

ABANDONED MINE SITE INVESTIGATION OF THE BULLION MINE SITE ALONG JACK AND JILL CREEKS, MONTANA

Prepared for:

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July 28, 2003

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EXECUTIVE SUMMARY

In the fall of 2002, Bitterroot Restoration, Inc. (BRI) completed fieldwork for a site characterization of the Bullion Mine project site along Jack and Jill Creeks, which are located on Federal lands within the Basin Mining District, Montana. The purpose of the site assessment was to determine the nature and extent of potential contamination on the site, to broadly assess possible impacts to human health and the environment, and to recommend whether or not affected materials should be removed. The findings of this site investigation will help guide future efforts to manage contaminated materials in the watershed and to restore the Jack and Jill Creek drainages.

The Bullion Mine project site is located on a half-mile stretch of two tributaries, known locally as Jack and Jill Creeks. Jill Creek is a tributary to Jack Creek, while Jack Creek subsequently leads to Basin Creek, a major tributary of the Boulder River. The Basin Creek Drainage contains mining and milling waste associated with numerous historic mining and milling sites. On October 22, 1999, United States Environmental Protection Agency added the Basin Creek Drainage, including the Bullion Mine and Milling Complex, to the National Priorities List. Currently, the United States Forest Service and United States Environmental Protection Agency (EPA) are partners in a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) response action at the mine and mill site. The Jack and Jill Creek project site contains eroded tailings that have re-deposited downstream from the mine and mill site.

This characterization occurred from July 2002 through March 2003. The field investigation took place over six days, from September 23 through September 28, 2002. Fieldwork was conducted by Bitterroot Restoration, Inc. and EMC². A topographic/site features survey of the mine-waste impacted area was completed by Territorial Engineering and Surveying, a licensed professional surveying company. Data analysis and reporting occurred from March 15 to March 21, 2003.

The field initiative involved: 1) collecting nine mine waste samples and nine soil samples, as well as the field analysis of 45 mine waste samples and 46 soil samples by X-ray fluorescence (XRF); 2) collecting surface water and sediment samples from seven stream cross-sections; 3) gathering stream hydrological information; 4) estimating the volume of contaminated soils; and 5) assessing the riparian health, including the types, health, and density of riparian vegetation, as well as geomorphic features, of the injured area.

The results from this site investigation indicate that the levels of contamination in and around Jack and Jill Creeks exceed established protective limits for recreational populations. Arsenic is the major chemical of potential concern (COPC) in the system. Chemicals of potential concern are those metals present at concentrations elevated with respect to local conditions. They are determined by comparing concentrations of metals at the site to a body of data representative of local conditions unaffected by site activities (Human and Ecological Risk Division, Dept. of Toxic Substances Control, California EPA, 1997).

Seventy-two percent of soil and mine waste samples contained arsenic concentrations above chemical of potential concern limits of recreational visitors, and the average arsenic concentration in these samples was over three times higher than the concentration limits for

recreational populations. In addition, all streambed sediments collected exceeded Montana's chemicals of potential concern soil arsenic exposure limit for recreational users of 700 parts per million. Lead concentrations are also of concern with 39 percent of soil and mine waste samples containing concentrations above chemicals of potential concern limits for recreational visitor concentrations. The surface water in Jack and Jill Creeks also shows elevated levels of chemicals of potential concern. This is the likely cause of the complete absence of observed aquatic life in the injured area on Jack and Jill Creeks. Jill Creek is more impacted than Jack Creek. Water samples from Jill Creek display concentrations of arsenic, cadmium, zinc, and lead above the Montana water quality standards for human health concentrations.

Additionally, the surface water was acidic (5.81 pH) on Jill Creek, reflecting both its closer proximity to the acid mine drainage of the Bullion Mine site, as well as the slight dilution effect occurring below the confluence with Jack Creek.

The riparian health assessments also indicate that the ecological integrity of the system is compromised. Many parts of the flood-prone zone are devoid of vegetation, likely due to the high concentrations of metals in the floodplain soils. In addition, the channels of both Jill and Jack Creeks are moderately to significantly entrenched, reflecting probable historic changes in the hydrology of the system.

Based upon the results of the site investigation, Jack and Jill Creek are significantly impacted, with levels of chemicals of potential concern in the floodplain materials, streambed sediments and water exceeding the limits for recreational exposure and human health. It is recommended that approximately 284,157 cubic feet of contaminated tailings materials be removed, the impacted stream channel and floodplain areas be reconstructed, and the impacted riparian zone be restored.

1.0 PROJECT GOALS AND OBJECTIVES

The fieldwork for a site characterization of the Bullion Mine project site along Jack and Jill Creeks, which are located on Federal lands within the Basin Mining District, Montana, was completed in the fall of 2002. The purpose of the assessment was to determine the nature and extent of potential contamination, to broadly assess possible impacts to human health and the environment, and to recommend whether or not affected materials should be removed. The findings of this investigation will help guide future efforts to manage contaminated materials in the watershed and to restore the Jack and Jill Creek drainages.

This document has been prepared in fulfillment of the requirements of the U.S. Army Corps of Engineers contract DACW05-01-D-0019 / Bullion, delivery order no. 003.

2.0 PROJECT SETTING

The Bullion Mine project site is located on a half-mile stretch of two tributaries, known as Jack and Jill Creeks. Jill Creek is a tributary to Jack Creek, while Jack Creek subsequently leads to Basin Creek, a major tributary of the Boulder River. The creeks are part of the Basin Creek Drainage, which is within the Beaverhead-Deerlodge National Forest approximately eight miles north of Basin, Montana in Section 13 and 14 Township 7 North, and Range 6 West, Montana Principle Meridian. The site location is illustrated in Figure 1.

Elevations at the Bullion Mine site span from 6,610 to 6,790 feet (2,015 to 2,070 meters). The surrounding vegetation is dominated by coniferous forest – predominately lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and subalpine fir (*Abies lasiocarpa*) – with numerous shrub species, including grouse whortleberry (*Vaccinium scoparium*), Labrador tea (*Ledum glandulosum*) and mountain alder (*Alnus incana*), in the understory. Drummond's willow (*Salix drummondii*), bluejoint reedgrass (*Calamagrostis canadensis*), water sedge (*Carex aquatilis*), and field horsetail (*Equisetum arvense*) are the principal species in the wide marshy floodplains.



Forested riparian area in Reference Reach

Average temperatures in this region range from a minimum of 8.9° F (-12.8° C) in January to a maximum of 82.2° F (27.9° C) in July. The annual average precipitation is less than 12 inches (30.5 cm) and the average annual total snowfall is between 2 and 3 feet (61 to 91 cm) (Western Regional Climate Center 2002).

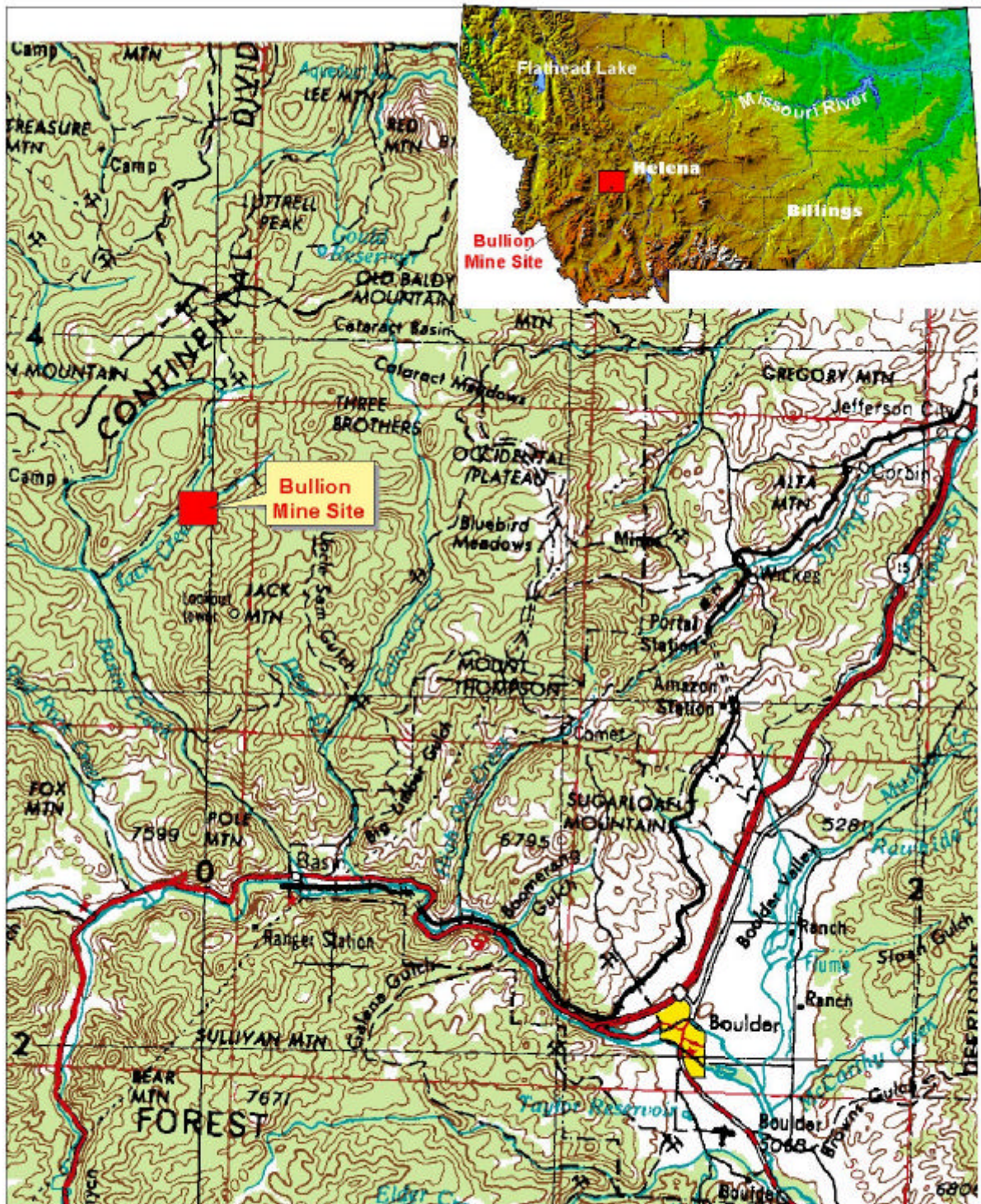


Figure 1

Location Map
Bullion Mine Site
Jefferson County, Montana

Source: NRIS
1:250,000 DRG

0 20 40 Miles



3.0 PROJECT BACKGROUND

The Basin Creek Drainage contains mining and milling waste associated with numerous historical mining and milling sites. On October 22, 1999, United States Environmental Protection Agency (EPA) added the Basin Creek Drainage, including the Bullion Mine and Milling Complex, to the National Priorities List. Currently, the United States Forest Service and



Eroded tailings piles, re-deposited on Jack Creek

United States EPA are partners in a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) response action at the mine and mill site. The Jack and Jill Creeks project site contains eroded tailings that have re-deposited downstream from the Bullion mine and mill. The re-deposition of eroded tailings are highly visible on the privately owned riparian corridor directly downstream of the Jack and Jill Creek project site. It is beyond the scope of this project, however, to address historic mining impacts outside of USFS boundaries.

4.0 SITE ASSESSMENT METHODS

4.1 Project Planning

The Standard Operating Procedures (SOPs), outlined in the *Restoration of Abandoned Mine Sites Final Workplan* (U.S. Army Corps of Engineers, Omaha District, 2002), were adhered to during the course of this field investigation: A1 (Surface Soil/Rock Sampling Equipment and Procedures); A3 (Subsurface Soil/Rock Sampling Equipment and Procedures); A4 (Soil/Rock Homogenization Equipment and Procedures); A7 (Investigative Derived Waste Procedures); A11 (Surface Water and Sediment Sampling Equipment and Procedures), A12 (Equipment Decontamination Procedures); A13 (Sample Handling, Documentation, and Tracking Procedures); and A14 (Field Documentation).

4.1.1 Health and Safety Plans

Prior to conducting fieldwork, BRI developed a health and safety plan for the Bullion project. Information on health and safety issues associated with this field effort may be found in the Bullion Site Safety and Health Plan (SSHP), Sept. 2002.

4.1.2 Sampling Methodology

Sampling plans were developed for the collection of surface water, sediment, soil, and mine waste material. Information on sampling methods followed is found in *The Standard Operating Procedures (SOPs), Surface Soil/Rock Sampling Equipment and Procedures* (U.S. Army Corps of Engineers, Omaha District, 2002).

4.1.3 Sample Identification Scheme

The sample identification (ID) scheme for soil and mine waste samples, described in *The Standard Operating Procedures (SOPs)* (U.S. Army Corps of Engineers, Omaha District, 2002) used the following designation.

AB-CC-DD-EEE where:

A = Designation of sampling area location – B (For Bullion)

B = T for mine tailings sample; S for soil sample

CC = A numerical digit that indicates if the sample is normal, a duplicate, or a confirmation. 01 = Normal; 02 = Duplicate; 04 = Confirmation (analyzed by XRF and at the laboratory)

DD = A numerical digit that indicates the depth from which the sample is extracted. 01 = between 0 and 1 foot; 02 = greater than 1 foot to 2 feet; 03 = greater than 2 feet to 3 feet; 04 = greater than 3 feet to 4 feet;

EEE = two or three digit sample identification number

For example, a confirmation soil sample collected from a depth of 1.5 feet at the Bullion Mine site would be coded B-S-0402100. The last three digits (100) are the sample identification number.

The sample ID scheme for water and stream sediment samples used the designation below.

AA-CSB-CCC where:

AA = Designation of sampling area location – MT (For Bullion, in Montana)

CSB = Three character identification code that identifies the sample with the subreach where it was collected. CS stands for “Cross-Section.”

CCC = Identifies if the sample is water (H₂O) or sediment (SED)

For example, a sediment sample collected from Subreach C at the Bullion Mine site in Montana would be coded MT-CSC-SED.

4.2 Field Investigation Activities

This investigation occurred from July 2002 through March 2003. The field investigation, described in the *Site Specific Addendum to RAMS General Work Plan and Safety and Health Plan for Bullion Mine* (Bitterroot Restoration, Inc. [BRI], 2002), took place over six days, from September 23 through September 28, 2002. The first project task involved developing sampling and safety plans in mid-summer 2002. Fieldwork was conducted by BRI and EMC². A topographic/site features survey of the mine waste impacted area was completed by Territorial Engineering and Surveying, Inc., a licensed professional surveying company. Data analysis and reporting occurred from March 15 to March 21, 2003.

Upon arrival at the project site, the field team first delineated the boundary of the injured area. The field team then collected mine waste, soil, surface water, and sediment data; estimated the depth and extent of contaminated material; and completed riparian health assessments. Finally, Territorial Engineering and Surveying, Inc. created a topographic site map on one-foot contours,

delineated areas of interest, and surveyed all sampling locations (See Appendix B). Field notes from the field investigation are contained in Appendix A.

4.3 Boundary Delineation

Delineating the project boundary first involved a physical examination of the project site. Boundary limits were based upon visual clues regarding the extent of contamination including: the absence of ground cover; type, quantity, and diversity of plant species; the location of the flood plain; old stream channels; tailings/waste materials; and erosion features on either side of the stream. Boundaries were subsequently confirmed or relocated according to contamination levels recorded with X-ray Fluorescence (XRF). White flags were placed every 100 feet along the border of the project site. Boundaries were used to determine the extent of the survey, to delineate the riparian assessment survey subreaches, and to provide XRF sampling boundaries. Sampling location coordinates, obtained from a hand-held Garmin Etrex Global Positioning System (GPS) device with an accuracy of 15 meters, were recorded in the field logbook. The boundaries and sampling locations were also mapped by Territorial Engineering and Surveying, Inc. The survey met minimum conventional theodolite traverse control standards (third order geodetic control and 1:5000 accuracy).

In addition to boundary determinations, the project area was divided into seven subreaches, which are displayed in Figure 2. Subreach boundaries were based on hydrologic and geomorphic changes within the stream channel, distinct changes in mine waste deposition, and by vegetation characteristics within the riparian zone. Subreaches are described below sequentially from the top (highest elevation) boundary on Jill Creek to the lower boundary on Jack Creek at the USFS property line.

Subreach A is located at the top boundary of the injured area on Jill Creek. This short segment ranges from 6774 feet to 6790 feet in elevation. It is characterized as a boulder/step pool stream sequence with a steep incline and a narrow floodplain. The riparian zone associated with this subreach should be lush and somewhat impenetrable. Instead, it is sparsely vegetated, consisting of bare ground and numerous dead lodgepole pine, Engelmann spruce, and subalpine fir. The large, woody debris is making its way to the channel area.

Subreach B, located on Jill Creek directly below Subreach A, is characterized as a boulder/log cascade sequence with a very steep incline. Elevations range from 6714 to 6774 feet. The vegetation types and characteristics are similar to those described in Subreach A.

Subreach C is characterized as a woody debris stream sequence with a moderate incline. With elevations ranging from 6664 to 6714 feet, this subreach is located on Jill Creek directly below Subreach B. The floodplain in this subreach widens dramatically to encompass extensive



Woody debris stream sequence, Subreach C

overflow channels on the right side of the stream.

Subreach D runs from a logjam on Jill Creek below Subreach C to the confluence of Jack and Jill Creeks. With elevations ranging from 6645 to 6664 feet, it is characterized as a boulder/step pool stream sequence with a steep incline and moderate floodplain width. It is braided with a side channel on the right (looking downstream), and an inundated zone on the left (looking downstream) that is composed of wetland graminoids. Similar to Subreaches A, B, and C, Subreach D is sparsely vegetated.

Subreach E starts at the confluence of Jack and Jill Creeks. The highest elevation on this subreach is 6664 feet, while the lowest is 6622 feet. It is characterized as a flat, moderately wide, highly braided stream delta. The additional discharge from Jack Creek has flushed the floodplain relatively free of tailings.



Confluence of Jack and Jill Creeks

Subreach F, situated directly below Subreach E, is characterized as a slow-moving logjam stream sequence with a moderate incline. The elevation ranges from 6616 to 6622 feet. The surrounding floodplain zone is wide and contains a historic beaver dam complex. Large tailings piles exist here, and the current system has cut back down to an equilibrium channel elevation.

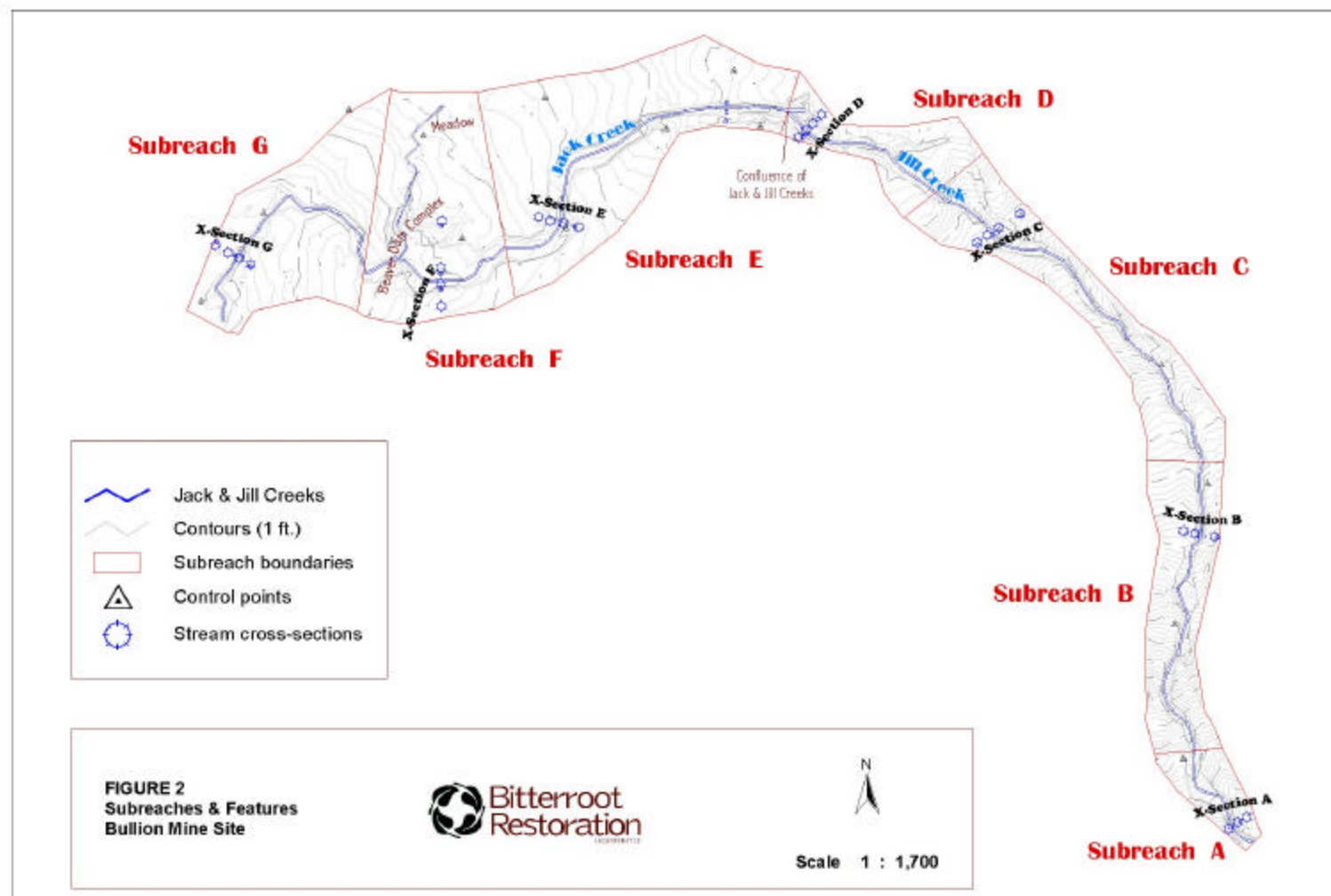


Tailings piles at historic beaver dam complex



Forested riparian zone on Subreach G

Subreach G has a moderate incline, with elevations ranging from 6607 to 6616 feet. The lower boundary of this subreach is defined by the USFS property line, and the upper boundary is immediately below the main beaver complex (Subreach F). This subreach has healthier, denser plant life and a more typical stream morphology than the subreaches described above. The surrounding floodplain zone is wide and marshy.



4.4 Mine Waste and Soil Sampling

The field investigation involved the collection of nine mine waste samples and nine soil samples, as well as the field analysis of 45 mine waste samples and 46 soil samples by XRF following EPA Method 6200. Sample locations are displayed and numbered on the map in Figure 3. The field distinction between “mine wastes” and “soils” was based upon a cursory field assessment of textural and color properties. The mine waste sampling locations were located on and around mine waste tailings piles, while the soil samples were collected from soils underlying or adjacent to mine waste materials. These areas included surface soils in places exposed to runoff/erosion from waste areas and/or soils beneath waste piles. The sampling sites, located at cross-sections along the contaminated stream, were designed to determine the types and amounts of contamination. For the most part, sampling locations were evenly distributed throughout the site. The exception was that representative mine waste piles were sampled. Composite samples were extracted to a maximum depth of one meter (39.4 inches). The samples were composited by mixing them in a clean container (a new heavy gauge plastic “trash compactor” bag for each sample, lining a five-gallon plastic bucket).



Field analysis for total metals concentration using an XRF

All samples were analyzed for total metals concentration using a Spectrace 9000 portable XRF, which allows for an on-site rapid assessment of the elemental spectrum. The XRF's detection limits, precision, and accuracy are provided in Appendix F. Additionally, a subset of 18 confirmation samples, co-located with the XRF sampling sites, was analyzed for total metals, (Laboratory analyses for chemicals of potential concern (COPC) concentrations occurred via atomic emission spectrometry (EPA Methods 200.2 series))

water extractable metals, pH, electrical conductivity and Acid-Base Accounting (ABA). Total metal concentration results from the 18 co-located sites were used for confirmatory analysis and to calibrate the XRF against the more accurate laboratory-analyzed samples. Following collection, laboratory samples, each weighing approximately one kilogram, were stored in individually sealed containers and shipped on ice to SVL Analytic in Kellogg, Idaho for analysis. Standard Chain of Custody (COC) procedures were followed to track and identify the individual samples. COC procedures are described in SOP A13 – Sample Handling, Documentation, and Tracking Procedures.

4.5 Surface Water Sampling

A total of seven representative sites, located along cross-sections within each subreach, were sampled within the area of potential mine waste impact. Cross-section locations are displayed and numbered on the map in Figure 2. Surface water sampling was performed to monitor stream water volumes, flows, and analyte concentrations. Surface water quality analyses included total

metals concentrations, hardness, temperature, and pH. Laboratory analyses for COPC concentrations occurred via atomic emission spectrometry (EPA Methods 200.7 series).



Setting-up a cross section on Jill Creek

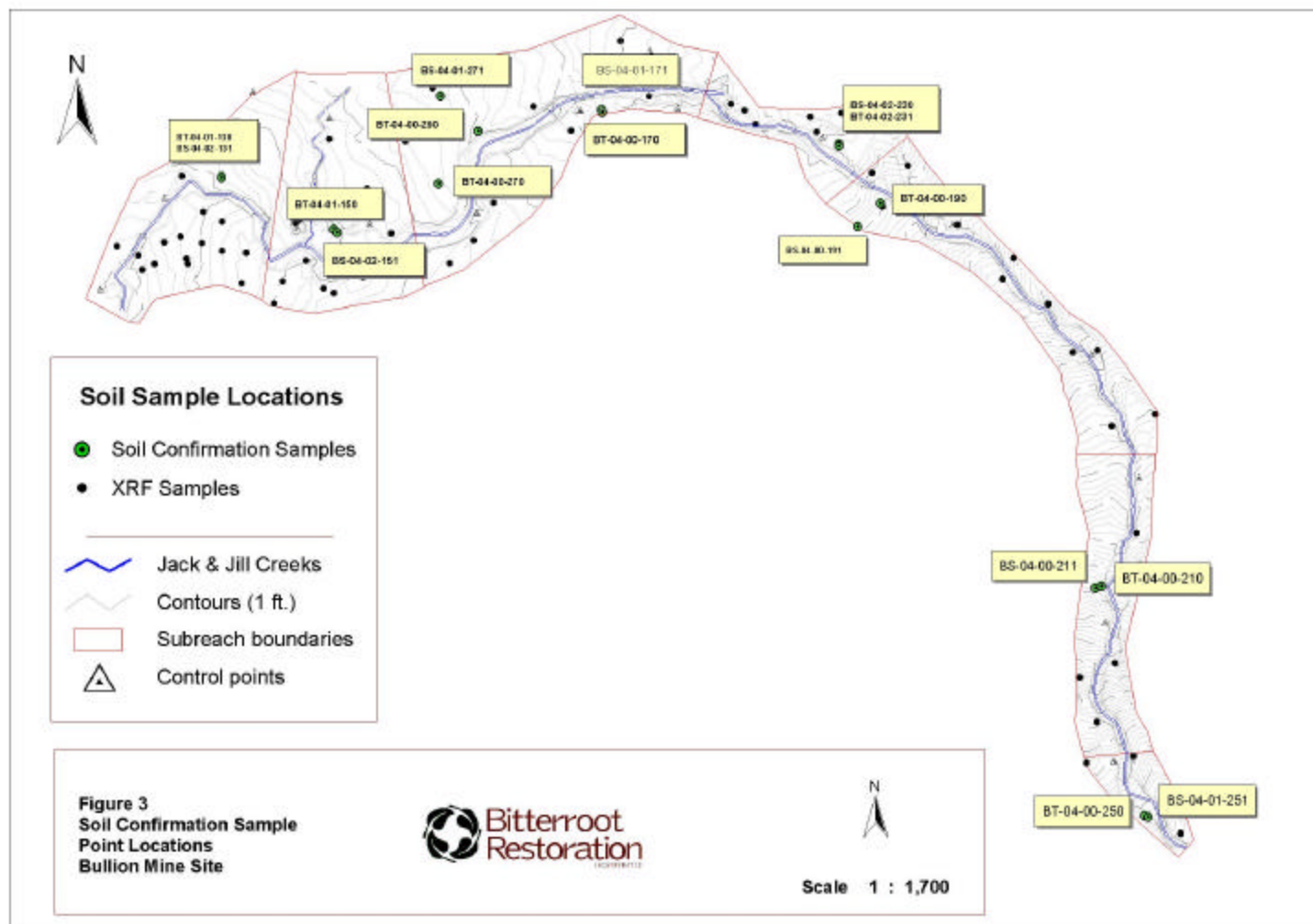
At each cross-section, the stream channel was subdivided into one to 10 segments of equal length depending on the width of the channel. The depth of the stream was measured in the middle of each segment. Velocity measurements were obtained from each stream segment using an FP201 Global Flow Probe hand-held flow meter with a five- to 15-foot expandable handle. Velocity readings were measured in feet per second with accuracies of plus-or-minus 0.1 feet per second for instantaneous velocity and plus-or-minus 0.01 feet per second for average and maximum velocity.

Velocity readings were determined by extending the flow meter handle to the appropriate length and placing the probe in the center of the channel of each stream segment within the respective cross-sections. The flow probe was moved slowly back and forth from the top of the water surface to the bottom of the channel for a minimum of one-minute to obtain a vertical flow profile. The average flow velocity for the stream cross-section, along with the date and time was recorded in the field logbook. The stream discharge was calculated by first determining the cross-sectional area of each stream channel segment, then multiplying the average velocity by the cross-sectional area, and finally averaging together the discharge of each segment to obtain a total stream discharge. Where flows are below the instrument's Limit of Detection (LOD) of 0.3 feet per second, flows are estimated as half the difference between zero and the LOD (e.g., 0.15 feet per second).

Stream temperature and pH measurements were collected using a waterproof Hanna instruments HI-9023 microcomputer pH and temperature meter. The pH meter is accuracy to 0.01 units and its collection capabilities range from 0.00 to 14.00 pH. The temperature meter can record temperatures ranging from 32 to 212 degrees Fahrenheit. It is accurate to 0.7 degrees Fahrenheit. The instrument was calibrated before each set of samples was obtained. To use the instrument, the probe was placed in the stream at the cross-section. Keeping the probe submerged, it was moved it slowly back and forth across the stream until the pH and temperature readings stabilized (approximately 2 minutes). The results were recorded into a permanent notebook.

Surface water samples were collected at each of the seven cross-sections with a depth-integrated wading device and were placed in sample containers supplied by SVL. To operate the wading device, it was moved up and down through the water column at set locations across the stream for a predetermined timeframe that depended on the stream size. The device was calibrated to collect equal amounts of water through the water column and across the stream. All excess water was disposed of by pouring gently out on the stream bank adjacent to the sampling location.

Once collected, the water samples were immediately preserved with nitric acid. The filled sample bottles and jars were labeled as specified in the *The Standard Operating Procedures*



(SOPs), (U.S. Army Corps of Engineers, Omaha District, 2002). The labeled bottles were placed in ice chests and cooled to approximately 4° C with the appropriate chain-of-custody paperwork. The cooler was shipped by overnight mail to SVL Analytic in Kellogg, Idaho.

4.6 Sediment Samples

Seven streambed sediment samples were collected from the streambed directly under the surface water sampling location. Samples, gathered at depths ranging from one-half inch to four inches, were collected in the interstices of cobbles with a stainless steel spoon. The samples were labeled and stored in one-liter sample containers provided by SVL Analytical with the appropriate chain-of-custody paperwork. The samples were shipped by overnight mail to SVL Analytic in Kellogg, Idaho. Laboratory analyses followed EPA Method 200.7.

4.7 Riparian Health Assessment

Riparian assessments were conducted with a focus on vegetative health. The rationale for looking at vegetation data is that the condition of plants in the riparian zone is a major component in determining the vigor of riparian ecosystems (Hansen, et al., 1995).

Riparian health assessments were conducted along four stream reaches in the injured area and one Reference Reach upstream of the injured area. Each Riparian Reach was representative of unique stream and vegetation characteristics found on Jack and Jill Creeks. The riparian vegetation is uniform over the entire length of the injured area on Jill Creek, thus, it was classified in the field as a single Riparian Reach. The hydrologic characteristics differ from the top to the bottom of the creek. Ultimately, Jill Creek was merged into one Riparian Reach, corresponding with Subreaches A through D, which are described in **Section 4.3 Boundary Delineation** of this report. Riparian Reach E, located at the confluence of Jack and Jill Creeks, corresponds with Subreach E. Riparian Reaches F and G correspond with Subreaches F and G, respectively.

Detailed vegetation data, physical site data, some wildlife data, trend commentary, and photograph were collected. The vegetation data gathered included species identification and canopy cover estimations, as well as age class breakdowns for each tree and shrub species. Physical site data included channel morphology and condition, substrate composition, disturbance degree and kind, amount and cause of bare ground, and commentary. Wildlife data included details of beaver activity and observations of fishery, amphibian, and reptile data.

The riparian inventory data collected for this project was originally gathered on the entire riparian zone, which extends laterally out to the valley toe slope foot. This area includes both the near-channel zone of mine tailing deposits, and a wide outer band on both sides unimpacted by these tailings contaminants. Subsequently, the width dimension was adjusted to reflect only the narrower floodplain impacted by deposition of mine tailings. The species data was also adjusted by eliminating those species found only under the forest canopy at the outer edge of the riparian zone. These steps were undertaken to reflect conditions within the narrower impacted zone, as opposed to the entire riparian habitat area.

The assessment used was developed by Dr. Paul Hansen and his team at the Riparian and Wetland Research Program, University of Montana at Missoula. Refer to Bitterroot Restoration's riparian and wetland website (<http://bitterrootrestoration.com/index.html>) for more information on the methodology used to conduct the riparian health assessments.

4.8 Rosgen Stream Classification—Level II

Reaches of stream channel may be classified according to morphological characteristics that reflect the stream's capacity to store/transport sediment. The relevant parameters, in order of importance, are channel slope, channel pattern, channel material size, the ratio of channel width to depth, the entrenchment ratio, and channel sinuosity (Rosgen 1996).

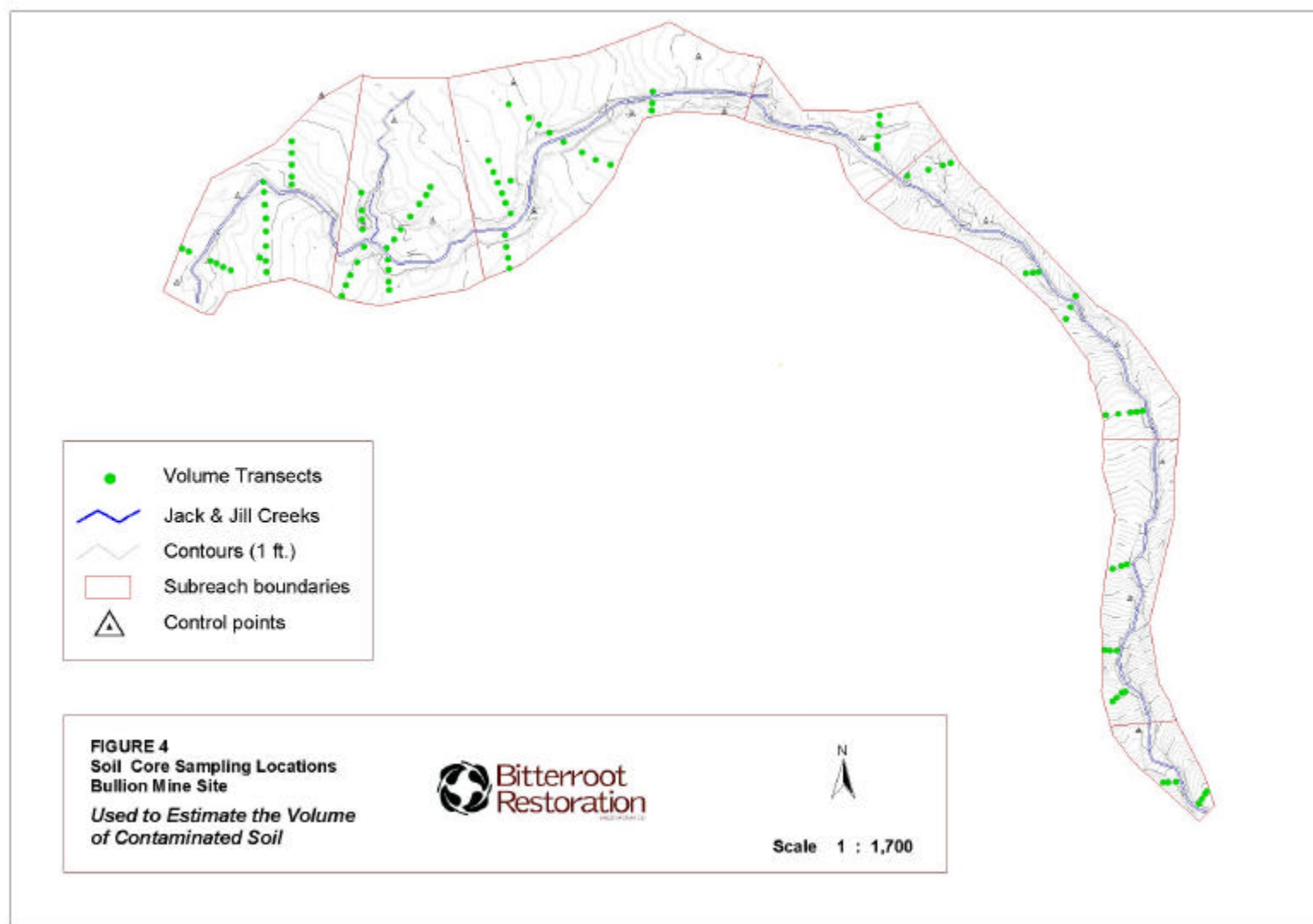
The bankfull channel width, flood prone width, the maximum and mean stream depths at bankfull stage, and the average channel material size were measured at a representative cross section within each subreach. These measurements were used to determine the width-to-depth ratio (bankfull width divided by bankfull mean depth), the width of the flood prone area (the flood prone area is defined as the area of floodplain inundated by a flood that reaches a depth twice the maximum bankfull stage depth), and the entrenchment ratio (entrenchment is the ratio of width of the channel at bankfull stage and that of the flood prone area). The channel material size was visually estimated within each subreach.

The channel slope and channel pattern data were derived in Geographic Information System (GIS) from the one-foot contour survey map. For each subreach of stream classified, average channel slope was determined as the percent drop (rise/run). The change in elevation and the segment length were used for this calculation. Channel pattern refers to sinuosity and number of threads (split around islands or a single stream body). Sinuosity was calculated as the ratio of channel length to valley length for the reach. These parameters are described by Rosgen (1996) and the calculations are in Appendix C.

4.9 Volume of Contaminated Material

The thickness and the extent of mine wastes were determined through soil core sampling. These calculations were used to estimate the volume of impacted floodplain materials. The soil depth/characteristics were examined at 100 sampling locations that were taken along 24 transects that intersected with mine waste and/or soil testing sites. Each transect ran from the stream edge to the site boundary. Sample locations are portrayed on Figure 4. To obtain representative depths of mine tailings across the cross section, sample locations were spaced apart 15 to 20 feet. Soil core samples were obtained with a soil auger. Soil was examined to a maximum depth of 3 feet. In many cases, water or river cobbles above 3 feet were encountered. Soil cores were divided into sections determined by variations in color and composition. The depth of each section to either cobbles or the water table was then measured and recorded. Data supporting the mine waste volume estimates are contained in Appendix D.

To obtain volume measurements, the soil depth for each sample was entered into GIS and interpolated across the injured area. When analyzing the field data, it was found that the



sampling density was insufficient for GIS interpolation, so the density of points was increased using ArcView 3.2, a GIS software, following the assumptions listed below:

- All locations in the streambed equal zero. In other words, no materials would be excavated from the actual streambed and no material would be removed below groundwater level.
- For a given contour line, the removal depths are equal at the site boundary on stream right and stream left.
- No material would be excavated from sampling locations with COPC levels below the recreation levels described in Table 6-1.

4.10 Topographic/Site Features Survey

A Topographic/Site Features Survey of the mine-waste impacted area was completed by Territorial Engineering and Surveying, Inc. and is found in Appendix B. The site was mapped on a local coordinate system using traditional surveying methods. Key points were mapped in latitude/longitude using a survey grade (sub-centimeter accurate) Global Positioning System (GPS) unit. The survey met minimum conventional theodolite traverse control standards (third order geodetic control and 1:5000 accuracy). In addition to constructing a survey with one-foot contours of the injured area, the surveying team mapped features of interest (old beaver dams, for example), stream cross-sections, and mine waste and soil sampling locations.

4.11 Quality Assurance and Control

Quality Control (QC) procedures used for mine wastes, soil, and water testing were consistent with methods described by the EPA and the *The Standard Operating Procedures (SOPs)* (U.S. Army Corps of Engineers, Omaha District, 2002). All samples collected in the field were prepared with appropriate COC documentation, including sample logs, sample identification (ID) numbers, and appropriate seals.

All samples were individually sealed in plastic bags prior to shipment. Mine waste and soil sample containers were wrapped in bubble wrap or other protective wrapping and stored in plastic boxes. Upon collection, nitric acid (reagent grade) was added to all water samples. The samples were immediately placed in ice chests and cooled to 4⁰ C or less. Boxes and ice chests were taped shut and sealed with custody seals. COC forms were signed as relinquished and sealed in bags and taped inside each box. COC forms were reviewed and signed by the laboratory upon receipt. The laboratory sent the final analytical results to BRI.

Field notes were kept in bound, waterproof notebooks. Notes were written in waterproof ink or pencil. Sample numbers were transferred to COC forms.

QC of the XRF analysis followed EPA Standard Operating Procedure No. 1713 (1995). The XRF calibration procedures included verification of potential multiple soil matrix types. Matrix differences, such as large variations in calcium or iron content, may affect XRF measurements.

5.0 LABORATORY ANALYSIS

5.1 Mine Waste and Soil Analysis

Eighteen confirmation samples, co-located with the XRF sampling sites, were analyzed for total metals. Data from the 18 co-located sites were used to calibrate the XRF against the more accurate laboratory-analyzed samples. Samples were analyzed in a laboratory via atomic emission spectrometry (see Table 5.1 below). In addition, the confirmation samples were assessed for acid generating potential (Acid-Base accounting).

TABLE 5.1 TOTAL METALS ANALYSIS

Target Constituent	Analytical Method
Arsenic	EPA M200.2 ICP-Total metals
Cadmium	EPA M200.2 ICP- Total metals
Copper	EPA M200.2 ICP- Total metals
Lead	EPA M200.2 ICP- Total metals
Zinc	EPA M200.2 ICP- Total metals

In addition, six mine waste samples (surface rock/soil samples) were analyzed for water extractable metals (Table 5.2).

TABLE 5.2 WATER EXTRACTABLE METALS ANALYSIS

Target Constituent	Analytical Method
Arsenic	EPA M200.7 ICP-water-extractable
Cadmium	EPA M200.7 ICP- water-extractable
Copper	EPA M200.7 ICP- water-extractable
Lead	EPA M200.2 ICP- water-extractable
Zinc	EPA M200.7 ICP- water-extractable

5.2 Surface Water and Sediment Analysis

Table 5.3 presents target metals for the surface water and streambed sediment samples.

TABLE 5.3 WATER AND STREAMBED SEDIMENT ANALYSES

Target Constituent	Analytical Method
Arsenic	EPA M200.2 ICP-Total metals
Cadmium	EPA M200.2 ICP- Total metals
Copper	EPA M200.2 ICP- Total metals
Lead	EPA M200.2 ICP- Total metals
Zinc	EPA M200.2 ICP- Total metals
pH	EPA M150.1
Conductivity	EPA M120.1

Sample analysis followed the quality control criteria set by the Environmental Chemistry Branch Laboratory and/or as per the *Final Work Plan, Restoration of Abandoned Mine Sites*, June 2002. Laboratory QC data are included with the raw analytic results in Appendix E.

6.0 DATA SCREENING CRITERIA

6.1 Mine Waste and Soil Standards

This report concentrates on five COPCs for recreational users: Arsenic, Cadmium, Copper, Lead, and Zinc. These COPCs are the standard suite of contaminants investigated on minelands in western Montana and northern Idaho. The remoteness of the site suggests that recreationists will be the population most likely to visit. The EPA's exposure limits for recreational users, presented in Table 6.1, govern contact to the COPCs in soil material. The primary exposure pathways are soil contact, inhalation and water ingestion. The standards assume that potential carcinogenic and non-carcinogenic health risks vary between recreational populations. The cleanup guidelines used in this report are based on a Hazard Index of 0.5 or an increased cancer risk of 5×10^{-4} . The latter is the carcinogenic risk for the gold panner/rock hound recreational population (Tetra Tech, 1996).

TABLE 6.1 EPA CLEANUP GUIDELINES FOR FIVE CHEMICALS OF POTENTIAL CONCERN FOR RECREATIONAL VISITORS

COPC	Arsenic	Cadmium	Copper	Lead	Zinc
Soil Ingestion/ Inhalation Cleanup Guideline (mg/kg)*	700	19,500	27,100	1,100	220,000

* Concentrations for Arsenic and Cadmium are based on an increased cancer risk of 5×10^{-4} , while Copper, Lead, and Zinc are based on a Hazard Index of 0.5.

6.2 Surface and Groundwater Standards

Table 6.2 presents water quality guidelines for the COPCs for this study. These standards govern exposure to COPCs by water ingestion.

TABLE 6.2 WATER QUALITY GUIDELINES

COPC	Montana DEQ Water Quality Standards Aquatic Life		Montana DEQ Water Quality Standards Human Health		Required Reporting Value	EPA National Primary Drinking Water Standards
	Acute	Chronic	Surface Water	Groundwater		
Arsenic	340	150	18	20	3	10 (as of 1/23/06)
Cadmium	1.05*	0.16*	5	5	0.1	5
Copper	7.3	5.2	1,300	1,300	1	1,300
Lead	82**	3.2**	15	15	3	15
Zinc	67*	67*	2,000	2,000	10	n/a

All values stated as micrograms/liter ($\mu\text{g/L}$)

* @ 50 mg/L hardness

** @ 100 mg/L hardness

7.0 RESULTS AND DISCUSSION

7.1 Mine Waste and Soil Results and Discussion

This investigation resulted in the collection of nine soil and nine mine waste samples, which were analyzed for total metals via ICP, water extractable metals, pH, conductivity and Acid-Base Accounting. In addition, 91 soil and mine waste samples were analyzed for total metals concentrations via XRF. Data for all lab analyses are in Appendix E, and XRF field analyses data are included in Appendix F.

An initial review of the results of the analysis, presented in Table 7.1, suggested little to no difference between the soil and mine waste samples. A Student's t-Test was utilized to examine whether this observation was statistically relevant (see Appendix G). As also shown in Table 7.1, there was no significant difference in analytic values between the soil and mine waste samples at $\alpha = 0.05$. This is likely due to the mixing of materials as a result of the disturbance ecology of the creek systems as well as to leaching of COPCs from mine wastes into pre-disturbance substrates. For the purpose of the remainder of the analyses, analytic results from the soil and mine waste samples were condensed into a single data set.

TABLE 7.1 COMPARISON OF ANALYTIC RESULTS FOR SOIL VERSUS MINE WASTE SAMPLES

Analyte	Soil*	Mine Waste*	t-Value	p-Value**
Arsenic (total mg/kg by ICP)	1,609 (2,015)	2,941 (2,247)	-1.32	0.20
Cadmium (total mg/kg by ICP)	5 (8)	1 (1)	1.53	0.15
Copper (total mg/kg by ICP)	464 (471)	178 (160)	1.73	0.10
Lead (total mg/kg by ICP)	887 (1,433)	1,526 (1,193)	-1.03	0.32
Zinc (total mg/kg by ICP)	429 (508)	157 (91)	1.59	0.13
Arsenic (total mg/kg by XRF)	1,978 (2,676)	2,866 (3,056)	-0.66	0.52
Cadmium (total mg/kg by XRF)	152 (122)	102 (37)	1.18	0.26
Copper (total mg/kg by XRF)	233 (177)	314 (268)	-0.76	0.46
Lead (total mg/kg by XRF)	867 (1,370)	1,101 (1,107)	-0.40	0.70
Zinc (total mg/kg by XRF)	316 (270)	194 (109)	1.26	0.23
Arsenic (mg/kg water extractable by ICP)	1 (2)	0 (0)	0.72	0.51
Cadmium (mg/kg water extractable by ICP)	0 (0)	0 (0)	1.08	0.34
Copper (mg/kg water extractable by ICP)	1 (1)	0 (0)	1.00	0.38
Lead (mg/kg water extractable by ICP)	1 (1)	0 (0)	0.87	0.44
Zinc (mg/kg water extractable by ICP)	12 (19)	0 (0)	1.04	0.36
pH (standard units)	4 (0)	4 (0)	2.04	0.06
Conductivity	381 (738)	115 (65)	1.08	0.30
Total Sulfur (total mg/kg)	0 (1)	0 (0)	0.62	0.54
Pyritic Sulfur (total mg/kg)	0 (0)	0 (0)	0.85	0.41
Sulfate Sulfur (total mg/kg)	0 (0)	0 (0)	0.37	0.71
Non-extractable Sulfur (total mg/kg)	0 (0)	0 (0)	1.30	0.21
Acid generating potential	4 (9)	1 (1)	0.84	0.41
Acid neutralizing potential	5 (3)	4 (3)	0.82	0.43
Acid-Base potential	1 (10)	3 (4)	-0.37	0.71

* Mean and standard deviation are reported as #(#)

** Significant difference at $\alpha = 0.05$

7.1.1 Total Metals from Field XRF Results

Table 7.2 presents total metal concentrations statistics for the soil and mine waste samples collected from Jack and Jill Creeks as analyzed by field XRF. In general, the XRF trends for these elements tend to follow the results of the laboratory analyses, although cadmium concentrations via XRF are an order of magnitude higher than the laboratory results.

TABLE 7.2 TOTAL METAL CONCENTRATIONS FROM FIELD XRF RESULTS

COPCs	Average Sample Concentration from Jack and Jill Creeks (mg/kg)*	Minimum Sample Concentration from Jack and Jill Creeks (mg/kg)	Maximum Sample Concentration from Jack and Jill Creeks (mg/kg)	Screening Criteria for Recreational Visitors (mg/kg)	Percent of 18 samples above COPC limits for Recreational Visitors
Arsenic	2,422 (2,823)	104	9240	700	56 percent
Cadmium	127 (91)	90	458	19,500	0 percent
Copper	274 (224)	36	680	27,100	0 percent
Lead	984 (1,214)	15	4191	1,100	28 percent
Zinc	255 (209)	35	882	220,000	0 percent

* Mean and standard deviation are reported as #(#)

** Shading indicates exceedance of screening criteria.

7.1.2 Total Metals from Laboratory Results

Table 7.3 presents mean total metal concentrations for the soil and mine waste samples collected from Jack and Jill Creeks. The results indicate that while arsenic and lead are significant metals of concern, arsenic is the major contributor in this system. In all cases where lead exceeds recreational exposure limits, arsenic is also exceeded, but arsenic levels may exceed exposure limits without a simultaneous exceedance in lead concentrations (Figures 4 and 5).

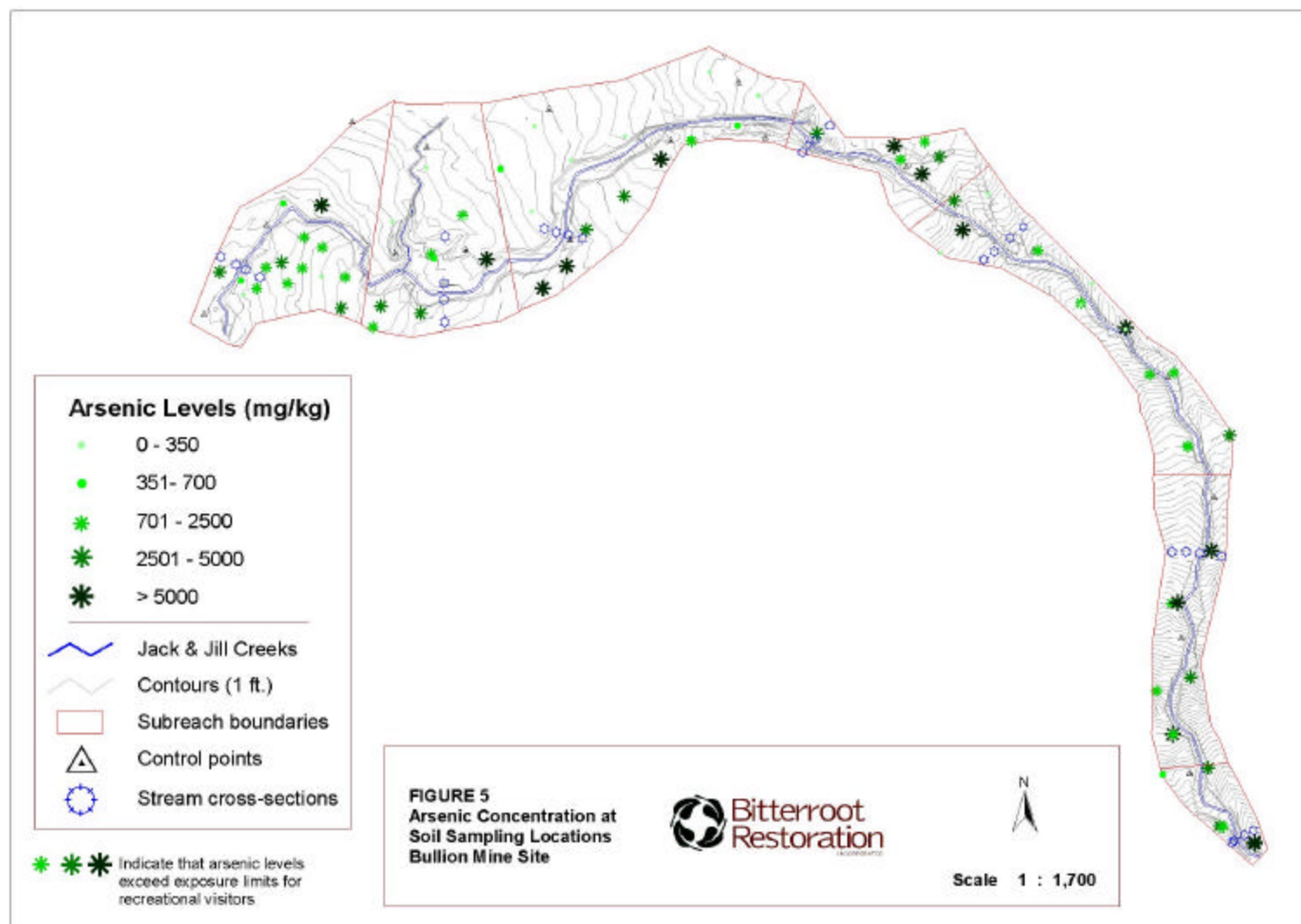
TABLE 7.3 TOTAL METAL CONCENTRATIONS FROM LABORATORY RESULTS

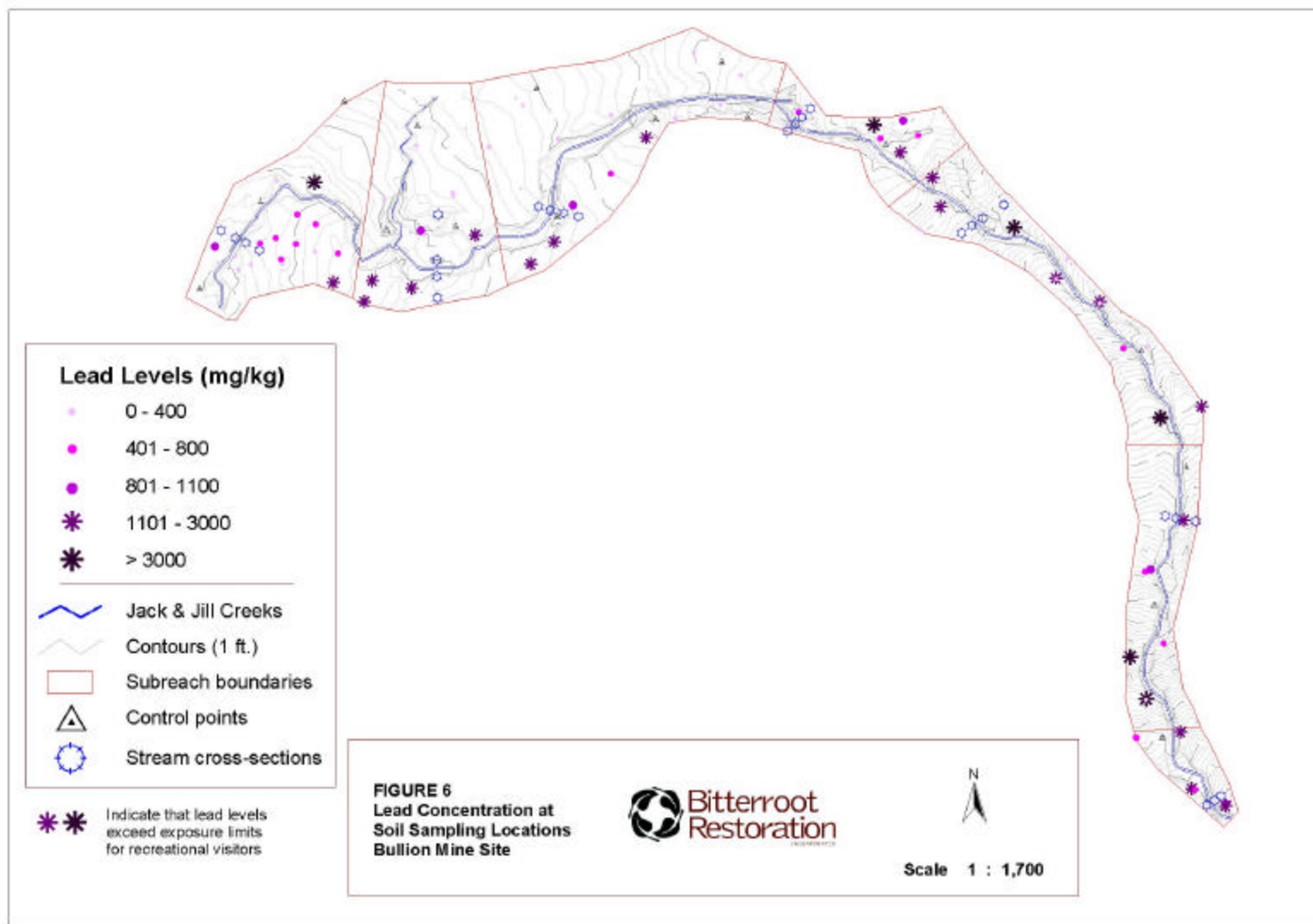
COPCs	Average Sample Concentration from Jack and Jill Creeks (mg/kg)	Minimum Sample Concentration from Jack and Jill Creeks (mg/kg)	Maximum Sample Concentration from Jack and Jill Creeks (mg/kg)	Screening Criteria for Recreational Visitors (mg/kg)	Percent of 18 samples above COPC limits for Recreational Visitors
Arsenic	2,275 (2,181)	82.2	6220	700	72 percent
Cadmium	3 (6)	0.2	24.7	19,500	0 percent
Copper	321 (372)	42.1	1280	27,100	0 percent
Lead	1,207 (1,321)	50.9	4620	1,100	39 percent
Zinc	293 (380)	43.4	1750	220,000	0 percent

* Shading indicates exceedance of screening criteria.

7.1.3 Statistical Comparison of XRF Results and Laboratory Results

A least squares regression analysis was utilized to determine whether the apparent trend is statistically significant. EPA Method 6200 stipulates that the correlation coefficient (R-squared) between ICP and XRF data needs to be greater than 0.7 for the XRF data to be considered





screening level data. The method also stipulates that if the data range spans greater than one magnitude, a log scale shall be used for analysis. As both data sets for all elements range across multiple magnitudes, a log-log correction was utilized. Least squares regression analysis, which was utilized to determine whether the apparent trend is statistically significant, is described in Appendix G. As shown in Table 7.4, a comparison of the two log-corrected data sets via least squares regression analysis indicates a poor relationship between results obtained by the two methods.

TABLE 7.4 LEAST SQUARES COMPARISON OF LOG-CORRECTED METAL CONCENTRATIONS VIA ICP AND FIELD XRF

COPCs	R ² for regression line	p-Value of regression line	R for regression
Arsenic	0.338	0.01*	0.58
Cadmium	0.116	0.17	0.34
Copper	0.200	0.06	0.45
Lead	0.374	0.007*	0.61
Zinc	0.631	<0.0001*	0.79

*Statistical significance at alpha = 0.05

While three of five regression analyses are statistically significant at alpha = 0.05, in no case is the correlation coefficient sufficiently strong to permit the analytic results via XRF to be used as screening level data. Nonetheless, the moderately strong correlations ($0.25 < R < 0.8$) for all elements, and particularly for zinc, lead and arsenic, indicate that the XRF data supports the more limited laboratory results data set and suggests that the Jack and Jill Creek floodplains contain significantly elevated levels of arsenic and lead.

7.1.4 Water-Extractable Metals Results for Soils and Mine Wastes

Table 7.5 presents water-extractable metal concentrations statistics for the soil and mine waste samples collected from Jack and Jill Creeks, as analyzed by EPA Method 200.7. Zinc has the highest concentration, which is to be expected given that it is among the most soluble of trace elements. All samples fell below Montana Department of Environmental Quality's water quality standards for human health.

TABLE 7.5 WATER-EXTRACTABLE METAL CONCENTRATIONS OF SOILS AND MINE WASTES VIA ICP

COPCs	Average Sample Concentration from Jack and Jill Creeks (mg/kg)*	Minimum Sample Concentration from Jack and Jill Creeks (mg/kg)	Maximum Sample Concentration from Jack and Jill Creeks (mg/kg)	Surface Water Threshold Concentration (mg/kg) for Human Health Concerns (MT DEQ)
Arsenic	0.7 (1.3)	0.005	3.4	18
Cadmium	0.1 (0.2)	0.001	0.4	5
Copper	0.4 (0.5)	0.035	1.3	1,300
Lead	0.3 (0.7)	0.003	1.6	15
Zinc	6.0 (13.2)	0.124	33.0	2,000

* Mean and standard deviation are reported as #(#)

7.1.5 pH and Conductivity Results for Soils and Mine Wastes

Table 7.6 presents pH and conductivity statistics for the soil and mine waste samples collected from Jack and Jill Creeks. All samples had highly acidic values. Five of the 18 samples had values less than 3.5 standard units, a level of extreme acidity where acid sulfates can be readily present (see 7.1.6 *Acid-Base Accounting Results for Soils and Mine Wastes* below). Twelve of the samples had pH values between 3.5 and 4.5, a level of high acidity at which exchangeable aluminum can be significantly phytotoxic.

TABLE 7.6 pH AND CONDUCTIVITY VALUES OF SOILS AND MINE WASTES

Analyses	Average Sample Values from Jack and Jill Creeks*	Minimum Average Sample Values from Jack and Jill Creeks	Maximum Average Sample Values from Jack and Jill Creeks
pH (standard units)	3.82 (0.48)	2.98	4.74
Conductivity (µmho/cm)	248 (526)	54.2	2340

* Mean and standard deviation are reported as #(#)

There are two major diagnostic thresholds that use soil electrical conductivity as a prime measure. Conductivity of greater than 2,000 µmho/cm @ 25 C° is one of the indications of an Aridisol, while conductivity of greater than 4,000 µmho/cm @ 25 C° defines a saline soil (Boul and others 1989). Only one sample from Jack and Jill Creek exceeds the 2,000 µmho/cm threshold. Soil salinity is not a significant problem in these soils.

7.1.6 Acid-Base Accounting Results for Soils and Mine Wastes

Table 7.7 presents Acid-Base Accounting results for the soils and mine wastes from Jack and Jill Creeks. The most significant results are the Acid-Base Potential values. Three of 18 samples displayed negative Acid-Base Potential values, indicating that they are acid generating. While the floodplain materials are strongly acidic, the acid generating potential of these materials is being exhausted.

TABLE 7.7 ACID-BASE ACCOUNTING RESULTS FOR SOILS AND MINE WASTES

Analyses	Average Sample Values from Jack and Jill Creeks*	Average Sample Values from Jack and Jill Creeks	Maximum Average Sample Values from Jack and Jill Creeks
Total sulfur (mg/kg)	0.15 (0.38)	0.01	1.67
Pyritic sulfur (mg/kg)	0.08 (0.20)	0.01	0.86
Sulfate sulfur (mg/kg)	0.07 (0.18)	0.005	0.75
Non-extractable sulfur (mg/kg)	0.01 (0.01)	0.005	0.06
Acid generating potential (TCaCO ₃ /1000T)	2.4 (6.2)	0.15	26.9
Acid neutralizing potential (TCaCO ₃ /1000T)	4.3 (2.9)	1.08	9.29
Acid-Base potential (TCaCO ₃ /1000T)	2.0 (7.3)	-24.3	8.67

* Mean and standard deviation are reported as #(#)

7.2 Surface Water Quality Results and Discussion

Seven water quality samples were collected and analyzed for total metals, pH, temperature, and hardness. The results of these analyses are shown in Table 7.8 and Figure 6. A review of the results suggested that there was a significant difference between values for Jack Creek and Jill Creek.

TABLE 7.8 WATER SAMPLE RESULTS

Analyses	Average Sample Values from Jack and Jill Creeks*	Minimum Sample Values from Jack and Jill Creeks	Maximum Sample Values from Jack and Jill Creeks	Average Sample Values from Jack Creek*	Average Sample Values from Jill Creek*
Arsenic (dissolved metal mg/L)	30 (43)	5	126	8 (5)	47 (53)
Cadmium (dissolved metal mg/L)	29 (18)	8	44	10 (1)	43 (2)
Copper (dissolved metal mg/L)	480 (314)	121	798	149 (25)	729 (67)
Lead (dissolved metal mg/L)	10 (13)	3	39	3 (0)	16 (15)
Zinc (dissolved metal mg/L)	3,066 (1,880)	869	4680	1,060 (167)	4,570 (100)
pH (standard units)	6.5 (0.9)	5.61	7.48	7.4 (0.05)	5.81 (0.2)
Temperature (° F)	44.3 (4.5)	40.5	49.1	43.6 (4.8)	44.75 (4.9)
Hardness (mg/L)	79.9 (23.8)	51.3	99.7	54.6 (2.8)	98.90 (0.9)

* Mean and standard deviation are reported as #(#)

A Student's t-Test was utilized to examine whether the apparent differences were statistically relevant (See Appendix G). Also shown in Table 7.9, there was a significant difference in all analytic values between most sediment analytic results at alpha = 0.05 except for total arsenic and lead concentrations and water temperature.

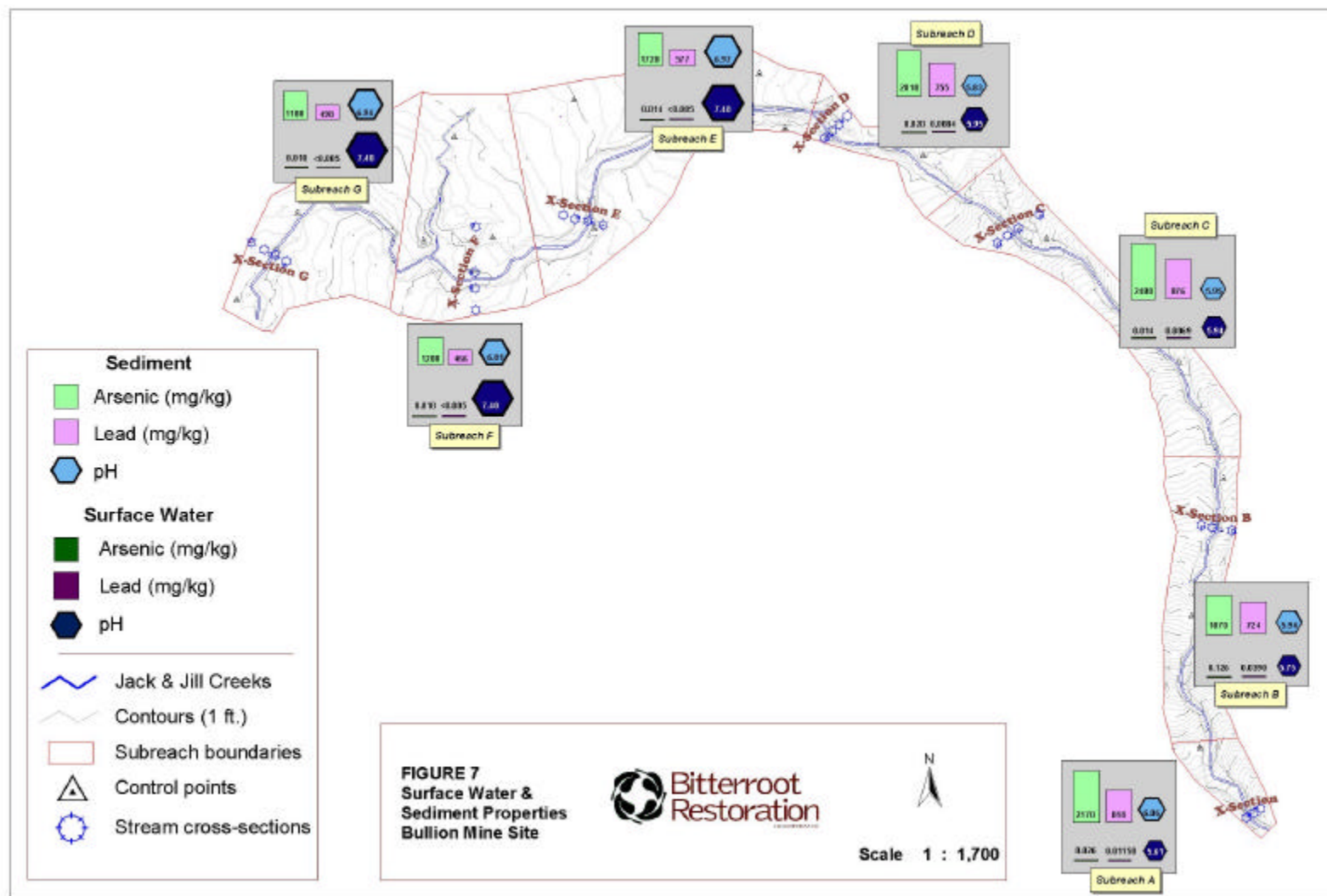
TABLE 7.9 COMPARISON OF WATER SAMPLE RESULTS JACK CREEK VERSUS JILL CREEK

Analyses	Average Sample Values from Jack Creek*	Average Sample Values from Jill Creek*	t-Value	p-Value
Arsenic (dissolved metal mg/L)	8 (5)	47 (53)	-1.2	0.3
Cadmium (dissolved metal mg/L)	10 (1)	43 (2)	-28.5	<0.0001**
Copper (dissolved metal mg/L)	149 (25)	729 (67)	-13.9	<0.0001**
Lead (dissolved metal mg/L)	3 (0)	16 (15)	-1.6	0.2
Zinc (dissolved metal mg/L)	1,060 (167)	4,570 (100)	-35.0	<0.0001**
pH (standard units)	7.4 (0.05)	5.8 (0.2)	16.3	<0.0001**
Temperature (° F)	43.6 (4.8)	44.8 (4.9)	-0.3	0.8
Hardness (mg/L)	54.6 (2.8)	98.9 (0.9)	-30.2	<0.0001**

* Mean and standard deviation are reported as #(#)

**Statistically significant difference at alpha = 0.05

Jill Creek lies upstream of Jack Creek and therefore closer to the source of mine wastes and acid mine drainage from the Bullion Mine Adit and has a significantly lower pH and higher concentration of metals than Jack Creek. The probable cause for this trend is that the metals under consideration generally show greater solubility at lower pH levels. Arsenic, a metalloid,



has the reverse relationship, with its solubility increasing as pH increases. Increases of arsenic solubility are not as significant until pH values increase above the ranges measured in the two drainages. This last factor is a likely explanation for no significant change in dissolved arsenic concentration between Jack and Jill Creek.

While Jill Creek exceeds Jack Creek in percent of water samples above water quality standards for human health, all water samples exceeded cadmium standards (Table 7.10).

TABLE 7.10 WATER QUALITY SAMPLE COMPLIANCE WITH HUMAN HEALTH STANDARDS

Analyses	Montana DEQ Water Quality Standards for Human Health	Percent of Samples Above MT DEQ Water Quality Standards for Human Health: Jack and Jill Creeks	Percent of Samples Above MT DEQ Water Quality Standards for Human Health: Jack Creek	Percent of Samples Above MT DEQ Water Quality Standards for Human Health: Jill Creek
Arsenic (dissolved metal mg/L)	0.018	29	0	50
Cadmium (dissolved metal mg/L)	0.005	100	100	100
Copper (dissolved metal mg/L)	1.300	0	0	0
Lead (dissolved metal mg/L)	0.015	0	0	0
Zinc (dissolved metal mg/L)	2.000	57	0	100

With the exception of arsenic, all of the COPC values from the Jack and Jill Creeks water samples exceeded the chronic values recommended in the Montana DEQ aquatic life water quality standards. Cadmium, copper, and zinc concentrations exceeded the aquatic life criterion acute values (Table 7.11).

TABLE 7.11 WATER QUALITY SAMPLE COMPLIANCE WITH AQUATIC LIFE STANDARDS

Analyses	MT DEQ Water Quality Standards for Aquatic Life		Percent of Samples Above MT DEQ Water Quality Standards for Aquatic Life: Jack Creek		Percent of Samples Above MT DEQ Water Quality Standards for Aquatic Life: Jill Creek	
	Acute	Chronic	Acute	Chronic	Acute	Chronic
Arsenic (dissolved metal mg/L)	0.340	0.150	0	0	0	0
Cadmium (dissolved metal mg/L)	0.00105*	0.00016*	100	100	100	100
Copper (dissolved metal mg/L)	0.0073	0.0052	100	100	100	100
Lead (dissolved metal mg/L)	0.082**	0.0032**	0	100	0	100
Zinc (dissolved metal mg/L)	0.067*	0.067*	100	100	100	100

* @ 50 mg/L hardness

** @ 100 mg/L hardness

7.3 Streambed Sediment Results and Discussion

Seven sediment samples were collected and analyzed for total metals, pH and conductivity. The results of these analyses, shown in Table 7.12, indicated that there was a significant difference in sediment samples between Jack and Jill Creeks.

TABLE 7.12 SEDIMENT ANALYTICAL RESULTS

Analyses	Average Sample Values from Jack and Jill Creeks*	Minimum Sample Values from Jack and Jill Creeks	Maximum Sample Values from Jack and Jill Creeks	Average Sample Values from Jack Creek*	Average Sample Values from Jill Creek*
Arsenic (total metal mg/kg)	1,804 (483)	1180	2480	1,367 (306)	2,133 (262)
Cadmium (total metal mg/kg)	27 (14)	13.6	51.6	40 (10)	16 (2)
Copper (total metal mg/kg)	1,051 (375)	653	1790	1,093 (610)	1,020 (171)
Lead (total metal mg/kg)	673 (160)	466	876	514 (57)	793 (68)
Zinc (total metal mg/kg)	2,021 (1,070)	1110	4060	3,000 (927)	1,288 (200)
pH (standard units)	6 (1)	5.83	6.94	7 (0.1)	6 (0.1)
Conductivity (µmho/cm)	390 (55)	317	445	366 (63)	409 (48)

* Mean and standard deviation are reported as #(#)

A Student's t-Test was utilized to examine whether the apparent differences were statistically relevant. Also shown in Table 7.13, there was a significant difference in all analytic values between most sediment analytic results at alpha = 0.05, except for total copper concentration and conductivity.

TABLE 7.13 COMPARISON OF ANALYTICAL RESULTS FOR JACK CREEK AND JILL CREEK

Analyses	Average sample value from Jack Creek*	Average sample value from Jill Creek*	t-Value	p-Value
Arsenic (total metal mg/kg)	1,367 (306)	2,133 (262)	-3.6	0.02*
Cadmium (total metal mg/kg)	40 (10)	16 (2)	4.8	0.01*
Copper (total metal mg/kg)	1,093 (610)	1,020 (171)	0.2	0.82
Lead (total metal mg/kg)	514 (57)	793 (68)	-5.8	0.002*
Zinc (total metal mg/kg)	3,000 (927)	1,288 (200)	3.7	0.01*
pH (standard units)	7 (0.1)	6 (0.1)	14.5	<0.0001*
Conductivity (µmho/cm)	366 (63)	409 (48)	-1.0	0.35

* Mean and standard deviation are reported as #(#)

*Statistically significant difference at alpha = 0.05

These trends in sediment do not parallel those from the surface water results. While Jill Creek exhibits more acidic sediments and higher lead concentrations than Jack Creek, Jill Creek has higher arsenic concentrations but lower cadmium and zinc concentrations than Jack Creek. As pH increases downstream, metals such as cadmium and zinc may become less mobile and precipitate, while arsenic may become more mobile and therefore may be reduced in relative concentration along Jack Creek.

Exhibited in Table 7.14, all sediment samples from both Jack and Jill Creeks exceed Montana's 700 ppm soil arsenic concentration limits for recreational visitors. The remaining COPCs

examined for this investigation were in compliance with EPA cleanup guidelines for recreationalists.

TABLE 7.14 COMPLIANCE WITH EPA CLEANUP GUIDELINES FOR RECREATIONALISTS

Analyses	Soil Ingestion/ Inhalation Cleanup Guidelines (mg/kg)	Percent of Samples Above EPA Soil Ingestion/Inhalation Guidelines: Jack and Jill Creeks	Percent of Samples Above EPA Soil Ingestion/Inhalation Guidelines: Jack Creek	Percent of Samples Above EPA Soil Ingestion/Inhalation Guidelines: Jill Creek
Arsenic	700	100	100	100
Cadmium	19,500	0	0	0
Copper	27,100	0	0	0
Lead	1,100	0	0	0
Zinc	220,000	0	0	0

7.4 Riparian Health Assessment

Table 7.15 illustrates the functional scores and habitat/community types found on the project site. Functional scores, ranging from zero to 100 percent, were derived by rating riparian vegetation and soil/hydrology conditions. A stream that scores between 100 and 80 percent is considered in proper functioning condition (healthy). Scores between 79 and 60 percent indicate that the stream is functional, but at-risk of degradation (healthy, but with problems).

Nonfunctioning (unhealthy) streams score below 60 percent. The vegetation and soil/hydrology factors assessed included diversity, cover, and regeneration of vegetation, as well as the amount of bare ground present, and the condition of the stream banks. A healthy stream system supports dense vegetation that is regenerating and has little to no exposed ground. The stream banks do not experience much erosion due to armoring from large rocks and binding root mass.

This assessment/scoring system, developed by Dr. Paul Hansen, is thoroughly described on BRI's riparian and wetland website (<http://bitterrootrestoration.com/index.html>).

The vegetation within the project site scored between 63 and 70 percent, which is considered functional, but at-risk of further degradation. The soils and hydrology, with scores between 73 and 87 percent, is also functional, but at-risk of further degradation. In contrast, the reference reach, located approximately one-half mile above the Jack and Jill Creek confluence, scored 93 percent for vegetation health and 90 percent for soil/hydrology health. The Reference Reach is therefore considered as functional and healthy.

The most common vegetation community type identified across the Reference Reach, the four Riparian Reaches on Jill Creek, and one Riparian Reach on Jack Creek consists of Engelmann Spruce (*Picea engelmannii*) (overstory) and Bluejoint Reedgrass (*Calamagrostis canadensis*) (understory). Significant portions of Riparian Reaches A through D and Riparian Reach E are unvegetated. These bare areas are categorized as an "Unclassified" habitat/community type. Riparian Reaches F and G, located on slower moving, meandering stream sections of Jack Creek, are dominated by the Subalpine Fir (*Abies lasiocarpa*) (overstory) and Bluejoint Reedgrass (*Calamagrostis canadensis*) (understory) habitat type. Both Riparian Reaches host a second habitat type – Drummond Willow (*Salix drummondiana*) (overstory), and Beaked Sedge (*Carex*

rostrata) (understory) for Riparian Reach 5 and Planeleaf Willow (*Salix planifolia*) (overstory), Water Sedge (*Carex aquatilis*) (understory) for Riparian Reach G. The riparian health assessments for the Bullion project are provided in Appendix C.

TABLE 7.15 RIPARIAN HEALTH ASSESSMENT RESULTS, FUNCTIONAL SCORES, & HABITAT TYPES

Location	Vegetation	Soil/ Hydrology	Overall Health	Habitat/ Community Type 1	Habitat/ Community Type2
Reference Reach	93	90	91	Engelmann Spruce/Bluejoint Reedgrass	N/A
Jill Creek					
Riparian Reach A	70	73	72	Engelmann Spruce/Bluejoint Reedgrass	Unclassified
Riparian Reach B	70	73	72	Engelmann Spruce/Bluejoint Reedgrass	Unclassified
Riparian Reach C	70	73	72	Engelmann Spruce/Bluejoint Reedgrass	Unclassified
Riparian Reach D	70	73	72	Engelmann Spruce/Bluejoint Reedgrass	Unclassified
Jack Creek					
Riparian Reach E	63	80	72	Engelmann Spruce/Bluejoint Reedgrass	N/A
Riparian Reach F	70	60	65	Subalpine Fir/Bluejoint Reedgrass	Drummond's Willow/Beaked Sedge
Riparian Reach G	70	87	79	Subalpine Fir/Bluejoint Reedgrass	Planeleaf Willow/Water Sedge

7.5 Hydrologic and Geomorphic Characteristics (Rosgen Stream Classification—Level II)

From a topographic and geomorphic perspective, Jill and Jack Creeks are very different. Jill Creek, a tributary of Jack Creek flows down a steep mountainside. Jack Creek flows through a valley with moderate to gentle slopes and a fairly wide floodplain. These differences are reflected in the hydrologic measurements described below. Riparian Reaches A through C on Jill Creek exhibit very low discharges. The rate increases significantly on Riparian Reach D, probably due to a series of springs toward the bottom of this section. Discharge is at its highest, 1.86 cubic feet per second (cfs), at the confluence of Jack and Jill Creeks (Riparian Reach E). It steadily declines thereafter. Water diffusion into the broad hydrology of the beaver dam complex may account for the decline.

The stream gradient decreases as one moves downstream, from an average of 8.5 percent on Jill Creek to 2.3 percent on Jack Creek. Sinuosity scores also reflect the topographic differences

between Jack and Jill. The average sinuosity of Jill is 1.07; it increases to 1.23 on Jack Creek where the stream has room to meander. The flood-prone width widens from an average of 46 feet on Jill to 69 feet on Jack Creek.

The Rosgen stream typing method was used to characterize stream Riparian Reach morphology on Jack and Jill Creeks.

- **Rosgen Stream Types A4/A4+:** Riparian Reaches A through D on Jill Creek were rated as A4 or A4a+. Briefly described, an A4 and A4a+ streams are cascading step/pool sequences that are steep, confined, and entrenched. These high-energy systems with low sinuosity are capable of heavy debris transport. The substrate materials are mainly composed of gravel.
- **Rosgen Stream Type B:** Riparian Reach E at the top of Jack Creek, is a B3 Rosgen stream type. It has a moderate gradient with moderate entrenchment, and moderate to high sinuosity. It is dominated by riffles with infrequently spaced pools. The substrate material is principally cobbles. Riparian Reach F, located directly below Riparian Reach E, is a B4 Rosgen stream type. It has a moderate gradient with moderate entrenchment, and moderate to high sinuosity. It is dominated by riffles with infrequently spaced pools. The substrate material is principally gravel.
- **Rosgen Stream Type C:** Riparian Reach G at the bottom of the injured area on Jack Creek is classified as a C3 Rosgen stream type. C3 stream reaches tend to reside in broad valley with floodplains and alluvial soils. These moderately sloped, meandering reaches have moderate to high sinuosity, and are associated with riffle/pool bed morphology. Cobbles are the main substrate material.

Analytical data are presented in Table 7.16 below.

TABLE 7.16 HYDROLOGIC AND GEOMORPHIC CHARACTERISTICS

Location	Discharge (ft ³ /sec)	Flood prone Width (ft.)	Slope (%)	Sinuosity	Rosgen Stream Type	Channel Materials
Jill Creek averages	0.41	46	8.5	1.07	N/A	N/A
Riparian Reach A	0.12	17.6	8	1.12	A4	Gravel
Riparian Reach B	0.19	48.50	12	1.09	A4a+	Gravel
Riparian Reach C	0.03	81.2	8	1.04	A4	Gravel
Riparian Reach D	1.32	36.3	6	1.05	A4	Gravel
Jack Creek averages	1.21	69	2.3	1.23	N/A	N/A
Riparian Reach E	1.86	42.7	3	1.03	B3	Cobbles
Riparian Reach F	1.19	100.0	2	1.21	B4	Gravel
Riparian Reach G	0.93	64.9	2	1.46	C3	Cobbles

7.6 Volume Estimate of Contaminated Materials

Based upon methods previously discussed, the following field estimate of contaminated materials recommended for removal was developed for the Bullion site. These figures were not calculated using formal engineering tools and are not intended to take the place of a thorough engineering estimate and cost analysis. They are presented to give stakeholders a general idea of the volume of contaminated materials present at the Bullion project site.

As Table 7.17 portrays, the materials exceeding screening criteria are spread fairly evenly across the site. With the exception of subreaches A and D, approximately 50,000 cubic feet of mine waste and soils are recommended for removal in each subreach. The total amount of contaminated materials is estimated at 284,157 cubic feet.

TABLE 7.17 VOLUME ESTIMATE OF CONTAMINATED MATERIALS

Volume (ft. ³)	Subreach A	Subreach B	Subreach C	Subreach D	Subreach E	Subreach F	Subreach G
	7,610	48,914	53,109	15,876	50,428	56,896	51,324

8.0 CONCLUSIONS

The results from this site investigation indicate that the levels of contamination in and around Jack and Jill Creeks exceed established protective limits for recreational populations. Arsenic is the major COPC in the system. Seventy-two percent of soil and mine waste samples contained arsenic concentrations above screening criteria for recreational visitors, and the average arsenic concentration in these samples was over 3 times higher than the limits. In addition, all streambed sediments collected exceeded Montana's soil arsenic exposure limit of 700 ppm. Lead concentrations for 39 percent of soil and mine waste samples exceeded the screening criteria for recreational visitors.

The surface water in Jack and Jill Creeks also shows elevated levels of metals. This is the likely cause of the complete absence of observed aquatic life in the injured area on Jack and Jill Creeks. Jill Creek is more heavily impacted than Jack Creek. Water samples from Jill Creek display concentrations of arsenic, cadmium, zinc, and lead above the Montana water quality standards for human health. Additionally, the surface water was acidic on Jill Creek, reflecting both its closer proximity to the acid mine drainage of the Bullion Mine site, as well as the slight dilution effect occurring below the confluence with Jack Creek.

The riparian health assessments also indicate that the ecological integrity of the system is compromised. Many parts of the flood-prone zone are devoid of vegetation, likely due to the high concentrations of metals in the floodplain soils. In addition, the channels of both Jill and Jack Creeks are moderately to significantly entrenched, reflecting probable historic changes in the hydrology of the system.

Based upon its site investigation, BRI therefore concludes that Jack and Jill Creek are significantly impacted, with levels of COPCs in the floodplain materials, streambed sediments and water exceeding the limits for recreational exposure and human health. The removal of

approximately 284,157 cubic feet of contaminated tailings materials, the reconstruction of the impacted stream channel and floodplain areas, and the restoration of the impacted riparian zone are recommended.

9.0 REFERENCES

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APPENDICES

For

ABANDONED MINE SITE INVESTIGATION OF THE BULLION MINE SITE ALONG JACK AND JILL CREEKS, MONTANA

Prepared for:

U.S. Army Corps of Engineers, Sacramento District and
U.S. Army Corps of Engineers, Omaha District

Prepared By:

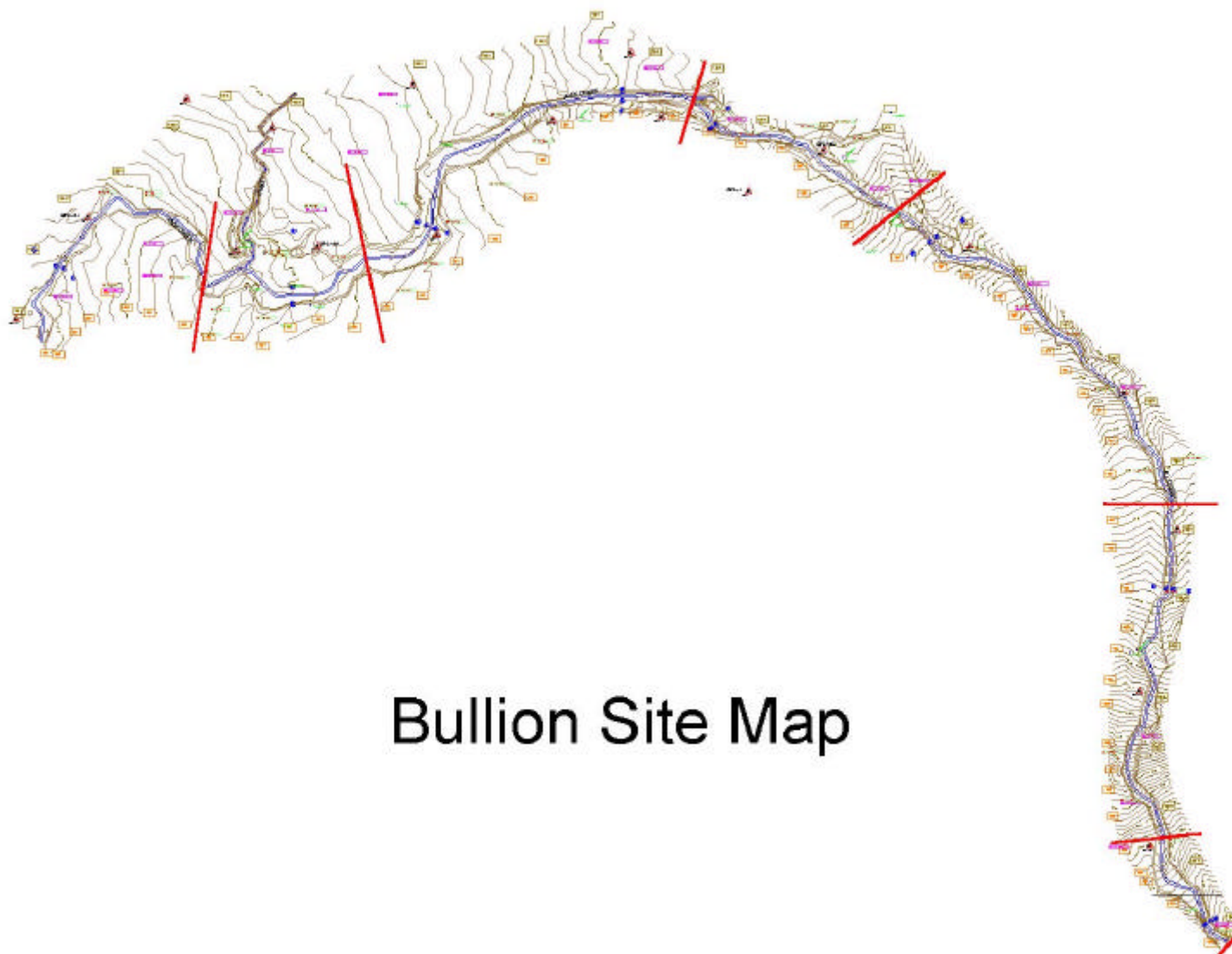
Bitterroot Restoration, Inc.
445 Quast Lane
Corvallis, MONTANA 59828



July 7, 2003

Appendix A.
Bullion Investigative Field Notes

Appendix B.
Topographic/Site Features Survey
of the
Impacted Area at Bullion Mine



Bullion Site Map

Appendix C.
Riparian Assessment Data
and
Rosgen Stream Classification Calculations

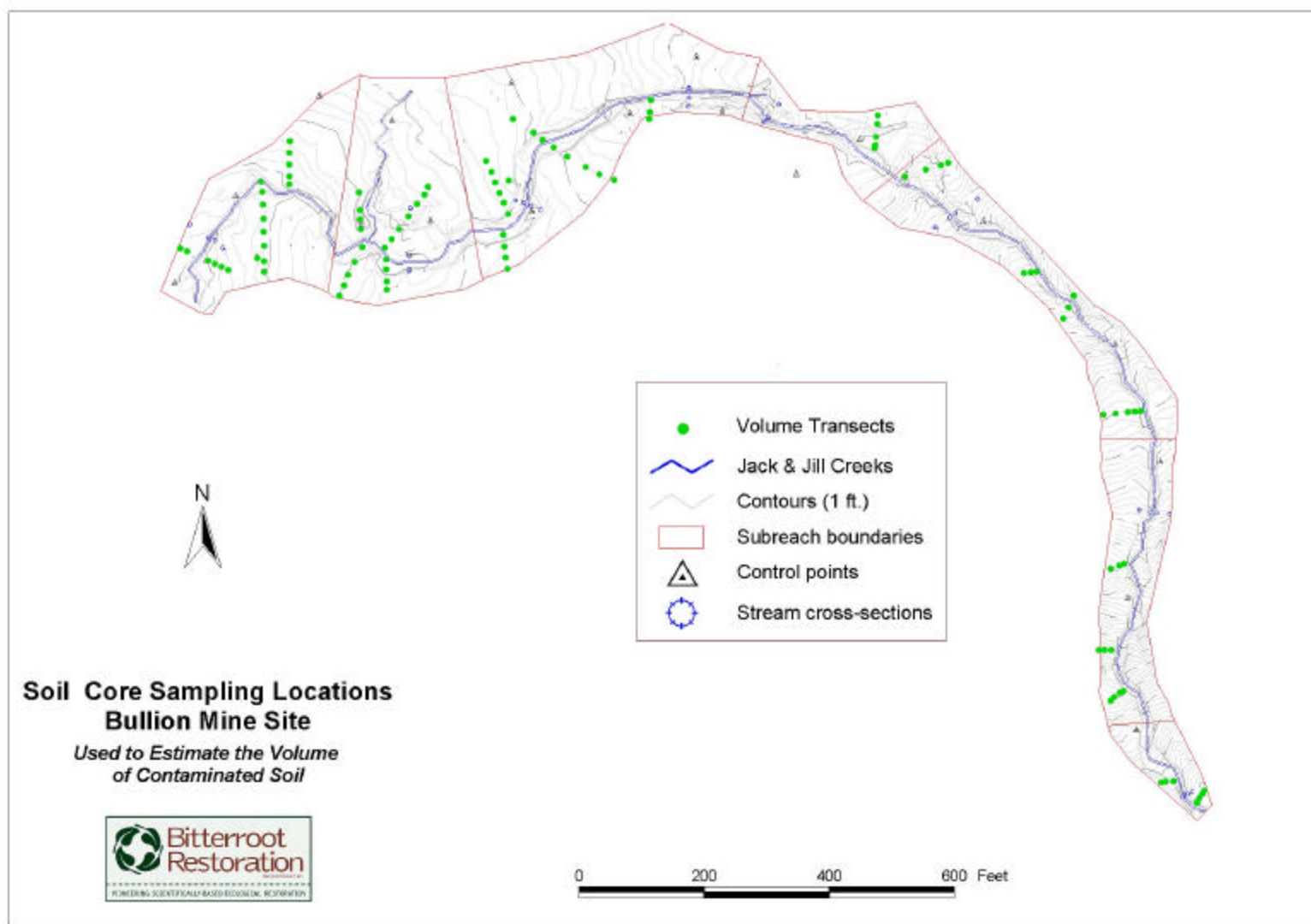
**SUMMARY OF
CROSS SECTION DATA
BULLION MINE SITE**

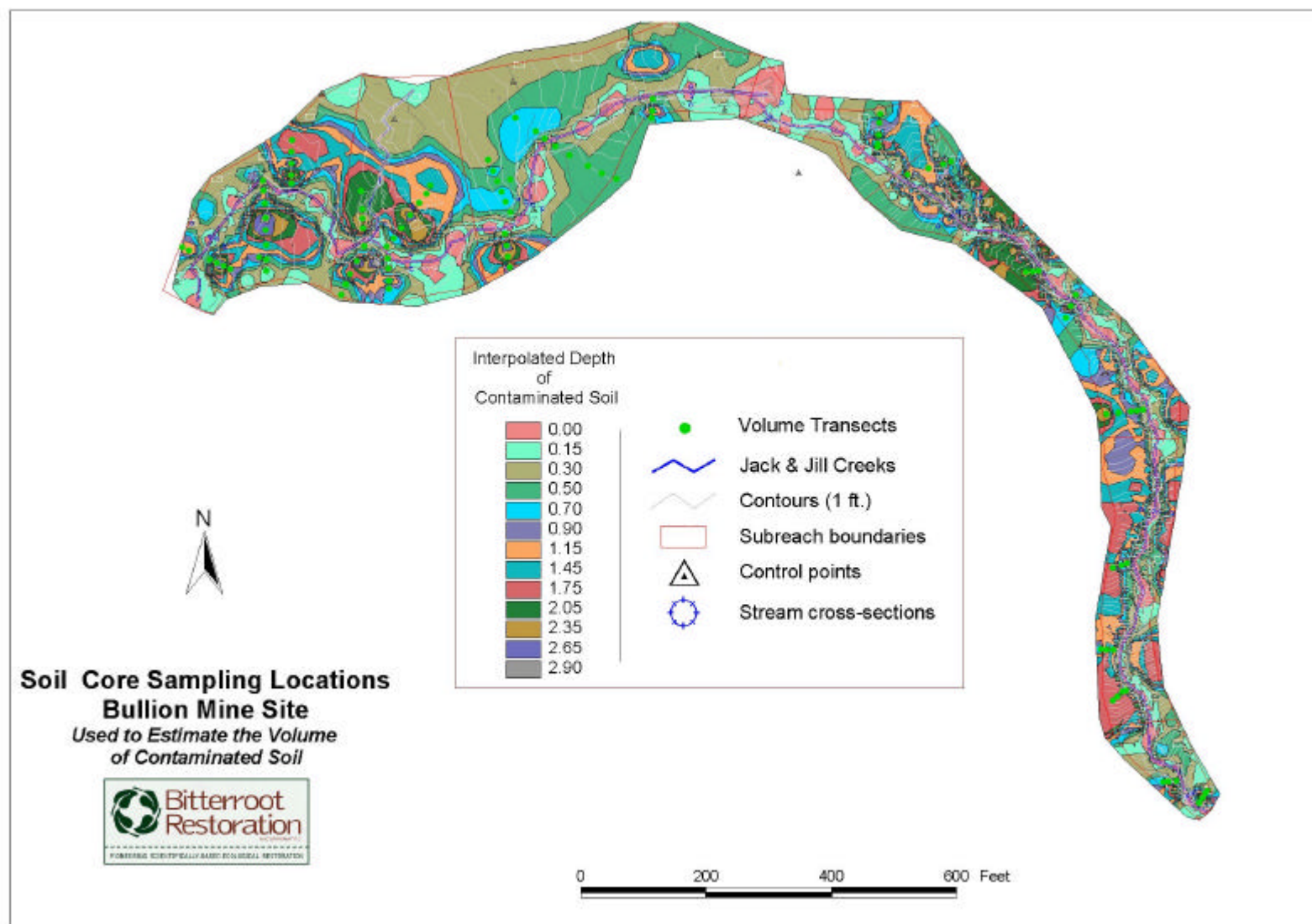
Cross-Section	Channel Area (ft²)	Discharge (cfs)	Floodplain width (ft)	pH	Temperature	Gradient	Sinuosity
CS A (1)	2.45	0.12	17.58	5.61	49	8%	1.12
CS B (2)	3.74	0.19	48.50	5.75	49	12%	1.09
CS C (3)	0.67	0.03	81.17	5.94	40.46	8%	1.04
CS D (4)	1.52	1.32	36.33	5.95	40.46	6%	1.05
CS E (7)	0.71	1.86	42.75	7.48	40.46	3%	1.03
CS F (5)	3.85	1.19	66.08	7.4	49.1	2%	1.21
CS G (6)	1.12	0.93	64.92	7.4	41.18	2%	1.46

Variable	Cross Section A	Cross Section B	Cross Section C	Cross Section D	Cross Section E	Cross Section F	Cross Section G
bankfull width (ft)	8.66	9.78	12.00	9.50	12.50	22.25	11.42
bankfull mean depth (ft)	0.77	1.12	0.49	0.61	0.36	0.79	0.81
bankfull area (ft ²)	7.07	11.02	5.78	6.35	4.93	18.65	10.23
width/depth ratio	11.19	8.70	24.71	15.56	35.21	28.33	14.06
bankfull max. depth (ft)	1.84	1.84	0.95	1.30	0.67	1.45	1.55
flood-prone width (ft)	17.58	48.50	81.17	36.33	42.75	100.00	64.92
entrenchment ratio	2.03	4.96	6.76	3.82	3.42	4.49	5.68
channel materials (D50)	0.6 - 2.5 in. (coarse gravel)	0.6 - 2.5 in. (coarse gravel)	0.6 - 2.5 in. (coarse gravel)	0.6 - 2.5 in. (coarse gravel)	2.5 - 5 (small cobbles)	0.6 - 2.5 in. (coarse gravel)	2.5 - 5 (small cobbles)
water surface slope (rise/run)	8%	12%	8%	6%	3%	2%	2%
channel sinuosity	1.12	1.09	1.04	1.05	1.03	1.21	1.46

Appendix D.

Volume of Contaminated Material Calculations





**ESTIMATED VOLUME OF CONTAMINATED MATERIALS
BULLION MINE SITE**

DEPTH (FT)	AREA (SQ_FT)	VOLUME(CU FT)
0.00	37019.6910	0.0
0.15	51216.2060	7682.4
0.30	97441.8210	29232.5
0.50	68698.3080	34349.2
0.70	31164.9810	21815.5
0.90	20896.3030	18806.7
1.15	33278.9860	38270.8
1.45	28702.6970	41618.9
1.75	26141.4260	45747.5
2.05	14397.2550	29514.4
2.35	5898.9360	13862.5
2.65	1907.7710	5055.6
2.90	433.3310	1256.7
TOTAL		287212.7

Note: Calculations are based on the estimated amounts of contaminated material that are recommended for removal at given depths.

Appendix E.

SVL Laboratory Raw Analytic Results

Appendix E. SVL Laboratory Raw Analytic Results for the Bullion Mine Site Soil Analysis for Acid-Base Accounting and Soil/Mine Waste Results																	
Sample Number	Sample Date	Comments	Job_Id	Arsenic (mg/kg)	Cadmium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Ph	Conductivity (umhos/cm)	S-Total (%)	S-Pyritic (%)	S-Sulfate (%)	S-Non-Extractable (%)	AGP (TCaCO ₃ /1000T)	ANP (TCaCO ₃ /1000T)	ABP (TCaCO ₃ /1000T)
BS-04-02-131	9/25/02	-80 SIEVE	105123	6210	24.7	1190	4620	1750	3.7	2340	1.67	0.86	0.75	0.06	26.9	2.62	-24.3
BS-04-02-151	9/25/02	-80 SIEVE	105123	3520	3.03	613	756	330	4.4	74.9	0.02	0.02	<0.01	<0.01	0.62	9.29	8.67
BS-04-00-171	9/25/02	-80 SIEVE	105123	1130	3.07	229	523	510	4.45	134	0.02	<0.01	<0.01	0.01	0.31	8.27	7.96
BS-04-00-191	9/26/02	-80 SIEVE	105123	128	0.65	83.4	76.8	150	3.92	71.8	0.01	<0.01	<0.01	0.01	<0.3	4.67	4.67
BS-04-00-211	9/26/02	-80 SIEVE	105123	841	2.34	144	902	271	3.93	56.4	0.04	0.04	<0.01	<0.01	1.25	1.08	<0.17
BS-04-00-231	9/26/02	-80 SIEVE	105123	207	2.65	1280	68.9	255	3.32	268	0.03	<0.01	<0.01	0.02	<0.3	3.13	3.13
BS-04-01-251	9/26/02	-80 SIEVE	105123	1340	2.73	427	621	167	4.74	102	0.04	0.04	<0.01	<0.01	1.25	6.73	5.48
BS-04-00-271	9/25/02	-80 SIEVE	105123	979	1.92	120	348	272	3.85	169	0.01	0.01	<0.01	<0.01	0.31	6.21	5.9
BS-04-00-291	9/25/02	-80 SIEVE	105123	123	0.97	91	71.2	159	4.03	213	0.06	0.05	<0.01	0.01	1.56	1.33	<0.23
BT-04-01-130	9/25/02	-80 SIEVE	105123	2580	0.82	135	2170	129	3.23	195	0.08	0.02	0.05	<0.01	0.62	3.65	3.03
BT-04-01-150	9/25/02	-80 SIEVE	105123	2570	<0.2	53.6	1500	43.4	2.98	247	0.07	0.03	0.04	<0.01	0.94	3.9	2.96
BT-04-00-170	9/25/02	-80 SIEVE	105123	894	0.52	521	385	167	3.56	123	0.05	0.04	<0.01	0.01	1.25	1.08	<0.17
BT-04-00-190	9/26/02	-80 SIEVE	105123	6220	1.42	164	2280	270	3.47	76.8	0.19	0.08	0.1	0.01	2.5	1.08	-1.42
BT-04-00-210	9/26/02	-80 SIEVE	105123	4560	2.23	361	1580	299	3.39	113	0.09	0.04	0.05	<0.01	1.25	3.65	2.4
BT-04-00-230	9/26/02	-80 SIEVE	105123	4330	0.55	104	1960	106	3.62	81.1	0.13	0.05	0.08	<0.01	1.56	2.62	1.06
BT-04-00-250	9/26/02	-80 SIEVE	105123	5090	<0.2	155	3700	54.8	3.61	59.9	0.23	0.06	0.17	<0.01	1.88	1.08	-0.8
BT-04-00-270	9/25/02	-80 SIEVE	105123	82.2	<0.2	42.1	50.9	119	4.18	54.2	0.02	0.01	<0.01	0.01	<0.3	8.27	8.27
BT-04-00-290	9/25/02	-80 SIEVE	105123	142	1.2	65.9	110	225	4.46	84.9	0.01	0.01	<0.01	<0.01	<0.3	8.01	8.01

**Appendix E. SVL Laboratory Raw Analytic Results
for the Bullion Mine Site
Water Extractable Analysis**

Sample 1.1. Number	Sample Date	Comments	Job_Id	Arsenic (mg/L)	Cadmium (mg/L)	Copper (mg/L)	Lead (mg/L)	Zinc (mg/L)
BS-04-02-131	9/25/02	EXTRACTION 1:10 RATIO	105126	3.41	0.414	0.456	1.63	33
BS-04-00-191	9/26/02	EXTRACTION 1:10 RATIO	105126	0.037	0.0028	0.0347	<0.005	0.124
BS-04-00-231	9/26/02	EXTRACTION 1:10 RATIO	105126	<0.010	0.0267	1.3	<0.005	1.64
BT-04-01-130	9/25/02	EXTRACTION 1:10 RATIO	105126	0.761	0.0051	0.266	0.185	0.385
BT-04-00-170	9/25/02	EXTRACTION 1:10 RATIO	105126	0.116	<0.002	0.287	0.0148	0.2
BT-04-00-210	9/26/02	EXTRACTION 1:10 RATIO	105126	0.104	0.0069	0.115	0.0194	0.637

**Appendix E. SVL Laboratory Raw Analytic Results
for the Bullion Mine Site
Surface Water Sample Results**

Sample 1.2. Num ber	Sample Date	Comments	Job_Id	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Copper (mg/L)	Lead (mg/L)	Zinc (mg/L)
MT-CSA-H2O	9/27/02	AS VALUES < 0.033MG/L ARE ESTIMATED.	105127	28.9	6.59	99.4	0.026	0.0444	0.771	0.0115	4.68
MT-CSB-H2O	9/27/02		105127	28.9	6.68	99.7	0.126	0.044	0.798	0.039	4.63
MT-CSC-H2O	9/27/02	AS VALUES < 0.033MG/L ARE ESTIMATED.	105127	28.7	6.58	98.8	0.014	0.0419	0.691	0.0069	4.48
MT-CSD-H2O	9/27/02	AS VALUES < 0.033MG/L ARE ESTIMATED.	105127	28.4	6.49	97.7	0.02	0.0411	0.654	0.0084	4.49
MT-CSE-H2O	9/27/02	AS VALUES <0.033 MG/L ARE ESTIMATED.	105127	16.4	3.64	55.9	0.014	0.0105	0.167	<0.005	1.18
MT-CSF-H2O	9/27/02		105127	16.5	3.71	56.5	<0.01	0.0102	0.159	<0.005	1.13
MT-CSG-H2O	9/27/02		105127	14.9	3.43	51.3	<0.01	0.0079	0.121	<0.005	0.869

NOTE: Sample numbers are labeled as follows in the field notes and in the SVL analytical reports:

MT-CSA-H2O = CS1
MT-CSB-H2O = CS2
MT-CSC-H2O = CS3
MT-CSD-H2O = CS4
MT-CSE-H2O = CS7
MT-CSF-H2O = CS5
MT-CSG-H2O = CS6

Appendix E. SVL Laboratory Raw Analytic Results for the Bullion Mine Site Stream Sediment Sample Results										
Sample 1.3. Number	Sample Date	Comments	Job_Id	Arsenic (mg/kg)	Cadmium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Ph	Conductivity (umhos/cm)
MT-CSA-SED	9/27/02	NONE	105124	2170	13.6	911	818	1120	6.06	445
MT-CSB-SED	9/27/02	NONE	105124	1870	16.3	838	724	1110	5.94	410
MT-CSC-SED	9/27/02	NONE	105124	2480	18.1	1180	876	1480	5.95	439
MT-CSD-SED	9/27/02	NONE	105124	2010	17.6	1150	755	1440	5.83	341
MT-CSE-SED	9/27/02	NONE	105124	1720	51.6	1790	577	4060	6.92	437
MT-CSF-SED	9/27/02	NONE	105124	1200	31.6	653	466	2340	6.81	317
MT-CSG-SED	9/27/02	NONE	105124	1180	38.2	837	498	2600	6.94	344

NOTE: Sample numbers are labeled as follows in the field notes and in the SVL analytical reports:

MT-CSA-SED = CS1
 MT-CSB-SED = CS2
 MT-CSC-SED = CS3
 MT-CSD-SED = CS4
 MT-CSE-SED = CS7
 MT-CSF-SED = CS5
 MT-CSG-SED = CS6

SVL QUALITY CONTROL INFORMATION

SVL ANALYTICAL, INC.

Quality Control Report
Part I Prep Blank and Laboratory Control Sample

Client :BITTERROOT RESTORATION INC SVL JOB No: 105123

Analyte	Method	Matrix	Units	Prep Blank	True—LCS—Found	LCS %R	Analysis Date
Arsenic	6010B	SOIL	mg/kg	<1.0	283	283	100.0 3/16/03
Cadmium	6010B	SOIL	mg/kg	<0.20	50.7	49.4	97.4 3/16/03
Copper	6010B	SOIL	mg/kg	0.43	169	178	105.3 3/16/03
Lead	6010B	SOIL	mg/kg	<0.50	84.7	86.9	102.6 3/16/03
Zinc	6010B	SOIL	mg/kg	<0.50	149	142	95.3 3/16/03
pH	9045	SOIL		N/A	9.07	8.56	94.4 3/15/03
Spec. Cond.	120.1	SOIL	umhos/cm	N/A	400	413	103.3 3/16/03
ABP	EPA600	SOIL	TCaCO3/k	N/A	42.0	40.5	96.4 3/15/03
Acid Generating	EPA600	SOIL	TCaCO3/k	N/A	9.31	9.37	100.6 3/15/03
Acid Neut. Pot.	EPA600	SOIL	TCaCO3/k	N/A	52.0	49.9	96.0 3/15/03
Non-Ext Sulfur, S	LECO	SOIL	%	<0.010	N/A	N/A	N/A 3/15/03
Pyritic Sulfur, S	LECO	SOIL	%	<0.010	N/A	N/A	N/A 3/15/03
Sulfate Sulfur, S	LECO	SOIL	%	<0.010	N/A	N/A	N/A 3/15/03
Total Sulfur, S	LECO	SOIL	%	<0.010	0.298	0.300	100.7 3/15/03

LEGEND:

LCS = Laboratory Control Sample

LCS %R = LCS Percent Recovery

N/A = Not Applicable

3/17/03 12:03

SVL ANALYTICAL, INC.

Quality Control Report
Part II Duplicate and Spike Analysis

Client : BITTERROOT RESTORATION INC				SVL JOB No: 105123				Analysis #	
Test Method Matrix	QC SAMPLE ID	Units	Result	Duplicate or MSD	Found	RPD%	Result	SPK ADD	Date
As	6010B SOIL	1 mg/kg	6210	5630	M	2.8	6450	100	R > 4S 3/16/03
Az	6010B SOIL	2 mg/kg	2570	N/A	N/A	N/A	2680	100	110.0 3/16/03
Cd	6010B SOIL	1 mg/kg	24.7	119	M	0.0	119	100	94.3 3/16/03
Cd	6010B SOIL	2 mg/kg	<0.20	N/A	N/A	N/A	93.0	100	93.0 3/16/03
Cu	6010B SOIL	1 mg/kg	1190	1320	M	0.8	1310	100	120.0 3/16/03
Cu	6010B SOIL	2 mg/kg	93.6	N/A	N/A	N/A	159	100	105.4 3/16/03
Pb	6010B SOIL	1 mg/kg	4620	4780	M	0.8	4820	100	R > 4S 3/16/03
Pb	6010B SOIL	2 mg/kg	1500	N/A	N/A	N/A	1620	100	120.0 3/16/03
Zn	6010B SOIL	1 mg/kg	1750	1910	M	0.0	1910	100	R > 4S 3/16/03
Zn	6010B SOIL	2 mg/kg	43.4	N/A	N/A	N/A	132	100	88.6 3/16/03
pH	9045 SOIL	1	3.70	3.65		1.4	N/A	N/A	N/A 3/15/02
COND	120.1 SOIL	1 umhos/c	2340	2330		0.4	N/A	N/A	N/A 3/16/03
ABP	EPA600 SOIL	1 TCaCO3/	-24.3	-20.9		15.0	N/A	N/A	N/A 3/15/02
AGP	EPA600 SOIL	1 TCaCO3/	26.9	26.6		1.1	N/A	N/A	N/A 3/15/02
ANP	EPA600 SOIL	1 TCaCO3/	2.62	5.70		74.0	N/A	N/A	N/A 3/15/02
S N-EX	LECO SOIL	1 %	0.060	0.060		0.0	N/A	N/A	N/A 3/15/02
S-PYR	LECO SOIL	1 %	0.860	0.850		1.2	N/A	N/A	N/A 3/15/02
S-SO4	LECO SOIL	1 %	0.750	0.740		1.3	N/A	N/A	N/A 3/15/02
S-TOT	LECO SOIL	1 %	1.67	1.65		1.2	N/A	N/A	N/A 3/15/02

LEGEND:

RPD% = $\frac{(|SAM - DUP|)}{((SAM + DUP)/2)} * 100$ UDL = Both SAM & DUP not detected. *Result or *Found: Interference required dilution.
 RPD% = $\frac{(|SPK - MSD|)}{((SPK + MSD)/2)} * 100$ M in Duplicate/MSD column indicates MSD.

SPIKE ADD column, A = Post Digest Spike; RR = Percent Recovery N/A = Not Analyzed; R > 4S = Result more than 4X the Spike Added

QC Sample 1: SVL SAM No.: 326240 Client Sample ID: BULL-XS-04-02-131

QC Sample 2: SVL SAM No.: 326250 Client Sample ID: BULL-XT-04-01-150

SVL ANALYTICAL, INC. Quality Control Report
Part 1 Prep Blank and Laboratory Control Sample

Client :BITTERROOT RESTORATION INC SVL JOB No: 105126

Analyte	Method	Matrix	Units	Prep Blank	True	LCS	Found	LCS %R	Analysis Date
Arsenic	200.7	ESOIL	mg/L Ext	<0.010	1.00	1.07	107.0	107.0	3/17/03
Cadmium	200.7	ESOIL	mg/L Ext	<0.0020	1.00	1.04	104.0	104.0	3/16/03
Copper	200.7	ESOIL	mg/L Ext	<0.0030	1.00	0.965	96.5	96.5	3/17/03
Lead	200.7	ESOIL	mg/L Ext	<0.0050	1.00	0.995	99.5	99.5	3/16/03
Zinc	200.7	ESOIL	mg/L Ext	<0.0050	1.00	1.02	102.0	102.0	3/16/03

LEGEND:
LCS = Laboratory Control Sample LCS %R = LCS Percent Recovery N/A = Not Applicable

3/16/03 14:32

MAX-12-02 11-08 FROM SVL ANALYTICAL

*2587620891

T-024 P 11/11 JOB-022

SVL ANALYTICAL, INC.

Quality Control Report
Part II Duplicate and Spike Analysis

Client: BITTERROOT RESTORATION INC					SVL JOB No: 105126			
QC SAMPLE ID			Duplicate or MSD		Matrix Spike		Analysis	
Test Method Matrix	Units	Result	Found	RPD%	Result	SPK ADD	%R	Date
As 200.7 ESOIL	1 mg/L Ex	0.761	0.671	12.6	1.82	1.00	105.9	3/17/03
Cd 200.7 ESOIL	1 mg/L Ex	0.0051	0.0050	2.0	1.04	1.00	103.5	3/16/03
Cu 200.7 ESOIL	1 mg/L Ex	0.266	0.240	10.3	1.26	1.00	99.4	3/17/03
Pb 200.7 ESOIL	1 mg/L Ex	0.185	0.150	20.9	1.08	1.00	89.5	3/16/03
Zn 200.7 ESOIL	1 mg/L Ex	0.385	0.386	0.3	1.42	1.00	103.5	3/16/03

LEGEND:
 $RPD\% = (|SAM - DUP| / ((SAM + DUP) / 2)) * 100$ UOL = Both SAM & DUP not detected. *Result or *Found: Interference required dilution.
 $RPD\% = (|SPK - MSD| / ((SPK + MSD) / 2)) * 100$ M in Duplicate/MSD column indicates MSD.
 SPIKE ADD column, A = Post Digest Spike; %R = Percent Recovery N/A = Not Analyzed; E > 45 = Result more than 4X the Spike Added
 QC Sample 1: SVL SAM No.: 326275 Client Sample ID: BULL-XT-04-01-130

3/18/03 14:35

SVL ANALYTICAL, INC.

Quality Control Report
Part I Prep Blank and Laboratory Control Sample

Client :BITTERROOT RESTORATION INC							SVL JOB No: 105127	
Analyte	Method	Matrix	Units	Prep Blank	True—LCS—Found	LCS %R	Analysis Date	
Arsenic	200.7	WATER	mg/L	<0.010	1.00	0.929	92.9	3/07/03
Calcium	200.7	WATER	mg/L	<0.040	20.0	19.5	97.5	3/07/03
Cadmium	200.7	WATER	mg/L	<0.0020	1.00	0.950	95.0	3/07/03
Copper	200.7	WATER	mg/L	0.0048	1.00	0.993	99.3	3/07/03
Hardness	200.7	WATER	mg/L	<0.265	132	126	95.5	3/07/03
Magnesium	200.7	WATER	mg/L	<0.040	20.0	18.8	94.0	3/07/03
Lead	200.7	WATER	mg/L	<0.0050	1.00	0.965	96.5	3/07/03
Zinc	200.7	WATER	mg/L	<0.0050	1.00	0.926	92.6	3/07/03

LEGEND:

LCS = Laboratory Control Sample

LCS %R = LCS Percent Recovery

N/A = Not Applicable

3/11/03 8:37

SVL ANALYTICAL, INC.

Quality Control Report
Part II Duplicate and Spike Analysis

Client :BITTERROOT RESTORATION INC									
SVL JOB No: 105127									
Test Method	Matrix	QC SAMPLE ID		Duplicate or MSD		Matrix Spike		Analysis	
		Units	Result	Found	RPDs	Result	SPK ADD	%R	Date
As	200.7 WATERS	1 mg/L	0.014	0.010	33.3	0.955	1.00	94.1	3/07/03
Ca	200.7 WATERS	1 mg/L	16.4	16.6	1.2	36.1	20.0	98.5	3/07/03
Cd	200.7 WATERS	1 mg/L	0.0105	0.0109	3.7	0.958	1.00	94.8	3/07/03
Cu	200.7 WATERS	1 mg/L	0.167	0.171	2.4	1.16	1.00	99.3	3/07/03
Hdms	200.7 WATERS	1 mg/L	55.9	56.5	1.1	184	132	97.0	3/07/03
Mg	200.7 WATERS	1 mg/L	3.64	3.68	1.1	22.7	20.0	95.3	3/07/03
Pb	200.7 WATERS	1 mg/L	<0.0050	<0.0050	UDL	0.958	1.00	95.8	3/07/03
Zn	200.7 WATERS	1 mg/L	1.18	1.19	0.8	2.08	1.00	90.0	3/07/03

LEGEND:

RPD% = $(|SAM - DUP| / ((SAM + DUP)/2)) * 100$ UDL = Both SAM & DUP not detected. *Result or *Found: Interference required dilution.
 RPD% = $(|SPK - MSD| / ((SPK + MSD)/2)) * 100$ M in Duplicate/MSD column indicates MSD.

SPIKE ADD column, A = Post Digest Spike; %R = Percent Recovery N/A = Not Analyzed; R > 4S = Result more than 4X the Spike Added
 QC Sample 1: SVL SAM No.: 326280 Client Sample ID: CS7

3/11/03 8:37

SVL ANALYTICAL, INC.

Quality Control Report
Part I Prep Blank and Laboratory Control Sample

Client: BITTERROOT RESTORATION INC				SVL JOB NO: 105124				
Analyte	Method	Matrix	Units	Prep Blank	True—LCS—Found	LCS %R	Analysis Date	
Arsenic	6010B	SOIL	mg/kg	<1.0	283	280	96.9	3/17/03
Cadmium	6010B	SOIL	mg/kg	<0.20	50.7	49.9	98.4	3/16/03
Copper	6010B	SOIL	mg/kg	<0.30	169	175	103.6	3/17/03
Lead	6010B	SOIL	mg/kg	<0.50	84.7	87.9	103.8	3/16/03
Zinc	6010B	SOIL	mg/kg	<0.50	149	144	96.6	3/16/03
pH	9045	SOIL	N/A	N/A	8.60	8.53	99.2	3/14/03
Spec. Cond.	120.1	SOIL	umhos/cm	0.010	465	439	94.4	3/14/03

LEGEND:

LCS - Laboratory Control Sample

LCS %R - LCS Percent Recovery

N/A - Not Applicable

SVL ANALYTICAL, INC.

Quality Control Report
Part II Duplicate and Spike Analysis

Client :BITTERROOT RESTORATION INC									
Test Method Matrix		QC SAMPLE ID	Units	Result	Duplicate or MSD		Matrix Spike		SVL JOB No: 105124
					Found	RPD%	Result	SPK ADD	Analysis Date
As	6010B SOIL	2	mg/kg	2170	2420	M 0.8	2440	100	R >4S 3/17/03
Cd	6010B SOIL	2	mg/kg	13.6	112	M 0.9	111	100	97.4 3/16/03
Cu	6010B SOIL	2	mg/kg	911	1100	M 0.0	1100	100	R >4S 3/17/03
Pb	6010B SOIL	2	mg/kg	818	961	M 2.1	941	100	123.0 3/16/03
Zn	6010B SOIL	2	mg/kg	1120	1440	M 3.5	1390	100	R >4S 3/16/03

LEGEND:

$RPD\% = ((SAM - DUP) / ((SAM + DUP) / 2)) * 100$ UDL = Both SAM & DUP not detected. *Result or *Found: Interference required dilution.
 $RPD\% = ((SPK - MSD) / ((SPK + MSD) / 2)) * 100$ M in Duplicate/MSD column indicates MSD.
 SPIKE ADD column, A = Post Digest Spike; %R = Percent Recovery N/A = Not Analyzed; R > 4S = Result more than 4X the Spike Added
 QC Sample 2: SVL BAM No.: 326266 Client Sample ID: CS01

3/17/03 13:16

SVL ANALYTICAL, INC.

Quality Control Report
Part II Duplicate and Spike Analysis

Client : BITTERROOT RESTORATION INC									
SVL JOB No: 105124									
Test Method	Matrix	QC SAMPLE ID		Duplicate or MSD		Matrix Spike			Analysis Date
		Units	Result	Found	RPD%	Result	SPK ADD	%R	
COND	120.1 SOIL	1 umhos/c	437	435	0.5	N/A	N/A	N/A	3/14/03
pH	9045 SOIL	1	6.92	6.93	0.1	N/A	N/A	N/A	3/14/03

LEGEND:

$RPD\% = \frac{(|SAM - DUP|)}{((SAM + DUP)/2)} * 100$ UDL = Both SAM & DUP not detected. *Result or *Found: Interference required dilution.
 $RPD\% = \frac{(|SPK - MSD|)}{((SPK + MSD)/2)} * 100$ M in Duplicate/MSD column indicates MSD.
 SPIKE ADD column, & = Post Digest Spike; %R = Percent Recovery N/A = Not Analyzed; R > 4S = Result more than 4X the Spike Added
 QC Sample 1: SVL SAM No.: 326260 Client Sample ID: CS07

3/17/03 13:16

**CHAIN OF CUSTODY RECORDS
FOR
BULLION MINE**

xvii

Do Not Begin Analysis

Until Given Order To Proceed by BRT

CHAIN OF CUSTODY RECORD

Page 1 of 4

Client: Bitterroot Restoration, Inc. (BRT)

Contact: Grant Massey

Address: 445 Quast Lane

Corvallis, MT 59828

Phone Number: 406-961-4991

FAX Number: 406-961-4446

NOTES:

1) Ensure proper container packaging.

2) Ship samples promptly following collection.

3) Designate Sample Reject Disposition

PO#: _____

Project Name: Bullion - RAMS

Table 1. -- Matrix Type

1 = Surface Water, 2 = Ground Water

3 = Soil/Sediment, 4 = Rinsate, 5 = Oil

6 = Waste, 7 = Other (Specify)

Samplers Signature: *Trace Fitzgerald*

FOR SVL USE ONLY

SVL JOB #

Lab Name: SVL Analytical, Inc. (208) 784-1258 FAX (208) 783-0891

Address: One Government Gulch, Kellogg, ID 83837-0929

Sample ID	Collection		Miscellaneous			Preservative(s)					Analyses Required					Comments			
	Date	Time	Collected by: (Init.)	Matrix Type	From Table 1	No. of Containers	Sample Filtered ? Y/N	Unpreserved (Ice Only)	HNO3	HCL	H2SO4	NaOH	Other (Specify)	Total Metals	AS	CU	CD	PB	ZN
1. CS7 CS7	9/27/02	5:30 PM	CF/DC	1	1	1	N												
2. CS01 - CS07	9/27/02	5:30 PM	CF/DC	3	3	3	N												
3. CS6	9/27/02	5:40 PM	CF/DC	1	1	1	N												
4. CS6	9/27/02	5:40 PM	CF/DC	3	3	3	N												
5. CS5	9/27/02	4:40 PM	CF/DC	1	1	1	N												
6. CS5	9/27/02	4:45 PM	CF/DC	3	3	3	N												
7. CS4	9/27/02	3:11 PM	CF/DC	1	1	1	N												
8. CS4	9/27/02	3:15 PM	CF/DC	3	3	3	N												
9. CS3	9/27/02	10:00 AM	CF/DC	7	7	7	N												
10. CS03	9/27/02	10:15 AM	CF/DC	3	3	3	N												
Relinquished by: <i>Trace Fitzgerald</i>																			
Relinquished by: <i>Trace Fitzgerald</i>																			
Date: 9/27/02 Time: 10:15 AM																			
Date: 9/27/02 Time: 10:15 AM																			

* Sample Reject: | | Return | | Dispose | | Store (30 Days)

White: LAB COPY Yellow: CUSTOMER COPY

SVL-COC 12/99

Page 2 of 4 **SVL**

FOR SVL USE ONLY
SVL JOB # 1

CHAIN OF CUSTODY RECORD

Client: Bullion Mine Restoration, LLC (BMR)
 Contact: Grant Massey
 Address: 4445 Quist Lane
Corvallis, MT 59828
 Phone Number: 406-967-4991
 FAX Number: 406-967-4626

Table 1 -- Matrix Type
 1 = Surface Water, 2 = Ground Water
 3 = Soil/Sediment, 4 = Rinsate, 5 = Oil
 6 = Waste, 7 = Other (Specify)

Sampler's Signature: Grant Massey
 Date: 7/28/03

Project Name: Bullion - RAMS

Lab Name: SVL Analytical, Inc. (208) 784-1258 FAX (208) 783-0891
 Address: One Government Gulch, Kellogg, ID 83837-0929

Notes:
 1) Ensure proper container packaging.
 2) Ship samples promptly following collection.
 3) Designate Sample Reject Disposition
 PO#: 7144002

Sample ID	Collection		Collected by: (Init.)	Miscellaneous		Preservative(s)					Comments		
	Date	Time		From Table 1	No. of Containers	Sample Filtered ? Y/N	Unpreserved (Ice Only)	HNO3	HCL	H2SO4		NAOH	Other (Specify)
1. <u>0501-0507</u>	<u>9/27/02</u>	<u>12:15</u>	<u>CM</u>	<u>1</u>	<u>1</u>	<u>2</u>							
2. <u>0502</u>	<u>9/27/02</u>	<u>12:15</u>	<u>CM</u>	<u>3</u>	<u>1</u>	<u>2</u>							
3. <u>0503</u>	<u>9/27/02</u>	<u>11:25</u>	<u>CM</u>	<u>1</u>	<u>1</u>	<u>2</u>							
4. <u>0504</u>	<u>9/27/02</u>	<u>11:25</u>	<u>CM</u>	<u>3</u>	<u>1</u>	<u>2</u>							
5. <u>0505</u>	<u>9/26/02</u>	<u>4:30</u>	<u>SB</u>	<u>6</u>	<u>1</u>	<u>2</u>							
6. <u>0506</u>	<u>9/26/02</u>	<u>3:00</u>	<u>SB</u>	<u>3</u>	<u>1</u>	<u>2</u>							
7. <u>0507</u>	<u>9/26/02</u>	<u>2:45</u>	<u>SB</u>	<u>6</u>	<u>1</u>	<u>2</u>							
8. <u>0508</u>	<u>9/26/02</u>	<u>2:45</u>	<u>SB</u>	<u>3</u>	<u>1</u>	<u>2</u>							
9. <u>0509</u>	<u>9/26/02</u>	<u>3:05</u>	<u>SB</u>	<u>6</u>	<u>1</u>	<u>2</u>							
10. <u>0510</u>	<u>9/26/02</u>	<u>4:35</u>	<u>SB</u>	<u>3</u>	<u>1</u>	<u>2</u>							

Relinquished by: Grant Massey Date: 7/28/03 Time: 6:05 PM
 Received by: SVL Date: 7/28/03 Time: 8:41

* Sample Reject: | | Return | | Dispose | | Store (30 Days)

White: LAB COPY Yellow: CUSTOMER COPY SVL-COC 12/95

PO#: 7244002
Project Name: Bullion- RAMS
Project by: SKI
Samples' signatures: [Signature]
Relinquished by: [Signature] 14/6/02

Lab: SVL Analytical, Inc 208-784-1258
One Government Gulch, Kellogg, ID 83837-0929

[illegible]

Client: Butterroot Restoration, INC

PO# 2244003

Sample(s) Signature Jeff Barry

Do Not begin Analysis until

Given order to proceed by BARI

page 4 of 4

Sample ID	Date	Time	Matrix (see 11)	Analysis Required
BT-11-1-101	9/24/02	12:15:00	S	X
BT-14-102	9/24/02	12:25:00		X
BT-101-134	9/25/02	12:15:00		X
BT-101-115	9/25/02	17:30:00		X
Bull-1-02-300	9/28/02	12:00:00		X
Bull-1-15-301		12:30:00		X
Bull-1-03-302		13:00:00		X
Bull-1-05-303		13:30:00		X
Bull-1-15-304		14:00:00		X
Bull-1-02-305		14:15:00		X
Bull-1-02-306		14:45:00		X
Bull-1-02-307		15:00:00		X
Bull-1-03-308		15:30:00		X
Bull-1-02-309		16:00:00		X
5 FLS Bull 300		16:30:00		X
Relinquished by - <u>Jeff Barry</u>	10/1/02	11:00:00		
				10/02/02 @ 8:47

Bull-1-01-306 5F-5

Revised 000 - Bullion Mine Restoration 2/27/03: (see attached for complete address) 105126

Sample ID	Date Collected	Material	Total Metals (As, Cd, Cu, Pb, Zn)	Water Extractable Metals (As, Cd, Cu, Pb, Zn)	Acid Based Accounting	pH	Specific Conductance	Hardness	Total Dissolved Solids
1-XS-04-02-131	09/25/03	Soil	X	X	X	X	X		
1-XS-04-02-151	09/25/03	Soil	X		X	X	X		
1-XS-04-00-171	09/25/03	Soil	X		X	X	X		
1-XS-04-00-191	09/26/03	Soil	X	X	X	X	X		
1-XS-04-00-211	09/26/03	Soil	X		X	X	X		
1-XS-04-01-231	09/26/03	Soil	X	X	X	X	X		
1-XS-04-00-271	09/25/03	Soil	X		X	X	X		
1-XS-04-00-291	09/25/03	Soil	X		X	X	X		
1-XS-04-01-430	09/25/03	Waste	X	X	X	X	X		
1-XS-04-01-450	09/25/03	Waste	X		X	X	X		
1-XS-04-00-170	09/25/03	Waste	X	X	X	X	X		
1-XS-04-00-190	09/25/03	Waste	X		X	X	X		
1-XS-04-00-210	09/26/03	Waste	X		X	X	X		
1-XS-04-00-230	09/26/03	Waste	X		X	X	X		
1-XS-04-00-250	09/26/03	Waste	X		X	X	X		
1-XS-04-00-270	09/26/03	Waste	X		X	X	X		
1-XS-04-00-290	09/26/03	Waste	X		X	X	X		
CS01 CS07, CS07	12/17/03	Sediment	X		X	X	X		
CS6	12/17/03	Sediment	X		X	X	X		
CS5	12/17/03	Sediment	X		X	X	X		
CS4	12/17/03	Sediment	X		X	X	X		
CS3	12/17/03	Sediment	X		X	X	X		
CS02	12/17/03	Sediment	X		X	X	X		
CS01	12/17/03	Sediment	X		X	X	X		
CS7	12/17/03	Surface Water	X					X	
CS6	12/17/03	Surface Water	X					X	
CS5	12/17/03	Surface Water	X					X	
CS4	12/17/03	Surface Water	X					X	
CS3	12/17/03	Surface Water	X					X	
CS21 CS7	12/17/03	Surface Water	X					X	
CS1	12/17/03	Surface Water	X					X	

Just Marney 2/27/03

Appendix F.

XRF Field Analytical Results for Total Metals



7220 North 16th Street, Suite E
Phoenix, AZ 85020
(602) 331-3859
Fax (602) 331-4104

May 21, 2003

1034-1 & 1034-2

Ms. Clare Fitzgerald
Bitterroot Restoration, Inc.
445 Quast Lane
Corvallis, Montana 59828

X-Ray Fluorescence (XRF) Instrument Details – Response to United States Forest Service (USFS) Comments for Bullion and Idora Site Characterization Reports

Dear Clare:

As discussed during our telephone conversation on Friday, May 9, 2003 the USFS commented on the Bullion and Idora Site Characterization Reports and requested additional information regarding the XRF instrument used in the field. Information regarding the USFS' XRF comment, "To be consistent with the other sections below (e.g. pH, flow meters, etc.) this should state what type of XRF instrument was used, it's approximate upper and lower detection limits, precision, accuracy and limitations," is discussed below. I've included as attachments the XRF summary brief text for the Bullion and Idora sites submitted to BRI in March 2003 and EPA's Method 6200 – 'Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentration in Soil and Sediment' for your reference.

- The type of XRF instrument used: Spectrace 9000 portable XRF
- The approximate upper detection limits or quantitation limits is determined as 10 times the sample result's associated standard deviation, which is reported by the instrument. This quantitation limit varies from sample to sample. Typically, an average would be used to determine upper detection limits; however, because the XRF instrument was being used to characterize the site and site-specific characterization samples were not available the above method was employed.
- The approximate lower detection limits is determined as 3 times the sample result's associated standard deviation, which is reported by the instrument. This detection limit varies from sample to sample. Typically, an average would be used to determine lower detection limits; however, because the XRF instrument was being used to characterize the

site and site-specific characterization samples were not available the above method was employed. Additionally, the EPA Method 6200 includes a guide for lower detection limits based on no interference, 600 counts per source and quartz soil, they are as follows:

- Arsenic (As) 40 ppm
 - Lead (Pb) 20 ppm
 - Copper (Cu) 50 ppm
 - Cadmium (Cd) 100 ppm
 - Zinc (Zn) 50 ppm
- Precision: The precision for the XRF instrument is based on site-specific conditions and is discussed in detail in the Quality Assurance/Quality Control section of the XRF summary briefs submitted to BRI for Bullion and Idora sites on March 20, 2003 and March 24, 2003, respectively.
- Accuracy: The accuracy for the XRF instrument is based on site-specific conditions and is discussed in detail in the Quality Assurance/Quality Control section of the XRF summary briefs submitted to BRI for Bullion and Idora sites on March 20, 2003 and March 24, 2003, respectively.
- Limitations: The XRF instrument limitations are discussed in detail in EPA's Method 6200 Section 4.0 – 'Interferences'.

Sincerely,
EMC²

(sent via email)

Lisa N. Gonzales
Principal

Enclosures

cc: Joe Flynn, EMC²

Appendix G.

Statistical Procedures (Student's t-Test, Least Squares Regressions)

Regression Summary**Log_XRF_Arsenic vs. Log_Arsenic**

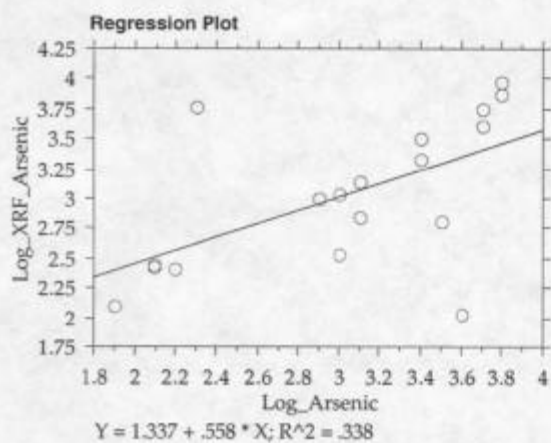
Count	18
Num. Missing	0
R	.581
R Squared	.338
Adjusted R Squared	.296
RMS Residual	.523

ANOVA Table**Log_XRF_Arsenic vs. Log_Arsenic**

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	2.231	2.231	8.155	.0114
Residual	16	4.377	.274		
Total	17	6.608			

Regression Coefficients**Log_XRF_Arsenic vs. Log_Arsenic**

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1.337	.606	1.337	2.208	.0422
Log_Arsenic	.558	.195	.581	2.856	.0114



Regression Summary**Log_XRF_Cadmium vs. Log_CADMIUM**

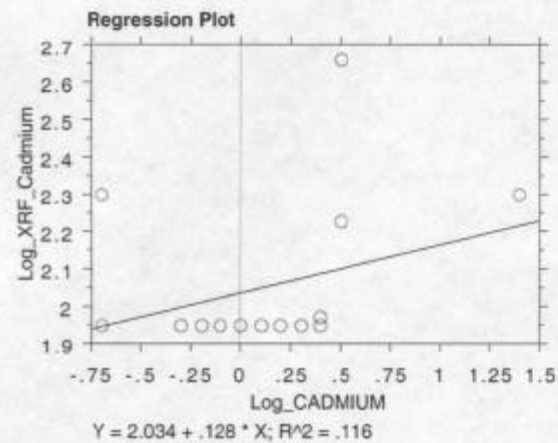
Count	18
Num. Missing	0
R	.341
R Squared	.116
Adjusted R Squared	.061
RMS Residual	.192

ANOVA Table**Log_XRF_Cadmium vs. Log_CADMIUM**

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	.077	.077	2.102	.1664
Residual	16	.588	.037		
Total	17	.665			

Regression Coefficients**Log_XRF_Cadmium vs. Log_CADMIUM**

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	2.034	.046	2.034	44.435	<.0001
Log_CADMIUM	.128	.088	.341	1.450	.1664



Regression Summary**Log_XRF_Copper vs. Log_COPPER**

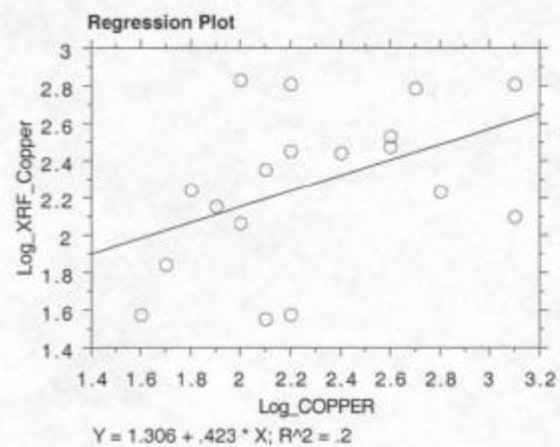
Count	18
Num. Missing	0
R	.447
R Squared	.200
Adjusted R Squared	.150
RMS Residual	.392

ANOVA Table**Log_XRF_Copper vs. Log_COPPER**

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	.612	.612	3.990	.0631
Residual	16	2.456	.153		
Total	17	3.068			

Regression Coefficients**Log_XRF_Copper vs. Log_COPPER**

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1.306	.492	1.306	2.653	.0174
Log_COPPER	.423	.212	.447	1.998	.0631



Regression Summary**Log_XRF_Lead vs. Log_LEAD**

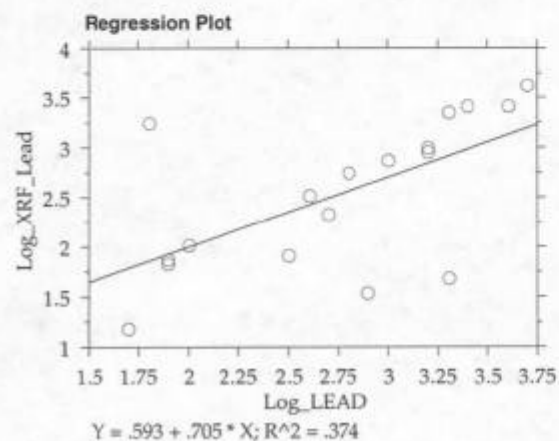
Count	18
Num. Missing	0
R	.612
R Squared	.374
Adjusted R Squared	.335
RMS Residual	.614

ANOVA Table**Log_XRF_Lead vs. Log_LEAD**

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	3.603	3.603	9.559	.0070
Residual	16	6.032	.377		
Total	17	9.635			

Regression Coefficients**Log_XRF_Lead vs. Log_LEAD**

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	.593	.644	.593	.922	.3704
Log_LEAD	.705	.228	.612	3.092	.0070



Regression Summary**Log_XRF_Zinc vs. Log_ZINC**

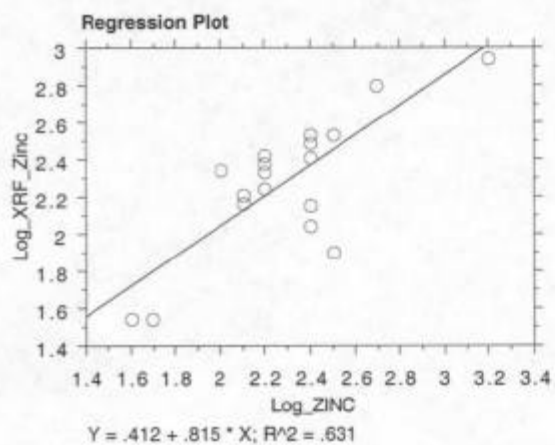
Count	18
Num. Missing	0
R	.794
R Squared	.631
Adjusted R Squared	.608
RMS Residual	.229

ANOVA Table**Log_XRF_Zinc vs. Log_ZINC**

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	1.433	1.433	27.347	<.0001
Residual	16	.839	.052		
Total	17	2.272			

Regression Coefficients**Log_XRF_Zinc vs. Log_ZINC**

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	.412	.361	.412	1.143	.2698
Log_ZINC	.815	.156	.794	5.229	<.0001



t-STATISTIC & P-VALUE DESCRIPTION

The **t statistic** is used for small samples (less than 30 samples) to determine the probability whether a sample mean is not equal to the expected population mean. In general terms, the greater the value of a t statistic for a given sample size, the stronger the probability a sample mean does not follow the expected population mean (i.e., the sample and population means are different). The **p-value** indicates this probability. The smaller the p-value, the greater the likelihood that the sample mean does not follow the expected population mean.

LEAST SQUARES REGRESSION DESCRIPTION

Least squares regression describes how two measurement variables are related. Most importantly for the purpose of this exercise, the least squares regression method describes how accurately we can predict the value of one variable (the cause) if we know the value of another variable (the response). The coefficient of determination (R^2) is interpreted as the proportion of the total variation of the response that can be explained by the cause. The rule of thumb for interpreting the R^2 and the correlation coefficient (R) is that there is a strong relationship between the cause and effect if $R^2 > 0.64$ ($|R| > 0.8$), a moderate relationship if $R^2 > 0.25$ ($|R| > 0.5$), and a weak relationship if $R^2 > 0.04$ ($|R| > 0.2$). In this test, the p-value indicates the probability that the observed relationship between the two variables is not false or artificial. The smaller the p-value, the greater the likelihood that the observed relationship is not false.