (μm) with ambient river water, and combined to create one composite sample for each stream site. Streambed sediment samples were analyzed for 19 total trace-metals, including mercury. However, no sample was collected from site 3c due to a dry streambed.

Because trace-metals are disproportionately associated with different particle sizes, the particle-size distribution of a bulk sample can greatly influence metal concentrations of that sample (Salomons and Forstner, 1984). Sieving bed-sediment samples to a common size class of particles allows comparisons of metal concentrations to be standardized among sites and reduces potential biases that could distort interpretations of the spatial distribution in metal concentration. The interpretation of sieved sediment is also more biologically relevant because fine particles are often trapped within the matrix of periphyton and filamentous algae, part of the microhabitat of many insect species. Fine-grained sediment concentrations have correlated significantly to metal concentrations in benthic insects and are a useful indicator of the metal exposure to the biota (Cain et al., 1992).

For sediments, multiple screening values are available, and each metal may not have the same type of screening value. To assess the biological relevance of the sediment data, the sediment concentrations were compared to consensus-based sediment guidelines developed by MacDonald et al. (2000). Although these guidelines identify contaminants that pose a threat to aquatic organisms in a freshwater system, they do not represent official policy or clean-up levels. In this report, the Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) are based on a cross-section of field data that developed associations between chemical concentrations and biological effects, as well as laboratory toxicity test results. The TEC is a conservative screening value, below which concentrations of contaminants have not been shown to cause an effect on aquatic organisms. The PEC is a screening value above which toxic effects are likely to occur, and compounds that exceed it are more probably elevated to toxic levels.

Although selenium was not included in the development of the consensus-based sediment guidelines by MacDonald et al. (2000), two papers have proposed the use of a sediment-based criterion expressed on a particulate basis, such as sediment selenium concentration or a measure of the organic content of sediment (Canton and Van Derveer, 1997; Van Derveer and Canton, 1997). In an example in their second paper, Van Derveer and Canton (1997) present a sediment selenium model and use it to derive a site-specific chronic dissolved selenium standard of 31 ppb, using a sediment selenium toxicity threshold of 2.5 ppb and a site-specific mean sediment total organic carbon of 0.5%. For purposes of screening potential risks to aquatic life from selenium, this threshold proposed by Van Derveer and Canton (1997) was used for comparison by this investigation.

3.4 Trace-Metals in Aquatic Biota

3.4.1 Aquatic Invertebrates

Several studies have associated elevated metals concentrations in sediment with elevated metal concentrations in benthic organisms (Moore et al., 1991; Ingersoll et al., 1994; Besser et al., 1996). Benthic organisms are important components of aquatic food chains, and dietary exposure is an important pathway of metal exposure in fish. In some cases, exposure to metals in diet caused greater adverse effects than exposure to metals in solution (Woodward et al., 1994). Diets contaminated by metals associated with acidic drainage are associated with reduced growth, and reduced survival of trout (Woodward et al., 1994).

To assess impacts to fish and wildlife from food chain contamination, invertebrates were collected using procedures described by Hoffman et al. (1990) and Tuttle et al. (1996) to determine their accumulation of trace-metals and the potential for food chain transfer of contaminants. Due to their wide distribution and tolerance of elevated metal burdens, invertebrates of the Tricopteran genus *Arctopsyche* have been widely used to monitor metal bioavailability in streams of the western United States (Cain et al., 1992; Kiffney and Clements 1993; Farag et al., 1998). Therefore, *Arctopsyche* taxa were targeted for collection to standardize comparisons among sites with a similar feeding guild. One composite sample was collected at each of the three stream sites for each study area. However, no invertebrates were collected from sites 3c, 5a, and 5c either due to lack of water or because invertebrate abundance did not meet the minimum sample weight required for trace-metal analyses. Upon collection, invertebrates and debris were sieved using an 800 μm mesh screen and placed in a pre-cleaned stainless steel pan containing water from the site. A minimum of 5 grams of *Arctopsyche* spp. were separated from debris and non-target invertebrates and placed into certified clean 60 milliliter glass containers with Teflon-lined enclosures. Samples were stored on ice in the field and frozen within 10 hours of collection until submitted for chemical analysis.

3.4.2 Fish

Inorganic contaminants may accumulate in different organs and tissues in higher trophic level animals. For example, aluminum may collect on gills, and a variety of metals may accumulate in livers and muscle of fish. Therefore, a variety of fish tissues were needed to assess accumulation and to evaluate the potential to adversely affect fish.

Up to four whole body samples were collected at each stream site among the six study areas. However, whole body samples were not collected from sites 3c and 5c due to lack of water or no presence of fish. Whole fish were analyzed to enable comparison of concentrations associated with adverse effects in other published studies.

Collections of gill, liver, and muscle tissues were also made from fish among stream sites within a study area to form a single composite sample of each tissue type from each study area. However, due to limited abundance of salmonids captured within each study area, these tissue samples were only collected from Birch Creek, Thomas Creek and San Juan Creek. The muscle sample extracted from each fish consisted of one fillet with the skin attached. Whole body samples were weighed and measured for length and put into labeled Ziploc bags. All tissue samples were removed in the field with pre-cleaned stainless steel instruments and placed in certified clean 60 to 250 ml glass jars with Teflon-lined enclosures. Instruments and working surfaces were cleaned with a brush and Citranox detergent, rinsed with a dilute nitric acid solution, and triple rinsed with de-ionized water prior to use at each sample location. Fish tissue composites were not collected from Study Areas 1 (American Beauty Mine Complex), 5 (McCormick Group & National Buckskin mines), and 6 (Washington District) due to the lack of the numbers of fish needed to make minimum composite sample weights for analyses. All fish samples were placed in chemically clean glass jars with Teflon-lined lids in the field, placed on ice, and frozen until chemical analysis.

Trace-element concentrations in whole body, gill, and liver, tissues were compared to known toxicological benchmarks derived from previous studies to assess risk. Trace-metal concentrations determined in salmonid muscle tissue were compared to EPA screening values (SV) to assess potential human exposure risks. EPA SVs are defined as concentrations of target analytes in fish tissue that are of potential public health concern and that are used as threshold values against which levels of contamination in similar tissue collected from the ambient environment can be compared (EPA, 2000).

3.5 Aquatic Community Health Assessment

Aquatic invertebrate community samples were collected at each of three stream sites for all six study areas. Methods followed standard NAWQA protocols reported in Cuffney et al. (1993). The objective of the sampling was to obtain as complete a list of invertebrate taxa in a sampling reach as possible by sampling multiple habitat types. A D-frame kick net with a 210-µm mesh was used to collect the samples. Taxonomic identification was conducted by the Service's Nevada Fish and Wildlife Office. Taxa were identified to the lowest taxonomic group possible and enumerated.

Two invertebrate metrics were calculated to assess the relative health of the stream sites. Taxa richness, or the number of distinct taxa collected, is a common measure representing the diversity of a macroinvertebrate sample. Increasing diversity correlates with increasing health of the assemblage and indicates that niche space, habitat, and food source, as well as water quality, are adequate to support survival and propagation of many species (Barbour et al., 1999). A second common richness metric is the percentage of distinct taxa belonging to the orders of Ephemeroptera, Plecoptera, and Trichoptera (% EPT). The EPT orders are sensitive to perturbation and generally decline in relative importance as health of the assemblage declines (Barbour et al., 1999). In addition, Clements et al. (1992) found a reduction in abundance and diversity of mayflies (Ephemeroptera) at sites contaminated by heavy metals.

To compare macroinvertebrate metrics to metals concentrations at the selected sites, a metals index was calculated. Concentrations (µg/g) of arsenic, cadmium, chromium, copper, iron, lead, nickel, and zinc in sediments were standardized for the selected sites on a scale from 0 to 10 as follows:

$$\text{Index} = \sum_{i=1}^{N} (X_i / X_{imax}) 10$$

where:

N = number of metals in the index,

X_i = concentration of one of the N metals at a site, and

X_{imax} = maximum concentration of the metal observed at all sites.

Because the index number represents the relative concentration of these seven metals at the six selected sites, the site with the highest concentrations of these metals has the highest index number.

4.0 RESULTS

4.1 Trace-Metal Concentrations in Surface Water

Water quality parameters and total trace-metal concentrations for each stream site within study areas are reported in Appendix A. No surface water sample was collected from Site 3b because it was dry. With one exception of temperature and pH, water quality parameters at all stream sites were within values established by the State of Nevada for supporting beneficial uses of aquatic life. Stream temperature at Site 3b (Bodie Creek – middle portion) was 27.53 °C, which exceeded the beneficial use for coldwater fish for a Nevada-designated Class A water (20.0 °C). Site 5c (North Fork Little Humboldt River – upper portion) had a pH value of 3.48. All other stream sites exhibited circum-neutral pH values and ranged from a low of 7.36 (Site 4a) to a high of 10.92 (Site 1b). TDS values varied widely among stream sites and ranged from a low of 67 mg/L (Site 4c) to a high of 409 mg/L (Sites 3a and 3b).

For non-hardness-based criteria, barium concentrations exceeded chronic values at all stream sites for all study areas including the control site (Thomas Creek). With the exception of both stream sites in Birch Creek (Sites 3a and 3b) and the upper portion of the North Fork Little Humboldt River (Site 5c), all other non-hardness-based criteria were not exceeded at any stream site. Site 5c exceeded acute criteria for aluminum and iron; and chronic criteria for manganese and selenium. Sites 3a and 3b exceeded the chronic criterion for selenium.

Cadmium, chromium, copper, lead, nickel, and zinc criteria vary on the basis of the total hardness of the water. At hardness values derived from measured TDS concentrations, Site 5c was the only stream site among study areas that exceeded chronic criteria for cadmium and zinc; and the acute criterion for copper.

4.2 Trace-Metal Concentration in Streambed Sediment

Concentrations of trace-metals determined in streambed sediment along with comparisons to the consensus-based guidelines developed by MacDonald et al. (2000) are provided in Appendix B.

Arsenic concentrations in streambed sediment exceeded the consensus-based TEC of 9.79 mg/kg (MacDonald et al., 2000) at the lower stream site in Birch Creek (Site 3a) and the upper stream site in San Juan Creek (Site 6c). Arsenic concentrations in streambed sediment exceeded the consensus-based PEC of 33 mg/kg (MacDonald et al., 2000) at the middle portion of Birch Creek (Site 3b), North Fork Little Humboldt River (Site 5c), and San Juan Creek (Sites 6a and 6b).

Cadmium concentrations in streambed sediment exceeded the consensus-based TEC of 0.99 mg/kg (MacDonald et al., 2000) at all sites in Birch Creek (Sites 3a and 3b) and San Juan Creek (Sites 6a, 6b, and 6c), but fell below the PEC.

Copper concentrations in streambed sediment exceeded the consensus-based TEC of 31.6 mg/kg (MacDonald et al., 2000) at the middle portions of Birch Creek (Site 3b) and San Juan Creek (Site 6b) and at the upper portion of the North Fork Little Humboldt River (Site 5c), but fell below the PEC.

Mercury concentrations in streambed sediment exceeded the consensus-based TEC of 0.18 mg/kg (MacDonald et al., 2000) at the middle portion of Bodie Creek (Site 2b) and the lower portion of San Juan Creek (Site 6a), but fell below the PEC. Mercury concentrations in streambed sediment exceeded the consensus-based PEC of 1.06 mg/kg (MacDonald et al., 2000) at the upper portions of Bodie Creek (Site 2c) and the North Fork Little Humboldt River (Site 5c).

Lead concentrations in streambed sediment exceeded the consensus-based TEC of 35.8 mg/kg (MacDonald et al., 2000) in the middle and upper portions of both Long Canyon (Sites 1b and 1c) and San Juan Creek (sites 6b and 6c), but fell below the PEC.

The nickel concentration in streambed sediment from the lower portion of Bodie Creek exceeded the consensus-based TEC of 22.7 mg/kg (MacDonald et al., 2000). Nickel concentrations in streambed sediment exceeded the consensus-based PEC of 48.6 mg/kg (MacDonald et al., 2000) at all sites sampled in Birch Creek (Sites 3a and 3b).

Zinc concentrations in streambed sediment exceeded the consensus-based TEC of 121 mg/kg (MacDonald et al., 2000) at all stream sites in Birch Creek (Sites 3b and 3c) and San Juan Creek (Sites 6a, 6b, and 6c), but fell below the PEC.

4.3 Trace-Metal Concentrations in Aquatic Biota

4.3.1 Macro-Invertebrates

Results of trace-metal concentrations in invertebrate samples collected from this investigation are provided in Appendix C. A summary of select trace-metal concentrations compared across all sample sites is illustrated in Figure 2 below.

Arsenic concentrations in aquatic invertebrates were highly enriched at the middle portion of the North Fork Little Humboldt River (Site 5b) and the lower portion of San Juan Creek (Site 6a), and slightly enriched at the middle portion of Birch Creek (Site 3b) when compared to other sites. Cadmium concentrations were highly enriched at the upper portion of San Juan Creek (Site 6c) and moderated to become slightly enriched

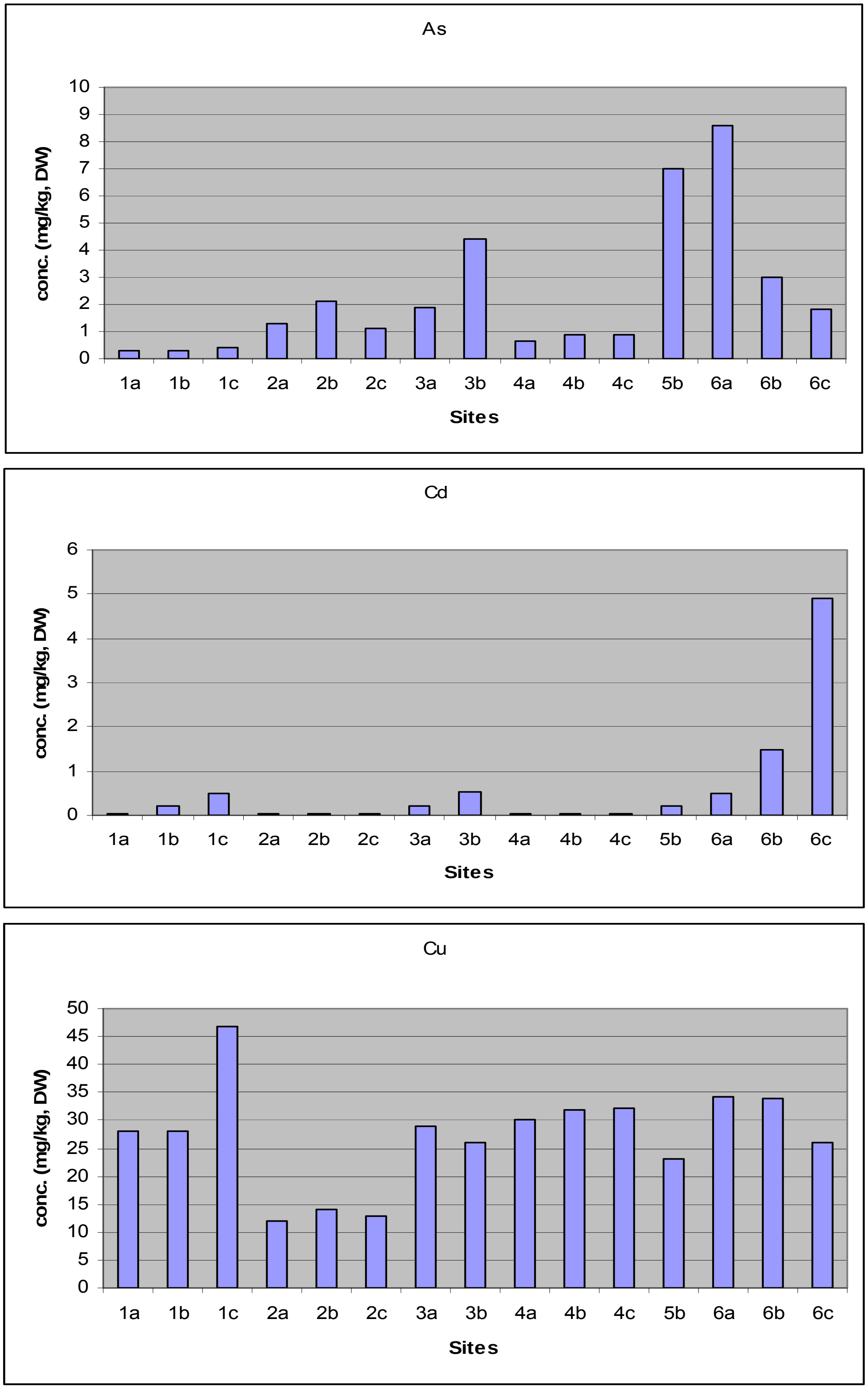


Figure 2. Select trace-metal concentrations in *Arctopsyche* spp. samples collected from stream sites receiving historic mine drainage in the western Great Basin.

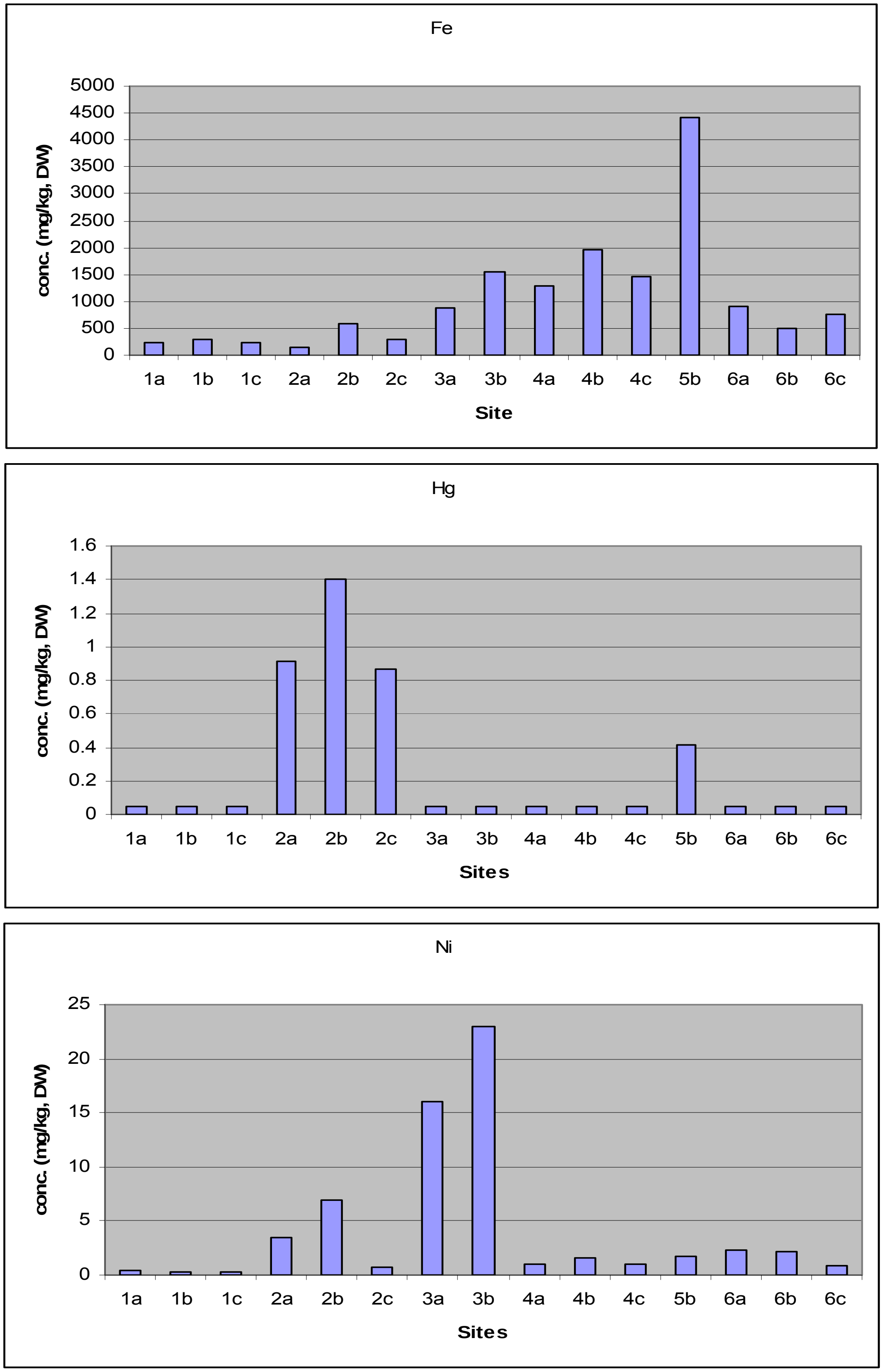
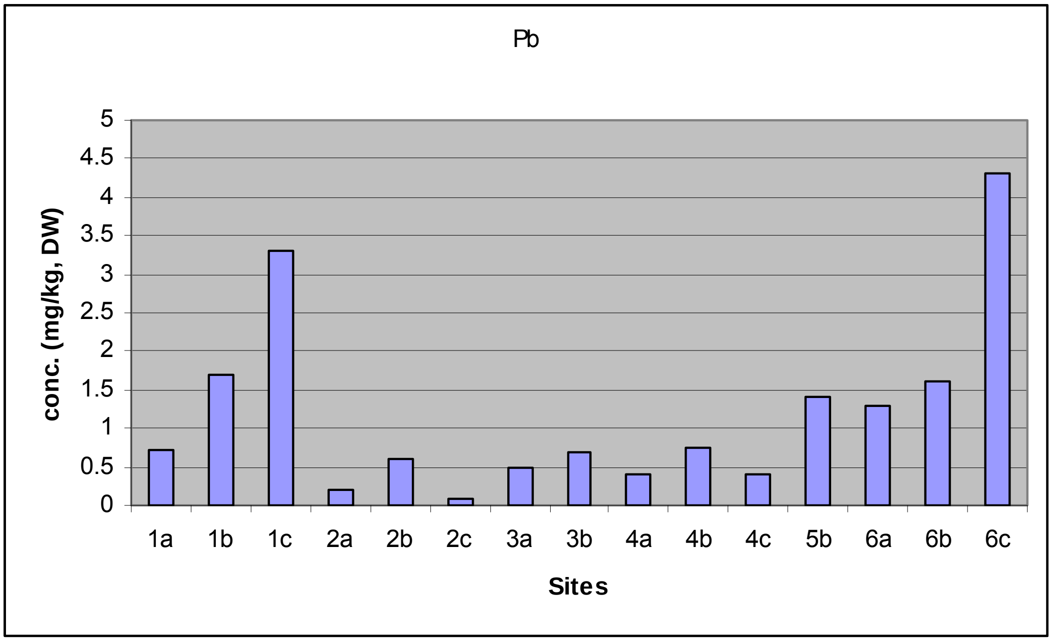


Figure 2 (cont.). Select trace-metal concentrations in *Arctopsyche spp.* samples collected from stream sites receiving historic mine drainage in the western Great Basin.



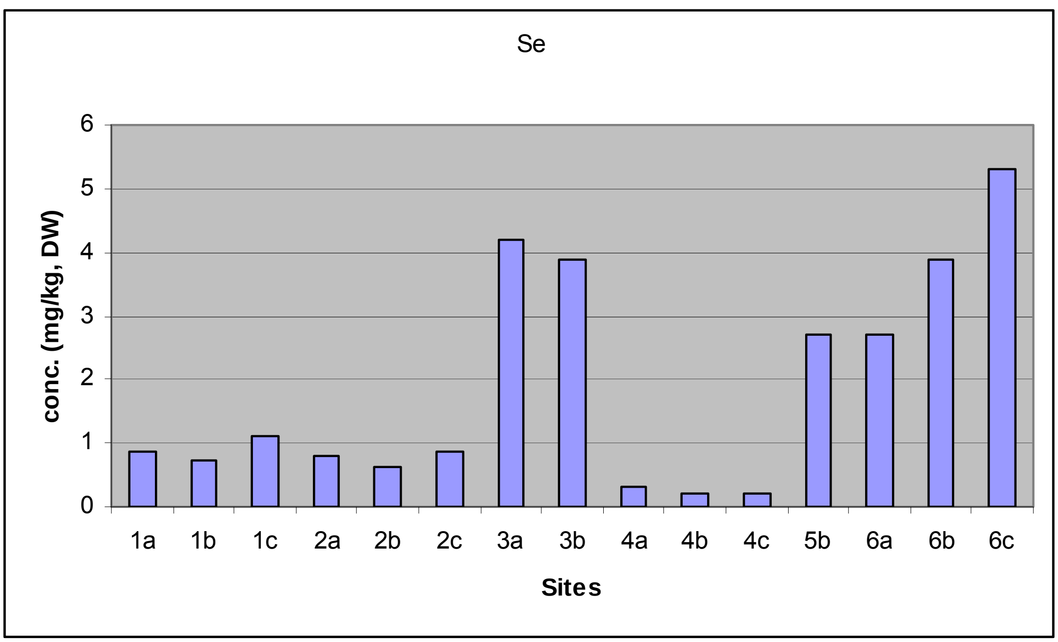


Figure 2 (cont.). Select trace-metal concentrations in *Arctopsyche spp.* samples collected from stream sites receiving historic mine drainage in the western Great Basin.

downstream at its middle portion (Site 6b). Mercury concentrations were highest among all sites in Bodie Creek (Sites 2a, 2b, and 2c) and were slightly enriched at site 5b on North Fork Little Humboldt River. The upper portions of Long Canyon (Site 1c) and San Juan Creek (Site 6c) contained the highest concentrations of lead among all sites. Nickel concentrations were highest in Birch Creek (Sites 3a and 3b) and slighted enriched in Bodie Creek when compared to other sites. Selenium concentrations in aquatic invertebrates collected from all sample sites in Birch Creek (Sites 3a, 3b) and San Juan Creek (Sites 6a, 6b, 6c), and the middle portion of the North Fork Little Humboldt River (Site 5b) were enriched when compared to other sites.

Pearson correlation analyses revealed trace-metal concentrations in aquatic invertebrates were positively related to sediment concentrations and were particularly strong for arsenic, cadmium, iron, nickel and lead (Pearson's r (r^2)= 0.66, 0.64, 0.75, 0.91, and 0.95). Moderate positive relationships between aquatic invertebrates and sediment were also determined for chromium, selenium, and zinc (Pearson's r (r^2)= 0.34, 0.36, and 0.42 respectively). No relationship was indicated for aluminum concentrations between aquatic invertebrates and sediment.

Trace-metal concentrations were compared to select known dietary effect levels determined for salmonids from published literature in order to assess risks to salmonids within the various study areas. Based upon the available literature, cadmium concentrations in aquatic invertebrates from the upper portion of San Juan Creek may reduce survival and growth if consumed by salmonid fry (Woodward et al., 1994). Selenium in aquatic invertebrates sampled from the lower and middle portions of Birch Creek (Sites 3a and 3b) exceed concentrations associated with reduced growth and development in salmonids (Hamilton et al., 1990; Lemly, 1996).

4.3.2 Fish

4.3.2.1 Whole Body

Geometric mean and range of dry weight metals concentrations in salmonid whole bodies are presented in Appendix D. Sixteen of 19 trace-metals were detected. Boron, beryllium, and molybdenum were below detection limits for all sites.

Aluminum concentrations were the highest in whole fish collected from the North Fork Little Humboldt River (Sites 5a and 5b) and exceeded all other sites by at least three-fold.

Arsenic concentrations varied among sites and ranged from below detection limits of 0.2 mg/kg to a high of 3.8 mg/kg in the upper portion of San Juan Creek (Site 6c), which exceeded a concentration associated with reduced growth of *Oncorhynchus* spp. (Cockrell and Hilton, 1988).

Barium concentrations were highest in the North Fork Little Humboldt River (54.5 mg/kg-site 5a; and 47.7 mg/kg-site 5b) and exceeded all other sites by at least three-fold. However, little information is known about the toxic effects, if any, of barium to salmonids so risks from this exposure cannot be ascertained.

Cadmium concentrations at most sites were below a detection limit of 0.1 mg/kg with exception to the lower and middle portions of Birch Creek (Sites 3a and 3b), and middle and upper portions of San Juan Creek (Sites 6b and 6c). The highest cadmium concentration found was in the upper portion of San Juan Creek (site 6c) which exceeded a concentration associated with reduced growth of *Oncorhynchus* spp. (Kumada et al., 1973).

Chromium concentrations at most sites were below a detection limit of 0.5 mg/kg with exception to some locations within Thomas Creek (Sites 4a and 4b), North Fork Little Humboldt River (Site 5a), and San Juan Creek (Sites 6b and 6c). Thomas Creek, which is a control site, had the highest chromium concentration of 3.8 mg/kg. However, none of these concentrations were at levels known to pose a risk to salmonid health or well-being.

Copper concentrations in whole body fish from all sites ranged from a low of 2.0 mg/kg at the upper portion of Bodie Creek (Site 2c) to a high of 21 mg/kg at the lower portion of Birch Creek (Site 3a), which exceeded a concentration associated with mortality in *Oncorhynchus* spp. (Julshamn et al., 1988).

Mercury concentrations were below detection limits of 0.1 mg/kg at all sites in Long Canyon (Sites 1a, 1b, and 1c), Thomas Creek (Sites 4a, 4b, and 4c) and portions of Birch Creek (Site 3a) and San Juan Creek (Site 6b). All whole fish samples collected from Bodie Creek had the highest mercury concentrations observed among all sites and ranged from 1.8 to 3.5 mg/kg. However, none of these concentrations were at levels known to pose a risk to salmonid health or well-being.

Lead concentrations were below a detection limit of 0.2 mg/kg at all sampled sites within Bodie Creek, Birch Creek, and Thomas Creek. Of those sites where lead was detected, concentrations ranged from a low of 0.3 mg/kg at the middle portion of the North Fork Little Humboldt River (Site 5b), to a high of 4.4 mg/kg at the upper portion of San Juan Creek (Site 6c). Lead was also detected in salmonids collected from Long Canyon (Sites 1a, 1b, and 1c) and ranged from 0.4 to 0.6 mg/kg.

Nickel concentrations were below a detection limit of 0.5 mg/kg at all sites with the exception of the lower portion of Thomas Creek (Site 4a) and the middle portion of San Juan Creek (Site 6b) which had concentrations of 1.9 and 1.0 mg/kg, respectively. Both of these concentrations are below values associated with risks to salmonids.

Selenium was detected in whole body samples collected from all sites and ranged from a low of 0.86 mg/kg at the middle portion of Thomas Creek (Site 4b) to a high of 8.2 mg/kg at the lower portion of Birch Creek (Site 3a). Based upon information from Lemly (1996), the selenium concentrations observed from sites in Birch Creek, North Fork Little Humboldt River, and San Juan Creek exceed levels associated with detrimental health and reproductive effects to freshwater fish.

Zinc concentrations ranged from a low of 75.4 mg/kg at the lower portion of Long Canyon (Site 1a) to a high of 201 mg/kg at the middle portion of the North Fork Little Humboldt River (Site 5b). All sites, with the exception of Site 1a, exceed what is considered normal background levels of 88 mg/kg for fish (Schmitt and Brumbaugh, 1990). However, little information is known about the toxic effects of zinc body burdens to salmonids; therefore risks from these exposures cannot be ascertained.

4.3.2.2 Gill Tissues

Fourteen of 19 trace-elements were detected in at least one gill sample among the three study areas sampled (Appendix E). Boron, beryllium, cadmium, molybdenum, and lead dry weight concentrations were below detection limits for all three study areas. Among the three study areas, mercury was detected at Bodie Creek (1.9 mg/kg) and below detection limits for Birch Creek and Thomas Creek (0.1 mg/kg). Nickel was detected at Birch Creek (71.6 mg/ kg) and below the detection limit at Bodie Creek and Thomas Creek (0.5 mg/kg). Vanadium was detected in Birch Creek and Thomas Creek (1.0 mg/kg) and below the detection limit at Bodie Creek (0.5 mg/kg).

Comparisons of trace-metal concentrations between the three study areas are subjective because gill tissue samples were not replicated for each study area (N=1). However, subjective comparisons revealed Birch Creek had the highest concentrations for aluminum, arsenic, chromium, copper, iron, magnesium, nickel and selenium among the three sites. Birch Creek concentrations of copper and iron exceeded other sites by at least two-fold. Chromium and nickel concentrations in the Birch Creek sample also exceeded the other sites by at least seventy and one hundred and forty-fold respectively when using the detection limit as a comparison guide (1.0 mg/kg Cr; 0.5 mg/kg Ni).

Bodie Creek had the highest concentrations of barium, mercury, manganese, and strontium. Of those trace-metals, manganese exceeded the other two sites by three-fold and mercury exceeded by at least nineteen-fold when using the detection limit as a comparison guide for the other two sites (0.1 mg/kg).

Thomas Creek, the control study area not impacted by mining activities, had the highest concentration of zinc among sites, but the level was not considered significant.

4.3.2.3 Liver Tissues

Fourteen of 19 trace-metals were detected in at least one liver sample among the three study areas sampled (Appendix E). Barium, beryllium, chromium, molybdenum, and lead dry weight concentrations were below detection limits for all three study areas. Among the three study areas, boron was only detected in Bodie Creek, but was at the detection limit (2.0 mg/kg). Cadmium was detected in both Birch Creek and Bodie Creek (5.4 and 0.2 mg/kg, respectively), but below the detection limit in Thomas Creek (0.1 mg/kg). Nickel was detected in Birch Creek (1.0 mg/kg), but below the detection limit in Bodie Creek and Thomas Creek (0.5 mg/kg).

Comparisons of trace-metal concentrations between the three study areas are subjective because liver tissue samples were not replicated for each study area (N=1). However, subjective comparisons revealed Birch Creek had the highest concentrations of arsenic, cadmium, copper, nickel, and selenium among sites. Of those trace-metals, cadmium, copper, and selenium exceeded other study areas by at least twenty-seven, four, and thirteen-fold respectively. The cadmium concentration in Birch Creek begins to approach a liver concentration associated with reduced reproduction in salmonids (5.8 mg/kg dry weight; Brown and Parsons, 1978). The copper concentration in the Birch Creek composite sample is within the range associated with physiological impairment in brown trout (*Salmo trutta)* (Farag et al., 1995). Selenium concentrations at both Birch Creek and Bodie Creek exceeded a concentration of 8.84 mg/kg associated with reduced growth in rainbow trout (*O. mykiss)* determined by Hilton et al. (1982). The selenium concentration in the Birch Creek sample alone exceeded the adverse effect observed by Hilton et al. (1982) by almost twenty-fold.

Bodie Creek had the highest concentrations of boron, iron, mercury, manganese, strontium, and zinc. Of those trace-metals, mercury exceeded the other two sites by at least sixteen-fold. However, this mercury concentration did not exceed any known toxicological benchmarks for salmonid liver tissue.

Thomas Creek, the control study area not impacted by mining activities, had the highest concentration of vanadium and exceeded the other sites by at least three-fold. However, little information is known about the toxic effects of vanadium to salmonids, therefore risks from this potential exposure cannot be ascertained.

4.3.2.4 Muscle Tissues

Eleven of 19 trace-metals were detected in at least one muscle sample among the three study areas sampled (Appendix E). Boron, beryllium, cadmium, chromium, molybdenum, nickel, lead, and vanadium dry weight concentrations were below detection limits for all three study areas. Among the three study areas, aluminum was detected in Birch Creek and Thomas Creek (4.0 and 11.0 mg/kg, respectively) but below the detection limit in Bodie Creek (2.0 mg/kg).

Comparisons of trace-metal concentrations between the three study areas are subjective because muscle tissue samples were not replicated for each study area (N=1). However, subjective comparisons revealed Birch Creek had the highest concentrations of arsenic, copper, iron, selenium, and zinc. Bodie Creek had the highest concentrations of barium, mercury, manganese, and strontium. Thomas Creek had the highest concentrations of aluminum.

Of the calculated SV's established for trace-metal, Birch Creek and Thomas Creek exceeded the SV for arsenic among recreational fishers and Bodie Creek exceeded the SV for mercury among recreational fishers.

4.4 Health of Macroinvertebrate Communities

Aquatic identification and enumeration data are provided in Appendix F. A summary of calculated metrics is presented in Table 5. Calculated metrics indicate low community quality at Sites 5a and 5c in the National District study area; Sites 6b and 6c in the Washington District study area; Sites 3a and 3b in the Birch Creek District study area; and Site 2a in the Aurora-Bodie Historic Mining Area. The first metric, taxa richness, is a measure of species diversity. Taxa richness was lowest at Sites 5c, 3b, 6b, 6c, 2a, 3a, and 5a; intermediate at 1b, 1c, 2c, 6a, 2b, and 5b; and highest at 4c, 4b, 4a and 1a. The second metric, percent EPT, is the percentage belonging to the orders Ephemeroptera (E = mayflies), Plecoptera (P = stoneflies), and Trichoptera (T = caddisflies) (EPT). There were no aquatic invertebrates present at Site 5c, which created the lowest % EPT among all sites (0%). Sites 6b, 3b, and 6a had very low % EPT values at 14%, 19%, and 23% respectively. Other sites with low % EPT values indicating reduced aquatic health included 2a, 3a, and 5a with values in the 30-percent range. Highest values of % EPT were observed at all control sites (Sites 4a, 4b, and 4c) and at Site 1a. The number of mayfly species observed at Site 5c was zero and increased from one at Sites 2a, 2c, 3a, 3b, 6b and 6c to two species at Sites 2b, 5a, and 6a; to three species at Sites 1b, 1c, and 5a; to four species at Site 1a; and to five species at all of the control sites (4a, 4b, and 4c).

Table 5. Aquatic macro-invertebrate metrics (taxa richness; percent in the orders of Ephemeroptera, Plecoptera, and Tricoptera (EPT); number of Ephemeroptera species) by metals index values for stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Site #	Stream Site	Date (2004)	Metals Index	Taxa Richness	% EPT	#E
1a	Long Canyon- lower	8/25	14.01	12	79	4
1b	Long Canyon - middle	8/24	23.02	7	69	3
1c	Long Canyon - upper	8/24	24.69	7	46	3
2a	Bodie Creek- lower	8/2	33.32	5	32	1
2b	Bodie Creek - middle	8/2	16.14	10	68	2
2c	Bodie Creek - upper	8/2	22.50	8	49	1
3a	Birch Creek- lower	8/9	39.18	5	37	1
3b	Birch Creek- middle	8/9	53.58	3	19	1
4a	Thomas Creek- lower	7/22	16.94	12	78	5
4b	Thomas Creek - middle	7/27	17.38	12	85	5
4c	Thomas Creek - upper	7/27	9.68	15	94	5
5a	N. Fork Little Humboldt River - lower	8/31	38.37	5	36	2
5b	N. Fork Little Humboldt River - middle	8/31	13.80	10	71	3
5c	N. Fork Little Humboldt River - upper	8/30	35.52	0	0	0
6a	San Juan Creek- lower	8/9	22.89	8	72	2
6b	San Juan Creek - middle	8/17	44.11	4	14	1
6c	San Juan Creek - upper	8/17	42.73	4	23	1

To examine the relation between these metrics and the metals concentrations at the sites, the metals index was used. The index compares the concentrations of arsenic, cadmium, chromium, copper, iron, lead, nickel, and zinc in sediments at the six study areas where macroinvertebrate samples were collected. The metals index was negatively correlated to both taxa richness and percent EPT (R^2 = 0.76, R^2 = 0.78, respectively) (Figures 3 and 4), indicating taxa and EPT richness declined as metals concentration increased.

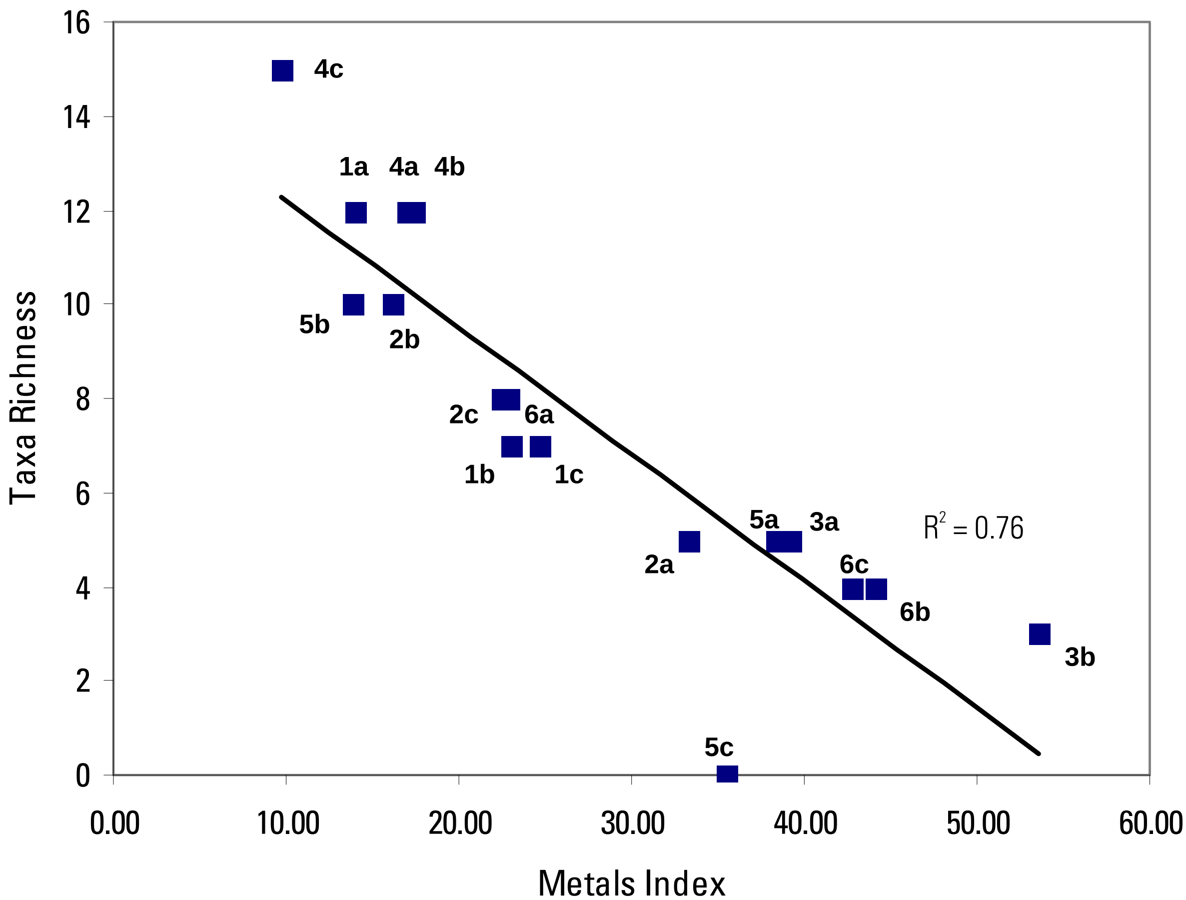


Figure 3. Macroinvertebrate taxa richness by metals index for stream sites receiving drainage from historical mine sites in the western Great Basin.

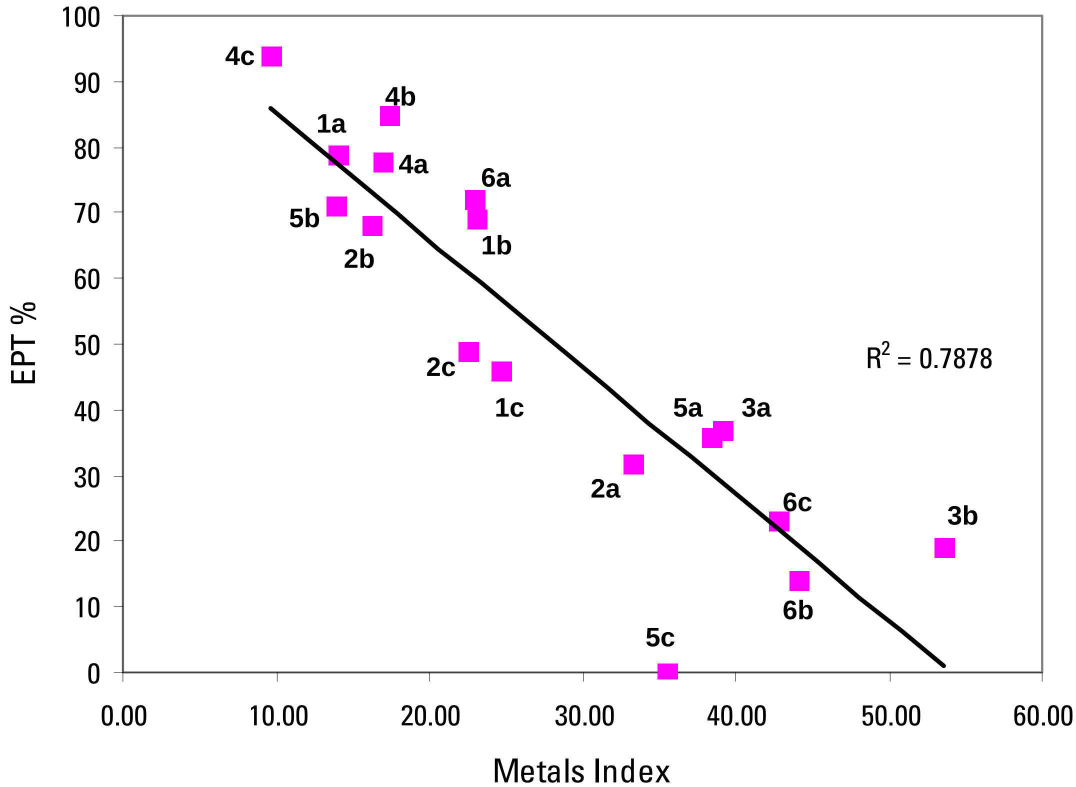


Figure 4. Macroinvertebrate EPT percentage by metals index for stream sites receiving drainage from historical mine sites in the western Great Basin.

5.0 DISCUSSION

5.1 Surface Water Chemistry

Biota of streams receiving mine drainage can be adversely affected by exposure to trace-metals via multiple exposure routes (Besser et al., 2001). Toxic effects can result from short-term exposures to metal-contaminated stream water in affected habitats (Henry et al., 1999). In addition, several studies have demonstrated that salmon and trout species will avoid copper and zinc concentrations that are much lower than concentrations that would normally be lethal under similar water quality conditions (Sprague, 1964; Saunders and Sprague, 1967; Sprague, 1967).

Toxicity of surface water to aquatic organisms is dependent on discharge volume, pH, total acidity, and concentration of dissolved metals. pH is the most critical component, since the lower the pH, the more severe the potential effects of mine drainage on aquatic life. The overall effect of mine drainage is also dependent on the flow (dilution rate), pH, and alkalinity or buffering capacity of the receiving stream. The higher the concentration of bicarbonate and carbonate ions in the receiving stream, the higher the buffering capacity and the greater the protection of aquatic life from adverse effects of acid mine drainage (Kimmel, 1983). Alkaline mine drainage with low concentrations of metals may have little discernible effect on receiving streams. Acid mine drainage with elevated metals concentrations discharging into headwater streams or lightly buffered streams can have deleterious effects on the aquatic life. Surface water chemistry from most study areas affected by mine drainage indicate little risk to aquatic life, likely due to the alkalinity or buffering capacity from the geology of the surrounding areas.

However, the upper portion of the North Fork Little Humboldt River (Site 5c) was the only stream site among study areas that contained low pH levels and exceeded chronic criteria for cadmium and zinc; and the acute criterion for aluminum, copper, iron, and or selenium. Considering the low buffering capacity of the acid-generating tailings in the headwater of Site 5c, trace-metals in water have likely led to the absence of all aquatic biota.

Selenium concentrations observed in Birch Creek and the upper portion of the North Fork Little Humboldt River also present a significant risk to aquatic biota within their respective watersheds. Once in the aquatic environment, selenium can rapidly attain levels that are toxic to fish and wildlife because of bioaccumulation in food chains and resultant dietary exposure. In addition, the response curve for selenium poisoning is very steep due the narrow range between beneficial and toxic whole body concentrations. For example, a transition from no effect to complete reproductive failure in fish can occur within a range of only a few parts per billion. Thus, activities that cause even slight increases in the water concentration of selenium pose a major ecological risk and, much too often, leave natural resource managers trying to deal with selenium problems after they happen rather than anticipating and preventing them in the first place (Lemly, 2002).

5.2 Streambed Sediment

The metal concentrations obtained from streambed sediment can be useful for comparison to aquatic threshold guidelines because they represent the concentration of metals potentially available for uptake by aquatic organisms. Elevated trace-metals in sediments can also pose a long-term threat to aquatic organisms (McIntosh, 1991). Sediments, which may contain concentrations of contaminants that are orders of magnitude greater than in the overlying water column, act as a sink and a source of contaminants (Harrahy and Clements 1997). All study areas, with the exception of Thomas

Creek (control), had stream sites with streambed sediment trace-metal concentrations that exceeded at least one of the consensus-based TEC or PEC guidelines developed by MacDonald et al. (2000). Exceedances of MacDonald et al. (2000) consensus-based sediment guidelines occurred as far as the lower stream sites within study areas and indicate that contamination of aquatic habitats can occur at distances from source areas (mine tailings). The contamination of streambed sediment occurs even though trace-metal concentrations in solution decrease or are not detected within a few kilometers down stream of the source areas.

Study sites with the most exceedances of the MacDonald et al. (2000) consensus-based sediment guidelines were San Juan Creek (11 TEC and 2 PEC exceedances), Birch Creek (5 TEC and 3 PEC exceedances), North Fork Little Humboldt River (1TEC and 2 PEC exceedances), and Bodie Creek (2 TEC and 1 PEC exceedances). The sediment trace-metals of most concern in these affected drainages include arsenic, cadmium, mercury, lead, and selenium. The observed trace-metal exceedances are consistent with the type of mining activities that historically occurred within these drainages and/or co-occur with the trace-metals that were extracted in these areas. The enrichment of these trace-metals within these study areas further demonstrates that historical mine sites are the source of contaminants.

Using information from Canton and VanDerveer (1997) as a guide, sediment selenium concentrations in Birch Creek, San Juan Creek, and the upper portion of the North Fork Little Humboldt River exceed this proposed guideline by 32 to over 600-fold. Transfer of selenium to higher trophic levels is likely occurring via the accumulation of selenium from benthic food webs residing within the sediment compartment, as corroborated by the elevated selenium concentrations observed in aquatic macro-invertebrates and fish samples collected from these sites and described in this report.

5.3 Trace-Metal Impacts to Aquatic Biota and Stream Health

Concentrations of trace-metals in aquatic macro-invertebrates, whole fish, and limited samples of fish tissue indicate uptake from water, sediment, and dietary pathways. The bioavailability of the observed trace-metals is highly variable and dependent upon several environmental factors which are outside the scope of this investigation. However, low pH levels and water hardness are significant factors that will increase bioavailability of trace-metals in surface water. The initial site of impact of waterborne metals in freshwater fish is the gill and accumulations of metal on or in the gill are assumed to be causative of the initial damage. According to Nieboer and Richardson (1980), the relative binding affinity of a metal for biological ligands is a function of the tendency of a metal to form ionic vs. covalent bonds, as well as the chemistry of the particular ligand. Therefore, metal binding to gill surfaces could be dependent upon the ionic interactions with the epithelial tissue (Reid and MacDonald 1991). However, higher values of pH and hardness existed at most of the study areas (with the exception of the upper portion of the North Fork Little Humboldt River) and suggest limited bioavailability of trace-metals to aquatic biota from surface water exposures. Therefore, uptake by fish is likely the result of sediment and/or diet exposures.

Concentrations of select trace-metals in aquatic macro-invertebrates did correlate with sediment concentrations, particularly for arsenic, cadmium, chromium, iron, nickel, lead, selenium, and zinc. This suggests the dominant source of trace-metals available to aquatic biota in these study areas is from the sediment. Aquatic invertebrate metrics are commonly calculated to compare communities at several sites (Barbour et al., 1999). Metrics are a way of summarizing complex macroinvertebrate data into easy to understand measures of the community. Measures of taxa richness and %EPT indicate significant impairment of the aquatic community at a majority of sites sampled in the Birch Creek, North Fork Little Humboldt River, and San Juan Creek watersheds. Correlation of the metals index with aquatic-invertebrate community metrics also demonstrated a strong inverse relationship between trace-metal concentrations in the sediment and the health of the macro-invertebrate community in the receiving streams.

Uptake of trace-metals by higher trophic levels (fish) is occurring from the sediment and/or diet components, but the relative contribution from each component is unknown and likely varies from site to site. The liver is typically important for metal accumulation and storage in fish, especially in metal contaminated environments (Sorenson 1991, Giguére et al., 2004). In addition, the response time of the liver to short-term fluctuations in ambient metal concentrations is slower than for organs in direct contact with the external environment, such as the gills and gut (Kraemer et al., 2005), and would reflect more chronic long-term exposures. Based upon trace-metal concentrations in liver tissues, salmonids within Birch Creek are likely experiencing long-term exposures to cadmium, copper, and selenium at levels that are detrimental to their health.

There is generally a correlation between levels in muscle tissue and those in other internal tissues in fish (Denton and Burdon-Jones 1996). Tissue levels can provide information on potential risk to the fish themselves and to consumers of those fish. Based upon comparisons of trace-metal concentrations in whole salmonids and tissues to known adverse effect levels, several study areas have significant challenges to maintaining healthy salmonid populations. Study areas at greatest risk for maintaining healthy salmonid populations include San Juan Creek (arsenic, cadmium, and selenium), Birch Creek (copper and selenium), North Fork Little Humboldt River (selenium), and Bodie Creek (mercury).

6.0 MANAGEMENT RECOMMENDATIONS

This investigation indicates significant impacts may be occurring to aquatic biota in streams that are identified as potential LCT recovery areas (Service 1995); or to waterfowl and piscivorous birds in select drainages. Specific management recommendations based upon the data collected by this investigation are as follows:

Based upon data collected, any future recovery efforts conducted for LCT in the North Fork Little Humboldt River will likely not be successful due to the elevated levels of several trace-metals in sediment and subsequent acid-generating water created by tailings exposures at the National Buckskin Mine. *Recommendation #1: Any planning or implementation of LCT recovery actions in the North Fork Little Humboldt River watershed should be delayed until removal of mining-associated sediments in the headwater area can demonstrate success in eliminating acute and chronic toxicity from trace-metal exposures to aquatic biota.*

Lead concentrations in whole fish are highly elevated in the upper portion of Long Canyon near the American Beauty Mine site. Long Canyon contains LCT and is located within the South Fork Humboldt River Sub-basin. The displacement of LCT by introduced trout species, primarily brook trout (*Salvelinus fontinalis*), has had a significant impact on the population in this sub-basin (Elliott and Layton, 2006). There exists a potential for impacts to LCT from lead exposures; however, they do not appear to be significant enough to pose a long-term risk unless drought conditions limit their distribution to the upper reaches. *Recommendation #2: From a meta-population standpoint, risk to LCT from lead exposures could be significant in the upper reaches of Long Canyon and should be addressed in future recovery plan revisions.*

Bodie Creek is located within the Walker River basin and supports a population of hybridized LCT (USFS, 2006). USFS (2006) identified several factors that might be negatively impacting these fish, including historical mining within and around Bodie State Park that may be leading to elevated levels of metals or harmful contaminants in the water. Results from this investigation showed elevated levels of mercury in sediment, macro-invertebrate, and fish samples. Risks to aquatic biota are less than those for human consumption. *Recommendation #3: Although LCT in this drainage are not at risk from current levels of trace-metal exposures, recovery efforts that incorporate developing a population of LCT as a recreational resource in Bodie Creek should avoided until human risks from consumption can be ascertained. The Service should be engaged in ecological and human risk efforts currently being conducted by EPA Region 9 and California State Parks for inclusion into future species recovery planning and decision-making.*

Birch Creek and San Juan Creek are not identified as potential recovery habitat by the 1995 LCT Recovery Plan. However, selenium concentrations in these drainages put any waterfowl or piscivorous birds that may forage in these drainages at significant risks. *Recommendation #4: Future development of management plans identifying important bird areas or habitat (such as those developed with Intermountain West Joint Venture or Audubon Society) should consider risk of selenium exposure in deciding which areas to include in such plans. Furthermore, out-of-basin populations of LCT should not be considered or established in these drainages.*

The Environmental Contaminants Program of the Nevada Fish and Wildlife Office has been involved in the Abandoned Mine Land Environmental Task Force (AMLETF), a multi-agency coalition designed to achieve mitigation of water quality problems from abandoned mine lands (AML) on Federal lands in Nevada. The AMLTF has received $2.2 million from the U.S. Army Corps of Engineers since 2004 for planning efforts in characterization studies and planning of abandoned mine sites. The USFS is also coordinating efforts to characterize contamination concerns and prioritize clean up activities at historical mine sites using funding under Section 106 of the Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA) for removal actions. *Recommendation #5: The Service should provide information from this investigation to AMLETF and USFS and assist in prioritizing future mitigation activities that would reduce threats to trust resources of the Department of the Interior including fish and wildlife and their habitat at these sites. Additional funding from these entities should be directed towards the most impacted site - National Buckskin Mine.*

Recommendation #6: Information from this investigation should be used by the Service during Clean Water Act triennial reviews to evaluate and, if necessary, modify water quality standards (via Section 7 consultation) to ensure adequate protection of trust resources. The information should also be used during Section 7 consultations for various development and land use projects, such as mine development projects and grazing allotment reviews.

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Appendix A. Water quality measurements and trace-metal concenrations of surface water (mg/L - wet weight) from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site #	Temp. (°C)	Specific Cond. (µmohs/S)	Dissolved Oxygen (mg/L)	Salinity (ppt)	pH	Al
American Beauty Mine Complex	Long Canyon	1a	10.52	193.9	N/A	0.09	10.62	< 0.02
		1b	12.93	189	N/A	0.08	10.92	< 0.02
		1c	8.23	204.3	N/A	0.09	10.7	< 0.02
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	18.64	232.8	8.34	0.11	8.62	0.073
		2b	27.53	244.4	7.9	0.12	8.68	0.03
		2c	19.56	188.9	7.78	0.09	8.11	< 0.02
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	14.82	601.4	11.65	0.31	11.03	< 0.02
		3b	15.32	621.3	11.82	0.32	10.61	< 0.02
		-	-	-	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	9.16	102.4	9.83	0.04	7.36	0.05
		4b	9.3	101.4	9.66	0.04	7.69	0.02
		4c	10.81	98.6	9.53	0.04	8	< 0.02
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River	5a	17.99	151.8	10.06	0.07	8.59	< 0.02
		5b	12.24	137.9	7.35	0.06	7.86	< 0.02
		5c	18.6	1128	7.29	0.59	3.48	51.7
Washington District	San Juan Creek	6a	17.89	252.1	9.49	0.12	10.65	< 0.02
		6b	7.73	212.9	16.48	0.1	10.46	< 0.02
		6c	8.98	189.2	13.07	0.09	10.69	< 0.02

Appendix A. Water quality measurements and trace-metal concenrations of surface water (mg/L - wet weight) from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site #	As	Ba	Be	B	Cd	Cr
American Beauty Mine Complex	Long Canyon	1a	< 0.001	0.0082	< 0.0005	< 0.04	< 0.0005	< 0.002
		1b	< 0.001	0.0092	< 0.0005	< 0.04	< 0.0005	< 0.002
		1c	< 0.001	0.014	< 0.0005	< 0.04	< 0.0005	< 0.002
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	0.0067	0.016	< 0.0005	< 0.04	< 0.0005	< 0.002
		2b	0.0071	0.024	< 0.0005	0.05	< 0.0005	< 0.002
		2c	0.01	0.045	< 0.0005	< 0.04	< 0.0005	< 0.002
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	0.0033	0.077	< 0.0005	< 0.04	< 0.0005	< 0.002
		3b	0.0032	0.079	< 0.0005	< 0.04	< 0.0005	< 0.002
		-	-	-	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	0.001	0.055	< 0.0005	< 0.04	< 0.0005	< 0.002
		4b	0.001	0.054	< 0.0005	< 0.04	< 0.0005	< 0.002
		4c	0.001	0.056	< 0.0005	< 0.04	< 0.0005	< 0.002
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River	5a	0.002	0.042	< 0.0005	0.05	< 0.0005	< 0.002
		5b	0.002	0.041	< 0.0005	< 0.04	< 0.0005	< 0.002
		5c	0.011	0.014	0.0044	< 0.04	0.0031	0.002
Washington District	San Juan Creek	6a	0.01	0.017	< 0.0005	< 0.04	< 0.0005	< 0.002
		6b	0.003	0.008	< 0.0005	< 0.04	< 0.0005	< 0.002
		6c	0.002	0.012	< 0.0005	< 0.04	< 0.0005	< 0.002

Appendix A. Water quality measurements and trace-metal concenrations of surface water (mg/L - wet weight) from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site #	Cu	Fe	Mg	Mn	Mo	Hg
American Beauty Mine Complex	Long Canyon	1a	< 0.002	< 0.05	2.08	< 0.002	< 0.02	< 0.0005
		1b	< 0.002	< 0.05	1.93	< 0.002	< 0.02	< 0.0005
		1c	< 0.002	< 0.05	2.34	< 0.002	< 0.02	< 0.0005
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	< 0.002	< 0.05	10	< 0.002	< 0.02	< 0.0005
		2b	< 0.002	< 0.05	6.09	0.0076	< 0.02	< 0.0005
		2c	< 0.002	0.1	5.39	0.016	< 0.02	< 0.0005
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	< 0.002	< 0.05	31.4	< 0.002	< 0.02	< 0.0005
		3b	< 0.002	< 0.05	32	< 0.002	< 0.02	< 0.0005
		-	-	-	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	< 0.002	0.1	4.19	0.005	< 0.02	< 0.0005
		4b	< 0.002	0.1	4.06	0.017	< 0.02	< 0.0005
		4c	< 0.002	< 0.05	3.96	< 0.002	< 0.02	< 0.0005
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River	5a	< 0.002	< 0.05	3.35	< 0.002	< 0.02	< 0.0005
		5b	< 0.002	< 0.05	2.91	0.0078	< 0.02	< 0.0005
		5c	0.13	5.75	3.09	2.79	< 0.02	< 0.0005
Washington District	San Juan Creek	6a	< 0.002	< 0.05	6.22	< 0.002	< 0.02	< 0.0005
		6b	< 0.002	< 0.05	5.96	< 0.002	< 0.02	< 0.0005
		6c	< 0.002	< 0.05	6.1	< 0.002	< 0.02	< 0.0005

Appendix A. Water quality measurements and trace-metal concenrations of surface water (mg/L - wet weight) from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site #	Pb	Ni	Se	Sr	V	Zn
American Beauty Mine Complex	Long Canyon	1a	< 0.005	< 0.005	< 0.0002	0.094	< 0.001	< 0.005
		1b	< 0.005	< 0.005	< 0.0002	0.0968	< 0.001	< 0.005
		1c	< 0.005	< 0.005	< 0.0002	0.0993	< 0.001	< 0.005
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	< 0.005	< 0.005	< 0.0002	0.173	0.0083	< 0.005
		2b	< 0.005	< 0.005	0.0003	0.174	0.0039	0.007
		2c	< 0.005	< 0.005	< 0.0002	0.173	0.0031	< 0.005
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	< 0.005	< 0.005	0.0028	0.348	0.001	0.006
		3b	< 0.005	< 0.005	0.0029	0.35	< 0.001	0.007
		-	-	-	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	< 0.005	< 0.005	< 0.0002	0.107	0.0042	< 0.005
		4b	< 0.005	< 0.005	< 0.0002	0.105	0.0037	< 0.005
		4c	< 0.005	< 0.005	< 0.0002	0.106	0.0036	< 0.005
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River	5a	< 0.005	< 0.005	< 0.0002	0.0918	0.001	< 0.005
		5b	< 0.005	< 0.005	< 0.0002	0.0861	< 0.001	< 0.005
		5c	< 0.005	0.01	0.0093	0.128	< 0.001	0.761
Washington District	San Juan Creek	6a	< 0.005	< 0.005	0.0003	0.163	< 0.001	< 0.005
		6b	< 0.005	< 0.005	0.0005	0.0932	< 0.001	< 0.005
		6c	< 0.005	< 0.005	0.0002	0.0945	< 0.001	< 0.005

Appendix B. Trace-metal concentrations of streambed sediment (mg/kg - dry weight) from stream sites receiving drainage from historical mine sites in the western Great Basin, July to August, 2004.

Study Area	Stream	Site #	Al	As	B	Ba	Be	Cd
	Macdonald et al. (2000) sediment guidelines	TEC	-	9.79	-	-	-	0.99
		PEC	-	33	-	-	-	4.98
American Beauty Mine Complex	Long Canyon	1a	12700	2.4	< 10.0	59.3	1.2	0.5
		1b	21200	3.5	10	94.4	1.4	0.62
		1c	20300	3.3	< 10.0	88.2	2	0.71
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	18900	8.5	< 10.0	139	1.2	0.1
		2b	10800	8.4	< 10.0	129	0.64	0.4
		2c	13800	11	< 10.0	264	0.82	0.5
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	9990	26	10	197	0.68	2.3
		3b	19600	36	10	312	1	3
Carson Range (Control Site)	Thomas Creek	4a	20800	2.3	< 10.0	262	0.5	0.1
		4b	21200	2.7	< 10.0	263	0.5	0.3
		4c	10700	1	< 10.0	125	0.2	0.1
McCormick Group/ Buckskin National Mine	NFLHR	5a	10900	4.4	< 10.0	118	0.5	0.5
		5b	16200	6.5	< 10.0	187	0.99	0.4
		5c	17200	570	10	234	0.7	0.1
Washington District	San Juan Creek	6a	13400	107	10	98.5	1.4	1.1
		6b	20300	43	10	137	1.4	3.7
		6c	10900	25	< 10.0	58.1	0.61	3.1

yellow= exceeds Threshold Effect Concentration

pink= exceeds Probable Effect Concentration

Appendix B. Trace-metal concentrations of streambed sediment (mg/kg - dry weight) from stream sites receiving drainage from historical mine sites in the western Great Basin, July to August, 2004.

Study Area	Stream	Site #	Cr	Cu	Fe	Hg	Mg	Mn
	Macdonald et al. (2000) sediment guidelines	TEC	43.4	31.6	-	0.18	-	-
		PEC	111	149	-	1.06	-	-
American Beauty Mine Complex	Long Canyon	1a	9.8	8	9080	0.05	2770	248
		1b	14	14	12700	0.05	4460	506
		1c	14	14	11800	0.05	6630	598
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	29	29	22700	0.1	13800	601
		2b	11	11	10500	0.3	3030	290
		2c	20	22	16200	2.4	3820	1120
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	11	28	18800	0.05	4300	358
		3b	21	42	23800	0.05	5560	586
Carson Range (Control Site)	Thomas Creek	4a	12	15	19200	0.05	2620	565
		4b	12	15	18500	0.05	2510	686
		4c	6.4	7.9	11600	0.05	1630	275
McCormick Group/ Buckskin National Mine	NFLHR	5a	4.8	6.3	13900	0.1	1280	259
		5b	7	11	16800	0.05	2010	371
		5c	7.9	32	35600	1.4	1680	490
Washington District	San Juan Creek	6a	8.2	12	15900	0.53	2560	589
		6b	16	31	19400	0.05	4920	432
		6c	14	21	19600	0.05	5160	329

yellow= exceeds Threshold Effect Concentration

pink= exceeds Probable Effect Concentration

Appendix B. Trace-metal concentrations of streambed sediment (mg/kg - dry weight) from stream sites receiving drainage from historical mine sites in the western Great Basin, July to August, 2004.

Study Area	Stream	Site #	Mo	Ni	Pb	Se	Sr	V
	Macdonald et al. (2000) sediment guidelines	TEC	-	22.7	35.8	-	-	-
		PEC	-	48.6	128	-	-	-
American Beauty Mine Complex	Long Canyon	1a	< 5.00	6	21	0.25	48	14
		1b	< 5.00	9	50	0.7	74	23
		1c	< 5.00	8	81	0.25	91	19
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	< 5.00	40	10	0.25	101	43
		2b	< 5.00	19	10	0.25	55	26
		2c	< 5.00	10	10	0.8	89	52
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	< 5.00	49	10	3.5	69	38
		3b	< 5.00	64	10	5	78	73
Carson Range (Control Site)	Thomas Creek	4a	< 5.00	7	8	0.25	101	67
		4b	< 5.00	7	9	0.25	107	67
		4c	< 5.00	2.5	7	0.25	56	39
McCormick Group/ Buckskin National Mine	NFLHR	5a	< 5.00	2.5	10	0.25	19	18
		5b	< 5.00	2.5	8	0.25	30	23
		5c	< 5.00	5	18	19	19	22
Washington District	San Juan Creek	6a	< 5.00	6	26	1	35	19
		6b	< 5.00	10	70	4.6	50	37
		6c	< 5.00	10	110	1	19	30

yellow= exceeds Threshold Effect Concentration

pink= exceeds Probable Effect Concentration

Appendix B. Trace-metal concentrations of streambed sediment (mg/kg - dry weight) from stream sites receiving drainage from historical mine sites in the western Great Basin, July to August, 2004.

Study Area	Stream	Site #	Zn
	Macdonald et al. (2000) sediment guidelines	TEC	121
		PEC	459
American Beauty Mine Complex	Long Canyon	1a	59
		1b	110
		1c	80
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	75
		2b	51
		2c	55
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	250
		3b	305
Carson Range (Control Site)	Thomas Creek	4a	52
		4b	52
		4c	31
McCormick Group/ Buckskin National Mine	NFLHR	5a	44
		5b	53
		5c	76
Washington District	San Juan Creek	6a	140
		6b	216
		6c	214

yellow= exceeds Threshold Effect Concentration

pink= exceeds Probable Effect Concentration

Appendix C. Trace-metal concentrations of aquatic invertebrates (Arctopsyche spp.) from stream sites receiving historical mine site drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site ID #	Al	As	B	Ba	Be
American Beauty Mine Complex	Long Canyon	1a	200	0.3	3	15	<0.1
		1b	240	0.3	< 2.00	3.4	<0.1
		1c	261	0.4	< 2.00	3.5	<0.1
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	150	1.3	2	21.7	<0.1
		2b	592	2.1	3	86.8	<0.1
		2c	130	1.1	< 2.00	27.7	<0.1
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	551	1.9	10	24.9	<0.1
		3b	733	4.4	10	42.6	<0.1
		3c	-	-			
Carson Range (Control Site)	Thomas Creek	4a	1020	0.64	< 2.00	37.4	<0.1
		4b	1580	0.89	< 2.00	57	<0.1
		4c	1210	0.91	< 2.00	40.8	<0.1
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River		-	-			
		5b	3170	7	3	80.9	0.2
			-	-			
Washington District	San Juan Creek	6a	814	8.6	12	12	<0.1
		6b	505	3	6.9	8.1	<0.1
		6c	485	1.8	< 2.00	5.3	<0.1

Appendix C. Trace-metal concentrations of aquatic invertebrates (Arctopsyche spp.) from stream sites receiving historical mine site drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site ID #	Cd	Cr	Cu	Fe	Hg
American Beauty Mine Complex	Long Canyon	1a	0.05	0.25	28	220	0.05
		1b	0.2	0.25	28	292	0.05
		1c	0.48	0.25	46.7	225	0.05
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	0.05	0.25	12	160	0.91
		2b	0.05	0.6	14	585	1.4
		2c	0.05	0.25	13	287	0.87
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	0.2	0.8	29	888	0.05
		3b	0.52	0.9	26	1550	0.05
		3c	-	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	0.05	0.6	30	1280	0.05
		4b	0.05	1	31.9	1960	0.05
		4c	0.05	0.9	32.2	1460	0.05
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River		-	-	-	-	-
		5b	0.2	1.9	23	4410	0.41
			-	-	-	-	-
Washington District	San Juan Creek	6a	0.5	0.25	34.3	916	0.05
		6b	1.5	0.8	33.9	497	0.05
		6c	4.9	0.8	26	748	0.05

Appendix C. Trace-metal concentrations of aquatic invertebrates (Arctopsyche spp.) from stream sites receiving historical mine site drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site ID #	Mg	Mn	Mo	Ni	Pb
American Beauty Mine Complex	Long Canyon	1a	2020	72	< 2.00	0.5	0.71
		1b	1820	49	< 2.00	0.25	1.7
		1c	1710	55.7	< 2.00	0.25	3.3
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	1280	339	< 2.00	3.4	0.2
		2b	1370	945	< 2.00	6.9	0.6
		2c	1310	460	< 2.00	0.7	0.1
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	2630	218	< 2.00	16	0.5
		3b	2840	770	< 2.00	23	0.7
		3c	-	-		-	-
Carson Range (Control Site)	Thomas Creek	4a	1710	201	< 2.00	1	0.4
		4b	1730	353	< 2.00	1.6	0.76
		4c	1980	226	< 2.00	1	0.4
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River		-	-		-	-
		5b	1550	1090	< 2.00	1.7	1.4
			-	-		-	-
Washington District	San Juan Creek	6a	2200	271	< 2.00	2.3	1.3
		6b	2400	55	< 2.00	2.2	1.6
		6c	1990	49	< 2.00	0.9	4.3

Appendix C. Trace-metal concentrations of aquatic invertebrates (Arctopsyche spp.) from stream sites receiving historical mine site drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site ID #	Se	Sr	V	Zn
American Beauty Mine Complex	Long Canyon	1a	0.85	14	< 0.500	403
		1b	0.72	12	< 0.500	372
		1c	1.1	9.1	< 0.500	271
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	0.8	6.6	< 0.500	176
		2b	0.64	8.5	1.6	210
		2c	0.87	7.3	0.7	101
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	4.2	33	2.8	243
		3b	3.9	35.9	4	222
		3c	-			-
Carson Range (Control Site)	Thomas Creek	4a	0.3	23.8	4.3	187
		4b	0.2	28.1	7	197
		4c	0.2	31.9	5.3	177
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River		-			-
		5b	2.7	17	7.2	187
			-			-
Washington District	San Juan Creek	6a	2.7	32.4	1	278
		6b	3.9	22.6	1	456
		6c	5.3	7.3	1	770

Appendix D. Trace-metal concentrations of whole-body salmonids (Oncorhynchus spp.) collected from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site ID#	Al	As	B	Ba	Be
American Beauty Mine Complex	Long Canyon	1a	36	< 0.200	< 2.00	1.1	< 0.100
		1b	35	< 0.200	< 2.00	0.92	< 0.100
		1c	18	0.5	< 2.00	1	< 0.100
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	21	< 0.200	< 2.00	6.6	< 0.100
		2a	22	0.4	< 2.00	11	< 0.100
		2b	25	0.3	< 2.00	14	< 0.100
		2c	14	0.3	< 2.00	15	< 0.100
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	27	1	< 2.00	2	< 0.100
		3b	100	0.68	< 2.00	3.7	< 0.100
		3c	-	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	120	1	< 2.00	11	< 0.100
		4b	180	0.71	< 2.00	13	< 0.100
		4c	50	< 0.200	< 2.00	8	< 0.100
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River	5a	915	1.4	< 2.00	54.5	< 0.100
		5b	588	1	< 2.00	47.7	< 0.100
		5c	-	-	-	-	-
Washington District	San Juan Creek	6a	18	0.93	< 2.00	1.8	< 0.100
		6b	253	1.8	< 2.00	1.6	< 0.100
		6c	24	1.3	< 2.00	0.97	< 0.100
		6c	170	3.8	< 2.00	2.2	< 0.100
		Minimum	14	<0.200	-	0.92	-
		Maximum	915	3.8	-	54.5	-
		Geometric Mean	60.17	0.85	-	4.84	-

Appendix D. Trace-metal concentrations of whole-body salmonids (Oncorhynchus spp.) collected from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site ID#	Cd	Cr	Cu	Fe	Hg
American Beauty Mine Complex	Long Canyon	1a	< 0.100	< 0.500	4.1	89	< 0.100
		1b	< 0.100	< 0.500	4.1	74	< 0.100
		1c	< 0.100	< 0.500	3.5	99	< 0.100
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	< 0.100	< 0.500	3.4	100	2.7
		2a	< 0.100	< 0.500	3.4	110	1.8
		2b	< 0.100	< 0.500	2.5	120	3.5
		2c	< 0.100	< 0.500	2	85	2.4
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	0.1	< 0.500	21	120	< 0.100
		3b	0.1	< 0.500	6.6	256	0.1
		3c	-	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	< 0.100	3.8	7.7	220	< 0.100
		4b	< 0.100	0.5	3.3	264	< 0.100
		4c	< 0.100	< 0.500	9.9	120	< 0.100
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River	5a	< 0.100	0.8	3.5	959	0.99
		5b	< 0.100	< 0.500	3.5	692	1
		5c	-	-	-	-	-
Washington District	San Juan Creek	6a	< 0.100	< 0.500	2.5	78	0.2
		6b	0.73	2.1	4	437	< 0.100
		6c	1.5	< 0.500	3.6	88	< 0.100
		6c	2.7	0.6	5.5	321	0.1
		Minimum	<0.100	<0.500	2	74	<0.100
		Maximum	2.7	3.8	21	959	3.5
		Geometric Mean	0.49	1.14	4.33	166.82	0.76

Appendix D. Trace-metal concentrations of whole-body salmonids (Oncorhynchus spp.) collected from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site ID#	Mg	Mn	Mb	Ni	Pb
American Beauty Mine Complex	Long Canyon	1a	1120	8.2	< 2.00	< 0.500	0.4
		1b	1270	6	< 2.00	< 0.500	0.6
		1c	1090	3.5	< 2.00	< 0.500	0.6
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	1270	13	< 2.00	< 0.500	< 0.200
		2a	1330	57.6	< 2.00	< 0.500	< 0.200
		2b	1390	46	< 2.00	< 0.500	< 0.200
		2c	1320	36	< 2.00	< 0.500	< 0.200
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	1310	6.4	< 2.00	< 0.500	< 0.200
		3b	1480	14	< 2.00	< 0.500	< 0.200
		3c	-	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	1290	23	< 2.00	1.9	< 0.200
		4b	1360	16	< 2.00	< 0.500	< 0.200
		4c	1510	11	< 2.00	< 0.500	< 0.200
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River	5a	1610	174	< 2.00	< 0.500	0.4
		5b	1600	65.9	< 2.00	< 0.500	0.3
		5c	-	-	-	-	-
Washington District	San Juan Creek	6a	1220	15	< 2.00	< 0.500	< 0.200
		6b	1350	14	< 2.00	1	2.4
		6c	1180	4.2	< 2.00	< 0.500	0.4
		6c	1320	13	< 2.00	< 0.500	4.4
		Minimum	1090	3.5	-	<0.500	<0.200
		Maximum	1610	174	-	1.9	4.4
		Geometric Mean	1327.13	16.70	-	1.38	0.72

Appendix D. Trace-metal concentrations of whole-body salmonids (Oncorhynchus spp.) collected from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

Study Area	Stream	Site ID#	Se	Sr	V	Zn
American Beauty Mine Complex	Long Canyon	1a	0.92	13	< 0.500	75.4
		1b	1.2	13	< 0.500	89.3
		1c	1.1	7.4	< 0.500	110
Aurora-Bodie Historic Mining Area	Bodie Creek	2a	1.2	50.8	< 0.500	128
		2a	1.5	46.7	< 0.500	128
		2b	1.6	59.5	< 0.500	108
		2c	1.3	63.8	< 0.500	104
Birch Creek District/ Austin Gold Venture Mine	Birch Creek	3a	8.2	23.4	< 0.500	139
		3b	7.1	37.6	0.7	152
		3c	-	-	-	-
Carson Range (Control Site)	Thomas Creek	4a	0.95	41.6	0.9	123
		4b	0.86	50.8	1	117
		4c	1	49	0.6	169
McCormick Group/ Buckskin National Mine	North Fork Little Humboldt River	5a	3.3	91.6	1.7	170
		5b	4.9	101	1	201
		5c	-	-	-	-
Washington District	San Juan Creek	6a	2.7	23.6	< 0.500	91.9
		6b	4.8	16	1	96.1
		6c	4	17	< 0.500	95.7
		6c	4	18	< 0.500	120
		Minimum	0.86	7.4	<0.500	75.4
		Maximum	8.2	101	1.7	201
		Geometric Mean	2.12	31.79	0.94	119.39

Appendix E. Trace-metal concentrations of gill, liver, and muscle tissues (parts per million- dry weight) of salmonids (Oncorhynchus spp.) collected from streams receiving historic mine drainage, western Great Basin, July to August, 2004.

	Bodie Creek			Birch Creek			Thomas Creek (control)		
Trace-element	gill	liver	muscle	gill	liver	muscle	gill	liver	muscle
Al	77	12	< 2.00	95	10	4	70	6	11
As	0.6	0.3	0.2	1.3	1	3.1	0.4	0.5	1.4
B	< 2.00	2	< 2.00	< 2.00	< 3.00	< 2.00	< 2.00	< 2.00	< 2.00
Ba	29.5	< 0.200	2.8	7.5	< 0.200	0.75	18	< 0.200	0.5
Be	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cd	< 0.100	0.2	< 0.100	< 0.100	5.4	< 0.100	< 0.100	< 0.100	< 0.100
Cr	1	< 0.500	< 0.500	73.3	< 0.500	< 0.500	1	< 0.500	< 0.500
Cu	1.9	187	2.1	4.9	1680	3.8	2	408	2.8
Fe	217	1890	30	937	1780	51	454	732	24
Hg	1.9	6.7	4.2	< 0.100	0.41	0.2	< 0.100	0.1	0.1
Mg	1800	684	1400	1980	647	1410	1410	641	1340
Mn	84.6	6.4	7.7	25	3.5	2.4	19	6	1
Mb	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00
Ni	< 0.500	< 0.500	< 0.500	71.6	1	< 0.500	< 0.500	< 0.500	< 0.500
Pb	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200
Se	2.8	13	1.4	7.8	170	6	1.2	5.1	1.1
Sr	109	0.61	13	82.2	0.3	11	67.1	0.5	2.8
V	< 0.500	0.8	< 0.500	1	0.9	< 0.500	1	2.7	< 0.500
Zn	131	178	59.2	158	107	80.3	270	140	24

Appendix F. Aquatic macroinvertebrate survey data from stream sites receiving historical mine drainage, western Great Basin, July to August, 2004.

	San Juan Creek			Thomas Creek			Bodie Creek			Birch Creek			N. Fork Little Humboldt			Long Canyon Creek		
SPECIES	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Arachnid																		
Arthropoda																		
Coleoptera																		
Elmidae																		
Collembola																		
Diptera	**46**	**162**	**145**	**56**	**41**	**14**	**88**	**25**	**50**	**98**	**171**	**0**	**162**	**96**	**0**	**97**	**127**	**173**
Chironimidae	46	162	145	43	26	10	88	25	50	98	171		162	89		97	127	173
Simuliidae				5		4								6				
Tipulidae				8	15									1				
Ephemeroptera	**12**	**13**	**28**	**124**	**179**	**280**	**28**	**27**	**14**	**14**	**28**	**0**	**22**	**102**	**0**	**144**	**74**	**52**
Baetidae	12	13	28	68	129	193	28	13		14	28		5	6		98	62	21
Ephemerellidae				33	22	64										23		
Heptageniidae				8	13	10							17	67		16	12	31
Leptophlebiidae				5		6		14	14					29		7		
Potamanthiidae				10	15	7												
Hemiptera																		
Nepidae																		
Megaloptera																		
Odonata																		
Coenagrionidae				13		25	12	10	4									
Gomphidae						12		8										
Oligochaeta																		
Plecoptera	**133**	**5**	**12**	**12**	**63**	**27**	**0**	**15**	**5**	**11**	**0**	**0**	**35**	**100**	**0**	**82**	**37**	**33**
Chloroperlidae	43	5	12		16	12		6					35	78		13		19
Peltoperlidae					16													
Perlidae	90			12	31	15			3					22		62	37	14
Perlodidae																7		
Pteronarcyidae								9	2	11								
Trichoptera	**28**	**10**	**12**	**36**	**53**	**58**	**37**	**15**	**33**	**32**	**12**		**33**	**22**	**0**	**131**	**124**	**56**
Brachycentridae	12															41	23	
Glossosmatidae																		
Arctopsyche	6	10	12	8	12	12	23	2	3	28	12		33	20		14	66	4
Hydropsychidae				28	17	7	14	5	27	4				2				
Hydroptilidae								8	3									
Limnephilidae	10				24	10										68	35	
Philopotamidae																		
Polycentropodidae						29										8		52
Abundance	231	203	225	228	336	379	153	82	102	155	211	x	252	320	0	454	362	314
Species Richness	8	5	5	12	12	15	5	10	8	5	3	x	5	10	0	12	7	7
EPT %	0.75	0.14	0.23	0.75	0.88	0.96	0.42	0.70	0.51	0.37	0.19	x	0.36	0.70	0.00	0.79	0.65	0.45
# Eph	1	1	1	5	4	5	1	2	1	1	1	x	2	3	0	4	2	2