FINAL SITE CHARACTERIZATION REPORT
TALACHE MINE TAILINGS SITE,
ATLANTA, IDAHO

VOLUME I - TEXT

MAY 2000

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ABBREVIATIONS & ACRONYMS

AB-DTPA	ammonium bicarbonate diethylenetriaminepentaacetic acid
ADS	Advanced Drainage Systems
ANOVA	analysis of variance
AOC	Administrative Order on Consent
ASCE	American Society of Civil Engineers
AWQC	Aquatic Water Quality Criteria
BGS	below ground surface
BMP	Best Management Practice
BNF	Boise National Forest
CEC	cation exchange capacity
CI	confidence interval
CMP	corrugated metal pipe
CSM	conceptual site model
COPC	Constituent of Potential Concern
cy	cubic yard
EE/CA	Engineering Evaluation/Cost Analysis
FDM	Fugitive Dust Model
FS205	Forest Service Road No. 205
FS207	Forest Service Road No. 207
FS268	Forest Service Road No. 268
ft	feet
GIS	Geographic Information System
GPS	Global Positioning System
IDEQ	Idaho Division of Environmental Quality
IDWR	Idaho Department of Water Resources
IGS	Idaho Geological Survey
IMI	Idaho Mining Inspector
kg	kilogram
L	liter
lbs	pounds
MCE	Maximum Credible Earthquake
MCL	Maximum Contaminant Level
MFBR	Middle Fork Boise River
mg	milligrams
NTCRA	Non-Time Critical Removal Action
ORP	oxidation-reduction potential
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RQD	rock quality designation
SOW	Statement of Work
SPT	Standard Penetration Test
TCLP	Toxicity Characteristic Leaching Procedure
TLV	Threshold Limit Value
TOC	total organic carbon
TWA	Time-Weighted Average
U.S. EPA	United States Environmental Protection Agency
UAO	Unilateral Administrative Order

USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service

FINAL SITE CHARACTERIZATION REPORT

TALACHE MINE TAILINGS SITE
ATLANTA, IDAHO

1.0 INTRODUCTION

The Talache Mine Tailings Site ("Site") contains two historic tailings piles. On May 15, 1997, the Upper Tailings Pile sustained slope failure apparently due to excessive water accumulation. This event is hereinafter referenced as the "1997 release." The Upper and Lower Tailings Piles are located about ½ mile east of community of Atlanta in the northwest ¼ of Section 2, Township 5 north, Range 11 east, Elmore County, Idaho (Figure 1-1, Appendix A).

Prior to the 1997 release, the volume of the Upper Tailings Pile was estimated to total about 432,000 cubic yards (cy) and the volume of the Lower Tailings Pile was estimated to total about 94,000 cy (Hubble Engineering, 1987). Drilling and survey data collected during the 1998 field season indicated that, following the 1997 release, the volume of the Upper Tailings Pile is approximately 334,000 cy and the volume of the Lower Tailings Pile is approximately 175,000 cy. The elevation of the Upper Tailings Pile is approximately 5,690 feet. The upper surface of the lower tailings is about 30 to 40 feet below, and about 200 feet west-northwest of the surface of the Upper Tailings Pile. The Tailings Piles are situated on a west-facing hillside that culminates at an elevation of 7,182 feet.

A previous estimate of tailings volume lost from the upper pile during the 1997 release (approximately 31,000 cy) was made by the Boise National Forest (BNF). This estimate has been modified by Terracon using elevation survey data to approximately 16,000 cy. During the 1997 release, tailings were entrained in a debris flow that traveled in a northwesterly direction. The debris flow materials were deposited in a layer of variable thickness over an area estimated by BNF at 59 acres (Figure 1-2, Appendix A). The area in which tailings were deposited as a result of the 1997 release, and from reported earlier releases from the Tailings Piles, is hereinafter referenced as the "Depositional Area." The majority of the tailings in the Depositional Area were deposited in a layer less than six inches thick. However, a very limited number of tailings pockets within the primary debris flow channels were deposited as deep as eight feet. Additionally, isolated pockets of tailings in the Depositional Area, primarily where natural dams were created behind logs, debris, and along the leading edge of the willows, contained tailings deposits approximately two feet thick.

On July 11, 1997, a Consent Order was finalized between the Idaho Department of Health and Welfare, Division of Environmental Quality (IDEQ) and Monarch Greenback LLC.

On October 16, 1997, an Administrative Order on Consent (AOC) was finalized between the U.S. Department of Agriculture, Forest Service (USFS) Region 4 and Monarch Greenback LLC. This agreement stipulates additional steps where Forest Service - administered lands are affected.

On June 23, 1998, Monarch Greenback LLC accepted requirements identified in the Unilateral Administrative Order (UAO) issued by the United States Environmental Protection Agency (U.S. EPA) on June 18, 1998.

On October 28, 1998, the U.S. EPA issued Additional Response Actions Required Pursuant to the Unilateral Administrative Order for Removal Response Activities. This document specifies additional response actions required to support the Non-Time Critical Removal Actions (NTCRAs) at the Site.

On February 4, 1999, the U.S. EPA finalized an AOC with an attached Statement of Work (SOW). This AOC supersedes previous orders. Monarch Greenback LLC accepted the requirements identified in this AOC/SOW. The February 1999 AOC/SOW divides the Site into two areas (the Tailings Piles and the Depositional Area) and requires the conduct of an NTCRA for each area. As part of the NTCRA process, an engineering evaluations/cost analysis (EE/CA) has been prepared for the Tailings Piles, and will be prepared for the Depositional Area, to establish appropriate removal actions.

Per U.S. EPA guidance (EPA/540-R-93-057, August 1993), EE/CAs typically require streamlined human health and ecological risk evaluations to aid in the establishment of removal actions. While such an evaluation was conducted for the Tailings Piles EE/CA, the AOC/SOW requires the conduct of more detailed baseline human health and ecological risk assessments for the Depositional Area. At the time of writing, the EE/CA for the Tailings Piles has been completed and approved by U.S. EPA (MFG and Terracon, 1999a), and the removal action for the Tailings Piles has been selected by U.S. EPA. In addition, a Work Plan and Quality Assurance Plan for the Depositional Area has also been prepared in accordance with the February 1999 AOC/SOW and approved by the U.S. EPA (MFG, Terracon, and Pentec, 1999). The field work and analyses

required by that Work Plan were implemented during 1999 and the results of these activities are reported in this Site Characterization Report, where appropriate. This report also includes and evaluates data collected in 1998 and 1997. The data collected during 1999 will also be used in the Depositional Area risk assessments. It is expected that the selected removal action for the Tailings Piles will be implemented during the 2000 construction season. It is also expected that the Depositional Area removal action will be implemented in 2000, pending completion and approval of the baseline risk assessments and the Depositional Area EE/CA.

The February 1999 AOC/SOW has been amended by U.S. EPA and Monarch Greenback LLC and The Doe Run Resource Company (a successor-in-interest to the St. Joe Minerals Corporation with respect to environmental issues at the Site). This amendment specifically addresses the implementation of the Tailings Piles removal action design, as selected by U.S. EPA. As such, the amended AOC/SOW describes engineering design deliverables that U.S. EPA will require in connection with the Tailings Piles removal action.

A list of deliverables that have been prepared to date for this project is presented in Appendix B. Land swaps are being considered that would cause lands affected by the 1997 release to become Monarch Greenback LLC property. Other properties affected by the 1997 release include those administered by the Forest Service and those owned by Mr. Alva Greene and/or Greene Tree, Inc.

This Site Characterization Report provides information regarding the Upper and Lower Tailings Piles as well as the Depositional Area. The information presented in this report is part of the Administrative Record in support of the EE/CAs for both the Tailings Piles and the Depositional Area. In addition, information presented in previous drafts of this report has provided a basis for scoping data needs for the Work Plan and Quality Assurance Project Plan for the Depositional Area (MFG, Terracon, and Pentec, 1999). As previously noted, this Site Characterization Report includes data collected during implementation of that Work Plan, and interpretations of those data. This report includes:

1. discussion of the characteristics of the Site area, including physical setting, demographics of the area, ecological setting, and cultural and natural resource features;

2. a summary of historic mining activities;

3. presentation of investigations, response actions, and construction activities that have occurred at the Site; and

4. presentation and evaluation of relevant data that characterize the nature and extent of constituents of potential concern (COPCs) at the Site, and the fate and transport of those constituents.

2.0 SITE DESCRIPTION AND HISTORY

The following subsections provide a summary Site description and a summary of historic mining activities.

2.1 SITE DESCRIPTION

This section includes a description of the Atlanta area and the Site. Subsections address geography and physiography, demographics, ecological features, cultural features, and natural resource features.

2.1.1 Geography and Physiography

Atlanta is located 56 air miles east-northeast of Boise, Idaho near the southwest margin of the Sawtooth Range. In general, the USFS-BNF administers the majority of land in the area (Figure 1-1, Appendix A). The town of Atlanta was formed following the discovery of gold and silver in 1864. Currently, approximately 35-40 people are full-time residents. The town is situated on an alluvial fan and glacial till at the mouth of Quartz Gulch in a relatively wide portion of the MFBR valley near its confluence with Montezuma Creek.

Generally, the climate of the Atlanta area is characterized by moderately cold winters with abundant moisture. Spring and early summer months typically provide alternating periods of rainy cool weather and sunny warm days. Average annual precipitation at Atlanta is estimated at 35 inches. Most of the precipitation is during the autumn, winter, and spring months (Gelhaus, 1987). The growing season is short and limits crop production to a few hay fields and small gardens. Based on 1960-1999 data from a climatic station at the Graham Guard Station, located approximately 12 miles north-northwest of Atlanta and at the same approximate elevation, average snow cover occurs from mid November until the beginning of May each year. This information was derived from the Snotel web site.

The project Site, as defined by the tailings pile area and Depositional Area, is oriented in a northwesterly-southeasterly direction. The land slopes moderately towards the northwest and the MFBR (the direction of the tailings flow). The valley floor, including the Depositional Area, is

located at an elevation of approximately 5,300 feet. Greylock Mountain, with a maximum elevation of approximately 9,300 feet, is located to the north of the project Site, and the Atlanta Mine Hill, with a maximum elevation of approximately 7,200 feet, is located to the south of the project Site. Peaks to the east and west of the project Site reach elevations between 6,000 and 7,200 feet.

As previously noted, property comprising the Site is owned by several entities. Figure 2-1 (Appendix A) indicates the approximate boundaries of properties owned by Monarch Greenback LLC and Mr. Alva Greene, as well as public properties administered by the USFS. The property boundaries shown on Figure 2-1 may change in the near future, pending land swap negotiations that are currently underway.

2.1.2 Demographics

The Atlanta area has a low population density and a relatively low projected growth rate. The Elmore County Comprehensive Plan (1994) stated that the permanent population of the Atlanta Townsite in 1990 was 40 people. The Planning and Zoning Staff of Elmore County projected that the population of Atlanta would be 40 to 50 people in the year 2000, 50 to 70 people in the year 2005, 70 people in 2010, and 75 to 80 people in 2015. The document predicted that 16 housing units would be used in 1995, 18 in 2000, 22 in 2005, 28 in 2010, and 32 housing units in 2015, based on 2.1 people per household.

The county public facilities inventory lists a fire station, elementary school (recently reopened), library, post office, water system, and federal offices (probably referring to the USFS station). The townsite is zoned commercial and the surrounding area is zoned 'Agriculture B', the primary uses being farming, grazing, forest products, and mining. The BNF's Forest Management Direction, published in 1993, indicated that the area would be managed for undeveloped recreation.

Linda Gill, the Postmistress in Atlanta, estimated that there were about 35 to 40 permanent residents in Atlanta in 1999, with as many as 100 people visiting in the summer. She stated that, to her knowledge, there were eight children but no infants living in Atlanta, the youngest child being eight years old. She did not know of any pregnant or nursing women in Atlanta (Gill, 1999).

2.1.3 Ecological Features

Ecological features include terrestrial and aquatic resources, as discussed below.

2.1.3.1 Terrestrial Resources

Between September 29, and October 1, 1998, CH2M Hill performed a Site visit to conduct field work for the terrestrial habitat evaluation. A second round of terrestrial ecology field work was implemented during the summer of 1999. This included an assessment of both vegetation and wildlife. The results of the 1998 terrestrial habitat evaluation are presented in Appendix C-1. The results of the 1999 wildlife survey are presented in Appendix C-2.

2.1.3.2 Aquatic Resources

Between October 21, and October 24, 1998, Pentec Environmental performed a Site visit to conduct field work for the aquatic habitat evaluation. Follow-up work, including in-stream and overbank sediment sampling in Montezuma Creek, Unnamed Creek, and the MFBR was conducted by Pentec during July and September, 1999. Results from the sediment sampling effort are presented in Appendix D-1. The results of the 1998 and 1999 aquatic physical habitat assessment field work are contained within Appendix D-2.

2.1.4 Cultural Features

According to Mr. Greg Visconty (USFS-BNF), the USFS conducted a survey to determine what cultural resources exist on federal land that could affect the proposed land exchange involving USFS and Monarch Greenback lands (Visconty, 1998). This survey identified two potential cultural resource sites on federal land within the Depositional Area, neither one of which were found to be significant. The first site is an old dump, consisting of trash and other debris, located on the slope towards the MFBR, behind the Ours' cabin, along Forest Service Road 205 (FS205; approximate location of the Ours' cabin is shown on Figure 1-2, Appendix A). The second site is located at the confluence of Montezuma Creek and the Historic Powerhouse Flume. This site consists of wood and other debris. Neither of these sites contained cultural artifacts of significant importance to hinder the proposed land exchange.

Additionally, Mr. Visconty identified one potential cultural resource site located on private land (Visconty, 1998). This site is an historic mill site, located opposite Montezuma Creek from the Ours' cabin, adjacent to the MFBR. While the USFS did not assess the cultural significance of this site, it is believed that this site received little or no impact from the 1997 release or subsequent response activities.

Another important cultural feature in the Atlanta area is Kirby Dam, located approximately 2 miles west (downstream) of Atlanta on the MFBR. The dam was designed as a low-head hydroelectric structure for the purpose of supplying electrical power to working mines in the Atlanta district, as well as for domestic purposes.

2.1.5 Natural Resource Features

The area surrounding Atlanta contains abundant natural resources. The MFBR and its tributaries, including Montezuma Creek, support active fisheries. Geothermal springs in the vicinity support unique species of fish (e.g., dace) and provide recreational opportunities for people. Wetlands, in low-lying areas, support various wildlife species, including songbirds, beaver, and migratory waterfowl. Upland areas also support wildlife species, including elk, deer, bear, mountain lions, and coyotes.

Gold and other precious metals located in ore deposits represent significant natural resource reserves. Doug Glaspey of Twin Gold Corporation, which is exploring in the Atlanta area, stated that the Atlanta Mine Hill still contains over one million ounces of proven gold resources (Glaspey, 1998).

Timber in the area surrounding Atlanta represents another natural resource. Logging activities in the BNF operate during the summer and early fall months to harvest timber resources.

2.2 HISTORIC MINING ACTIVITIES

The Atlanta Mining District was worked as early as 1864 and small mines in the area continue to operate today. History of the area was available from several sources (Anderson, 1939;

Taylor, 1986; Skidmore, 1941; Campbell, 1932; Campbell, 1936; and Mining World, 1941). A summary of historical events is presented in Table 2-1 (Appendix E). The dates and events presented in Table 2-1 indicate that a number of mines have operated in the area since the 1860s. Early mining occurred in Quartz Gulch and in the central portion of the Atlanta Hill west of Montezuma Creek. Information specific to the Boise-Rochester mine [which included the same minerals claim as the St. Joseph Lead Company ("St. Joe") and Talache Mines, Inc.] is presented in the following subsections.

2.2.1 Boise-Rochester Mine

St. Joe acquired the Boise-Rochester mine in 1917; however, no work was done until 1929 when about 650 feet of tunnel was driven at the 600 level[1]. In 1929, St. Joe also acquired an option on the Monarch property. All work was temporarily suspended at the Site in July 1930. In September 1931, construction of a new amalgamation-flotation mill was begun. The mill was put in service on February 1, 1932. St. Joe mined and milled at the Site through early 1936.

St. Joe sold its Atlanta holdings to the Sawtooth Company (a predecessor to Talache Mines, Inc.) on May 31, 1936. Talache began milling at the former St. Joe facility on September 27, 1938. Talache operations peaked in 1941 when an average of 225 men were employed in the mine and mill. Operations were reduced through the 1940s and early 1950s when 20 to 50 men were employed.

Talache suspended mining on October 15, 1953 and beneficiated lessee ore at the mill until 1965. Table 2-2 (Appendix E) lists production data from the Atlanta Lode and associated veins exploited by St. Joe and Talache Mines, Inc., from 1932 to 1963. Inspector of Mines reports indicate that the Talache mill beneficiated 3,398 tons of antimony ore from Hermada Mining Company (owned by the Oberbillig family according to the Idaho Geological Survey); an additional 500 tons of this ore was beneficiated in 1950 by Talache Mines, Inc.

[1] The 600 level is defined as the area approximately 600 feet below the summit of the mine hill (Atlanta Hill).

2.2.2 Milling Operations

Milling operations by St. Joe in the 1930s are summarized in reports by the Idaho Mine Inspector (Campbell, 1932) and articles in Mining Congress Journal (Skidmore, 1941), Mining World (Mining World, 1941), and in a report by the Idaho Geological Survey (IGS, 1998). The ore was transported from production zones to the 900 Level tunnel. The ore was fed through a series of crushers, rollers and screens to an amalgamation circuit. The St. Joe milling operation is shown graphically in the process flowsheet (Figure 2-2, Appendix A).

The following paragraphs from Idaho Mine Inspector's Reports (Campbell, 1932) describe amalgamation and flotation processes at the St. Joe Mill ca. 1932. The beneficiated ore flowed over copper plates on which the amalgamation occurred. The plates were cleaned and dressed each morning, and the amalgam was removed with a hard rubber scraper. After scraping, the plates were scrubbed and washed with a whiskbroom and a weak solution of lye. The plates were then similarly cleaned with a weak solution of ammonia, after which they were flushed with clean water. Mercury was then sprinkled on the plates and rubbed in with a whiskbroom. Following application of the mercury, small chunks of clean gold-amalgam were added and thoroughly rubbed in with a whiskbroom. The plates were then ready for 8 to 24 hours of operation, depending on ore and process characteristics.

The flotation operation involved addition of reagents as follows (in pounds per ton of ore milled): Cresylic acid 0.15 pounds; pine oil 0.15 pounds; xanthate 0.12 pounds; potassium cyanide 0.002 pounds. The reagents were fed into pump intakes and mixed into the primary flotation cell. The tailing from the primary flotation cell was wasted, and the overflow flowed into launders and then into the secondary flotation cell. The tailing from the secondary cell was recycled to the primary cell, and the overflow flowed into the launders where additional reagents may have been added. Overflow from the secondary cell was washed down a launder to a filtration process. The cake from the filter dropped directly onto a hot plate for drying. The dry filter cake was then shoveled into sacks for shipment to the smelter.

It is noted that numerous reagents were used in the milling operations. Potassium and sodium cyanide are highly reactive and generally do not persist in the near-surface environment. Cyanide tends to be consumed by common soil bacteria, degraded by ultraviolet light, and oxidized

by common chemicals. As a result, it is generally not persistent in Tailings Piles, except in reduced conditions where it tends to react with iron and other metals to form complexes that sorb onto tailings solids.

The tailings were disposed of in 1931 as follows (Campbell, 1932). The tailings were conveyed in a launder (essentially, an elevated wooden chute) for a distance of 500 feet from the mill and dumped into a ditch 1,000 feet in length, which led to three impounding ponds built in tandem in Montezuma Gulch (the locations of the impounding ponds is estimated on Figure 2-3, Appendix A). The ditch and ponds were so arranged that but one pond at a time was in use. The overflow from these ponds led to a 2,000-foot ditch, which emptied into a settling or clarifying pond with an area of approximately 300 square yards.

Talache Mines purchased the holdings of St. Joe on May 31, 1936 according to the 1937 Idaho Mining Inspector (IMI) Report (IMI, 1937). The Talache mill, a "modern" amalgamation-flotation plant, using one 6-by-6 Marcy grate ball mill for fine grinding, was placed in operation in 1938. In late 1940, an 8-foot by 22-inch Harding ball mill was installed in parallel with the Marcy. The Talache milling operation is shown graphically in the process flowsheet (Figure 2-4, Appendix A).

In 1941, ore beneficiation at the Talache mill was described in an article by Mining World (Mining World, 1941).

> "Ore is transferred from a 1,000 ton coarse ore bin over apron feeders and fed over a grizzly to a Type A Traylor crusher. Bucket elevator then transfers the crushed ore to a Hum-mer No. 39 vibrating screen. The screen undersize drops directly into the 600 ton fine ore bin while the over-size is returned in closed circuit to Empire rolls. Crushed ore is drawn from the fine ore bin by belt feeders that discharge onto a conveyor belt. A splitter takes approximately one–half of the feed off the belt and discharges it into the scoop box of the Harding ball mill, while the other half of the feed discharges into a Dorr duplex classifier. Sands from the classifier are sent to one or both of the two ball mills.
>
> At the discharge end of each ball mill a Bendelari jig catches about 45 percent of the total gold recovery. Concentrates from these jigs are drawn off periodically and amalgamated in two pan amalgamators. The overflow from the jigs goes to the classifier in closed circuit with the ball mills. Classifier overflow averages 27% solids by weight and 55% minus 200 mesh. Flotation feed is transferred by sand pump to a Sawtooth conditioner. At the start of mill operations, the

classifier overflow was first passed over amalgamation plates. Still later, English corduroy was substituted, but neither of these methods recovered enough gold to justify their continuation."

The conditioned pulp was fed to Denver Sub-A flotation cells. Rougher concentrates flowed to a thickener and the settled concentrates were pumped to an American disc filter. Concentrates containing approximately 10% moisture were sacked and trucked to Boise where they were shipped via railroad to the Garfield, Utah plant of the American Smelting and Refining Company.

Numerous reagent combinations were used between 1938 and 1940 (Mining World, 1941). The following reagent combinations, including a variety of (unknown) proprietary reagents, were implemented:

- Slime dispersion with starch and sodium silicate in an alkaline circuit using soda ash or caustic soda to obtain alkalinity;
- All acid circuit, using sulfuric acid with and without Reagent 239;
- All alkaline circuit, using varying amounts of soda ash and caustic soda;
- Two independent circuits: acid and basic;
- Barium sulfide with and without an acid circuit;
- Sodium dichromate added to the ball mill or conditioner; and
- Reagents 208, 239, 404, Minerec "A", and fuel oil used with varying amounts of standard reagents.

The process changes presented above were reported to not have significantly affected gold recovery. However, cyanidation of the final mill tailings was reported to have significantly enhanced gold recovery (Mining World, 1941).

The Upper and Lower Tailings Piles have been the subject of various mining and exploration activities since the 1970s as a potential source for the recovery of gold and other metals.

2.2.3 Tailings Dispersal

As has previously been described, wet conditions during the Spring of 1997 resulted in excess water accumulation on top of the Upper Tailings Pile, which ultimately led to the 1997 release and the dispersal of approximately 16,000 cy of tailings to the Depositional Area. During response activities in 1997 and 1998 (described in detail in Sections 3.6.1 and 3.6.2), removal of selected accumulations of tailings associated with the 1997 release revealed the presence of older layers of buried tailings in the Montezuma Creek valley. The origin of these older tailings layers is not clear. Anecdotal information gathered from long-time residents suggests that the tailings may have been released during an older slope failure event at the Tailings Piles, possibly occurring around 1940. However, aerial photographs dated July 22, 1939 show neither a breach in the lower tailings pile nor a depositional area. Characterization of the historical buried tailings is provided later in this Site Characterization Report.

3.0 INVESTIGATIONS AND ACTIONS CONDUCTED TO DATE

Limited environmental data are available prior to the 1997 release, and these data were not necessarily collected or analyzed with appropriate quality assurance and quality control (QA/QC) measures. After the 1997 release, extensive sampling of environmental media was conducted by the IDEQ, the U.S. EPA and Terracon. Additional samples were collected in 1997 by Montgomery Watson for the Atlanta Gold Corporation. Terracon continued to conduct monitoring of surface water and groundwater through 1999. The following subsections present data associated with investigations conducted to date.

3.1 ATLANTA (TWIN) GOLD

During the 1980s, Atlanta Gold Corporation (now Twin Gold), and its subsidiary, Atlanta Gold Corporation of America, performed exploration, testing, and evaluation near Atlanta to support a potential new gold mine near the Site. A baseline hydrology investigation included two wells (AG-1 and AG-3) that were installed on property owned by Mr. Alva Greene (Hydrometrics 1986b). These wells were groundwater supply exploration sites for the potential mine operations facility. Atlanta Gold also installed two piezometers (P1 and P2) in the Upper Tailings Pile. Well and piezometer locations are shown in Figure 3-10 (Appendix A). Surface water sampling was also conducted by Hydrometrics (1987), Environet (1996), and Montgomery Watson (1997). Some of these investigations have produced environmental data such as soil samples and surface water samples. Four samples with historical data, two collected by Hydrometrics in MFBR and Montezuma Creek in 1987 and two samples collected by Environet in the MFBR and Montezuma Creek in 1996, were excluded from this investigation. They were excluded because they did not meet the criteria for data usability specified in Guidance for Data Usability in Risk Assessment, Part A (U.S. EPA 1992). In particular, the data were excluded for the following reasons:

- Inadequate documentation of sampling techniques;
- Inadequate documentation of analytical techniques;
- Detection limits were not provided; and,
- No indication was given regarding whether the data had been adequately reviewed.

3.2 IDEQ

IDEQ collected surface water and soils/tailings samples at several locations in the project area following the 1997 release. These samples have been collected under correct chain-of-custody procedures and analyzed at a State of Idaho certified laboratory using U.S. EPA-approved methods. Where appropriate, these data will be used in this investigation.

3.3 U.S. EPA

U.S. EPA and its contractors collected surface water and soils/tailings samples from around the project area following the 1997 release. These samples have been collected under correct chain-of-custody procedures and analyzed at an U.S. EPA-approved laboratory using U.S. EPA-approved methods. Where appropriate, these data will be used in this investigation.

3.4 TERRACON

Terracon has collected surface water, soil, sediment, and tailings samples since work began on this Site in May, 1997. Sediment, soil, and tailings samples have been collected to determine background concentrations of metals and the extent of the 1997 release. In July, 1997, Terracon set up a surface water sampling network to evaluate water quality in Montezuma Creek and the MFBR. Samples were collected on a monthly basis for the first 3 months, then collected every other month over the winter and bi-monthly surface water samples were collected during spring 1998. Beginning in the summer of 1998, surface water sampling intervals were changed. Currently, samples are collected quarterly, except in the spring when samples will be collected on a weekly basis. Groundwater monitoring wells were installed in 1998. Air monitoring samples were collected to help determine the impact of the tailings on the general public and on the workers performing the cleanup activities. In addition, geotechnical data has been collected to support engineering evaluations of various alternatives. These elements are presented and discussed in this report, where appropriate.

A data quality assessment of samples collected from the Site during 1997 and 1998 by Terracon was conducted during the Spring of 1999 (MFG, 1999a). Data evaluation checklists were utilized to perform the assessment. The evaluation checklists assessed the accuracy, precision, completeness, and representativeness of the data. Data evaluated included: soil samples collected during June 1997 through October 1998; surface water samples collected during May 1998 through

December 1998; groundwater samples collected during July 1998 through December 1998; and air quality data collected in 1997 and 1998. Through evaluation of the data, all soil, surface water, groundwater, and air data collected during 1997 through July 1998 are considered to be of screening quality. Soil, surface water and groundwater data for samples collected from August 1998 through December 1998 are considered to be of enforcement quality. Samples collected under the Work Plan and Quality Assurance Project Plan for the Depositional Area (MFG, Terracon, and Pentec, 1999) also are expected to be of enforcement quality. Use of the older screening level data will require care to ensure that appropriate conclusions are reached.

3.5 MONTGOMERY WATSON

Montgomery Watson collected surface water samples on October 9 and 10, 1997. This work was performed for Atlanta Gold to characterize water quality in the drainage, streams, and rivers in the vicinity of Atlanta, Idaho. Of the samples collected by Montgomery Watson, two sampling stations, MFBR at Kirby Dam and Montezuma Creek at Forest Service Road 268 (FS268), appear to be the same stations that have been used as part of Terracon's regular surface water monitoring program. The results from these two stations are presented in the designated section of this report.

3.6 RESPONSE ACTIVITIES

The following subsections describe response actions taken in 1997, 1998, and 1999. These response actions include construction activities aimed at stabilizing and removing tailings associated with the 1997 release, as well as environmental monitoring undertaken to support risk assessment and EE/CA activities.

3.6.1 1997 Response Activities

Response activities performed during 1997, and the first part of 1998 until the U.S. EPA issued the Unilateral Administrative Order on June 18, 1998, were performed under the Voluntary Consent Order between Monarch Greenback LLC and Idaho Department of Health and Welfare, Division of Environmental Quality. The Voluntary Consent Order was entered into on July 11, 1997. On October 16, 1997 an Administrative Order on Consent was finalized between the United States

Department of Agriculture, Forest Service Region 4 and Monarch Greenback. This agreement stipulates additional steps where Forest Service - administered lands are affected.

3.6.1.1 Initial Response Activities

Several initial mitigation actions designed to retard the transport of tailings materials were performed during the first two months following the 1997 release. On May 16, 1997 the initial Site visit was performed. This reconnaissance-level visit resulted in immediate installation of silt fences and sediment barriers (Figures 3-1 and 3-2, Appendix A). Short-term mitigation and initial data gathering activities were conducted in the period from May 19, 1997 through June 27, 1997. This work included the excavation of channels in the vicinity of the tailings pile area to divert surface water runoff away from the piles.

The 24" corrugated metal pipe (CMP) FS207 was initially installed to divert water away from the tailings area to minimize ongoing erosion and transport. Temporary ditches were constructed to carry water not impacted by the breach away from the tailings transport channel. The waters initially intercepted included that from a flume associated with the East Fork of Montezuma Creek and the diverted spring water from above the upper tailings. No tailings were observed in the diversion any time.

3.6.1.2 1997 Construction Activities

On July 21, 1997, Terracon submitted Work Plans for Talache Mine Tailings Site to the IDEQ. This document included three sections: Mapping and Field Investigation Work Plan, Environmental Monitoring Plan, and Interim Corrective Action Plan. Critical elements of the Interim Corrective Action Plan were completed during 1997 (Figures 3-3 and 3-4, Appendix A). Construction activities completed during 1997 included the following items:

- The lower tailings impoundment structure (Sedimentation Basin #1; approximately 20 feet high and 300 feet long) was complete on September 19 and includes a water outlet structure and emergency spillway. The impoundment behind the structure has a capacity of about 4,400 cy.

- Three separate sedimentation basins (total capacity of approximately 8,200 cy) have been constructed in series downstream of the impoundment structure. The two

middle basins (Sedimentation Basins #2 and #3) have rock-lined spillways. The lowest basin (Sedimentation Basin #4) has two outlet structures: an adjustable outlet structure and an emergency spillway.

- Water is conveyed from Sedimentation Basin #4 into two land application areas located north of FS268. The land application areas each consist of a series of parallel trenches constructed on contours. As Site-related water from the sedimentation basins flows through the trenches the water evapotranspires and infiltrates.

- A surface water diversion structure was constructed north of FS268 to divert water from Sedimentation Basin #4 into the two land application areas (western and eastern) located north of FS268.

- An additional sedimentation basin (Sedimentation Basin #5) and land application area was constructed west of FS207.

- A surface water diversion structure was constructed at the base of Sedimentation Basin #1 to divert water into the two sedimentation basin systems (Sedimentation Basins #2, #3, #4 and Sedimentation Basin #5).

- A baseflow surface water diversion structure was constructed approximately 5 feet east of FS207, between the Lower Tailings Pile and FS207. The baseflow diversion structure collects water from the roadside ditch that runs along the east side of FS207. Baseflow water, consisting primarily of groundwater from seeps and springs along FS207, is diverted into the trench that leads to Sedimentation Basin #5 and the land application area, while stormflow is diverted into the 24" culvert, under FS207, and into Montezuma Creek.

During construction of sedimentation basins 1, 2, and 3, and placement of the toe drain at the base of the upper tailings in 1997, water was directed to the sedimentation basins, and the ditches leading to 24" CMP FS207 were filled or plugged. By November 1, 1997, the diversion had been modified so that base-flow water from springs and seeps along FS 207 is routed into the sedimentation basin

and land application systems, while diverting storm water runoff along FS 207 into the 24" CMP, underneath FS207, and into Montezuma Creek. Storm water runoff contribution to the 24" CMP FS207 is primarily from the roadside ditch and other upgradient sources that are not part of the project site. The only tailings pile storm water that could enter 24" CMP FS207 is that from the western outer slope of the lower tailings pile, which is vegetated and stable. With the exception of overflow stormwater runoff from the western outer slope of the lower tailings piles, seeps and springs, which are routed through the 24" CMP FS 207, all water from the upper and lower tailings piles is routed through the sedimentation basin system to land application sites. The diversion structure at 24" CMP FS 207 was constructed to collect and treat water that surfaces west of the lower tailings impoundment and divert non-tailings stormwater runoff into Montezuma Creek. The 24" CMP could act as a potential pathway for tailings on the western outer slope of the lower tailings pile to enter Montezuma Creek. However, because this slope is vegetated and stable, is not likely that tailings will migrate to the creek via this route.

Following snow melt runoff in 1998, the diversion structure was re-constructed using concrete and four horizontal PVC pipes (two one-inch diameter, and two two-inch diameter) with removable caps. The PVC pipes are situated just below the elevation of the 24" CMP. Using the removable caps, the water level is adjusted in the small pool upgradient of the diversion structure. This allows regulation of the flow into the sedimentation basin versus that diverted to Montezuma Creek. Except during high runoff events, the diversion structure operates to route water into the sedimentation basin and land application system.

- A surface water diversion channel was constructed above the upper tailings. The channel is approximately 2,000 feet long and should be capable of diverting the calculated 500-year, 24-hour rainfall runoff event. Supporting calculations are presented in Appendix A of the Tailings Piles EE/CA (MFG and Terracon, 1999a).

- A toe berm was constructed in the breach area of the upper tailings embankment. Rockfill, geotextile, and a groundwater collection drain were placed for a distance of approximately 400 feet across the breach area and along the base of the upper tailings embankment. Water collected from the drain was directed through a series

of Best Management Practice (BMP) sedimentation basins on the surface of the lower tailings before entering the previously described sedimentation basin and land application systems.

- In the Depositional Area, Unnamed Creek was diverted into a constructed channel. The constructed channel is located north of the Depositional Area, and approximately 50 feet north of the natural channel of Unnamed Creek. Unnamed Creek re-enters its natural channel approximately 75 feet above the confluence with Montezuma Creek. It should be noted that Unnamed Creek flows across a historic tailings pile (the Greene tailings) that is unrelated to the Site before entering the north side of the Depositional Area created by the 1997 release. The location of the Greene tailings is shown on Figure 1-2 (Appendix E).

- Water management features and BMP structures were inspected and maintained throughout 1997.

This diversion was completed on June 24, 1997 and modified by November 1, 1997. Following the slope failure event, most of the surface water in the tailings area flowed through the lower tailings breach and contributed to ongoing erosion and transport. Temporary ditches were constructed to carry non-tailings water away from the tailings transport channel. The waters initially intercepted included that from a flume associated with the East Fork of Montezuma Creek and the diverted spring water from above the upper tailings. Additional surface water collector ditches were excavated in non-tailings areas below the upper tailings and south of the lower tailings. The total flow at 24" CMP FS207 was measured at 40 gpm upon completion, and no tailings were allowed to enter it at any time.

During construction of sedimentation basins 1, 2, and 3, and placement of the toe drain at the base of the upper tailings in 1997, water was directed to the sedimentation basins, and the ditches leading to 24" CMP FS207 were filled or plugged. By November 1, 1997, the diversion had been modified so that base-flow water from springs and seeps along FS 207 is routed into the sedimentation basin and land application systems, while diverting storm water runoff along FS 207 into the 24" CMP, underneath FS207, and into Montezuma Creek. This storm water runoff receives virtually no contribution from the tailings piles due to topographic slope. Storm water runoff contribution to the 24" CMP FS207 is primarily from the roadside ditch and other upgradient

sources that are not part of the project site. The only tailings pile storm water that could enter 24" CMP FS207 is that from the outer slope of the lower tailings pile, which is vegetated and stable. All water from the tailings piles is routed through the sedimentation basin system to land application sites. The diversion structure at 24" CMP FS 207 was constructed to collect and treat water that surfaces west of the lower tailings impoundment and divert non-tailings stormwater runoff into Montezuma Creek.

3.6.1.3 1997 Tailings Excavation and Removal Operations

During the 1997 field season, approximately 7,000 cy of tailings were removed from the Depositional Area and placed on the surface of the Lower Tailings Pile. The removals were conducted in specific "zones." Each zone was selected based on the general criteria of ecological sensitivity, quantity of tailings present, and ease of access. For example, areas along Montezuma and Unnamed Creeks (sensitive areas) that contained significant quantities of tailings and that could easily be accessed without significant disruption of wetland function were identified as priorities for tailings removal during the response actions.

The majority of the tailings were removed from Zone 1A (Figure 3-5, Appendix A). Additionally, minor quantities of tailings were removed from Unnamed Creek channel on USFS property (Zone 10A). Prior to excavation and removal operations, tailings in Zone 1A were as deep as two feet in some locations. The tailings removed from the Depositional Area were placed on the surface of the lower tailings, contoured to drain through the BMP basins, and compacted. Portions of the Depositional Area were then hydro-mulch-seeded. The specific areas hydroseeded included:

- Zone 1A;
- Upland areas upgradient of Zone 1A where tailings were not removed, where vegetation was absent or inadequate (as determined in the field); and
- Areas associated with the sedimentation basin / land application system where vegetation was disturbed during construction activities.

Following reseeding operations approximately 500 straw bales were placed at strategic locations on-site and 160 additional bales were stockpiled on-site for future use. Also, 300 sand bags were stockpiled onsite for use during spring run-off.

3.6.1.4 1997 Environmental Monitoring

Environmental monitoring and sampling of surface water, air, and tailings/soil were conducted in 1997. No sampling of groundwater for chemical analysis was performed in 1997. Surface water samples were collected at several irregular locations or sites that no longer exist by Terracon, IDEQ, and U.S. EPA. Surface water samples collected by IDEQ and U.S. EPA, as well as the surface water samples collected by Terracon prior to initiation of regular surface water monitoring, were grab samples collected sporadically from selected locations throughout the Site. The grab sample data are difficult to compare with the width- and depth-integrated sample data collected by Terracon as part of the regular surface water monitoring program, initiated on August 13, 1997. During the year, additional surface water samples were collected as part of the regular monitoring program on the following dates: September 16 - 17, October 15, and December 16 - 17. Surface water sampling dates and locations for 1997 are presented in Table 3-1 (Appendix E). With some modifications, the surface water sampling stations have remained the same for Terracon's regular surface water monitoring program. Further details concerning Terracon's surface water monitoring program, including field parameters, chemical analysis results, sampling stations, sampling intervals, and monitoring parameters are presented in the surface water hydrology section of this report.

Other than the May and June sampling, no additional soils/tailings samples were collected from the tailings pile area in 1997. Soil and tailings samples were collected from the Depositional Area in 1997 by IDEQ, U.S. EPA, and Terracon. Additionally, Terracon collected one sample from the Greene tailings pile in 1997, and U.S. EPA and Terracon each collected one sediment sample from Montezuma Creek. Additional sampling of soils that were not impacted by the 1997 release event was conducted by IDEQ and Terracon. The results of chemical analysis of soils/tailings are reported in the designated section of this document.

Air quality sampling was performed between October 17 and October 22, 1997. Two Wedding Critical Flow High Volume PM-10 air samplers were used. One of the monitors was situated to measure an upper limit of chronic exposure and the other was situated to measure an upper limit of acute exposure. The chronic exposure site was located adjacent to residences within about 400 feet of the tailings Depositional Area. The acute exposure site was located in the Depositional Area 12 feet north of FS268 and 40 feet east-northeast of the intersection with FS207.

The chronic and acute exposure sites are shown on Figure 3-6 (Appendix A). The results of the air quality sampling activities are presented in the designated section of this report.

3.6.1.5 1997 Piezometer Installation

Ten piezometers were installed in 1997 to estimate depth to groundwater and groundwater flow direction. Groundwater depth measurements and groundwater flow direction estimates are presented in the designated section of this report.

3.6.2 1998 Response Activities

Response activities performed during the first six months of 1998 were performed under the Voluntary Consent Order between Monarch Greenback LLC and the IDEQ, and the Administrative Order on Consent between the USFS, Region 4, and Monarch Greenback LLC. On June 23, 1998, Monarch Greenback LLC accepted requirements identified in the Unilateral Administrative Order issued by the U.S. EPA on June 18, 1998. The construction activities and tailings removal operations that were performed during the late summer and early fall of 1998 were conducted under this order. On October 28, 1998, the U.S. EPA issued Additional Response Actions Required Pursuant to the Unilateral Administrative Order for Removal Response Activities. This document specifies additional response actions required to support the NTCRA activities at the Site. This Site Characterization Report, and other reports, are being prepared under the October 28, 1998 document.

3.6.2.1 1998 Construction Activities

Construction activities were performed during 1998 in the vicinity of the Tailings Piles, primarily to stabilize the tailings and prevent releases of water that has contacted tailings into surface water features, such as Montezuma Creek and the MFBR. The various construction features that were completed during 1998 are indicated on Figures 3-7 and 3-8 (Appendix A). The 1998 construction activities included the items listed below.

- An access road was constructed from FS207 to the base of the Lower Tailings Pile to provide access during breach stabilization and sediment removal operations.

- Rock drains were placed in the bottom of the lower tailings embankment erosional area to drain water prior to the initiation of backfill and stabilization activities. Groundwater springs located in the base of this erosional area were discharging substantial quantities of water into the area and making the footing very poor for the equipment to begin installing and grading the fill material. This problem was addressed by placing rock drains, consisting of several layers of filter fabric and coarse rock into the base of the eroded area to segregate the water from the backfilled pit-run.

- The Lower Tailings Pile erosional area was stabilized using pit-run excavated from two sources: the new emergency sedimentation basin constructed north of FS268, and the borrow source southwest of the Lower Tailings Pile. According to measurements conducted after the pit-run was installed and compacted, approximately 8,000 cy of pit-run was to stabilize this area (Photos 1 and 2; Appendix F).

- The berm between Sedimentation Basins #3 and #4 was removed (creating Sedimentation Basin 3/4). This increased the storage in the sedimentation basin system by approximately 500 cy. Following this activity, the total storage capacity of Sedimentation Basins #2 and 3/4 was approximately 8,700 cy.

- The surface water diversion structures located at the 24" CMP along FS207 (baseflow diversion structure), at the base of Sedimentation Basin #1, and at the outlet to Sedimentation Basin #4, were redesigned. Following snow melt runoff in 1998, the diversion structure was re-constructed using concrete and four horizontal PVC pipes (two one-inch diameter, and two two-inch diameter) with removable caps. The PVC pipes are situated just below the elevation of the 24" CMP. Using the removable caps, the water level is adjusted in the small pool upgradient of the diversion structure. This allows regulation of the flow into the sedimentation basin versus that diverted to Montezuma Creek. Except during high runoff events, the diversion structure operates to route all water into the sedimentation basin and land application system. Prior to construction, each of these diversions were sandbag structures. Although the sandbag structures performed adequately during the prior

year and provided the basis for the design of the concrete structures, more permanent fixtures, in the form of concrete diversion structures, were necessary.

- Vertical sidewalls were removed from the upper tailings breach area (Photo 3; Appendix F). This was done to prevent sloughing and stabilize the tailings in the upper breach.

- Surface water conveyance pipe was installed from the surface of the Upper Tailings Pile to Sedimentation Basin #1. A water collection drain [perforated 12" diameter vertical Advanced Drainage System (ADS) pipe] was positioned near the breach in a depression on the surface of the Upper Tailings Pile to collect water and convey it in a pipe away from the breach area. This should reduce overland flow and erosion of tailings in the Upper Tailings Pile breach, and reduce the amount of water collecting on the surface of the Lower Tailings Pile.

- Water collection drains (perforated 12" diameter vertical ADS pipe) and BMP berms/sediment retention dikes were installed in three locations on the surface of the Lower Tailings Pile to prevent water accumulation on the surface of the lower pile. Approximately 730 cy of fill material, from the new sedimentation basin located north of FS268, was used to construct the sediment retention dikes. Each of the berms was installed in series and connected with 12" diameter ADS pipe. The final berm/drain is located on top of the pit-run used to stabilize the lower pile breach. From this location water is conveyed in a pipe into Sedimentation Basin #1.

- Approximately 150 cy of sediment and tailings were excavated and removed from the sedimentation basins.

- Approximately 630 cy of fill material from the new sedimentation basin located north of FS268 was used to construct a snow-melt retention dike. The snow-melt retention dike is located west of the Upper Tailings Pile and is designed to convey snow-melt water west, across FS207, and into Montezuma Creek. If necessary, due to an unusually wet winter, snow will be pushed off the surface or the Upper Tailings Pile using a track-mounted blade ("dozer") into the area upgradient from the snow-melt retention dike. Once the snow melts, the water will be conveyed,

without contacting tailings, away from the Tailings Piles and into Montezuma Creek.

- A 24" CMP was installed underneath FS207 to convey water from the snow-melt retention dike to the west, across FS207, and into Montezuma Creek.

- The surface water diversion channel above the Upper Tailings Pile was regraded to remove high spots in the channel.

- Newly installed diversion structures were adjusted to function as designed.

- BMP structures were inspected.

3.6.2.2 1998 Tailings Excavation and Removal Operations

This section contains a zone-by-zone summary of tailings removal actions performed in the Depositional Area of the site during the 1998 construction season. Figure 3-5 (Appendix A) shows the various zones involved in the tailings removal operations during 1998.

On Wednesday July 29, and Thursday July 30, 1998, a field meeting was conducted to determine tailings removal criteria for the 1998 field season. Representatives of U.S. EPA, USFS, United States Fish and Wildlife Service (USFWS), IDEQ, Nelson Construction, and Terracon were present. During the meeting, it was decided that tailings excavation and removal would be conducted around Montezuma Creek (Zones 4B, 6B, 7B, and 4A), Unnamed Creek (Zones 10A and 4B), the upland area immediately upgradient from the willows in the lower deposition area (Zones 1A and 9A), areas immediately adjacent to FS205 (Zones 1B, 2B and 3B), and from some of the tailings draws that extend into the willows (Zones 2A, 3A, and 4A). A representative of Terracon was on-site during removal activities, along with representatives from U.S. EPA and USFS, to define areas for excavation and removal of tailings. In general, tailings were excavated and removed in areas with stressed or non-existent vegetation that are susceptible to erosion. Tailings that were near areas that people may occupy (i.e., roads) were also targeted for removal.

3.6.2.3 Zone 1A

Zone 1A is the open area immediately upgradient from the willows. Tailings in Zone 1A were excavated and removed from non-vegetated areas and vegetated areas. Excavation and removal operations were accomplished primarily using a dozer and a front-end loader. Two ten-wheel dump trucks hauled the material to the surface of the lower tailings. The edges of the removal area were cleaned up using a Bobcat® loader and shovels.

3.6.2.4 Zone 2A

Zone 2A was a small deposit in the willows along the southern edge of the Site. Tailings in Zone 2A were excavated and removed from non-vegetated areas, primarily using a backhoe. The edges of the removal area were cleaned up using shovels.

3.6.2.5 Zone 3A

Zone 3A was a deposit in the willows along the southern edge of the Site (located just northwest of Zone 2A). Tailings in Zone 3A were excavated and removed from non-vegetated areas, primarily using an excavator. Tailings located deeper into the willows were removed primarily using shovels. The edges of the removal area were cleaned up using a Bobcat® loader and shovels.

3.6.2.6 Zone 4A

Zone 4A was a deposit in the willows along the southern edge of the Site (located just north of Zone 3A). Tailings in Zone 4A were two feet deep in some locations. Tailings in Zone 4A were excavated and removed from non-vegetated areas and areas with severely stressed vegetation using an excavator. Tailings located deeper into the willows were removed primarily using shovels.

3.6.2.7 Zones 5A through 8A

Zones 5A through 8A were deposits in the willows in the central and northern part of the removal area. As discussed in the July field meeting, tailings in each of these zones were removed only back to the leading edge of the willows. In the areas beyond (west of) the willows, the abundant native vegetation was not disturbed.

3.6.2.8 Zone 9A

Zone 9A is the area immediately upgradient of Zone 1A. Tailings in Zone 9A were removed from all non-vegetated areas, including from readily accessible areas along Unnamed Creek channel on the northern edge of the Depositional Area. Tailings were removed from open areas using a dozer and a front-end loader. In difficult access areas the backhoe and shovels were used where there was adequate footing, and excavators were used where the footing was insufficient for rubber-tired vehicles.

3.6.2.9 Zone 10A

Zone 10A is the original channel and floodplain of Unnamed Creek. Unnamed Creek was placed in an excavated channel following the 1997 release. Tailings excavation and removal activities were attempted in the Unnamed Creek channel during 1998. Although the stream had been diverted for over a year, adequate footing for the track-mounted excavator in Unnamed Creek did not exist. Given Site conditions, the U.S. EPA and other agency representatives decided not to attempt removal of material in this reach of Unnamed Creek. Unnamed Creek remained in the constructed channel until 1999, when tailings were removed from the former creek channel and the creek flow was restored to the former channel (see Section 3.6.3.1).

3.6.2.10 Zone 1B

Zone 1B consists of the areas immediately adjacent to FS205. Nearly all tailings from the 1997 release were excavated and removed from Zone 1B. USFS personnel were concerned about this area because of the close proximity to areas occupied by people (e.g., FS205 and the Ours' cabin), and wanted tailings removal to be as complete as possible, regardless of the quantity or quality of existing vegetation. Tailings excavation and removal was accomplished in Zone 1B using all available equipment and personnel on the Site. In open areas, tailings were removed using a dozer and front end loader. In moderately accessible areas, tailings were removed using the backhoe and excavators. In difficult access areas and for cleanup, tailings were removed using the Bobcat® loader and shovels. Approximately 90 cy of fill dirt (pit run from the borrow source north of FS268) was brought in to provide a cap in areas where tailings from the 1997 release were removed.

3.6.2.11 Zone 2B

Zone 2B is the triangular pasture immediately adjacent to FS205, on the east side of the road, south of Montezuma Creek. Nearly all tailings from the 1997 release were excavated and removed from Zone 2B. USFS personnel were concerned about this area because of the close proximity to areas occupied by people (e.g., FS205). Excavation and removal operations in Zone 2B were accomplished primarily using a dozer and a front-end loader. The edges of the removal area were cleaned up using a Bobcat® loader and shovels.

3.6.2.12 Zone 3B

Zone 3B is the ditch area immediately adjacent to FS205, on the east side of the road. Nearly all tailings from the 1997 release were excavated and removed from Zone 3B. USFS personnel were concerned about this area because of the close proximity to areas occupied by people (e.g., FS205). Excavation and removal in Zone 3B was accomplished primarily using a backhoe and excavator. The edges of the removal area were cleaned up using a Bobcat® loader and shovels.

3.6.2.13 Zone 4B

Zone 4B is the area adjacent to Unnamed Creek, before the confluence with Montezuma Creek, and the area adjacent to Montezuma Creek, after the confluence with Unnamed Creek. Excavation and removal in Zone 4B was accomplished primarily using a backhoe and excavator. The edges of the removal area and areas immediately adjacent to the creeks were cleaned up using a Bobcat® loader and shovels.

3.6.2.14 Zone 5B

Zone 5B is the area just south of Unnamed Creek channel. This area was identified as potential habitat for an endangered orchid (*Spiranthes diluvialis*) by the USFS and USFWS. Additionally, this area was largely unimpacted by the 1997 release. Although no *Spiranthes diluvialis* were located on the project Site during surveys conducted by USFS, no excavation and removal operations were conducted in Zone 5B, and equipment was excluded from operating in this area.

3.6.2.15 Zones 6B, 7B, and 8B

Zones 6B, 7B, and 8B are areas within the interior of the willows. These areas were difficult to access because of a lack of inroads into this area, and wet conditions provided poor footing for vehicles. To provide access into this area, a road was constructed from Zone 2B, along the south side of Montezuma Creek, into the interior of the willows. Additional access roads were constructed along both sides of Montezuma Creek, east to Zone 4A and west to Zone 6B. Tailings in this zone were removed from non-vegetated, readily erodible areas. Tailings removal was accomplished primarily using shovels and tailings were hauled out of this area using a 6-wheel ATV with a 6-cubic foot reclining bucket. Areas with adequate footing were accessed using a Bobcat® loader (Photo 4; Appendix F).

Tailings excavation and removal from active stream channels, primarily Montezuma Creek, proved to be very difficult. This work began by installing a straw bale dam with a 20-foot section of 12-inch diameter plastic pipe inserted through the dam to dry out a 20-foot section of the stream channel. Once the stream channel was relatively dry, tailings excavation and removal, using shovels, was initiated. Digging in the stream channel was very difficult due to cobbles and larger rocks in the stream bed.

3.6.2.16 Reclamation of Disturbed Areas

Seventeen acres of disturbed areas, where tailings excavation and removal occurred, were reseeded using hydroseeding and hand broadcasting of seeds following the conclusion of removal operations. The specific areas hydroseeded included:

- All open and accessible areas where tailings excavation and removal occurred this year (this includes Zones 1A, 9A, 1B, 2B, 3B, and portions of Zone 4B, and excludes areas within the willows where vegetation was transplanted, plugs were planted, and some seed was hand broadcast);

- Areas within the project Site where tailings were not removed, where vegetation was absent or inadequate (as determined in the field);

- Areas associated with the sedimentation basin / land application system where vegetation was disturbed during construction activities;

- The erosion fill area at the outlet of the lower tailings embankment;
- Portions of the snow water diversion trench immediately adjacent FS207; and
- Areas used by Nelson Construction for the main decontamination station and vehicle parking / storage.

The specifications used for hydroseeding were as follows:

- Wood fiber mulch with tackifier was applied at 1,600 pounds per acre;
- Fertilizer (16-16-16-S) was applied at 400 pounds per acre;
- Foli-Gro nutrient enhancer was applied at 5 gallons per acre; and
- Seed was planted at 60 pounds per acre, allocated approximately as follows:
  - Covar sheep fescue (20%);
  - Rosana western wheatgrass (18%);
  - Secar bluebunch wheatgrass (15%);
  - Trailhead basin wildrye (15%);
  - Climax timothy (15%);
  - Annual ryegrass (10%);
  - Alsike clover (5%); and
  - White yarrow (2%).

Approximately one acre within the willows, adjacent to Montezuma Creek, was seeded by hand broadcasting approximately 65 pounds of seed and raking the seed into the soil (includes portions of Zones 7B, 4A, and 8B). Hand broadcasting was done primarily on the access roads constructed on both sides of Montezuma Creek, upgradient of the braided section of Montezuma Creek within the Depositional Area. Some bare spots, where pods of tailings were removed, were also seeded by hand broadcasting.

Vegetation was transplanted into wetland areas where tailings removal operations occurred (includes portions of Zones 7B, 4A, 2A, 3A, 4A, 5A, 9A, and 1A). Sedges (*Carex* spp.) and rushes (*Juncus* spp.) were transplanted from unimpacted source areas into areas stripped of vegetation by

tailings removal operations. Additionally, 3,000 plugs of beaked sedge (*Carex rostrata*) were purchased and planted in areas with little or no access to unimpacted source material.

Approximately 600 straw bales were placed within the removal area to protect against erosion during spring runoff. Four rows of straw bales were placed, in series, across the entire removal area, upgradient from the willows. Additional bales were placed in strategic locations downgradient from Zone 1A, where overland flow is likely.

3.6.2.17 1998 Wetlands Delineation

A wetlands delineation was performed during the week ending August 18, 1998. Two wetlands were identified within the Tailings Piles area of the Site. The extent of the wetlands was surveyed during the following week to develop a wetlands boundaries map (Figure 3-9, Appendix A).

3.6.2.18 1998 Surface Water and Soils/Tailings Sampling

Surface water and solid matrix samples were collected during 1998. Surface water sampling dates and locations for 1998 are presented in Table 3-2 (Appendix E). Surface water samples were collected as part of Terracon's regular surface water monitoring program on the following dates: February 18 and 19, April 7, April 22, May 13, May 28, June 17, July 15, October 14, and December 22 and 23. Results are available for each of these sampling events, and are presented and discussed in the designated section of this report. In addition, U.S. EPA collected one surface water sample in 1998. This sample was collected on February 3, 1998 from the 12" CMP at FS268 that delivers water to the land application areas north of FS268. Field parameter measurements, chemical analysis results, sampling stations, sampling intervals, and monitoring parameters are presented in the surface water hydrology section of this report.

Tailings, soil, and stream sediment samples were collected by Terracon during 1998. These include the samples listed below. The sample results are discussed in detail in Section 5; references to tables identified in Section 5 are listed below for clarity.

- Three tailings samples were collected from the Lower Tailings Pile during October 1998 (St. Joe Tailings Imp.-1, -2, and -3; Table 5-12).
- Four tailings samples were collected from the tailings Depositional Area in August, prior to initiation of tailings excavation and removal operations (SOIL-1, -2, -5, and-6; Table 5-12).
- Two tailings samples were collected from the Greene tailings pile in August (SOIL-3 and -4; Table 5-12).
- Seven samples were collected from historically deposited tailings depositional layers located within the Depositional Area created by the 1997 release (see "Soil Samples Associated with Historic Tailings Depositional Layers"; Table 5-12).
- Four sediment samples were collected from active stream channels within the Depositional Area created by the 1997 release (see "Samples Collected from within Active Stream Channels"; Table 5-12).
- Two sediment samples and one soil sample were collected in September from Montezuma Creek, following completion of tailings excavation and removal operations (POST-REMOVAL SED-1 and -2, and POST-REMOVAL SOIL-1; Table 5-12).
- Two soil samples were collected in September from within each of the three land application areas (for a total of six samples; see "Samples Collected from within Land Application Areas"; Table 5-12)
- Six soil and tailings samples were collected in September to support revegetation activities. Two soil samples each were collected from Zones 1A and 1B following completion of tailings removal operations, and two tailings samples were collected from the Depositional Area upgradient of the tailings removal areas. These samples were analyzed for the following parameters: calcium, nitrate, potassium, sodium, phosphorus, cation exchange capacity, organic matter, pH, and arsenic. These parameters were chosen to estimate the nutrient status and fertility of the soil and raw tailings. Arsenic was included in the suite of parameters to estimate the effectiveness of tailings excavation and removal operations in reducing the arsenic

concentrations in the remaining substrate (see Table 5-14; metals data for samples from Zones 1A and 1B are presented in Table 5-12).

- Three stream sediment samples were collected in August from stream channels not impacted by the 1997 release (SED-1, -2, and -4; Table 5-13).

3.6.2.19 1998 Air Quality Monitoring

This section describes the methodology that was employed to ensure the safety of workers and the public during the response actions. The results of monitoring implemented using this methodology are described in detail in Section 5.3.5.

Additional air monitoring was conducted during the 1998 construction season. The primary goal of 1998 sampling activities was to provide for worker and public health and safety. Therefore, MIE PDM-3 Miniram dust, aerosol, fume, and mist monitors were used to provide instantaneous readings of ambient dust concentrations during construction activities. The purpose of such monitoring was to notify workers when "alert" levels and/or "action" levels of airborne dust concentration were being approached. "Alert" levels are airborne dust concentrations that correspond to the possible need to employ engineering controls (e.g., dust suppression) and/or the possible need to don appropriate personal protective equipment (e.g., respirators). "Action" levels are airborne dust concentrations that signify the definite need to don appropriate personal protective equipment. Alert and action levels for dust concentrations were established based on the assumption that arsenic concentrations would be proportional to those measured in soil and air during 1997 monitoring activities, and then back-calculating particulate levels corresponding to the measured arsenic concentrations. The result was alert and action levels of airborne dust concentrations of 2.0 and 4.17 mg/m^3, respectively. The Miniram monitors were worn by workers during the 1998 construction season.

To further confirm that monitoring activities are adequately protective of worker and public health, one Miniram dust monitor was fitted with a pump and filter apparatus during one week of the 1998 construction season (the week ending Saturday, September 19, 1998) for filter gravimetric and chemical analysis.

3.6.2.20 1998 Groundwater Well Installation and Sampling

In 1998, 24 exploration borings and 22 monitoring wells were installed on the project Site to evaluate groundwater conditions (Table 3-3, Appendix E and Figure 3-10, Appendix A). Depth to groundwater and hydraulic conductivity measurements were performed. Additionally, the wells were sampled for chemical analysis between July 27 and July 30, between October 12 and October 15, and between December 14 and December 24. Hydraulic conductivity estimates based on aquifer test results are presented in Section 4 and the results of chemical analysis of samples taken from the wells are discussed in Section 5.

Depth to groundwater measurements are summarized in Table 3-4 (Appendix E). Generally, water levels have declined steadily in the upper tailings embankment since the May 1997 event. For example, the water level in well B-7 declined from 49 feet BGS in July 1997 to 60 feet BGS in December 1998. Water levels elsewhere at the Site fluctuate seasonally one to two feet, with high water levels typically occurring in early summer and low water levels typically occurring in winter.

3.6.3 1999 Response Activities

Limited interim construction activities were implemented during 1999, consisting primarily of further tailings removal and re-routing of surface water flow in the Depositional Area and repair/improvement of drainage at the Upper Tailings Pile. In addition, significant environmental monitoring was implemented pursuant to the Work Plan and Quality Assurance Plan for the Depositional Area (MFG, Terracon, and Pentec, 1999). The 1999 response activities are summarized in the following subsections.

3.6.3.1 1999 Construction Activities

Response activities performed during 1999 were performed under the U.S. EPA-issued Additional Response Actions Required Pursuant to the Unilateral Administrative Order for Removal Response Activities (October 28, 1998). This document specifies additional response actions required to support the NTCRA at the Site. This Site Characterization Report, and other reports, are being prepared under the October 28 document.

Tailings Removal

Response activities performed on October 22 through 24, 1999 included excavation of tailings in the vicinity of the historic Powerhouse Flume and Unnamed Creek (Zones 1A and 10A, respectively, Figure 3-5, Appendix A). Figure 3-5a (Appendix A) shows the zones or pods in Unnamed Creek that were involved in the tailings removal operations during October 1999. The following paragraphs summarize these activities.

Terracon conducted limited removal of tailings from the Depositional Area along Unnamed Creek and the historic Powerhouse Flume. Excavation and removal operations were tailored to fit each removal area. Prior to excavation and removal operations, tailings were as deep as two feet in some locations. A track-mounted excavator equipped with a five-foot toothless bucket was used to load tailings into a haul truck. Approximately 200 cy of excavated tailings were transported to the Lower Tailings Pile and contoured to match the existing topographic surface. For erosion control, straw bales were installed around the lower edge of the tailings.

Following removal, flow to Unnamed Creek and Powerhouse Flume channels was restored. Restoring flow to these channels also resulted in water being reintroduced to the wetlands south of Unnamed Creek. The flow was reintroduced in such a way to approximate pre-1997 conditions in the area. Straw bales were installed in portions of the Unnamed Creek channel to provide erosion control.

Repair/Improvement of Drainage at Upper Tailings Pile

In early August 1999 interim measures were taken to repair and replace the damaged drain pipe that had conveyed precipitation water off the Upper Tailings Pile. Minor and isolated mass movement at the Upper Tailings Pile during 1999 spring run-off damaged the drainage system. The drain pipe that had conveyed water from the Upper Tailings Pile was damaged and was no longer functional. The drainage system installed in 1998 was designed to convey water from the Upper Tailings Pile during precipitation events in 1999 and spring runoff in 2000.

Following completion of the 1999 work, water from the surface of the upper tailings is directed into two outlets and drained separately (north and south basins, respectively). The drains

are separated by berms that direct the water into a discharge pipe. The drainage pipes are 12-inch diameter ADS dual-wall polyethylene pipe. The south pipe extends down the slope of the tailings pile and discharges to the existing water drain channel at a point where the toe of the tailings pile will not be impacted. The north pipe is connected to the original drain pipe that extends down to Sedimentation Pond #1 below the Lower Tailings Pile. On the surface of the upper tailings, the pipes are buried in shallow trenches to provide an adequate drainage slope. Erosion measures are incorporated at the discharge points to reduce erosion during runoff events. The pre-existing inlet pipe above the breach was connected to the north drainage basin in a sloped drainage pipe.

Closure of Well B-22

On January 22, 1999, monitoring well B-22 was sealed and abandoned. This well had been installed to a depth of 118 feet below ground surface with an inappropriate screened interval. A stiff bentonite-based slurry was introduced to the bottom of the well and pumped from the bottom up until the bentonite slurry overflowed at ground surface. The remaining concrete around the well protector was broken away and removed. The two-inch diameter PVC casing was removed to a depth of about 10 feet BGS and the remaining hole was filled with a stiff mixture of bentonite and cement. The upper one-foot was backfilled with native soil to ground surface.

3.6.3.2 1999 Environmental Monitoring

Tailings/Soil

Samples of upland soils and wetland soils at 82 locations were collected by MFG staff during July and August 1999 (Figures 3-11 and 3-12, Table 3-5). The sampling locations included 18 sites in upland-reference areas, mostly north and east of the Depositional Area; 8 wetland-reference sites located south and west of the Depositional Area; and 29 upland sites and 26 wetland sites, located in the Depositional Area. The specific sampling locations for 62 of these sites were determined using a stratified randomized design, implemented using sites picked from random grid locations overlying a geographic information system (GIS) map of the study area (MFG, Terracon, and Pentec, 1999). An additional 20 samples were collected outside of the stratified random grid locations. Chemical analysis of these samples consisted of eleven constituents of potential concern (COPCs) for aquatic and terrestrial resources (Ag, Al, As, Cd, Cu, Fe, Hg, Pb, Sb, Se, and Zn). Results from these 82 sites

are discussed in later sections of this report. Soil samples from 20 additional randomly selected contingency sampling sites were also collected by MFG staff during August 1999.

In 1999, five exploratory borings (618A, 618B, 619, 620, and 621 Figure 3-15) were conducted in the Depositional Area. The exploration locations were selected in an effort to define the limits of historic buried tailings based on previous observations. Continuous split-spoon sampling was conducted in each boring from ground surface to the maximum depth explored. Selected samples were submitted for laboratory analysis of COPCs.

MFG staff also completed a seeding trial study during 1999 as part of the baseline ecological risk assessment for the Site. This study provides information on (1) the potential survivability of various plant species in the Depositional Area tailings; (2) how the survival of these plants may be affected by several soil fertility amendments; and (3) how these amendments may affect the potential accumulation of metals by surviving plant communities within these plots (MFG, Terracon, and Pentec, 1999). Chemical analyses for the eleven COPCs were completed on samples from each of the 18 experimental plots included in this study. The chemical analysis also included 13 agricultural soil-fertility parameters. For completeness, the results for these soil chemical analyses are included in this report. Other results from the seeding trial study and overall discussion of this study will be presented as part of the baseline ecological risk assessment for the Depositional Area.

Subsequent to completing the soil sampling design and while sampling was in progress, U.S. EPA directed that wetland reference sites be established in locations lacking historic tailings. Therefore, when the field crews arrived at each of the *a priori* selected random wetland-reference sites, preliminary analysis of the site was conducted to determine whether historic tailings were present. If evidence of historic tailings were found, the sampling site was relocated, using non-biased techniques, to a nearby site lacking tailings, if an appropriate sampling location was available. If an appropriate nearby site was not available, the sample was collected from one of the contingency sites previously identified using random techniques. Based on laboratory analysis and a review of field notes, two of the wetland reference sites (Sites 53 and 55) along the riparian zone of Montezuma Creek, up-gradient of the Depositional Area, were suspected of containing historic or other non-site related tailings. These sites also provided important wetland reference information on plant community composition, uptake of metals by vegetation, and uptake of metals by invertebrates (see the next subsection), all of which cannot be summarily discarded. Consequently, for each of these

ecological and chemical characteristics within the reference wetlands, statistical summaries are presented in the following sections that both include and exclude data from Sites 53 and 55).

In addition to the soils sampling by MFG staff, Terracon sampled soils in conjunction with their 1999 work. At the request of the USEPA, samples of road materials were collected to evaluate metals concentrations on Forest Service roads in the vicinity of the Site. The roads were scraped in 1997 to clear debris resulting from the release. The roads were also scraped after the 1998 removal action to remove contaminated soils that may have been transported by the hauling equipment. Equipment used to scrape the roadways in 1997 and 1998 included the Atlanta Highway District road grader and the Nelson Construction's front-end loader, respectively. Samples were collected on June 8, 1999 by hand-excavating using a decontaminated shovel across the width of the road to a depth of about one inch; laboratory-supplied sample jars were filled with a composite of material of approximately equal proportions across the width and depth of the sample "trench". Samples were sent under chain-of-custody to SVL Analytical in Smelterville, Idaho. The laboratory followed "functional guidelines" criteria. Three samples were collected at locations as described below.

- FSR-1: From FS207 (the mine road) adjacent to the Lower Tailings Pile; this area was not directly affected by the 1997 release.

- FSR-2: From FS268 (the Powerplant Campground road) at the location of tailings removal in 1997; this road surface had a deposit of tailings that resulted from the 1997 release and was sampled by IDEQ prior to the removal.

- FSR-3: From FS205 (the Riverside Campground road) at the location of tailings removal in 1997; this road surface had a deposit (relatively small) of tailings that resulted from the 1997 release and was not sampled by IDEQ.

Results of the road base sampling are discussed in Section 5 of this report.

Post-removal soil samples were collected by Terracon in late October 1999 from the natural channel of Unnamed Creek, following limited removal of tailings during channel restoration. The limited removal action and sampling was conduced in accordance with a workplan dated October

20, 1999. Activities were related to excavation of material along the Unnamed Creek channel and the historic flume, and diversion of water into the original channel and wetlands. Representative soil samples were collected following excavation from the six removal areas; two of the samples were submitted for laboratory analysis of contaminants of the concern. Locations and laboratory results are described in Section 5 of this report.

Surface Water

1999 surface water samples were collected in accordance with work plans dated April 14, 1999 (spring run-off), and October 18, 1999. Samples were collected from Montezuma Creek, Unnamed Creek, and the MFBR. The following stations were routinely sampled during the 1999 field season (station locations are shown on Figure 3-13):

- MC-1 Montezuma Creek below East Fork;
- MC-2 Montezuma Creek at FS268;
- MC-3 Montezuma Creek Upgradient from Depositional Area;
- MC-4 Montezuma Creek at FS205;
- UC-1 Unnamed Creek below Greene Tailings;
- UC-2 Unnamed Creek Above Confluence with Montezuma Creek;
- MFBR-1 Middle Fork Boise River at Riverside Campground; and
- MFBR-2 Middle Fork Boise River Below Montezuma Creek but Above Monarch Tailings

Chemical analysis of these samples consisted of eleven COPCs for aquatic and terrestrial resources (Ag, Al, As, Cd, Cu, Fe, Hg, Pb, Sb, Se, and Zn). Results are presented and discussed in Section 5.3.1 of this report. Surface water sampling dates and locations for established or regular sites in 1999 are presented in Table 3-2a (Appendix E). Field parameter measurements, chemical analytical results, sampling stations, sampling intervals, and monitoring parameters are presented in the surface water hydrology section (5.3.1) of this report.

Temporary Pond Surface Water Sampling

Opportunistic surface water samples were collected by MFG staff from four temporary ponds during July 1999 to characterize metals concentrations present in surface waters of the Site, other than the waters of Montezuma and Unnamed Creeks and the MFBR. These samples were collected from sites both within and adjacent to the boundaries of the Depositional Area, where standing water occurred in quantities sufficient to permit sample collection. The four sample locations are shown on Figure 3-13. While all these sampling locations appeared to be isolated, there may be hydrologic connectivity between some sites. This could not be clearly determined due to the highly altered hydrography of the Site.

Pore Water Sampling

Pore water samples were collected from soil sampling sites in wetlands where sufficiently saturated soils were found. All wetland soils sampling sites (both primary and alternative sites) were located and examined for their potential to obtain a pore water sample. If surficial soils appeared dry, a small test pit to a depth of about 6 inches was excavated using a spade to determine if underlying soils showed any signs of saturation. Of all the sites examined, only four sites exhibited saturated soils either directly at the site or within about 10 feet of the site. Pore waters collected were measured for total metal only, due to the small sample size available through the extraction device and because sample collected could not be isolated from exposure to ambient air, which would have greatly affected dissolved metal measurement data. Pore water samples were collected at the four locations shown on Figure 3-13. Sites 1, 2, and 3 were located in the Depositional Area, while Site 4 was located in the reference area.

Sediment

Two types of sediment samples were taken in September 1999: in-stream sediment samples and overbank sediment deposit samples. The methods used to collect the sediment samples, and the locations from which they were collected, are summarized below. Detailed discussions are provided in Appendix D-1.

In-stream samples were taken from the finest sediments that were found at each water quality sampling station in Montezuma Creek, Unnamed Creek, and the Middle Fork Boise River

(MFBR) (Figures 3-13 and 3-14). Usually these sediments were in relatively shallow water (a few cm deep) in back eddies or along shorelines adjacent to areas with low water velocities. In-stream samples were taken with a 2-inch diameter stainless steel corer that was decontaminated with Alconox and distilled water rinses between each station. For deep-water (e.g., greater than 0.5 m) samples, the lower end of the corer was also stoppered for transport through the water column. Where only a thin lens of sediment was present, multiple cores were taken to fill the required sample containers.

Overbank samples were taken from deposits with the finest grain size that could be found at each sample station. Overbank samples (except at MFBR-7) were taken from 0.5 to 1 m above the water line at the time of sampling. The sample from MFBR-7 was composited from sediments taken at and just above the water line. Where layers of sediment with differing grain sizes were encountered, material with the finest grain size was over-sampled to the extent practicable. Sample jars were filled with a decontaminated stainless steel spoon.

In-water sediment samples were analyzed for total metals, grain size, and total organic carbon (TOC) except that some replicate samples from a given station were analyzed for total metals only. Overbank samples were analyzed for total metals and grain size. All analyses were performed by Silver Valley Laboratories (Smelterville, Idaho) using analytical procedures described elsewhere in this document.

Sediment samples were obtained from 15 locations: in Montezuma Creek (5 locations), Unnamed Creek (2 locations), and the MFBR (8 locations) in September 1999. Replicate in-water sediment samples were collected at MC-3T, MC-4, and MFBR 4 and 5. Only overbank samples were taken at MFBR 6, 7, and 8 although the sample from MFBR 7 was at the waters edge and thus differed from the other over bank samples. Both in-water and overbank samples were collected at MFBR-3, -4, and -5. Sample locations are depicted in Figures 3-13 and 3-14.

All aquatic sediments for 1999 were targeted to collect the likely worse case accumulations of tailings. That is, the samples were selectively collected from areas within or adjacent to the wetted stream channels that had the greatest areas of the finest sediments available in each sample reach. For most sites, several tens, hundreds, or thousands of meters of stream, depending on stream size, was searched to find each specific area sampled. Then, within each sediment deposit ultimately

selected for sampling, the finest grained sediments present anywhere in the deposit were selectively sampled. Under the assumption that higher COPC concentrations would be associated with finer sediment fractions, the sediment incorporated into each sample container represent a likely maximum or worse case estimate of COPCs present at each station. Considering the heavy bias involved in selection of sampling locations, focusing only on those with likely worst case conditions, the results for each sampled site characterize likely only a small fractional percentage of the overall stream sediment conditions along that reach.

Groundwater

In 1999, 51 exploration borings were drilled in accordance with the Work Plan for Supplemental Investigations (URS Greiner Woodward Clyde, 1999). Forty-one monitoring wells and four lysimeters were installed in these borings; the remaining six borings were sealed and abandoned. A summary of monitoring wells and soil borings is presented in Table 3-3 (Appendix E); exploration locations completed in 1999 are shown on Figure 3-15 (Appendix A). Depth to groundwater was measured, hydraulic conductivity tests were performed, and groundwater sampling was conducted.

Depth to groundwater, groundwater potentiometric surface, and flow direction are discussed in section 4.5 of this report. Groundwater monitoring wells were sampled for chemical analysis in March 1999, May 1999, and September 1999. Results of chemical analyses are discussed in Section 5.3.3 of this report.

Terrestrial Resource Characterization

Sampling by MFG staff during July and August 1999 included a series of studies to characterize the terrestrial ecological resources across the Depositional Area and in neighboring reference areas. Information was collected on the structures of the vegetation communities, accumulation of metals in plant and in invertebrate tissues, and an inventory of wildlife species inhabiting the area (MFG, Terracon, and Pentec 1999). Sampling for terrestrial vegetation and vegetative tissue accumulation of metals occurred on 30 of the randomly selected soil sites, with the sites for the vegetation sampling distributed evenly between upland and wetland habitats (Table 3-5). Sampling for terrestrial invertebrate tissue concentrations occurred on a subset of 12 of these

random sites, and again these sites were distributed evenly between wetland and upland habitats (Table 3-5).

Field surveys for vertebrate wildlife were conducted by MFG staff between July 18 and 22, 1999, with additional sightings of mammals from the summer of 1999 added where appropriate. July was chosen as the primary inventory period because breeding birds were still actively singing, mammal reproduction had increased populations, thereby increasing potentials for trapping success, and amphibians were breeding. For the purposes of potential wildlife use, the Depositional Area and the surrounding reference area were divided into three potential wildlife habitat categories: forests, meadows, and wetlands (MFG, Terracon, and Pentec, 1999). The field surveys categorized wildlife observation into these three habitats for both the deposition and wetland areas.

Aquatic Resource Characterization

Elements of physical habitat, conventional water quality, and biological productivity were quantified in aquatic systems within and outside of zones that received tailings from the 1997 release. Aquatic resources were specifically characterized in Montezuma Creek, and Unnamed Creek. Montezuma Creek was evaluated from its confluence with the MFBR upstream to the confluence of the eastern and western forks. Physical habitat surveys quantified channel morphology, large wood loading, pool area and depth, substrate and riparian condition along four reaches in Montezuma Creek, and two reaches in Unnamed Creek. Two reaches in Montezuma Creek and one within Unnamed Creek were positioned within the Depositional Area. The other two reaches examined in Montezuma Creek were above the Depositional Area, and the second Unnamed Creek reach was the original channel (now dry) prior to diversion. These evaluations were coupled with conventional water quality measurements using both field calibrated probes, and continuous monitoring satellite units at two stations.

Biological studies were focused on ascertaining whether, and to what extent, chemical and/or physical stressors in aquatic systems were causing changes in biological community structure or function. Biological investigations assessed fish abundance, distribution, diversity, health and growth. Removal and mark/recapture estimates and quantitative fish health assessment techniques were used to address population structure and health, respectively. Fish age and reproduction was assessed through scale pattern analysis. Abundance and distribution was considered in relation to

habitat variables and disturbance regimes. In addition to fish studies, macroinvertebrate species richness and diversity within and outside of the Depositional Area was addressed by deploying multi-plate samplers for 5 weeks at 4 stations in Montezuma Creek and 2 stations within Unnamed Creek. Multiplate samplers served the dual function of providing a substrate upon which to measure colonization and species richness, along with collections for tissue analysis.

3.6.4 2000 Monitoring Activities

Additional groundwater sampling was conducted at the Talache Site in early 2000 to support an evaluation of the future residential land use scenario for the Depositional Area. Two domestic wells in the area (owned by Ann Aastum and Theron Scott) were sampled at the request of the EPA. These wells are located in a cluster of cabins several hundred feet south of the Depositional Area (Figure 3-10). For the domestic wells, two samples were collected at the tap for each well. The first sample was collected after a relatively short purge of the system piping and the second sample was collected after a relatively long purge to remove sediment from the well. Sampling of monitoring wells was implemented after a significant purge period of at least three well volumes. Groundwater samples were collected in accordance with applicable requirements of the Final Work Plan for Supplemental Investigations (URS Greiner, 1999).

4.0 GEOLOGY AND GEOTECHNICAL DATA EVALUATION

This section provides an overview of the geologic setting of the Talache Mine Tailings Site, including bedrock geology and geologic structures. In addition, the discussions address geotechnical and hydrogeological investigations that have been undertaken at the Site.

4.1 GEOLOGIC SETTING

The relatively broad U-shaped valleys of the MFBR (upstream of Atlanta) and Montezuma Creek are the result of alpine glaciation (Anderson, 1939). The near-surface geology of the Site is composed of thin and discontinuous recent alluvium and glacial sediments. In the tailings Depositional Area along Montezuma Creek, upstream from its confluence with the MFBR, the glacial material appears to be ground moraine with glacial outwash deposits. These unconsolidated materials are underlain by granitic rock of the Idaho Batholith (Figures 4-1 and 4-2 through 4-4, Appendix A).

4.1.1 Glacial Deposits

The glacial till comprises a majority of the recent deposits and consists of unsorted boulders and gravels in a silty sand matrix. The boulders are up to 6 feet in diameter, subangular to subrounded and occasionally show evidence of glacial action. The till fills and flanks the basin forming subparallel ridges along Montezuma Gulch that would suggest that these ridges are lateral moraines. Exploration into these ridges encountered localized zones of well sorted sand and gravel suggesting fluvial environments were active along the glacial margins. Hydraulic conductivity (K) tests conducted in the glacial deposits resulted in K values ranging from 3.3 to 250 ft/day and averaging 60.1 ft/day (Figure 4-5, Appendix A and Table 4-1, Appendix E) The conductivity is directly related to the grading and amount of fine-grained soils in the glacial deposits.

4.1.2 Alluvial Deposits

Alluvial deposits form the terraces along the MFBR and fans at the mouth of major drainage such as Montezuma Creek and Quartz Creek. Minor alluvial deposits are associated with Montezuma Creek but, in general, the gradient of Montezuma Creek is sufficiently steep in the upper reach that the creek is downcutting. The Montezuma Creek gradient decreases in its lower reach

below FS268 where stream deposits are more abundant. The alluvium is composed of poorly graded subrounded to rounded gravel to boulder size in a sand matrix with occasional lenses of fine-grained sediments. Hydraulic conductivity (K) tests conducted in the alluvial deposits resulted in K values ranging from 972 to 1,870 ft/day and averaging about 1,300 ft/day (Figure 4-5, Appendix A and Table 4-1, Appendix E)

4.1.3 Colluvial Deposits

Colluvial deposits (slope wash or mass-movement material) consist of subangular gravels in a silty sand matrix and silty/clayey sands deposited on the glacial till along the basin margins. These soils have occasional glacial erratics (boulders) on the surface.

4.2 BEDROCK GEOLOGY

The granitic bedrock beneath the Site is a biotite granodiorite emplaced during the Cretaceous Period approximately 75 to 100 million years ago. These rocks have been shattered and sheared during several periods of uplift. Locally, particularly near fault zones, the biotite granodiorite is intensely altered and mineralized. The feldspar minerals have altered to clay and the biotite to chlorite. Generally, this rock is gray to light gray, moderately hard, porphyritic, and medium to coarse grained (Taylor, 1986). Earlier investigators such as Anderson (1939) classified these rocks as quartz monzonite, which usually denotes a higher plagioclase feldspar content than a granodiorite.

4.2.1 Mineralogy

Analysis by Taylor for his 1986 thesis revealed that the biotite granodiorite is composed of plagioclase feldspar, quartz, potassium feldspar represented by microcline, and orthoclase. Biotite is the dominant dark mineral. The accessory minerals include hornblende, zircon, apatite, allanite, chlorite, magnetite, sericite, rutile, calcite, sphene, pyrite, and epidote. The plagioclase feldspar ranges from oligoclase to andesine (An 20-35) and comprises approximately 50 percent of the total rock volume. Quartz makes up approximately 20 percent of the total rock volume. The potassium feldspar is predominantly microcline with some orthoclase and comprises approximately 15 to 20 percent of the entire rock. Biotite generally comprises 5 to 10 percent of the rock volume and is the dominant dark mineral. The biotite granodiorite contains less than 1 percent hornblende.

Extensive information regarding mineralogy of the Atlanta Lode is available from several sources (Anderson, 1939; Campbell, 1936; Mining World, 1941; Taylor, 1986). The following excerpts are from the "Idaho Bureau of Mines and Geology Report on Geology and Ore Deposits of the Atlanta District" (Anderson, 1939).

> "Ore deposits consist largely of fine-grained quartz, part of which contains widespread and relatively abundant fine-crystalline arsenopyrite and lesser pyrite. The valuable minerals, gold and an assemblage of complex silver sulphosalts accompanied by minor amounts of pyrite and negligible amounts of lead, zinc, and copper sulfides, are associated with comb and drusy quartz. Deposition of the minerals was repeatedly interrupted and the deposits have been built up by successive deposition in breccias; first, breccias of country rock and thereafter breccias of the earlier minerals. Two generations of fine-grained quartz, the second accompanied by arsenopyrite, preceded the introduction and deposition of the comb and drusy quartz and associated ore minerals. A minor amount of quartz and calcite was deposited later. Although minor assemblages of silver minerals of supergene origin have added somewhat to the value of the surface ores, the shallow bonanzas appear to have been largely the product of hypogene enrichment."

> "Although exceeded in weight by silver, native gold is by far the most valuable ore mineral in the deposits. In some of the rich bonanzas mined in the early days the ratio of silver to gold, by weight, was as much as 200 to 1. The amount of gold appeared to increase materially in the silver-rich bonanzas. It was more widely distributed than the silver, both laterally and vertically, and its ratio to silver increased downward and laterally from the bonanza zones. With depth the gold content declines less abrupt than the silver. Although most bonanzas were characterized by an abundance of silver minerals, a few contained a preponderance of gold."

4.3 GEOLOGIC STRUCTURE

The project area has been subjected to repeated structural movement and deformation. The deformation is expressed in two major fault patterns: one pattern strikes northwest and one pattern strikes northeast.

The Montezuma Fault is a major structural feature that trends north-northwest along the east side of Montezuma Creek (Figure 4-1 and Figure 4-6, Appendix A). Anderson (1939) and Kiilsgaard and Bacon (1992) found evidence to suggest that the Montezuma Fault dips steeply toward the southwest with up to 2,000 feet of vertical offset. The Montezuma Fault was traced over 15 miles by Anderson (1939), and Worl and others (1991) show this structural feature for over 40 miles. In

the Site area, the fault has formed a major shear zone of broken granitic rock that was encountered in borings along Montezuma Creek both above and below the Tailings Piles.

The bedrock in the shear zone is so highly broken and reworked it is soil-like in nature. The hydraulic conductivity appears to be variable in this shear zone. Slug tests performed in two borings in the shear zone resulted in two K values of 0.033 and 0.50 ft/day (Table 4-1, Appendix E). Core samples exhibited slickensides and healed joints filled with thick zones of clayey gouge material. Such samples from boring B-28 (a horizontal boring at the base of the upper tailings), the landform east of the upper tailings, and locations of springs suggest that the primary fault zone arcs to the east under the upper tailings. This fault zone location is also supported by the historic stream that formerly flowed north-northwest near the middle of where the tailings embankments are presently located (Figure 4-7, Appendix A). The headwaters of this historic stream appear to be located at the south end of the upper tailings embankment. The trace of the fault to the north and south is only generally known and postulated based on landforms. Kiilsgaard and Bacon (1992) plotted the location of the Montezuma Fault coincident with the spring above the upper tailings embankment; the strike of the fault at that location is N 7° W. Figure 4-6 (Appendix A) is a map showing fault trace locations, as plotted by various investigators.

The Atlanta lode fault is a major well-mapped feature that strikes northeast. The shear zone associated with the Atlanta Lode is the locus of mineralization on Atlanta Hill, which was the site of over a dozen mining operations (Anderson, 1939). Detailed analysis of this zone provides important clues to the movement of the Montezuma Fault. Kiilsgaard and Bacon (1992) concluded that the Montezuma Fault hanging wall (west side) has moved southeast, opposite of the movement concluded by Anderson (1939).

A gradient array resistivity survey of the area near the Tailings Piles was conducted during the week of January 25, 1999 by Practical Geophysics, Inc. This surficial geophysical method is used to delineate high-angle structural features in bedrock. Faults are defined by their linear, relatively low resistivity anomalies. Fault zones generally conduct electricity more readily than adjacent rock due to groundwater with a higher dissolved solids. Spontaneous potential measurements were also conducted. Spontaneous electrical potential is created along some fault zones due to the oxidation of metallic sulfides.

A baseline oriented northwest-southeast was established near previous exploration sites where the fault zone features had been observed. Electric current dipole sources were placed perpendicular to the base line near the center of the area of interest. The dipoles were energized using a 3.2 KVA signal transmitter. Resistivity measurements were conducted on five grid lines (900 NW, 450 NW, 200 SE, 400 SE, and 800 SE).

Results of the geophysical survey indicated that several fault segments exist near the Tailings Piles. Figure 4-8 (Appendix A) is a map showing results of the geophysical survey as well as the locations of grid lines and well clusters. Locations for clusters 601 and 604 were moved based on the locations of fault zones inferred from the geophysical survey.

4.4 GEOTECHNICAL INVESTIGATIONS

The following subsections address subsurface exploration procedures, laboratory testing of geotechnical samples and their engineering properties and provide a summary of geotechnical analyses conducted in support of the Tailings Piles EE/CA. Additional subsections discuss Site seismicity, design criteria for closure of the Tailings Piles, and stability and liquefaction potential evaluations also conducted in support of the Tailings Piles EE/CA.

4.4.1 Subsurface Exploration Procedures

In general, the subsurface exploration consisted of drilling geotechnical borings and excavating test pits to determine the nature of the subsurface soils. Construction of observation wells and drilling of angle holes were performed to evaluate the groundwater conditions beneath the Site.

Specifically, 26 borings and test pits were completed in the Upper and Lower Tailings Piles during 1998 to determine the nature of the existing Tailings Piles and native soils beneath the Tailings Piles. Five borings were drilled along the alignment for a potential large containment structure (near the lower tailings embankment) to determine the nature of the foundation soils beneath the proposed structure. Five borings and three observation wells were drilled and three test pits were excavated in the proposed area for the earth fill source (the same location as the proposed double-lined repository identified in the Tailings Piles EE/CA) to determine the nature of the foundation soils and groundwater conditions at the proposed site. In addition, several other borings and test pits were excavated in the surrounding area to evaluate sites for potential borrow sources

for construction of embankments. The locations of the borings and observation wells are shown on Figure 3-10 (Appendix A). The locations of the test pits are shown on Figure 4-9 (Appendix A). The logs of the borings, monitoring wells and test pits are attached in Appendix G.

The boring locations were selected and field located by Terracon. Hubble Engineering, Inc., using conventional survey methods, determined the locations and elevations of the borings. The locations and elevations of the borings should be considered accurate only to the degree implied by the means and methods used to define them.

The borings were drilled with either an Acker track mounted drill rig or a CME 75 truck-mounted rotary drill rig using either wash rotary with casing or continuous flight hollow stem augers. Angle holes and selected monitoring wells were drilled with a Lang track-mounted drill rig using reverse circulation and compressed air. Disturbed soil samples were obtained at various depths using a 2-inch outside-diameter split-spoon sampler driven as described for the Standard Penetration Test (SPT) by ASTM D1586. The result of the SPT is a blow count (N). The blow count is the number of blows from a 140-pound hammer free-falling from a height of 30 inches that are required to drive the split-spoon sampler one foot (or the distance indicated). Blow counts and graphic descriptions of materials encountered are on the boring logs. Undisturbed samples were obtained by pushing either a 3-inch diameter thin walled Shelby tube sampler or a 3-inch diameter, California ring sampler. Bulk, disturbed samples of the subsurface soils were obtained from the auger flights or from the backhoe pits for testing. Soils were visually inspected, classified, and logged in the field by a Terracon geotechnical engineer or geologist.

Coring of the rock was accomplished using HQ and NQ wireline core barrels. Characteristics of the core samples were recorded on the logs and included percent recovery, Rock Quality Designation (RQD), fractures per foot, and a description of the rock materials recovered from each core run. RQD is the cumulative lengths of core pieces that are 4 inches and longer expressed as a percentage of the length of core run. Cores were logged in general accordance using the procedures recommended in American Society of Civil Engineers (ASCE) Manual No. 56 and ASTM D2113.

Soil strata were observed prior to backfilling the test pits and recorded on the test pit logs presented in Appendix G. Disturbed bulk sack samples of the soils were taken. Depths of the

samples are shown on the test pit logs. Soils were visually inspected, classified, and logged in the field by a Terracon geologist or geotechnical engineer.

The standard penetration value provides a reasonable indication of the in-place density of sandy type materials. However, the standard penetration value only provides an indication of the relative stiffness of cohesive materials, since the penetration resistance for these soils is a function of the moisture content. Considerable care must be exercised in interpreting the standard penetration value in gravelly soils, particularly where the size of the gravel particle exceeds the inside diameter of the sampling spoon.

In early 1999, further geotechnical evaluations were conducted in the Tailings Piles area. These included the drilling of additional borings in the piles, performance of additional laboratory testing on selected samples, and performance of stability analyses for the Tailings Piles removal action alternatives. Borings 606, 607, and 608 were drilled in the Upper Tailings Pile and borings 609, 611, and 622 were drilled in the Lower Tailings Pile to determine the nature of the tailings and the native soil beneath the piles. The boring locations were selected and field located by Terracon. The borings were drilled with either a CME 850 track-mounted drill rig or a BK81 truck-mounted rotary rig using either was rotary with casing or continuous-flight hollow stem augers. Disturbed samples were obtained at various depths using a 2-inch O.D. split spoon sampler driven using SPT methods. Selected samples were analyzed in by a geotechnical laboratory, as discussed in Section 4.4.2. Details regarding the early 1999 geotechnical investigations are provided in Appendix C of the Tailings Piles EE/CA (MFG and Terracon, 1999a).

At the time of writing, limited additional geotechnical evaluations were being conducted in support of the Tailings Piles removal action. These activities included cone penetrometer testing at the Upper and Lower Tailings Piles to assess in situ material properties (e.g., moisture, density, and shear strength); test pit excavation in the proposed soil borrow area located approximately 2,000 feet to the north of the Tailings Piles, and test pit excavation in the 900-level adit waste rock pile. The test pits in the borrow area and waste rock pile were excavated to gather information regarding material properties and potentially available volumes. These geotechnical evaluations will be described in a forthcoming Design Criteria Technical Memorandum for the Tailings Piles.

4.4.2 Laboratory Testing and Classification

Samples obtained from the borings and test pits during the field exploration were transferred to the laboratory under chain-of-custody procedures where they were observed, tested, and classified in general accordance with ASTM D2487 and D2488, which are based on the Unified Soil Classification System. Descriptions of the soils are indicated on the boring logs.

Representative samples were selected for testing to determine the engineering and physical properties of the soil in general accordance with ASTM or other approved procedures.

Tests Conducted	Brief Description
Natural Moisture Content	Moisture content representative of field conditions at the time samples were taken.
Percent Passing No. 200 Sieve	Amount of clay and silt in a sample.
Grain-Size Distribution	Size and distribution of soil particles; that is, clay, silt, sand, and gravel.
Atterberg Limits	The consistency and stickiness, as well as the range of moisture content within which the material is workable.
Moisture Density	The optimum moisture content for a compacted soil and the maximum dry unit weight (density) for a given compactive effort.
Direct Shear	Soil shear strength under varying load and/or moisture conditions. For use in foundation design and slope stability evaluation.
Triaxial Shear	Soil shear strength of cohesive soils under varying confining pressures. For use in slope stability evaluation.

Results of the 1998 field and laboratory tests are presented in Appendix H and summarized in Table 4-2 (Appendix E). A detailed discussion of the results of the geotechnical investigations presented herein was first presented in the Technical Memorandum on Design Criteria (Terracon, 1998b) and later refined in the Tailings Piles EE/CA (MFG and Terracon, 1999a). The 1998 geotechnical evaluations are summarized below. The results of the early 1999 geotechnical investigations are detailed in the Tailings Piles EE/CA.

4.4.3 Engineering Properties

The results of the triaxial shear and direct shear tests for geotechnical samples collected during 1998 are summarized in Table 4-3 (Appendix E) With the exception of the unconsolidated,

undrained (UU) triaxial shear tests performed on samples from Test Pits TP-6 and TP-8, all other tests were performed in the direct shear test apparatus under saturated conditions.

4.4.4 Summary of Geotechnical Analysis

Geotechnical data collected during 1998 (as presented in this Site Characterization Report) and geotechnical data collected during early 1999 (as presented in the Tailings Piles EE/CA; MFG and Terracon, 1999a) were integrated to prepare a comprehensive geotechnical analysis for the Tailings Piles. This integrated geotechnical analysis is presented in the Tailings Piles EE/CA.

A suite of five removal action alternatives were developed to address the Upper and Lower Tailings Piles within the EE/CA context, as follows:

- Alternative 1 - the no-action alternative.

- Alternative 2 - stabilization of the piles by buttressing the exterior slopes of the Upper and Lower Tailings Piles, regrading the upper and lower tailings surfaces, placing a soil cover, and revegetating.

- Alternative 3 - stabilization of the lower pile by constructing a new containment buttress/dike, relocating/regrading a majority of the tailings from the upper pile behind the new dike, placing a soil cover over the entire area, and revegetating.

- Alternative 4 - consolidation and stabilization of the piles by removing the lower tailings, using the sandy portion of the lower tailings material to buttress the Upper Tailings Pile, transporting the slimes from the lower to the upper pile, placing a soil cover, and revegetating.

- Alternative 5 - construction of a repository, transporting and placing the tailings from the Upper and Lower Tailings Piles within the repository, placing a soil cover, revegetating, and reclaiming the existing Tailings Piles site.

Removal action at the Tailings Piles may also include treatment of seeps issuing from the toes of the Tailings Piles. If the available information indicates that arsenic present in the seep waters originates from the tailings within the piles, and is not substantially attributable to mineralized bedrock or other pervasive sources in the area, U.S. EPA may require such treatment. Because the source of the arsenic in the seep waters was not known at the time the Tailings Piles EE/CA was prepared, water treatment was included as a contingency with each removal action alternative. Based on the information available, the Tailings Piles EE/CA identified passive aeration of the seep waters as a viable treatment approach. Details are provided in the Tailings Piles EE/CA (MFG and Terracon, 1999a).

Discussion of geotechnical factors pertaining to the evaluation of removal action alternatives 1 through 5 are provided in the ensuing subsections.

4.4.5 Site Seismicity

The Site acceleration was determined using probabilistic relationships developed by Greensfelder (ITD, 1994) and by Algermissen (Algermissen et al., 1982). The Greensfelder relationships indicate that for a probability of exceedance of 10% in 50 years that the Site acceleration is 0.14g. The Algermissen relationships indicate that for a probability of not being exceeded of 90% in 250 years that the Site acceleration is 0.15g.

The Site acceleration was also determined using deterministic relationships developed by Seed and Idriss (1983) and by Joyner and Boore (1981). The nearest active fault (Wisconsin or younger) is the Deadwood fault located about 50 km to the north, which was assumed to be capable of a Maximum Credible Earthquake (MCE) of Magnitude 7.5. Based on the Seed/Idriss relationships, the Site acceleration on rock is about 0.19g and on the Joyner/Boore relationships the Site acceleration on rock is about 0.15g for the 50th percentile and 0.19 for the 84th percentile. Based on these relationships, the Site acceleration was assumed to range from 0.15g to 0.19g for the MCE.

4.4.6 Design Criteria

4.4.6 Design Criteria

The removal action alternatives were evaluated in general accordance with the Rules and Regulations for Mine Tailings Impoundment Structures (IDWR, 1980). Those rules require a factor of safety of at least 1.5 for the static condition and 1.0 for the appropriate earthquake load.

4.4.7 Stability Analysis

Stability analyses were performed using the computer program PCSTABL5M (JHRP, 1984) which uses a limit equilibrium method for calculating factors of safety against sliding on an assumed failure surface. PCSTABL5M evaluates numerous potential failure surfaces, with the most critical failure surface identified as the one yielding the lowest factor of safety of those evaluated.

Stability analyses were performed for existing conditions at the Upper Tailings Pile. These analyses were performed on sections taken through the right (north) side of the Upper Tailings Pile breach, the left (south) side of the breach, and on a section through the breach. Stability analyses were first performed on the existing slope configuration using laboratory-determined soil strength data. Factors of safety for the right side of the breach, left side of the breach, and through the breach were calculated to be 0.90, 1.3, and 0.74, respectively. Given that areas of instability exist under current conditions, the calculated factors of safety appear to be reasonable, indicating that the soil strength parameters used in the analyses are appropriate (MFG and Terracon, 1999a).

4.4.8 Liquefaction Potential

The liquefaction potential of the Tailings Piles was evaluated to determine if the Tailings Piles would liquefy during a seismic event. The evaluation consisted of reviewing the Site seismicity and determining the Site acceleration; reviewing the N-values, percent passing the No. 200 sieve, and Atterberg Limits; determining the seismic shear stress ratio and comparing results to relationships presented in Seed and De Alba (1986) for soils that would liquefy. Only those tailings located below the static ground water level were evaluated for potential liquefaction. The results of the evaluation are summarized below.

The tailings consist of a fine sand and silt/clay size ("slimes") fraction. The existing dikes are constructed of predominantly the fine sand size fraction and the slimes are contained within the pile behind the dikes. N-values in the tailings generally ranged from 5 to 14 in the tailings located below the groundwater table. In borings B-10 and B-11 located in the upper reaches of the Lower Tailings Pile, N values ranged from 1 to 2.

Sieve analysis performed on the tailings indicate that the percent passing the No. 200 sieve is generally greater than 50%, only one sample had 21% finer than the No. 200. Hydrometer analysis on two samples of the slimes indicated that the percent finer than the .005 mm ranges from 53 to 75 %. Plastic limits, as determined by the Atterberg limits tests, ranged from 8 to 44%.

Results of the above analysis indicates that for the deeper tailings located below the groundwater table the seismic shear stress ratio is about 0.09 for the Site acceleration of 0.15g and 0.12 for the Site acceleration of 0.19g. Based on relationships presented in Seed and De Alba, the tailings located at that depth are not likely to liquefy. The high fines content, greater than 50% passing the No. 200 sieve, further support this conclusion. Calculations to support these conclusions are included in Appendix C.1 to the Design Criteria Technical Memorandum (MFG, 2000).

For the shallow tailings located below the ground water table as observed in B-10 and B-11, the seismic shear stress ratio is about 0.15 for the Site acceleration of 0.15g and 0.19 for the Site acceleration of 0.19g. Based on relationships presented in Seed and De Alba, liquefaction of these tailings is possible during either of the estimated Site accelerations. However, based on the high fines content of the tailings, these shallow tailings are not expected to liquefy.

4.4.9 Selected Removal Action Alternative for the Tailings Piles

The Tailings Piles EE/CA (MFG and Terracon, 1999a) identified Alternative 2 as the preferred alternative for closure of the Tailings Piles, based on the primary evaluation criteria of effectiveness, implementability, and cost. As previously noted, Alternative 2 consists of stabilization of the piles by buttressing the exterior slopes of the Upper and Lower Tailings Piles, regrading the upper and lower tailings surfaces, placing a soil cover, and revegetating. Stability analyses of Alternative 2 indicate long-term factors of safety ranging from 1.7 to 2.0 under static conditions and 1.2 to 1.4 under pseudo-static (seismic) conditions. These estimated factors of

safety exceed those required by the Rules and Regulations for Mine Tailings Impoundment Structures (IDWR, 1980; factor of safety of at least 1.5 for the static condition and 1.0 for the appropriate earthquake load).

Alternative 2 was selected by U.S. EPA as the removal action that will be implemented at the Tailings Piles. As has previously been discussed, design and construction activities for the Tailings Piles closure will likely be implemented under a separate AOC and SOW. Treatment of seeps from the Tailings Piles may also be included in the selected removal action. U.S. EPA will determine the need for such treatment based on water quality and hydrogeological data presented in this Site Characterization Report.

4.5 HYDROGEOLOGIC INVESTIGATIONS

Exploration procedures, sample point installation, depth to groundwater, and groundwater flow direction are discussed in the following subsections.

4.5.1 Subsurface Exploration Procedures

Subsurface exploration coincided with geotechnical borings where appropriate and used specific techniques in other areas. The locations of the borings and observation wells are shown on Figures 3-10 and 3-11 (Appendix A). A summary of monitoring well location, depth, equipment used, and target zone is presented in Table 3-3 (Appendix E). The logs of the borings and monitoring wells are attached in Appendix G. This appendix also include logs of domestic (water supply) wells in the Atlanta area. With the exceptions of wells AG-1 and AG-3, installed on Mr. Alva Greene's property in 1986, the domestic wells included in Appendix G have not been visited nor sampled. The well logs are included for the purpose of completeness.

In 1998, 24 exploration borings and 22 monitoring wells were installed on the project Site. Fourteen borings were drilled using a reverse circulation drill rig and 10 were drilled using a combination of hollowstem auger (in unconsolidated sediments) and rotary wash (in bedrock) techniques. Three of the reverse circulation borings were angle holes (approximately horizontal) from the base of the upper tailings into the Upper Tailings Pile to explore for bedrock contribution to nearby springs. All other drill sites were vertical borings.

In 1999, 51 exploration borings were drilled with 41 monitoring wells and 4 lysimeters installed. Five exploratory borings were conducted in the Depositional Area in search of buried tailings and were not completed at monitoring points. One additional geotechnical investigation boring (622) was constructed on the Lower Tailings Pile between locations 609 and 610. Forty-five borings were drilled using a combination of hollowstem auger (in unconsolidated sediments) and rotary wash (in bedrock) techniques and six borings were drilled with a forward circulation (ODEX) drill rig.

The boring locations were selected and field located by Terracon. Hubble Engineering, Inc., using conventional survey methods, determined the locations and elevations of the borings.

A drill site geologist logged subsurface samples. Disturbed soil samples were obtained at various depths using a 2-inch outside-diameter split-spoon sampler driven as described for the Standard Penetration Test (SPT) by ASTM D1586. Core sampling and description methods were described in Section 4.4. Both reverse and forward circulation drill cuttings were logged based on material observations, and drilling response such as rate of penetration, drill bit reaction, and drill fluid conditions.

4.5.2 Sampling Point Installation

Monitoring well drilling and installation permits were obtained from the Idaho Department of Water Resources (IDWR). Monitoring wells were installed in the borings for use as water quality sampling points and for water level measurements from discrete subsurface intervals. The wells were constructed using threaded, flush joint, 2-inch diameter schedule 40 PVC casing and 0.020-inch factory slotted pipe with flush threaded bottom cap. Colorado Silica Sand (8 to 12 mesh) was placed in the annular space around the slotted pipe to a point 2 to 3 feet above the top of the slotted pipe. During installation of the sand pack, the level of sand pack in the annular space between the PVC well casing and the borehole (or 6" steel casing) was monitored with a weighted probe. A layer of bentonite pellets six inches thick was installed above the sand pack. The remaining well annulus was sealed with a bentonite slurry to a point three feet BGS. The remaining annular space was filled with concrete to the ground surface and the locking well protector installed. A three-foot diameter concrete pad was constructed to slope away from the center of the well protector. Inside the well

protector, the upper end of the PVC monitoring well pipe was covered with a slip-on PVC cap. A 0.125 inch diameter vent hole was drilled in the PVC cap.

All monitoring wells were developed to maximize the hydraulic connection between the wells and the water bearing zone, and minimize sediment content of the water. Depending depth of the well, water level, and initial sediment content of the water, well development included bailing, pumping, and/or surging.

Unsaturated zone water was sampled using lysimeters. Generally, lysimeters consist of a porous tip attached with an airtight seal to the lower end of a PVC pipe. The upper end of the pipe is also tightly capped so that a vacuum can be applied through connections in the upper cap. The vacuum draws pore water into the sampler for collection. Lysimeters were obtained from TIMCO Mfg., Inc., Prairie du Sac, Wisconsin. The pressure-vacuum ceramic cup lysimeters were assembled, decontaminated, leak tested, installed, and sampled in accordance with the manufacturer's instructions and technical literature. A 200-mesh silica flour – deionized water slurry was used to surround the porous cup and provide a continuum between the lysimeter and pore water in the surrounding soil. The initial water sample from each lysimeter was discarded prior to sample collection for laboratory analysis.

4.5.3 Groundwater Levels

Static groundwater elevations were measured to estimate hydraulic head, groundwater migration direction and gradient. Static water levels were measured from the surveyed point on the well casing using a calibrated electric water level probe. Depth to groundwater measurements are summarized in Table 4-6 (Appendix E). Figures 4-10a through 4-10i are diagrammatic sections showing monitoring well depth, static water elevation, and lithologic horizons at selected wells. Generally, water levels have declined in the Upper Tailings Pile since the May 1997 event. Seasonal water level fluctuations are also apparent. Water levels in the tailings area fluctuate five to ten feet. Water levels elsewhere at the Site fluctuate seasonally one to two feet. High water levels typically occur in early summer and low water levels typically occur in winter.

The colluvial sediments are composed of alluvial, glacial and slope wash deposits consisting of silt, sand, and some clay with cobbles and boulders or blocks. The water table in the

colluvial aquifer is generally about 10 to 30 feet below the ground surface. The near-surface groundwater gradient in the shallow aquifer is generally toward the north-northwest (Figure 4-11, Appendix A). In the Tailings Piles area, the hydraulic gradient is steeper than it is in the Depositional Area (Figure 4-12, Appendix A).

Figure 4-13 (Appendix A) is a sectional diagram through the Tailings Piles area showing static water elevation and the approximate contacts between tailings, colluvium, and bedrock.

The deeper, bedrock aquifer associated with the Montezuma Fault appears to have discontinuous hydraulic conductivity that is greatest in fractures and fault zones. Because the discontinuous and confined nature of this water bearing zone, a groundwater piezometric map is problematic. Based on exploration borings in the Depositional Area, the bedrock surface is about 10 to 20 feet BGS near FS268 and 50 to 100 feet BGS in the lower part of the Depositional Area. Based on the regional hydrology and springs that occur in the area, an artesian bedrock influence in the Depositional Area is inferred.

Groundwater underlying the Depositional Area is similar and is composed of two aquifers: a near-surface alluvial or glacial aquifer and a deeper, bedrock aquifer. The water table in the alluvial aquifer is generally less than 10 feet below the ground surface.

Glacial sediments apparently cause localized water level anomalies in the Depositional Area. Well 616A was drilled to a depth of 45 feet in the Depositional Area adjacent to MW6 (19 feet deep); Well 616A was dry but MW6 exhibited a static water level about 7 feet BGS in September 1999.

4.5.4 Groundwater Sampling

Sample collection in 1999 was performed in accordance with the Supplemental Investigations Work Plan (URS Greiner Woodward Clyde, 1999) and standard operating procedures. Prior to sampling, at least three well volumes of water were evacuated from each well. Groundwater samples were collected using disposable Teflon bailers. Equipment decontamination was performed where necessary and appropriate in accordance with the work plan and standard operation procedures. Groundwater samples were analyzed in the field for dissolved oxygen, temperature,

specific conductivity, pH and oxidation-reduction potential (Eh) in accordance with the applicable work plan and standard operating procedure. Groundwater samples were properly preserved, placed in a chilled cooler and delivered promptly to the analytical laboratory with appropriate chain of custody.

A groundwater sample from the water supply well at the Riverside Campground was collected directly from the pump spigot. The well was pumped for about 30 minutes prior to sampling in order to provide a fresh, representative water sample.

Presentation and discussion of groundwater sampling and results of lysimeter sampling are presented in Section 5 of this report.

4.5.5 Aquifer Testing

Saturated zone hydraulic conductivity tests were performed by placing a "slug" (a capped, weighted length of PVC) into the well, allowing the water level in the well to stabilize at the static level, and quickly removing the slug while recording the rate at which the water level in the well recovered. The rate of water level recovery in the wells was recorded using an In-Situ, Inc. Hermit 1000C data recorder and In-Situ PXD-260 pressure transducer. Test data were downloaded to an IBM compatible computer, linearized on a semi-logarithmic scale, and analyzed using standard linear regression techniques and methodology developed by Bouwer and Rice as described by Dawson and Istok (1991).

Estimated hydraulic conductivity in the colluvial sediments ranged from 0.06 feet per day to 250 feet per day. In general, the hydraulic conductivity is higher in colluvial sediments composed primarily of gravel with sand than in colluvial sediments composed primarily of silty sand.

Estimated hydraulic conductivity in the bedrock ranged from 0.003 feet per day to 3.4 feet per day. Hydraulic conductivity in igneous bedrock is influenced by the degree of fracturing and faulting, and the amount and composition of fault gouge present in fractures.

5.0 SITE CHEMISTRY DATA PRESENTATION AND EVALUATION

5.1 CONSTITUENTS OF POTENTIAL CONCERN

Eleven constituents of potential concern (COPCs) have been identified for the Talache Mine Tailings Site, as set forth in the Work Plan and Quality Assurance Project Plan for the Depositional Area (MFG, Terracon, and Pentec, 1999). As previously noted, these are:

- aluminum (Al);
- antimony (Sb);
- arsenic (As);
- cadmium (Cd);
- copper (Cu);
- iron (Fe);
- lead (Pb);
- mercury (Hg);
- selenium (Se);
- silver (Ag); and
- zinc (Zn).

This list of COPCs was developed in consultation with U.S. EPA based on: (1) the potential for these elements to be present in mine wastes derived from the Atlanta district, and (2) the potential adverse health effects that these elements may have on human and environmental receptors. Of the COPCs listed above, arsenic is considered a primary risk driver due to its distribution in environmental media at the Talache Site and its known toxicity to human and environmental receptors. Arsenic at the Site occurs with many of the other COPCs listed above. Therefore, mitigation of arsenic concentrations in the Site media should also address other COPCs. The baseline human health and ecological risk assessments to be conducted for the Depositional Area will screen this list of COPCs to develop more refined lists for detailed risk assessment purposes.

The Tailings Piles EE/CA (MFG and Terracon, 1999) included streamlined risk evaluations. These evaluations, which were conducted by U.S. EPA contractors, screened the above list of COPCs relative to the Tailings Piles removal action and identified preliminary removal goals (PRGs) for elements surviving the screening step. The PRGs for the Tailings Piles removal action are as follows.

For protection of human health:

- 320 mg/kg arsenic in soil assuming a child-only noncancer hazard.

For protection of terrestrial plants (soil concentrations):

- 5.0 mg/kg antimony;
- 77 mg/kg arsenic;
- 2.0 mg/kg silver; and
- 50 mg/kg zinc.

For protection of wildlife and soil invertebrates (soil concentrations):

- 420 mg/kg arsenic;
- 0.4 mg/kg chromium[2]; and
- 0.1 mg/kg mercury.

5.2 SOURCE CHARACTERISTICS

Arsenic and iron occur in tailings material and in surface and groundwater at the Site. Tailings material and waste rock have been transported from the Tailings Piles into the Depositional Area by mass wasting events, as happened in May 1997. This report evaluates the effects of the 1997 release as well as the potential contributions of other upgradient sources of metals and arsenic to the Tailings Piles area and the Depositional Area. This section describes the Conceptual Site Model (CSM) and characterizes the tailings in the Upper and Lower Tailings Piles.

5.2.1 Conceptual Site Model

A preliminary CSM was prepared in March 1999 to guide supplemental investigations at the Site and identify the most likely sources of elevated arsenic and iron occurrences. Schematics of this preliminary CSM are presented in Figure 5-1 (Appendix A) and Figure 5-2 (Appendix A).

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[2] Chromium was added as a COPC for the Tailings Piles by U.S. EPA.

The principal surface features of the Site also are illustrated in Figure 5-1 (Appendix A). The Upper and Lower Tailings Piles are located within the watershed of Montezuma Creek. Several mine waste rock dumps and mine adits are located in the upper watershed. The combined Upper and Lower Tailings Piles contain about 500,000 cy of tailings. A watershed of approximately 60 acres is located upgradient of the piles. A surface water diversion ditch constructed above the Upper Tailings Pile controls surface run-on to the area of the Tailings Piles. The collected run-off is diverted into the main stem of Montezuma Creek. The East Fork of Montezuma Creek enters the main stem just above the Upper Tailings Pile. The Montezuma Creek watershed drains to the MFBR. As described in detail in Section 3.6.1.2, a 24" CMP was installed under FS207 following the 1997 release to collect and treat water that surfaces west of the lower tailings impoundment and divert non-tailings stormwater runoff under FS207 into Montezuma Creek. This storm water runoff receives little to no contribution from the tailings piles due to topographic slope but could act as a potential pathway for tailings to enter Montezuma Creek from the outer slope of the lower tailings pile, which is vegetated and stable. Baseflow water, consisting primarily of groundwater from seeps and springs along FS207, is diverted into the trench that leads to Sedimentation Basin #5 and the land application area, while stormflow is diverted into the 24" culvert, under FS207, and into Montezuma Creek. Dissolved arsenic concentrations in samples collected from the diversion typically exceeded the USEPA chronic AWQC for arsenic of 0.15 mg/L and the dissolved arsenic concentrations often exceeded the USEPA acute AWQC for arsenic of 0.34 mg/L. The Tailings Piles are a source that likely contributed to these exceedances.

A flowing mine adit and a waste rock pile are present upstream of the site in the Montezuma Creek Valley. Present conditions downgradient of the Tailings Piles have been influenced by tailings dispersal, including the 1997 release. As previously discussed, the 1997 release resulted in the dispersal of approximately 16,000 cy of tailings to the Depositional Area. In addition, mine wastes in the Unnamed Creek watershed have also influenced this area.

The Depositional Area down slope of the Tailings Piles has been substantially cleaned-up in 1997 and 1998 by the removal of tailings and contaminated soils and by the disposal of the material on the existing Lower Tailings Pile. Other response actions have been implemented in the Tailings Piles area, including flattening of the slope at the tailings breach area, installing a surface water diversion ditch, installing a subsurface water collection and drainage system downgradient of

the breach area, and constructing five interconnected sedimentation ponds below the Lower Tailings Pile for sediment control and drainage water routing for land application.

Preliminary evaluation of conditions at the Tailings Piles and possible interactions between tailings and water are summarized in the CSM presented in Figure 5-2 (Appendix A). Unique characteristics and geochemical properties that would affect tailings interactions with surface water and groundwater, including springs and upwelling groundwater, are noted on Figure 5-2 (Appendix A).

5.2.2 Tailings Characterization

In 1999, field work and laboratory analyses were conducted to characterize tailings material from the Upper and Lower Tailings Piles. The field program was designed to collect tailings, soil, groundwater, and tailings pore water as described in the work plan, "Final Plan for Supplemental Investigations, Talache Mine Tailings Site, Atlanta, Idaho" (URS Greiner Woodward Clyde, 1999). Extensive laboratory test work and analyses were conducted at ACZ Laboratories, in Steamboat Springs, CO, on four tailings samples composited from the 39 bulk tailings samples retrieved from the Site during the 1999 drilling and well installation activities. The 39 tailings samples were first analyzed for total arsenic content. Tailings composites were prepared to represent material with relatively high, medium, and low arsenic concentrations, and to include mixtures of tailings slimes and sands, comprising both reduced and oxidized material. The tailings composites were analyzed for mineralogical and geochemical properties, and for arsenic leaching characteristics. The results of this laboratory test work and analyses were reported in a Technical Memorandum prepared in May 1999, which is included as Appendix I to this report. Table 1 of Appendix I provides arsenic concentration data for the tailings samples.

5.2.2.1 Mineralogical Properties

The mineralogy of the bulk and clay-size fractions of the tailings composites was examined by conventional x-ray diffraction techniques. X-ray diffraction analysis of the tailings composites indicated that the tailings material consists of quartz, mica, or illite, with lesser amounts of feldspar and chlorite, and traces of the secondary iron-arsenate mineral, scorodite. No sulfides were identified in the x-ray patterns of the bulk fraction, and no iron hydrous-oxides were identified in

the x-ray patterns of the clay-size fraction. However, arsenopyrite has been reported to be the primary arsenic-containing mineral in the tailings. It is possible that traces of arsenopyrite and amorphous iron hydrous-oxides occur in the tailings, but detection by x-ray diffraction was masked in "unidentified" mineral assemblages.

5.2.2.2 Geochemical Properties

In addition to the mineralogical characterization, the tailings composites were also characterized chemically. They were analyzed for iron and manganese content and for cation-exchange capacity (CEC) and exchangeable cations, measured for soil pH, and tested for acid generation / neutralization potential.

Chemical analyses of the tailings composites indicated the presence of iron at concentrations ranging between 13,600 mg/kg and 4,370 mg/kg. These levels may reflect iron associated with primary tailings minerals such as illite, chlorite, or even arsenopyrite, or iron associated with weathering products of the primary minerals. The iron could be present in mineral forms such as ferric arsenate (scorodite) or as amorphous iron hydrous-oxides. Both are by-products of arsenopyrite oxidation. The manganese content of the tailings composites ranged between 299 mg/kg and 105 mg/kg. The reported iron and manganese levels suggest that amorphous hydrous-oxides of iron and manganese may be present in the tailings, but are difficult to identify by x-ray diffraction. If present, these hydrous-oxides could contribute to the ability of the tailings solids to attenuate the migration of arsenic.

The CEC of the tailings composites ranged between 2 and 4 meq/100g, which is typical of sandy material. Calcium is the principal exchangeable cation; the cation-exchange sites on the clay minerals associated with the tailings are probably calcium-saturated. As a general rule, the anion-exchange capacity of illite clay, for example, is roughly 40 percent of its cation-exchange capacity. In themselves, the tailings have limited capacity to undergo anion-exchange with arsenite and arsenate anions.

The soil pH of the tailings composites was near-neutral, with pH values ranging between 7.3 and 7.5. A high neutralization potential and a low sulfur content confirm that the tailings are not acid generators, but net acid consumers. The neutralization potential of the tailings composites

ranged between 0.6 percent and 1.7 by weight, as $CaCO_3$. Pyritic sulfur ranged between 0.02 percent and 0.11 percent by weight, as sulfur. Excess carbonate mineralization is available in the tailings material for neutralizing any acidity that would form during the oxidation of arsenopyrite. The tailings have not generated acidity in the past, are presently not generating acidity, nor are the tailings expected to generate typical acid-rock drainage in the future.

5.2.2.3 Leaching Properties

The tailings composites were analyzed for total arsenic, water-soluble arsenic, and ammonium bicarbonate-diethylenetriaminepentaacetic acid (AB-DTPA) extractable arsenic. The "total" analysis represents arsenic incorporated in primary and secondary mineral assemblages, as well as the arsenic adsorbed on clay minerals, metal hydrous oxides, and dissolved in tailings pore water. The AB-DTPA extractable arsenic includes that fraction of the total arsenic that is dissolved in the pore fluids, and essentially all of the arsenic that is exchanged on the surface of clay minerals or adsorbed on metal hydrous-oxides or organic matter. The water-soluble arsenic represents that fraction of the total arsenic that is primarily dissolved in pore fluids.

The AB-DTPA and water extractions indicate that only a small fraction of the total arsenic reported in the tailings at the Site is geochemically mobile. About 0.5 percent of the total arsenic reported in the tailings was water-soluble, and about 5 percent of the total arsenic was AB-DTPA extractable.

Leaching of the tailings composites by circulating synthetic meteoric water adjusted in pH to simulate acid rain indicated that the tailings may desorb small amounts of arsenic, between 0.65 and 0.73 mg/L. The meteoric leaching tests reaffirmed that the tailings are not acid generators.

The composites composed of tailings material with the highest total arsenic concentrations (greater than 2,000 mg/kg and 2,000 - 1,000 mg/kg, respectively) were also subjected to Toxicity Characteristic Leaching Procedure (TCLP; EPA Method 1311). The amount of arsenic leached under TCLP conditions was between 1.29 and 0.92 mg/L. Based on the TCLP results, the tailings do not exhibit toxicity characteristics for arsenic. 40CFR part 261.24 defines the "toxicity" limit for arsenic as 5 mg/L in the TCLP extract.

5.3 NATURE AND EXTENT OF CONSTITUENTS OF POTENTIAL CONCERN

The following subsections summarize analytical data collected to characterize environmental conditions the Talache Mine Tailings Site with respect to the nature and extent of COPCs. Quality assurance/quality control issues for data collected during 1998 are discussed in Appendix J-1. Data validation issues for data collected during 1999 are summarized in Appendix J-2.

5.3.1 Creeks and Streams

Montezuma Creek occupies a U-shaped valley and has a drainage area of about 1,600 acres above FS268. The creek flows generally northwest immediately west of FS207 near the Site, crosses under FS268 in a culvert, and eventually enters the Depositional Area. The gradient of Montezuma Creek becomes less steep and the channel becomes braided in the section below FS268 and above FS205. After crossing under FS205, Montezuma Creek flows through a steep channel armored with boulders and logs until it enters the MFBR.

The source of Unnamed Creek is a hot spring located northeast of the tailings Depositional Area (the approximate location of the hot spring is indicated on Figure 5-3, Appendix A). Unnamed Creek flows generally northwest toward the Depositional Area (Figure 1-2, Appendix A). After the 1997 release, Unnamed Creek was removed from its original channel and placed in a constructed channel north and upgradient from the Depositional Area. As described earlier in this report, Unnamed Creek was restored to its original channel in 1999. Unnamed Creek flowed generally west in the constructed channel along the northern edge of the Depositional Area until it returned to its natural channel approximately 100 feet before its confluence with Montezuma Creek. After completing removal actions in the Depositional Area in 1998 and 1999, Unnamed Creek was routed back into its original channel. Unnamed Creek joins the flow of Montezuma Creek about 150 feet east of FS205.

Site-related waters originating from the vicinity of the Tailings Piles are routed into the sedimentation basin and land application systems. This water consists primarily of baseflow groundwater during the majority of the year. Flow is increased into the land application system during spring runoff and during storm events. The land application area consists of a series of

trenches, constructed on elevation contours, designed to enhance evaporation and infiltration of Site-related water and limit, to the extent practicable, releases of Site-related water to natural surface water features.

5.3.1.1 Surface Water Sampling

IDEQ, U.S. EPA, Terracon, and Pentec have collected surface water samples at the Site since May 1997. Locations of surface water sampling sites are shown on Figures 5-3, 5-4, 5-5, and 5-6 (Appendix A) and are summarized in Tables 3-1, 3-2, and 3-2A (Appendix E). Note that Pentec's sample site MC-3P was located further downstream from the normally-sampled MC-3 location to coincide with sediment and biota sampling (Figure 3-13, Appendix A). A summary of laboratory analytical results for samples collected by IDEQ, U.S. EPA, Terracon, and Pentec is presented in Tables 5-1A and 5-1B (Appendix E). Table 5-1A summarizes surface water quality data for sites that are no longer monitored or no longer exist. Table 5-1B summarizes surface water data for regularly monitored locations. A summary of field parameters (temperature, pH, dissolved oxygen, specific conductance and oxidation-reduction potential [ORP]), and water flow or discharge for samples collected by Terracon at regular surface water sampling locations is presented in Tables 5-2 A and 5-2B (Appendix E). Table 5-2A summarizes field parameters for sites that are no longer monitored or no longer exist. Table 5-2B summarizes field parameters for regularly monitored locations. Surface water common ions data are presented in Tables 5-3A and 5-3B (Appendix E). Table 5-3A summarizes surface water common ion data for sites that are no longer monitored or no longer exist. Table 5-3B summarizes surface water common ions data for regularly monitored locations.

In August 1997, Terracon initiated a regular surface water monitoring program. The dates for surface water sampling performed by Terracon were selected using the following rationale. Starting in August 1997, surface water samples were collected once per month for three months to measure late-summer flows and establish concentration variability. By late November, flow and concentration variability were minimal and the samples were collected bimonthly to provide an indication of base flow conditions during the winter months. Once spring flows began to rise in April, samples were collected twice monthly in order to obtain information on the quality of the surface water during runoff conditions. After two months of bi-monthly sampling, the frequency of sampling reverted to once a month through June 1998.

Starting in July 1998, two of the sampling locations were eliminated: the 24-inch culvert that crosses FS207, and MFBR at Kirby Dam. The first station was eliminated because the diversion structure at the 24-inch culvert has diverted baseflow into the sedimentation basin system, drying up the water in the 24-inch culvert except during storm events. The Kirby Dam sampling location was eliminated because it did not contribute additional information beyond that acquired from the sampling station located downstream from the confluence with Montezuma Creek (MFBR-2).

Two sampling locations were added starting with the October 1998 sampling episode: Montezuma Creek just before the creek enters the willow area, upgradient of the Depositional Area (MC-3), and Unnamed Creek below the Greene tailings (UC-1). These sites were added in an effort to determine groundwater influences and quantify off-site contributions to natural surface water features. Another sampling station was added to the surface water monitoring program in December 1998. This station is Unnamed Creek Above Montezuma Creek (UC-2). This station was added to further evaluate groundwater influences and to quantify off-site contributions to Unnamed Creek and Montezuma Creek.

Three sampling events were completed in April and May 1999 to document conditions during the 1999 spring runoff. After spring runoff, surface water sampling was conducted in June, July and September 1999.

Prior to sample collection, the surface water flow rate was estimated. Surface water samples were collected and analyzed in accordance with the Quality Assurance Sampling Plan. Results of Quality Assurance / Quality Control (QA/QC) analyses on duplicates, blanks and standards are presented in Appendix J-1.

5.3.1.2 Reference Sites for Surface Water

There are three reference sites used in this report for the surface water evaluations: MC-1, MFBR-1, and UC-1. MC-1 is Montezuma Creek downgradient of the confluence with East Fork Montezuma Creek and upgradient of the Tailings Piles and Depositional Area resulting from the 1997 release. Therefore, MC-1 is the appropriate location for estimating the reference condition for water quality in Montezuma Creek relative to the Site. MFBR-1 is the MFBR upstream of the confluence of the MFBR and Montezuma Creek, and is an appropriate location for estimating reference conditions in the MFBR relative to the Site. UC-1 is located in Unnamed Creek immediately downgradient of the historic Greene tailings area but upstream of the area impacted by the 1997 release.

5.3.1.3 Arsenic in Surface Water

This subsection presents 1999 surface water data including flow volume, arsenic concentrations and arsenic loading. Pre-1999 data are referenced to compare time-related changes in arsenic concentration or loading. As previously noted, the surface water monitoring program was initiated in August 1997. This monitoring program included three sampling stations along Montezuma Creek (MC-1, MC-2, and MC-4) and two stations along the Middle Fork Boise River (MFBR-1 and MFBR-2). Arsenic concentration and loading data are presented in the following paragraphs, and dissolved arsenic concentration data are compared with the chronic ambient water quality criterion (AWQC) for arsenic (0.15 mg/L). Arsenic loading is also discussed in Section 5.4. Arsenic is selected for detailed evaluation, relative to other COPCs, due to its known presence in tailings derived from the Site and the potential risk it may pose to human and environmental receptors. Screening of all metals evaluated at the Site is conducted separately in the Baseline Human Health Risk Assessment and the Baseline Ecological Risk Assessment.

Arsenic loads were estimated by multiplying the flow (cfs) times the metal concentration [milligrams per liter (mg/L)] and converting to the appropriate units to arrive at the arsenic load in pounds per day. Note that flow measurement in the MFBR was not possible during high flow for reasons of safety which precluded the calculation of arsenic loads in the MFBR for those time periods. The formula used to estimate loads arsenic loading was as follows:

As Loading (pounds per day)	=	As Concentration (mg/L)	x	Flow (cfs)	x	Conversion Factor

Where Conversion Factor = 5.4 (lbs/day)/ (mg ft^3 / L sec).

Arsenic in Montezuma Creek

Montezuma Creek surface water sampling station, MC-1, located upgradient of the Tailings Piles just below the confluence of Montezuma Creek and the East Fork of Montezuma Creek, was not impacted by the 1997 release. Total and dissolved arsenic concentrations in surface water samples collected from MC-1 and other Montezuma Creek sampling stations are presented in Table 5-1B (Appendix E), in the tables on pages 5-12 and 5-13, and in Figures 5-8 and 5-9 (Appendix A). Total arsenic concentrations at MC-1 in 1999 ranged from approximately 0.03 to 0.18 mg/L. Dissolved arsenic concentrations in 1999 ranged from approximately 0.011 to 0.049 mg/L. The ratio of dissolved arsenic to total arsenic generally trended inversely proportional to flow. For example, at a relatively high flow of approximately 15 cubic feet per second (cfs) in May 1999, dissolved arsenic comprised only 14 percent of the total arsenic. At a relatively low flow of 0.28 cfs (September 1999), dissolved arsenic comprised 66 percent of total arsenic. Dissolved arsenic concentrations in samples collected from MC-1 in 1999, consistent with 1997 and 1998 data, did not exceed the AWQC standard of 0.15 mg/L. Figure 5-17 (Appendix A) indicates the maximum and minimum dissolved arsenic concentrations detected since the 1997 release at selected sampling locations in the MFBR and Montezuma Creek. Surface water flow at MC-1 ranged from 0.28 to 15 cfs in 1999, with higher flows occurring in the springtime.

Figure 5-7 (Appendix A) is a histogram showing the flow at each of the Montezuma Creek sampling stations with time. The rising limb of spring runoff generally began during early to mid-April and appeared to peak in mid to late May. Total arsenic loading ranged from approximately 0.11 to 13 pounds per day and was generally proportional to flow. For example, at a relatively low flow of 0.28 cfs (September 1999), total arsenic loading was 0.11 pound per day. At a relatively high flow of approximately 15 cfs (May 1999), total arsenic loading was 13 pounds per day. Total arsenic loading at MC-1 in April and May 1999 was approximately 8 times higher than total arsenic

loading at MC-1 in April and May 1998. Figures 5-10 and 5-11 (Appendix A) show total and dissolved arsenic loading measured at each of the Montezuma Creek sampling stations.

The Montezuma Creek surface water sampling station MC-2, located crossgradient of the Tailings Piles at the point where Montezuma Creek crosses FS268, apparently was not impacted by the 1997 release. Total arsenic concentrations at MC-2 in 1999 ranged from approximately 0.028 to 0.20 mg/L. Dissolved arsenic concentrations in 1999 ranged from approximately 0.011 to 0.045 mg/L and comprised from 14 percent to 80 percent of total arsenic. Consistent with data for MC-1, dissolved arsenic generally trended inversely proportional to flow. For example, at a relatively high flow of approximately 20 cfs (May 1999), dissolved arsenic comprised only 14 percent of the total arsenic. At a relatively low flow of 0.21 cfs (September 1999), dissolved arsenic comprised 80 percent of total arsenic. Dissolved arsenic concentrations in samples collected from MC-2 in 1999, consistent with 1997 and 1998 data, did not exceed the AWQC of 0.15 mg/L. Surface water flow at MC-2 ranged from 0.21 to 20 cfs in 1999, with higher flows occurring in the springtime. Total arsenic loading ranged from approximately 0.06 to 22 pounds per day and was generally proportional to flow. For example, at a relatively low flow of 0.21 cfs (September 1999), total arsenic loading was 0.06 pound per day. At a relatively high flow of approximately 20 cfs (May 1999), total arsenic loading was 22 pounds per day. Similar to MC-1, total arsenic loading at MC-2 in April and May 1999 was an average of approximately 8 times total arsenic loading for April and May 1998. Dissolved arsenic loading in 1999 ranged from 14 percent to 80 percent of total arsenic loading, with relatively low percentage dissolved arsenic loading occurring during relatively high flows.

The Montezuma Creek surface water sampling station MC-3, located downgradient of the Tailings Piles, just upgradient of the Depositional Area, apparently was not impacted by the 1997 release. Total arsenic concentrations at MC-3 in 1999 ranged from approximately 0.028 to 0.25 mg/L. Dissolved arsenic concentrations in 1999 ranged from approximately 0.012 to 0.047 mg/L and comprised from 12 percent to 87 percent of total arsenic. Consistent with data for MC-1 and MC-2, dissolved arsenic generally trended inversely proportional to flow. For example, at a relatively low flow of 0.34 cfs (September 1999), dissolved arsenic comprised 87 percent of total arsenic. At a relatively high flow of approximately 19 cfs (May 1999), dissolved arsenic comprised only 12 percent of the total arsenic. Dissolved arsenic concentrations in samples collected from

MC-3 in have remained below the AWQC of 0.15 mg/L since sampling of this station began in October 1998. Surface water flow at MC-3 ranged from 0.34 to 19 cfs in 1999, with higher flows occurring in the springtime. During high flows, Montezuma Creek becomes braided and occupies several channels. Therefore, during high flows a fraction of the flow in Montezuma Creek may not be measured at MC-3. Total arsenic loading ranged from approximately 0.10 to 25 pounds per day and was generally proportional to flow. For example, at a relatively low flow of 0.34 cfs (September 1999), total arsenic loading was 0.10 pound per day. At a relatively high flow of approximately 19 cfs (May 1999), total arsenic loading was 25 pounds per day. There were not enough previous (1998) data to determine time-related trends in total arsenic loading at MC-3 (Figures 5-10 and 5-11, Appendix A).

The sampling station MC-4 is located on Montezuma Creek downgradient from the Depositional Area. Three grab samples were collected from MC-4 in the first weeks following the 1997 release. These three samples, collected by IDEQ on May 19, 1997 and May 28, 1997, and by Terracon on May 29, 1997, had total arsenic concentrations ranging from 2.8 mg/L to 3.5 mg/L and dissolved arsenic concentrations from 0.2 mg/L to 0.227 mg/L. These results indicate that this reach of Montezuma Creek was impacted by the 1997 release, at the time of that release. Total arsenic concentrations at MC-4 in 1999 ranged from approximately 0.028 to 0.22 mg/L. Dissolved arsenic concentrations in 1999 ranged from approximately 0.020 to 0.051 mg/L and comprised from 18 percent to 93 percent of total arsenic. Consistent with data for upgradient Montezuma Creek stations, dissolved arsenic generally trended inversely proportional to flow. For example, at a relatively low flow of 1.1 cfs (July 1999), dissolved arsenic comprised 93 percent of total arsenic. At a relatively high flow of approximately 25 cfs (May 1999), dissolved arsenic comprised only 18 percent of total arsenic. Dissolved arsenic concentrations in samples collected from MC-4 in 1999 did not exceed the AWQC of 0.15 mg/L. Surface water flow at MC-4 ranged from 0.60 to 25 cfs in 1999, with higher flows occurring in the springtime. Total arsenic loading ranged from approximately 0.09 to 30 pounds per day and was generally proportional to flow. For example, at a relatively high flow of approximately 25 cfs (May 1999), total arsenic loading was 30 pounds per day. At a relatively low flow of 0.60 cfs (September 1999), total arsenic loading was 0.09 pound per day. Total arsenic loading at MC-4 in April and May 1999 was an average of approximately four times total arsenic loading at MC-4 in April and May 1998 (Figure 5-10 and 5-11, Appendix A).

Total Arsenic Concentrations and Total Arsenic Loading in Montezuma Creek At MC-1, MC-2, MC-3, and MC-4 During Selected Sampling Episodes

	MC-1		MC-2		MC-3		MC-4	
Sample Date	Conc. (mg/L)	Loading (ppd)	Conc. (mg/L)	Loading (ppd)	Conc. (mg/L)	Loading (ppd)	Conc. (mg/L)	Loading (ppd)
May 1997	NC	NC	0.05	NC	NC	NC	NC	NC
June 1997	NC	NC	NC	NC	NC	NC	0.274	NC
August 1997	0.100	0.70	0.063	0.44	NC	NC	0.202	1.63
September 1997	0.119	0.29	0.071	0.33	NC	NC	0.119	0.77
October 1997	0.074	0.27	0.068	0.30	NC	NC	0.060	0.36
December 1997	0.086	0.27	0.051	0.16	NC	NC	0.050	0.32
February 1998	0.066	0.18	0.047	0.21	NC	NC	0.050	0.32
Early-April 1998	0.053	0.49	0.055	0.62	NC	NC	0.092	1.74
Mid-April 1998	0.075	1.05	0.055	0.95	NC	NC	0.083	2.06
Mid-May 1998	0.020	1.28	0.024	2.07	NC	NC	0.054	4.52
Late-May 1998	0.041	3.49	0.041	5.18	NC	NC	0.055	6.44
June 1998	0.025	1.26	0.0238	1.91	NC	NC	0.038	2.63
July 1998	0.042	0.73	0.035	0.64	NC	NC	0.067	1.41
October 1998	0.082	0.18	0.068	0.18	0.063	0.14	0.044	0.26
December 1998	0.127	0.23	0.057	0.11	0.041	0.00	0.016	0.07
Mid-April 1999	0.182	7.07	0.204	9.31	0.174	3.54	0.129	8.35
Late-April 1999	0.076	3.36	0.085	4.59	0.084	4.80	0.074	5.59
May 1999	0.164	13.38	0.198	21.74	0.246	25.06	0.222	29.94
June 1999	0.03	1.20	0.0283	1.48	0.028	1.18	0.0325	1.40
July 1999	0.051	0.39	0.0362	0.20	0.038	0.10	0.0456	0.27
September 1999	0.0751	0.11	0.0526	0.06	0.0546	0.10	0.028	0.09

Note:

NC = Data not collected or not collected as part of Terracon's regular sampling program.

mg/L = milligrams arsenic per liter.

ppd = pounds arsenic per day.

Dissolved Arsenic Concentrations and Dissolved Arsenic Loading in Montezuma Creek At MC-1, MC-2, MC-3, and MC-4 During Selected Sampling Episodes

	MC-1		MC-2		MC-3		MC-4	
Sample Date	Conc. (mg/L)	Loading (ppd)	Conc. (mg/L)	Loading (ppd)	Conc. (mg/L)	Loading (ppd)	Conc. (mg/L)	Loading (ppd)
May 1997	NC	NC	NC	NC	NC	NC	0.227	NC
June 1997	NC	NC	NC	NC	NC	NC	0.181	NC
August 1997	0.057	0.40	0.051	0.36	NC	NC	0.182	0.73
September 1997	0.075	0.21	0.063	0.29	NC	NC	0.113	0.73
October 1997	0.065	0.24	0.061	0.27	NC	NC	0.054	0.32
December 1997	0.045	0.14	0.042	0.13	NC	NC	0.037	0.24
February 1998	0.046	0.12	0.043	0.19	NC	NC	0.050	0.32
Early-April 1998	0.042	0.39	0.044	0.50	NC	NC	0.074	1.40
Mid-April 1998	0.037	0.52	0.037	0.64	NC	NC	0.065	1.61
Mid-May 1998	0.014	0.90	0.017	1.47	NC	NC	0.042	3.51
Late-May 1998	0.019	1.62	0.021	2.65	NC	NC	0.037	4.33
June 1998	0.010	0.50	0.012	0.96	NC	NC	0.028	1.96
July 1998	0.020	0.35	0.021	0.39	NC	NC	0.055	1.16
October 1998	0.077	0.17	0.064	0.17	0.058	0.13	0.038	0.23
December 1998	0.046	0.08	0.043	0.09	0.041	0.00	0.016	0.07
Mid-April 1999	0.045	1.75	0.045	2.05	0.046	0.94	0.049	3.17
Late-April 1999	0.037	1.64	0.040	2.16	0.039	2.23	0.051	3.85
May 1999	0.023	1.91	0.028	3.06	0.030	3.01	0.040	5.33
June 1999	0.0114	0.46	0.0109	0.57	0.0122	0.51	0.0199	0.86
July 1999	0.0278	0.21	0.0277	0.15	0.0332	0.09	0.0424	0.25
September 1999	0.0493	0.07	0.0422	0.05	0.0473	0.09	0.0253	0.08

Note:
NC = Data not collected or not collected as part of Terracon's regular sampling program.
mg/L = milligrams arsenic per liter.
ppd = pounds arsenic per day.

Arsenic in Unnamed Creek

The Unnamed Creek surface water sampling station UC-1, located immediately downgradient of the historic Greene tailings area, was not impacted by the 1997 release. Total and dissolved arsenic concentrations at UC-1 in 1999 both ranged from approximately 0.02 to 0.05 mg/L (the majority of total arsenic was in the dissolved form). Dissolved arsenic ranged from 81 percent to 100 percent of total arsenic. Dissolved arsenic concentrations of samples collected from UC-1 in 1999, consistent with limited 1998 data, did not exceed the AWQC of 0.15 mg/L. Surface water flow at UC-1 ranged from 0.10 to 1.5 cfs in 1999, with higher flows occurring in the springtime. Total arsenic loading ranged from approximately 0.01 to 0.25 pound per day and was generally proportional to flow. For example, at a relatively low flow of 0.10 cfs (September 1999), total arsenic loading was 0.01 pound per day. At a relatively high flow of approximately 1.5 cfs (April 1999), total arsenic loading was 0.25 pound per day. There were not enough previous (1998) data to determine long-term time-related trends in total arsenic loading at UC-1.

The Unnamed Creek surface water sampling station UC-2, located immediately upgradient of the confluence of Unnamed Creek and Montezuma Creek, was impacted by historic tailings releases and the 1997 tailings release. Total and dissolved arsenic concentrations at UC-2 in 1999 ranged from approximately 0.013 to 0.088 mg/L (the majority of total arsenic was in the dissolved form). Dissolved arsenic ranged from 73 percent to 100 percent of total arsenic. Dissolved arsenic concentrations of samples collected from UC-2 in 1999, consistent with limited 1998 data, did not exceed the AWQC of 0.15 mg/L. Surface water flow at UC-2 ranged from 0.42 to 3.0 cfs in 1999, with higher flows occurring in the springtime. Total arsenic loading ranged from approximately 0.03 to 0.95 pound per day and was generally proportional to flow. For example, at a relatively low flow of 0.43 cfs (September 1999), total arsenic loading was 0.03 pound per day. At a relatively high flow of approximately 3 cfs (April 1999), total arsenic loading was 0.95 pound per day. There were not enough previous (1998) data to determine long-term time-related trends in total arsenic loading at UC-1.

Arsenic in the MFBR

Total and dissolved arsenic concentrations in the MFBR are presented in Table 5-1B (Appendix E), the table below and Figures 5-13 and 5-14 (Appendix A). The upgradient MFBR surface water sampling station, MFBR-1, located at the bridge where FS 205 crosses the MFBR, was not impacted by the 1997 release. Total and dissolved arsenic concentrations at MFBR-1 in 1999 ranged from approximately 0.002 to 0.006 mg/L (the majority of total arsenic was typically in the dissolved form). Dissolved arsenic ranged from 33 percent to 100 percent of total arsenic. Dissolved arsenic concentrations in samples collected from MFBR-1 in 1999, consistent with 1997 and 1998 data, did not exceed the AWQC of 0.15 mg/L. Flows at MFBR-1, presented in Figure 5-12 (Appendix A), ranged from 42 to approximately 500 cfs (estimate) in 1999. Similar to flows in Montezuma Creek, flows in the MFBR increased as spring runoff began in April and peaked in late May. Flows were not available during spring runoff for MFBR-1 due to high water levels and dangerous wading conditions. Total and dissolved arsenic loading in the MFBR are presented in Figures 5-15 and 5-16 (Appendix A). Similar to Montezuma Creek, arsenic loading was greatest during spring runoff from April through July. Loading estimates were not available for some sampling stations due to the lack of flow information. Total arsenic loading ranged from approximately 1.2 to 14.3 pounds per day (estimate) and was generally proportional to flow. For example, at a relatively low flow of 42 cfs (September 1999), total arsenic loading was 1.2 pounds per day. At a relatively high flow of approximately 500 cfs (May 1999, estimated), total arsenic loading was 14.3 pounds per day. The long-term change in total arsenic loading over time was not determined due to unavailable flow data for high-runoff (springtime) events.

Arsenic Concentration and Loading in Middle Fork Boise River At MFBR-1 and MFBR-2 During Selected Sampling Episodes

	MFBR-1				MFBR-2			
Sample Date	Total Conc. (mg/L)	Total Loading (ppd)	Dissolved Conc. (mg/L)	Dissolved Loading (ppd)	Total Conc. (mg/L)	Total Loading (ppd)	Dissolved Conc. (mg/L)	Dissolved Loading (ppd)
May 1997	0.008	NC	NC	NC	0.054	NC	NC	NC
June 1997	NC	NC	NC	NC	0.016	NC	0.014	NC
August 1997	0.007	4.49	0.006	3.85	0.016	6.65	0.009	6.65
September 1997	0.006	2.10	0.005	1.75	0.009	3.88	0.008	3.45
October 1997	0.009	2.43	0.008	2.16	0.009	3.06	0.01	3.40
December 1997	<0.005	1.03	<0.005	1.03	0.009	1.29	<0.005	1.08
February 1998	0.007	1.36	0.007	1.36	0.006	2.21	0.007	1.55
Early-April 1998	0.009	3.30	0.007	2.57	0.010	6.27	0.012	5.37
Mid-April 1998	<0.005	2.64	0.007	3.70	0.014	3.02	0.011	6.65
Mid-May 1998	0.004	NC	0.005	NC	0.005	NC	0.009	NC
Late-May 1998	0.005	NC	0.005	NC	0.009	NC	NC	NC
June 1998	0.0044	NC	0.0036	NC	0.0075	NC	0.0062	NC
July 1998	0.005	7.69	0.005	7.69	0.006	9.42	0.005	7.85
October 1998	0.007	1.47	0.006	1.26	0.006	1.39	0.006	1.39
December 1998	0.005	0.84	0.004	0.67	0.005	1.19	0.005	1.19
Mid-April 1999	0.006	5.15	0.006	NC	0.032	NC	0.018	NC
Late-April 1999	0.006	NC	0.002	NC	0.015	NC	0.010	NC
May 1999	0.0053	NC	0.0037	NC	0.018	NC	0.0075	NC
June 1999	0.0027	NC	0.0038	NC	0.0048	NC	0.0061	NC
July 1999	0.0049	3.01	0.005	3.08	0.0055	3.44	0.0054	3.38
September 1999	0.0053	1.20	0.0049	1.11	0.0064	1.52	0.0055	1.31

Note:

NC = Data not collected or not collected as part of Terracon's regular sampling program.

mg/L = milligrams arsenic per liter.

ppd = pounds arsenic per day.

The downgradient MFBR surface water sampling station, MFBR-2, is located below the confluence with Montezuma Creek. Total arsenic concentrations at MFBR-2 in 1999 ranged from approximately 0.005 to 0.032 mg/L. Dissolved arsenic concentrations at MFBR-2 in 1999 ranged from approximately 0.005 to 0.018 mg/L and comprised from 42 percent to 100 percent of total arsenic. Dissolved arsenic concentrations in samples collected from MFBR-1 in 1999, consistent with 1997 and 1998 data, did not exceed the AWQC of 0.15 mg/L. Surface water flow at MFBR-2 ranged from 44 to approximately 500 cfs (estimate) in 1999, with higher flows occurring in the springtime. Flows were not available during spring runoff for MFBR-2 due to high water levels and dangerous wading conditions. Total arsenic loading ranged from approximately 1.5 to 49 pounds per day (estimate) and was generally proportional to flow. For example, at a relatively low flow of 44 cfs (September 1999), total arsenic loading was approximately 1.5 pounds per day. At a relatively high flow of approximately 500 cfs (May 1999, estimated), total arsenic loading was approximately 49 pounds per day. The long-term change in arsenic loading over time was not determined due to unavailable flow data for high-runoff (springtime) events.

Arsenic in Site-Related Waters

Arsenic concentrations in some Site-related surface waters at the Tailings Piles (Table 5-1A, Appendix E) were measured through June 1998. Many of the Site-related sampling locations were eliminated from the sampling program or no longer exist due to excavation and construction activities. Arsenic concentrations in Site-related surface waters at the Tailings Piles (Table 5-1A, Appendix E) have been detected up to 1,250 mg/L total arsenic and 5 mg/L dissolved arsenic. However, these waters are routed into the sedimentation basin and land application systems.

Samples collected from the diversion at the 24"CMP beneath FS207 from the 13 sampling dates between 8/14/97 and 6/17/98, show that dissolved arsenic on 12 of the 13 sampling dates exceeded the USEPA chronic AWQC for arsenic of 0.15 mg/L. On 9 of the 13 dates the dissolved arsenic concentrations exceeded the USEPA acute AWQC for arsenic of 0.34 mg/L. The Tailings Piles are a source that likely contributed to these exceedances.

Total Arsenic Concentrations (mg/l) Measured in Site-Related Surface Waters During Selected Sampling Episodes

Sample Date	12" CMP FS 207	24" CMP FS 207	DIV. @ 24" CMP @ FS 207	Outlet, Sed. Basin #1	Springs @ Base of Upper Tailings	Spring @ Base of Lower Tailings
May 1997	NC	NC	NC	NC	9.0	NC
June 1997	5.51	NC	NC	NC	NC	NC
August 1997	5.53	0.255	NC	NC	NC	NC
September 1997	4.22	2.78	NC	NC	NC	NC
October 1997	3.85	1.01	NC	NC	NC	NC
December 1997	NC	0.732	NC	2.75	NC	NC
February 1998	MC	0.490	NC	2.59	NC	NC
Early-April 1998	NC	0.306	NC	1.67	NC	NC
Mid-April 1998	NC	0.203	NC	3.05	NC	NC
Mid-May 1998	NC	NC	0.532	1.97	NC	NC
Late-May 1998	NC	NC	0.606	1.73	NC	NC
June 1998	NC	NC	0.662	2.20	NC	NC
July 1998	NC	NC	NC	2.86	NC	NC
September 1998	NC	NC	NC	NC	1.14	NC
October 1998	NC	NC	NC	2.27	NC	NC
December 1998	NC	NC	NC	1.26	0.798	4.27
May 1999	NC	NC	NC	NC	2.48	0.055
October 1999	NC	NC	NC	NC	1.09	2.6

Note:
1) NC = Data not collected or not collected as part of Terracon's regular sampling program.

As described in Sections 3.6.1.1 and 3.6.1.2, and Figures 3-1 and 3-2 of this report, the 24" CMP FS207 was initially installed to divert water away from the tailings area to minimize tailings erosion and transport. The 24" CMP was installed in June 1997, after the release, and modified by November 1997. The waters initially intercepted included that from a flume associated with the East Fork of Montezuma Creek and the diverted spring water from above the Upper Tailings Pile. The total flow at 24" CMP FS207 was measured at 40 gpm in June 1997 but decreased to about 5 gpm by August 1997. No tailings were observed to enter it at any time. By November 1, 1997 the diversion had been modified so that base-flow water from springs and seeps along FS 207 was routed into the sedimentation basin and land application systems, while diverting storm water runoff along FS 207 into the 24" CMP, underneath FS207, and into Montezuma Creek. Following damage during Spring runoff in 1998, the diversion structure was re-constructed using concrete and a series of discharge pipes. Except during high runoff events, the diversion structure was designed to route all water away from Montezuma Creek and into the sedimentation basin and land application system.

Surface water sampling and flow measurements were conducted at 24"CMP FS207 during seven sampling events beginning in August 1997 through April 1998. Dissolved arsenic concentrations ranged from 0.18 to 1.57 mg/L and averaged 0.59 mg/L. Flow averaged about 3 gallons per minute during these measurement events. Dissolved and total arsenic loads averaged 0.015 and 0.018 pound per day, respectively (Table 5-26). The arsenic load contribution from 24"CMP FS 207 represented an average of about 6.2 percent of the load at MC-2, which is a downstream sampling site on Montezuma Creek.

5.3.1.4 Arsenic Speciation

A total of six surface water samples were collected and analyzed for arsenic speciation. These samples included one surface water sample from Montezuma Creek (MC-4), two samples from tailings-related surface waters (from the 12-inch diameter culvert that crossed under FS207 below the lower tailings area and the 18-inch diameter culvert from the lower sedimentation basin that crossed under FS268), one sample from a spring at the base of the Upper Tailings Pile, one sample associated with a seep at the base of the lower tailings (from a 24-inch diameter culvert that crossed under FS207 below the lower tailings area), and one sample from a batch test to determine arsenic partitioning between solid (tailings) and surface water.

In the batch test, a temporary lined containment vessel (approximately 5 feet in diameter and 1-foot deep) was filled approximately half-full with tailings. The tailings were saturated with water from the East Fork of Montezuma Creek. After 20 days, a water sample was collected from the test vessel and analyzed for arsenic speciation.

Results of the arsenic speciation analyses are summarized in Table 5-4 (Appendix E). Surface water samples exposed to oxidizing conditions, including samples collected from Montezuma Creek, the batch test and tailings-related surface waters, contained primarily pentavalent arsenic (As^{+5}), arsenate. Trivalent arsenic (As^{+3}), arsenite, was more prevalent in samples associated with the spring at the base of the upper tailings. Additional samples for arsenic speciation, i.e. from the seep at the base of the lower tailings, were not collected due to insufficient flow.

Arsenate is typically less toxic and less mobile than arsenite (Bhumbla and Keefer, 1994; and Will and Suter, 1995). Arsenite readily oxidizes to arsenate in oxidizing conditions typical in mountain creeks and rivers. Also, arsenate readily adsorbs to silt and clay particles composed of manganese and iron oxides, which reduces the mobility of arsenic (Prasad, 1994). Manganese and iron oxides are likely to be prevalent in the soil and geology of the Atlanta area (Anderson, 1939; Krauskopf, 1979).

5.3.1.5 Antimony in Surface Water

The maximum detected antimony concentration in Montezuma Creek, 0.14 mg/L (Table 5-1B, Appendix E), was measured in a grab sample collected by the IDEQ from MC-4 on May 19, 1997. The maximum detected antimony concentration measured in Montezuma Creek after May 1997 was 0.0038 mg/L in samples MC-2 and MC-3 collected on April 19, 1999. Total antimony in Montezuma Creek samples collected during Terracon's regular sampling program ranged from <0.0005 to 0.14 mg/L. Dissolved antimony in Montezuma Creek samples collected during Terracon's regular sampling program ranged from <0.0005 to 0.0335 mg/L.

The maximum detected antimony concentration in the MFBR, 0.009 mg/L (Table 5-1B, Appendix E), occurred in a grab sample collected by the IDEQ from MFBR-2 on May 19, 1997. The maximum detected concentration of antimony measured in the MFBR after May 1997 was 0.0012 mg/L in sample MFBR-2 collected on April 20, 1999. Total antimony in MFBR samples

collected during Terracon's regular sampling program ranged from <0.0005 to 0.009 mg/L. Dissolved antimony was detected in only two MFBR samples (MFBR-2 on April 20 and April 26, 1999) at concentrations of 0.0009 and 0.0006 mg/L.

The maximum antimony concentration in Site-related surface water, 1.9 mg/L (Table 5-1A, Appendix E), was measured in a grab sample collected by the IDEQ from the Tailings Piles on May 19, 1997 immediately following the 1997 release. The data for this sample (Sample 0656, L. Tails Q) are presented in Table 5-1A (Appendix E). Total antimony concentrations in other samples collected from Site-related surface water samples after June 1997 ranged from <0.002 to 0.060 mg/L. Dissolved antimony concentrations in other samples collected from Site-related surface water samples after June 1997 ranged from <0.002 to 0.088 mg/L.

5.3.1.6 Cadmium in Surface Water

The majority of Montezuma Creek samples had less than detectable cadmium concentrations, based on detection limits ranging from 0.00004 to 0.001 mg/L. The maximum detected cadmium concentration in Montezuma Creek samples, 0.0012 mg/L, (Table 5-1B, Appendix E), was measured in a flow integrated sample collected by Terracon from MC-3 on October 14, 1998. Total cadmium was detected in approximately 14 percent of Montezuma Creek samples. Excluding the maximum concentration, detected total cadmium concentrations in Montezuma Creek samples ranged from 0.00004 to 0.00046 mg/L. Dissolved cadmium was detected in approximately 8 percent of Montezuma Creek samples at concentrations ranging from 0.00008 to 0.0002 mg/L. Dissolved cadmium concentrations in Montezuma Creek samples were less than the chronic Aquatic Water Quality Criterion (AWQC) of 0.0004 mg/L.

The majority of MFBR samples had less than detectable cadmium concentrations, based on detection limits ranging from 0.00004 to 0.001 mg/L. The maximum detected cadmium concentrations in MFBR samples, 0.0001 mg/L, (Table 5-1B, Appendix E), were measured in flow integrated samples collected by Terracon on July 15 and December 23, 1998. Total cadmium was detected in approximately 19 percent of MFBR samples. Detected total cadmium concentrations in MFBR samples ranged from 0.000042 to 0.0001 mg/L. Dissolved cadmium was detected in approximately 6 percent of MFBR samples at concentrations ranging from 0.000045 to 0.00005

mg/L. Dissolved cadmium concentrations in MFBR samples were less than the chronic Aquatic Water Quality Criterion (AWQC) 0.0004 mg/L.

The maximum cadmium concentration in Site-related surface water, 0.214 mg/L (Table 5-1A, Appendix E), was measured in a grab sample collected by the U.S. EPA from the Tailings Piles on June 5, 1997. The data for this sample (Sample 97234390, Tails Q) are presented in Table 5-1A (Appendix E). Total detected cadmium concentrations in other samples collected from Site-related surface water samples after June 1997 ranged from 0.000041 to 0.0041 mg/L. Dissolved cadmium concentrations in other samples collected from Site-related surface water samples after June 1997 ranged from 0.000058 to 0.0025 mg/L. One sample (and its duplicate) collected from the outlet of Sedimentation Pond 1 in December 1998 had a dissolved cadmium concentration greater than the chronic Aquatic Water Quality Criterion (AWQC) of 0.0004 mg/L.

5.3.1.7 Copper in Surface Water

The majority of Montezuma Creek samples had less than detectable copper concentrations, based on detection limits ranging from 0.0005 to 0.02 mg/L. The maximum detected copper concentration in Montezuma Creek samples, 0.06 mg/L, (Table 5-1B, Appendix E), was measured in a grab sample collected by IDEQ from MC-4 on May 19, 1997, immediately following the 1997 release. After May 1997, detected total copper concentrations in Montezuma Creek samples ranged from 0.00065 to 0.012 mg/L. Total copper was detected in less than 27 percent of Montezuma Creek samples. Dissolved copper was detected in less than 19 percent of Montezuma Creek samples at concentrations ranging from 0.00055 to 0.0164 mg/L. Dissolved copper concentrations exceeded the chronic AWQC of 0.011 mg/L in two Montezuma Creek samples, one collected from MC-2 in June 1998, the other collected from MC-4 in June 1997.

The majority of MFBR samples had less than detectable copper concentrations, based on detection limits ranging from 0.0005 to 0.02 mg/L. The maximum detected copper concentration in MFBR samples, 0.02 mg/L, (Table 5-1B, Appendix E), was measured in a flow integrated sample collected by Terracon on October 14, 1998. Total copper was detected in approximately 25 percent of MFBR samples. Detected total copper concentrations in MFBR samples ranged from 0.0008 to 0.02 mg/L. Dissolved copper was detected in approximately 6 percent of MFBR samples at

concentrations ranging from 0.0023 to 0.01 mg/L. Dissolved copper concentrations in samples collected from the MFBR did not exceed the chronic AWQC of 0.011 mg/L.

The maximum copper concentration in Site-related waters, 17.5 mg/L (Table 5-1A, Appendix E), was measured in a grab sample collected by the IDEQ from the Tailings Piles on May 19, 1997 immediately following the 1997 release. The data for this sample (Sample 0656, L. Tails Q) are presented in Table 5-1A (Appendix E). Total detected copper concentrations in other samples collected from Site-related surface water samples after June 1997 ranged from 0.00066 to 0.0315 mg/L. Dissolved detected copper concentrations in samples collected from Site-related surface water samples ranged from 0.00066 to 0.0082 mg/L and did not exceed the chronic AWQC of 0.011 mg/L.

5.3.1.8 Iron in Surface Water

The maximum detected iron concentration in Montezuma Creek samples, 9.34 mg/L, (Table 5-1B, Appendix E), was measured in a grab sample collected by IDEQ from MC-4 on May 19, 1997, immediately following the 1997 release. After May 1997, detected total iron concentrations in Montezuma Creek samples ranged from 0.0254 to 3.05 mg/L. Total iron was detected in 100 percent of Montezuma Creek samples. Total iron concentrations in Montezuma Creek are shown in Figures 5-20 and 5-21 (Appendix A). Figure 5-22 (Appendix A) indicates the maximum and minimum detected dissolved iron concentrations at selected sampling locations in Montezuma Creek since the May 1997 release. During peak flow in May 1999, total iron concentrations and loading generally increased from MC-1 through MC-4. In Montezuma Creek, dissolved iron concentrations and loading generally increase in the downstream direction (Figures 5-18 and 5-19, Appendix A). There are relatively large increases in dissolved iron between MC-2 and MC-4 which may be attributed to groundwater input. Dissolved iron was detected in approximately 84 percent of Montezuma Creek samples at concentrations ranging from 0.005 to 0.86 mg/L.

The maximum detected iron concentration in MFBR samples, 0.67 mg/L (Table 5-1B, Appendix E), was measured in a grab sample collected by IDEQ from MFBR-2 on May 28, 1997. Figure 5-22 (Appendix A) indicates the maximum and minimum detected dissolved iron concentrations at selected sampling locations in the MFBR since the May 1997 release. After May 1997, detected total iron concentrations in MFBR samples ranged from 0.01 to 0.26 mg/L. Total iron

was detected in approximately 90 percent of MFBR samples. Dissolved iron was detected in approximately 71 percent of MFBR samples at concentrations ranging from 0.004 to 0.039 mg/L. Total iron concentrations appear to generally increase in the downstream direction between MFBR-1 and MFBR-2. Dissolved iron was detected in approximately 71 percent of MFBR samples at concentrations ranging from 0.004 to 0.039 mg/L. In the MFBR, dissolved iron concentrations appear to generally increase in the downstream direction between MFBR-1 and MFBR-2.

The maximum total iron concentration in Site-related waters, 5000 mg/L (Table 5-1A, Appendix E), was measured in a grab sample collected by the IDEQ from the Tailings Piles on May 19, 1997, immediately following the 1997 release. The data for this sample (sample # 0656, L. Tails Q) are presented in Table 5-1A (Appendix E) and the sample location is shown on Figure 5-6 (Appendix A). Total detected iron concentrations in other samples collected from Site-related surface water samples after June 1997 ranged from 0.01 to 48.7 mg/L. Dissolved detected iron concentrations in samples collected from Site-related surface water samples after June 1997 ranged from 0.009 to 4.4 mg/L.

5.3.1.9 Lead in Surface Water

The majority of Montezuma Creek samples had less than detectable lead concentrations, based on detection limits ranging from 0.0001 to 0.005 mg/L. The maximum detected lead concentration in Montezuma Creek samples, 0.027 mg/L, (Table 5-1B, Appendix E), was measured in a grab sample collected by IDEQ from MC-4 on May 19, 1997, immediately following the 1997 release. Total lead was non-detectable (<0.005 mg/L) in a grab sample collected at the same time at MC-2, upgradient of the Tailings Piles. After May 1997, detected total lead concentrations in Montezuma Creek samples ranged from 0.0003 to 0.00426 mg/L. Total lead was detected in less than 36 percent of Montezuma Creek samples. Dissolved lead was detected in approximately 13 percent of Montezuma Creek samples at concentrations ranging from 0.0001 to 0.0057 mg/L. Two surface water samples, collected from MC-2 and MC-4 in September 1999, had dissolved lead concentrations exceeding the chronic AWQC of 0.0025 mg/L.

Total lead was detected in approximately 36 percent of samples from the MFBR. The maximum detected value (0.0062 mg/L) was measured in water collected from MFBR-1 on September 13, 1999 (Table 5-1B, Appendix E). Detected total lead concentrations in MFBR

samples ranged from 0.0002 to 0.0062 mg/L. Dissolved lead was detected in less than 10 percent of MFBR samples at concentrations ranging from 0.00011 to 0.0024 mg/L. Surface water samples collected from the MFBR had dissolved lead concentrations less than the chronic AWQC of 0.0025 mg/L.

The maximum total lead concentration in Site-related waters, 16 mg/L (Table 5-1A, Appendix E), was measured in a grab sample collected by the IDEQ from the Tailings Piles on May 19, 1997, immediately following the 1997 release. The data for this sample (sample # 0656, L. Tails Q) are presented in Table 5-1A (Appendix E) and the sample location is shown on Figure 5-6 (Appendix A). Total detected lead concentrations in other samples collected from Site-related surface water samples after June 1997 ranged from 0.0002 to 0.00372 mg/L. Dissolved detected lead concentrations in samples collected from Site-related surface water samples after June 1997 ranged from 0.0001 to 0.0039 mg/L. Only one surface water sample, collected from the 12" CMP at FS 207 in June 1997, had a dissolved lead concentration exceeding the chronic AWQC of 0.0025 mg/L.

5.3.1.10 Mercury in Surface Water

The majority of Montezuma Creek samples had less than detectable mercury concentrations, based on detection limits ranging from 0.0001 to 0.005 mg/L. The maximum detected total mercury concentration in Montezuma Creek samples, 0.001 mg/L, (Table 5-1B, Appendix E), was measured in a grab sample collected by IDEQ from MC-4 on May 19, 1997, immediately following the 1997 release. After May 1997, detected total mercury concentrations in Montezuma Creek samples ranged from 0.00016 to 0.000356 mg/L. Total mercury was detected in approximately 10 percent of Montezuma Creek samples. Dissolved mercury was detected in less than 7 percent of Montezuma Creek samples at concentrations ranging from 0.00015 to 0.00016 mg/L. Dissolved mercury was detected in MC-1, MC-2, MC-3, and MC-4 only in May 1999. All four of these samples had dissolved mercury concentrations exceeding the chronic AWQC of 0.000012 mg/L.

Concentrations of total mercury were detected in 3 of 50 total samples collected from the MFBR. The maximum detected value (0.0005 mg/L) was measured in water collected from MFBR-2 on May 30, 1997 (Table 5-1B, Appendix E). Detected total mercury concentrations in MFBR samples ranged from 0.00015 to 0.0005 mg/L. Dissolved mercury was detected in 3 of 47 MFBR

samples at concentrations ranging from 0.00015 to 0.000206 mg/L. All three of the MFBR samples in which dissolved mercury was detected had dissolved mercury concentrations exceeding the chronic AWQC of 0.000012 mg/L.

The maximum concentration of total mercury in Site-related waters was 0.51 mg/L (Table 5-1A, Appendix E). This concentration was measured by the IDEQ on May 19, 1997, immediately following the 1997 release, in water associated with the Tailings Piles (sample # 0656, L. Tails Q; Figure 5-6, Appendix A). Detected total mercury concentrations in Site-related waters ranged from 0.0003 to 0.51 mg/L. Dissolved mercury was not detected in samples of Site-related waters.

5.3.1.11 Silver in Surface Water

In Montezuma Creek, total silver was detected in 5 of 53 analyses. Of the five samples with total silver concentrations above detection limits, total silver concentrations ranged from 0.0005 to 0.014 mg/L. The maximum concentration of total silver in Montezuma Creek, 0.014 mg/L was measured by IDEQ at MFBR-2 on May 28, 1997. Total silver was detected at MC-4 in each of the first four analyses (May and June 1997) and at MC-2 in October 1997, but has not been detected since. Dissolved silver has not been detected in Montezuma Creek.

In the MFBR, total silver was detected in four samples, two from MFBR-1 and two from MFBR-2. Total silver concentrations in the MFBR ranged from 0.000045 to 0.0012. The maximum concentration of total silver in the MFBR, 0.0012 mg/L (Table 5-1A, Appendix E), was measured by the IDEQ on May 19, 1997 in water associated with the Tailings Piles (sample # 0656, L. Tails Q; Figure 5-6, Appendix A). Total silver was detected at MFBR-2 in each of the first two analyses (May and June 1997), but has not been detected since. Dissolved silver was not detected in the MFBR.

Detected total silver concentrations in Site-related waters ranged from 0.0003 to 6.56 mg/L. The maximum concentration of total silver detected in Site-related waters was 6.56 mg/L (Table 5-1A, Appendix E). This concentration was measured by the IDEQ on May 19, 1997, immediately following the 1997 release, in water associated with the Tailings Piles (sample # 0656, L. Tails Q; Figure 5-6, Appendix A). Detected dissolved silver concentrations in Site-related waters ranged

from 0.000042 to 0.0003 mg/L. Dissolved silver concentrations in Site-related waters did not exceed the acute AWQC of 0.0034 mg/L.

5.3.1.12 Zinc in Surface Water

Total zinc was detected in 82 percent of Montezuma Creek samples. The maximum detected zinc concentration in Montezuma Creek samples, 0.049 mg/L (Table 5-1B, Appendix E), was measured in a grab sample collected by IDEQ from MC-4 on May 19, 1997, immediately following the 1997 release. After June 1997, detected total zinc concentrations in Montezuma Creek samples ranged from 0.001 to 0.0028 mg/L. Dissolved zinc was detected in approximately 82 percent of Montezuma Creek samples at concentrations ranging from 0.001 to 0.021 mg/L. Dissolved zinc concentrations in Montezuma Creek samples did not exceed the chronic AWQC of 0.1 mg/L.

In the MFBR, total zinc was detected in approximately 74 percent of surface water samples. Detected total zinc concentrations in the MFBR ranged from 0.0015 to 0.018 mg/L. The maximum concentration of total zinc in the MFBR, 0.018 mg/L, was measured at MFBR-1 by the IDEQ in June 1997. Detected dissolved zinc concentrations in MFBR samples ranged from 0.0009 to 0.019 mg/L. Dissolved zinc concentrations in MFBR samples did not exceed the chronic AWQC of 0.1 mg/L.

Detected total zinc concentrations in Site-related waters ranged from 0.0016 to 16.6 mg/L. The maximum concentration of total zinc detected in Site-related waters was 16.6 mg/L (Table 5-1A, Appendix E). This concentration was measured by the IDEQ on May 19, 1997, immediately following the 1997 release, in water associated with the Tailings Piles (sample # 0656, L. Tails Q; Figure 5-6, Appendix A). Detected dissolved zinc concentrations in Site-related waters ranged from 0.0003 to 0.051 mg/L. Dissolved zinc concentrations in Site-related waters did not exceed the chronic AWQC of 0.1 mg/L.

5.3.1.13 Summary of Observations: Creeks and Streams

- Immediately following the 1997 release, dissolved arsenic concentrations in Montezuma Creek downstream of the Tailings Piles (station MC-4) commonly

exceeded the AWQC for arsenic of 0.15 mg/L. Dissolved arsenic concentrations decreased to below the arsenic AWQC in September 1997 and have remained below the arsenic AWQC since.

- Arsenic concentrations in Site-related waters at the Tailings Piles have been detected up to 1,250 mg/L total arsenic and 5 mg/L dissolved arsenic. However, these waters are routed into the sedimentation basin and land application systems.

- Arsenic and metal loading in Montezuma Creek increase during periods of high flow from early April to June, and are lowest during periods of low flow, from September through February. Total and dissolved arsenic loading in Montezuma Creek tended to be greatest at MC-4, the furthest downstream station.

- Surface water data indicate that the total/dissolved arsenic ratio in surface water in Montezuma Creek increased during 1999 high flow associated with spring runoff. That is, during baseflow conditions, most of the arsenic present is in the dissolved form but during periods of high flow, more of the arsenic that is present is in the particulate phase. This indicates that particulates were mobilized during high flow, suggesting that some erosion occurred from adjacent unvegetated areas, possibly as a result of disturbance during 1998 removal actions in the creek.

- During low flow conditions, Montezuma Creek contributes only 6 to 8 percent of the total arsenic load in the MFBR at station MFBR-2. The majority of the total arsenic load in the MFBR (79 to 88 percent) originates from sources upstream of MFBR-1 in the Sawtooth Wilderness Area.

- Montezuma Creek contributes a greater percentage of dissolved arsenic to the MFBR than total arsenic. As shown on Table 5-26, approximately 2.5 pounds of dissolved arsenic load were added per day to the MFBR between MFBR-1 and MFBR-2. However, Montezuma Creek (as measured at MC-4) contributed only about 40 percent of that amount which indicates that other sources in the MFBR between MFBR-1 and MFBR-2 are contributing 60 percent of the dissolved arsenic load.

- A total of six surface water samples were collected and analyzed for arsenic speciation. Surface water samples exposed to oxidizing conditions, including samples collected from Montezuma Creek, the batch test and tailings-related surface waters, contained primarily pentavalent arsenic (As^{+5}), arsenate. Trivalent arsenic (As^{+3}), arsenite, was more prevalent in samples associated with the spring at the base of the upper tailings.

5.3.2 Groundwater

The Upper and Lower Tailings Piles were constructed on colluvial material that overlies bedrock. These glacial and slope wash deposits consist of silt, sand, and some clay with cobbles and boulders or blocks. The water table in the colluvial aquifer is generally about 10 feet below the ground surface. The near surface groundwater gradient in the shallow aquifer is generally toward the northwest with a magnitude of approximately 0.16 foot per foot. The elevations of water in seeps at the bases of the upper and lower tailings are consistent with the groundwater gradient in the shallow aquifer.

Clusters of monitoring wells with depths varying from 14 to 151 feet below grade, were installed to assess hydraulic head and chemical variability in the deeper, bedrock aquifer associated with the Montezuma Fault. Based on the results of geophysical investigations, exploration sampling, and hydraulic conductivity tests, flow in the bedrock aquifer appears to be greatest in fractures and fault zones, one of which lies directly under the Tailings Piles. The hydraulic gradient in the deeper, bedrock aquifer was similar to the hydraulic gradient in the colluvial aquifer. The gradient in the deeper, bedrock aquifer is generally toward the northwest, with a magnitude of approximately 0.13 foot per foot.

Figures 4-10a through 4-10i are diagrammatic sections showing monitoring well depth, static water elevation, and lithologic horizons at selected well clusters. At monitoring well clusters 605, 606, and 607, located on or adjacent to the upper tailings, an upward vertical hydraulic gradient between the bedrock and colluvium was observed. A downward hydraulic gradient was observed between the tailings and the colluvium. At monitoring well cluster 612, located at the toe of the lower tailings, the vertical hydraulic gradient between the bedrock and colluvium was negligible.

At monitoring well cluster 611, located near the bottom of the lower tailings breach, a slight downward hydraulic gradient between the colluvium and bedrock was observed.

Groundwater underlying the Depositional Area is similar and is composed of two aquifers: a near-surface alluvial or glacial aquifer and a deeper, bedrock aquifer. The water table in the alluvial aquifer is located less than 10 feet below the ground surface. Groundwater flow is toward the northwest, with a hydraulic gradient of approximately 0.04 foot per foot. The water table in the deeper, bedrock aquifer is over 35 feet below ground surface. Flow in the bedrock aquifer is generally limited to the fractures and fault zones.

5.3.2.1 Groundwater Sampling

Ten piezometers were installed in 1997, 22 monitoring wells were installed in 1998, and in 1999, 44 additional monitoring wells were installed at 15 cluster locations. Two wells (AG-1 and AG-3; Appendix G) were installed on Alva Greene's property by Atlanta Gold in 1986 as groundwater supply exploration wells. The locations of Site water wells and a groundwater elevation contour map are shown on Figure 4-11 (Appendix A). Well clusters installed in 1999 are shown on Figure 5-27. The wells that are that are located on the project Site are also listed on Table 3-3 (Appendix E). Table 3-4 (Appendix E) lists static water levels and perforated intervals of the monitoring wells.

Groundwater sampling was conducted at selected monitoring wells in July, October, and December 1998, and in March 1999. A complete groundwater sampling event was conducted in September 1999 at a total of 50 monitoring wells/lysimeters at the Site. Results of these sampling events are discussed in the following sections.

5.3.2.2 Reference Sites for Groundwater

Monitoring wells located upgradient of the tailings pile area (MW-9A, MW-10, and MW-11; Figure 3-10, Appendix A) and at clusters 601, 602, and 604 are the reference sites for comparing onsite groundwater with that not impacted by the tailings. These wells are completed in both the alluvial aquifer and in the deeper bedrock aquifer, and represent groundwater located upgradient of

the Site that has not been impacted by Site-related factors (i.e. the Tailings Piles and the Depositional Area).

5.3.2.3 Major Ion Fingerprint of Groundwater

Surface and groundwaters can be fingerprinted by their major ion composition. Major ions typically include a grouping of cations (sodium and potassium, calcium, magnesium) and a grouping of anions (bicarbonate and carbonate, sulfate, chloride). These cations and anions comprise the principal inorganic constituents that are dissolved in natural water systems. Most of these major ions are conservative in their geochemistry; that is, they persist in solution and are less affected by attenuation mechanisms than are trace metals, for example. As such, the major ions can impart a diagnostic geochemical fingerprint to water that permits distinguishing one water type from another. Major ion concentrations are plotted in trilinear diagrams (also known as Piper diagrams) and Stiff diagrams, which have widespread utility in water-quality investigations. Piper diagrams are designed so that different water "types" plot in different locations on a trilinear diagram, in a cation triangle and in an anion triangle. Typically, mixtures of two water types plot along a line connecting the two end points of the water types. Stiff diagrams fingerprint water by depicting water chemistry as a unique shape that is illustrative of the relative concentrations of the major ions. This fingerprint or shape of the Stiff diagram is diagnostic of water type.

During 1999, groundwater monitoring wells upgradient and downgradient of the Tailings Piles, and in the area of the piles were sampled and analyzed for major ions. The results of this effort are reported in Table 5-5 (Appendix E). The major ion fingerprint of groundwater from each monitoring well was plotted on Piper and Stiff diagrams which are included as Appendix K to this report.

Piper and Stiff diagrams illustrating the major ion fingerprints of groundwater from upgradient monitoring wells (series 601, 602 and 604) are presented as Figures 5-24 (Appendix A) and 5-25 (Appendix A). The Piper diagram in Figure 5-24 (Appendix A) clearly shows clustering of groundwater in two plotting locations; one location defining groundwater that is calcium-bicarbonate in composition, another location defining groundwater that is sodium-bicarbonate in composition, with several monitoring wells indicating groundwater that is a mixture of both water

types. The Stiff diagrams in Figure 5-25 (Appendix A) clearly show fingerprint differences in the water types.

Groundwater from monitoring wells 601C and 601F, 602A and 602C, and 604F were distinctly calcium-bicarbonate in composition; groundwater from monitoring wells 604A, 604B, 604D, and 604E, and 601A and 601B were distinctly sodium-bicarbonate in composition. The sodium-bicarbonate groundwater was associated with deep monitoring wells, screened in bedrock within the Montezuma fault zone. Most of the calcium-bicarbonate groundwater samples were associated with shallow monitoring wells. Water from deep monitoring well 602A was calcium-bicarbonate in composition, but 602A exhibited artesian conditions with groundwater flowing to the surface. Deep monitoring wells at locations 604C and 604F indicated calcium-bicarbonate type water also, but the major ion chemistry may be influenced by their proximity to Montezuma Creek.

The two types of water are present in the footprint of the Upper Tailings Pile, at monitoring well locations 606 and 607. Deep groundwater at this location is sodium-bicarbonate in composition; shallow groundwater is calcium-bicarbonate in composition. Immediately downgradient of the Lower Tailings Pile, at monitoring well location 612, the groundwater is distinctly calcium-bicarbonate in composition, to a depth of 67 feet below ground surface. At downgradient monitoring well location 613, the two types of water reappear; groundwater near the surface has a calcium-bicarbonate fingerprint, whereas, slightly deeper groundwater has a sodium-bicarbonate fingerprint. In the Depositional Area, groundwater has an intermediate composition reflecting a mixture of major ion chemistries. Piper and Stiff diagrams of groundwater from all the monitoring well locations are included in Appendix K.

Sodium-containing chemicals may have been used in the original milling process. However, there is no evidence for any residual effects on the chemistry of the groundwater from such chemicals. Shallow groundwater in the footprint of the Tailings Piles is calcium-bicarbonate in composition.

5.3.2.4 Arsenic Concentrations in Groundwater

In 1998, groundwater samples were collected from 23 groundwater wells at the Site. Laboratory analyses of the groundwater are presented in Table 5-6 (Appendix E). Field parameters,

measured during the sampling of the wells, are presented in Table 5-7 (Appendix E). Ion concentrations in groundwater are presented in Table 5-5 (Appendix E). Figure 5-26 (Appendix A) presents the minimum and maximum detected dissolved arsenic concentrations in all groundwater wells sampled for this project during 1998. Dissolved arsenic concentrations in groundwater samples ranged from less than detection (<0.001 mg/L) to 0.454 mg/L[3]. During 1998, three monitoring wells had dissolved arsenic concentrations that exceeded the current drinking water MCL of 0.05 mg/L[4]:

- AG-1 at 0.099 mg/L;
- MW-8 at 0.073 mg/L; and
- B-10 at 0.454 mg/L.

In 1999, field work significantly increased the number of monitoring wells upgradient and downgradient of the Tailings Piles, within the tailings area, and in the Depositional Area. Another 41 monitoring wells (the 600 series wells) were installed and 39 were sampled (wells 616A and 607C were dry). Laboratory analyses of the groundwater from these wells are presented in Table 5-8 (Appendix E); field parameters measured during sampling of these wells are presented in Table 5-7 (Appendix E). Dissolved arsenic concentrations in groundwater ranged from less than detection (<0.002 mg/L) to 88.2 mg/L. Twelve monitoring wells reported dissolved arsenic concentrations that exceeded the current drinking water MCL of 0.05 mg/L:

- 604A at 0.220 mg/L;
- 604E at 0.065 mg/L;
- 606C at 2.29 mg/L;
- 606D at 1.56 mg/L;
- 607A at 0.140 mg/L;
- 608A at 0.136 mg/L;
- 610A at 50.1 mg/L;
- 612A at 0.459 mg/L;
- 612B at 0.323 mg/L;
- 612C at 0.193 mg/L; and

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[3] The previous draft of this Site Characterization Report included relatively high arsenic concentrations from well B-22. However, the construction of this well was determined to be suspect, the data were rejected, and the well was abandoned.

[4] The EPA and other federal agencies are considering lowering the MCL for arsenic in the future.

- 607D at 88.2 mg/L;
- 613B at 0.089 mg/L.

Of the 12 groundwater wells listed above, two (604A and 604E) are located upgradient of the Tailings Piles. The other groundwater wells are located either in the footprint of the Tailings Piles (606C, 606D, 607A, 607D, 608A and 610A) or immediately downgradient of the tailings (612A, 612B, 612C and 613B). The highest arsenic concentrations were reported in shallow monitoring well 610A (50.1 mg/L), completed within tailings of the lower pile, and in shallow monitoring well 607D (88.2 mg/L), completed within tailings of the upper pile. Maximum arsenic concentrations detected in the 600-series wells are shown on Figure 5-27. Note that lysimeters also are shown on this figure; these are discussed below following the Piper and Stiff diagram discussions.

Plotting groundwater chemistry on trilinear diagrams indicates that elevated arsenic concentrations are present in both water types. Groundwater wells with arsenic concentrations greater than 0.1 mg/L are plotted on the Piper and Stiff diagrams of Figure 5-28 (Appendix A) and Figure 5-29 (Appendix A). As would be expected, elevated arsenic concentrations were detected in calcium-bicarbonate waters typical of shallow groundwater in the immediate area of the tailings (locations 606, 610, and 612). However, elevated arsenic concentrations were also found in sodium-bicarbonate waters that are typical of deep bedrock groundwater associated with Montezuma fault zone. For example, groundwater in monitoring well 604A has the sodium-bicarbonate fingerprint of deep fault zone groundwater, and was also elevated in dissolved arsenic. Monitoring well 604A is upgradient of the Tailings Piles. Monitoring wells 607A and 608A are located in the footprint of the upper tailings but are screened in deep bedrock. Clearly, major ion chemistry confirms the presence of two groundwater sources of arsenic, one associated with shallow groundwater that has a calcium-bicarbonate fingerprint, and the other, a deep groundwater source that has a sodium-bicarbonate fingerprint probably associated with the Montezuma fault zone.

Lysimeter sampling of pore water in the unsaturated portion of the tailings has reported high levels of dissolved arsenic. Pore water recovered by pressure-vacuum lysimeters emplaced in reduced tailings material (606E Lysimeter) contained 65.9 mg/L arsenic; pore water recovered from oxidized tailings material (606F Lysimeter) contained 0.226 mg/L arsenic. As is evident from the

Piper and Stiff diagrams presented in Figures 5-30 and 5-31 (Appendix A), tailings pore water has a distinct sulfate component in its fingerprint. This would be expected, since the tailings are reported to contain arsenopyrite. Oxidation of arsenopyrite would release sulfate.

It is important to note that pore water in the unsaturated tailings is really interstitial moisture. Interstitial moisture is not groundwater. Dissolved solids (such as the arsenic) present in interstitial moisture move through the slow process of diffusion between pore spaces. Due to surface tension and other physical forces, pore water is not free to move as groundwater.

5.3.2.5 Arsenic Speciation in Groundwater

Groundwater samples were collected at numerous locations for arsenic speciation analyses on September 14 and October 6, 1999. The laboratory results are reported in Table 5-8 (Appendix E). At location 601, which is upgradient of the tailing site, only traces of arsenic (up to 0.02 mg/L) were detected in the groundwater from wells 601A, 601B, 601C and 601F. Iron concentrations were also very low (to 0.36 mg/L). Speciation results indicated most all of the arsenic in the groundwater samples was reduced, +3 oxidation state (arsenite). However, groundwater from well 601D was different. Arsenic concentrations approached 0.05 mg/L and speciation results indicated that the +5 oxidation state (arsenate) predominated. In addition, the iron concentrations in 601D were very high (76.3 mg/L). A second series of wells (604) were drilled upgradient from the tailings area also. Speciation of water from well 604A where arsenic concentrations from 0.106 to 0.220 mg/L were reported, indicated that the arsenic was essentially all oxidized. Iron concentrations in well 604A were relatively low (0.635 mg/L). At location 612, arsenic ranged in maximum concentrations between 0.538 mg/L in well 612A, and to a maximum of about 0.34 mg/L in wells 612B and 612C. For wells 612 B and C, essentially all of the arsenic was found to be in the reduced (+3) state (arsenite). Iron concentrations ranged between 20.3 and 3.73 mg/L. At well 612A, one analysis indicated mostly reduced arsenic but another indicated the arsenic was predominately in the oxidized +5 state. Subsequent data validation indicated that sample W217924 (Table 5-8, Appendix E) was not acidified in the field. Failure to follow sampling procedure falsely reported that the oxidized +5 state (arsenate) predominated in the sample. Well 612A is in deep bedrock whereas wells 612B is a shallower bedrock well and 612C is a colluvial well. At downgradient locations 613A, only traces of arsenic were detected (to 0.01 mg/L) in the bedrock groundwater along with 6.82 mg/L iron.

Slightly higher concentrations were reported in near surface colluvial groundwater from well 613B along with 3.24 mg/L iron. Virtually all of the arsenic appeared to be in the reduced, arsenite form. At location 617A, in the Depositional Area, only traces of arsenic were detected (less than 0.01 mg/L) and this arsenic was also in the reduced, arsenite form.

5.3.2.6 Colloidal Transport of Arsenic in Groundwater

Speculation that very fine colloidal arsenic could be passing through a 0.45 micron filter used to routinely define total from dissolved arsenic during routine sampling activities prompted a series of filtration tests. Non-filtered and non-preserved groundwater samples were collected from monitoring wells 604A, 612A, 612B, and 612C and delivered promptly to the laboratory for testing. In the laboratory, a "total" sample was collected from each bulk groundwater sample, acidified and analyzed for total arsenic and iron content. The bulk groundwaters were then filtered in sequence through 0.45 micron, 0.1 micron, and 0.02 micron filters. Filtrates from each step were collected, acidified and analyzed for dissolved arsenic and iron. The results of the analyses are presented in Table 5-9 (Appendix E).

Results of these filtration tests proved interesting. Well 604A results indicated that about 70 percent of the total arsenic passed through the 0.45, 0.1 and 0.02 micron filters. This is supported by the fact that the speciation indicated the arsenic was in the +5 oxidation state which would tend to precipitate arsenic with iron. For well 604A essentially all of the "total" iron (15.6 mg/l) was also removed by filtering the bulk groundwater through the 0.45 micron filter which further supports that the colloids are present.

Similar analytical results were obtained on bulk groundwater from monitoring wells 612A, 612B, and 612C. Essentially all of the "total" arsenic from each bulk groundwater was removed from solution by filtering through 0.45 micron filter but the speciation data suggests that the arsenic is in the +3 reduced state and would be dissolved. Such data is contradictory since dissolved arsenic should pass through all of the filters used. It is possible that the kinetics of arsenic oxidation are so fast that the mere handling of groundwater solutions in the laboratory facilitated the oxidation of arsenic +3 to the arsenic +5 state. Likewise, filtration tests for iron had similar conflicting results

as well. In summary, the microfiltration test results were confusing and should not play a major role in the subsequent interpretation of data.

5.3.2.7 Other Chemical Concentrations in Groundwater

Groundwater samples collected during December 1998 were analyzed for other metals including antimony (Sb), cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), and zinc (Zn) (Table 5-6, Appendix E). Nine of these 26 samples contained dissolved antimony at concentrations greater than the detection limit of 0.0005 mg/L, but the maximum concentration detected was only 0.002 mg/L, less than the drinking water MCL of 0.006 mg/L. Eighteen of the 26 samples contained cadmium at concentrations greater than the detection limit of 0.0001 mg/L, but the maximum concentration detected, 0.0016 mg/L was less than the drinking water MCL of 0.005 mg/L. Eighteen samples contained detectable iron, with the maximum dissolved iron concentration of 2.86 in B-10. There is a direct correlation between elevated iron concentrations and elevated arsenic concentrations, reflecting the solubility of arsenic and iron in the reduced state. Four of the December 1998 samples contained lead above the detection limit of 0.0001 mg/L, but the maximum observed dissolved concentration of 0.003 mg/L is below the drinking water Action Level of 0.015 mg/L. No sample from the December 1998 groundwater sampling event contained mercury above the detection limit of 0.0002 mg/L. In summary, it is felt that groundwater contaminants other than iron and arsenic warrant no major concerns.

5.3.2.8 2000 Groundwater Monitoring Results

Samples were collected from six monitoring wells and two domestic wells in early 2000 to support an evaluation of the future residential land use scenario for the Depositional Area. Two domestic wells located in a cluster of cabins several hundred feet south of the Depositional Area were sampled at the request of the EPA. For the domestic wells, two samples were collected at the tap for each well. The first sample was collected after a relatively short purge of the system piping and the second sample was collected after a relatively long purge to remove sediment from the well. Sampling of monitoring wells was implemented after a significant purge period of at least three well volumes. Groundwater samples were collected in accordance with applicable requirements of the Final Work Plan for Supplemental Investigations (URS Greiner, 1999).

Samples were analyzed for total and dissolved metals and major ion chemistry. The results are presented in Table 5-8a. The fingerprints of the major ion chemistry of the groundwater from monitoring wells MW-3 through MW-7, and wells 601D and 601F, are essentially the same as reported for samples collected in 1999. Wells MW-3, MW-5, and MW-6 yielded samples indicative of groundwater that is primarily calcium-bicarbonate in composition, typical of shallow groundwater in the area of the tailings piles. Well MW-7, which is located further from the tailings piles, shows groundwater that is sodium-bicarbonate in composition, suggesting upwelling of deeper groundwater at this location. The major ion fingerprint of groundwater from upgradient shallow monitoring well 601F is calcium-bicarbonate in composition, and that of the deeper well 601D is sodium-bicarbonate in composition.

The major ion fingerprint of groundwater from the Aastum domestic well is calcium-bicarbonate in composition, suggesting that the well is taps shallow groundwater, even though the well log states that the well is screened between 166 and 196 feet below ground surface. The sample from the Drake domestic well exhibited sodium-bicarbonate compostion, consistent with it tapping deep groundwater (total depth of well: 262 feet).

Samples from the domestic wells did not yield arsenic concentrations that would be of concern. The second sample from the Drake well, collected after purging for an extended period, yielded arsenic at 0.005 mg/L, relative to the first sample which was reported by the analytical laboratory to have a concentration less than the laboratory detection limit (<0.002 mg/L). The higher concentration in the second sample is believed to be a result of stressing the well. That both domestic wells were stressed is indicated by increases in the total iron levels at the time of the second sampling. Total iron in the Aastum well increased from 0.49 to 3.56 mg/L from the first to the second sample while iron in the Drake's well increased from 0.0271 to 5.59 mg/L. The traces of total arsenic reported in the second sample from the Drake well could be associated with naturally occurring arsenic adsorbed on colloidal iron that was swept into the wells when the aquifer was pumped. It is believed that as the Drake well was pumped for an extended period, it may have induced aquifer material to be drawn into the well, resulting in increases in total iron.

Similar results for lead in samples from the Drake well were observed. Total lead in the first sample, collected after a relatively short purge of the system piping, was less than the detection limit

of 0.002 mg/L. The second sample, collected after purging for an extended period, yielded a sample with total lead of 0.0219 mg/L. The well was resampled with a lower rate of purging to further evaluate total lead concentrations in the well. The resulting sample was reported by the analytical laboratory to have a lead concentration less than the laboratory detection limit (<0.002 mg/L), suggesting that the high concentration from the first sample was a result of stressing the well.

5.3.3 Springs, Seeps, Temporary Ponds, and Pore Waters

Springs are located throughout the project Site. They are especially ubiquitous in the wetlands areas identified on Figure 3-9 (Appendix A). Locations of the springs or seeps in the vicinity of the Tailings Piles that were sampled for chemical analyses are presented on Figure 5-3 (Appendix A).

Additional springs or seeps in the vicinity of the Tailings Piles are presented on the Site Geology Map (Figure 4-1, Appendix A). It is believed that such springs and seeps likely mix with tailings infiltration water, tailings pore water and possibly upwelling waters from upgradient of the site which presently express themselves as seeps from numerous locations around the tailings piles. U.S. EPA may require treatment of these springs and seeps in connection with the Tailings Piles removal action, pending the data evaluations presented in this report. In 1998, the cumulative flow from these seeps remained relatively stable, approximately 30 gpm. Through fall, 1999, the cumulative discharge, as measured at the outlet to Sedimentation Basin #1, where most all of the water from seeps in the vicinity of the Tailings Piles is directed, seems to be decreasing, to a rate of 10 gpm. Water from these springs currently flows into the sedimentation basins and evapotranspires and infiltrates at land application sites (Figure 3-8, Appendix A).

Several additional warm-water springs that influence the project Site are located east-northeast of the Depositional Area. The flow from these geothermal springs is approximately 200 gpm, and appears seasonally stable. This water forms the base flow for Unnamed Creek. As previously noted, Unnamed Creek flows across the Greene Tailings (located outside of the project Site) and then enters the Depositional Area and joins Montezuma Creek.

In the wetlands portion of the Depositional Area there are many small springs and seeps that contribute to the surface hydrology in the wetlands and add to the flow in Montezuma Creek. The

locations of the springs in the wetlands have not been mapped and, therefore, are not shown on Figure 5-3 (Appendix A). However, these springs and seeps are evident by the iron "yellowboy" precipitates that are visible on the ground and in the stream. The iron precipitates when groundwater emerges and is exposed to oxidizing conditions.

5.3.3.1 Spring Water Sampling

IDEQ and Terracon have collected spring water samples since May 1997. Locations of surface water sampling sites, including springs, are shown on Figures 5-3 and 5-6 (Appendix A). A summary of laboratory analytical results for spring samples is presented in Table 5-10 (Appendix E). A summary of field parameters (temperature, pH, dissolved oxygen, specific conductance, ORP, and water flow or discharge) for spring samples collected by Terracon is presented in Tables 5-2a and 5-2b (Appendix E).

5.3.3.2 Major Ion Fingerprint of Spring and Seep Water

In October 1999, spring water was collected from seeps at the toes of the Upper and Lower Tailings Piles. These samples were analyzed for major ions. Figures 5-32 and 5-33 (Appendix A) fingerprint the major ion chemistry of the spring water emanating from the two seeps.

The major ion fingerprint of the upper seep has a distinct sulfate component. The major ion fingerprint of the upper seep is essentially the same as tailings pore water recovered by pressure-vacuum lysimeters emplaced in unsaturated tailings at location 606. For purposes of comparison, Figure 5-30 (Appendix A) and Figure 5-31 (Appendix A) illustrate Piper and Stiff diagrams of pore water recovered from reduced tailings (606E lysimeter) and from oxidized tailings (606F lysimeter). As expected, tailings pore water has a sulfate component in its fingerprint. The tailings are reported to contain arsenopyrite, which upon oxidation would release sulfate. Based on similarities between these major ion fingerprints, the water emanating from the upper seep is likely to be drainage of pore-water moisture from the tailings.

Water from the lower seep has primarily a calcium-bicarbonate composition. Its fingerprint is similar to the shallow groundwater below the tailings area, for example, at location 612C. These similarities in major ion composition suggest that the water emanating from the lower seep as

defined by wells 612A and 612B, where there are mixtures of calcium and sodium bicarbonate waters, the speciation of arsenic is predominately reduced, are mixtures of seeps, tailings infiltration, pore waters and upwelling groundwater.

5.3.3.3 Arsenic Concentrations in Springs and Seeps

Dissolved arsenic concentrations in springs located in Montezuma Creek valley range from 1.02 mg/L collected on September 15, 1998 at the base of the Upper Tailings Pile to 0.015 mg/L collected May 28, 1997 from the spring above the Upper Tailings Pile. Flow from the spring above the Upper Tailings Pile fluctuates seasonally, and metals concentrations appear to increase with decreased flow. Sampling of the spring water in October 1999 indicated that the upper seep carried about 1.1 mg/L arsenic and about 10 mg/L iron; the lower seep carried about 2.6 mg/L arsenic and about 10 mg/L iron.

The warm-water springs above the Greene tailings that are the source for Unnamed Creek were sampled by Terracon on September 15, 1998. The dissolved arsenic concentration measured in water sampled from the warm-water spring was 0.004 mg/L.

5.3.3.4 Temporary Pond Water Quality Sampling and Analysis

In July-August 1999, MFG staff sampled four temporary ponds to determine water qualities in surface waters that are not directly connected to either Montezuma or Unnamed creeks (see Figure 3-13). The following provides brief descriptions of the sites, ordered relative to apparent gradient among these sites (i.e., up gradient to down gradient through the Site):

Site Pond1 - This site is outside and up-gradient of the Depositional Area. It was near the origin of the diversion that rerouted Unnamed Creek around the Depositional Area where water surfaced from the old Greene tailings. Upgradient from this point, Unnamed Creek flows spread across the old Greene tailings, flowing through dense stands of wetland vegetation to discharge near the origin of the Unnamed Creek diversion.

Site Pond2 - This site is inside of the Depositional Area. It is approximately mid way between the Sites Pond1 and Pond3, and near soil sample Site 10, within a section of the old

Unnamed Creek channel. The shallow water depth at this site provided only marginally adequate water for sample collection.

Site Pond3 - This site is inside of the Depositional Area. After the depositional event, both the Historic Powerhouse Flume and Unnamed Creek were diverted around the Depositional Area. Part of the original flow path of Historic Powerhouse Flume was still apparent, which terminated approximately 150 to 200 yards into the Depositional Area with an earthen barrier. This site was located in a pond of water collected behind this barrier. This water appeared to have been ponded for some time, because it contained an abundant growth of filamentous algal and was colonized by abundant aquatic insects(hemipteran) and amphibians.

Site Pond4 - This site is outside and up-gradient of the Depositional Area and up-gradient of surface-water sampling Site MC-3P and downgradient of Site MC-3T on Montezuma Creek. This is seepage area adjacent to Montezuma Creek, located where water had ponded behind several sedimentation control blocks (hay bails). Based on information from the USFS on-site staff, the site apparently is within the old flow path of the Historic Powerhouse Flume, up-gradient and west of its intersection with Montezuma Creek.

Results from these surface water analyses are presented in Table 5-11. Concentrations of silver, cadmium, copper, mercury lead, antimony, selenium, and zinc in all these samples were less than detection or slightly above detection limits. Aluminum, arsenic, and iron occurred at higher concentrations. Total aluminum concentrations at the Pondl and Pond2 sites were elevated relative to chronic AWQC (0.087 mg/L); the concentration was slightly greater at the downgradient site. This trend did not continue, however to the most downgradient site, Pond3. Total aluminum at Pond4 was only slightly greater than the detection level and did not appear to be influenced by the total aluminum measured in Montezuma Creek. Total aluminum concentrations were higher outside the Depositional Area at MC-3T (0.0687 mg/L) than inside the Depositional Area at site MC-3P (0.0391 mg/L).

Arsenic concentrations in both the total and dissolved fractions at all pond water sites sampled ranged from a low of 0.0425 mg/L at the Unnamed Creek diversion site to a high of 1.19 mg/L at the Pond3 site for total arsenic concentrations. In waters from the Green tailings area,

dissolved arsenic represented the majority of the total measured arsenic. Downgradient at site Pond2, however, there was a substantial shift in arsenic partitioning as well as arsenic concentrations. Dissolved arsenic approximately doubled at Pond2 from those observed at Pond 1, while total As increased by an order of magnitude, from 0.0425 mg/L at Unnamed Creek diversion to 0.489 mg/L at Pond2. At this site, dissolved arsenic represents a minor fraction of the total arsenic measured at the site (about 13 percent).

At the Pond3 site high arsenic concentrations were measured, but unlike the previous site, almost all of the total arsenic (1.19 mg/L) measured occurred as dissolved arsenic (1.08 mg/L). Arsenic in this temporary pond, while highly elevated did not appear to be hydrologically connected to Unnamed Creek. That is, arsenic concentrations measured on the same dates, as well as those measured prior to and after the July sampling event, were not found at concentrations equal to that found for this temporary pond. The source of this elevated arsenic is unknown.

Arsenic concentrations measured at Site Pond4 were less than those measured at the Pond3 site. At Pond4, 59 percent of the arsenic was dissolved. Total arsenic in Montezuma Creek down gradient of Pond4 at MC-3P was only slightly elevated (0.046 mg/L) above the concentration of total arsenic observed from the upgradient site at MC-3T (0.038 mg/L). There appears to be little connectivity or effect on arsenic concentrations in Montezuma Creek relative to the Pond4 site. The high arsenic concentrations measured at Site Pond3 and at Site Pond4 indicates there may be some hydrologic connectivity between these two sites. If this connectivity does exist, it suggests that Arsenic concentrations decrease across the Depositional Area and the percentage of arsenic in the dissolved fraction also decreases in the measured total arsenic.

Total iron appeared elevated only at Sites Pond2 and Pond3. At Site Pond2 total iron was 3.99 mg/L and a high degree of iron staining occurred at this site. No iron staining as observed at Site Pond3 with a total iron concentration of 1.58 mg/L. As with the arsenic data, there did not appear to be relationship of iron concentrations at Pond4 and that found for Montezuma Creek. Iron concentrations at the neighboring Montezuma Creek sites were considerable less. Also, iron data for the Pond4 site do not suggest hydrologic connectivity with the Pond3 site.

5.3.3.5 Pore Water Quality Sampling and Analysis

Pore water samples were collected from four sites (see Figure 3-13) and the results from their chemical analyses are presented in Table 5-11. Sites Porel, Pore2, and Pore3 were in the Depositional Area, while Site Pore4 was in the reference area. This reference site had the greatest levels of metals across the four sites (Table 5-11). Soils at this site were fine grained and dark colored, indicating a large amount of organic matter; no tailings materials were observed. No clear explanation exists on why elevated metal concentrations occurred here. It may be due to the site's proximity to the Quartz Gulch drainage. Historic mining that occurred in upper part of this drainage could have released mining wastes downstream, with some becoming deposited in the wetlands under this site, which could have affected present day pore water quality at this site, or it could be a natural concentration of metals. Importantly the site contained no obvious tailing of either historic or recent origin. Because it was across Montezuma Creek and up-gradient from the Depositional Area, it especially had no direct relation to the tailings deposition event.

Site Porel was collected adjacent to the location of the temporary pond water sampling site Pond2. This site had concentrations of aluminum, arsenic, and iron, in concentrations similar to those found the pond water at Site Pore2. Site Pore2, also located in the Depositional Area, had similarly elevated levels of aluminum, arsenic, iron, and zinc (Table 5-11). This site in the removal zone showed little to no evidence of tailings being present, but older tailings were evident below the surficial material. Unlike other sites where the tailings were the color of beach sand and likely oxidized, these tailings were metal grey in color and were likely reduced. Reduced conditions would explain the high concentrations of these metals present in the pore water.

Site Pore3, approximately 100 yards west of Site Pore2 had elevated levels of aluminum, arsenic, iron, and zinc (Table 5-11). Oxidized tailings were observed in small amounts near this site. There did not appear to be tailings below the surface. Despite the relatively small distance separating these two sites, concentrations of metals, particularly arsenic and iron, were considerably less then those observed at Site Pore2.

5.3.3.6 Summary of Observations: Groundwater, Pore Water, and Seeps

As has been previously described, monitoring wells were installed upgradient of the tailings piles, in the footprint of the tailings piles, and downgradient of the tailings piles during extensive field work in 1999 to characterize spatial and vertical variations in groundwater chemistry and elevation. Lysimeters were used to collect pore water from the tailings; and groundwater seeps at the base of the tailings were measured and sampled. Based on these efforts, and the detailed information presented in the preceding sections, the following observations are summarized.

1. There is an upgradient arsenic signature in deeper groundwater that is not associated with the Talache Tailing Site (well 604A).

    - multiple well locations (well 604 A, B, C, D, E and F) suggest that the flowpath along the shear (mineralized) zone is very narrow in this location which is expected to be the case due to the physical hydraulic pinch point in this area.

    - arsenic concentrations range from 150-220 ug/l. Associated iron and sulfate concentrations indicate that the arsenic source is from the dissolution of arsenopyrite.

    - arsenic concentrations are essentially oxidized (As+5) which is supported by the Eh and DO data

    - pH is in the range of 7.8 and the water if of the sodium bicarbonate type.

    - Waters from the colluvium are of the calcium bicarbonate type

2. There are strong indications based upon earlier geophysical work and additional well data within the boundary of the tailings area that the shear zone extends underneath the tailings pond.

    - deeper bedrock waters are again of the sodium bicarbonate type.

    - alluvial waters are again of the calcium bicarbonate type.

3. Hydrogeologically, there are indications that the deeper groundwater is upwelling into the colluvium and tailings due to upward gradients. Nowhere are there any indications of significant downward gradients from the tailings pore waters into the colluvium.

4. Groundwaters from the tailings (porewater) are mixing with the upwelling deep bedrock groundwaters and moving downgradient. Some of these waters exit the tailings piles at the toe as seeps while a portion moves downgradient within the groundwater system.

   - seeps have higher concentrations of arsenic (up to 4.3 mg/L).
   - seeps contain both reduced (As+3) and oxidized (As+5) forms of arsenic.
   - the lower seep has significantly more sulfate (up to 291 mg/L).

5. Just downgradient from the toe of the lower tailings pile are wells 612A, 612B and 612C. Well 612A (deep bedrock) appears to be a mixture of calcium and sodium bicarbonate waters with arsenic concentrations elevated to 0.538 mg/L. Wells 612B (shallow bedrock) and 612C (colluvium) are also a mixture of calcium and sodium bicarbonate waters with arsenic concentrations elevated from 0.247 to 0.330 mg/L.

6. Just a few hundred feet further directly downgradient, well 613 A (bedrock) and 613 B (colluvium) had arsenic concentrations of 0.010 and 0.089 mg/L respectively. This indicates that the arsenic from the mixing of tailings pore water and upwelling bedrock groundwater is strongly attenuated in both the downgradient bedrock and colluvial groundwater systems.

7. Leach tests conducted earlier on the tailings indicate that the tailings do not release significant arsenic in solution in their existing environment.

8. Flow rates emanating from the tailings seeps have historically decreased since the tailings breach. This is to be expected given the additional opportunity for the pore waters to drain due to the preferential flow path caused by the breach. Flow rates in the fall of 1998 were measured at 30 gpm and in the fall of 1999 were even lower at 10 gpm.

9. It appears that the conceptual hydrogeologic and geochemical model developed in January 1999 has been validated.

5.3.4 Tailings, Soils, and Sediments

Prior to tailings excavation and removal operations in 1997 and 1998, tailings in the Depositional Area extended from FS268 to the MFBR and laterally from Montezuma Creek on the south and west to Unnamed Creek on the north and east. Figure 1-2 (Appendix A) depicts the area of tailings deposition. Mapping of the tailings Depositional Area was done by visual observation, with confirmatory samples analyzed for trace metals. Within the wetlands portion of the tailings Depositional Area, suspected historic deposits of tailings can be observed at depths of up to 3 to 4 feet below the ground surface. Additionally, multiple depositional layers of tailings, separated by soil and organic layers, can be observed near the Montezuma Creek and Unnamed Creek channels. It is likely that historical tailings are scattered throughout the valley, but have not been located because natural soil-building processes have capped these materials.

5.3.4.1 Soil, Tailings, and Aquatic Sediment Sampling

Since the 1997 release, U.S. EPA, IDEQ, Terracon, and MFG have sampled tailings, soil, and stream sediment to determine trace metal concentrations and concentration variability in impacted and background areas. Tailings samples have been collected from the upper and lower tailings impoundments, wetlands areas, uplands areas, and impacted roadways within the Depositional Area. Additional tailings samples were collected from historic tailings impoundments (e.g., the Greene tailings) and from historic tailings depositional layers within the Depositional Area created by the 1997 release. Soil samples have been collected from within the land application areas, from background areas not impacted by the 1997 release, and from areas following the excavation and removal of tailings. Additional soil samples have been collected for soil fertility assessment to support revegetation activities. Sediment samples have been collected from stream channels within the Depositional Area, from stream channels not impacted by the 1997 release and from stream channels following the excavation and removal of tailings.

During 1999, Pentec collected in-stream core samples of aquatic sediment from four sites along Montezuma Creek and two along Unnamed Creek, plus 15 core samples of in-stream and overbank sediments along the MFBR between Riverside and Queen's River Campgrounds. Also

in 1999, MFG collected soil samples from 82 sites to characterize COPCs in upland and wetland sites distributed across the deposition and neighboring reference areas. Additional samples to characterize COPC concentrations and agricultural fertility conditions were collected from 18 plots included in the seeding trial study. Additionally, Terracon collected three samples to characterize road base materials and two post-removal soil samples from Unnamed Creek.

As discussed earlier in this document, all aquatic sediments for 1999 were targeted to collect the likely worse case accumulations of tailings. That is, the samples were selectively collected from areas within or adjacent to the wetted stream channels that had the greatest areas of the finest sediments available in each sample reach. For most sites, several tens, hundreds, or thousands of meters of stream, depending on stream size, were searched to find each specific area sampled. Then, within each sediment deposit ultimately selected for sampling, the finest grained sediments present anywhere in the deposit were selectively sampled. Under the assumption that higher COPC concentrations would be associated with finer sediment fractions, the sediment incorporated into each sample container represent a likely maximum or worse case estimate of COPCs present at each station. Considering the heavy bias involved in selection of sampling locations, focusing only on those with likely worst case conditions, the results for each sampled site characterize likely only a small fractional percentage of the overall stream sediment conditions along that reach.

Aquatic sediments available for sampling in Montezuma Creek were typically in very thin (e.g., 2 to 5 mm) lenses located along quiescent stream margins in shallow water (1 to 5 cm). One sample (MC-3T rep. 1) was taken in about 0.3 m of water in a side eddy of a pool. In some cases, vegetative roots were present and incorporated into the sample (e.g., at MC-2 and MC-4). Sample UC-1 was taken in very fine silt and clay-sized sediment in the center (thalweg) of the excavated channel of Unnamed Creek just downstream of the historic Greene tailings. Sample UC-2 was taken along the margin of a relatively broad portion of the lower Unnamed Creek about 20 m upstream from Montezuma Creek.

In-stream aquatic sediment samples at MFBR-1, -2, -3, -4B, and -5 were taken along the south shoreline in areas of relatively shallow (2 to 6 cm), quiet water, either behind rocks or in small indentations in the shoreline. At MFBR-4 and -5, additional in-stream samples were taken by a SCUBA-equipped diver in deposits of relatively fine sediments mostly along the south shore of the Kirby Pool. Water depths ranged from 0.4 to 2 m. MFBR overbank samples (except at MFBR-7) were taken from 0.5 to 1 m above the water line existing at the time of sampling. The sample from

MFBR-7 was taken at the water's edge. Overbank deposits sampled consisted of light tan, medium to fine sands at all stations except MFBR-5, where the sample was a dark organic soil with lighter gray lenses, 0.5 to 1.5 cm thick. At MFBR-3 (overbank), MFBR-6 (overbank), and MFBR-8 (overbank) a layer of finer caked material was encountered and preferentially sampled to the degree practical; i.e., those finer materials composed a greater proportion of the sample than would have occurred in random coring of the overbank deposit in this stream reach.

The analytical data from the samples collected from 1997 to 1998 are presented in Tables 5-12 to 5-14 (Appendix E) and these sample locations are shown on Figures 5-34 through 5-37 (Appendix A). Related statistics for the COPCs identified for solid phase samples, including number of analyses, number of non-detects, and minimum and maximum concentrations, are presented in Table 5-15 (Appendix E). Analytical results of aquatic sediment sampling from 1999 are presented in Table 5-16[5], and Appendix D-1. Sampling locations are shown on Figures 3-13 and 3-14. Results and statistical summaries for the chemical analysis of soil samples collected by MFG during 1999 are presented in Tables 5-17 through 5-20 and the locations of these sampling sites are described in Section 3.6.3 (see also Figures 3-11 and 3-12). Additionally, sampling of tailings to determine the feasibility of reprocessing the tailings for resource extraction are presented in the Technical Memorandum on Design Criteria (Terracon 1998b).

5.3.4.2 Background Soil and Sediment Concentrations

Preliminary efforts to collect background samples were conducted in 1997 and 1998. Results from these sampling efforts do not sufficiently represent background conditions at the Site, necessitating the more comprehensive background sampling that was conducted in 1999. The 1997 and 1998 data were not used to calculate background concentrations.

Soil and sediment samples were collected during 1997 and 1998 from the vicinity of the Talache Mine Mill Tailings Site (Table 5-13, Appendix E). The 1998 samples are divided into four groups: samples collected from non-mineralized areas, samples collected from mineralized, but not mined, areas, samples collected from mined and mineralized areas, and samples collected from active streams channels. In the samples collected from non-mineralized areas, arsenic concentrations

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[5] Sediment sample results on Table 5-16 are presented in µg/g (micrograms per gram). These units are equivalent to units used to characterize other solid matrix results for soil and tailings, which are presented in mg/kg (milligrams per kilogram). Therefore, direct comparison of the units can be made.

range between 2.81 mg/kg and 21.9 mg/kg. IDEQ collected one sample from a mineralized, but not mined area. This sample was collected from the road to Powerplant Campground. The arsenic concentration in this sample was 197 mg/kg.

Two waste rock samples were collected from waste rock piles adjacent to the 900-level adit of the Talache Mine. One sample was collected from mineralized rock and exhibited an arsenic concentration of 879 mg/kg. The other sample was collected from non-mineralized (country) rock and exhibited an arsenic concentration of 21.6 mg/kg.

Background sediment samples were collected from sections of Montezuma Creek and Unnamed Creek, upgradient from the tailings Depositional Area. These sampling locations were not impacted by the 1997 release. In July 1999 samples, the background arsenic concentration measured below the Greene tailings and above the Depositional Area in Unnamed Creek was 70 mg/kg and in Montezuma Creek, upstream of the Depositional Area, the sediment arsenic concentrations were 279 and 138 mg/kg at sites MC-1 and MC-2, respectively (Table 5-16).

Additional background soil samples from upland and wetland reference sites were collected by MFG during 1999. Results from this effort are presented and summarized on the first and third pages of Table 5-17. These results show relatively low concentrations for total silver, cadmium, copper, mercury, antimony, and selenium. Mercury concentrations are occasionally slightly elevated in both reference habitat types, especially in the reference wetlands where about 40 percent of the sites had elevated concentrations. High concentrations of zinc and very high concentrations of aluminum and iron were found in the reference areas. Reference area concentrations averaged from about 16,000 to 20,000 mg/kg for total aluminum, from about 13,000 to 16,000 mg/kg for total iron, and from about 75 to 80 mg/kg for total zinc. Concentration averages were always greater across the wetland reference sites.

Background arsenic concentrations averaged about 25 to 30 mg/kg across the upland and wetland reference sites, with the greater average concentrations again tending to occur in the wetland area. Importantly, three of eight wetland reference sites (Sites 54, 56, and 60) originally selected for sampling as part of the planned stratified randomize design were found to contain historical tailings. Additionally, three alternative sites planned for use as contingency wetland reference sites also were found to hold historic tailings. All sites found to hold obvious historic tailings were moved, in accordance with U.S. EPA's direction, to sites lacking historical tailings. Two wetland

riparian reference sites that did not contain obvious deposits of tailings (Sites 53 and 55), were indicated in the chemical analysis to nevertheless likely contain tailings (see Table 5-17, page 3). These results suggest that reference wetland soils, i.e., those outside of the Depositional Area, likely contain average concentrations of arsenic that may or may not be greater than those indicated by the data presented and summarized in Table 5-17. Individual soil sampling locations such as sites 53 and 55 within the reference areas contain arsenic concentrations substantially higher than the average reference area arsenic concentration. The individual elevated concentrations in the samples from sites 53 and 55 cannot, at least on the basis of visual inspection, be attributed to the presence of historic tailings in the samples. In addition, the nature and extent of elevated arsenic and the source of the elevated arsenic in the reference area has not been determined.

The upper portions of Tables 5-19 and 5-20 show soil chemistry results from the nine upland reference plots included in the seeding trial study. These plots were located northeast of Site 26 in a small open meadow area near a forested area (see Figures 3-11 and 3-12). Total concentrations of arsenic averaged greater over these plots than the mean observed for other upland reference sampled in 1999, but well within the range of values observed. Total concentrations for silver, aluminum, cadmium, copper, iron, lead, mercury, antimony, selenium, and zinc were generally similar to the concentrations found in other upland reference plots sampled in 1999, based on 95 percent confidence intervals. Results of the agricultural fertility analyses for these upland plots prior to any soil treatments are presented in upper portion of Table 5-20.

5.3.4.3 Post-Tailings Removal Soil and Sediment Sampling

1998 Results and Discussion

Several soil and stream sediment samples have been collected from locations within the Depositional Area following the conclusion of tailings excavation and removal operations in 1998 and 1999. Table 5-14 (Appendix E) displays data collected to support revegetation activities. This table contains total arsenic concentrations and other parameters used to evaluate the fertility of the soil following tailings removal operations. Additional 1998 post-removal samples are included in Table 5-12 (Appendix E). In general, these data indicate that tailings excavation and removal operations were very successful in reducing total arsenic concentrations where the removal was completed to native substrate. Table 5-14 (Appendix E) indicates that arsenic concentrations following tailings removal were reduced to between 17.0 mg/kg and 24.7 mg/kg in zone 1A, and

between 103 mg/kg and 181 mg/kg in zone 1B. Tailings excavation and removal in these zones was completed to native substrate. These post-removal arsenic concentrations are significantly reduced relative to arsenic concentrations measured in tailings located in the Depositional Area. Arsenic concentrations in Depositional Area tailings prior to excavation and removal ranged between 108 mg/kg and 1,620 mg/kg (Table 5-12, Appendix E). Seventy five percent of the post-removal arsenic concentrations presented in Table 5-14 (Appendix E) were elevated relative to the average arsenic concentrations in the upland and wetland reference sites of 25 to 30 mg/kg. However, all of the post-removal arsenic concentrations presented in Table 5-14 (Appendix E) were significantly reduced relative to pre-removal concentrations presented in Table 5-13.

Post-removal samples collected in 1998 from within active stream channels (Table 5-12, Appendix E) indicate that the tailings excavation and removal operations in active stream channels were not as effective in reducing total arsenic concentrations as the removal operations in other areas of the site. Post-removal samples identified as "Post-Removal: Sed-1" and "Post-Removal: Sed-2" were collected from a reach of Montezuma Creek that received the most effort during tailings removal operations conducted during the 1998 field season. Tailings were removed from this area, primarily using shovels, during three operations in 1998. Despite this level of effort, the samples collected from this reach of the creek contained between 327 mg/kg and 754 mg/kg total arsenic. These concentrations, measured following tailings excavation and removal operations, are above the average background arsenic in the upland and wetland reference sites of 25 to 30 mg/kg. A post-removal sample identified as "Post-Removal: Soil-1" was collected from the bank of Montezuma Creek upstream from the two sediment samples discussed above. The material in this location was a mixture of cobbles, sand, and silt, and did not appear to be tailings. Because this material did not appear to be tailings, very little removal was attempted in this area. Additionally, tailings in this area, and in other areas adjacent to Montezuma Creek, extend to depths below the current grade of the creek. This makes excavation and removal operations difficult due to the inundation by water during removal. Further, removal of tailings in such saturated areas would severely disrupt existing wetland vegetation and could result in the release of arsenic by removing the material from its subsurface, reducing environment. The sample collected from this location ("Post-Removal: Soil-1") contained 1,040 mg/kg total arsenic which is above the average background arsenic in the upland and wetland reference sites of 25 to 30 mg/kg. Given that the material did not appear to consist of tailings, it is possible that the observed arsenic concentration reflects the material's origin from mineralized areas located higher in the Montezuma Creek valley.

Total arsenic concentrations of sediment samples collected from active stream channels prior to remediation activities are presented in Tables 5-12 and 5-13 (Appendix E). Arsenic concentrations in sediment samples collected prior to excavation ranged from 69.6 mg/kg (Unnamed Creek below where the creek was returned to its natural channel) to 1,140 mg/kg (Montezuma Creek near Riverside Campground Road).

1999 Results and Discussion

In 1999 additional removal efforts were limited to the historic channel of Unnamed Creek. Isolated removals were conducted to allow flows from Unnamed Creek and the Historic Powerhouse Flume to return to the creek bed and to resume the irrigation of downstream willow-wetland area in the lower portion of the Depositional Area. Concentrations of arsenic in the creek bed after removal were 121 and 29.3 mg/kg at the upstream and downstream extent of the removal action.

Also in 1999, three samples were collected to characterize road base materials and two post-removal soil samples were collected from the Unnamed Creek channel prior to restoring the creek. The results of these samples are listed in Table 5-12a (Appendix E), along with the results of road material samples collected by IDEQ in 1997. Samples from FS207 (the mine road) and FS268 (the Power Plant Campground Road) both contained arsenic at 363 mg/kg. The sample from FS205 (the Riverside Campground Road) contained arsenic at 39 mg/kg. Potential sources of arsenic in road materials include: residual impact from the 1997 release; Montezuma Creek deposits from flooding during 1999 spring runoff; use of roads during 1998 removal activities; use of roads during historical mining activities; and arsenic-containing road materials. Equipment used to scrape the roadways in 1997 and 1998 included the Atlanta Highway District road grader and the Nelson Construction's front-end loader, respectively. It is possible that road scraping was inadequate for the 1997/1998 arsenic removals. However, potential historical sources or other potential impacts are unknown.

Sampling of aquatic sediment in Montezuma Creek during 1999 showed no consistent pattern of metals with distance downstream from the uppermost station (MC-1) (Table 5-16). Most metals (all except iron, selenium, and zinc) were substantially higher at MC-4 (rep. 2) in the Depositional Area than in any other Montezuma Creek station. In contrast, MC-4 (rep. 1) taken a few meters downstream of rep. 2 in sediments of very similar appearance had among the lowest values for all metals except selenium, for which it had the highest value. This contrast in values

from replicates at the same station may indicate a high degree of patchiness in the distribution of areas of elevated metals within the deposition zone. Highest values for iron and zinc in Montezuma Creek were at MC-1, well above the Depositional Area and Tailings Piles.

Sediments at the lower of the two sample stations on Unnamed Creek (UC-2) exhibited higher levels of most COPCs sampled except for silver. UC-2 is near the confluence of the stream with Montezuma Creek and is in the tailings Depositional Area, whereas UC-1 lies just downstream of the historic Greene tailings.

In-stream samples from the MFBR showed high concentrations of aluminum, arsenic, cadmium, iron, antimony, and zinc in the Kirby Dam pool (MFBR-4 or MFBR-5) and of silver, copper, mercury, lead, and selenium in the shoreline sediments at MFBR-3, upstream of the pool (Table 5-16). Within the Kirby Pool, lenses of light gray material were seen in several samples. These stations are located downstream of several potential sources of tailings other than the Upper and/or Lower Tailings Piles, including a historic tailings deposit which is actively eroding into the river (this deposit is shown on Figure 1-2). In addition, it is known that other mills existed along the MFBR between Montezuma Creek confluence and Kirby Dam (e.g., the Buffalo Mill; IGS, 1998). It is probable that tailings streams from sources other than the Upper and Lower Tailings Piles contribute to COPC levels observed in the MFBR sediments. The level of mercury at MFBR-3 (15.7 mg/kg) was the highest observed in the samples. It is noteworthy that no sample collected from the Tailings Piles nor the Depositional Area exceeded 0.3 mg/kg (see "Soil Samples Associated with Tailings Impoundment Area" and "Soil Samples Associated with the Depositional Area", Table 5-12, Appendix E). This indicates that the Upper and/or Lower Tailings Piles are not a likely source of the mercury at MFBR-3. Stations MFBR-3 and MFBR-5 (in-stream) also had the highest TOC values at any stations in the MFBR. Levels of arsenic were generally lower in the MFBR than in Montezuma Creek, but iron levels tended to be higher in the MFBR.

Overbank samples generally held lower metals concentrations than the in-stream samples from the MFBR or Montezuma Creek. The one exception was at MFBR-5, where the overbank sample consisted of lenses of grayish fine sand in a darker sand matrix that appeared to be high in organic matter. The gray layer was selectively included in the sample and likely contributed to the fact that all metals except silver were highest, or tied for highest (with MFBR-7) at MFBR-5 (Table 5-16).

Statistical analysis (ANOVA) of aquatic sediment samples collected from Montezuma Creek within (i.e., stations MC-4, MC-3P, and UC-2) and upstream (i.e., stations MC-1, MC-2, and MC-3T) of the Depositional Area. These results indicated that, except for mercury, there were no significant differences in metal concentrations between the samples collected inside and outside of the Depositional Area (See Appendix D-1). Mercury concentrations were significantly higher inside the Depositional Area zone of impact as compared to outside the impact zone ($F = 6.389$, $p = 0.039$). When station UC-2 is removed from this analysis, no significant differences in metals concentrations existed between the two areas (Appendix D-1).

The results produced during the 1999 sampling provide a general contrast of chemical concentration between areas with tailings from the 1997 release and areas where such tailings had been removed during the 1997 and 1998 response actions (Table 5-18). In upland areas, removal efforts tended to decrease mean total concentrations of silver, arsenic, copper, mercury, and antimony. The 95 percent confidence intervals overlapped for average concentrations in removal and non-removal areas for aluminum, cadmium, copper, iron, mercury, lead, selenium, and zinc, indicating that removal did not statically affect mean concentrations for these metals. This suggests that concentrations for these metals may be at or near normal background concentrations in the Depositional Area uplands. For the wetland areas the data indicate that removal efforts appeared to decrease average total concentrations of silver, arsenic, cadmium, copper, mercury, lead, selenium, and zinc. The 95 percent confidence intervals indicated no differences between removal and non-removal wetland areas for silver, aluminum, iron, lead, selenium, and zinc. Again, this suggests that these metals now may occur at or near typical background concentrations for the Depositional Area.

The lower portions of Tables 5-19 and 5-20 show soil chemistry results from the nine upland Depositional Area plots included in the seeding trial study. These plots were located in an area where tailings removal had not occurred, near and slightly northwest of Site 25 (see, Figures 3-11 and 3-12). Average concentrations for total aluminum, iron , and zinc in samples from these plots were lower than the average concentrations found at the other removal sites in the Depositional Area during 1999; and total concentrations for silver, arsenic, and antimony were lower; and total concentration for cadmium, copper, lead, mercury, and selenium were similar (Table 5-18). These differences reflect the considerable variability in the chemical content of soils and tailings in the

Depositional Area seen is the samples collected during all years. Soil fertility characteristics for these plots, prior to adding soil amendments, are presented in the lower portion of Table 5-20.

5.3.4.4 Tailings Samples Collected From Multiple Tailings Depositional Layers

Locations within and adjacent to Montezuma Creek and Unnamed Creek channels contain multiple layers of tailings deposition. These multiple depositional layers of tailings are generally buried by organic soil layers and are not related to the 1997 release. The chemical analyses results from 1998 samples associated with historic tailings depositional layers are presented in the Tailings Soil Analytical Data Table (Table 5-12, Appendix E). Sample locations are shown on Figures 5-34 and 5-35 (Appendix A).

The chemical composition of sediments suspected of being historic tailings deposits varies across the Site. In the natural channel of Unnamed Creek, a layer of natural soils and organic matter overlies an apparent tailings layer. One sample was collected from this layer (Old Tailings, Table 5-12, Appendix E). The total arsenic concentration in this sample was 24.6 mg/kg. Although this sample had the color and texture of mill tailings, its chemical composition suggests that is of another origin. This value is slightly elevated relative to the maximum detected arsenic concentrations measured in non-mineralized areas (21.9 mg/kg; Table 5-13, Appendix E),and well below the arsenic concentration measured in sediment collected from Montezuma Creek below the East Fork (218 mg/kg).

Tailings depositional layers associated with Montezuma Creek exhibit two different characteristics. In the willow area of Montezuma Creek, upgradient from FS205, apparent tailings are visible in the cutbank of the creek at depths of up to 3 to 4 feet below the ground surface. Three samples have been collected from this area: SOIL-7, SOIL-8, and Historic Tailings Depositional Layer-4 (Table 5-12, Appendix E). Total arsenic concentrations in these samples ranged from 27.8 mg/kg to 157 mg/kg.

In the lower sections of Montezuma Creek, near FS205, apparent tailings are present in thin layers near the soil surface. In the southeast corner of the yard surrounding the Ours' cabin along FS205 (sample location: Historic Tailings Depositional Layer-1 and -2 (samples #53669 and 53670) on Figure 5-35, Appendix A), three layers were visible in the top 14 inches of the soil: a thin layer

of tailings on top (presumably from the 1997 release) and two additional layers of tailings, each separated by several inches of soil and organic matter. The lower two layers of historically deposited tailings were sampled for chemical analysis (Table 5-12, Appendix E): Historic Tailings Depositional Layer-1 (sampled 3 to 6 inches below the soil surface) and Historic Tailings Depositional Layer-2 (sampled 10 to 12 inches below the soil surface). These samples contained total arsenic concentrations of 1,260 mg/kg and 1,820 mg/kg, respectively. These materials were removed during the 1998 interim removal action and a layer of imported soil was placed in the Ours' Cabin yard. One additional sample was collected from the area near the confluence of Unnamed Creek and FS205. This sample was collected from the wooded area opposite Montezuma Creek from the cabin along FS205: Historic Tailings Depositional Layer-3. The total arsenic concentration from the sample collected from this historically deposited tailings depositional layer (7 to 16 inches below the soil surface) was 1,120 mg/kg. These materials were also removed in 1998. Each of the arsenic concentrations measured in the lower sections of Montezuma Creek were elevated relative to the background concentrations presented in Table 5-13 (Appendix E).

Five exploratory borings (618A, 618B, 619, 620, and 621; Figure 3-15, Appendix A) were conducted in areas potentially containing buried historic tailings. Exploration locations were selected in an effort to better characterize the extent of historic buried tailings based on previous observations. Continuous split-spoon sampling was conducted in each boring from the ground surface to the maximum depth explored. Borings were terminated when coarse alluvial sediments were encountered; depths ranged from 7 to 18.5 feet BGS. One sample from each of four of the borings was selected for laboratory analysis of COPCs based on color and texture. Based on physical descriptions, no distinctive layers of buried tailings were encountered. Laboratory results are included on Table 5-12. The results for selected parameters are provided below.

Boring (Depth)	Arsenic (mg/kg)	Iron (mg/kg)
618B (7-8.5')	22.8	7,350
619 (3.5-5')	26.9	8,980
620 (3.5-5')	4.2	10,400
621 (7-8.5')	21.2	11,600

5.3.4.5 Arsenic Concentrations in Tailings, Soil, and Sediment

From the 1997-98 samples, total arsenic concentrations measured in tailings from the Upper Tailings Pile range between 474 mg/kg and 2,040 mg/kg. Total arsenic concentrations measured in tailings from the Lower Tailings Pile range between 1,450 mg/kg and 3,040 mg/kg. Also from the 1997-98 samples, total arsenic concentrations measured in tailings in the Depositional Area range between 108 mg/kg and 1620 mg/kg (Table 5-12, Appendix E).

Total arsenic concentrations measured during 1997-98 in sediment samples collected from active stream channels located within the Depositional Area ranged between 69.6 mg/kg and 1140 mg/kg (Table 5-12, Appendix E). For comparison, during the 1999 sampling, arsenic concentrations in upstream sediment samples in Montezuma and Unnamed Creeks ranged from 70 to 279 mg/kg (Sites UC-1, MC-1, and MC-2, Table 5-16, Appendix E).

The mean total (including the minimum and maximum range) in soils from the upland reference area was 23.8 (range: 6.6 - 102) mg/kg, compared to the mean of 532 (range: 19 - 1,780) mg/kg in the Depositional Area (Table 5-18). In the wetland reference area soils total arsenic averaged 166 (range: 7.7 - 638) mg/kg, as compared to the average of 396 (range: 99 - 1,280) mg/kg found in the Depositional Area wetland soils (Table 5-18).

Arsenic concentrations in the road bed samples collected in 1999 ranged from 39 to 363 mg/kg; this is within the concentration range found in 1997 for roadbed samples. Concentrations of total arsenic of the aquatic sediments of Montezuma and Unnamed Creeks averaged 295 (range: 78.1 - 580) mg/kg and 77.6 (range: 70.0 - 85.2) mg/kg, respectively. Following removal of tailings material from the channel of Unnamed Creek (an action completed to allow flows to return to the willows wetland in the lower portion of the Depositional Area), total arsenic concentrations at the upstream and downstream sites in the creek channel ranged between 29.3 and 121 mg/kg.

Total arsenic concentrations for sediment samples from the MFBR averaged 74.4 (range: 24 - 144) mg/kg from in-stream samples and 191.6 (range: 36.7 - 575) mg/kg for overbank samples (Table 5-16). Concentrations of arsenic in MFBR in-stream aquatic sediment increase from 24 to 33.5 mg/kg from station MFBR-1 to station MFBR-2 (above and below the Montezuma Creek confluence, respectively), while the next sample site downstream (MFBR-3, downstream of Quartz

Gulch and the historic Monarch Tailings) exhibited an arsenic concentration of 92.2 mg/kg. The maximum arsenic concentration in the historic Monarch tailings measured during a sampling effort implemented by the USFS is 10,900 mg/kg (Envirosearch, 1996). By contrast, the maximum arsenic concentration measured in tailings associated with the Site is 3,040 mg/kg at the Lower Tailings Pile, with other measured arsenic concentrations in the Depositional Area, Upper Tailings Pile, and Lower Tailings Piles typically ranging from 1,000 mg/kg to 2,000 mg/kg (MFG, Terracon, and Pentec, 1999a). These data suggest that the historic Monarch tailings may be a source of arsenic in MFBR in-stream aquatic sediment at MFBR-3 and other downstream sediment sampling sites.

5.3.4.6 Aluminum Concentrations in Tailings, Soil, and Sediment

Aluminum was included as an analyte during 1997-98 for 22 solid phase samples. The maximum concentration of total aluminum detected was 16,300 mg/kg (Table 5-15, Appendix E). This concentration was measured by Terracon in a composite soil sample collected from the 0- to 12-inch profile of Land Application Area 1 (Figure 5-35, Appendix A). The minimum concentration of total aluminum detected was 972 mg/kg (Table 5-15, Appendix E). This concentration was measured by U.S. EPA in a tailings sample collected from the Upper Tailings Pile (sample # 4599, Figure 5-36, Appendix A). There were no (0 percent) non-detects for total aluminum.

From the 1999 soil samples, total aluminum concentrations averaged commonly between 10,000 to 20,000 mg/kg. The soil concentrations averaged greater in the reference areas than the Depositional Area, and generally greater in the deposition soils with removal than without removal (Tables 5-17 and 5-18). Total aluminum concentration averaged 15,950 (range: 10,200 - 25,600) mg/kg in the upland reference area soils and 10,783 (range: 3,620 - 22,600) mg/kg in the Depositional Area upland soils. In the reference wetland soils, total aluminum averaged 19,195 (range: 5,270 - 40,700) mg/kg, compared to 12,380 (range: 3,500 - 33,000) mg/kg in the deposition wetland soils. For in-stream aquatic sediment samples, total aluminum concentrations averaged 6,940 (range: 3,380 - 10,500) mg/kg in Unnamed Creek, 4,951 (range: 3,020 - 8,010) mg/kg in Montezuma Creek, and 6,286 (range: 3,220 - 11,100) mg/kg in MFBR, with overbank samples from MFBR averaging 4,928 (range: 2,680 - 10,300) mg/kg (Table 5-16).

5.3.4.7 Antimony Concentrations in Tailings, Soil, and Sediment

Antimony was included as an analyte for 51 solid phase samples during 1997-98. The maximum concentration of total antimony detected was 30 mg/kg (Table 5-15, Appendix E). This concentration was measured in a tailings sample collected by IDEQ from the upper tailings impoundment (sample #0792, Figure 5-37, Appendix A). The minimum concentration of total antimony measured was a non-detected value (<0.2 mg/kg). There were 20 (39 percent) non-detects for antimony. Detection of total antimony in soils at low concentrations is problematic due to interference problems.

In the 1999 samples, total antimony concentrations did not exceed the detection limit in any of the reference soil samples from either upland or wetland areas. In the Depositional Area, total antimony was detected in 6 samples for an average of 1.7 (range: 1.6 -7.0) mg/kg in upland soils and 7 samples for an average of 3.6 (range: 1.8 - 13.2) mg/kg in wetland soils (Table 5-17). In aquatic sediments, total antimony exceeded the detection limit in only one sample from Montezuma Creek; while no samples from Unnamed Creek or from the MFBR (either in-stream of overbank samples) held detectable antimony.

5.3.4.8 Cadmium Concentrations in Tailings, Soil, and Sediment

Cadmium was included as an analyte for 63 solid phase samples during 1997-98. The maximum concentration of total cadmium detected was 11.2 mg/kg (Table 5-15, Appendix E). This concentration was measured by Terracon in tailings from the Lower Tailings Pile (sample # 53668, Figure 5-34, Appendix A). The minimum concentration of total cadmium measured was a non-detected value (<0.07 mg/kg). There were 24 (38 percent) non-detects for cadmium.

During 1999, total cadmium was detected in all upland reference soil samples, about one-half of the upland Depositional Area samples, three of eight reference wetland soil samples, and nearly 40 percent of the Depositional Area wetland soil samples. The greatest soil concentration for total cadmium recorded was 1.2 mg/kg (Table 5-17). In the aquatic sediment samples, total cadmium (1) was not detected in Unnamed Creek, and (2) had detectable concentrations in two of seven samples from Montezuma Creek as well as three of eight in-stream samples from MFBR, and two of five overbank sediment samples from MFBR. Maximum concentration for total cadmium

in aquatic sediments was 0.32 mg/kg from the most downstream site on Montezuma Creek (Table 5-16).

5.3.4.9 Copper Concentrations in Tailings, Soil, and Sediment

Copper was included as an analyte for 61 solid phase samples during 1997-98. The maximum concentration of total copper detected was 45.8 mg/kg (Table 5-15, Appendix E). This concentration was measured by Terracon in a tailings sample collected from the Greene tailings (sample #48665, Figure 5-34, Appendix A). The Greene tailings are located north of the Depositional Area created by the May 1997 event and are not part of the Site. The maximum copper concentration in the Talache Tailings Piles was 26.6 mg/kg (Table 5-12, Appendix E). The minimum concentration of total copper detected was a non-detected value (<1.24 mg/kg; Table 5-15, Appendix E). There were 2 (3 percent) non-detects for copper.

Total copper in soil samples from 1999 exhibited a maximum concentration of 84.3 mg/kg in one upland Depositional Area sample, and had greatest average area concentration in samples from the reference wetland with a mean of 11.7 (range: 7.6 - 30.1) mg/kg (Table 5-17). The maximum total copper concentrations in aquatic sediment samples was 12.1 mg/kg (Table 5-16).

5.3.4.10 Mercury Concentrations in Tailings, Soil, and Sediment

Mercury was included as an analyte for 74 solid phase samples during 1997-98. The maximum concentration of total mercury detected was 9.33 mg/kg (Table 5-15, Appendix E). This concentration was measured by Terracon in tailings collected from the Greene tailings pile (sample #31992, Figure 5-34, Appendix A). The Greene tailings are mill tailings, unrelated to the 1997 release, located upgradient and north of the Depositional Area on Alva Greene's property (Figure 5-34, Appendix A). The minimum concentration of total mercury measured was a non-detected value (<0.198 mg/kg). There were 20 (27 percent) non-detects for mercury.

In the 1999 soil samples, mercury was detected in 5 of the 18 upland reference samples, all but one of the 29 upland Depositional Area samples, 5 of 8 wetland reference samples, and 24 of 26 wetland Depositional Area samples (Table 5-17). The maximum total mercury concentration detected was 2.6 mg/kg at Site 101, the location of a historic mill that had been included in a past

removal effort by the USFS. Concentrations of total mercury averaged 0.12 (range: 0.03 - 0.80) mg/kg in the upland reference soils, 0.24 (range: 0.03 - 2.60) mg/kg in Depositional Area upland soils, 0.18 (range: 0.04 - 0.38) in wetland reference soils, and 0.36 (0.23 - 1.50) mg/kg in Depositional Area wetland soils.

In aquatic sediments, total mercury concentrations averaged 0.25 (range: 0.24 - 0.25) mg/kg in Unnamed Creek, 0.16 (range: 0.07 - 0.33) mg/kg in Montezuma Creek, 1.91 (range: 0.07 - 15.7) mg/kg in MFBR in-stream sediments, and 0.17 (range: 0.11 - 0.36) mg/kg in MFBR overbank sediments (Table 5-16, see also Appendix D-1). Concentrations of mercury in MFBR in-stream aquatic sediment increase from 0.07 to 0.13 mg/kg from station MFBR-1 to station MFBR-2 (above and below the Montezuma Creek confluence, respectively), while the next sample site downstream (MFBR-3, downstream of Quartz Gulch and the Historic Monarch Tailings) exhibited a mercury concentration of 15.7 mg/kg. The maximum mercury concentration in the historic Monarch tailings measured during a sampling effort implemented by the USFS is 29,480 mg/kg (Envirosearch, 1996). By contrast, mercury concentrations measured in tailings of the Depositional Area, Upper Tailings Pile, and Lower Tailings Piles do not exceed 0.5 mg/kg. The maximum mercury concentration measured in the off-site historic Greene tailings was 9.33 mg/kg (MFG, Terracon, and Pentec, 1999a). These data suggest that the historic Monarch tailings may be a source of mercury in MFBR in-stream aquatic sediment at MFBR-3 and other downstream sediment sampling sites.

5.3.4.11 Selenium Concentrations in Tailings, Soil, and Sediment

Selenium was included as an analyte for 5 solid phase samples in 1997-98. The maximum concentration of total selenium was a non-detected value (<10.0 mg/kg; Table 5-15, Appendix E).

In the soil samples from 1999, total selenium was detected in one sample from the upland reference sites, 12 of 29 samples from the upland sites in the Depositional Area, 3 of 8 wetland reference sites, and 9 of 26 wetland sites in the Depositional Area. Average concentrations for total selenium ranged from 0.1 mg/kg in the upland reference soils to 0.35 mg/kg in wetland Depositional Area soils (Table 5-17). Two wetland soil samples from the Depositional Area held total selenium concentrations of 1.3 and 2.2 mg/kg. Total selenium was not detected in 6 of 9 MFBR in-stream sediment samples and not in any MFBR overbank samples (Table 5-16). Total selenium in in-

stream sediment averaged 0.87 (range 0.63 - 1.10) in Unnamed Creek, 0.68 (range: 0.28 - 1.3) mg/kg in Montezuma Creek, and 0.48 (range: 0.29 - 0.87) in the MFBR.

5.3.4.12 Silver Concentrations in Tailings, Soil, and Sediment

Silver was included as an analyte for 32 solid phase samples during 1997-98. The maximum concentration of total silver detected was 5.49 mg/kg (Table 5-15, Appendix E). This concentration was measured by IDEQ in tailings collected from the upper tailings impoundment (sample # 0791, Figure 5-37, Appendix A). The minimum concentration of total silver measured was a non-detected value (<0.1 mg/kg). There were 9 (28 percent) non-detects for silver.

Silver was detected in most soil samples collected in 1999. Total silver concentrations averaged 0.21 (range 0.03 - 0.93) mg/kg in upland reference soils, 2.03 (range: 0.03 - 9.40) mg/kg in upland Depositional Area soils, 1.11 (range: 0.24 - 5.00) mg/kg in wetland reference soils, and 2.42 (range: 0.44 - 11.9) mg/kg in wetland Depositional Area soils (Table 5-17). For aquatic in-stream sediments, total silver concentrations averaged 0.44 (range: 0.21 - 0.67) mg/kg in Unnamed Creek, 0.53 (range: 0.06 - 2.33) mg/kg in Montezuma Creek, and 1.45 (range 0.07 - 5.70) mg/kg in the MFBR, with an average of 1.46 (range: 0.45 - 3.50) mg/kg found for the MFBR overbank sediment (Table 5-16).

5.3.4.13 Zinc Concentrations in Tailings, Soil, and Sediment

Zinc was included as an analyte for analysis of 74 solid phase samples during 1997-98. The maximum concentration of total zinc detected was 81.6 mg/kg (Table 5-15, Appendix E) as measured by Terracon in a composite soil sample collected from the 0- to 12-inch profile of Land Application Area 1 (Figure 5-35, Appendix A). The minimum concentration of total zinc measured was 5.59 mg/kg (Table 5-15, Appendix E) and was measured by IDEQ in tailings collected from the upper tailings impoundment (sample # 0794, Figure 5-37, Appendix A). There were no non-detects for zinc.

Concentrations of total zinc were detected in all soils samples from 1999. The concentrations in soils averaged 74.2 (range 39.7 - 102.0) mg/kg in upland reference samples, 56.6 (range: 30.8 - 97.6) mg/kg in upland Depositional Area samples, 80.5 (range: 70.5 - 92.9) mg/kg in

reference wetland samples, and 55.6 (range: 29.2 - 107) mg/kg in wetland Depositional Area samples (Table 5-17). In-stream sediment samples contained total zinc concentrations averaging 31.9 mg/kg (range: 17.2 - 46.6) mg/kg in Unnamed Creek, 44.3 (range: 31.4 - 59.3) mg/kg in Montezuma Creek, 46.8 (range: 28.9 - 77.5) mg/kg in the MFBR (Table 5-16). Overbank sediments from the MFBR averaged 36.8 (range: 21.0 - 63.7) mg/kg for total zinc.

5.3.4.14 Lead Concentrations in Tailings, Soil, and Sediment

Total lead was detected in all samples collected from the Depositional Area and from reference areas during 1999 (Table 5-17, Appendix E). Average concentrations were essentially equal in the reference and Depositional Area wetlands (11.8 and 11.9, respectively), and were not significantly different between the reference and Depositional Area wetlands (17.5 and 15.4 mg/kg, respectively, see Table 5-17). Lead was detected in all aquatic sediment samples during 1999. Concentrations of total lead in aquatic sediments averaged 7.7 (range: 5.0 - 10.3) mg/kg in Unnamed Creek, 8.3 (range: 4.6 - 13.8) mg/kg in Montezuma Creek, 9.6 (range: 4.4 - 19.6) in the MFBR instream samples and 7.4 (range: 4.0 - 12.5) mg/kg in the MFBR overbank samples (Table 5-16, Appendix E). Total lead will also be included in the ecological and human health risk assessments for the Site.

5.3.4.15 Iron Concentrations in Tailings, Soil, and Sediment

Concentrations of total iron were detected in all terrestrial and aquatic samples collected during 1999 (Table 5-17, Appendix E). The soil data suggest that concentrations of total iron were similar across the Site, with the greatest average concentrations found at the upland and wetland reference sites. Total iron concentrations in aquatic sediments averaged 5,990 (range: 4,100 - 7,889) mg/kg in Unnamed Creek, 7673 (range: 5,300 - 10,200) mg/kg in Montezuma Creek, 9,794 (6,250 - 16,100) mg/kg in the MFBR instream sediments, and 8,117 (range: 5,140 - 12,900) mg/kg in the MFBR overbank sediment (Table 5-16, Appendix E). Total iron will be included in the ecological and human health risk assessments for this Site, especially for aquatic ecological resources.

5.3.4.16 Summary of Observations: Tailings, Soil, and Sediment

- Arsenic concentrations in tailings samples from the Talache Tailings Piles range from 535 to 3,660 mg/kg (Table 1, Appendix I).

- The pH of the tailings samples is near-neutral, with pH values ranging between 7.3 and 7.5. A high neutralization potential and a low sulfur content confirm that the tailings are not acid generators, but net acid consumers. The tailings have not generated acidity in the past, are presently not generating acidity, nor are the tailings expected to generate typical acid-rock drainage in the future.

- Leaching properties of the tailings composites were evaluated by analyzing for total arsenic, water-soluble arsenic, and ammonium bicarbonate-diethylenetriamine-pentaacetic acid (AB-DTPA) extractable arsenic. The AB-DTPA and water extractions indicate that only a small fraction of the total arsenic reported in the tailings at the Site is geochemically mobile. In addition, TCLP testing of the tailings samples revealed that the tailings are not toxic with respect to arsenic.

- Arsenic concentrations in soil samples collected from upland reference areas averaged about 25 mg/kg compared to average arsenic concentrations of over 500 mg/kg in upland locations within the Depositional Area (Table 5-17, Appendix E). Arsenic concentrations in wetland reference areas averaged about 165 mg/kg compared to almost 400 mg/kg in wetland Depositional Area soil samples.

- In general, post-removal soil and sediment samples data indicate that tailings excavation and removal operations in the Depositional Area were very successful in reducing total arsenic concentrations where the removal was completed to native substrate. Post-removal arsenic concentrations are significantly reduced relative to arsenic concentrations measured in tailings located in the Depositional Area. Seventy five percent of the post-removal arsenic concentrations presented in Table 5-14 (Appendix E) were elevated relative to the average arsenic concentrations in the upland and wetland reference sites of 25 to 30 mg/kg. However, all of the post-removal arsenic concentrations presented in Table 5-14 (Appendix E) were

significantly reduced relative to pre-removal concentrations presented in Table 5-13.

- Post-removal samples collected in 1998 from within active stream channels (Table 5-12, Appendix E) indicate that the tailings excavation and removal operations in active stream channels were not as effective in reducing total arsenic concentrations as the removal operations in other areas of the site. Post-removal samples identified as "Post-Removal: Sed-1" and "Post-Removal: Sed-2" were collected from a reach of Montezuma Creek that received the most effort during tailings removal operations conducted during the 1998 field season. Tailings were removed from this area, primarily using shovels, during three operations in 1998. Despite this level of effort, the samples collected from this reach of the creek contained between 327 mg/kg and 754 mg/kg total arsenic.

5.3.5 Air

The following subsections address air sampling and monitoring activities during the 1997 and 1998 response actions. No further air sampling nor monitoring were implemented during 1999, though a dispersion modeling analysis was implemented. The purpose of this analysis was to evaluate whether deposition of wind-blown particulates from the Tailings Piles could significantly affect soil arsenic concentrations in areas distant from the piles. The results of this evaluation are summarized in Section 5.4.6.

5.3.5.1 1997 Air Sampling and Monitoring Activities

Air quality monitoring was performed during the 1997 field season to provide analytical information regarding human exposure risks associated with the inhalation of air. Air quality sampling began on Friday, October 17, 1997, and continued daily through Wednesday, October 22, 1997.

Interim corrective action efforts were ongoing during the 1997 air quality sampling study. These activities included hydroseeding and construction activities, both of which resulted in heavy

vehicular traffic. Additionally, public traffic between town, the Atlanta Hot Springs area, and Power Plant Campground, as well as elk hunter traffic up FS207, was heavy for much of the study period.

Two Wedding Critical Flow High Volume PM-10 air samplers were used. One of the monitors was situated to measure an upper limit of chronic exposure and the other was situated to measure an upper limit of acute exposure (Figure 3-6, Appendix A). The chronic exposure site was located adjacent to residences within about 400 feet of the tailings Depositional Area. The acute exposure site was located in the Depositional Area 12 feet north of FS268 and 40 feet east northeast of the intersection with FS207. Due to traffic in the area, the location of the acute exposure site probably represents the maximum potential airborne exposure site in the area affected by the tailings deposition. However, because there are no houses or businesses, exposure to dust and/or tailings in this area is generally short-term. Also, many road surfaces in the vicinity of the Atlanta townsite are treated with dust suppression agents each summer.

The 1997 air quality sampling period was characterized by generally warm and dry weather with light to moderate winds. The warm, dry weather and dominant high pressure pattern set in Monday, October 13, four days before the first sample was collected. That warm, high pressure pattern, which maximized re-entrainment of particulates and generally ensured a conservative, high-end estimate of potential particulate concentrations, persisted throughout the sampling period. The soils and road surfaces were dry enough during the study that passing vehicles created a visible dust plume.

During 1997, the roadside sampler had consistently higher PM-10 concentrations, ranging from a low of 35.6 micrograms of particulates per cubic meter of air (ug/m^3) on October 19, (atmospheric pressure was a bit lower this day, and road activity light to moderate) to 123.1 ug/m^3 on October 18 (high pressure, heavy vehicular traffic accompanying opening day of elk hunting season) (Table 5-21, Appendix E). The residential area sampler measured consistently lower PM-10 concentrations, with all observations yielding PM-10 concentrations below 20 ug/m^3 (Table 5-21, Appendix E).

Chemical analyses of samples collected during 1997 with the highest PM-10 mass were performed. One sample was selected for chemical analysis from the roadside site; and one sample

was selected from the residential site. The eight hour average arsenic concentrations that were measured at these two sites are presented below:

- the arsenic concentration measured at the roadside sampling location was 0.161 ug/m^3; and

- the arsenic concentration measured at the residential sampling location was 0.0106 ug/m^3.

The measured values were well below short-term exposure criteria including the NIOSH arsenic standard of 2.0 ug/m^3 and the OSHA standard of 10.0 ug/m^3. The measured values did exceed the IDEQ Annual Average Allowable Ambient Concentration of 0.0023 ug/m^3 and the ACGIH Threshold Limit Value (TLV) for arsenic of 0.01 ug/m^3. However, the measured values represent short-term maximum concentrations measured under high impact scenarios and are likely not indicative of arsenic concentrations in air during the entire year (e.g., during periods of sub-freezing temperatures (6+ months/year) the area is covered by snow, vehicular traffic is minimal, and fugitive dust emissions are reduced relative to the dry summer months when vehicular traffic is highest).

5.3.5.2 1998 Air Sampling and Monitoring Activities

Air monitoring was conducted during the 1998 construction season. The primary goal of 1998 sampling activities was to provide for worker and public health and safety. Therefore, MIE PDM-3 Miniram dust, aerosol, fume and mist monitors were used during construction and tailings excavation and removal operations to provide instantaneous readings of ambient dust concentrations. Action and alert levels for particulate concentrations were established based on data collected at the Site, and were designed to estimate the concentration of particulates necessary to yield the TLV for arsenic of 0.01 mg/m^3. It was assumed that arsenic concentrations in air would be proportional to those measured in soil and air during 1997 monitoring activities, and then back-calculating particulate levels corresponding to the measured arsenic concentrations. The result was alert and action levels of particulate concentrations, 2.0 and 4.17 mg/m^3, respectively. The action level was calculated conservatively by assuming that all particulates in air were from tailings, and using the highest concentration of arsenic measured in tailings at that time (2,400 mg/kg) to establish the

particulate concentration corresponding to the arsenic TLV. The Miniram monitors were worn by workers during the 1998 construction season. Readings from the Miniram monitors were recorded and compared with the alert and action levels presented above to determine if worker exposures were within acceptable levels.

The primary method of data gathering was through instantaneous readings from the Miniram particulate monitors carried by response workers during the 1998 construction season, and supplemented by the monitor's Time Weighted Average (TWA) output at the end of the shift. Data reporting sheets required operators to regularly record particulate levels, as well as weather, soil moisture, and activity in the vicinity. The reporting interval was every hour or two when no dust was visible, and every half hour or less when there was visible dust. Equipment operators and laborers onsite were instructed to regularly check particulate levels whenever dust was visible. Miniram monitors were not used during periods of wet weather. Project managers compared monitor levels with action levels derived from ACGIH threshold limits, and adjusted project activity or worker protection when measured concentrations approached action levels to prevent excess exposure.

During the 1998 field season, only three daily TWA values exceeded 1 mg/m^3 (Table 5-22, Appendix E). The higher values were typically measured by equipment operators. All equipment operators carried respirators in their vehicles and were instructed to put them on when action levels were exceeded. The highest daily TWA recorded was 1.66 mg/m^3, still conservatively below the alert level of 2.0 mg/m^3. The maximum instantaneous Miniram particulate reading was 9.28 mg/m^3, and was recorded the same day (September 2, 1998). The equipment operator that measured this value wore his respirator, Site activity was altered so that work could be performed in an area with less dust generation, and water application to the soil surface was increased. No other Miniram dust concentration readings were recorded at or above the project action level of 4.17 mg/m^3. Only one other Miniram reading (3.6 mg/m^3 on August 27, 1998) indicated a confirmed instantaneous Miniram concentration above the alert level of 2.0 mg/m3.

To further confirm that monitoring activities are adequately protective of worker and public health, one Miniram particulate monitor was fitted with a pump and filter apparatus during one week of the 1998 construction season (the week ending Saturday, September 19, 1998) for filter gravimetric and chemical analysis.

Two filters were chosen for particulate component analyses. The first filter analyzed was the filter with the largest particulate volume, since more volume typically provides better resolution. That filter was from a September 15 sample of over seven hours duration. The Miniram-pump-filter apparatus was onboard a dump truck hauling tailings and soil from the northwest end of the Depositional Area up to the Lower Tailings Pile. The second filter chosen for elemental analysis was from a September 17 sample of similar duration collected from an excavator working on the Lower Tailings Pile. The excavator was digging in pure tailings for much of the day, and was believed likely have the highest percentage of tailings materials among the filter samples.

Because the particulate volume on the filters was reasonably low, and the particulates were concentrated in a small area on the filters, the laboratory report was limited to estimating comparative densities of different elements. The ratio of relative mass of tailings materials, such as arsenic, to other components, such as aluminum, calcium, and iron, in both the 1997 and the 1998 air monitoring data, was used to estimate arsenic concentrations in the 1998 samples. Using this comparative analytical method the arsenic concentration estimates for the 1998 samples are presented below:

- for the September 15 dump truck sample, the arsenic concentration in air was estimated to be 0.00016 mg/m^3.

- for the September 17 excavator sample, the arsenic concentration in air was estimated to be 0.00014 mg/m^3.

Neither sample approached the TLV for arsenic of 0.01 mg/m^3. These two samples both confirmed the conservatism of the alert level of 2.0 mg particulates per cubic meter of air, and the action level of 4.17 mg particulates per cubic meter of air. An action level calculated from the September 17 excavator sample would be 5.54 mg particulates per cubic meter of air. The September 15 sample would require a particulate concentration of 8.69 mg/m^3 before the arsenic TLV would have been reached. During 1998 field activities no daily TWA particulate concentrations exceeded these levels (maximum TWA was 1.66 mg/m^3), and only one or two recorded instantaneous Miniram readings exceeded these levels. During these transient events, appropriate measures were taken to minimize potential worker exposures, including altering Site activity to

reduce dust generation, increasing the application of water to the soil surface to reduce dust generation, and donning protective equipment, such as respirators.

5.3.5.3 Summary of Observations: Air

- Air quality monitoring was performed during the 1997 field season to provide analytical information regarding human exposure risks associated with the inhalation of air. Air quality sampling began on Friday, October 17, 1997, and continued daily through Wednesday, October 22, 1997.

- Two Wedding Critical Flow High Volume PM-10 air samplers were used. One of the monitors was situated to measure an upper limit of chronic exposure and the other was situated to measure an upper limit of acute exposure (Figure 3-6, Appendix A). The chronic exposure site was located adjacent to residences within about 400 feet of the tailings Depositional Area. The acute exposure site was located in the Depositional Area 12 feet north of FS268 and 40 feet east northeast of the intersection with FS207. Due to traffic in the area, the location of the acute exposure site probably represents the maximum potential airborne exposure site in the area affected by the tailings deposition.

- During 1997, the roadside sampler had consistently higher PM-10 concentrations, ranging from a low of 35.6 (ug/m^3) on October 19, 1997 to 123.1 ug/m^3 on October 18, 1997 (Table 5-21, Appendix E). The residential area sampler measured consistently lower PM-10 concentrations, with all observations yielding PM-10 concentrations below 20 ug/m^3 (Table 5-21, Appendix E).

- Chemical analyses of samples collected during 1997 with the highest PM-10 mass were performed. One sample was selected for chemical analysis from the roadside site; and one sample was selected from the residential site. The measured values were well below short-term exposure criteria including the NIOSH arsenic standard of 2.0 ug/m^3 and the OSHA standard of 10.0 ug/m^3. The measured values did exceed the IDEQ Annual Average Allowable Ambient Concentration of 0.0023 ug/m^3 and the ACGIH Threshold Limit Value (TLV) for arsenic of 0.01 ug/m^3.

However, the measured values represent short-term maximum concentrations measured under high impact scenarios and are likely not indicative of arsenic concentrations in air during the entire year (e.g., during periods of sub-freezing temperatures (6+ months/year) the area is covered by snow, vehicular traffic is minimal, and fugitive dust emissions are reduced relative to the dry summer months when vehicular traffic is highest).

- Air monitoring was conducted in 1998 for worker safety purposes. Estimated arsenic concentrations in air samples were orders of magnitude below the TLV for arsenic of 0.01 mg/m^3. The sampling event confirmed the conservatism of the alert level of 2.0 mg particulates per cubic meter of air, and the action level of 4.17 mg particulates per cubic meter of air.

5.4 FATE AND TRANSPORT

This section discusses fate and transport issues related to the Tailings Piles and the Depositional Area. It focuses on the likely sources of arsenic and on possible mechanisms effecting arsenic migration as arsenic is the primary risk driver at the Site. Other metals are co-located with arsenic. The discussion examines geochemical interactions that will control the behavior and migration of arsenic and other trace metals in tailings and soil, in surface water, and in groundwater. This discussion is guided by the CSM addressed in an earlier section of this report (Section 5.2.1) and illustrated in supporting Figures 5-1 and 5-2 (Appendix A).

The principal media for transporting arsenic and other trace elements at the Talache Mine Tailings Site are air, surface water and groundwater. Air quality was monitored immediately after the 1997 release, during a period when response activities were being implemented. The transport of arsenic-bearing tailings by winds has been reduced in the Depositional Area by cleanup activities which, in 1997 and 1998, removed much of the tailings and affected soil associated with the 1997 release. As previously noted, the potential for air transport and deposition of tailings material from the existing tailings piles was evaluated by dispersion modeling, as summarized in Section 5.4.6. The fate and transport of arsenic and other trace metals from tailings by way of surface and groundwater can be described through a conceptual geochemical model. Discussion of this model is provided in the following section.

5.4.1 Conceptual Geochemical Model

A Site-specific conceptual geochemical model for arsenic and iron in the Tailings Piles area is illustrated in Figure 5-38 (Appendix A). The illustration is helpful in visualizing potential water-borne arsenic and other COPCs migrating from a source, and interacting with tailings, soils, or colluvium. As solutions containing arsenic or other trace metals come in contact with natural material, geochemical reactions occur that can affect the mobility of the potential contaminants. The effect on mobility will depend, in large part, on the geochemical properties of the solid material coming in contact with the solution. If the properties are conducive and conditions are established that favor interaction, the potential contaminants can be attenuated in their movement and essentially immobilized in the subsurface. Geochemical mechanisms such as cation- and anion-exchange, precipitation and co-precipitation, and adsorption work to "fix" potential contaminants in geochemical traps that limit mobility.

Such interactions are illustrated in the conceptual geochemical model as taking place in the saturated zone. Similar interactions can occur in the unsaturated zone, also. The conceptual geochemical model describes three zones of interaction. The "active " zone is the area of intense geochemical interaction between colluvium, for example, and seepage solutions. Very often, geochemical mechanisms are triggered in the active zone by neutralization of pH or changes in redox potentials. The downgradient "neutralized" zone consists of seepage solutions that have been geochemically purged of potential contaminants and are transporting only constituents that are unreactive and unattenuated. Typically, such constituents include major ions such as sodium and potassium, calcium, and magnesium, bicarbonate and carbonate, sulfate, and chloride. As illustrated in earlier sections of this report, the major ions can be used with trilinear graphing techniques to identify different water types or to define areal extent and directions of contaminant plumes.

Existing water-quality data are indicating that arsenic is presently being removed from surface water and groundwater at the Site. Such areas, where arsenic concentrations are diminished, correspond to "active" zones in the geochemical model. Downgradient locations, where monitoring wells no longer detect elevated concentrations of arsenic, correspond to "neutralized" zones in the geochemical model.

Typically, where anomalous concentrations of arsenic are reported, the water is elevated in iron content. This is a common observation at the Site and is very fortuitous. The association of arsenic with iron enhances the natural attenuation of arsenic. As water becomes oxygenated, arsenic readily precipitates as an insoluble iron arsenate. The solubility product (Ksp) of $FeAsO_4$ is very low ($10^{-20.2}$). The iron arsenate mineral, scorodite ($FeAsO_4 \cdot 2H_2O$), is a conspicuous, naturally-occurring mineral found in soils near exposed croppings of rock that contain such minerals as arsenopyrite. Co-precipitation of arsenic with iron is practiced in the mining and power-generating industries as a treatment for removing arsenic from wastewater. Using this method, arsenic removal can be achieved to concentrations less than the drinking water levels of 0.05 mg/L.

5.4.2 Tailings and Soils

The tailings in the upper and lower piles are potential sources of arsenic and trace metals. Arsenic concentrations in excess of 3,000 mg/L have been reported in samples of tailings from the Site (see Table 1 of Appendix I). The mineralogy of the tailings consists of quartz, mica or illite, with lesser amounts of feldspars and chlorite, and traces of the iron-arsenic mineral, scorodite. However, most of the arsenic that is associated with the tailings is believed to occur as the sulfide mineral, arsenopyrite. Under oxidizing conditions, it is possible for the tailings to release water-soluble arsenic during oxidation of the arsenopyrite. This tendency of the tailings to leach small amounts of arsenic was demonstrated in laboratory test work. Although the tailings clearly did not exhibit toxicity characteristics for arsenic based on TCLP analyses, results of leaching studies indicated that the tailings may desorb small amounts of arsenic when leached with rain water. Arsenic leaching data from extraction tests indicated that about 0.5 percent of the total arsenic reported in the tailings is water-soluble, and about 5 percent of the total arsenic is AB-DTPA extractable. This indicates that only a small fraction of the arsenic reported in the tailings is geochemically mobile or capable of migrating into groundwater or exiting as seeps. A detailed description of the laboratory testing that was completed on the tailings as part of this characterization effort is provide in the Technical Memorandum prepared in May 1999, and included as Appendix I.

Once capped with a soil and vegetative cover as part of the removal action being performed at the Tailings Piles, the arsenic in the Tailings Piles would become geochemically stable in the chemically-reducing conditions that would occur below the surface. Any diffusion of oxygen into

the unsaturated tailings through soil and vegetative cover would be slow, and therefore would limit the oxidation of arsenopyrite and control the release of arsenic into the groundwater regime. In the interim, the small amounts of arsenic that are liberated from the tailings as seeps and seepage are being prevented from migrating downgradient by naturally-occurring geochemical mechanism described in the conceptual geochemical model. The ability of soil material from the Site to attenuate arsenic migration was demonstrated in laboratory simulation, using serial batch-contact procedures (Appendix I).

The fate and transport of arsenic and other trace metals in the Depositional Area can be described in similar ways. Any residual tailings in the Depositional Area associated with the 1997 release should have the same mineralogical and geochemical properties as the tailings in the piles. Moreover, any buried historical tailings should be similar to those released in 1997, given that they are derived from the same rock. Most of the arsenic associated with tailings in the Depositional Area probably occurs as arsenopyrite or scorodite. Under oxidizing conditions, it is possible for buried tailings to release water-soluble arsenic from the arsenopyrite. Slow diffusion of oxygen should limit the oxidation process. Dissolution would occur slowly over time. Furthermore, once water-soluble arsenic is released into the hydrologic regime, the conceptual geochemical model dictates that geochemical reactions will attenuate the movement of the arsenic. The arsenic would be prevented from migrating by adsorption on organic matter, adsorption and co-precipitation with manganese and iron hydrous-oxides, and by anion exchange with clay minerals.

Any residual tailings in the Depositional Area will either be incorporated into the soil profile or eroded and transported downgradient. Where a good vegetative cover can be maintained, the tailings will be incorporated into the soil profile just as historic tailings from previous redistribution events have been incorporated. There are numerous locations where multiple tailings depositional layers can be seen in the soil profile. This observation indicates that naturally occurring soil-building activities will eventually provide a natural cap for tailings in the Depositional Area. The length of time necessary for soil building to cap the tailings depends on Site-specific factors, such as topography and the local abundance of organic material.

Where tailings depth is less than six inches, vegetation would be able to grow through the tailings and roots would be able to attach to the native substrate below. Following tailings excavation and removal operations in 1998, tailings in the majority of the Depositional Area are less

than six inches thick. As the vegetation in this area becomes reestablished, erosion of tailings materials will be reduced and soil-building activities will begin to provide a natural cap for the underlying tailings.

5.4.3 Groundwater

Groundwater analyses and fingerprinting have identified two sources of arsenic and iron, one affecting the near-surface, alluvial aquifer and the other affecting a deeper, bedrock aquifer. The near-surface aquifer is composed of alluvial, glacial, and colluvial deposits. The deeper, bedrock aquifer is associated with the Montezuma fault zone. Groundwater from each aquifer has a unique major ion fingerprint. The alluvial aquifer carries water that is calcium-bicarbonate in composition; the bedrock aquifer transports water that is sodium-bicarbonate in composition. Downgradient of the Tailings Piles, in the Depositional Area, the shallow and deep groundwater merge. The major ion fingerprint of groundwater in the Depositional Area becomes a mixture of both water types.

Leaching of the tailings is contributing arsenic and iron to the shallow groundwater in the footprint of the Tailings Piles, and immediately downgradient of the Tailings Piles. But, arsenic and iron are also being transported to the Site in groundwater from upgradient areas. This groundwater originates in deep mineralized bedrock structures associated with the Montezuma fault zone. The arsenic and iron reported in the deeper, bedrock aquifer are likely due to natural weathering within the Montezuma fault zone, and not associated with the Site.

Natural attenuation of arsenic takes place as shallow groundwater moves downgradient through soil and colluvium. Over 99 percent of the dissolved arsenic in tailings monitoring well 610A (50.1 mg/L) is removed from groundwater by the time the flow reaches downgradient monitoring well 612C (0.193 mg/L); and essentially all of the dissolved arsenic is removed from groundwater by the time the flow reaches monitoring well 613B (0.089 mg/L). Concurrently, iron concentrations in groundwater are reduced from 22.6 mg/L at location 610A, to 3.7 mg/L in well 612C and 3.2 mg/L in well 613C.

Where high concentration of arsenic have been reported at the Site, groundwater is also elevated in dissolved iron. As previously stated, the geochemical association of dissolved arsenic with dissolved iron is fortuitous. Such an association leads to conditions that enhance natural

attenuation of arsenic in groundwater. At the near-neutral pH that is reported at the Tailings Piles and in the Depositional Areas, any dissolved iron must occur in the chemically-reduced, ferrous (+2) iron oxidation state. As groundwater becomes oxygenated, the ferrous iron is oxidized to the water-insoluble, ferric (+3) iron oxidation state and precipitates from solution as ferric hydrous-oxide. Evidence of this oxidation can be seen in the precipitation of "yellowboy" in the seeps at the toe of the Upper and Lower Tailings Piles. In this aerobic environment, dissolved arsenic would be expected to co-precipitate with ferric hydrous-oxide, as an insoluble ferric arsenate. Ferric arsenate occurs as a natural mineral called scorodite ($FeAsO_4 \cdot 2H_20$), which is found in soils near exposed croppings of rock containing such minerals as arsenopyrite.

Co-precipitation with iron is just one of the geochemical mechanisms working to remove and "fix" not only arsenic, but other trace metals associated with tailings material. Geochemical fixation can occur as tailings pore water enters an oxygenated groundwater regime, or as the water breaks the surface and leaves the area as surface water flow.

In the Depositional Area, the same geochemical processes are active and are largely responsible for diminished arsenic in groundwater. Residual traces of arsenic are being removed by co-precipitation with iron; other trace metals are being continuously removed by precipitation and co-precipitation, by adsorption on organic and mineral matter, and by cation- or anion-exchange with clays present in the soil matrix.

Lysimeter sampling of the pore water in unsaturated material has reported elevated arsenic concentrations (0.425 mg/L) at lysimeter installation 614B, which may be related to tailings deposition in the past. It is important to note that the pore water of the unsaturated, fine-grained sediments that was sampled by the lysimeter is interstitial moisture. Interstitial moisture is less mobile than groundwater in similar sediments due to surface tension and other physical forces. Left undisturbed, any dissolved solids present in interstitial moisture moves through the slow process of diffusion between pore spaces. However, when such sediments are disturbed, the equilibrium is upset and pore spaces may be drained or re-saturated. Once saturated, the dissolved solids can be released to move with normal groundwater throughflow.

5.4.4 Surface Water

Sources of arsenic and trace metals were assessed by evaluating changes in arsenic loads from upstream to downstream in the individual drainages in the Site area. This section concentrates mainly on arsenic due to the risks it may impose to environmental receptors and because other metals were either not detected or were only detected occasionally and at levels slightly above the instrument detection limits.

5.4.4.1 Montezuma Creek

The average arsenic concentrations at regular surface water measuring stations during the period of record are listed below. As expected, MC-4 has the highest average dissolved arsenic concentration (0.054 mg/L) which is slightly above the maximum contaminant level (0.050 mg/L). The averaged dissolved arsenic concentration at each of the four stations in Montezuma Creek was below the AWQC for arsenic of 0.15 mg/L. Note that the highest average total arsenic concentration is at MC-3, which is upstream of the Depositional Area.

Average Arsenic Concentrations (mg/L) Detected at Regular Surface Water Measurement Stations

STATION NAME	Total As (mg/L)	Dissolved As (mg/L)
MC-1 (below East Fork)	0.077	0.039
MC-2 (FS268)	0.066	0.038
MC-3	0.091	0.038
MC-4 (FS205)	0.077	0.054

Total and dissolved arsenic loading in Montezuma Creek (including 1999 data) are graphically presented on Figures 5-10 and 5-11 (Appendix A). Total and dissolved arsenic loading data from 1997 and 1998 are also listed in Table 5-23. The upper portions of Figures 5-10 and 5-11 show flow as measured at MC-4. As anticipated, arsenic loads were greatest during periods of high flow from early April to June, and lowest during periods of low flow, from September through February. Total and dissolved loading tended to be greatest at MC-4, the furthest downstream station.

Arsenic loading at MC-2, upgradient of the Depositional Area and essentially all Site-related impacts to Montezuma Creek, was compared to arsenic loading at MC-4, located at the downstream end of the Depositional Area, to evaluate the relative contribution of the Depositional Area to arsenic

loading in Montezuma Creek. MC-2 data were used for comparison rather than MC-3 data because during high flows, Montezuma Creek at station MC-3 becomes braided, and it appears that not all of the flow was measured at MC-3 during some sampling events (see Section 5.3.1.3).

The total arsenic load measured for December 1998 through September 1999 at MC-2 (Table 5-26, Appendix E; Figure 5-11, Appendix A) was about 74 percent of the total arsenic loading measured at MC-4 (which includes loading from UC-2). The calculation of percent of total arsenic load at MC-4 which was attributed to MC-2 is as follows:

$$74\% \text{ (percent of total arsenic loading at MC-4 attributed to MC-2)} = \frac{\text{50 lbs (sum of total arsenic loading at MC-2 for December 1998 through September 1999)}}{\text{68 lbs (sum of total arsenic loading at MC-4 for December 1998 through September 1999)}} * 100$$

Therefore, about 26 percent of the total arsenic loading at MC-4 appears to originate from sources downstream of MC-2, likely including tailings in the Depositional Area.

Sources of arsenic in Montezuma Creek at MC-4 were further evaluated by comparing the total arsenic loads at MC-4 with loads at MC-2 and UC-2 in Unnamed Creek for several 1999 sampling events. Loading data were compared for both high (April and May) and low flow (late June to September) periods in 1999 in the following table:

Sources of Total Arsenic Loading at MC-4, 1999 Data

Date	4/19/99	4/26/99	5/24/99	6/30/99	7/29/99	9/14/99
MC-2	9.31 ppd (111%)	4.59 ppd (82%)	21.74 ppd (72%)	1.48 ppd (106%)	0.20 ppd (74%)	0.06 ppd (67%)
UC-2	0.70 ppd (8%)	0.95 ppd (17%)	0.66 ppd (2%)	0.13 ppd (9%)	0.06 ppd (21%)	0.03 ppd (34%)
Other Sources	-1.66 ppd (-20%)	0.05 ppd (1%)	7.54 ppd (25%)	-0.21 ppd (15%)	0.01 ppd (4%)	0.0 ppd (0%)
MC-4	8.35 ppd (100%)	5.59 ppd (100%)	29.94 ppd (100%)	1.40 ppd (100%)	0.27 ppd (100%)	0.09 ppd (100%)

Notes:
ppd = pounds of arsenic per day.
The total arsenic loading attributable to other sources was calculated by subtracting the total arsenic load at MC-2 and UC-2 from the total arsenic load at MC-4.
Negative numbers indicate a potential arsenic sink between MC-3 and MC-4.

The percentage contributions from upstream stations to loading at MC-4 were calculated by dividing the load at the upstream station by the loading at MC-4. The percentage contribution from other sources was calculated by subtracting the arsenic loads from UC-2 and MC-2 from the load at MC-4. This comparison shows that the contribution of total arsenic from other sources varied from -20 percent to 25 percent. Given the uncertainty inherent in stream flow measurements, the contribution of total arsenic to Montezuma Creek at MC-4 from other sources between MC-2 and MC-4 is relatively small and generally within the margin of error for these loading estimates. This suggests that erosion between MC-2 and MC-4 is contributing little total arsenic to Montezuma Creek at MC-4. Comparison of the total arsenic loadings at MC-2 and MC-4 further supports that the majority of total arsenic loading to MC-4 is from sources upstream of MC-2 (67 percent to over 100 percent). Potenital sources of arsenic to the Montezuma Creek drainage above MC-2 include drainage from old mine workings flowing out of the Atlanta Mine 900-level adit portal and into upper Montezuma Creek as well as the waste rock pile associated with the 900-level adit, and other mine workings in the upper Montezuma Creek basin. Provided data indicate that dissolved arsenic concentrations in drainage from the 900-level adit are 1.96 mg/L inside the mine (approximately 800 feet from the adit portal), 1.19 mg/L at the portal, and 0.38 mg/L following discharge from a small, lined settling pond. The consistent decrease in arsenic concentrations is attributable to oxidation and co-precipitation of the arsenic with iron as the mine water becomes aerated during flow down the tunnel and through the settling pond. These observations confirm the conceptual geochemical model discussed in Section 5.4.1.

The fate of arsenic in Montezuma Creek in the Site vicinity was evaluated further by assessing iron loading in conjunction with arsenic loading in Montezuma Creek. Table 5-23 (Appendix E) presents the dissolved arsenic loadings within Montezuma Creek and Table 5-24 (Appendix E) presents the dissolved iron loadings (also see Figures 5-11 and 5-19, Appendix A, for a graphical presentation of dissolved arsenic and iron loads, respectively). These tables show an increase in both dissolved iron and dissolved arsenic load between MC-2 (FS268) and MC-4 (FS205). Dissolved iron is an indicator of a groundwater input as dissolved iron rapidly changes into insoluble ferric hydrous-oxides under oxidizing conditions at the surface. The dissolved iron that is measured in Montezuma Creek at MC-4 is still in the reduced, ferrous state. This suggests that the sources of iron are groundwater springs along Montezuma Creek. The dissolved arsenic that is measured in Montezuma Creek most likely enters the surface water system using the same pathways as the dissolved iron. Flow measurements also support the notion that a groundwater input

exists in this reach of Montezuma Creek. During low flows, Montezuma Creek experiences a net gain about 0.5 cubic feet per second (cfs) between MC-2 and MC-4 (Table 5-25, Appendix E and Figure 5-7, Appendix A). Unnamed Creek adds about 0.2 cfs to Montezuma Creek and the remainder of the increase (0.3 cfs) appears to be input from groundwater.

Spring runoff sampling data were used in lieu of thunderstorm sampling to determine the affects of high-flow conditions on surface water contaminant transport and loading. Arsenic loading data for Montezuma Creek springtime runoff sampling events (presented in Section 5.3.1.3) indicate that increases in springtime total arsenic loading in Montezuma Creek are primarily attributable to increased flow and increased concentrations of insoluble arsenic. In 1999, increases in total arsenic loading were apparent at all Montezuma Creek sampling stations during spring runoff. Increases in insoluble arsenic loading occurred both upgradient and downgradient of areas impacted by the 1997 release. Entrainment of insoluble arsenic from the stream-bed and stream-banks was the likely cause of the increased insoluble arsenic loading. Insoluble arsenic loading in Montezuma Creek during springtime runoff may also be partly attributed to oxidation of otherwise dissolved arsenic inputs (from groundwater) to insoluble forms of arsenic.

Tailings in the Depositional Area from the 1997 release are a source of arsenic and trace metals to the Montezuma Creek drainage. During runoff events, exposed tailings are likely eroded into the creek and carried downgradient. Transport of arsenic and trace metals are in both the dissolved or the particulate phase. Transport of dissolved constituents occurs when arsenic and other metals are leached from the tailings. Particulate-phase transport occurs when tailings solids are mobilized by erosion and carried entrained and suspended in surface water. Particulates entrained in moving surface water may remain in suspension until the water velocity decreases sufficiently to allow deposition. This process is also a function of particle size, with larger particles falling from suspension first as flow velocity falls. Immediately following the 1997 release, significant quantities of particulates were present in Montezuma Creek, based on available data. Such particulates appear to have traveled downstream to areas of relatively quiescent water along Montezuma Creek and possibly the MFBR.

Surface water data indicate that the total/dissolved ratio in surface water in Montezuma Creek increases dramatically during high flow. That is, during baseflow conditions, most of the arsenic present is in the dissolved form but during periods of high flow, more of the arsenic that is

present is in the particulate phase (Table 5-1B, Appendix E). This indicates that particulates are being mobilized during high flow, suggesting that some erosion occurs from adjacent unvegetated areas, contributing arsenic to Montezuma Creek.

Available surface water data indicate that relatively low dissolved arsenic concentrations in the Depositional Area under current conditions. The relatively low dissolved arsenic concentrations are due, in part to geochemical attenuation previously described. In addition, although the "total" arsenic concentration of the tailings themselves is in the thousands of mg/kg range (as determined by acid digestion of the tailings), laboratory leaching tests on tailings indicate that only a fraction of this total concentration is water-soluble or available. The pH buffering capacity of the tailings for acidity is high, and this property of the tailings retards the oxidation of arsenopyrite. The arsenic that is released is generated slowly. Once the arsenic enters oxygenated surface water, coprecipitation of ferric arsenate takes place quickly, according to the geochemical processes already described. The ferric arsenate co-precipitate can be filtered from solution by stream sediment material, removed from solution by adsorption on sediments, or transported downgradient during high stream flow in suspended colloidal form.

5.4.4.2 Unnamed Creek

Sources of arsenic in Unnamed Creek at UC-2 were evaluated by comparing the arsenic loads at UC-2 with loads at upstream station UC-1 to evaluate the contribution of sources of arsenic between UC-1 and UC-2. Loading data were compared for both high (April and May) and low flow (late June through September) periods in 1999 in the following table. Percentage contributions from upgradients stations were calculated as described before.

Sources of Total Arsenic Loading at UC-2, 1999 Data

Date	4/19/99	4/26/99	5/24/99	6/30/99	7/29/99	9/14/99
UC-1	0.23 ppd (32%)	0.25 ppd (26%)	0.20 ppd (30%)	0.11 ppd (81%)	0.03 ppd (58%)	0.01 ppd (36%)
Other Sources	0.47 ppd (68%)	0.70 ppd (74%)	0.46 ppd (70%)	0.03 ppd (19%)	0.02 ppd (42%)	0.02 ppd (64%)
UC-2	0.70 ppd (100%)	0.95 ppd (100%)	0.66 ppd (100%)	0.13 ppd (100%)	0.06 ppd (100%)	0.03 ppd (100%)

Notes:
ppd = pounds of arsenic per day.
The total arsenic loading attributable to other sources was calculated by subtracting the total arsenic load at UC-1 from the total arsenic load at UC-2.

The Unnamed Creek surface water sampling station UC-1, located immediately downgradient of the historic Greene tailings area, was not impacted by the 1997 release. The Unnamed Creek surface water sampling station UC-2, located immediately upgradient of the confluence of Unnamed Creek and Montezuma Creek, was impacted by the 1997 release. The loading estimates in the table above suggest that the contribution of total arsenic from UC-1 to UC-2 is variable (26 to 81 percent). However, in most cases, UC-1 provides a higher percentage contribution during low flow. Conversely during high flow, in most cases, a higher percentage of total arsenic contribution to UC-2 is from other sources between UC-1 and UC-2. Given that UC-2 was in an area affected by the 1997 release, some of this additional arsenic may be from tailings that remain in the Depositional Area at present from the 1997 release.

5.4.4.3 MFBR

Total and dissolved arsenic loading in the MFBR are presented in Figures 5-15 and 5-16 (Appendix A). Similar to Montezuma Creek, arsenic loading was greatest during spring runoff from April through July. Station MFBR-1 is located above the Montezuma Creek confluence and the Depositional Area (Figure 3-13, Appendix A). Station MFBR-2 is located below the Montezuma Creek confluence. A comparison of total arsenic loading MFBR-2 to loading from upstream stations MFBR-1 and Montezuma Creek station MC-4 is made in the following table to evaluate the contributions from other sources:

Sources of Total Arsenic Loading at MFBR-2, 1999 data

Date	4/19/99	4/26/99	5/24/99	6/30/99	7/29/99	9/14/99
MC-4	8.35 ppd	5.59 ppd	29.94 ppd	1.40 ppd	0.27 ppd (8%)	0.09 ppd (6%)
MFBR-1	ND	ND	ND	ND	3.01 ppd (88%)	1.20 ppd (79%)
Other Sources	ND	ND	ND	ND	0.16 ppd (5%)	0.23 ppd (15%)
MFBR-2	ND	ND	ND	ND	3.44 ppd (100%)	1.52 ppd (100%)

Notes:
ppd = pounds of arsenic per day.
The total arsenic loading attributable to other sources was calculated by subtracting the total arsenic load at MC-4 and MFBR-1 from the total arsenic load at MFBR-2.
ND = not enough flow data for analysis.

Loading estimates were not available for sampling stations MFBR-1 and MFBR-2 during high flow due to the lack of flow information as a result of dangerous river conditions. However,

during lower flow conditions, only 6 to 8 percent of the total arsenic load at station MFBR-2 is from Montezuma Creek. The majority of the total arsenic load in the MFBR (79 to 88 percent) originates from sources upstream of MFBR-1.

Montezuma Creek contributes a greater percentage of dissolved arsenic to the MFBR than total arsenic. Table 5-26 (Appendix E) presents concentrations and loading calculations for arsenic from August 1997 to September 1999 in Montezuma Creek and the MFBR. The total period of record is about 716 days. Because discharge measurements were not always possible, the period of record for the two MFBR sampling points is 569.5 days; the flow at MFBR-2 on April 20, 1999 was estimated at 165 cfs based on MFBR-1 data and previous measurements. As shown on Table 5-26, approximately 2.5 pounds of dissolved arsenic load was added per day between MFBR-1 and MFBR-2. However, Montezuma Creek (as measured at MC-4) contributed only about 1.1 pounds of dissolved arsenic load per day, which indicates 1.4 pounds per day from other sources to the MFBR. Such other sources to the MFBR between MFBR-1 and MFBR-2 may include:

- groundwater input from near-surface perched groundwater seeps downgradient of MC-4;
- mine waste not associated with the Site, such as historic mills; and/or
- historic placer mining along the north side of MFBR.

Near-surface groundwater in the vicinity of MC-4 and the MFBR may be affected by relatively high arsenic concentrations potentially originating from the Depositional Area and may contribute to the increased total arsenic load observed at MFBR-2. Mine waste not associated with the Site, such as historic mills or historic placer mining along the north side of the MFBR may also contribute to total arsenic loading at MFBR-2. This may include entrainment of insoluble arsenic from the stream bed or river bed between MFBR-1 and MFBR-2.

5.4.5 Deposition of Airborne Particulates from the Tailings Piles

A dispersion modeling study was conducted to evaluate the potential for fugitive dust emissions from the Tailings Piles to significantly increase concentrations of arsenic in adjacent soil. A technical memorandum was prepared to present the methods and findings of this evaluation (MFG, 1999b). This technical memorandum, which provides details to support the following summary, is provided in Appendix L.

The evaluation consisted of three primary steps:

- estimate the emission rate of arsenic and other metals that might result from the tailings pile;

- model the transport and deposition of the emitted metals resulting in the calculation of a peak deposition rate; and

- interpret the deposition rate in terms of potential soil concentrations that might result from the addition of these metals over time.

The emission rate was estimated based on a series of conservative assumptions due, in part, to the lack of accurate meteorological data characterizing the Tailings Piles area. The assumptions are conservative in the sense that they likely result in an over-prediction of the true emission rate. The emission rate so estimated is 0.102 tons/acre-year, or approximately 1.77 tons/year for the 17-acre foot-print of the Tailings Piles area.

The Fugitive Dust Model (FDM) was used to model the transport and deposition of particulates from the Tailings Piles. Due to the lack of accurate meteorological data, the modeling analysis was performed using hypothetical worst-case conditions. Based on experience with similar modeling studies at other sites, it is known that maximum air-quality impacts from ground-level sources occur under low wind speed, stable conditions, and close to the source. Accordingly, a constant wind speed of 2.5 meters per second (5.5 miles per hour) was used in the model analysis. With these input conditions, and further conservative assumptions regarding wind variations over a full year, a peak annual dust deposition rate of 0.382 g/m^2-year was estimated. This peak deposition was predicted to occur at a location less than 100 meters to the west of the Lower Tailings Pile.

The peak annual dust deposition rate was used to estimate incremental increases in soil arsenic concentrations that could have resulted during the period in which the Tailings Piles have been present. Further input variables for this calculation are as follows:

- Period of time Tailings Piles have been present: 100 years (conservative because piles have been present for approximately 70 years).

- Soil density: 1.7 tons per cubic yard.

- Depth of dust incorporation into the soil profile: 10 inches.

- Arsenic concentration in the deposited dust: 1,572 mg/kg (average of available concentration data for the Tailings Piles).

Using these conservative input variables, it was estimated that arsenic concentrations would be expected to increase at the point of maximum deposition (100 meters west of the Lower Tailings Pile) by approximately 0.1 mg/kg. This small incremental increase is not expected to significantly increase human exposure and risk at the Site relative to conditions that would be present in the absence of such dust deposition.

5.5 CONCLUSIONS

Eleven COPCs have been identified for the Talache Mine Tailings Site, as set forth in the Work Plan and Quality Assurance Project Plan for the Depositional Area (MFG, Terracon, and Pentec, 1999). As noted in Section 5.1, these are:

- aluminum (Al);
- antimony (Sb);
- arsenic (As);
- cadmium (Cd);
- copper (Cu);
- iron (Fe);
- lead (Pb);
- mercury (Hg);
- selenium (Se);
- silver (Ag); and
- zinc (Zn).

Of these COPCs, arsenic is considered a primary risk driver due to its distribution in environmental media at the Talache Site and its known toxicity to human and environmental receptors. Arsenic at the Site occurs with many of the other COPCs listed above. Therefore, mitigation of arsenic concentrations in the Site media should also address other COPCs. Screening

of the eleven COPCs against background concentrations, and against risk-based screening criteria, is presented separately in human health and ecological risk assessment documents that will be prepared for the Site.

The following conclusions are supported by the data presented and interpreted in Section 5:

- The 1997 release from the Upper Tailings Pile resulted in the distribution of approximately 16,000 cubic yards of tailings to the Lower Tailings Pile and the Depositional Area along the lower Montezuma Creek and Unnamed Creek drainages. Some tailings likely entered the MFBR.

- Response actions implemented in 1997 and 1998 resulted in the removal of 15,000 cy of tailings and soil from the Depositional Area. This material was placed on the Lower Tailings Pile. Though significant cleanup was implemented, residual tailings remain in the Depositional Area.

- Arsenic concentrations in tailings samples from the Talache Tailings Piles range from 535 to 3,660 mg/kg (Table 1, Appendix I).

- The pH of the tailings samples is near-neutral, with pH values ranging between 7.3 and 7.5. A high neutralization potential and a low sulfur content confirm that the tailings are not acid generators, but net acid consumers. The tailings have not generated acidity in the past, are presently not generating acidity, nor are the tailings expected to generate typical acid-rock drainage in the future.

- Leaching properties of the tailings composites were evaluated by analyzing for total arsenic, water-soluble arsenic, and ammonium bicarbonate-diethylenetriamine-pentaacetic acid (AB-DTPA) extractable arsenic. The AB-DTPA and water extractions indicate that only a small fraction of the total arsenic reported in the tailings at the Site is geochemically mobile. In addition, TCLP testing of the tailings samples revealed that the tailings are not toxic with respect to arsenic.

- Arsenic concentrations in soil samples collected from upland reference areas averaged about 25 mg/kg compared to average arsenic concentrations of over 500 mg/kg in upland locations within the Depositional Area (Table 5-17, Appendix E). Arsenic concentrations in wetland reference areas averaged about 165 mg/kg compared to almost 400 mg/kg in wetland Depositional Area soil samples.

- Groundwater analyses and "fingerprinting" through the use of Piper and Stiff diagrams have identified two sources of arsenic and iron, one affecting the near-surface, alluvial aquifer and the other affecting a deeper, bedrock aquifer. The alluvial aquifer carries water that is calcium-bicarbonate in composition; the bedrock aquifer transports water that is sodium-bicarbonate in composition.

- Downgradient of the Tailings Piles, in the Depositional Area, the shallow and deep groundwaters merge. The major ion fingerprint of groundwater in the Depositional Area becomes a mixture of both water types.

- Natural attenuation of arsenic takes place as shallow groundwater moves downgradient through soil and colluvium. Over 99 percent of the dissolved arsenic in groundwater within the Lower Tailings Pile (well 610A, 50.1 mg/L, Figure 4-11, Appendix A) is removed from groundwater a short distance downgradient (well 612C, 0.193 mg/L); and additional dissolved arsenic is removed from groundwater further downgradient (well 613B, 0.089 mg/L). Concurrently, iron concentrations in groundwater are reduced from 22.6 mg/L (well 610A) to 3.7 mg/L (well 612C) and 3.2 mg/L (well 613C, Figure 4-11, Appendix A).

- The attenuation of arsenic in groundwater is related to the presence of dissolved iron which leads to conditions that enhance natural attenuation of arsenic in groundwater. At the near-neutral pH of the Tailings Piles and in the Depositional Areas, any dissolved iron must occur in the chemically-reduced, ferrous (+2) iron oxidation state. As groundwater becomes oxygenated, the ferrous iron is oxidized to the water-insoluble, ferric (+3) iron oxidation state and precipitates from solution as ferric hydrous-oxide. Evidence of this oxidation can be seen in the precipitation of "yellowboy" in the seeps at the toe of the Upper and Lower Tailings Piles. In

this aerobic environment, dissolved arsenic would be expected to co-precipitate with ferric hydrous-oxide, as an insoluble ferric arsenate.

- Immediately following the 1997 release, dissolved arsenic concentrations in Montezuma Creek downstream of the Tailings Piles commonly exceeded the AWQC for arsenic of 0.15 mg/L. Dissolved arsenic concentrations decreased to below the arsenic AWQC in September 1997 and have remained below the arsenic AWQC since.

- Arsenic and metal loading in Montezuma Creek increase during periods of high flow from early April to June, and are lowest during periods of low flow, from September through February. Total and dissolved arsenic loading in Montezuma Creek tended to be greatest at MC-4, the furthest downstream station.

- Surface water data indicate that the total/dissolved arsenic ratio in surface water in Montezuma Creek increased during 1999 high flow associated with spring runoff. That is, during baseflow conditions, most of the arsenic present is in the dissolved form but during periods of high flow, more of the arsenic that is present is in the particulate phase. This indicates that particulates are being mobilized during high flow, suggesting that some erosion occurs from adjacent unvegetated areas.

- A significant portion of the sediment transported from the Depositional Area during spring runoff in 1999 may be due to a combination of removal efforts in the summer and fall of 1998 followed by the greater than average runoff that occurred in 1999. It is expected that as vegetation becomes better established in the areas disturbed by removal activities that sediment transport from the Depositional Area during high flow will decrease.

- Comparison of the total arsenic loadings at MC-2 (upgradient from the Depositional Area) and MC-4 indicates that the majority of total arsenic loading to MC-4 is from sources upstream of MC-2 (67 percent to over 100 percent). Some of the arsenic loading at MC-4 (2 to 34 percent) is contributed by Unnamed Creek. Potential sources of arsenic to the Montezuma Creek drainage above MC-2 include

drainage from old mine workings flowing out of the Atlanta Mine 900-level adit portal and into upper Montezuma Creek as well as the waste rock pile associated with the 900-level adit, and other mine workings in the upper Montezuma Creek basin.

- During low flow conditions, Montezuma Creek contributes only 6 to 8 percent of the total arsenic load in the MFBR at station MFBR-2. The majority of the total arsenic load in the MFBR (79 to 88 percent) originates from sources upstream of MFBR-1 in the Sawtooth Wilderness Area.

- Montezuma Creek contributes a greater percentage of dissolved arsenic to the MFBR than total arsenic. As shown on Table 5-26, approximately 2.5 pounds of dissolved arsenic load were added per day to the MFBR between MFBR-1 and MFBR-2. However, Montezuma Creek (as measured at MC-4) contributed only about 40 percent of that amount which indicates that other sources in the MFBR between MFBR-1 and MFBR-2 are contributing 60 percent of the dissolved arsenic load. Such other sources to the MFBR may include: groundwater input from near-surface perched groundwater seeps downgradient of MC-4; mine waste not associated with the Site, such as historic mills; and/or historic placer mining along the north side of MFBR.

6.0 BIOLOGICAL RESOURCES

The following subsections summarize the findings of the aquatic and terrestrial biological resource evaluations. Detailed discussion of these evaluations are provided in appendices, referenced where appropriate below.

6.1 AQUATIC RESOURCE CHARACTERIZATION

Physical habitat and aquatic biological surveys were performed in surface waters of Montezuma Creek, Unnamed Creek, and the MFBR to characterize habitat and biotic communities within streams along the path of the 1997 release (Pentec 1998b; Terracon 1999). The physical habitat and biological studies summarized here were conducted in accordance with methodologies proposed in earlier work plans to support aquatic and terrestrial risk assessments (Pentec 1998a; MFG, Terracon, and Pentec 1999). The evaluation of physical habitat conditions followed a watershed analysis approach, where the stream network was classified into geomorphic segments with similar characteristics. Under this approach, the relative sensitivity of the various segments to changes in watershed inputs and habitat conditions can be characterized.

The biological sampling summarized here was focused on ascertaining whether, to what extent, and by what physical or chemical mechanism(s), tailings in the Depositional Area caused or are causing changes in biological community structure or function. Biological data collected included indices of redband trout abundance, growth, and health, as well as indices of benthic macroinvertebrate abundance and diversity. Tissue samples for residue analysis of metal concentrations were collected for both fish and macroinvertebrates. Comparisons of such biological data between areas where tailings were deposited within active stream channels versus areas upstream these depositional reaches were used to characterize differences, and to define, on a more general level, the factors potentially limiting production in the aquatic systems near the site.

6.1.1 Methods

Investigations of physical habitat within Montezuma Creek, Unnamed Creek, and the MFBR in 1998 are detailed in Appendix D-2, along with the results of all 1999 aquatic resource characterization studies. Table 2, Appendix D-2 provides locations and descriptive information

about selected samples sites. In 1999, aquatic resource studies were conducted in Montezuma Creek and Unnamed Creek only. Physical habitat was quantified over six reaches of approximately 100 m to 120 m each (four reaches in Montezuma Creek, two in Unnamed Creek). Biological and habitat surveys conducted in 1998 and 1999 were done at locations UC-1 and UC-2. UC-1 was located in the diverted portion of Unnamed Creek while Site UC-2 is in the unmodified creek channel downgradient of the diversion. As described previously, Unnamed Creek has been restored to its original channel. The physical habitat elements recorded within each specific habitat included: (1) spawning gravel (presence/absence and embeddedness), (2) percentage of pool area, (3) pool depth and cover class, (4) dominant and subdominant substrate, (5) large woody debris (LWD) density and size (6) geomorphic habitat type (i.e., pools, riffles, and cascades), (7) pool type, (8) bankfull width, (9) wetted width, (10) channel type, and (11) pool forming units (e.g., boulders, rootwads, LWD).

To support the physical and biological sampling, conventional water quality sampling at discrete locations and times (i.e., spot-check sampling) was conducted with field probes. Most, but not all spot-check sampling locations corresponded with established surface water sampling locations for the site (Terracon 1998). Parameters evaluated with field probes included temperature, pH, dissolved oxygen, specific conductivity, turbidity, and flow. Measurements were also taken with continuous recording HydroLab units during 1999 field visits at two stations, one upstream from and one within the reach of Montezuma Creek within the Depositional Area. Parameters evaluated with the HydroLab units included temperature, dissolved oxygen (percent saturation and total dissolved concentration), conductivity, total dissolved solids, and pH.

Biological investigations were conducted to assess fish population abundance, growth, distribution and health in Montezuma Creek within and above the area of tailings deposition. Double-pass electroshocking fish population assessments were conducted upstream from the confluence of Montezuma Creek with the Middle Fork Boise River in July and September 1999. Ten fish population subreaches (e.g., FR-x, Appendix D-2, Table 7) were sampled separately to identify where in the drainage the fish were captured. These reaches comprised over 90% of the habitat available from the confluence of Montezuma Creek with the MFBR, upstream to where Montezuma Creek crosses Sawmill Road. In some, but not all cases, these fish population subreaches corresponded to the six reaches evaluated formally for physical habitat. In addition to this overlapping relationship between the fish population studies and the quantitative physical

habitat studies, some physical habitat elements (e.g., wood loading, geomorphic habitat type as a pool/riffle, etc.) were recorded at each location where fish were captured; these latter "biophysical" data were therefore acquired over and above the specifications in the work plan (MFG, Terracon, and Pentec 1999) but were considered relevant parameters to identify during the field investigations. Finally, a total of 36 multi-plate invertebrate samplers were deployed over six stations in Montezuma Creek and Unnamed Creek to address species diversity and abundance of colonizing invertebrates, and to assess potential uptake of metals into the base of the animal food web.

6.1.2 Results

6.1.2.1 Physical Habitat

The MFBR upstream from Kirby Dam showed no measurable impacts to physical habitat conditions related to the 1997 tailings release in 1998 studies, nor was there qualitative evidence of impact identified during 1999 field studies.

The low to moderate gradients (~1-3%) throughout most of Montezuma Creek within the Depositional Area are generally better for trout production than the steeper gradients documented in physical habitat reaches above the Depositional Area (4 to 10%) (Appendix D, Table 6). However, the lack of channel complexity resulting from past stream channelization, low wood loading, and poor riparian contributions reduce the present ability of this habitat to support trout populations in high density (Appendix D-2, Table 10 and Attachment Tables 6 to 8). The numbers of trout in the Depositional Area were reduced relative to upstream locations, especially between the confluence of Unnamed Creek and FS 205, a fish population subreach (i.e., FR-3, Appendix D-2, Table 7) that also corresponded with a physical habitat reach (i.e., MC_{PHR} I). With few exceptions this lack of wood and riparian coverage could not be attributed to tailings deposition impacts. In some areas, it appeared that wood was removed from the channel to facilitate tailings removal; however, riffle habitat dominated over pool habitat within the Depositional Area reaches. The abundant tailings observed in October 1998 within the Depositional Area stream reaches were not observed in either Montezuma or Unnamed Creeks in July or September 1999 surveys, suggesting that tailings formerly documented in the active stream channel were flushed with the spring snow melt. In general, the geomorphic character of the Montezuma Creek channel in both 1998 and 1999 surveys within the Depositional Area could not be attributed to the 1997 release, but previous

tailings removal activities have locally exposed banks causing lateral erosion and a loss of riparian vegetation in isolated locations.

At the time of the aquatic resource evaluation, Unnamed Creek flowed in a constructed ditch from just below the historic Greene tailings to about 80-m upstream of its confluence with Montezuma Creek. This channelized portion of Unnamed Creek, as well as much of lower reach of the creek shortly upstream of its confluence with Montezuma Creek, offers little useable habitat for fish. The naturally warm waters in Unnamed Creek, which originates in a hot spring, makes it unsuitable for trout during most of the year, although the lower portion of the original creek bed appeared to be a meandering meadow channel that would have provided good thermal habitat to trout in the winter, when available. In addition, large numbers of dace likely utilized the original creek channel. At present, the highest dace concentrations are observed at the confluence of Unnamed Creek with Montezuma Creek, and much further upstream, where Unnamed Creek flows out of the historic tailings pile.

Spawning redband rainbow trout lay their eggs from April to early June in areas 2 ft^2 or less with substrate ranging from 0.5 cm to 4.1 cm gravel. In areas where fines (<6.35 mm) are greater than 25%, survival rates decline. Incubation of the redds occurs from spring to midsummer. Survival is dependant amount of scouring or siltation that occurred during incubation. Once the trout have emerged, summers (May to December) are spent in areas that provide cover from predators and where they can forage. Redband rainbow trout prefer water temperatures between 13 to 21°C (lethal temperature is 26°C). In winter (January to April), once temperatures drop below 4°C, redband rainbow trout move into interstitial spaces in the cobble/gravel or into pools (Behnke 1992, Magee et al. 1996, Meehan 1991, Simpson and Wallace 1982, Wydoski and Whitney 1979).

Spawning longnose dace lay their eggs in spring, when temperatures are above 12°C in riffles with gravel substrate. Incubation lasts 7 to 10 days. Once the dace have emerged, summers are spent in swift riffles, and are rarely found in areas with muddy substrates. Dace will stay in these areas while the water temperature ranges from 13 to 21°C. In winter, it is thought longnose dace prefer pools (Simpson and Wallace 1982 and Wydoski and Whitney 1979).

Spawning shorthead sculpin lay their eggs in the spring, however their habitat preferences are unknown. Once the sculpins have emerged, they prefer cold, fast riffles with rubble/gravel

substrates, and prefer temperatures less than 15°C, but will tolerate temperatures up to 26°C (Simpson and Wallace 1982 and Wydoski and Whitney 1979).

6.1.2.2 Conventional Water Quality and Hydrology

Conventional water quality parameters monitored with continuous satellite probes documented high maximum and extreme diurnal temperature fluctuations in lower Montezuma Creek at station MC-4. This finding alone may be the most limiting factor preventing significant use of the lower portion of Montezuma Creek habitat by redband rainbow trout during the summer months. The high and variable temperatures in this portion of the Montezuma Creek drainage may be the result of the limited riparian vegetation, and the contributions of thermally heated water from Unnamed Creek. The high temperatures and extreme diurnal fluctuations were not observed at stations above the Depositional Area (Appendix D-2, Figures 4, 6, 8 10).

The chronological record of hydrological manipulations at this site has not been formally recorded, to our knowledge, although numerous changes have been implemented that have affected habitat availability and quality in Montezuma Creek, and especially Unnamed Creek. According to the USGS 7.5 minute quadrangle of the area, and through conversations with local residents, the Powerhouse Flume formerly cut across the site and drained south of the Montezuma Creek channel. This information suggests that these thermally heated waters did not mix with those of Montezuma Creek. It is also unclear to what extent Unnamed Creek historically mixed with Montezuma Creek. Following the tailings deposition event, Unnamed Creek and the Powerhouse Flume were diverted into a ditch around the northern edge of the Depositional Area within the Unnamed Creek basin and its surrounding wetland habitats. This diversion dehydrated the original channel of Unnamed Creek resulting in a temporary loss of biotic resources for the benefit of removing areas of deposited tailings. The loss of biotic resources following the diversion was not quantified at that time, but was likely to have resulted in the death of resident aquatic plants, fish, and amphibian populations. Unnamed Creek was recently diverted back into its original channel to encourage recovery of biotic resources.

In October 1998 flows from Unnamed Creek (0.7 cfs) constituted 53% of the base flow recorded in Montezuma Creek at water quality sampling station MC-4 (1.373 cfs). At that time, the adit discharge (0.12 cfs) was nearly twice the stream flow measured downstream at Sawmill Road MC_{PHR} III (0.073 cfs), suggesting that Montezuma Creek loses water to groundwater under base flow

conditions (Appendix D-2 Attachment Table 5). The 1999 field studies demonstrated that base flow was not yet achieved by late July, and that base flow conditions were more representative of conditions measured in September 1999. At both times, however, flows measured at the uppermost station (MC-1), exceeded those measured at MC-2 and MC-3P (MC-3T was within the braided reach, and therefore did not represent total flows from the system; see Figure 3-13). Because MC-3P was upstream from the confluence of Unnamed Creek, it can be concluded that under post-snowmelt conditions that Montezuma Creek loses surficial flow to groundwater as the stream flows down gradient into the wetland/depositional zone. The flows from Unnamed Creek measured in July and September 1999 did not vary (i.e. 0.4 cfs on both dates); thus, when these contributions are subtracted from the flows measured at MC-4 (1.1 cfs in July, 0.6 cfs in September), it appears that there is no further loss of flows to groundwater between MC-3P and MC-4. The effect of this flow regime on the ability of Montezuma Creek to support aquatic life will be explored further in the evaluation of ecological risks at the site.

6.1.2.3 Biological Investigations

Results from fish abundance and distribution surveys conducted in 1998 and 1999 are detailed in Appendix D-2 (Tables 12 to 15). Three fish species were captured in Montezuma Creek, including redband rainbow trout, long-nosed dace, and shorthead sculpin in 1998 and 1999. Total abundance of these three species at all Montezuma Creek sites also appeared to increase between the 1998 and 1999 sampling events, from 78 fish to 123 fish, respectively. Total estimated redband trout densities appeared to increase in Montezuma Creek from 0.35 fish/meter in 1998 to 0.51 fish/meter in 1999. Long-nose dace was the predominant fish species collected in Unnamed Creek in 1998 and 1999, while only a few redband rainbow trout were collected in this small stream. No sculpins were collected in Unnamed Creek. All three species were collected or observed in the Middle Fork Boise River in 1998 presence/absence surveys, although the trout captured in 1998 were hatchery trout, not wild trout; in 1999 roughly two-thirds of the trout captured (via hook and line) were of wild origin. In Unnamed Creek only dace and wild redband trout were captured, and all trout captured were obtained near the confluence with Montezuma Creek.

In Montezuma Creek, trout densities in reaches upstream of the Depositional Area were at least twice those measured within Depositional Area in 1999 (1998 data are qualitative). The correlation of low trout densities with both the location of the Depositional Area and within areas of poor physical habitat, highlights the need to carefully consider habitat elements in the ecological

risk assessment of the site. Trout were highly associated with in-channel wood and pools. Measures to increase these habitat components likely increase the productivity of the system, which is currently producing below rates recorded from the ecoregion.

Dace, sculpin, and trout samples from Montezuma and Unnamed Creeks were analyzed for tissue metal concentrations to support subsequent terrestrial ecological risk assessments. While the data are reported (dry weight basis) in Appendix D-2 (Attachment Tables 14 to 17), they are not interpreted at this time.

Macroinvertebrates were sampled for species diversity, abundance and tissue residues of total metals. These samples have yet to be completely processed, although organisms collected from the multi-plate samplers provided sufficient tissue biomass for metals analysis from only two stations. Interpretations of these data are not yet available, although specimens from the following families have been observed: Ephemeroptera, Plecoptera, Odonata, and Chironomidae.

6.1.3 Summary

- Physical habitat characteristics appear to be a factor, among others, limiting trout production within the Depositional Area of Montezuma Creek and Unnamed Creek. With few exceptions, physical habitat limitations in Montezuma Creek result from poor wood loading and hydraulic factors in the channel that limit creation of holding pools for rearing.

- With the exception of discrete areas where tailings removal activities were clearly disruptive to riparian conditions, the effects of the 1997 release on in-channel and riparian physical habitat could not be easily discerned.

- Natural limitations are likely for physical habitat, perhaps in conjunction with a very old disturbance regime that has limited the riparian habitat in the reach (e.g., grazing), and that in turn has manifest over time to yield channel conditions that are not as favorable to the redband rainbow trout.

- Additional assessments of water quality, physical habitat, and biological community structure and function will be assessed in the baseline ecological risk assessment.

6.2 TERRESTRIAL RESOURCE EVALUATION

6.2.1 Characterization of Terrestrial Vegetation Community

Terrestrial vegetation community composition was assessed at a subset of 30 upland and wetland sites as part of the August 1999 sampling work to characterize the vegetation communities comprising different habitat types occurring in reference, depositional and removal areas.

6.2.1.1 Methods

Vegetation community composition was assessed in August 1999 using visual estimation and line intercept techniques. The tree and shrub layer compositions were visually estimated within a 10-m radius circle of the mid-point of each sampling site to determine the percent cover for dominant and co-dominant species. Average percent cover for the plant communities was calculated by adding the percent cover values for species from all the sites within a community type (i.e., upland reference forest) and dividing by the number of sites.

Composition in the herbaceous layer was determined along two 10-m transects at each site. All plant species that intersected the transect length were recorded as present. Species which intersected a wire point at 0.3 meter intervals along a transect were identified and counted. These totals were used to determine relative abundance (RA) within the community type for each species. Relative abundance was determined by adding totals for each species from all sites within a community type and dividing by the number of sites. A minimum of 60 points was collected from each sampling site. The first of these transects was aligned in the direction most representative of the plant community being sampled. The second transect was aligned at 90 degrees from the first.

Sample sites were located by a combined technique using: (1) handheld global positioning system (GPS) as defined by the GIS-generated 35-m grid; (2) field location by compass, physical landmark, and distance measurement. To assist in identification of sampling sites, the defined sites were plotted on a Site map and aerial photograph, as shown in Figures 3-11 and 3-12.

For each assessed site, the GPS reading was recorded and the location marked on a topographic map and an aerial photograph. A stake was driven to permanently mark the site, and the aboveground portion of the stake was flagged with fluorescent tape to facilitate the finding of these locations in subsequent efforts.

6.2.1.2 Results

Reference Areas

Four major plant community types were assessed to determine composition. These communities are (1) upland forest, (2) upland meadow, (3) wetland scrub-shrub-forested, and (4) wetland wet meadow. In addition, each community was characterized by deposition status (deposition or reference), and among sites located in the Depositional Area, characterized by removal status (removal/no removal). The sampling results are discussed below according to plant community types and deposition status.

Upland Reference Meadow (Sites 47, 48 and 49)

The upland meadow reference communities are located east of Unnamed Creek and west of FS268 (Sites 47, 48, and 49). The plant community is composed of herbaceous growth, with a very sparse shrub component of squaw current (*Ribes cereum*) and pacific willow (*Salix lasiandra*). The dominant herb species are elk sedge (*Carex geyerii*), hood sedge (*Carex hoodii*) and Kentucky bluegrass (*Poa pratensis*) and thickstem aster (*Aster integrifolius*). A sub-dominant component included western wheatgrass (*Elymus smithii*) and rough horsetail (*Equisetum arvense*). Field sampling results are discussed below and exhibited in Table 6-1, Appendix E.

Elk sedge, hood sedge, Kentucky bluegrass and thickstem aster were the dominant plant species on sites 47, 48 and 49 with relative abundance values of 14, 11, 6.7 and 5.7 respectively. Bearded wheat grass (*Elymus smithii*), rough horsetail, yarrow (*Achillea millefolium*), showy daisy (*Erigeron speciosa*), dalmatian toadflax (*Linaria dalmatica*), beaked sedge (*Carex utriculata*), bearded wheat grass and northwest cinquefoil (*Potentilla gracilis*) were present with RA values between 1 and 4 (Table 6-1, Appendix E).

Squaw current, pacific willow and lodgepole pine were noted as present in the tree and shrub layers, with average estimated percent cover values of 2 or less (Table 6-1, Appendix E).

Upland Deposition Meadow (Sites 20, 22, and 23)

Two of the upland deposition meadow communities are located north of Montezuma Creek and south of the Historic Powerhouse Flume (Sites 20 and 23), and one is located north of Unnamed Creek just east of FS205 (Site 22). All three of these sites are removal areas and dominated by bare ground due to poor regrowth. The plant community is composed of sparse herbaceous growth dominated by two weedy species, prostrate knotweed (*Polygonum aviculare*) and red sand spurry (*Spergularia rubra*). There were no tree or shrub layers in the upland deposition meadows. Field sampling results are discussed below and exhibited in Table 6-2, Appendix E.

Sampling results showed bare ground was the most common cover encountered with a relative value of 21.7. Knotweed and red sand spurry were the dominant plants in the community with RA values of 17 and 11, respectively. Kentucky bluegrass, Idaho fescue, intermediate wheatgrass (*Elymus intermedium*), lupine (*Lupinus perennis*), western wheatgrass (*Elymus smithii*) and dalmatian toadflax were present with RA values ranging between 1 and 3.

Upland Reference Forest (Sites 35, 36, 37)

The upland reference forest plant community is located in two areas adjacent and upgradient of the Depositional Area. The first area is east of FS268 (Site 35). The second area is west of FS268 and south of Unnamed Creek (Site 36). A third area is north of the Greene Tailings, between Unnamed Creek and Historic Powerhouse Flume (Site 37). The communities are made up of a tall conifer tree layer dominated by douglas fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*), with a sub-dominant component of lodgepole pine (*Pinus contorta*).

The upland forest community appears to be a mature forest with little evidence of disturbance. Characteristics of the community to the north of Greene tailings suggested fire disturbance within the last 25-30 years, including single-age, dog-hair stands of ponderosa pine, and mono-typic stands of pinegrass. Field sampling results are discussed below and exhibited in Table 6-3, Appendix E.

Douglas fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) dominated the overstory with average estimated covers of 23 percent and 20 percent, respectively. Estimated cover for Lodgepole pine was 3 percent (Table 6-3, Appendix E).

Lodgepole pine, squaw current and serviceberry (*Almelanchier alnifolia*) dominated the shrub cover with average estimated percent covers of 12, 9 and 8, respectively. Oregon-grape (*Berberis repens*) and quaking aspen (*Populus tremuloides*) were also present.

The herb layer was dominated by pinegrass (*Calamagrostis rubens*) and elk sedge, with relative abundance (RA) values of 15 and 14.3, respectively. Forest litter was also frequently observed with a RA value of 14.3. Thickstem aster, Oregon-grape, broad petal strawberry (*Fragaria virginiana*), Yarrow, Idaho fescue, Pussy toes (*Antennaria microphylla*), and bearded wheatgrass (*Elymus hispidus*) were also present with RA values between 1 and 3 (Table 6-3, Appendix E).

Upland Deposition Forest (Sites 18, 19, 21)

The first upland deposition forest plant community site is located south of the confluence of Unnamed Creek and the Historic Powerhouse Flume (Site 18). The second area is located northeast of Montezuma Creek, in the northeast quadrant formed by the intersection of FS207 and FS268 (Site 19 and 21). The forest overstory is dominated by ponderosa pine with a sub-dominant component of quaking aspen. Quaking aspen is the dominant shrub and elk sedge is the dominant herbaceous species. Sampling results are discussed below and exhibited in Table 6-4, Appendix E.

The overstory is dominated by ponderosa pine with an average estimated percent cover of 27 and quaking aspen with 15 percent. Estimated cover for Lodgepole pine was 3 percent (Table 6-4, Appendix E).

Quaking aspen dominated the shrub cover with average estimated percent cover of 23. Serviceberry and Oregon-grape were also common with 6 and 4.3 percent estimated cover, respectively. Woods rose was also present. (Table 6-4, Appendix E).

The herbaceous layer was dominated by elk sedge with a RA value of 16.3. Thickstem asters, and Kentucky bluegrass were sub-dominant components, with RA values of 8.7 and 6.3 respectively. Tailings and forest litter were also significant with RA values of between 8 and 9.

Dalmatian toadflax, Alsike clover (*Trifolium hybridum*), Hood sedge, Bentgrass, dandelion (*Taraxacum laevigatum*), and mountain brome (*Bromus carinatus*) were all present with RA values between 1 and 4 (Table 6-4, Appendix E).

Wetland Reference Meadow (Site 57, 58, 60 and 80)

The wetland reference meadow communities are located southwest of Montezuma Creek and east of FS205, behind the U.S. Forest Service buildings (Sites 57, 58, 60, 80). There were no tree or shrub layers in the wetland reference meadows. The plant community is composed of herbaceous growth dominated by beaked sedge (*Carex utriculata*), Nebraska sedge (*Carex nebrascensis*), and slender rush (*Juncus tenuis*). Dense monotypic stands of these species were observed throughout the sites. Field sampling results are discussed below and exhibited in Table 6-5, Appendix E.

Beaked sedge, Nebraska sedge and slender rush were the dominant plant species with relative values of 31, 14 and 11, respectively. Bentgrass was a subdominant species with an RA value of 5.8. Sticky willow weed (*Epilobium watsonii*), False groundsel (*Senecio pseudoaureus*) Douglas spirea (*Spirea douglasii*) and litter all were present with RA values of less than 1 (Table 6-5, Appendix E).

Wetland Deposition Wet Meadow (Sites 14, 15, and 16)

The wetland deposition meadow communities are located in the area south of Unnamed Creek and north of Montezuma creek. The non-removal zone (sites 14 and 15) plant community is composed of dense herbaceous growth dominated by slender rush (*Juncus tenuis*), Nebraska sedge and beaked sedge. Geyers willow and pacific willow were found on the fringes of the meadow and dominated the shrub layer. There were no trees represented in the wetland deposition meadows. The plant community in the removal area (site 14) was dominated by bare ground and had intermediate wheatgrass and Kentucky bluegrass dominating the herbaceous layer. Field sampling results are discussed below and exhibited in Table 6-7, Appendix E.

Sampling results showed slender rush and Nebraska sedge were the dominant plant species with RA values of 24 and 12, respectively. Beaked sedge was sub-dominant species with RA value of 4.7 In the removal area, bare ground was present with an RA value of 26, there was no shrub

layer, and intermediate wheatgrass, Kentucky bluegrass and yarrow were dominant herbs with RA values of 12, 11, and 10, respectively. These plants indicate an upland composition and are probably present due to a change in surface water hydrology (Table 6-7, Appendix E). Geyers willow and pacific willow were present in the non removal areas with 10 and 5 percent cover, respectively.

Wetland Reference Scrub-Shrub Forested (Sites 53, 54, 55, 56, and 59)

The first wetland scrub-shrub forested plant community is located along the riparian area of Montezuma Creek, northwest of the intersection of FS207 and FS268, and downstream of the FS268 crossing with Montezuma Creek. The second area is located south of Unnamed Creek, and west of FS268. The wetland scrub-shrub forest communities are composed of riparian forest (sites 53 and 55) and willow thickets with inclusions of trees (sites 54, 56, 59). The tree layer is composed of ponderosa pine, willow species (*Salix sp.*), quaking aspen and lodgepole pine. In the shrub layer, Geyers willow (*Salix geyerana*) and Pacific willow (*Salix lasiandra*) are dominant, while red-oiser dogwood (*Cornus stolonifera*) and alder (*Alnus incana*) are common components. The herbaceous layer is dominated by grass species including bentgrass, Kentucky bluegrass, northwest manna grass (*Glyceria occidentalis*) and beaked sedge. Field sampling results are discussed below and exhibited in Table 6-6, Appendix E.

The overstory generally consisted of inclusions of trees throughout a shrub community and was dominated by ponderosa pine with a average percent cover of 18. Quaking aspen, willow species, and lodgepole pine were also common with average percent cover values ranging from 2 to 4 (Table 6-6, Appendix E).

Geyers willow and Pacific willow dominated the shrub cover with estimated 17 percent cover for each. Red-osier dogwood and alder were also common with average percent covers of 3.4 and 1.4, respectively. Bearberry honeysuckle, squaw current, prickly current, alder buckthorn and Douglas' spirea were also present (Table 6-6, Appendix E).

Bentgrass, Kentucky bluegrass, northwest manna grass and beaked sedge are the dominant plant species with relative values of 13.4, 9.4, 7.8 and 5.2, respectively. Litter was also common with a 4.4 RA value. Rough horsetail, field horsetail, sticky willow weed, tufted hairgrass (*Deschampsia cespitosa*), squaw current, twisted stalk (*Streptopus amplexifolius*), red-oiser

dogwood, broad petal strawberry, toad rush (*Juncus bufonius*) and sword leaf rush (*Juncus ensifolius*) were also common with RA values between 1 and 4.4 (Table 6-6, Appendix E).

Wetland Deposition Scrub Shrub Forest (Sites 1, 2, 3, 9, 10, 11, 16)

The first wetland deposition scrub shrub forest plant community begins in the riparian area of Montezuma Creek just upstream from the confluence with Unnamed Creek, and continues southwest toward FS205 (Sites 1 and 3). The second area is north of Montezuma Creek and south of Unnamed Creek below the confluence with the Historic Powerhouse Flume (Site 2). The third area is southeast of the intersection of FS207 and FS268 (Site 11). The fourth area is in a removal zone, south of Unnamed Creek upstream from the confluence with the Historic Powerhouse Flume (Sites 9 and 10). The last site (Site 16) is located at the edge of the removal area southwest of the confluence of the Historic Powerhouse Flume and Unnamed Creek. Ponderosa pine and quaking aspen dominate the open canopy forest overstory with Geyers willow and pacific willow as the dominant shrubs. Quaking aspen is also a sub-dominant shrub component. Beaked sedge, bentgrass, Kentucky bluegrass, rough horsetail (*Equisetum hymale*) and Nebraska sedge generally dominate the understory. Sampling results are discussed below and exhibited in Table 6-8, Appendix E.

Ponderosa pine and quaking aspen dominated the tree layer with average estimated percent covers of 4.1 and 3.8 percent. Geyers willow and pacific willow had the highest average shrub cover values with 9.8 and 10.7 percent, respectively. Quaking aspen also had relatively high values with an average estimated percent cover of 3.8. Service berry, red-osier dogwood, lodgepole pine and prickly current (*Ribes lacustre*) were also present. Three dead lodgepole pines, cause of death unknown, were noted in Site 1 (Table 6-8, Appendix E).

The herbaceous layer is dominated by beaked sedge, bentgrass, Kentucky bluegrass, rough horse tail, field horse tail, and Nebraska sedge with a RA values of 8.5, 11.0, 4.3, 4.2, 4.3 and 4.0, respectively. Bare ground was prevalent with an RA value of 12.5. This value was skewed upwards by the high values of bare ground observed in sites 9 and 10, which were removal sites. Litter and water were common with RA values ranging from 1.2 to 1.7 (Table 6-8, Appendix E.).

6.2.1.3 Summary

Four major plant community types (1) upland forest, (2) upland meadow, (3) wetland scrub-shrub-forested, and (4) wetland wet meadow and its deposition status (deposition or reference) were assessed to determine species composition using visual estimation techniques and 10 meter transects. The dominant components of the plant communities are as follows.

- Upland Reference Meadows - Elk sedge, hood sedge, Kentucky bluegrass and thickstem aster.

- Upland Deposition Meadow - Bare ground, knotweed and red sand spurry.

- Upland Reference Forest- Douglas fir and ponderosa pine dominated the overstory, lodgepole pine, squaw current and serviceberry dominated the shrub cover, and the herb layer was dominated by pinegrass and elk sedge.

- Upland Deposition Forest - Ponderosa pine dominated the overstory, quaking aspen dominated the shrub cover and the herbaceous layer was dominated by elk sedge.

- Wetland Reference Meadow - Dominated by beaked sedge, Nebraska sedge, and slender rush.

- Wetland Deposition Wet Meadow - Slender rush and Nebraska sedge were the dominant plant species, Geyers willow and pacific willow were present.

- Wetland Reference Scrub-Shrub Forested – Overstory inclusions dominated by ponderosa pine, Geyers willow and Pacific willow dominated the shrub cover, and Bentgrass, Kentucky bluegrass, northwest manna grass and beaked sedge are the dominant herbs.

- Wetland Deposition Scrub Shrub Forest -Ponderosa pine and quaking aspen dominated the tree layer, Geyers willow and pacific willow had the highest average shrub cover and beaked sedge, bentgrass, Kentucky bluegrass, rough horse tail, field horse tail, and Nebraska sedge dominated the herb layer.

Both the field plots and terrestrial vegetation characterization indicated that the plant populations at the Site are generally healthy, especially in areas not affected by the removal efforts. That is, visible signs of stressed vegetation were generally lacking, including in removal areas where seeded and invading new growth is rapidly covering the soil. A possible exception to this conclusion relates to the reduced growth of plants in the seeding trails for test plots in the Depositional Area. Such reductions in growth are consistent with the potential for sublethal toxic effects possibly related to arsenic and/or other soil contaminants. As discussed in more detail in the BERA, the original design of the seeding plot study intended to distribute individual study plots across locations within both the Depositional Area and reference area, corresponding with sites used in other components of the 1999 studies. This design was intended in part to reduce the influences of microclimatic and microenvironmental variables, such as wind protection, shade, and soil texture. When locating the actual test plots, it was determined that the random distribution of the plots across the site was not feasible; instead all reference area plots were situated in one location. All Depositional Area plots were situated in another location. Thus, the original intent of eliminating microclimate and microhabitat as variables was not achieved. Specifically, the plots in the Depositional Area were in an open area lacking shade and wind protection and consisting of well drained sandy soil. In contrast the reference area plots were in locations marginally protected from wind, with partial shade and consisting of loamy soil.

The influence of tailings on plant germination and growth between the Depositional and reference area seeding plots cannot be quantitatively evaluated. Both tailings related and tailings unrelated factors (or a combination of both) potentially affected the results of the seeding plot study. Factors which potentially affected the results of the seeding plot study are numerous, and include microclimate (e.g. shading, wind protection), microhabitat (e.g. soil moisture, particle size distribution, organic matter content), soil contaminant concentrations, and soil amendments used during the study. Seeding germination and emergence was consistently greater in the Depositional Area plots relative to the reference area plots. However, plant biomass production at 90 days post-seeding was consistently and significantly lower in the Depositional Area plots compared to biomass production in the reference area plots. Arsenic concentrations in plant tissues from the Depositional Area were significantly higher than arsenic concentrations in plant tissues from the reference area plots. Fertilization and soil amendments did not have a statistically significant effect on biomass at the end of the seeding plot study. Arsenic concentrations in plant tissues from Depositional Area plots treated with fertilizer were significantly lower than arsenic concentrations in plant tissues from Depositional Area plots without fertilizer treatments. Soil amendments had variable impacts on seedling

emergence, depending on the amendment evaluated. Results of the seeding plot study support the hypothesis that the tailings are not associated with adverse effects on seedling emergence. The results of the seeding study are also consistent with the hypothesis that tailings are associated with reductions in plant growth, when growth is expressed as total plant biomass per unit area. The overall results appear to be consistent with the assumption that metals in tailings may be associated with chronic phytotoxicity as it relates to a potential reduction in plant biomass, but cannot be used to provide definitive confirmation of this assumption. Based on the results of the seeding plot study, it is concluded that tailings are not associated with adverse effect on seedling emergence, but may be associated with potential reductions in plant biomass production. The results of this study do not appear to support a conclusion that the presence of tailings will preclude the long-term revegetation of the Depositional Area, although initially the plant biomass in the revegetated tailings may be lower than the currently existing plant biomass in comparable reference areas without tailings.

Several dead lodgepole pines were observed in the Wetland Deposition Scrub Shrub Forest. These deaths may have resulted from the depth of material deposited over the root system, change in hydrologic conditions associated with the soils, insect infestations, or phytotoxicity. In addition, removal areas exhibited sparse growth and were dominated by bare ground. For most plants throughout the Depositional Area no overt symptoms of phytotoxicity were observed.

6.2.2 Characterization of Metals Content in Terrestrial Vegetation

Samples to characterize the accumulation of metals in upland and wetland plants growing in the deposition and reference areas were collected during August 1999. The 30 sampling sites used were the same sites used for the plant community characterization studies (see Section 6.2.1), and the sites were evenly divided between upland and wetland sites and between reference and Depositional Area sites. These sites are shown on Figure 3-11.

The principal objective of vegetation tissue analysis was to determine whether and how concentrations for metals in plants varied between the deposition and reference areas. The information is also needed as input to tropic transfer models for estimating potentials for risk to organisms that may ingest metals contained in plants consumed in these areas. The following sections describe the sample types, locations, and methods for upland and wetland vegetation collection for the vegetation tissue analyses, and present the results from the metal analyses of these tissues.

6.2.2.1 Methods

The methods follow procedures describe in the Site's Work Plan (MFG, Terracon, and Pentec, 1999). Plant tissue sampling included the collection and analysis of two key species identified for each of the four habitat/cover types. These types included upland meadow, upland forest, wetland meadow, and wetland scrub-shrub/forest.

Selection of the specific plant species at each site was based on three criteria: (1) being dominant or sub-dominant representation within the habitat type; (2) its potential as a forage species for key receptor animal species; and (3) indications of use of the plant at the site as forage or browse. Plants selected for sampling included native and introduced species. Plant tissue was collected at 30 of the soil sampling sites. Metal analytes included silver, aluminum, arsenic, cadmium, copper, iron, mercury, lead, selenium, antimony, and zinc.

Wherever available, the two plant species sampled per site included one herbaceous species and one shrub (woody) species; where no shrub species occurred (typically the case in removal areas), two herbaceous species were selected. Samples were collected for each species at each site in triplicate. Sampling was conducted in the reference area and in the Depositional Area, for a total of 60 tissue samples from the 30 sites.

6.2.2.2 Results

The results of the metal analysis for vegetation tissues are presented in series of data sets and summaries contained in 21 tables. These tables are ordered in subsets from upland to wetland sites and from reference to Depositional Area sites. Each set includes summaries of tissue analysis results for all vegetation, for herbaceous vegetation alone, and for shrubby vegetation alone. For data sets from Depositional Area sites additional table subsets are included to allow an evaluation of the effects of removal relative to all vegetation, herbaceous vegetation, and shrubby vegetation. The four main tables dividing the four principal subsets of vegetation tissue analysis results are Table 6-9, Appendix E, presenting all results from sites in the upland reference area; Table 6-12, Appendix E, presenting all results from the upland Depositional Area; Table 6-20, Appendix E, presenting all results from the wetland reference area sites; and Table 6-24, Appendix E, presenting all results from sites in the Depositional Area.

Questions exist on whether samples from Sites 53 and 55 should remain in the set of data used to characterize metal concentrations in plant tissues from wetland reference sites. These questions exist because the soil samples from these two sites contain relatively high arsenic concentrations from unknown sources, but that are unrelated to the 1997 release. Table 6-23, Appendix E, presents the results and data summary from all vegetation tissue sample analyses for the wetland reference sites other than Sites 53 and 55. Comparing these results to those in Table 6-20 indicate that no statistical difference existed for any metal between mean concentrations in the summarized data for wetland reference sites including or excluding Sites 53 and 55. Therefore, in the remaining analyses and discussions, all references to the tissue concentration for metals from wetland reference sites include data from Sites 53 and 55.

Two additional tables (Tables 6-31 and 6-32, Appendix E) provide a comparison of metal concentrations in herbaceous plants from all Depositional Area sites with removal of tailings versus those without removal. Shrubby vegetation was not included in this comparison because many of the removal sites did not have regrowth by shrubby species at the time of the sampling. Based on the 95% confidence intervals, total aluminum and total arsenic concentrations averaged greatest at sites with removal, whereas all other metals were statistically equal for sites with or without removal.

In general, the results show relatively low concentrations for total silver, cadmium, copper, lead, selenium, and zinc across upland and wetland reference and deposition sites. Concentrations of total aluminum, arsenic, and iron in vegetation tissues from upland sites in the Depositional Area were slightly elevated compared to average concentrations from upland reference sites (Table 6-9, and Table 6-12, Appendix E,). For wetland sites only total arsenic concentrations averaged significantly greater across Depositional Area sites compared to reference sites, and mean total mercury concentrations were significantly lower at the wetland sites. Mercury concentrations were slightly elevated in both upland reference and upland deposition sites compared to reference sites. The following discusses the analytical findings in additional detail on a metal by metal basis.

Total Silver

Total silver concentrations in plant tissues were consistently low across all habitat types, in both reference and deposition areas . Silver was detected in only 2 vegetation samples from the upland reference area, in 3 samples from the upland deposition area, in 4 samples from the wetland

reference sites, and in 3 samples from wetland sites in the Depositional area. With one exception, detectable silver concentrations occurred in herbaceous vegetation samples.

In wetland and upland reference sites, only one sample was found to hold a silver concentration greater than the detection limit of 0.05mg/kg . This herbaceous sample held 0.18 mg/kg total silver and was collected from Site 53, a riparian reference site in upper Montezuma Creek (Table 6-20, Appendix E). Total silver concentrations were higher in the upland deposition area (mean = 0.05mg/kg) than in the wetland deposition area (mean= 0.03mg/kg), where then mean concentration is below detection limits. At a 95% confidence interval, there was no difference between reference and deposition mean concentrations for silver. At all sites, including the four habitat types in reference and deposition areas, and for removal areas, mean total concentrations of silver were statistically similar for herbaceous vegetation (Table 6-30, Appendix E) and in all but removal sites, herbaceous and shrubby vegetation were also statistically similar.

Total Aluminum

Relatively high mean concentrations of total aluminum in plant tissues were found in the upland deposition area, where the mean was 450 mg/kg (Table 6-12, Appendix E). In the upland deposition removal areas, the mean concentration was higher (mean = 624 mg/kg; Table 6-15, Appendix E). In the upland reference, the wetland reference and the wetland deposition, Al concentrations were relatively low [mean = 55 mg/kg and 70 mg/kg, respectively (Tables 6-9, 6-20, 6-24, Appendix E)]. Between the wetland reference and wetland deposition areas, a 95% confidence interval test showed no statistical difference in mean aluminum concentrations, whereas a difference existed between upland reference and upland deposition mean concentrations (upland reference mean aluminum concentration = 92 mg/kg). Total aluminum concentrations were similar across all sites for herbaceous and shrubby vegetation.

Total Arsenic

Total arsenic concentrations in plant tissues were relatively low in the upland reference sites (mean = 1.6 kg/mg; Table 6-9, Appendix E), and were slightly elevated in the upland deposition sites (mean = 10.8 mg/ kg; Table 6-12, Appendix E). The mean wetland reference arsenic concentration was 2.9 mg/kg (Table 6-20, Appendix E) and the wetland Deposition Area mean arsenic concentration was 6.5 mg/kg (Table 6-24, Appendix E,), but mean concentrations were not statistically different between the wetland reference area and wetland Depositional Area based on the

95% confidence interval. However, mean arsenic concentrations were greater for upland deposition areas compared to upland reference areas (Tables 6-9 and 6-12, Appendix E). Total arsenic concentrations were statistically similar across all sites for herbaceous and woody vegetation.

Total Cadmium

Mean concentrations of total cadmium were consistently low across all habitat types in reference and deposition areas, ranging from a low of 0.08 mg/kg for the upland deposition sites to 0.22 mg/kg for the wetland reference sites (Tables 6-12 and 6-20, Appendix E,). Mean cadmium concentrations tended to be lower in both deposition areas than in the reference areas. Based on the 95% confidence intervals, mean concentrations were statistically different only in wetland reference and wetland deposition areas. Cadmium concentrations were statistically different between herbaceous and shrubby vegetation in the deposition wetland sites (herb mean = 0.07 mg/kg; shrub mean = 0.37 mg/kg; Tables 6-13 and 6-14, Appendix E).

Total Copper

Total copper concentrations in plant tissues were also consistently low across all habitat types and reference/deposition areas (Tables 6-9, 6-12, 6-20, and 6-24, Appendix E). Copper is an essential nutrient for plants, with a normal elemental level in plant tissue generally held to be between 3 and 30 mg/kg dry plant tissue (Munshower, 1994). Mean total concentration for upland reference and deposition areas were 5.39 mg/kg and 6.08 mg/kg respectively, and were not statistically different at a 95% confidence interval. In the wetland reference, the mean copper concentration was 5.19 mg/kg, and was not statistically different than the wetland deposition area mean copper concentration of 6.19 mg/kg. Copper concentrations did not differ at a 95% confidence interval for herbaceous and shrubby vegetation at any site.

Total Iron

Total iron, another essential element for plants, averaged within normal ranges for elemental composition of plant tissue (Munshower 1994, Bowen 1979). Reference area mean concentrations were 123.96 mg/kg in the upland, and 119.95 mg/kg in the wetland. Depositional Area mean concentrations were 256.08 mg/kg in the upland, a value that only slightly exceeds normal ranges, and 115.38 mg/kg in the wetland. Wetland reference and deposition values were not statistically different at a 95% confidence interval (CI) (Tables 6-20 and 6-24, Appendix E,), although upland mean

concentrations did differ statistically (Tables 6-9 and 6-12, Appendix E). Herbaceous vegetation at upland deposition sites had statistically higher total Fe concentrations than did shrubby vegetation at these same sites (herb mean = 545 mg/kg; shrub mean = 251 mg/kg; Tables 6-13 and 6-14, Appendix E).

Total Mercury

Average total mercury concentrations in plant tissues ranged from 16 mg/kg at the wetland Depositional Area sites to 0.33 mg/kg at the upland reference sites (Tables 6-9, 6-12, 6-20 and 6-24, Appendix E). While the mean wetland deposition concentration was slightly less than that for the reference wetland, they were not statistically different at the 95% confidence interval (Tables 6-20 and 6-24, Appendix E). Mercury concentrations differed between herbaceous and shrubby vegetation for the wetland deposition sites (herb mean = 0.36 mg/kg; shrub mean = 0.25 mg/kg; Tables 6-25 and 6-27, Appendix E).

Total Lead

Total lead concentrations in plant tissues were relatively low across all habitat types and reference/depositional status, ranging from 0.47 mg/kg for the wetland reference sites to 1.07 mg/kg for the upland deposition sites (Tables 6-9, 6-12, 6-20 and 6-24). Mean concentrations between upland reference and deposition sites and between wetland reference and deposition sites were not statistically different. Similarly, total lead concentrations between herbaceous and shrubby vegetation did not differ statistically at any of the habitat types.

Total Antimony

Total antimony concentrations were detected in only two plant tissue samples (Tables 6-9, 6-12, 6-20 and 6-24, Appendix E). Antimony was detected at concentrations of about twice the detection limit in one herbaceous sample from the upland Depositional Area, and in one shrub sample from the wetland Depositional Area (Tables 6-12 and 6-24, Appendix E).

Total Selenium

Total selenium concentrations were detected in only three plant tissue samples (Tables 6-9, 6-12, 20 and 6-24, Appendix E). Selenium was detected in one herbaceous and one shrub sample from

the upland reference sites and one herbaceous sample for the wetland reference sites (Tables 6-9 and 6-20, Appendix E).

Total Zinc

Total zinc concentrations were detected in all plant tissue samples, ranging from a low of 27.8 mg/kg for the upland deposition sites to 100.5 mg/kg for the wetland reference sites. Although mean concentrations tend to be greater for the upland and wetland reference sites, compared to mean concentrations for upland and wetland sites in the Depositional Area, there was not a statistical difference between the respective pairs.

6.2.2.3 Summary

- In general, the results show relatively low concentrations in vegetation tissues for total silver, cadmium, copper, lead, selenium, and zinc across upland and wetland reference and deposition sites.

- Concentrations of total aluminum, arsenic, and iron in vegetation tissues from upland sites in the Depositional Area were elevated compared to average concentrations from upland reference sites.

- For metal concentrations in vegetation tissues from wetland sites only total arsenic concentrations averaged significantly greater across Depositional Area sites compared to reference sites, and mean total mercury concentrations were significantly lower at the wetland sites.

- Comparing average tissue concentrations between herbaceous and shrubby vegetation samples revealed no significant difference for any metal concentration for sites in the upland reference areas; significantly greater concentrations of iron in herbaceous vegetation from upland sites in the Depositional Area; significantly lower concentrations of cadmium and zinc in herbaceous plants from wetland reference sites; and significantly greater concentrations of mercury and lower concentrations of cadmium and zinc in herbaceous vegetation from wetland sites in the Depositional Area.

- Total aluminum and total arsenic concentrations averaged significantly greater at sites with removal, all other metals were statistically equal for sites with or without removal.

6.2.3 Characterization of Metals Content in Terrestrial Invertebrates

Terrestrial invertebrates were collected from the soils, litter, and vegetation at a subset of 12 upland and wetland sites as part of the July 1999 sampling work to characterize the concentration of metals in the invertebrate tissues collected from each site. These samples were collected primarily to aid in assessing potential metal transfer via the food web to higher order consumers (e.g., American Robin) during risk assessment evaluations. These samples were not collected specifically to assess potential for bioaccumulation of these metals in these invertebrates or the potential for metals-induced effects to them.

6.2.3.1 Methods

An equal number of wetland and upland sites (six each) in reference and deposition areas were sampled for terrestrial invertebrates. The individuals collected from the soil, litter, and vegetation layers were counted by general taxonomic categories and then composited for each site for chemical analysis. Tissue concentrations of metals in invertebrate tissues are reported as mg/kg wet weight (Table 6-33, Appendix E). Where the tissue concentration reported was less than the detection limit, the value was included in the summary statistic as one-half the reported detection limit. For this comparison, sites were grouped by reference and Depositional Area locations and summary statistics were calculated. Additional summary statistics were calculated for the reference area excluding Sites 53 and 55 (these soils contain relatively high metals concentrations unrelated to the 1997 release).

6.2.3.2 Results

Invertebrate numbers in all three habitat layers were low across all sites. The greatest number of organisms was collected at wetland Site 1 in the Depositional Area (Table 6-33, Appendix E). Of the removal and non removal sampling sites, lowest numbers of organisms were collected generally at removal sites. This likely is related to the general lack of litter and vegetation in the removal area after the completion of removal. The mean number of organisms collected in the reference area was similar to the mean number collected in the Depositional Area, at 63.8 (95% CI = 66) and 88.2 (95% CI = 43.2) and is not considered statistically different. Practically all of the terrestrial invertebrates

collected for this assessment were collected from sweeps of the vegetation immediately adjacent to each site. Field observations indicated that the predominant soil condition was very dry, and that litter material was sparse. At only one site (Site 54) did the sampling effort find earthworms in the soil. The general lack of soil invertebrates in both reference and Deposition Area soils would suggest that the consumers of invertebrate prey in this area necessarily emphasize feeding efforts on invertebrates found in above-ground vegetation.

The following is a discussion and summary of the data for metals in invertebrate tissues by each metal.

Total Silver

Concentrations of total silver in invertebrate tissues from the reference area averaged 0.08 mg/kg (95% CI = 0.07 mg/kg). Silver concentrations were higher in invertebrate tissues collected in the Depositional Area averaging 0.18 mg/kg (95% CI = 0.13 mg/kg). Excluding Sites 53 and 55 from calculation of the statistical summary produced an average silver concentration in invertebrate tissues for the reference sites of 0.04 mg/kg (95% CI = 0.03 mg/kg).

Total Aluminum

Concentrations of total aluminum in invertebrate tissues from the reference area averaged 249 mg/kg (95% CI = 211 mg/kg). Aluminum concentrations were higher in invertebrate tissues collected in the Depositional Area, averaging 677 mg/kg (95% CI = 874 mg/kg. The high average tissue residue concentration in the Depositional Area is largely driven by a single value which was several times the values reported at the remaining Depositional Area sites. Exclusion of Sites 53 and 55 produced an average aluminum concentration in invertebrate tissues for the reference sites of 129 mg/kg (95% CI = 139 mg/kg).

Total Arsenic

Invertebrate tissues collected from the reference sites averaged 28.4 mg/kg total arsenic (95% CI = 52.77 mg/kg) but were highly variable. When sites 53 and 55 are excluded, arsenic in tissues averaged 1.15 mg/kg (95% CI = 0.76 mg/kg) and is considerably less variable. Arsenic in invertebrate tissues from Site 55 appears to be the cause, where the total arsenic concentration was 163 mg/kg. Concentration of total As at reference Site 53 was only slightly greater (2.8 mg/kg) than that found

at reference site 35 (2.3 mg/kg). The remaining sites had concentrations below 0.9 mg/kg. Tissue concentrations of total arsenic in invertebrates collected from the depositional zone averaged 17.95 mg/kg (95% CI = 14.17 mg/kg).

Total Cadmium

Total cadmium in reference site invertebrate tissue samples averaged 0.26 mg/kg (95% CI = 0.18 mg/kg). Mean concentration of cadmium when Sites 53 and 55 were removed increased to 0.32 mg/kg (95% CI = 0.25). With and without Sites 53 and 55 tissue concentrations were almost identical. Tissue concentrations of cadmium in samples collected from the Depositional Area averaged lower than those observed in the reference area: 0.16 mg/kg (95% CI = 0.010 mg/kg).

Total Copper

Total copper concentrations in tissues collected from the reference area, reference area without Sites 53 and 55, and Depositional Area were very similar, averaging 9.15 mg/kg (95% CI = 6.81 mg/kg), 10.45 mg/kg (95% CI = 10.18 mg/kg) , and 9.96 mg/kg (95% CI = 2.02 mg/kg), respectively, although total copper in tissues from the reference sites tended to be more variable than that found in samples from the Depositional Area.

Total Iron

Reference area invertebrate tissue samples averaged 370.8 mg/kg (95% CI = 425 mg/kg) total iron, whereas without Sites 53 and 55, tissues averaged 131.4 mg/kg (95% CI = 114 mg/kg). The maximum concentration of iron in tissues was measured at site 55 (1510 mg/kg). Tissue concentrations in the Depositional Area were considerably greater, averaging 598 mg/kg (95% CI = 701 mg/kg). Depositional Area tissue concentrations of iron were highly variable and affected by the maximum iron concentration measured in tissue of 2350 mg/kg.

Total Mercury

Tissue concentrations of total mercury at reference sites, reference sites without Sites 53 and 55, and the Depositional Area were very similar, averaging 0.09 (95% CI = 0.08 mg/kg), 0.05 (95% CI = not calculable), and 0.03 mg/kg (95% CI = 0.01 mg/kg), respectively. Tissue concentrations tended to be greatest in samples collected from the reference area.

Total Lead

Concentrations of total lead in reference area tissue samples averaged 0.59 mg/kg (95% CI = 0.46 mg/kg) and the average decreased with the exclusion of Sites 53 and 55 to 0.30 mg/kg (95% CI = 0.18 mg/kg). In the Depositional Area, tissue concentrations of lead averaged 0.99 mg/kg (95% CI = 0.83 mg/kg).

Total Antimony

Tissue concentrations of total antimony at reference sites, reference sites without Sites 53 and 55, and Depositional Area were very similar, averaging 2.88 mg/kg (95% CI = 1.61 mg/kg), 2.68 mg/kg (95% CI = 2.11 mg/kg), and 2.18 mg/kg (95% CI = 0.60 mg/kg), respectively, yet were less variable in Depositional Area samples.

Total Selenium

Tissue concentrations of total selenium at reference sites, reference sites without Sites 53 and 55, and Depositional Area were similar, averaging 0.49 mg/kg (95% CI = 0.32 mg/kg), 0.33 mg/kg (95% CI = 0.38 mg/kg), and 0.46 mg/kg (95% CI = 0.22 mg/kg), respectively.

Total Zinc

In reference area tissues, total zinc averaged 68.92 mg/kg (95% CI = 22.25 mg/kg) and decreased with the exclusion of Sites 53 and 55 to 57.35 mg/kg (95% CI = 24.10 mg/kg). In the Depositional Area, total zinc in tissues averaged slightly higher at 75.97 mg/kg (95% CI = 10.18 mg/kg).

6.2.3.3 Summary

- Invertebrate numbers in all three habitat layers were low across all sites.
- The greatest number of organisms collected was at a wetland site in the Depositional Area.

- Of the removal and non removal sampling sites, lowest numbers of organisms were collected generally at removal sites, likely attributable to the reduced density of plants and litter at these sites..

- Metal concentrations in terrestrial invertebrate tissues generally were highly variable for samples collected across reference and Depositional Area sites.

- For all but two metals, mean (± 95% CI) concentrations were no different between reference sites and depositional sites, likely due to the variability in the measured tissue concentrations.

- Arsenic and silver are the only metals measured in invertebrate tissues having concentrations in Depositional Area statistically greater than in those found for the reference area.

6.2.4 Characterization of Wildlife Community

Wildlife studies conducted in July 1999 included areas holding similar vegetative structure and composition in the Depositional Area and in adjacent reference areas to help assess the effects of tailings deposition to the terrestrial ecosystem. Based on previous vegetation-community information for the Site, the area was divided into three wildlife habitats: forests, meadows, and wetlands. ***Forests*** include areas dominated by a Ponderosa pine (*Pinus ponderosa*) overstory, with a limited understory of shrubs and grasses. Downed timber was an important part of the ground cover. ***Meadows*** include drained uplands, dominated by grasses and forbs with sparse or no tree or shrub cover. Portions of the meadows in the Depositional Area were thinly reseeded areas where the tailings had been removed. ***Wetlands*** include areas with wet soils during the July field survey and areas adjacent to perennial streams. Wetlands are dominated by willows (*Salix* sp.), with openings dominated by sedges (*Carex* sp.). There were portions of the wetlands and upland meadows in the Depositional Area that had been scarified during tailings removal. These had sparse vegetation during the wildlife surveys.

The studies followed the methods presented in the Work Plan (MFG, Terracon, and Pentec, 1999). Appendix C-2 provides details on these studies and their results are in Table 6-34, Appendix E. The following subsections highlight the approach and key findings.

6.2.4.1 Methods

Field surveys for vertebrate wildlife were conducted at the Talache site between 18 and 22 July 1999, with additional sightings of mammals from throughout the summer of 1999 added where appropriate. July was chosen as the primary inventory period because breeding birds were still actively singing, mammal reproduction had increased populations, increasing possibilities of trapping success, and amphibians were also actively breeding. All birds seen or heard during the 5-day field visit were identified and recorded. Evidence of breeding activity (singing, nests, independent young were also noted).

The upland reference area for this wildlife inventory was located directly east of the Depositional Area and north of Forest Road 268. It included similar sized stands of upland forests and meadows. Reference wetlands were located south and west of the Depositional Area and along Unnamed Creek, with smaller areas of willows and sedges than in the Depositional Area.

Trap lines of 30 Sherman live traps were placed at approximately 10-m intervals within each habitat type in both deposition and reference areas. In addition, 12 one-gallon pitfall traps were placed in the same six areas, though less were available in wetlands because water pressure forced buckets above the surface in some wetland areas. Pitfall traps were placed along side of barriers, (i.e, as logs, straw bales, and streams) which could lead animals to the traps. All traps were out for 3 nights. Voucher specimens were preserved to verify field identification; all others will be released. All other mammals and/or their sign encountered were also recorded. Additional observations by MFG personnel outside of the period of the primary field visit were also included.

The same series of pitfall traps were also expected to provide a sample of active reptiles and amphibians. Additionally, amphibians were opportunistically captured by hand when encountered. Voucher specimens were preserved to verify field identification. All specimens, both mammalian and amphibian, were added to public museum collections.

Wildlife, because of their mobility, were also noted when encountered anywhere within a mile of the Depositional Area on the assumption that they could eventually or irregularly occur on there.

6.2.4.2 Results

Thirty-eight species of birds, 13 species of mammals, and two species of amphibians were recorded during the field visit (18-22 July; MFG, Terracon, Pentec, 1999a). MFG personnel documented two additional mammalian species during the summer of 1999.

Breeding by four species was documented during the 5-day survey period. Spotted sandpiper fledglings were found in Depositional Area wetlands on 19 July, Cassin's vireo and chipping sparrow fledglings were observed breeding in forest within both the Depositional Area and reference areas throughout the survey, and red-naped sapsuckers were feeding young in a cavity just west of the Depositional Area on July 18.

Forests were primary habitats for all woodpeckers, Cassin's vireos, western tanagers, yellow-pine chipmunks, and red squirrels. Spotted sandpipers, fox sparrows, song sparrows, masked and montane shrews, long-tailed and montane voles, spotted frogs, and western toads were largely restricted to wetlands. Though no birds or amphibians were limited to meadows, most deer mice and all Columbian ground squirrels were found in this habitat.

Most of all bird species recorded (61%) occurred in both deposition and reference areas. Two species, Downy woodpecker and white-crowned sparrow were recorded only on the depositional area. Eight species, mallard, broad-tailed hummingbird, black-backed woodpecker, willow flycatcher, Hammond's flycatcher, warbling vireo, cedar waxwing, and yellow-rumped warbler were only seen on the reference area. Six species, Canada goose, pileated woodpecker, Steller's jay, common raven, yellow warbler, evening grosbeak were only observed in the general vicinity. Birds, with their great mobility, moved easily between similar habitats in the depositional area and the reference area. No census was made in either area, but numbers of those species found in both areas were low, because of the small areas involved, but quite comparable.

Eighty-one individuals of seven species of small mammals were captured in Sherman live traps or pit fall traps. Most shrews (*Sorex*; 14 of 15) and voles (*Microtus*; 12 of 17) were retained because they could not be identified in the field by external features. Some released individuals were likely recaptured on subsequent nights. In total, 40 voucher specimens of the seven species were retained, identified, and placed in a public natural history museum collection. Though about twice as many shrews and voles were captured in wetlands within the Depositional Area (11 shrews,

11 voles) than in reference wetlands (5 shrews, 6 voles), wetlands were more extensive in the Depositional Area than in reference areas. Minimum numbers of chipmunks were comparable in forests of the Depositional Area (7) and reference areas (9), as were minimum numbers of deer mice in the Depositional Area (4) and reference areas (5) meadows. Predators (long-tailed weasel, coyote, black bear) and ungulates (deer and elk) moved freely through the Depositional Area and reference areas.

Only two species of amphibians [spotted frog (*Rana pretiosa*) and western toad (*Bufo boreas*)] and no reptiles were encountered during the survey period. Some species of reptiles (i.e., snakes) likely occur on these areas in low numbers or seasonally. A few frogs and sometimes hundreds of toads were seen in both reference areas and especially the Depositional Area through the summer and early fall.

6.4.2.3 Summary

- The Talache site is utilized by a wide variety of vertebrate wildlife.
- This survey documented 55 vertebrate species, including 38 bird, 15 mammal, and two amphibian species.
- Population composition and use of the Depositional Area are comparable to that occurring on the neighboring reference areas.

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