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Lower Silver Creek
Data Summary Report

Prepared for:

US Environmental Protection Agency
Region 8

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1.0 INTRODUCTION

The Lower Silver Creek drainage is currently under review by the U.S. Environmental Protection Agency (EPA) to determine possible clean-up actions aimed at addressing metal contamination resulting from historic mining practices. This Data Summary Report is a product of Phase I and Phase II activities in the Lower Silver Creek (LSC Site) corridor for the Silver Creek Load Reduction Alternatives Assessment. Tetra Tech is performing this work for the EPA under Contract Number 68-C-02-108.

Field activities occurred from August to December, 2007. Field activities included sampling surface soil, subsurface soil, groundwater and surface water. Subsurface sampling included borings and test pits, and the installation of piezometers at select locations. Field activities also included wetlands delineation and a geophysical survey.

The chemicals of concern (COCs) at the LSC Site include zinc, cadmium, lead, and arsenic. Phase I and Phase II resulted in a total of 280 surface soil samples, 134 subsurface soil samples, 22 groundwater samples and seven surface water samples. Results of these samples are discussed further in Section 4.

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2.0 BACKGROUND INFORMATION

2.1 Site Location and Description

Silver Creek begins in the Wasatch Mountains above the town of Park City, Utah, and lies within the Weber River Basin in Summit County, Utah. The LSC Site is situated east of Highway 40, bounded by Highway 248 on its southern end and Interstate 80 to the north. It is located in Township 1 South Range 4 East, in Sections 10, 11, 15, 14, 22, 23, 27, 26, and 35, with approximately 500 feet occurring in Section 2 of Township 2 South Range 4 East. The LSC Site ranges in width from 2,100 feet at the southern boundary to 3,800 feet near Pivotal Promontory Road, encompassing approximately three square miles or 1,875 acres. The Rail Trail State Park runs north-south through the Site, paralleling the valley bottom between the floodplain and eastern rise. The Rail Trail is a former Union Pacific Railroad rail bed. The LSC Site includes the floodplain and riparian habitat and upland areas adjacent to Silver Creek. The region is currently undergoing significant development.

Silver Creek is fed by precipitation (snowmelt), groundwater, springs, and mine tunnel discharges near the headwaters. Silver Creek is classified for beneficial use Class 3A for protection of cold water fish and cold water species (UDEQ - DWQ, 2004). Water rights for domestic water, stock, irrigation, and recreation are held by public and private entities in Silver Creek. Portions of the LSC Site are flood irrigated, and the stream is impacted by irrigation runoff and groundwater return flows. Several irrigation ditches have been constructed in the basin. US Geological Survey (USGS) stream flow gauging station 10129900 is located within the LSC Site downstream of the Snyderville Water Reclamation Facility outfall.

2.2 Site History and Previous Investigations

Mining in the Park City area began around 1869. The first shipment of ore, 40 tons, was transported out by rail in July 1870 (UDEQ - DERR, 2002). As many as 10 mills operated along the banks of Silver Creek throughout the history of mining in Park City. Tailings from the mining operations were washed downstream and deposited in over-bank deposits in the floodplain throughout the LSC Site. Irrigation diversions may have spread the tailings and/or impacted Silver Creek waters to areas outside the floodplain. The Big Four Mill, located near the present Pivotal Promontory access road, was the primary mill operating within the LSC Site. The mill was erected to process the zinc-lead-silver tailings accumulated in the LSC flats (Williams, 1916). The Big Four was reportedly the third largest mill in Utah in 1916, consisting of a two-month stockpile of 50,000 tons of ore and the capacity to process 1,800 tons of ore tailings per day (UDEQ – DERR, 2002). The mine operated from 1915 to 1918. The Big Four tailings field was reportedly 3.5 miles long by 400 to 1,200 feet wide and two inches to eight feet deep. Today, the tailings exist in mounds, berms, and hummocks. There are two Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) listed sites upstream of the LSC Site, Richardson Flat and Empire Canyon.

The Utah Division of Water Quality (UDWQ) and USGS have monitored the LSC Site for over 13 years. Silver Creek is listed on Utah's 303(d) list as impaired with a high ranking due to elevated concentrations of zinc and cadmium. In 2004, UDWQ published a Total Maximum Daily Load (TMDL) report in which Silver Creek was listed as impaired by zinc and cadmium, which both exceeded their 4-day chronic aquatic-life standard (UDEQ – DWQ, 2004). Elevated metal concentrations in soils are also a concern. Lead and arsenic are the risk drivers for soil contamination. The UDEQ completed an Innovative Assessment in 2002 on the LSC Site;

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based on elevated lead and arsenic concentrations, UDEQ recommended the LSC Site for CERCLIS listing.

The Lower Silver Creek project represents a joint EPA water and waste program. The initial TMDL assessment included gross (watershed-scale) load allocations and provided a summary of best management practices (BMPs) to reduce loading. Estimates for non-locationally-specific source control measures were nearly $100 million. However, it was not the intent of the TMDL report to provide sufficient level of detail necessary to justify the expense of specific source reduction and remediation efforts. This report provides additional water quality and soils data and analysis to describe the nature and extent of mine waste and metals loading; a companion Tetra Tech modeling report provides insight into transport pathways under high flow conditions. The goal of Tetra Tech's work is to provide the information necessary to develop management options that maximize the efficiency (pollution reduction and cost) of restoration efforts in the watershed.

2.3 Waste Characteristics

Metals in LSC Site originate from sulfide mineral bearing ore deposits in the Park City Mining District. Some ores stem from skarn deposits hosted in carbonate rocks. Carbonate minerals also occur in intrusions as gangue minerals. Tailings from these ores should thus be abundant in sulfide and carbonate minerals (Utah Geological Society, 1968) and (USGS, 1989). Tailings material is distributed relatively uniformly across the majority of the floodplain area of the LSC Site and also exists in mounds, berms, and hummocks.

The chemicals of concern (COCs) at the LSC Site are zinc, cadmium, lead, and arsenic. The media affected by these contaminants are surface water, groundwater, sediment and soils. Contamination in these media could potentially affect ecological receptors (zinc, cadmium, and lead) and humans (lead and arsenic). TMDL reductions are required for surface water cadmium and zinc. The COCs in sediment and soil are lead and arsenic. Additionally, UDEQ issued a fish consumption advisory in October 2004 for trout caught in Silver Creek due to elevated levels of arsenic in these fish.

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3.0 FIELD ACTIVITIES

3.1 Sampling Work Plan

A sampling work plan was developed by Tetra Tech and submitted to the EPA on August 6, 2007 for Phase I and Phase II investigation activities. Phase I activities included surface soil, subsurface soil and groundwater sampling along six transects of the Lower Silver Creek (LSC) area (Section 3.2). The initial scope of Phase II activities included additional XRF sampling, low flow surface water, sediment and groundwater sampling. Based on Phase I results, site conditions at the time of Phase II sampling, and discussions between Tetra Tech and EPA Region 8 representatives, a modified Phase II scope was developed which included additional surface soil sampling with laboratory metals analysis, test pit sampling, and groundwater sampling. The full surface water sampling and tracer studies were not conducted as Lower Silver Creek was not flowing at the time of the planned sampling activities. Limited surface water sampling was performed in late fall. Phase II activities are described in Section 3.3.

The sampling work plan was used with the companion Quality Assurance Project Plan (QAPP). The QAPP described the policy, organization, functional activities, and quality assurance and quality control protocols employed to verify that the data and measurements collected achieved the specified data quality objectives. The QAPP document was developed by the Utah Department of Environmental Quality, Division of Environmental Response and Remediation (UDEQ DERR) and approved by EPA Region 8 personnel.

Sampling was conducted on parcels within the LSC site where signed access agreements were obtained from property owners. Access agreements for parcels where sampling was allowed are provided in Appendix A.

3.2 Phase I Investigation

The Sampling Plan for Phase I proposed sampling along six transects spanning the study area located in the LSC watershed (Figures 5A & 5B). Two landforms were sampled across each transect, the floodplain area and the uplands area.

Sampling stations were to be located every 250 feet across the floodplain portion of each transect and every 500 feet in the uplands areas. At each transect, between two and twelve sample stations were identified within the floodplain area and between one and five sample stations were established in the uplands. A Geoprobe was used in the floodplain area to collect subsurface soil samples and to assess the thickness of tailings material. In areas where tailings were present, samples were collected from the tailings profile and from the material underlying the tailings, if practicable. The Geoprobe investigation was intended to help quantify the volume of tailings present. Soil samples were to be collected at upland locations from the 0- to 6-inch depth interval if tailings material was not visibly apparent. Boring Logs from the Geoprobe investigation are provided in Appendix B of this report. The floodplain and uplands sample locations were surveyed with a handheld GPS unit.

X-Ray Fluorescence (XRF) analysis was performed on soil samples to quantify soil metal concentrations for arsenic, cadmium, lead, and zinc. XRF analysis was performed in Colorado upon completion of sampling. Soil nutrient, paste pH, and organic analyses were performed by Colorado Analytical Laboratory on ten soil samples. Acid Base Accounting analyses were performed by ACZ Laboratories on ten soil samples.

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Piezometers were installed at select Geoprobe boring locations to allow the measurement of groundwater levels and the collection of groundwater samples. Two to four one-inch diameter piezometers were installed on each transect to provide insight on the direction of groundwater flow and groundwater chemistry. Groundwater samples were analyzed for calcium, magnesium, sulfate and the dissolved metals aluminum, cadmium, iron, manganese, and zinc. Groundwater samples were also analyzed for iron speciation between the ferrous and ferric states. Piezometers were generally located within the floodplain area. Piezometer locations were surveyed by a professional surveyor.

A qualitative rhodamine dye tracer test was to be used to locate the main water course. Surface water sample locations for the low flow sampling event (Phase II) were to be assigned along the main water course based on the results of the rhodamine test. Stream geometry and flow measurements were to be made at select locations. However, because no flow was observed in the main channel during Phase I activities, this test was not performed.

The Sampling Plan for Phase I activities also included a wetlands delineation of the LSC Site. The wetlands delineation is discussed in Section 3.5.

3.2.1 Surface Soil Sampling

During the Phase I investigation, a total of 50 surface soil samples (0-6") were obtained from the locations along the six established transects identified on Figures 1A, 1B, and 1C. Each sample was analyzed for metals using XRF, as specified in the sampling plan. Fourteen samples were sent to an EPA Contract Laboratory Program (CLP) facility using the ILM05.3 Statement of Work (SOW) which defines the analytical methods accepted by the CLP for the isolation, detection, and quantitative measurement of 23 target analyte metals (including mercury) for quality assurance and quality control (QAQC) on the XRF samples. Analyses were performed using Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) and/or Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Soil nutrient, paste pH and organic analyses were performed on five surface soil samples by Colorado Analytical Laboratory. Acid Base Accounting (ABA) analyses were performed on five surface soil samples by ACZ Laboratories. Investigation derived waste (IDW) was handled as specified in the sampling work plan. Sampling occurred August 13-15, with XRF analysis occurring August 24-28, 2007 in Tetra Tech's Fort Collins Laboratory. Selected results from the XRF analyses of these samples are listed in Table 1a and shown on Figures 1A, 1B and 1C. ABA results are listed in Table 5a. Complete results are provided in Appendix D.

3.2.2 Subsurface Investigation

During the Phase I investigation, a total of 72 subsurface soil samples were taken at 25 locations using a direct push Geoprobe drill rig. The samples were analyzed for metals using XRF, as specified in the sampling plan. These samples were collected from depths varying from 1-foot to 14 feet. Soil nutrient, paste pH and organic analyses were performed on five subsurface soil samples by Colorado Analytical Laboratory. ABA analyses were performed on five surface soil samples by ACZ Laboratories. Sample locations along the six transects of the LSC site are identified on Figures 2A, 2B and 2C. IDW was handled as specified in the sampling work plan. Sampling occurred August 13-15, with XRF analysis occurring August 24-28, 2007 in Tetra Tech's Fort Collins Laboratory. Selected results from the XRF analyses of these samples are listed in Table 2a and are displayed on Figures 2A, 2B and 2C. ABA results are listed in Table 5a. Complete results are provided in Appendix D.

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3.2.3 Groundwater Sampling

During the Phase I Investigation, a total of 21 piezometers were installed, each with a screened interval of five to ten feet below ground surface (bgs). These piezometers were surveyed by a licensed surveyor to obtain the elevations of the piezometers. Sixteen piezometers were sampled August 15-16; four of the wells were dry and one well did not recharge after purging, preventing samples from being taken from these five piezometers. The locations of the piezometers are indicated on Figures 3A, 3B and 3C. The water samples were submitted to ACZ Laboratories for iron speciation analysis, and to a CLP facility using the ILM05.3 SOW which defines the analytical methods accepted by the CLP for the isolation, detection, and quantitative measurement of 23 target analyte metals (including mercury) in water samples. Analyses were performed using ICP-AES and/or ICP-MS. Samples were analyzed for sulfate and dissolved and total metals and as specified in the sampling plan. IDW was handled as specified in the sampling work plan. Results from the analyses of these samples are listed in Table 3a and are displayed on Figures 3A, 3B and 3C.

3.3 Phase II Investigation

The original Sampling Plan stated that Phase II sampling would consist of additional XRF sampling to supplement that performed during Phase I. Phase II was also to include low flow surface water, sediment and groundwater sampling to support the metals transport modeling. Modifications to the Phase II activities resulted from discussions between Tetra Tech and EPA Region 8 personnel based on the results of the Phase I sampling and site conditions at the time of the Phase II sampling event. Modifications included performing additional surface soil sampling (0-6" depth interval) in upland areas, shallow subsurface samples (6-12" depth interval) at select surface soil sample locations, installation of additional piezometers for groundwater level measurement and sampling, and digging test pits in the floodplain area. Surface soil and shallow subsurface soil samples were sent to a CLP facility using the ILM05.3 SOW which defines the analytical methods accepted by the CLP for the isolation, detection, and quantitative measurement of 23 target analyte metals (including mercury) in both water and soil/sediment samples. Analyses were performed using ICP-AES and/or ICP-MS. Five Phase II upland surface soil samples were also analyzed for arsenic, cadmium, lead, and mercury using the Toxicity Characteristic Leaching Procedure (TCLP).

Test pit samples were sent to ACZ Laboratories for analysis of arsenic, cadmium, lead, zinc, soil pH and neutralization potential. Ten test pit samples were also to be analyzed for acid base accounting analysis for acid base potential, acid neutralizing potential (ANP) and acid generating potential (AGP).

Groundwater samples were sent to a CLP facility using the ILM05.3 SOW which defines the analytical methods accepted by the CLP for the isolation, detection, and quantitative measurement of 23 target analyte metals (including mercury) in both water and soil/sediment samples. Analyses were performed using ICP-AES and/or ICP-MS.

3.3.1 Surface Soil Sampling

During the Phase II investigation, a total of 230 surface soil samples (0-6" depth interval) were obtained to evaluate the presence of metals contamination in the upland areas adjacent to the floodplain. These samples were collected on a 425 ft grid throughout the LSC site. IDW was handled as specified in the sampling work plan. Sample locations were surveyed using a GPS unit with sub-meter accuracy. Sampling occurred October 29 through November 10, 2007.

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Selected results from the analyses of these samples are listed in Table 1b and shown on Figures 1A, 1B and 1C. Complete results are provided in Appendix D.

3.3.2 Subsurface Investigation

The Phase II subsurface investigation was comprised of two parts. Shallow subsurface samples (6-12" depth interval) were collected at selected surface soil sample locations. Deeper samples, varying in depth from 0.5 to 4 feet, were collected from test pit locations within the floodplain area. The 6-12" sampling occurred October 29 through November 10, 2007, while the test pit sampling occurred Nov. 5-10, 2007. Subsurface sampling locations are identified on Figures 2A, 2B and 2C. A total of 26 samples were collected from the 6-12" depth interval in select surface soil sampling locations. A total of 22 test pits were dug to further delineate the extent of tailings material within the primary floodplain (tailings depositional) area. A total of 36 test pit samples were collected. IDW was handled as specified in the sampling work plan. Test pit samples were sent to ACZ Laboratories for metals and acid base accounting analyses. Lead speciation and mineralogical analysis was conducted by the University of Colorado on samples from four test pits. Selected results from the analyses of these samples are listed in Tables 2b and 2c and are displayed on Figures 2A, 2B and 2C. ABA results are listed in Table 5b. Complete results are provided in Appendix D. Test Pit Logs are provided in Appendix C of this report.

3.3.3 Groundwater Sampling

Eight additional piezometers were installed during the Phase II investigation. Groundwater from six of these piezometers was sampled on November 19, 2007, one piezometer was dry and one piezometer did not recharge sufficiently to allow for sample collection. The Phase II piezometers were screened at various depths depending on site conditions. Six of these piezometers were in three nested pairs, to measure metals in groundwater relative to screened interval. Screened depths are listed along with observed metals concentrations in Table 3b. The groundwater samples were submitted to an EPA CLP laboratory and analyzed for dissolved metals as specified in the sampling plan. IDW was handled as specified in the sampling work plan. Selected results from the analyses of these samples are listed in Table 3b and are displayed on Figures 3A, 3B and 3C. Complete results are provided in Appendix D.

3.3.4 Surface Water Sampling

As no locations were identified in Phase I for surface water or sediment samples along the main stream channel due to the lack of continuous flow in Silver Creek, Phase II surface water and sediment sampling was not conducted as prescribed in the sampling plan. However, an opportunistic sampling event was conducted in December to obtain surface water samples, primarily from the irrigation ditch paralleling Lower Silver Creek to the east. The amended surface water sampling approach specified locations for up to 14 surface water samples. Sample locations were selected based on access constraints. On December 17, 2007, seven surface water samples were taken from the LSC Site. Seven of the proposed samples were not obtained due to ice over the stream or insufficient stream flow. The surface water samples were analyzed for 23 metals (both total and dissolved) by an EPA CLP lab, and sulfate and iron speciation by ACZ laboratories. Selected results for cadmium, zinc, sulfate, ferrous iron and ferric iron are presented in Table 4a and sampling locations are shown on Figures 4A, 4B and 4C. Complete results are provided in Appendix D.

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3.4 Geophysical Survey

A geophysical survey using Ground Penetrating Radar (GPR) was conducted December 3, through December 7, 2007. The purpose of the GPR survey was to determine if the results could be used to determine the depth and lateral extent of the tailings deposition areas. GPR is a geophysical technique which employs radio waves, typically in the 1 to 1,000 MHz frequency range, to map subsurface structures and features (man made and natural). GPR operates on the simple principal that electromagnetic waves, emitted from a transmitter antenna, are reflected from buried objects and detected by the receiver antenna. GPR data is presented in the form of time-distance plots that are analogous to conventional seism ic records that provide a cross-sectional image or profile of reflections representing shallow subsurface conditions.

Fifty-two transects were taken at approximately 500 foot intervals across the floodplain/suspected tailings deposition area along the LSC Site. In general, the quality of the GPR data collected at the site was good, and limited interpretation of the data conducted in the field at the time of the survey implied that the data may be useful in determining the depth and lateral extent of tailings material. However, due to the limitations of the equipment and processing tools available in the field, a definitive interpretation and evaluation could not be conducted. Following the field data collection efforts, the interpretation process involved a detailed review of the field record to determine the presence of anomalous areas that may represent the presence of tailings deposits. A specialized software package (RADAN) created by the GPR equipment manufacturer was used to view and plot data and various filters were applied to enhance the records for interpretation.

Typically, material with a higher clay and water content has a greater conductivity, and based on the observations made during the test pit investigations, it was anticipated that a signature in the GPR record could be observed that would indicate the interface between the tailing material and the underlying organic clay (observed in most locations). Breaks in continuous shallow reflectors in the GPR record are typically indicative of possible trenching, excavation, and/or active depositional environments. The presence of buried utilities is typically indicated by parabolic-type reflectors.

The interpretation of the GPR record was performed first on transects in the vicinity of previously excavated test pits and borings, where a relatively clear understanding of the subsurface conditions had been developed. The figure presented in Appendix E is an image created from the GPR record along Transect 18 which was located in the immediate vicinity of test pits TP-8, TP-20 and TP-7, just north of Promontory Road. Based on observations of the surface along the transect and subsurface materials encountered in the test pit excavations, it appears that tailings material has been deposited across the entire width of the floodplain and that the depth of tailings material increased gradually from east to west. As indicated on Figure 5B, the tailings depth was 1.0 foot at TP-8 (east), 2.5 feet at TP-20 (center), and 5.5 feet at TP-7 (west; near the main stream channel). The tailing in each of these test pits was observed to be underlain by approximately 2 to 2.5 feet of black organic clay, with a sandy gravel material beneath. Within the tailings layer, inter-bedded layers of varying thickness (from several inches to a foot or more) and varying grain-size were observed. The tailings material observed varied from coarse sand to very fine silt. The white line on the figure included as Appendix E indicates the boundaries of an anomalous area within the GPR record represented by breaks in continuous shallow reflectors. The horizontal axis of the figure is distance along the transect and the vertical axis is an observed measurement from the receiver that can be converted to depth. The length of the anomalous area bounded by the white line in this figure is on the order of 20 to 25 feet. Several of these anomalous areas were observed along transects in this area,

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however, no distinctive pattern of a nearly continuous layer of tailing material (or the underlying black organic clay layer) was observed.

Based on this comparison of the interpreted GPR data and site test pit data, we concluded that the nature of the deposited tailing did not provide a geophysical record that could be used to definitively determine the depth and lateral extent of the tailings material. Consequently, the majority of the GPR data was not processed.

3.5 Wetlands Delineation

Tetra Tech performed a wetlands delineation of the LSC area in late August through September, 2007. The wetlands delineation was conducted by Tetra Tech scientists experienced with the identification of wetland functions as they relate to jurisdictional status. Information collected in the field included the following: vegetative characteristics, soil type, geographic location, and hydrologic setting.

Delineation protocol followed the USACE Routine Wetland Determination. Fifty routine sample plots were located throughout the LSC Site to test for the occurrence of wetland hydrology, hydrophytic vegetation, and hydric soils. If all three of these wetland indicators were identified in a plot, then the area was classified as a wetland and the boundaries were marked with pin flags and recorded with a GPS device with sub-meter accuracy. Numerous informal shallow test pits were also hand excavated to assist in boundary determinations.

Waters of the U.S. (WUS) were also delineated. In addition to the Lower Silver Creek channel, irrigation ditches were investigated for whether their source of hydrology would qualify them for a WUS classification. Culverts and points of diversions were marked throughout the extensive irrigation system to document connectivity.

In total, 493.6 acres of wetlands were delineated, amounting to 26 percent of the LSC Site. Wetlands occupy most of the valley bottom west of the Rail Trail, as well as portions of the eastern side of the LSC Site. Wetland communities found in the valley bottom were dominated by Baltic rush (*Juncus balticus*). Species compositions changed moving eastward to include other dominant wetland indicator species such as blue-joint reed grass (*Calamagrostis canadensis*), redtop (*Agrostis stolonifera*), clustered field sedge (*Carex praegracilis*), and Nebraska sedge (*Carex nebrascensis*). Waters of the U.S. totaled 15.8 miles. An additional 4.1 miles of non-wetland waters of the U.S. were also identified.

The majority of the tailings deposition area within the floodplain has been preliminarily characterized as jurisdictional wetlands. Other wetland areas have also been identified outside of the floodplain area, consisting of both natural and irrigation-induced wetlands. The boundaries of the delineated wetlands are presented on the series of figures presenting sampling results. The Wetlands Delineation Report is presented in Appendix F of this report.

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4.0 SAMPLING RESULTS

The results of all data collected during both the Phase I and Phase II site investigation activities are presented and discussed in this Section, by media. Complete sampling results and analytical laboratory reports are provided in Appendix D.

4.1 Tailings Characteristics and Volume Estimate

Subsurface soil results were utilized to estimate tailings depths through various reaches of LSC. Figures 5A and 5B show eight distinct reaches, with a tailings depth of 0.5 ft to 4.0 ft. Field observations recorded on boring and test pit logs and sampling results were used to determine these depths. Tailings were identified by physical characteristics such as medium to coarse grained sand size, with inter-bedded layers of finer silt-sized tailings, brown to grey color, and by elevated concentrations of metals. Within the identified areas of tailings deposition, a relatively thick layer of black organic clay was observed immediately below the tailing in most areas underlain by a sandy-gravel substrate. This organic clay layer may represent the topsoil layer of the valley prior to the deposition of tailing material. Areas where this organic layer was not present include areas along the stream channel through the site, where the upper tailing and organic layers appear to have been eroded away by the water course, and the northern end of the site, identified as Area 1 on Figure 5B, where this organic layer was not observed in any of the test pits. The data collected from the geophysical survey was not used as part of this analysis, as preliminary analyses of the GPR results were inconclusive (Section 3.4). A preliminary tailings volume of approximately 1,479,000 cubic yards (CY) of tailings was estimated in the LSC Site based on the extents and tailings depth shown in Figures 5A and 5B. Areas delineated as tailings typically have arsenic, cadmium, lead, and zinc levels over the applicable EPA Region 9 Preliminary Remediation Goals (PRGs).

4.2 Surface Soil

Surface soil results can be split into two groups, upland samples and floodplain samples. The wetlands delineation lines on the figures are also used to distinguish between upland and floodplain samples. Floodplain samples typically coincide with tailings deposition areas having higher concentrations of metals, while upland samples typically have lower concentrations of metals. When compared to the residential and industrial PRGs for surficial soil, samples within the floodplain generally exceed the industrial PRGs for lead and occasionally exceed the residential PRGs for cadmium and zinc. Intermittently, samples in the upland areas exceed the residential PRG for lead and a few upland samples exceed the residential PRG for cadmium. The upland samples exceeding PRGs may correlate with their proximity to irrigation channels. A number of Phase I subsurface soil samples, analyzed by XRF, possessed arsenic and cadmium concentrations less than the limit of detection. Arsenic concentrations in surficial floodplain and upland samples exceed the EPA Region 9 residential PRG of 0.39 mg/kg. The fact that unimpacted soils in upland areas possess arsenic concentration above the PRG suggests that regional (background) concentrations are elevated. Note that the majority of the arsenic concentrations fall within the range observed in surface soils in the western United States of <0.10 to 97 mg/kg (Shacklette and Boerngen, 1984).

Data from surface soil samples is shown in Figures 1A, 1B, and 1C, and is listed in Tables 1a and 1b. Analytical data is presented in Appendix D of this report.

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4.3 Subsurface Soil

Subsurface soil sample results include Phase I boring samples in upland and floodplain areas, Phase II 6-12" samples in upland areas and Phase II test pit samples in floodplain areas. Samples from the Phase II test pits were categorized by soil type including clay, peat, sandy gravel, sandy silt, tailing and topsoil. Metal concentrations were above the industrial PRGs for arsenic and lead for all 20 of the test pit samples taken in tailings. Nineteen of 20 of the tailings samples also exceeded the residential PRG for cadmium. Six of 20 test pit samples identified as tailings exceeded the residential PRG for zinc. Of the Phase II 6-12" samples taken in upland locations, all samples exceeded the industrial PRG for arsenic, five of 26 samples exceeded the industrial PRG for lead, six of 26 samples exceeded the residential PRG for lead and one of 26 samples exceeded the residential PRG for cadmium. No samples exceeded the residential PRG for zinc. A number of Phase I subsurface soil samples, analyzed by XRF, had arsenic and cadmium concentrations less than the limit of detection. Approximately half of the Phase I subsurface samples taken in the floodplain area exceed the industrial PRG for arsenic and lead. Eight of 45 Phase I floodplain subsurface soil samples exceed the residential PRG for cadmium and zinc. Five of 27 Phase I upland subsurface soil samples exceed the industrial PRG for arsenic, and two samples exceed the industrial PRG for lead. No Phase I upland subsurface soil samples exceed the PRGs for cadmium or zinc.

Data from subsurface soil sampling is shown in Figures 2A, 2B, and 2C, and is listed in Tables 2a, 2b and 2c. Analytical data is presented in Appendix D of this report. Boring Logs are presented in Appendix B and Test Pit Logs are presented in Appendix C of this report.

4.4 Additional Waste Characteristic Analyses

Additional waste characteristic analyses included acid-base accounting (ABA), toxicity characteristic leaching procedure (TCLP), lead speciation and mineralogical analyses, soil nutrient, paste pH and organic analyses.

Five Phase I surface soil samples, five Phase I subsurface soil samples and ten Phase II test pit samples were selected for ABA analysis. ABA analysis compares the acid neutralizing potential (ANP) and acid generating potential (AGP) of a soil. An ANP/AGP greater than one indicates the sample has a net neutralization potential; whereas, an ANP/AGP ratio less than one indicates that a sample is acid generating. Samples with ANP/AGP ratios greater than three are considered non-acid generating.

Of the ten Phase I samples analyzed, eight had an acid base potential greater than one, indicating a net neutralization potential. The acid generating potential for two of the samples was not detected above the practical quantitation limit; therefore, the ANP/AGP ratio was not calculated for these samples. Two samples had an ANP/AGP ratio less than one, indicating that these samples are acid generating. These acid generating samples were taken from transect 5, E 0375 and W 0175 in the floodplain. Data from the Phase I ABA analysis is listed in Table 5a.

Of the ten Phase II samples analyzed, nine had an acid base potential greater than one, indicating a net neutralization potential (eight of the nine samples had an ANP/AGP ratio between one and three). One sample had an ANP/AGP ratio less than one, indicating that this sample is acid generating. This acid generating sample was taken from test pit 19, in parcel SS-28-A-X, very near the location of piezometer T6W0175. Data from the Phase II ABA analysis is listed in Table 5b.

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Five Phase II upland surface soil samples were analyzed using the TCLP. Arsenic, cadmium, lead, and mercury were tested in the TCLP extracts and compared to Resource Conservation and Recovery Act (RCRA) TCLP respective disposal limits. Four of the five samples have metals concentrations below the TCLP limits for arsenic, cadmium, lead and mercury (RCRA does not have a TCLP disposal limit for zinc). One sample, UE01-44-0.5, had a lead concentration higher than the RCRA TCLP disposal limit; however, concentrations for arsenic, cadmium and mercury for this sample were below the TCLP disposal limits. Data from the TCLP analysis is listed in Table 6.

Lead speciation was performed on samples from four test pits; TP-3, TP-4, TP-9 and TP-14 (Figures 2A, 2B, and 2C). The results indicate that, within the LSC tailing material, lead is present primarily as the lead carbonate mineral cerrusite ($PbCO_3$). Lead is also present in the sulfide galena (PbS), the sulfate anglesite ($PbSO_4$) and is associated with phosphates and iron hydroxides in the tailings. In general, lead is considered bioavailable in the tailings.

Complete data from the ABA and TCLP analyses, as well as the lead speciation, mineralogical analysis, soil nutrient, paste pH and organic analyses are provided in Appendix D.

4.5 Groundwater

Groundwater samples were collected from the piezometers installed in the Phase I and Phase II investigations. These results are presented in Tables 3a and 3b and Figures 3A, 3B, and 3C. These results are representative of the shallow groundwater within the Lower Silver Creek area. No uses of this shallow groundwater were identified in the area, although it is likely that this shallow groundwater interacts with the surface water in Lower Silver Creek. As no uses of groundwater were identified, the concentrations of metals in groundwater were not compared to PRGs.

As described in Section 3.0, the initial Phase I piezometers were installed with the screened interval of the well at depths of 5 to 10 feet bgs. This well construction placed the screened interval below the base of the tailings material in nearly every situation. Several well screens did intersect the tailings, as indicated in Table 3a, and in these cases higher metals concentrations in the groundwater were observed. Observations of conditions during the Phase II test pit excavations revealed that south of Promontory Road groundwater was observed only in the sandy gravel material beneath the organic clay, but that north of Promontory Road, some water was observed to occur within the tailings above the clay layer. At the northern portion of the Site, north of the gravel road near the wastewater treatment plant, the organic clay was not observed to be present and groundwater was observed within the tailing area. To further investigate the occurrence, and quality, of groundwater (or perched water) within the tailing, additional piezometers with shallower screened intervals were installed during Phase II. As indicated in Table 3b, the groundwater quality observed in the shallow piezometers screened within the tailings had much higher metals concentrations than in those screened below the tailing. Data from groundwater samples is shown in Figures 3A, 3B, and 3C, and is listed in Tables 3a and 3b.

4.6 Surface Water

Surface water samples were collected from seven of the 14 locations planned for surface water sampling. Two of the 14 samples were not obtained as the stream was frozen at the prescribed location, and five of the samples were not obtained due to insufficient stream flow. Cadmium

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concentrations in all seven samples were greater than the 0.6 ug/L applicable criteria for chronic water quality standard targets for aquatic wildlife. Zinc concentrations were above the water quality standard targets for aquatic life. Ferric iron and ferrous iron were not detected above the practical quantitation limit of 0.01 mg/L and 0.05 mg/L respectively for any of the samples. Data for cadmium, zinc, ferric iron, ferrous iron and sulfate are presented in Table 4a. Complete results for the surface water sampling are provided in Appendix D.

The results from these samples, obtained primarily from the irrigation ditch, indicate that metals concentrations do not significantly increase as the water flows the length of the site. Of notable exception are the results from station SW-4. Station SW-4 is located in a secondary channel which crosses through a tailings deposition area near the southern end of the Site. Zinc and cadmium concentrations at this location are elevated in comparison to the upstream location SW-2 (located on the irrigation diversion channel immediately north of Highway 248 and east of the rail trail). Water from Lower Silver Creek is diverted into the irrigation ditch system just above, or south of, Highway 248, and the majority of the diverted flow is directed through station SW-2. A relatively small amount of water is not diverted and flows along the west side of the rail trail and under Highway 248. Approximately 1,000 feet north of Highway 248, this water passes under the rail trail and is carried through a ditch which appears to be constructed through deposited tailings. Station SW-4 is located at the end of this diversion ditch immediately before the confluence with the main irrigation ditch.

A selection of surface water data from the April 2004 USGS Report: Principal Locations of Metal Loading from Floodplain Tailings, Lower Silver Creek, Utah is also presented in Figures 4A, 4B and 4C. This data was compared to the Chronic Water Quality Standard Targets for Aquatic Wildlife for Cadmium, Lead and Zinc (adjusted for a hardness of 400 mg/L) defined by the Utah Administrative Code Rule R317-2 – Standards of Quality for Waters of the State, Tables 2.14.2 and 2.14.3a (UDEQ-DWQ, 2008). Based on this comparison, all but five of the 114 samples exceed the Chronic Water Quality Standard Targets for Aquatic Wildlife for cadmium and all but eight of the 114 samples exceed the Chronic Water Quality Standard Targets for Aquatic Wildlife for zinc. Twenty-two of the 114 samples exceeded the Chronic Water Quality Standard Targets for Aquatic Wildlife for lead. Complete results from the April 2004 USGS report are included in Table 4b.

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5.0 CONCLUSIONS AND RECOMMENDATIONS

The information and data collected from the site investigation activities described in this report have advanced the understanding of the nature and extent of tailings material present within the Lower Silver Creek Site and will be useful in developing a conceptual site model. Tailings material is widely distributed throughout the floodplain area and exhibits significantly elevated metals concentrations, with lead concentrations ranging from 3,000 mg/kg to well over 20,000 mg/kg. While the groundwater conditions observed may not be indicative of typical conditions, due to the relatively dry conditions experienced in 2007 and previous years, there is evidence that groundwater (potentially perched) present within the tailing material (typically near the north end of the Site) has significantly higher metals concentrations than concentrations observed in what may be represented as the shallow alluvial aquifer occurring beneath the organic clay layer throughout much of the site. The degree of interaction between tailing material and surface water and between groundwater and surface water was not able to be determined due to the regional drought.

The results of the Phase II surface soil sampling efforts have more accurately described metals concentrations throughout the uplands areas within the study area boundary. From our preliminary evaluation of this data, it appears that concentrations of metals in general and lead in particular do not exceed typical health-based remediation goals in areas which are not influenced by irrigation. In areas where it appears likely that irrigation water may have been applied, diverted from Silver Creek upstream of the Site, elevated lead concentrations were observed ranging from 400 mg/kg to 4,000 mg/kg.

Previously collected surface water data for Silver Creek indicates that surface water entering the Lower Silver Creek floodplain area contains elevat ed concentrations of various metals. Through the LSC Site, metals concentrations continue to increase. The relative contribution from various potential sources remains uncertain. Additional sampling is recommended to allow the performance of additional reactive-transport modeling to assist in determining the primary contributing sources and develop comprehensive remedial alternatives for the Site.

Additional field investigations (test pits or borings) may also be required to more accurately determine the lateral and vertical extent of the tailings and estimate the volume of tailings material present.

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APPENDIX A
ACCESS AGREEMENTS

APPENDIX B
BORING LOGS

APPENDIX C
TEST PIT LOGS

APPENDIX D
ANALYTICAL DATA

APPENDIX E
GEOPHYSICAL SURVEY

APPENDIX F
WETLANDS DELINEATION REPORT