COLORADO DEPARTMENT OF PUBLIC HEALTH

AND ENVIRONMENT

HAZARDOUS MATERIALS AND WASTE MANAGEMENT DIVISION

FINAL ANALYTICAL RESULTS REPORT FOR SITE INSPECTION

CINNAMON GULCH AND PENNSYLVANIA MINE SITE
SUMMIT COUNTY COLORADO

Prepared by:
Mark Rudolph, CDPHE

Approved: ______________________ **Date:** 12/10/08
Daniel Scheppers Superfund Unit Leader, CDPHE Brownfields Assessment Manager

Approved: ______________________ **Date:** 12/10/08
Jean Mackenzie, EPA Project Manager

Pennsylvania Mine Site Final Site Inspection Analytical Results Report

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1.0 INTRODUCTION

The Hazardous Materials and Waste Management Division (HMWMD) of the Colorado Department of Public Health and Environment (CDPHE) conducted a Site inspection (SI) of the Cinnamon Gulch Watershed and Pennsylvania Mine Site, located in Summit County Colorado (Figure 1). This SI was conducted and is consistent with all requirements set forth under 40 CFR Part 312, Standards and Practices for All Appropriate Inquiries. The US Environmental Protection Agency (EPA), Region 8, has coordinated with, and provided assistance on the surface water, sediment, and macroinvertebrate sampling and analysis component of this investigation, as well as providing aquatic toxicity testing in the Region 8 Laboratory. Fieldwork for this SI was conducted over numerous weeks during the summer and fall of 2007.

This Site Inspection called for the collection of macroinvertebrates, ground water, surface water, sediment, mine drainage features and composite mine waste samples from Cinnamon Gulch and the adjacent portion of Peru Creek. Samples of mine drainage features were collected from identified mining features in the watershed that have been identified as wet or saturated or discharging water from an historic mining feature or if their proximity thus has a potential to be eroded into the waterway, or based on a prevalence of erosional gullies indicating previous erosion.

All mine waste soil samples were tested for the following list of total metals: aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, magnesium, mercury, nickel, selenium, silver, and zinc. Additionally, composite mine waste samples were analyzed for Acid Base Accounting (ABA) and the USGS Modified Leach Test Method which uses a de-ionized water solution instead of a dilute nitric acid solution as in the Synthetic Precipitation Leaching Procedure (SPLP). The modified SPLP method recommended by USGS was used as it more accurately represents the natural state of leaching by natural precipitation of historical mine waste. This method quantifies toxic inputs and the soluble constituents available to mobilization. All sample locations are shown in Figures 3 through 32 and are described in Tables 1 and 2.

Surface water and sediment samples were collected during the 2007 high and low flow events from all historic sampling locations. Surface water samples were analyzed for sulfate, chloride, alkalinity, dissolved organic carbon, and the following list of dissolved and total recoverable metals: aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, magnesium, nickel, mercury, selenium, silver, and zinc. Various cations, including sodium, potassium, calcium, and magnesium, were also analyzed from the dissolved metals fraction. Numerous locations within the Peru Creek watershed where chemistry samples were collected were also sampled for macroinvertebrates, sediment metals, and surface water toxicity to fish. Whenever a water chemistry or toxicity sample was collected, field parameters, including temperature, conductivity, pH, dissolved oxygen, and flow were taken using EPA protocols (CDPHE 2007a). Macroinvertebrate samples were collected from key locations as to bracket specific reaches of stream for the presence or absence of aquatic life.

Ground water samples were collected from locations in the vicinity of the wetlands near the El Jebel Mill Site and Peru Creek. Locations were selected o the presence of pre-existing wells and new locations identified to better understand and bracket potential sources to ground water contamination.

Table 3 describes the water quality sample locations that were collected during both high and low flow sampling events. Tables 4 through 9 describe all parameters to be analyzed for surface water, ground water, soil, sediment and macroinvertebrate samples and the required container types, preservatives, detection limits, and analytical holding times.

Sampling and analysis included appropriate laboratory and field quality assurance/quality control protocols to ensure data are of known quality and can be used for the intended purposes.

2.0 SITE DESCRIPTION

2.1 LOCATION AND DESCRIPTION

The Pennsylvania Mine Site and the associated Cinnamon Gulch drainage are located in Summit County, Colorado, in the Montezuma Mining District east-northeast of the town of Montezuma (Figure 1). Pennsylvania Mine and Cinnamon Gulch are adjacent to, and discharge directly into Peru Creek, which flows into the Snake River, and ultimately into the Dillon Reservoir. The headwaters of Peru Creek and Cinnamon Gulch originate from the highly mineralized and glaciated terrain found along the Continental Divide (Wood et al, 2005).

Cinnamon Gulch and the Peru Creek drainages are located approximately 14 miles east of Dillon and 4 miles northeast of Montezuma, Colorado. The site area is reached by traveling east on US 6 from Interstate 70 in Dillon to the town of Keystone. Continue on US 6 for approximately 1.2 miles past Keystone to Montezuma Road. Turn south at Montezuma Road and then turn left at the first fork in the road and proceed east, past the ski area parking lots, for 4.6 miles to where the road makes a sharp bend and crosses the Snake River. Immediately after crossing the Snake River turn left at the unpaved 4-wheel drive road and proceed first north then west up Peru Creek on a road that becomes increasingly rugged (URS 2002).

Elevations range from about 10,800 feet above sea level at the confluence between the lower branch of Cinnamon Gulch/Creek and Peru Creek, to 11,800 feet at the Silver Spoon Mine (apparent headwaters of Cinnamon Creek). The highest point in the Cinnamon Gulch watershed is 12,889 feet on Revenue Mountain. Cinnamon Gulch flows between Silver and Brittle Silver Mountains on the west, and Revenue and Decatur Mountains on the east (Wood et al, 2005).

The Snake River watershed is located in central Colorado’s Rocky Mountains immediately west of the Continental Divide. As a result of both historic mining activity and natural biogeochemical processes, a large percentage of the basin is impacted by acid rock drainage. Peru Creek is the major tributary that drains the study area and then flows into the Snake River, which in turn flows into Dillon Reservoir, a municipal source of drinking water for the City of Denver. The drainage basin of Peru Creek is enclosed by the continental divide on the north, east, and south and encompasses approximately 20 square miles (URS 2002).

The Snake River and Peru Creek are identified on Colorado’s 2000 303(d) list of impaired water bodies due to high concentrations of zinc, cadmium, copper, lead, and manganese. The headwaters of the Snake River receive inflow from acidic and metal-enriched tributaries and groundwater on the eastern side of the watershed, where disseminated pyrite is abundant in the country rock (Theobald 1963). This headwater reach also runs through a naturally occurring bog iron ore deposit. The inflow of Deer Creek, a pristine tributary of approximately equal flow, raises the pH and causes precipitation of aluminum and iron hydroxides (Wood et al, 2005).

Cinnamon Gulch receives inflow from numerous abandoned mines. The Pennsylvania Mine, located immediately upgradient of the Cinnamon Gulch and Peru Creek confluence, has been found to be one of largest sources of metals and acidity within the Peru Creek watershed (McKnight and Bencala, 1990). Large sections of the Snake River and Peru Creek are coated in metal hydroxides primarily iron and aluminum hydroxides—which precipitate out of solution as flow from pristine tributaries raises the pH of the stream water. The Snake River joined by the tributaries Keystone Gulch and the North Fork of the Snake River, flows into Dillon Reservoir, which is a major water supply for the City of Denver. Keystone and Arapaho Basin ski resorts are located within the basin and use water from these streams for snowmaking.

The Pennsylvania Mine Site, a single location and one of the major contributors to metals loading in the Peru Creek Watershed is located at 39.6003191138959° North latitude and -105.809631386592° West longitude.

2.2 SITE HISTORY AND PREVIOUS WORK

The Snake River watershed, which drains a portion of the Continental Divide from Loveland Pass south to Webster Pass in east central Summit County, Colorado, has been the site of extensive environmental research in the past two decades. Water quality issues within the Snake River basin impact numerous users and present complex policy decisions. Much of the research has been focused on the upper tributary basin of Peru Creek, which has been identified as a major contributor of metal solutes and acidity to the Snake River watershed through the processes of acid-rock-drainage (ARD). The Peru Creek basin contains several moderately sized historic narrow-vein silver/base metal mines that have been identified as discrete sources of metal loading. All of these mines are currently inactive. Historic data show that water quality in Peru Creek is also affected by zones of diffuse and unidentified naturally occurring ARD related to extensive alteration of country rock directly associated with the ore deposits.

An extensive amount of historical data have been collected and analyzed by various laboratories over the past 20 years. Each sampling and laboratory analyses was conducted with various Data Quality Objectives (DQOs) and results likely reflect different levels of acceptable quality control depending on the intended use of the data for each study design. In addition, site conditions have undergone significant changes over the past 20 years. For example, there was a potential mine blowout inside the workings of the Pennsylvania Mine and some historical data have been collected during periods of drought. While the historical data is useful in plotting trends and evaluating variability, this ARR will present a discussion of historical background data, but evaluate only current data collected during the 2007 field sampling season, the most recent comprehensive data collected by the state and EPA.

Initial environmental research was centered on the Pennsylvania Mine, the largest producing silver-lead-zinc mine in the Peru Creek area. Investigations were later expanded to include basin-wide and watershed scale sampling initiatives and abandoned mine inventories. The initial efforts led to more aggressive and area targeted assessments utilizing seasonal and synoptic constituent water sampling, streambed sediment analysis, and increased site mapping. In recent years more focused topical research including the innovative use of chemical tracers were initiated to reveal the complex interplay between anthropogenic and naturally occurring ARD on Peru Creek water quality. All of these studies have shed important additional information on seasonal fluctuation of metal loading dynamics that are central to understanding the Snake River basin as a whole. In addition, chemical tracer research has recently begun to address the possible effects of broader multi-year climatic fluctuations on discharge and metal loading from Peru Creek into the greater Snake River watershed greatly aiding the advent of sound basin-wide policy.

Initial Investigations/Mine Inventories/Site Assessments

The influences of the Pennsylvania Mine on the water quality of Peru Creek were investigated in 1984 through the collection of chemical data for select anion and cations. This study showed that effluent coming from the mine contained high concentrations of Ca, Mg, Al, Mn, Fe, and Zn. The study also suggested that dissolution of Al and Fe oxide in the streambed were pH dependant. This study provided an initial baseline for subsequent research (McKnight and Bencala, 1990).

The Colorado Division of Mines & Geology (CDMG) sampled the Pennsylvania Mine effluent and briefly operated (for testing and evaluation of a potential start up) a small water treatment facility that attempted to improve Peru Creek water quality by raising pH through the addition of powdered limestone. This operation was unsuccessful due to adverse winter operating conditions, excessive metal precipitation in the plant and settling pond, and Clean Water Act liability fears.

Synoptic water sampling was performed in 1996 and 1997 at Peru Creek to investigate spatial and temporal variability in stream chemistry. Over this two-year study, significant changes in all measured solute concentrations were observed due to tributary inflow. The study documented summer increases in dissolved concentrations of metals by factors of 2 to 12 with decreasing flow and reduced dilution by snowmelt. These authors reported that dissolved metal concentrations in Peru Creek increase by a factor of 10 immediately at and below the inflow from the Pennsylvania Mine (Sullivan and Drever 2001).

Initial mine site inventory work and reconnaissance level water testing in Peru Creek was performed by the Colorado Geological Survey (CGS) in 1993 as part of an eight-year study of abandoned mined lands on United States Forest Service (USFS) administered property. Although this work was focused on public lands, some of the privately held mining properties impacting adjacent USFS lands and ultimately affecting Peru Creek were also investigated. Mine site inventory work included site mapping and on-site measurement of field parameters (pH & conductivity) with limited constituent water sampling. This study identified two areas of greatly increased environmental degradation: the entire Cinnamon Gulch tributary of Peru Creek and the abandoned Pennsylvania Mine (USFS 1994). In September 2000, the USFS requested CGS to perform a watershed characterization for Cinnamon Gulch and a more detailed investigation of the smaller mines found there; as well as a full site evaluation for the Pennsylvania Mine/Mill inventory area (Wood 2005). Results of this study will be discussed in the following section on Seasonal Investigations: High Flow/Low Flow.

In September of 2001, The US Environmental Protection Agency (EPA) contracted URS Operating Services of Denver, Colorado to perform a Phase I Site Assessment (SA) for the Snake River Technical Support Project under START2-Region VIII. The objectives of this study included: 1) evaluation, characterization, and documentation of background water quality in the Peru Creek drainage; 2) evaluation, characterization, and documentation of potential release of metals to the environment from mine workings and mining wastes in Cinnamon Gulch and in Shoe Basin (Upper Peru Creek basin); and 3) evaluation of an existing water diversion design for Cinnamon Gulch (URS 2001).

A watershed scale study of the entire Snake River basin was conducted in 2001 and 2002 (Todd 2005). This study implicates the Pennsylvania Mine and Cinnamon Gulch as the major contributors to metal loading in Peru

Creek and downstream in the Snake River basin. These authors were able to show an increase in dissolved metal concentrations at 2002 sample sites during low flow, indicating the importance of flow variation related to drought conditions in assessing remediation alternatives.

Colorado Geological Survey Study – 2001

The Colorado Geological Survey (CGS) revisited selected sites in the Peru Creek drainage both in July and October of 2001 in an attempt to document changes in discharge and water quality during high and low flow regimes. A total of 39 water samples were collected during this study (19 high-flow samples in July, and 20 low-flow samples in October), including some in stream samples collected to bracket selected mines or groups of mines. These samples were all collected from within Cinnamon Gulch and from Peru Creek both above and below the Cinnamon Gulch outflow. No new samples were collected from the Pennsylvania Mine, as it was believed that pre-existing data from State of Colorado Division of Mines & Geology (CDMG) were available and sufficient (Wood 2005).

Direct measurements of surface water discharge from Cinnamon Gulch into Peru Creek are complicated by numerous alluvial fan distributaries at the mouth of this reach. For this study discharge was thus calculated indirectly by measurement in Peru Creek both immediately above and below the confluence of the various outputs from Cinnamon Gulch. Total discharge estimated in this manor for Cinnamon Gulch ranged between 460 gallons per minute (gpm) at low flow to 1,920 gpm at high flow. In Cinnamon Gulch itself this study recorded only 8.4-gpm discharge of surface water during low flow from discrete anthropogenic sources (9 mine adits), and 3-gpm discharge of surface water during low flow from identified natural sources (seeps & springs). This suggests that the overwhelming majority (97% to 98%) of total discharge from Cinnamon Gulch into Peru Creek is gained from ground water inflow (Wood 2005). Discharge from the Pennsylvania Mine ranged from 148 gpm at 162 gpm when measured by the CDMG in June and July of 1978 (Holm 1978). This is believed to have been a high flow event.

Throughout the Cinnamon Gulch watershed, pH ranged from a low of 2.91 to a high of 5.42, and 18 of 33 samples had a pH below 4. Due to the combined inflows from Cinnamon Gulch, Peru Creek was observed to suffer a decrease in pH and an increase in dissolved concentrations of Al, Cu, F, Fe, Mg, Mn, Si, Na, SO4, and Zn at both high and low flow regimes. At many sample sites there were generally higher concentrations of most ions at low flow than at high flow, reflecting the expected dilution from runoff at high flow. A few sites displayed the opposite (higher concentrations during higher flow), possibly reflective of dampened recharge in the unsaturated zone. As with discharge, total metal loading from Cinnamon Gulch was also determined by subtracting values of samples from above and below the inflow zone into Peru Creek, both at low and high flow. Cinnamon Gulch gains close to 400 gpm discharge during low flow in its lower portion that is not attributable to anthropogenic sources, suggesting that this reach is a groundwater discharge zone affected by hydrothermally altered bedrock. Metal loading calculations for both anthropogenic and natural sources indicate that discrete sources throughout Cinnamon Gulch account for only about 4% of total metal loading at base flow and 5-8% of total metal loading at high flow (Bird 2003). The small percentage of groundwater capture by the abandoned surface mine workings in Cinnamon Gulch presents numerous remediation challenges (Wood 2005).

High flow water samples from the Pennsylvania Mine portal in 1978 had a pH of 3.0 with constituent dissolved concentrations of the following metals: 12,000 parts per billion (ppb) Al, 10,600 ppb Cu, 27,000 ppb Mn, 76,000 ppb Zn, 83 ppb Pb, and .011 ppb Cd. Peru Creek above the Pennsylvania Mine and Cinnamon Gulch is relatively pristine with a recorded pH of 6.5 and dissolved constituent concentrations of 13 ppb Cu, 6 ppb Pb, 240 ppb Mn, and 150 ppb Zn as of June/July 1978 (Holm 1978).

URS/EPA Site Assessment (SA) – 2001/2002

A Phase I Site Assessment performed by URS Operating Services consisted of a number of synoptic sampling events spanning Peru Creek from its upper basin (Shoe Basin) to its confluence with the Snake River. The initial sampling event occurred on September 24-25, 2001 and was designed to establish a baseline prior to the removal of water from the North Fork Snake River for snowmaking at Arapahoe Basin ski area. Calculated low flow daily loading rates at the mouth of Peru Creek were about 119 Pounds Per Day (ppd), Al, 0.3 ppd Cd, 5.3 ppd Cu, 15 ppd Fe, 0.5 ppd Pb, 59 ppd Mn, 0.5 ppd Ni, and 70.6 ppd Zn. This study also concluded that the majority of metal loading to Peru Creek occurs in the middle reach in the area of the Pennsylvania Mine, Cinnamon Gulch, and from seeps along the creek downstream, including Warden Gulch. As in the CGS study, this first sampling event recognized a large contribution from non-discrete sources in the Cinnamon Gulch area to total metal loading in Peru Creek. The study also determined that although there is some degradation in upper Shoe Basin (upgradient of Pennsylvania Mine influence), winter season flows are so small that impact on Peru Creek is minimal to non-existent (URS 2001).

Phase II synoptic sampling was conducted on May 21, 2002 and was designed to capture a snapshot of high flow conditions. Discharge in Peru Creek at its confluence with Snake River was double the winter flow, however; it is important to consider that both the 2001 and 2002 sampling were conducted during the longest duration drought period in central Colorado in 100 years. Results confirm the initial findings that the majority of metal loading occurs in the Pennsylvania Mine/Cinnamon Gulch area and that Peru Creek above this area is only slightly impacted. Metal loading for most constituents at the confluence of Peru Creek with the Snake River was significantly reduced during the high flow-sampling event, except for Fe and Pb. This study also removes Chihuahua and Thurman Gulches from suspicion of environmental degradation. Water quality in Peru Creek consistently improves at and below the mouth of Chihuahua Gulch (Wood 2005).

Tracer Experiments

A number of thought-provoking chemical tracer experiments have been conducted in recent years by graduate students of Diane McKnight, PhD, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado-Boulder. These studies have reaffirmed some existing convention regarding environmental degradation and have added new areas of concern for metal loading into Peru Creek. The tracer experiments have also helped to clarify seasonal and climatic effects on metal loading through modeling of metal exchange between the in stream and hyporheic zones of Peru Creek. These experiments have also further clarified the relationship between metal transport and loading during years of drought conditions. The technique utilizes lithium injection in conjunction with synoptic sampling. Tests were conducted in 2002, during severe drought conditions, and then again in 2004 and 2005.

2002 Tracer Experiment:

A lithium tracer experiment coupled with synoptic sampling was conducted along a 7 km stretch of Peru Creek on August 5-6, 2002. The purpose of this test was to determine the main discrete and diffuse sources of metal loading along the reach from just above the Pennsylvania Mine to the confluence with Snake River. A 4.5M lithium chloride (LiCl) injectate solution was introduced into Peru Creek at a rate of 80 mL/min for 22.5 hours prior to synoptic sampling to ensure plateau concentrations (Duren 2004). Tracer experiments determine discharge and enable a mass balance of water to be calculated enabling identification of gaining reaches, effluent inflows, pristine tributary inflows, and groundwater contributions. The conclusions of this study add to the list of suspect areas for degradation in Peru Creek. At the time of this study the predominant source of metal/sulfate loading into Peru Creek was from diffuse groundwater inflow in the vicinity of Warden Gulch. Through analyses of percent total results, the study suggests that complete removal of degradation from the Pennsylvania Mine would only reduce loading into Peru Creek for Al, Cd, Cu, Fe, Mn, Pb, Zn, and SO4 by 11, 16, 27,7,18,7, 16, and 10%, respectively. By contrast, complete removal of the groundwater contribution from Warden Gulch would reduce loading of all metals and sulfate by 40%-80% into Peru Creek. It should be emphasized that this study was conducted in a severe drought year and that results must be viewed in light of this depressed flow regime. In addition, an intense rain event occurring the morning of the test is suspected of impacting results.

2004/2005 Tracer Experiments:

In order to document changes from the drought year of 2002, additional tracer experiments were conducted during 2004 & 2005. During the summer of 2004, a lithium tracer injection experiment focusing on the Warden Gulch area was executed to document effects on Peru Creek stream water chemistry during higher flows than in 2002. In the summer of 2005, another tracer experiment was conducted in the middle reaches of Peru Creek to document effects of the Pennsylvania Mine during a non-drought year. This second study included the application of the OTIS-P transient storage model with parameter optimization to quantify hydrologic changes between the 2002 drought year data and those collected during the higher-flow years of 2004-2005. Results indicated that compared to drought years, a return to more normal flow regimes may cause discrete tributaries to have a larger influence on metal loading and in stream metal concentrations in Peru Creek. In other words, higher flows lead to diminished loading and in stream concentration of metals from diffuse, generally non-anthropogenic sources. This was true for both Warden Gulch and for the Pennsylvania Mine. This study also discusses relationship between the metal storage capabilities of the hyporheic zone in Peru Creek during high and low flow years. During periods of more normal discharge, both the main channel and the hyporheic storage zone of Peru Creek are increased in area, allowing for diminished solute transport through dissolved metals retention in wetlands and beaver ponds, conspicuously absent in 2002. However, in both normal and low flow years, EPA toxicity threshold limits for aquatic life were exceeded for all dissolved metals at all sampled locations (Wong 2006).

Water and Sediment Study – Snake River

Between October 9 and 12, 2001 the USGS collected 36 surface water samples and 38 streambed samples from areas within the entire Snake River watershed. This study found low flow concentrations of several metals in both water and sediment to exceed aquatic life standards in various parts of the watershed. Zinc concentrations in water, corrected for the ameliorating effect of hardness, exceed the acute toxicity criteria for rainbow trout, and the chronic criteria for brown trout in the main stem of the Snake River, Peru Creek, and many upper tributaries affected by historic mining. Dissolved concentrations of copper and cadmium, corrected for the ameliorating effect of hardness, exceeded both the chronic and acute toxicity criteria for all species of trout in Peru Creek between the confluence of the Snake River and Cinnamon Gulch, as well as Cinnamon Gulch itself. Loading calculations from this study indict the entire reach of Peru Creek between the confluence with Snake River upstream to the Pennsylvania mine as the primary area where metal loads increase and are added to Peru Creek (Fey 2002).

2.3 SITE CHARACTERISTICS

Physical Geography

Cinnamon Gulch and the Pennsylvania Mine Site are located in the Rocky Mountains of central Colorado in alpine terrain characterized by steep-sided glaciated valleys and unvegetated rocky upland ridges and peaks. The site is located in a semiarid climate zone with the majority of annual precipitation falling as snow during the winter and spring.

Elevations range from about 10,800 feet above sea level at the confluence between the lower branch of Cinnamon Creek and Peru Creek, to 11,800 feet at the Silver Spoon Mine (apparent headwaters of Cinnamon Creek). The highest point in the Cinnamon Gulch watershed is 12,889 feet on Revenue Mountain. Cinnamon Gulch flows between Silver and Brittle Silver Mountains on the west, and Revenue and Decatur Mountains on the east (USGS 1974; USGS 1987a; USGS 1987b).

Geology and Hydrogeology

The Pennsylvania Mine is developed along a vein hosted primarily in schistose rocks near the contact with the Montezuma Stock. Quartz schist, quartz-biotite schist, injection gneiss, granite gneiss, quartz monzonite, and granite are common. Galena is the most abundant mineral in the veins, with pyrite and chalcopyrite also common (Wood 2005).

Cinnamon Gulch lies on the northeastern margin of the Montezuma Stock, a 40 million-year-old (Oligocene) quartz monzonite porphyry. The Montezuma stock and its associated intrusions are part of a voluminous suite of porphyries that was emplaced 45-35 million years ago along the north-central Colorado Mineral Belt from Empire to Climax. The copper, zinc, lead, silver, gold and molybdenum-bearing hydrothermal systems of the area are related to intrusions of this suite of late Eocene-early Oligocene granitic intrusions. The stock intruded Precambrian hornblende gneiss and schist (Wood 2005).

The Montezuma Shear Zone, a band of argillized, sericitized, and pyritized rocks, passes through Cinnamon Gulch, and is presumed to have localized mineralizing fluids in the area. Zones of the most intensely altered rock show a strong spatial correlation with the Montezuma Shear Zone. Hydrothermally altered rock and sulfide veins are common throughout the district. Sericitic and propylitic alteration are common, and argillic alteration is present locally. The ore deposits within the district are dominantly silver-lead-zinc veins. Pyrite, galena, and sphalerite are the dominant sulfides, generally with tetrahedrite and chalcopyrite and less commonly with sulfosalts of silver and bismuth. Minor amounts of other sulfides are present, including chalcopyrite, bismuthinite, molybdenite, and sphalerite. Gold is mostly insignificant. Ferricrete and ferrosinter deposits are common in the areas underlain and flanked by altered rocks (Wood 2005).

Ground water is present in the fractured bedrock and the valley alluvium. Valley alluvial water ranges from being saturated at the ground surface to deeper depths, all depending on time of year and surficial topography. Thickness of the valley alluvium varies depending on the specific location in the valley. Water in the fractured bedrock ranges from less than 10 feet to hundreds of feet bgs, depending on the location of the fracture containing ground water. Direction of groundwater flow in alluvial materials is expected to be downstream following stream valley contours (Wood 2005).

Hydrology

The Pennsylvania Mine is in a steep valley that is drained by Peru Creek. Peru Creek flows from its headwaters near Gray's Peak, Torrey's Peak, Ruby Mountain, Mount Edwards and Argentine Peak along the west side of the continental divide south and then east toward the Snake River (Figure 1). The stream is rapid and flows from approximately east to west in the vicinity of the mine.

Peru Creek is the major tributary that drains the study area and then flows into the Snake River which in turn flows into Dillon Reservoir, a municipal source of drinking water for the City of Denver (Figure 1). These water bodies are all within 15 miles downstream of the Pennsylvania Mine site. The Pennsylvania Mine site is immediately adjacent to Peru Creek and a draining adit at the mine discharges into Peru Creek. The drainage basin of Peru Creek is enclosed by the continental divide on the north, east, and south and encompasses approximately 20 square miles (URS 2002).

The headwaters of Peru Creek originate approximately 2.75 miles upstream of the Pennsylvania Mine site within Horseshoe Basin. There are several large gulches that discharge into upstream tributaries of Peru Creek including Falls Gulch and various other unnamed perennial and intermittent drainages upstream of the Pennsylvania Mine site.

There are several large contributing drainage gulches that flow into Peru Creek downstream of the site including (starting immediately below the Pennsylvania Mine Site and moving downstream): Cinnamon Gulch, Warden Gulch, and Chihuahua Gulch (Figure 1). There are also various smaller unnamed perennial and intermittent drainages that discharge into Peru Creek.

The Pennsylvania Mine discharges out of the adit portal at approximately 11,000 feet above sea level and flows northeast overland, over waste rock piles, for approximately 0.23 miles where it then enters Peru Creek (Figure 2). This location is the defined probable point of entry (PPE) from the site into the closest surface water body, Peru Creek. Peru Creek flows from the PPE an additional 3.5 miles to the confluence of Peru Creek and the Snake River which is one mile north of the town of Montezuma. The Snake River flows an additional 8.0 miles to the point where it enters Dillon Reservoir. The Harold D. Roberts Tunnel (Roberts Tunnel) is located at the end of the bay which the Snake River flows into Dillon Reservoir, which is an additional 2.1 miles further downstream. The Keystone Ski area utilizes a surface water intake on the Snake River at the town of Keystone for snow making at the Keystone Ski area. This intake supplements potable water at the Summit Lodge (top of ski area) for approximately 2 to 3 months during the winter season. The Summit Lodge is used by a transient population of recreational users; hence, there are no residents affected by this use (Figure 1).

The Roberts Tunnel water intake used by Denver Water for transporting water for the City and County of Denver and is located a total of 13.6 miles downstream from the Pennsylvania Mine PPE. The project diverts water through Roberts Tunnel under the Continental Divide into the South Platte River Basin and is used for drinking water to an approximate 1,124,000 persons residing in the City and County of Denver. The reservoir was completed in September 1963 and is the largest water storage facility in the Denver Water system and supplies approximately one quarter of the drinking water annually to the City of Denver residents. The reservoir storage capacity is approximately 254,000 acre-feet. Dillon Reservoir's surface area of 3,233 acres and 26.8 miles of shoreline also support many recreational activities including camping, fishing, boating and hiking (Colorado River Water Conservation District 2008).

Stream gradients in the site area are very steep and stream flow rates are rapid. There is considerable variation in flow volumes between low-flow and high-flow regimes. Flow in Peru Creek at SW049 (Peru Creek approx 0.5 miles upstream of the confluence with the Snake River) ranged in 2007 from 38.3 cfs (July 9, 2007) to as low as 10 cfs (September 26, 2007). Flow in the Snake River at SW082 (Snake River below confluence of North Fork Snake River) ranged in 2007 from 143 cfs (July 9, 2007) to as low as 34 cfs (September 26, 2007). Due to varying stream gradients and seasonal changes in flow at all locations, the reader should refer to tables 20 to 23 and Section 5.0 Surface Water Pathway, for discussion specific to varying flows and concentration effects specific to specific flow rates at those locations.

Peru Creek and Cinnamon Gulch are major tributaries to the Snake River, the major stream in the area that flows into Dillon Reservoir. The Cinnamon Gulch watershed encompasses approximately 780 acres (EPA 2006; USGS 2007). The closest stream gauge to the site is located on the Snake River near the town of Montezuma. The Snake River at Montezuma has an average annual stream flow of 61.8 cubic feet per second (CFS). Upstream of the site area, the Snake River has a drainage area of approximately 57.7 square miles (USGS 2007).

3.0 WASTE/SOURCE CHARACTERISTICS

The Cinnamon Gulch watershed is host to the relics of Colorado's mining heritage. As part this heritage, there are numerous residual waste rock piles, mine and mill tailings, and draining adits and seeps; all of which are major contributors to metals contamination in the Cinnamon Gulch and Peru Creek watersheds. While numerous locations exist in this drainage where human activity has considerably altered the geochemical conditions of the site, natural acid and reducing conditions do exist (Bird 2003). Limited remedial options exist where these commingled contaminant sources are present (i.e., natural vs. anthropogenic). Potential remedial options may be restricted to countering only the specific portions of the overall contamination that have been exacerbated by man made activity. Based on review of current data, it appears that the single major source area is comprised of the Pennsylvania Mine Adit, the associated mine waste pile at the Pennsylvania Mine Adit and the downgradient mine tailings associated with the wetlands area at the El Jebel Mill Site (Figure 2). Section 3.6, El Jebel Mill Site, and Section 3.7, Pennsylvania Mine Site, discuss these locations in further detail.

In July 2003, American Geological Services, Inc. was contracted by the Summit County Trails and Open Space Department to complete a Phase I Environmental Site Assessment (ESA) of mining features on patented mining claims in the Peru Creek drainage basin located approximately 5 miles east of Keystone, Colorado. The objective of this Phase I Assessment was to perform a background and historical investigation and preliminary site inspections to identify recognized environmental conditions that exist on patented mining claims found throughout the basin. The preliminary site inspections focused on the 252-patented mining claims. In addition to the claims, the mining features on the surrounding U.S. Forest Service (USFS) land were also inspected because of errors in how the claim boundaries were plotted on the U.S. Geological Survey (USGS) topographic maps and Summit County's tax database maps. From this initial investigation, a site screening was performed in order to prioritize three to five mining claims/claim blocks (groups of claims under the same ownership) to be addressed in a Phase II Assessment.

Approximately 45 American Geology Service (AGS) sites were identified in the Cinnamon Gulch watershed and the area around and including the Pennsylvania Mine. These sites have been identified as potential sources of metals loading to Cinnamon Gulch and the adjacent portion of Peru Creek. A total of 20 of the 45 AGS sites were identified to be potential sources of contaminant leaching based on their potential of being in contact with either surface water or shallow groundwater via seeps and springs. The Cinnamon Gulch watershed sites that were identified as being in contact with surface water/groundwater were sampled as part of the ARR and results are reported in subsequent sections of this ARR.

It has been reported that between 20 and 50 percent of the waste rock material in the Cinnamon Gulch watershed are sulfide minerals containing varying concentrations of aluminum, cadmium, chromium, cobalt, copper, lead, manganese, nickel, and zinc (Munroe 2000). These contaminants are prevalent throughout in mine source areas in the entire Cinnamon Gulch watershed, as shown in site surface water, ground water and soil samples collected in 2007 by EPA and CDPHE (Tables 10 to 25).

All mine waste soil samples were analyzed for the following total metals: aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver and zinc. Total metals samples were compared to the Superfund Chemical Data Matrix (SCDM) Reference Dose Screening Concentration (RDSC), the SCDM Cancer Risk Screening Concentration (CRSC), 2004 BLM Open Space Cleanup Guidance Values for a surveyor working on site, and the Colorado Soil Evaluation Values (CSEV) for a site worker.

Additionally, all mine waste soil samples were analyzed Synthetic Precipitate Leaching Procedure (SPLP) and as Acid Base Accounting (ABA) parameters. SPLP analysis simulates the natural leaching of site related wastes by precipitation. Comparison of SPLP analysis was to CDPHE drinking water standards. Comparison of SPLP analysis is for comparison purposes only to screen which mine waste piles have a higher tendency to leach metals through natural precipitation. Acid Base Accounting (ABA) analysis was conducted on all mine waste samples to test for potential treatability and remedial options in the future.

Area estimates of pile sizes was completed using ArcMap software measurements from aerial photography. Volume estimates (if given in the analytical tables have been based on the 2005 Wood Report. Complete volume estimates will be done during the 2008 field season based on field measurements and Lidar Photo Imaging.

All source water samples collected were analyzed for the total and dissolved metals fraction for the following metals: aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver and zinc. Source water samples were compared to the CDPHE drinking water MCL. CDPHE Drinking water MCL's are based on the dissolved metals fraction; hence, the comparison made to the total metals fraction is strictly for comparison purposes. The raw analytical data are provided on CD ROM at the end of this report.

The AGS sites in the Cinnamon Gulch watershed occur within six sub districts in Cinnamon Gulch and are described below:

3.1 Decatur Town Site

Soils – Decatur Town Site

The Decatur Town Site is comprised of one mining claim owned by May Louise Coors of San Luis Obispo, California. This claim is approximately 58 acres in size along the alluvial plain of Peru Creek. Mining features are limited to three small prospect pits and one waste rock dump. Waste rock mineralization is quartz, sericite and pyrite with iron oxides on the rock dumps. The waste dump is located 300 feet above Peru creek but no water discharge was observed. Several collapsed and erect wooden structures are found in this area (Wood 2005).

There is a high probability that mill tailings originated from the El Jebel Mill Site and possibly the Giant Mill Site. These tailings are located beneath the wetlands along Peru Creek on the southeast portion of the claim and in direct contact with alluvial ground water associated with Peru Creek. These alluvial tailings are not associated with any AGS identified site. AGS features present at or near the Decatur Town Site consist of AGS-63. In 2007, samples AGS110-S3 and AGS110-S4 were collected from the wetlands and dispersed mine tailings in the area of the Decatur Town Site.

All four samples collected from this area (AGS110-S1, S2, S3 and S4) contained elevated concentrations of arsenic and lead greater than one or more of the SCDM RDSC, SCDM CRSC or the CSEV for a site worker (Table 10). Concentrations ranged 1,910 to 13,700 mg/kg for lead and from 20.8 to 93.7 mg/kg for arsenic.

SPLP analysis on samples AGS110-S3 and AGS110-S4 exceeded drinking water MCL's for cadmium, iron, lead and manganese. Sample AGS110-S4 additionally exceeded the drinking water MCL for copper. Both samples were analyzed to be highly acid generating (Table 14). These sample locations are perennially saturated or wet due to the high ground water table in this area.

Preliminary area estimates for these tailings is approximately 160,000 ft2. Volume estimates will be completed during the winter of 2008/2009 when depth approximations are made as part of an ongoing study of ground water contribution to Peru Creek is completed.

Water Discharges – Decatur Town Site

While there are no draining adits or seeps at the Decatur Town Site, shallow ground water is in direct contact with contaminated soils and tailings at the Decatur Town Site. An unknown volume of mine tailings from the El Jebel Mill Site has resulted in tailings deposition along the alluvium of Peru Creek. Ground water though out the majority of these tailings is at the ground surface. It does not appear that this ground water is associated with the alluvium of Peru Creek but rather water discharging from the Cinnamon Gulch basin. Please refer to Section 4.2, "Ground Water Pathway" for more detail.

3.2 Brittle Silver Mill Site

The Brittle Silver Mill Site is located along Cinnamon Gulch approximately 200 meters upstream from the confluence of Cinnamon Gulch and Peru Creek. AGS features present at or near the Brittle Silver Mill Site consist of AGS-111 (Forest City Claim) and AGS-113 (Forest City Claim).

Soils – Brittle Silver Mill Site

The Brittle Silver Mill Site is comprised of mostly gravel to finer size material covering the surface of the waste dump. Abundant pyrite, and minor to moderate sphalerite and galena are present in these waste dumps (Wood 2005).

In 2007, a total of four mine waste samples were collected from the Forest City Claim of the Brittle Silver Group. Total metals analysis of mine waste samples AGS111-S1, AGS111-S2, AGS113-S1 and AGS113-S2 had elevated levels of lead ranging from 851 to 83,500 mg/kg. The same four samples had elevated levels of arsenic ranging from 35.4 to 251 mg/kg. All four samples exceeded all screening criteria (SCDM RDSC, SCDM CRSC, BLM guidance value and the CSEV for site worker) for arsenic and lead. Samples AGS111-S1 and S2 contained elevated concentrations of cadmium above the SCDM RDSC (Table 10).

SPLP analysis on samples AGS111-S1, AGS111-S2, AGS113-S1 and AGS113-S2 exceeded drinking water MCL's for cadmium, iron, lead and manganese with varying frequencies between the samples (Table 14). All four samples were analyzed to be highly acid generating (Table 14).

Area estimates in square feet associated for each of the four mine waste samples are as follows - volume estimates will be completed during the winter of 2008/2009 based on average depth of tailings estimated from GPS area measurements: AGS111-S1 – 3,500 ft2; AGS111-S2 – 3,500 ft2; AGS113-S1 – 4,600 ft2; and AGS113-S2 – 2,800 ft2.

Water Discharges – Brittle Silver Mill Site

Effluent from the caved adit at the Brittle Silver Mine emerges from a rocky area believed to be on USFS land above the Brittle Silver Mill Site and flows through the old timbered ruins of the collapsed portal and infiltrates into Brittle Silver Mill Site mine waste dumps. The effluent is clear and supports grass and moss below the portal ruins. Minor amounts of reddish precipitate were observed on rocks in the channel. A retaining wall partially retains waste material at the mine waste dump from eroding to the area below (Wood 2005).

Previous water samples (high-flow sample CG-01-4 and the low-flow counterpart CG-01-35) collected in Cinnamon Gulch Creek below the tailings, and just before the confluence with Peru Creek, had pH, aluminum, cadmium, copper, lead manganese, and zinc exceeding state standards (Wood 2005).

One mine adit discharge sample was collected during the 2007 field season from adit discharge at AGS111-W1 from the Forest City Claim. This sample had detectable concentrations of total and dissolved manganese above the CDPHE drinking water MCL (Tables 19 and 20).

3.3 Tram Mine Site

The Tram Mill Site is located north of the Delaware Mine Site grouping and immediately upgradient and south of the Pennsylvania Mine grouping and is located on the western slope of Decatur Mountain about ½-mile south of Peru Creek (AGS 2003; Wood 2005). AGS features present at the Tram Mill Site consists of the AGS-33 (Tram Mill Claim).

Soils – Tram Mill Site

In 2007, a total of four mine waste samples were collected from the Delaware Mine Area. Total metals analysis of mine waste samples AGS33-S1, AGS33-S2, AGS33-S3 and AGS33-S4 had elevated levels of arsenic ranging from 110 to 333 mg/kg in all four samples. These same samples had elevated levels of lead ranging from 1,310 to 37,300 mg/kg in all four samples. Arsenic and lead were the only metals which exceeded one or more of the SCDM RDSC, SCDM CRSC, BLM guidance value or the CSEV for a site worker (Table 12).

SPLP analysis on samples AGS33-S1, AGS33-S2, AGS33-S3 and AGS33-S4 exceeded drinking water MCL's for cadmium, copper, iron, lead and manganese with varying frequencies between the samples. All four samples were analyzed to be highly acid generating (Table 16).

Area estimates associated for each of the four mine waste samples are as follows - volume estimates will be completed during the winter of 2008/2009 based on average depth of tailings estimated from GPS area measurements: AGS33-S1 – 15,000 ft2; AGS33-S2 - 25,000 ft2; AGS33-S3 – 11,200 ft2; and AGS33-S4 – 16,500 ft2.

Water Discharges - Tram Mill Site

There are no identified mine related discharges at the Tram Mill Site.

3.4 Delaware Mine Area

The Delaware Tunnel is located on the Annex Claim near the north end of the Silver Spoon area. The Delaware Mine was one of the earlier producers in the area (AGS 2003; Wood 2005). AGS features present at or near the Delaware Mine Site consists of AGS-51 (Annex Claim).

Soils – Delaware Mine Area

A total of four mine waste samples were collected from the Delaware Mine Area during the 2007 sampling. Total metals analysis of mine waste samples AGS51-S1, AGS51-S2, AGS51-S3 and AGS51-S4 had elevated levels of arsenic ranging from 33.6 to 167 mg/kg. These same samples had elevated levels of lead ranging from 2,010 to 13,800 mg/kg. Arsenic (two of the four samples) and lead (four of the four samples) were the only metals which exceeded one or more of the SCDM RDSC, SCDM CRSC, BLM guidance value or the CSEV for a site worker (Table 12).

SPLP analysis on samples AGS111 AGS51-S1, AGS51-S2, AGS51-S3 and AGS51-S4 exceeded the drinking water MCL's for cadmium, copper, iron, lead and manganese with varying frequencies between the samples. All four samples were analyzed to be highly acid generating (Table 16).

Area estimates associated for each of the four mine waste samples are as follows - volume estimates will be completed during the winter of 2008/2009 based on average depth of tailings estimated from GPS area measurements: AGS51-S1 – 42,000 ft2; AGS51-S2 – 17,000 ft2; AGS51-S3 – 1,300 ft2; and AGS51-S4 – 3,300 ft2.

Water Discharges - Delaware Mine Area

The adit at the Delaware Tunnel is on the east side of FR #262 about ¾ of a mile south of the Peru Creek crossing. A mine waste dump is present and has effluent emerging from the portal area of a completely caved adit. The effluent is relatively clear, but has deposited an orange precipitate and supports the growth of moss. Low dissolved oxygen at the portal (1 ppm) indicates that minimal oxygen is able to migrate from the surface into the caved adit. From the portal area, the effluent flows down the adit trench and ditch, with a portion of the flow infiltrating into the mine waste dump and FR #262. The remainder of effluent from the adit discharging into a settling pond constructed on the western side of FR #262. This settling pond appears to combine flows from Cinnamon Gulch and the Delaware Mine Adit discharge. The combined length of the adit trench and ditch is about 280 feet (AGS 2003; CDPHE 2007a; Wood 2005).

Two adits, one of which appears to be on private land and one on USFS, discharge water. In July of 2001, the flows from the two adits were measured at 4.6 and 7.6 gpm, respectively. In October of 2001, the flows were 1.5 and 3.4 gpm. Water samples were collected in 2001 from both adits during both sampling events (CG-7 and CG-9, and their low-flow counterparts CG-30 and -33). The pH of the samples ranged from 3.62 to 4.92, with conductivity ranging from 177 to 629 µS/cm (Wood 2005).

In 2001, constituents exceeding State water quality standards in the two Delaware Mine adit discharges (high and low flow) included dissolved aluminum, cadmium, copper, iron, manganese, and zinc in all four samples; and dissolved lead in three samples (Wood 2005).

Effluent from the adit on USFS land contained higher metal concentrations than the adit on private land with the exception of aluminum and lead. The low flow sample at the adit on private land (CG-9) had the highest lead concentration of all Cinnamon Gulch samples at 560 µg/L. High-flow samples CG-7 and CG-9 have overall higher metal concentrations than low-flow samples CG-3- and CG-33 (Wood 2005).

In 2007, a total of two samples (AGS51-W1 (CG7/CG30) and AGS51-W2 (CG9/CG33)) were collected from the two Delaware Tunnel adit discharges. These samples had concentrations of total cadmium, iron, lead and manganese above the CDPHE drinking water MCL. Additionally sample AGS51-W1 was elevated for total zinc (Table 18).

The dissolved metals fraction had detectable concentrations of cadmium, iron and manganese above the CDPHE drinking water MCL. Additionally sample AGS51-W1 was elevated for dissolved zinc, while AGS51-W2 was elevated for dissolved lead (Table 19).

3.5 Silver Spoon Mine Area

The Silver Spoon Mine area includes sites on the following mining claims: Lucky Claim, Black Crow Claim, Delaware Extension, and the Lucky Dutchman Claim. This area also encompasses the Rich Ore Load area. This area is located high in the rugged terrain of Cinnamon Gulch, which requires considerable effort to reach. There are no fences or signage in this region of Cinnamon Gulch. AGS features sampled at the Silver Spoon Mine Area consist of the following source groupings: AGS16 (Lucky Claim), AGS17 (Black Crow Claim), AGS18 (Delaware Extension Claim), AGS19 (Lucky Dutchman Claim), AGS20 (Lucky Dutchman Claim), AGS22 (Delaware Extension Claim) and AGS23 (Black Crow Claim).

Soils – Silver Spoon Mine Area

At the Silver Spoon Mine (AGS16-S1) mine waste rock covers an area of approximately 50 feet by 50 feet and reaches a height of approximately 20 feet. It is estimated that the volume of mine waste rock at the location is approximately 1,000 cubic yards. The material at the Silver Spoon Mine waste rock pile was an unsorted mixture of angular mining rubble that is in size and coloring similar to the surrounding material mantling the hillside. Coarse angular rocks cover the mine waste rock pile and the finer grained material appears to have infiltrated into the depths of the waste rock pile. Mine waste water discharge from the Silver Spoon Mine flows along the north flank of the waste rock pile and is eroding and transporting some of the waste rock material. The majority of waste rock piles in the Silver Spoon area is similar to this site.

Other mine waste piles in the vicinity (AGS16-S2, AGS16-S3, AGS17-S1, AGS18-S1, AGS19-S1, AGS20-S1, AGS22-S1 and AGS23-S1), contain abundant amounts of quartz vein pyrite and moderate amounts of sphalerite, and less common galena. Galena from mines in this area contains high silver concentrations (Wood 2005).

In 2007, a total of nine mine waste samples were collected from the Silver Spoon Mine area including other areas immediately down valley and proximal to the Silver Spoon Mine. Total metals analyses of all mine waste piles (AGS16-S1, AGS16-S2, AGS16-S3, AGS17-S1, AGS18-S!, AGS19-S1, AGS20-S1, AGS22-S1, and AGS23-S1) contained arsenic greater than one or more of the SCDM RDSC, SCDM CRSC, BLM guidance value or the CSEV for site worker. Manganese was elevated above the SCDM RFSC in AGS19-S1 and AGS23-S1. Cadmium was elevated above the SCDM RFSC in AGS16-S1 and AGS16-S2. Lead was elevated above all screening criteria in seven of the ten samples (Table 13).

SPLP analysis on samples AGS16-S1, AGS16-S2, AGS16-S3, AGS17-S1, AGS18-S1, AGS19-S1, AGS20-S1, AGS22-S1 and AGS23-S1 all exceeded drinking water MCL's for cadmium, iron, lead, manganese and zinc with varying frequencies between the samples. All nine samples were analyzed to be highly acid generating (Table 17).

Area estimates associated for each of the four mine waste samples are as follows - volume estimates will be completed during the winter of 2008/2009 based on average depth of tailings estimated from GPS area measurements: AGS16-S1 – 4,700 ft2; AGS16-S2 – 6,000 ft2; AGS16-S3 – 3,000 ft2; AGS17-S1 – 1,900 ft2; AGS18-S1 – 700 ft2; AGS19-S1 - 500 ft2; AGS20-S1 – 1,500 ft2; AGS22-S1 - 700 ft2; and AGS23-S1 – 2,000 ft2.

Water Discharges - Silver Spoon Mine Area

In 2001, samples of mine waste water discharge were collected from Cinnamon Gulch from the Silver Spoon Mine. Metals concentrations of aluminum, cadmium, chromium, cobalt, copper, lead, manganese, nickel, and zinc contamination were potentially elevated with respect to Cinnamon Gulch and Peru Creek. Four separate adits in this area discharge water into upper Cinnamon Gulch. In 2001 these four adits had a combined flow of approximately 4.5 gpm. Additionally, numerous seeps exist in this area and have not all been individually characterized. Red orange precipitate is prevalent where water is draining from a mine feature (Wood 2005).

In 2004, water samples were collected from all adits with flowing or standing water. Numerous constituents exceeded State water quality standards from these adit discharges.

In 2007, a total of six samples (SS1, AGS17-W1, AGS18-W1, AGS19-W1, AGS20-W1, AGS22-W1) were collected from the draining features in the vicinity of the Silver Spoon Mine area. These samples had detectable concentrations of both dissolved and total aluminum, cadmium, copper, iron, lead, manganese and zinc at varying frequencies between samples above the CDPHE drinking water MCL (Tables 18 and 19).

3.6 El Jebel Mill Site

AGS features present at the El Jebel Mill Site Area consists of the following source groupings: AGS108 (El Jebel Claim), AGS109 (USFS) and AGS110 (El Jebel Claim). The following samples were collected from source areas within the El Jebel Mill Site: AGS-110-S1, AGS110-S2, AGS108-S1, AGS109-S1 and AGS108-

S2. The area surrounding the El Jebel area is largely owned by claims held by Transpacific Tourism.

There are numerous waste rock dumps and a large saturated tailings pond in the downgradient wetlands. Characteristic mineralization for this mine is pyrite, chalcopyrite, galena, minor sphalerite, manganese and iron oxides on rock dumps. Metallic mining equipment are found throughout the area. Historic wood mining facilities remain on site.

Soils – El Jebel Mill Site Area

Waste rock and tailings dumps at the El Jebel Mill Site area have a potential for significant environmental degradation. Numerous drainage gullies route surface water flow over and through the site waste areas and then infiltrate into the down gradient wetlands which are underlain by mill tailings from the El Jebel Mill.

A total of five mine waste samples were collected from the El Jebel Mill Site area during the 2007 sampling event. Total metals analysis of mine waste samples AGS108-S1 had elevated levels of arsenic, 153 mg/kg and lead 46,000 mg/kg. Samples AGS109-S1 and AGS109-S2 had elevated levels of arsenic and manganese. Samples AGS110-S1 and AGS110-S2 had elevated detections of arsenic and lead (Table 10).

All five samples had one or more detections of SPLP metals which exceeded drinking water MCL's for aluminum, cadmium, copper, iron, lead, manganese, and silver. These five samples had varying frequencies between the samples. Additionally, all five samples were analyzed to be highly acid generating (Table 15).

Area estimates associated for each of the nine mine waste samples are as follows - volume estimates will be completed during the winter of 2008/2009 based on average depth of tailings estimated from GPS area measurements: AGS108-S1 – 7,800 ft2; AGS109-S1 – 13,100 ft2; AGS109-S2 – 8,000 ft2; AGS110-S1 – 8,000 ft2; AGS110-S2 – 7,700 ft2.

Water Discharges – El Jebel Mill Site Area

While there are no draining adits or seeps at the El Jebel Mill Site, shallow ground water is in direct contact with contaminated soils and tailings at the Decatur Town Site. An unknown volume of mine tailings from the El Jebel Mill Site has resulted in tailings deposition along the alluvium of Peru Creek. Ground water though out the majority of these tailings is at the ground surface. It does not appear that this ground water is associated with the alluvium of Peru Creek but rather water discharging from the Cinnamon Gulch basin. Please refer to Section 4.2, "Ground Water Pathway" for more detail.

3.7 Pennsylvania Mine Site

AGS features present at the Pennsylvania Mine Site Area consists of the following source groupings: AGS114 (Badger Claim), AGS115 (Giant Mill Site), AGS117 (Giant Mill Site), AGS118 (Giant Mill Site) and AGS120 (Evergreen Tunnel Lode). The area surrounding the Pennsylvania Mine site is largely owned by claims held by Transpacific Tourism. The Pennsylvania Mine Site area includes sites on the following mining claims: Badger Claim, Giant Mill Site, and the Evergreen Tunnel Lode.

There is one large draining adit, numerous adits, and waste rock dumps. The draining adit appears to be on Forest Service land, but this is being verified at the time of this report. Characteristic mineralization for this mine is pyrite, chalcopyrite, galena, minor sphalerite, manganese and iron oxides on rock dumps. Metallic mining equipment are found throughout the area. Historic wood-frame mining facilities remain on site. A single uncontained and untreated draining adit (the Pennsylvania Portal) has flows that range from 150 gpm on average and has been recorded as high as 4,000 gpm. The Pennsylvania Mine Portal drains onto and through the down gradient waste dump (AGS114, AGS 115 and AGS117).

Soils – Pennsylvania Mine Site Area

Waste rock and tailings dumps in the Pennsylvania Mine area have a potential for significant environmental degradation. Mine adit discharge runs through a sizeable waste rock and mill tailings pile and continues down the watershed, discharging directly into Peru Creek (Wood 2005).

A total of nine mine waste samples were collected from the greater Pennsylvania Mine Site area in the recent 2007 sampling effort. These samples included the following locations: AGS114-S1, AGS114-S2, AGS115-S1, AGS115-S2, AGS117-S1, AGS117-S2, AGS118-S1, AGS118-S2, AND AGS120-S1. All samples analyzed for arsenic exceeded all the screening criteria but one. Sample AGS120-S1 exceeded both the CSEV site worker and the SCDM CRSC criteria. Samples analyzed for lead exceeded the BLM and CSEV values in seven of the nine samples. Samples analyzed for manganese exceeded the SCDM RDSC in two of the nine samples collected in this area. All other samples and analytes were below any of the screening criteria (Table 11). .

All nine samples had one or more detections of SPLP metals which exceeded drinking water MCL's for aluminum, cadmium, copper, iron, lead, manganese, mercury (one sample) and zinc. These nine samples had varying frequencies between the samples. Additionally, all nine samples were analyzed to be highly acid generating (Table 15) based on ABA results.

Area estimates associated for each of the nine mine waste samples are as follows - volume estimates will be completed during the winter of 2008/2009 based on average depth of tailings estimated from GPS area measurements : AGS114-S1 – 1,750 ft2; AGS114-S2 – 2,300 ft2; AGS115-S1 – 4,000 ft2; AGS115-S2 – 3,600 ft2; AGS117-S1 – 11,200 ft2; AGS117-S2 – 25,000 ft2; AGS118-S1 – 11,200 ft2; AGS118-S2 – 11,100 ft2; and AGS120-S1 – 3,200 ft2.

Water Discharges – Pennsylvania Mine Site Area

The Pennsylvania mine portal is a source of perennial contaminated drainage that discharges to Peru Creek. The discharge ranged from 0.33 to 0.36 cfs (148 to 162 gpm) measured by CDMG in June and July of 1978. The pH ranged from 3.0 to 4.85, and conductivity ranged from 1,400 to 1,525 µS/cm. An additional potential major contaminant source is the infiltration through waste-rock dumps and tailings in the alluvial wetlands along Peru Creek. Combining the surface areas of all the waste rock dumps and tailings piles in the Pennsylvania Mine area gives a cumulative surface area of approximately 70,000 sq ft. Assuming 36 inches of annual precipitation, it is possible that over 2 gpm is infiltrating through the dumps and tailings located immediately down gradient of the portal, and leaching contaminants to the alluvial groundwater and Peru Creek (Wood 2005).

The Pennsylvania Mine adit discharge has been frequently sampled by EPA as part of the ongoing water quality monitoring conducted in 2006 and 2007. The Pennsylvania Mine Adit discharge sample (AGS114-W1) had detectable concentrations of dissolved aluminum, cadmium, copper, iron, lead, manganese, nickel and zinc above the CDPHE drinking water MCL. Total metals analysis of the same sample revealed elevated levels of the same metals (Tables 18 and 19).

Data prior to 2007 indicated that the Pennsylvania mine discharge varies in flow rate from around 20 to 40 gallons per minute (gpm) in the winter to a peak flow of 150 to 300 gpm during spring runoff. During the summer of 2007, the Pennsylvania Mine discharged a peak flow in August, which corresponded to a large precipitation even in the upper Cinnamon Gulch Basin, estimated flows as high as 4,000 gpm. This high flow from the Pennsylvania Mine resulted in a fish kill occurring in the Snake River downstream of its confluence with Peru Creek.

It is recommended that monitoring of the Pennsylvania Mine discharge flow rates be continued as well as corresponding sample collection during these storm events continue in order to evaluate the frequency and potential impacts of large discharge events. Ground water sampled immediately downgradient of the Pennsylvania Mine Adit discharge (please refer to Section 4.0, Ground Water Pathway) appears to indicate that the Pennsylvania Mine Adit discharge is loosing water prior to the discharge point, thus infiltrating into the substrata and the down gradient waste rock pile. Future work scheduled for 2008 and 2009 will evaluate options that would address this loss of water to the substrata and control the adit discharge using a flow control bulkhead.

3.8 Conclusions - Waste/Source Characteristics

Based on analytical data from these waste source areas, all sources are considered to be acid generating and contain high levels of metals and are readily leachable (Tables 10 to 17). Future efforts to reduce loading to the watershed should start first with moving source areas out of, and away from contact with water and erosional migration.

The upper and middle Cinnamon Gulch drainage has numerous waste piles in direct contact with water that appear to be significant contributors to contamination in Cinnamon Gulch. Two of the larger acid-generating waste piles which are in direct contact with water are the piles associated with AGS16 and AGS51. AGS16 is located at the discharge point of the Silver Spoon Mine, where the adit discharge flows directly over and through the waste rock pile. Historic surface water sampling at the Silver Spoon discharge has only been collected after it has flowed past and over the waste rock pile in the water course. In 2008, additional sampling was completed immediately above the Silver Spoon Waste pile at AGS16 in an attempt to quantify potential contaminant contribution from this waste pile. AGS51 is located further downgradient in the Cinnamon Gulch drainage and consist of the Delaware Mine waste piles and adit discharge. The adit discharge flows through waste rock and into the remnants of an historical tailings impoundment. Additional locations have been added to better bracket and quantify source areas area around the Delaware Mine area, but are not available for this report.

The lower Cinnamon Gulch drainage has three distinct areas where waste piles or tailings are in direct contact with water. The first of these areas is represented by mine tailings and waste rock at the Pennsylvania Mine Adit discharge and immediately downgradient waste piles. Additionally, the adit discharge path and eroded channel contain elevated leachable metals concentrations. This area is represented by the piles associated with AGS 114, AGS115 and AGS117. Metals elevated in soil sample at AGS114, AGS115 and AGS117 samples were also elevated in the adit discharge sample. To date, the only sample collected from the Pennsylvania Mine adit discharge has been collected from the discharge point at the collapsed adit. No other surface water samples have been collected to date further downgradient on the discharge flow but prior to the confluence of Peru Creek. Future sampling should have an additional sampling point on the Pennsylvania Mine discharge immediately upgradient of the Peru Creek confluence.

The second area in the lower Cinnamon Gulch drainage is represented by mine tailings, waste rock and contaminated wetlands comprised of saturated tailings and organic matter originating from the El Jebel Mill Site. Tailings in the saturated wetlands are believed to be derived from the workings at the Pennsylvania Mine and the Tram Mine site located approximately ¼-mile south and uphill from the El Jebel Mill Site. The mine waste pile located at the Pennsylvania Mine site does not appear to contain mine tailings, thus indicating that the milled ore was transported down to the closest mill site. The mine waste piles at the Tram Mine site also appears to support this conclusion based on the lack of tailings at the upgradient Tram Site and the historic aerial tram which connected the Tram site to the El Jebel Mill Site. The supplemental ground water investigation with field work completed during the summer of 2008 should provide preliminary data as to contaminant contributions from the saturated wetlands to Peru Creek. Additional supplemental data will be collected during the summer of 2009 which will quantify the loading contribution from ground water to surface water via these saturated tailings/wetlands.

The upgradient portion of the wetland area is comprised of waste rock and tailings which have eroded into the lower downgradient wetlands. Numerous intermittent water drainages occur through the upper waste rock and tailings. The lower wetlands are completely saturated and, based on preliminary ground water results discussed in Section 4.0, Ground Water Pathway, are highly contaminated and appear to contribute substantial contaminant loading to Peru Creek. This area is represented by the piles associated with AGS 108, AGS109 and AGS110.

The third area in the lower Cinnamon Gulch drainage is represented by mine tailings, waste rock and potentially additional contaminated wetlands comprised of saturated tailings and organic matter originating from the Brittle Silver Mill Site. This site area is comprised of waste rock and tailings with water passing through the area from Cinnamon Gulch and the caved in Brittle Silver Mine with adit discharge. Both water sources flow across and through the associated mine waste dumps and tailings. The downgradient portion (wetlands and potential contaminated wetlands) of the Brittle Silver Mill Site was not assessed during the 2007 or 2008 field season; hence, it is unknown if tailings contaminated wetlands exist along the Peru Creek alluvial floodplain. This area is represented by the piles associated with AGS 111 and AGS113. Additional supplemental data will be collected during the summer of 2009 which will be quantifying the loading contribution from ground water to surface water via these saturated tailings/wetlands.

Due to limited sampling locations on Cinnamon Gulch which bracket these source areas, the total contribution to the overall loading has not been calculated, but based on the 2005 Wood estimate of 36 inches of annual precipitation and the associated adit discharges, an estimated minimum of over 2 gpm is infiltrating over and through the waste dumps and are contributing to the leaching of contaminants to Cinnamon Gulch and the alluvial groundwater. Additional locations which better bracket potential sources have been added at the Silver Spoon Mine and the Delaware Mine, but should also include the drainage emanating from the Pennsylvania Mine adit discharge upgradient of the confluence with Peru Creek.

4.0 GROUND WATER PATHWAY

In July 1986, a total of ten shallow wells were drilled using a gasoline powered four-inch auger to a rock base under the organic base. Wells range in depth from 5 to six feet each. All wells were completed with approximately 4 feet of perforated 2-inch PVC pipe with pea gravel surrounding the perforated sections of the well and one foot of solid PVC pipe with a bentonite pack surrounding the solid PVC. It is unknown if the rock base underneath the organic layer is comprised of native rock or waste rock from the El Jebel, Forest City and Giant Mill Site (Huskie 1987). Of the 10 wells installed in 1986, three wells (GWC1, GWE6 and GWE7) were sampled as part of the October 2007 ground water sampling (Figures 25 to 32).

All ground water samples collected were analyzed for the total and dissolved metals fraction for the following metals: aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver and zinc. Ground water results were compared to the CDPHE drinking water MCL. CDPHE drinking water MCL’s are based on the dissolved metals fraction; hence, the comparison made to the total metals fraction is strictly for comparison purposes (Tables 24 and 25).

4.1 Ground Water Targets

A review of groundwater well records maintained by the State of Colorado Division of Water Resources indicates that there are few groundwater wells permitted for beneficial use (drinking water) in the Peru Creek Drainage. The closest well to the site is located less than 0.5 miles down gradient of the site. This well located 0.5 miles downgradient of the site appears to consist of an intake of a natural spring seep on a hillside. It is not believed that water emanating from this seep is potentially affected from shallow groundwater in the alluvium of Peru Creek. One well is located between 1.0 and 2.0 miles from the site. Ground water wells within the 2.0 mile radius of the site are located in the Peru Creek drainage and may be impacted from the site. A total of 4 wells are located between 3.0 and 4.0 miles from the site; and approximately 83 wells are located between 3.0 and 4.0 miles of the site. These wells are located in or just outside of the town site of Montezuma, where the 83 wells are located in the 3.0 to 4.0 mile radius of the site, is located in the valley of the Snake River, upgradient of Peru Creek. There is no known mechanism to permit mixing of groundwater from the Peru Creek Valley with that from the Snake River Valley, upgradient of the confluence of the two streams (Colorado Division of Water Resources 2001).

Contaminated ground water in the region of the El Jebel, Forest City and Giant Mill Site is present in the shallow alluvium of Peru Creek. Based on ground water analytical data, significant metals contamination exists which is in direct contact with the Peru Creek alluvium. Contaminant concentrations in Peru Creek water samples suggests a spike in contaminant concentrations between water quality sample location SW-140 (upgradient of the Peru Creek Pennsylvania Mine discharge confluence) and the next down gradient sample locations PC-4 (Peru Creek downstream of Pennsylvania Mine discharge and upstream of Cinnamon Gulch confluence) and SW-158 (Peru Creek midway between Warden and Cinnamon Gulch) (Figures 25 to 32). No additional inflows exist in this reach of Peru Creek other than the potential for ground water to surface water interaction and surface water runoff. During the summer of 2009, the ground water to surface water interaction will be better characterized as well as estimating volumes of ground water discharges and contaminant concentrations impacting Peru Creek and volumes of tailings and contaminated soils in these wetlands immediately down gradient of the El Jebel, Forest City and Giant Mill Sites.

4.2 Ground Water Sample Locations

A total of 8 groundwater wells were installed and sampled during the 2007 field season (Tables 24 and 25) In addition, a total of 3 existing groundwater wells were sampled and analyzed for metals, anions, and other parameters as indicated on Tables 24 and 25. Please refer to Figures 25 through 32 for detailed information as to specific locations of all ground water samples collected.

Ground water well GW1 was completed to 40 feet through waste rock approximately 50 feet immediately down gradient of the Pennsylvania Mine Adit discharge. This well was screened from 18 to 38 feet bgs. No samples of the blown out rock substrata were collected for volume estimates of the waste pile. During the drilling, it appeared that native rock was encountered at between 12 and 15 feet bgs. The water level in this well was approximately 38 feet bgs, indicating a low water table and slow infiltration into the screened well interval. It is believed that the portal of the Pennsylvania Mine is loosing water prior to the actual discharge point at the collapsed adit discharge, thus infiltrating into the substrata and the down gradient waste rock pile.

Ground water well GW2 was completed to 13 feet through organic peat and intermixed tailings down gradient of the El Jebel Mill Site. This well was screened from 5 to 10 feet bgs. During drilling, it appeared that native rock was encountered at 10 feet bgs.

Ground water well GW3 was completed to 17.6 feet through into what appeared to be shallow waste rock and into the Peru Creek alluvium. This well was screened from 5 to 15 feet bgs. During drilling, it appeared that native rock was encountered at 10 feet bgs.

Ground water well GW4 was completed to 27.8 feet through waste rock adjacent to the former water treatment plant. This well was screened from 15 to 25 feet bgs. During drilling, it appeared that native rock was encountered at 15 feet bgs.

Ground water well GW5 was completed to 12.7 feet through organic peat and intermixed tailings on the eastern edge of the wetland complex, down gradient of the El Jebel Mill Site. This well was screened from 5 to 10 feet bgs. During drilling, it appeared that native rock was encountered at 10 feet bgs.

Ground water well GW7 was completed to 11.5 feet through organic peat and intermixed tailings down gradient of the El Jebel Mill Site. This well was screened from 5 to 10 feet bgs. During drilling, it appeared that native rock was encountered at 10 feet bgs.

Ground water well GW10 was completed to 17.5 feet through into what appeared as native bedrock in the upper Cinnamon Gulch watershed. This well was screened from 15 to 5 feet bgs.

Ground water well GW11 was completed to 32.4 feet through into what appeared as native bedrock in the upper Cinnamon Gulch watershed. This well was screened from 30 to 10 feet bgs.

4.3 Ground Water Analytical Results

Ground water samples collected in the alluvial area in Cinnamon Gulch and the Pennsylvania Mine area appear to have four different characteristics. The first characteristic appears to be that of alluvial ground water in the Peru Creek alluvium. Sample GW3, collected upgradient of the confluence of the Pennsylvania Mine adit discharge and Peru Creek had detections of manganese and zinc slightly above the CDPHE drinking water MCL's (Tables 24 and 25). It appears that there may be influence in this well via infiltrating water from the Pennsylvania Mine adit discharge.

The second characteristic ground water appears to be alluvial ground water in contact with tailings or waste rock tailings in and adjacent to the wetlands immediately down gradient of the El Jebel, Forest City and Giant Mill sites. Ground water wells GW2, GW5, GW7, GWC1, GWE6, GWE7 and to a lesser degree well GW4. All wells are completed into either waste rock or a mixture of waste rock and organic materials in the wetlands. Samples from these wells had varying frequencies of detections, but cadmium, copper, iron, manganese, nickel and zinc were detected above the CDPHE drinking water MCL's (Tables 24 and 25). It is unknown as to the source of this water and where it emanates from.

The third characteristic ground water appears to that which discharges from the Pennsylvania Mine adit and ground water immediately downgradient of the discharging adit. It has been theorized that prior to discharging from the Pennsylvania Mine Portal, water is potentially infiltrating into the substrate from within the collapsed portion of the Pennsylvania Mine. Ground water well GW1 is located approximately 50 feet immediately down gradient of the Pennsylvania Mine Adit discharge. Ground water collected at GW1 had elevated detections of cadmium, copper, iron, manganese, nickel and zinc above the CDPHE drinking water MCL's. Analytical results from GW1 were similar in detected metals and concentrations to the Pennsylvania Mine Adit sample (AGS114W1, with the exception of iron and lead, which were one order of magnitude higher in the adit discharge sample as compared to the ground water sample (Tables 18, 19, 24 and 25).

The fourth characteristic ground water appears to represent the shallow alluvial ground water in the upper Cinnamon Gulch watershed. Samples GW10 and GW11, collected upgradient of an area in the upper Cinnamon Gulch watershed where bedrock outcrops and appears to force all regional groundwater in the Cinnamon Gulch alluvium into a narrow channel. These samples had no detections of contaminants above the CDPHE drinking water MCL's (Tables 24 and 25).

Please refer to Figures 25 through 32 and Tables 24 and 25 for detailed information as to specific locations and specific analytical results of all ground water samples collected. The raw analytical data are provided on CD ROM at the end of this report.

4.4 Groundwater Conclusions

There is the potential that significant volumes of shallow ground water may be discharging to surface water in Peru Creek. Wetlands with buried tailings from the mine are immediately adjacent to the creek and exhibit significantly elevated concentrations of total and dissolved metals (Tables 24 and 25). Further characterization of ground water in the vicinity of Peru Creek (scheduled for completion during 2008/2009) will aid in the understanding of what the substrate consists of, as well as what contaminants and discharge volumes to Peru Creek are ongoing.

Additionally, further well sampling should continue with the addition of new monitoring wells (areas and locations to be determined). Sampling and analysis of the two drinking water wells within the 2.0 mile radius of the site should also be conducted.

5.0 SURFACE WATER PATHWAY

EPA's water program began surface water sampling in the Peru Creek watershed in 2001. Historic and current sample locations have bracketed major inflows into the Snake River and Peru Creek. In 2008, EPA began to add additional locations as well as the previous historic locations to gain a better understanding of specific mine waste piles or contaminant inflows (draining features) along these drainages. Rivers, creeks, gulch's and drainages include the following: Snake River, North Fork Snake River, Peru Creek, Deer Creek, Saints John Creek, Warden Gulch, Chihuahua Gulch, and Cinnamon Gulch. Additionally, numerous sample locations have been collected from un-named locations near the headwaters of the Peru Creek drainage. While upstream, or background locations of the Pennsylvania Mine site are included, the other headwater locations are not discussed in this report and have been sampled as to gain a better understanding of naturally occurring metals concentrations in the upper reaches of this basin.

All surface water samples collected have been analyzed for the total and dissolved metals fraction for the following metals: aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver and zinc. Additionally surface water samples were analyzed for sulfate, chloride, alkalinity, dissolved organic carbon, and various cations, including sodium, potassium, calcium, and magnesium, were also analyzed from the dissolved metals fraction. Surface water results were compared to the CDPHE drinking water MCL and the acute and chronic environmental SCDM benchmark. CDPHE Drinking water MCL's are based on the dissolved metals fraction; hence, the comparison made to the total metals fraction is strictly for comparison purposes.

5.1 Surface Water Pathway Targets

There are no recorded surface water intakes on Peru Creek and one recorded surface water intake on the Snake River. The intake on the Snake River is used primarily for snow making at the Keystone Ski area but supplements for potable water at the Summit Lodge (top of ski area) for approximately 2 to 3 months during the winter season (Keystone Resorts 2008). The Summit Lodge is used by a transient population of recreational users; hence, there are no residents affected by this use. Prior to being used in the potable water system, the water is filtered and treated (Keystone Resorts 2008). Denver Water, the principal water provider for the Denver metro area, owns and operates Dillon Reservoir, which borders the Towns of Silverthorne and Dillon in Summit County. Dillon Reservoir stores inflows from the Blue River and smaller basin tributaries, including inputs from the Snake River, and transports the water under the Continental Divide through the Roberts Tunnel to the southern end of Denver's water collection system. Annually, the water from the reservoir is directed into Roberts Tunnel pipeline that is used to augment the drinking water supply for the City of Denver. The water from the reservoir is blended with other sources and supplies approximately ¼ of the drinking water to the City of Denver and surrounding area of 1.2 million (http://www.denverwater.org/waterquality/pdfs/2008_water_quality_report.pdf).

Peru Creek, the Snake River, and the Dillon Reservoir are used for recreational fishing activities. Dillon Reservoir attracts large numbers of visitors annually with abundant hiking, biking, camping, hunting, watersports and fishing opportunities in the area. There are two active marinas and five developed recreation campgrounds at the reservoir. Dillon Reservoir is a municipal water supply locally and for the City of Denver.

While Peru Creek and the Snake River are not stocked by the Colorado Department of Fish and Wildlife, Keystone resort stocks portions of the Snake River with trout species in and around the Keystone area. Trout are present in Chihuahua Gulch (URS 2002). However, recent fish shocking results conducted by the Colorado Department of Wildlife (DOW) for Peru Creek and the Snake River indicate that fish are either completely absent (Peru Creek) or are the adult rainbow trout that are periodically stocked throughout the summer months (portions of Snake River). This information coincides with numerous past studies and research that have been conducted in Peru Creek and the Snake River (Todd 2006).

The presence of fish populations within the Snake River watershed has been quantitatively ascertained through the use of electro-fishing, but also qualitatively documented through creel surveys. Resident, reproducing populations of brook trout have been documented in several major tributaries to the Snake River (Deer Creek, North Fork of the Snake River) and Peru Creek (Chihuahua Gulch).

Electro-fishing by the CDOW on July 24, 2007 documented populations of brook trout in the Snake River below the confluence with the North Fork of the Snake River, and in Sts. John Creek, a tributary to the Snake River. On this date, both populations yielded many fish in multiple age classes, likely reflecting brook trout reproduction within those streams. Further, many large rainbow trout were captured in the Snake River below the confluence with the North Fork, however because all of these rainbow trout were very large, it was evident that these fish were stocked. Other sections of river sampled on this date included several locations on the Snake River between the confluence with Peru Creek and the North Fork of the Snake River, and several locations on Peru Creek including above and below the Pennsylvania Mine. Fish were absent from all of these locations. Finally, the Snake River was qualitatively electro-fished above the confluence with Peru Creek, and while several brook trout were captured, it is unclear whether this population is resident and reproducing. Additional surveys are scheduled for July 2008.

Results from fish shocking conducted in July 2007 indicated that a sustaining population of brook trout existed in the lower portion of the Snake River below the confluence of the North Fork of the Snake River (data from DOW). However, following a large storm event that occurred in August 2007, the station on the Snake River below the confluence with the North Fork of the Snake River was revisited and electro-fished again. This follow up effort yielded two large brook trout. This data confirmed that the storm event caused a significant fish kill within this reach. According to CDOW biologists, it is probable that the two large brook trout captured during this effort were fish from the North Fork of the Snake River moving downstream (Ewert and Todd 2008). The fish kill in the Snake River coincided with a heavy rainstorm event and a high water surge was reported by the data-logger at the Pennsylvania Mine adit. It is unknown if the storm and subsequent metals loading increased due to the storm or from the increased flow from the Pennsylvania, and if the increased flow from the Pennsylvania Mine was influenced directly from the coinciding storm event (Summit Daily News 2007). It is well documented that Keystone Resorts stocks the Snake River in Keystone with approximately 2,500 lbs of rainbow trout annually for summer angling. While this area is frequented by catch-and-release anglers, a major percentage of the angling witnessed during the summer of 2008 is for fish being harvested for consumption (CDPHE 2008).

Sensitive Environments

Wetlands

There are extensive palustrine scrub-shrub and emergent wetlands located along Peru Creek. Multiple small isolated semi-permanent palustrine open water wetlands are located along Peru Creek downstream of the site to Peru Creek's confluence with the Snake River (Figure 1). Approximately six acres of streamside wetlands are located along the Snake River from the confluence of Peru Creek to the inlet of Dillon Reservoir. There are small upland wetland areas located in upper Cinnamon Gulch near the Silver Spoon Mine and associated adits (URS 2002).

Federally Threatened and Endangered Species

The Pennsylvania Mine site is partially located on or immediately adjacent to the White River National Forest (WRNF). A recent Biological Assessment was prepared to evaluate the potential effects of the proposed Revised Forest Plan on federally listed species and their habitat (U.S. Department of Agriculture (USDA) 2008). The Biological Assessment discusses the federally threatened or endangered species associated with the White River National Forest. The T&E species evaluated and potentially existing in the WRNF include Penland alpine fen mustard, Uncompahgre fritillary butterfly, Southwestern willow flycatcher, bald eagle, Mexican spotted owl; Canada lynx, Colorado pikeminnow, humpback chub, bonytail, and razorback sucker.

Some of the area within the 15 mile downstream area from the site has been designated as lynx habitat and sites of re-introduced collared lynx are near and may be within the immediate area of the site (USFS 2005, Figure 2). Canada Lynx were listed as a threatened and Endangered Species by the USFWS on March 24, 2000. Lynx habitat has been mapped on the WRNF and indicates that 47% of the forest as suitable lynx habitat. Beginning in 1999, the CDOW initiated a reintroduction program for Canada lynx by relocating lynx trapped in Canada and Alaska to the Southwest portion of Colorado. While the majority of the reintroduced animals have established home ranges in the general vicinity of the releases in the southwest quarter of the state, many have immigrated into suitable habitats throughout Colorado, including the WRNF. A second core area of resident lynx has become established in the area of the Gunnison National Forest and the WRNF (USDA 2008).

5.2 Surface Water Sample Locations

Surface water and sediment was collected during two sampling events conducted in July 2007 and September 2007 to characterize water quality and sources contributing to contamination in Peru Creek and the Snake River. The first event was conducted following snowmelt during a period of high runoff on July 9, 2007. The second event was conducted during low-flow on September 26, 2007. Locations and rationale for sampling are described in Table 3 and are depicted on Figure 1. Analyses on samples collected during both 2007 events included: total metals, dissolved metals, alkalinity, anions, and dissolved organic carbon.

The July 2007 site investigation focused on the sites in Peru Creek, above and below the mine adit discharge, as well as additional locations on tributaries that discharge to Peru Creek including, Cinnamon Gulch, Warden Gulch, and Saints John Creek. These locations were sampled again in September 2007 with the exception of two locations on Warden Gulch that were found to be dry (site WG-4 and WG-Source). The September event also included additional locations on Peru Creek upstream of the Pennsylvania Mine and various upstream tributaries and groundwater discharges flowing into the main stem of the Peru Creek upstream of the Mine.

As indicated in Table 3, surface water at several sites in Peru Creek and the Snake River were also sampled for use in acute aquatic toxicity tests conducted in the laboratory using rainbow trout (Oncorhynchus mykiss).

5.3 Surface Water Analytical Results

Pennsylvania Mine Adit Discharge – Location SW-116

The Pennsylvania Mine is a significant cause of water quality deterioration in Peru Creek. Analytical results for the Pennsylvania Mine adit discharge (location SW-116) indicate extremely high levels of aluminum, cadmium, copper, manganese, and zinc, all exceeding State of Colorado acute water quality standards (Tables 17 through 24). For example, total and dissolved zinc concentrations reported in July 2007are reported at 55,500 ug/L and 56,100 ug/L (respectively). The concentrations reported on Tables 17 through 24 indicate that concentrations are also elevated above acute table value standards for cadmium, copper, and manganese metals. Chronic table value standards were also exceeded for other metals, including lead and nickel. Total iron in the discharge was also extremely high and concentrations ranged from 19300 to 99200 ug/L. The high iron concentrations resulted in orange colored staining in the bottom substrate and field conductivity readings in the 1100 to 2100 us/cm range. Field measured pH values ranged from 2.79 to 3.33 at the mine adit discharge.

The most significant increase in metals concentration and metals loading to Peru Creek occurred immediately downstream of the Pennsylvania Mine adit at site PC-4. Aluminum, cadmium, copper, and zinc all exceeded acute Colorado water quality standards at this location for both sampling events. Evaluation of flow and analytical results indicate that the Pennsylvania Mine has the most significant effect on water quality in the late summer after runoff has occurred. In September 2007, concentrations of cadmium, copper, and zinc increased by 1300%, 4300%, and 1000% when compared to the location immediately upstream of Pennsylvania Mine adit discharge (site SW-140) to the next downstream sample location in Peru Creek (PC-4). For this reason, the Pennsylvania Mine had the greatest effect on water quality in Peru Creek in the late fall because flow out of the mine was high while flow in the creek was low.

Peru Creek Analytical Results

Peru Creek - Upstream of Pennsylvania Mine (ET-4, ET-3, ET-3A, ET-2, ET-1, SB-1, WT-1, PC-9, PC-BP, PC10, SW-140 and PC-6:

Analytical results for Peru Creek headwaters (ET-4) and other upstream locations (PC-10) in Horseshoe Basin indicate non-detect or low concentrations for metals and further downstream at the Vidler Tunnel headgate (PC-9) (See Tables 17 through 24). The Vidler Tunnel transports water from the Horseshoe Basin to the City of Golden for drinking water purposes.

As indicated on Figure 1, the headwaters of Peru Creek originate as the first tributary on the eastern side of the basin. Analytical results for this tributary, designated ET-4, indicate non-detect or low concentrations and a pH of 6.51 (Tables 17 through 24). Metals that are reported at levels slightly above the detection limit include manganese and nickel.

Downstream of Peru Creek headwaters are four other tributaries that originate on the eastern side of the basin and two tributaries originating from the western side of the basin. The eastern tributaries are designated as ET-3, ET-3A, ET-2, and ET-1. Analytical results indicate that, similar to ET-4, these tributaries are clean with most metals reported below detection limits. The two western tributaries included the Shoe Basin Mine adit, designated as site SB-1, and an unnamed drainage called WT-1. Metals analyses indicate that SB-1 and WT-1 have low pH (2.92 and 4.69 respectively) and elevated levels of sulfate, aluminum, cadmium, copper, manganese, nickel, and zinc. Results for SB-1 also indicate elevated levels of iron and the highest amount of total strontium (3060 ug/L) of any site sampled during the September 2007 investigation. The results for the Shoe Basin Mine adit water are elevated when compared to the western tributary. For example, the adit, SB-1 indicates 14 times greater concentrations of cadmium, 45 times greater copper and manganese, and 57 times greater zinc.

During the September 2007 investigation, the location that sites ET-3, ET-3A, ET-2, ET-1, SB-1, WT-1 actually flowed into Peru Creek was difficult to determine because flow of all tributaries was very low and trickled through thick vegetation into a series of beaver ponds before reaching the creek. Peru Creek is also ponded in this area. Due to the low flow conditions, flow measurements could not be collected at these locations.

Field personnel collected a water and sediment sample from one pond for comparison to results from site PC-8. This site, designated PC-BP, was just downstream of ET-1, the last eastern tributary. Analytical results revealed that water quality in Peru Creek improved significantly when moving downstream from PC-8 to PC-BP even with the additional metals loading from sites WT-1 and SB-1. Because all five eastern tributaries were very clean and flowed at considerably greater rates than WT-1 and SB-1, they provided enough dilution to increase the pH in Peru Creek and caused metals to precipitate out of solution. For this reason, sediment quality was considerably worse at PC-BP even though water quality was better when compared to PC-8.

Peru Creek flows from the ponded area at site PC-BP to site PC-6. Water quality continued to improve in this reach of the creek with all metals decreasing in concentration. The decrease in metals concentrations was also observed to the next downstream site, SW-140, which is located immediately upstream of the Pennsylvania Mine adit confluence.

Although metals concentrations improved comparing upstream Peru Creek PC-6 to SW-140, pH measurements decreased in this reach from 6.2 to 4.0 during the September 2007 sampling event. This trend was not observed during the July 2007 event which indicate that pH was 5.96 at PC-6 and 6.12 at SW-140. Additional pH and other analyses will be collected in future sampling events.

Peru Creek – Downstream of Pennsylvania Mine (PC-4, SW-158, SW-085 and SW-049)

Peru Creek is the greatest source of metals loading to the Snake River. The most significant increase in metals concentration and loading to Peru Creek is reported immediately downstream of the Pennsylvania Mine adit at site PC-4. As indicated on Tables 17 through 24, aluminum, cadmium, copper, and zinc all exceeded acute Colorado water quality standards at this location for both sampling events. Evaluation of the data indicates that the Pennsylvania Mine adit discharge has the most significant effect on water quality in the late summer after runoff has occurred. Concentrations of cadmium, copper, and zinc increased by 1300%, 4300%, and 1000% from site SW-140 to PC-4 in September 2007.

Even though metals concentrations spiked significantly in Peru Creek downstream of the Pennsylvania Mine, they tended to decrease slightly due to dilution from the next tributary, Cinnamon Gulch. Lead concentrations in Cinnamon Gulch were also above the chronic TVS and caused concentrations to spike in Peru Creek downstream of the confluence.

Three quarters of a mile downstream of Cinnamon Gulch, Peru Creek next confluenced Warden Gulch, another tributary with elevated metals concentrations. Colorado acute standards for aluminum, cadmium, copper, manganese, and zinc were all exceeded in Warden Gulch at the mouth to Peru Creek. Metals concentrations in Peru Creek typically increased downstream of Warden Gulch at site SW-085 during periods of higher flow in the spring and summer. In the fall, however, most of the flow in Warden Gulch disappeared so water quality actually improved at SW-085 during the September 2007 sampling event. Metals loading, like metals concentrations, increased in Peru Creek downstream of Warden Gulch during the spring and summer.

After mixing with Warden Gulch, Peru Creek next confluences with Chihuahua Gulch ¾ of a mile further downstream. Unlike Warden and Cinnamon gulches, Chihuahua Gulch indicates excellent water quality during this site investigation with almost all metals reported below detection. This excellent water quality improved water quality in Peru Creek at site SW-049 and decreased metals concentrations by an average of 41%.

Approximately one mile downstream of site SW-049, Peru Creek flowed into the Snake River. Concentrations for most metals are elevated and continue to be above table value standards. There are no other tributaries that flow into Peru Creek downstream of site SW-049.

Cinnamon Gulch Surface Water Analytical Results (SS-1, SW-Cinn3, SW-ECinn, SW-UpCinn, DMA-1 and SW-Cina)

Cinnamon Gulch flows into Peru Creek about one third of a mile downstream from the confluence with the Pennsylvania Mine. The Silver Spoon Mine adit discharges in upper Cinnamon Gulch and is co-mingled with other groundwater seeps before reaching Peru Creek approximately one mile downstream. As shown on Table 17 through 24, results for the Silver Spoon mine adit discharge, designated as site SS-1, indicate elevated levels of aluminum, cadmium, copper, iron, lead, manganese, nickel, and zinc at concentrations above Colorado acute table value standards. Although most metals concentrations in this discharge were considerably lower than those found in the Pennsylvania Mine, lead was found at the highest concentration of any site sampled during this SI. Lead concentrations were detected at levels greater than 8 times the acute standard at SS-1. Flow out of the Silver Spoon Mine ranged from 10 gpm in September 2007 to 19 gpm in July 2007 while pH values remained close to 3.2 for both sampling events.

Downstream of SS-1, water in Cinnamon Gulch confluences several other groundwater seep discharges. Some of these appear to be natural springs while others are draining adits from old mine tunnels. Many of these sources were ephemeral; ones that flowed in the spring of 2007 did not flow during the September 2007 event. Because the Colorado Geological Survey had done extensive work characterizing the Cinnamon Gulch drainage in 2001, many of these groundwater seeps were not sampled during this SI.

The next downstream site that was sampled on Cinnamon Gulch was SW-Cinn3 and it is located just above a tributary that flows into Cinnamon Gulch water from the eastern side of the basin. As shown on Tables 17 through 24, concentrations of all metals were significantly reduced at SW-Cinn3 when compared to those from SS-1. The amount of reduction was typically greater during higher flow in July 2007 compared to the lower flow period in September 2007. Even though concentrations were reduced, they still exceeded acute standards for most metals.

The eastern tributary to Cinnamon Gulch, designated as site SW-ECinn, originated in several locations. A major portion of the flow came out of the ground at the base of a steep slope about ¼ to ½ mile to the east of the confluence. Field personnel found no evidence of mining at this location and the flow joined with several other groundwater seeps before reaching site SW-ECinn. Levels of aluminum, cadmium, copper, manganese, and zinc exceeded Colorado acute TVS at this site in September 2007. Acute standards were also exceeded when concentrations were lower in July 2007 for these same metals except for manganese. Because metals concentrations at site SW-ECinn were typically lower than those found at site SW-Cinn3, the confluence of this tributary resulted in a slight reduction in metals concentrations at SW-UpCinn, the next sampling location on Cinnamon Gulch.

Cinnamon Gulch next confluences with the Delaware Mine adit about 150 to 200 yards downstream of SW-UpCinn. The Delaware Mine adit, designated as site DMA-1, was only sampled in September 2007. Flow was just over 7 gpm and concentrations of aluminum and copper in this drainage were the lowest of all sites sampled on Cinnamon Gulch, but still exceeded acute standards. Cadmium and zinc, however, were detected at levels about twice in concentration while lead, manganese, and nickel were detected at similar concentrations to Cinnamon Gulch. After mixing with the Delaware Mine adit, Cinnamon Gulch next reached Peru Creek approximately ½ mile downstream. Results at this location indicate that acute standards are exceeded for aluminum, cadmium, copper, and zinc and the chronic standard was exceeded for lead.

Like Peru Creek, the Snake River, and the Pennsylvania Mine adit, metals concentrations were the highest in Cinnamon Gulch during periods of low flow while metals loading was greatest during periods of high flow. Although the headwaters of Cinnamon Gulch are highly contaminated at the Silver Spoon Mine adit, metals concentrations decreased as the stream flowed toward Peru Creek. Flow values at the furthest downstream location ranged from 0.6 cfs in September 2007 to 9.1 cfs in June 2006 while pH readings ranged from 3.60 to 4.00 for the same sampling events.

Warden Gulch Surface Water Analytical Results (WG-Source, WG-4, WG-3, WG-2, WG-SE, WGM-1 and SW-168)

Warden Gulch flows into Peru Creek approximately ¾ of a mile downstream from the confluence with Cinnamon Gulch. In July 2007, the most upstream location sampled on Warden Gulch is site WG-Source. As indicated on Tables 17 through 24, concentrations of aluminum, cadmium, copper, manganese, and zinc exceed Colorado acute standards and lead slightly exceeded the chronic standard at this location. Flow was measured at about 130 gpm and pH was 4.14 in July 2007. Concentrations of all metals except copper increased as flow moved from WG-Source to the next location, WG-4. A detailed reconnaissance of this stretch of stream was not performed during this SI so the cause of this increase is still unknown. Flow increased to about 600 gpm at WG-4 so the stream was gaining flow from some source that was not observed. Two locations, WG-Source and WG-4 were dry in September 2007 and thus were only sampled during the July event.

Downstream of WG-4, Warden Gulch next confluences a tributary that flowed from southeastern side of the basin. Analytical results for this tributary, designated WG-3, indicate considerably lower concentrations of aluminum, copper, and manganese than WG-4. The only metal that was greater in concentration was zinc. Field pH results also support this observation of improved conditions in that pH was reported at one standard unit higher at this location. The dilution provided by the confluence of the tributary at WG-3 appears to have resulted in a decrease in concentration of metals on Warden Gulch at the next downstream sampling site, WG-2. Approximately 350 yards downstream of WG-2, Warden Gulch next mixed with another tributary that sourced from the southeastern portion of the basin. This tributary, designated WG-SE, also had levels of aluminum, cadmium, copper, manganese, and zinc above the Colorado acute TVS. The source of this tributary were not observed during this SI so it is unknown if the high concentrations are natural or due to mining activity. Flow at WG-SE ranged from about 110 gpm in September 2007 to about 165 gpm in July 2007. pH values also ranged from 3.50 to 3.72 during these two sampling events. During this SI, field personnel observed a spring that came out of the ground very close in proximity to site WG-SE. Samples were not taken at this spring but field meter chemistry readings revealed that it had a pH of 3.99 and a conductivity of 325 us/cm thus indicating that it could be impacted by heavy metals.

After gaining flow from the spring and WG-SE, Warden Gulch next confluences a mine adit discharge about 200 yards downstream. In September 2007, this discharge, called WGM-1, had extremely high levels of aluminum (118,000 ug/L), iron (107,000 ug/L), manganese (22,200 ug/L), and zinc (12300 ug/L). As flow from this mine emerged from an unspecified spring, heavy metals precipitated out of solution and created colorful ferricrete formations just upstream of Warden Gulch. Flow was difficult to measure due to the ferricrete but a reading of 6 gpm was obtained during the September 2007 sampling event.

About ¼-mile downstream of WGM-1, is the Warden Gulch confluence with Peru Creek. Samples were taken just upstream of Peru Creek at site SW-168. During all sampling events Colorado acute standards were exceeded at this location for aluminum, cadmium, copper, manganese, and zinc. The chronic standard for nickel was also exceeded during July 2007 but not during September 2007. Although lead was detected above chronic levels at the headwater location, standards for this metal were not exceeded at site SW-168. Unlike the Snake River, Peru Creek, and Cinnamon Gulch, concentrations of cadmium, copper, manganese, nickel, and zinc all decreased at SW-168 in September 2007 when compared to levels observed during runoff in July 2007. The only metals that increased in the fall were aluminum and iron. Although further investigation is necessary to explain this result, it appears that the metals loading sources to Warden Gulch dry up after runoff has occurred. The lack of flow at sites WG-Source and WG-4 in September 2007 support this hypothesis. Because concentration and flow both decreased in Warden Gulch in the fall, metals loading to Peru Creek also decreased. Likewise, when concentrations and flow were high in the spring, loading increased.

Chihuahua Gulch Analytical Results (SW-Chi)

Chihuahua Gulch was the furthest downstream tributary to Peru Creek that was sampled during this SI. Only one location was sampled on this tributary and it was found to have excellent water quality. Almost all metals fell below detection limits during all sampling events. pH readings were always neutral and ranged from 6.93 to 7.66. Field conductivity measurements were typically low and never exceeded 160 us/cm. Flow was very difficult to measure at the sampling site due to a steep grade but a measurement of 18 cfs was obtained in July 2006 and decreased to 2.6 cfs in September 2007. Fish were also observed in several pools upstream of the sampling location. As was discussed in section 6.2.5, Chihuahua Gulch diluted metals concentrations downstream in Peru creek and greatly increased water quality at site SW-049.

Snake River Analytical Results (SW-044, SW-045, SW-047, SW-050, SW-117 AND SW-082)

Analytical data from both sampling events indicate that antimony, arsenic, barium, beryllium, chromium, cobalt, mercury, molybdenum, selenium, silver, thallium, titanium, and vanadium are not significantly elevated in the Snake River. For this reason, the discussion of results is provided for aluminum, cadmium, copper, iron, lead, manganese, nickel, and zinc.

Analytical results revealed that site SW-044, the most upstream sampling location on the Snake River, is impacted by aluminum, cadmium, copper, iron, manganese, and zinc. As water flowed downstream from site SW-044 to site SW-045, metals concentrations decreased due to dilution from Deer Creek (site SW-043). This tributary also caused the pH in the Snake River to increase by 0.8 to 1.8 standard units. This sudden change caused several metals to precipitate out of the water column thus improving water quality. As the stream flowed through the town of Montezuma, it next confluenced Saints John Creek, a tributary that is slightly impacted by historic mining activity. Water quality in the Snake River improved downstream of Saints John Creek at site SW-047 due to dilution. pH readings increased while concentrations of aluminum, cadmium, copper, iron, lead, manganese, and nickel all decreased. The only metal that increased in concentration downstream of Saints John was zinc. This was probably due to the fact that this metal was detected above acute and chronic TVS in Saints John. The next tributary that the Snake River confluenced as it flowed downstream was Peru Creek. Peru Creek, which is heavily impacted by mining activity, caused a decrease in water quality at site SW-050 due to increases in cadmium, manganese, copper, and zinc concentrations. Other metals, including aluminum, iron, lead, and nickel, decreased slightly or did not change in concentration with the confluence of Peru Creek. Water quality in the Snake River improved as it flowed downstream from SW-050 to the Keystone ski resort due to dilution from several other tributaries including Jones Gulch, Grizzly Gulch, and the North Fork of the Snake River. The only tributary that was sampled in this reach of stream was the North Fork and it was found to have excellent water quality.

Metals concentrations in the Snake River were highest during periods of low flow in the fall or early spring before runoff occurred. As runoff increased during the late May to early July timeframe, the higher flow caused concentrations to drop while metals loading increased. The greatest source of metals loading and impact to water quality in the Snake River observed during these investigations was Peru Creek. As the Snake River flowed downstream from Peru Creek toward Keystone, loading decreased. Zinc was observed to be the primary metal of concern because concentrations exceeded acute and chronic TVS at all Snake River sampling sites during all sampling events. Even the 654 ug/l temporary modification to the zinc standard was exceeded at many sites during low flow. Colorado water quality standards for aluminum, cadmium, and copper were also exceeded at acute levels at many sampling sites during several sampling events. Standards were typically exceeded during periods of low flow in the fall or early spring when concentrations were the highest. Manganese is another metal of concern. The Colorado 50 ug/L chronic water supply standard was exceeded at all Snake River locations during all sampling events. The acute TVS, however, was never exceeded and the chronic TVS was only exceeded at a couple of locations during low flow events. Metals that are not of great concern in the Snake River watershed include nickel, iron, and lead. There were some minor exceedances of the iron standards but they were not that significant and only occurred at the uppermost sampling site before dilution by Deer Creek.

Deer Creek Analytical Results (SW-043)

Deer Creek is a tributary to the upper reach of the Snake River. Only one site, site SW-043, was sampled on Deer Creek and the data indicate unimpacted water quality. Aluminum, iron, manganese, nickel, and zinc were detected in this tributary but they were detected at low levels. Deer Creek is a source of dilution and it caused pH levels to increase in the Snake River thus cleansing the river via precipitation.

Saints John Creek Analytical Results (EPA-SJ2, EPA-SJA and EPA-SJA2)

Two locations were sampled on Saints John Creek during the SI. The uppermost location, EPA-SJ2, was located just upstream of the historic mining town of Saints John. As indicated on Tables 17 through 24, water quality is unimpacted at this location with most metals reported below detection limits. As Saints John Creek flows downstream about ¼ mile, it confluences the Saints John mine adit. This discharge was found to be loaded with high levels of aluminum, cadmium, iron, manganese, and zinc as it emerged from the mine tunnel at site EPA-SJA (Tables 17 through 24). There were also elevated levels of lead and nickel even though copper fell below detection on all sampling events. Before the adit discharges to Saints John Creek, it mixes with another groundwater seep that appears to be clean. This groundwater source was never sampled during this SI but it is assumed to be clean because metals levels in the adit dropped off significantly below this confluence at site EPA-SJA2. Site EPA-SJA2 was located on the adit downstream of the groundwater confluence and just upstream of the confluence with Saints John Creek.

The next location that was sampled along Saints John Creek is site EPA-12345. This site is located just upstream of the Snake River and about ¾ of a mile downstream from the mine adit confluence. Analytical results from this location indicate elevated concentrations of cadmium, lead, manganese, nickel, and zinc. Zinc levels exceeded the acute and chronic TVS for all sampling events even though fish were observed swimming here on several occasions, which is also supported by fish surveys conducted by CDOW. This is likely due to relatively elevated hardness concentrations that may be ameliorating the acute effects of zinc. When comparing data on Saints John Creek from sites EPA-SJ2 and EPA-12345, it appears that the Saints John Mine adit is impacting water quality in the creek. When comparing loading values of zinc in the mine adit and at the mouth of the creek, there did not appear to be any additional sources of loading to Saints John Creek downstream of the mine adit confluence.

North Fork Snake River Analytical Results (SW-083)

The North Fork of the Snake River, like Deer Creek, is a clean tributary to the Snake River that originates on top of the Continental Divide at Loveland Pass and flows down to the Keystone ski resort. Site SW-083 was the only site that was sampled on the North Fork and was located above the confluence of the North Fork with the Snake River. Sample results are below detection limits for several metals, including: cadmium, copper, iron, lead, nickel, and zinc. The only metals that were detected at this site are aluminum and manganese and they were found at levels very close to the detection limit. The North Fork is a source of dilution to the Snake River and improves water quality downstream into Keystone.

The raw analytical data are provided on CD ROM at the end of this report.

5.4 Site-Specific Toxicity Testing

Reported concentrations in Peru Creek and the Snake River suggest acute toxicity may be occurring and additional site-specific testing was conducted to better assess the degree of effects to aquatic dwelling receptor groups. An initial set of aquatic toxicity testing has been completed at the site, and additional testing will likely be necessary. Site-specific sediment toxicity testing is scheduled to be performed in the fall of 2008.

Three separate toxicity tests using three trout species (rainbow, brown, brook) were conducted in September 2007, January 2008, and February 2008 (respectively), using water from various locations in Peru Creek and Snake River. The selection of the different species and associated toxicity testing was dependent on each species' spawning cycle and the availability of the appropriate size/stage fry for each species. In addition, Peru Creek and upstream locations in the Snake River are not easily accessible during the winter, therefore, according to availability of brown and brook trout, only a limited number of sample sites from the Snake River were tested during the winter months. Water from the site was collected and transported to the Region 8 laboratory in Golden, CO, and used in static-renewal toxicity testing protocols. Toxicity test locations are shown on Figure 1.

Tests were performed using Environmental Protection Agency (EPA) 96-hour static renewal toxicity test protocols (EPA, 2002) at the EPA Region 8 Laboratory to determine the acute toxicity of site water collected in drainages associated with the Pennsylvania Mine with an evaluation endpoint of mortality.

As a quality assurance step, a reference aquatic toxicity test was performed during each test simultaneously with the site water toxicity test. A reference test was performed for all three tests and consisted of two replicates, 5 concentrations plus a control. For testing purposes soft water was spiked with zinc sulfate heptahydrate using a serial dilution approach that ranged from 100% to 6.25%. Zinc concentrations were verified in the analytical laboratory using EPA Method 6010/6020. The reference aquatic toxicity test was performed using the same methodologies as the Site Water Toxicity Testing with one exception, 5 organisms per test chamber with a total of 2 replicates for each concentration were used. For the September testing only 5 organisms were used due to the average weight of organisms and loading density for each testing chamber.

In September 2007, a total of six toxicity tests were completed using rainbow trout. Testing was conducted using water from two locations in Peru Creek, one immediately upstream of Pennsylvania Mine adit discharge (SW-140), the second Peru Creek location, SW-049, is approximately 2 miles down gradient of the adit discharge. In addition, toxicity tests using rainbow trout were also completed at four sites in the Snake River. One location, SW-047, is in the Snake River upstream of the confluence of Peru Creek, the second location, SW-050, is 4 miles downstream of the mine adit discharge, the third location, SW-117, is upstream of the Snake River confluence with the North Fork of the Snake River, and SW-082 is downstream of the North Fork confluence.

In January and February 2008, three downstream locations in Snake River were tested using brown trout and brook trout, respectively. The first location is SW-050, located approximately 4 miles downstream from

Pennsylvania Mine. The second site is SW-117 which was located upstream of the confluence of the North Fork of the Snake River. The third site, SW-082, was located downstream of the North Fork and in Keystone and in the vicinity of the recent fish kill.

As summarized in Table 26, the results from this study indicate that the sites tested on Peru Creek and Snake River that were below the discharge of the Pennsylvania Mine adit discharges were acutely toxic to the three species tested over a 96-hour test period. Site SW-140 which is on Peru Creek upstream of the Pennsylvania Mine discharge did not show any mortality for tests using undiluted concentrations from this location (i.e., 100% of site water), or for any of the other dilutions tested. This indicates that although metals concentrations are elevated, likely due to other upstream mining inputs in Horseshoe Basin, survival of fish above the adit discharge may be supported. However, recent fish shocking activities at this location indicate that no fish are present upstream of the adit. It can be assumed that although concentrations may not be acutely toxic at the upstream location, fish would use the downstream segments of Peru Creek and thereby be exposed to the Pennsylvania Mine adit discharges and low pH concentrations.

It should be noted that although Table 26 presents observed LC50s for individual metals based on toxicity testing with site waters, it represents a gross simplification of the factors influencing toxicity in these chemically complex site waters. Both exacerbating (i.e., multiple metals) and ameliorative (i.e., dissolved organic carbon, low pH, hardness) influences affect the LC50s observed in these site water toxicity tests.

For the September test date, site SW-050 had 100% mortality in the 100% site water concentration, but only 10% mortality was observed in the 90% site water dilution. No mortality was observed in the lower dilutions/concentrations for site SW-050.

The results indicate that the site waters in Peru Creek would have to be diluted substantially for the site to sustain a population of salmonids. Snake River downstream LC50s for all species indicate that dilutions of 10% would improve survivability of all species in the Snake River.

5.5 Surface Water Pathway Conclusions

Peru Creek and the Snake River above the North Fork of the Snake River are severely impacted by discharges of low pH/high metals water related to historic mining in the watershed. Peru Creek and the Snake River from the confluence of Peru Creek to the confluence of the North Fork of the Snake River have some aquatic insects, but fish are not present in these segments. Fish and benthic invertebrate surveys in the Snake River above the confluence of Peru Creek indicate the presence of aquatic insects as well as fish species present.

The Snake River below the confluence of the North Fork of the Snake River (which occurs in the town of Keystone approximately 8 miles downstream of the PPE) appears to support aquatic insects and had a sustaining population of brook trout based on results of the July 2007 surveys. The town of Keystone stocks rainbow trout in the same area for recreational purposes on a monthly basis during the summer months and these adult stocked fish do not survive for long periods of time.

Discharges from the Pennsylvania Mine to Peru Creek have resulted in fish kills in the Snake River as far down as the town of Keystone Colorado, located 8.5 miles downstream of the PPE. Fish kills in the Snake River have been documented as little as 3 miles from the point where the Snake River enters Dillon Reservoir and are believed to have occurred all the way down to the point where the Snake River enters Dillon Reservoir. In

August 2007, a data logger installed by EPA at the Pennsylvania Mine adit to document flow volumes, recorded a jump in discharge from the normal 150 gallons per minute to as high as 4,000 gallons per minute. This spike in discharge from the Pennsylvania Mine coincided with the fish kill on the Snake River in Keystone, further documenting the need for further investigation as to potential solutions for this site and the remedial aspects for Peru Creek and the Snake River.

A fish shocking survey completed in late July 2007 on a 500-foot section of the Snake River in the town of Keystone yielded approximately 40 to 50 fish. A duplicate survey completed on the same 500-foot stretch of the Snake River within days after the fish kill yielded only two large brook trout that are believed to have been re-colonizing the area or were washed downstream by the same floods that killed nearly all of the stocked rainbow trout in the Snake River.

6.0 Soil Exposure and Air Pathways

6.1 Soil and Air Targets

All locations where mine waste occurs are not fenced and are accessible by various combinations of 4-Wheel Drive or recreational hiking. A four-wheel drive trail up Cinnamon Gulch provides easy access to areas up the drainage. Persons accessing the site area are exposed to potential site contaminants on a transient basis. Due to the proximal location of the site area and ease of access, the site is frequently used by residents of the mountains and the Colorado Front Range.

The site area has been documented to be used by the Keystone Center as a field trip destination for school classes. Members of EPA and the USFWS witnessed school children eating lunch on a waste pile adjacent to the Pennsylvania Mine adit on several different occasions during 2007.

Populations within a 4 mile radius are as follows: On Site – 0 persons; 0 – 1/4 Mile – 8 persons; >1/4 – 1/2 Mile – 23 persons; >1/2 Mile - 1 Mile – 91 persons; >1 - 2 Miles – 365 persons; >2 - 3 Miles – 608 persons; >3 - 4 Miles – 851 persons. This represents a total of 1,946 persons living within 4 miles of the site.

There are extensive palustrine scrub-shrub and emergent wetlands located along Peru Creek. Multiple small isolated semi-permanent palustrine open water wetlands are located along Peru Creek downstream of the site to Peru Creek's confluence with the Snake River (Figure 1). Approximately six acres of streamside wetlands are located along the Snake River from the confluence of Peru Creek to the inlet of Dillon Reservoir. There are small upland wetland areas located in upper Cinnamon Gulch near the Silver Spoon Mine and associated adits (URS 2002).

The Pennsylvania Mine site is partially located on or immediately adjacent to the White River National Forest (WRNF). Some of the area within the 15 mile downstream area from the site has been designated as lynx habitat and sites of re-introduced collared lynx are near and may be within the immediate area of the site (USFS WRNF March 2005, Figure 1). Canada Lynx were listed as a threatened and Endangered Species by the USFWS on March 24, 2000. Lynx habitat has been mapped on the WRNF and indicates that 47% of the forest as suitable lynx habitat (USFS WRNF Management Plan, 2005). Beginning in 1999, the CDOW initiated a reintroduction program for Canada lynx by relocating lynx trapped in Canada and Alaska to the Southwest portion of Colorado. While the majority of the reintroduced animals have established home ranges in the general vicinity of the releases in the southwest quarter of the state, many have immigrated into suitable habitats throughout Colorado, including the WRNF (USFS, 2005). A second core area of resident lynx has become established in the area of the Gunnison National Forest and the WRNF. Figure 1 displays the habitat across the NRNF that is being used by lynx (USFW 2005).

6.2 Soil Sample Locations

Please refer to Section 5.0 "Source Characterization" and Figures 3 through 8 for detailed information as to specific locations of all soil samples collected.

6.3 Soil Analytical Results

Please refer to Section 3.0 "Waste/Source Characterization and Sampling", Figures 3 through 8 and Tables 10 to 17 for detailed information as to specific locations and analytical concentrations of all soil samples collected. The raw analytical data are provided on CD ROM at the end of this report.

6.4 Potential Air Exposure

Air samples were not collected as part of this ESI. There are no residents located within one-mile of the site (CDPHE 2008).

6.5 Soil Exposure and Air Pathway Conclusions

Please refer to Section 3.8, "Conclusions - Waste/Source Characteristics And Sampling" for a more detailed description of waste source characterization conclusions.

7.0 Quality Assurance/Quality Control

Quality control (QC) samples were collected during all field events to test the quality of field sample procedures and to test the performance of the EPA analytical laboratory. QC samples were collected for ten percent of the site samples (for every 10 locations sampled in the field, one set of quality control samples were collected). Quality control samples consisted of field blanks and duplicate samples. Duplicates were collected alongside their corresponding site samples and blanks were prepared in the field using ultra-pure deionized water called Nanopure. Blanks were filtered and preserved, if needed, in the same manner as site samples and were submitted to the laboratory for the same analytical tests. All QC samples were collected to determine accuracy and precision of laboratory and field procedures and to test the quality of containers, filters, and acid preservatives used in sample preparation.

Water quality samples were collected in accordance with procedures outlined in the EPA Region 8 "Field Sampling Protocols" Standard Operating Procedures document. A grab technique was used to collect samples in the thalweg of the sampling location. Samples requiring filtering and preservation were usually filtered and preserved immediately onsite. Sample handling was performed in accordance with EPA approved analytical methods.

A composite sampling technique was used to collect sediment samples during the two 2007 investigations. Sediment was collected using Teflon scoops and was composited from several locations on both sides of the stream into the sampling container. Samples were chilled on ice at 4 ºC and were transported to the laboratory.

All data were collected in accordance with the CDPHE Quality Assurance Project Plan (QAPP), approved by the EPA in January of 2000 and sample bottles met EPA specifications. Field and laboratory data were collected using rigorous QA/QC procedures using standard guidelines as outlined below:

PARCC PARAMETERS

- Precision - the degree of agreement among repeated measurements of the same characteristic, or parameter, and gives information about the consistency (reproducibility) of the method.
- Accuracy - a measure of confidence that describes how close a measurement is to its 'true' value.
- Representativeness -the extent to which measurements actually represent the 'true' environmental conditions.
- Completeness - the comparison between the amount of data you planned to collect and analyze versus how much usable data was collected and analyzed. Normally expressed as a percentage.
- Comparability - the degree to which data can be compared directly to similar studies.

Field Parameters: Precision and accuracy for chemical measurements such as pH, temperature, conductivity and dissolved oxygen will be determined according to the EPA Chemical Methods Manual, EPA Region VIII's Standard Operating Procedures (SOP) for Field Samplers, or the manufacturer's specifications. Stream flow measurements will occur during the same general time period that the surface water samples are collected only if conditions allow safe access. Flow measurement methods followed the Regional SOP for field sampling.

All field meter calibration procedures will be conducted according to USEPA requirements and will follow the EPA Laboratory's Hydrolab SOP (EPA 2006). The pH, dissolved oxygen, and conductivity electrodes will be calibrated each morning before use.

Abiotic Media: Duplicate samples were collected from surface water and ground water and sent to the laboratory for chemical analyses. Field blanks, consisting of ultra-pure laboratory DI water, were processed in the field and submitted to the laboratory to check on the sample container, filtration apparatus and acids used in preservation. One set of duplicate and blank samples will be collected for every 20 locations sampled in the field. Additional sample volumes will be provided to the laboratory for internal QA/QC purposes for preparation of matrix-spike and matrix-spike-duplicate QC samples. All samples were analyzed by US EPA Region 8 Laboratory or through the Contract Laboratory Program (CLP) of the EPA. A privately contracted laboratory analyzed for non-metals analyte list. Post analysis review of the sample results, calibrations and Quality Control (QC) analysis or a Quality Assurance (QA) review of all analyses, samples and data was be conducted to ensure that data produced are of known quality and can be used as intended.

Laboratory QA/QC: Matrix Spike/Matrix Spike Duplicates (MS/MSD) for each matrix sampled on a one MS/MSD per 20 samples collected. These MS/MSD samples will be utilized for internal laboratory Quality Assurance/Quality Control (QA/QC) purposes. All samples will be analyzed by either a privately contracted laboratory or through the Contract Laboratory Program (CLP) of the EPA. Post analysis review of the sample results, calibrations and Quality Control (QC) analysis or a Quality Assurance (QA) review of all analyses, samples and data will be conducted to ensure that data produced are of known quality and can be used as intended.

Data Validation: The 2007 samples that were analyzed by the US EPA Region 8 Laboratory were submitted for validation by an independent validation reviewer. A total of 33 soil/sediment samples and 54 water samples were validated for this effort. The data packages were reviewed according to "USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review", February 1994, modified for the methods used. Raw data were reviewed for completeness and transcription accuracy onto the summary forms. Approximately 10-20% of the results reported in each of the samples, calibrations, and QC analyses were recalculated and verified. If problems were identified during the recalculation of results, a more thorough calculation check was
performed.

The results of the independent data validation effort for both soil/sediment and surface water data reviews indicated, "Data are acceptable with QUALIFICATIONS noted in review. A copy of the Data Validation Report Summary is provided as an attachment to this ARR. A complete copy of the validation report (e.g., marked data sheets) is stored in the US EPA Region 8 Records Center.

Raw analytical data and data validation reports can be found on CD-ROM at the end of this report.

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