ENGINEERING EVALUATION/COST ANALYSIS REPORT
PINE MOUNTAIN MINE
TONTO NATIONAL FOREST – MESA RANGER DISTRICT
MARICOPA COUNTY, ARIZONA

Administrative Order on Consent, Executed October 3, 2003

Prepared for:

United Nuclear Corporation
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MACTEC Project No. 4972-3-2006.04

January 28, 2008

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engineering and constructing a better tomorrow

January 28, 2008

Mr. Larry Bush, Vice President
United Nuclear Corporation
State Road 566 21 Miles Northeast of Gallup, New Mexico
Gallup, New Mexico 87301

Subject: **Engineering Evaluation/Cost Analysis Report**
Pine Mountain Mine Site
Administrative Order on Consent dated October 3, 2003
Tonto National Forest, Mesa Ranger District
Maricopa County, Arizona
MACTEC Project No. 4792-3-2006.04

Dear Mr. Bush:

MACTEC Engineering and Consulting, Inc. (MACTEC) is pleased to submit this *Engineering Evaluation/Cost Analysis Report, Pine Mountain Mine, Tonto National Forest, Mesa Ranger District, Maricopa County, Arizona* (EE/CA Report) to United Nuclear Corporation (UNC). This EE/CA Report has been prepared in accordance the *Administrative Order on Consent for Engineering Evaluation/Cost Analysis* (AOC), effective date of October 3, 2003.

If you have any questions or comments regarding this EECA Report, please contact Mr. James Clarke at (602) 437-0250.

Sincerely,

MACTEC Engineering and Consulting, Inc.

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ACRONYMS AND ABBREVIATIONS

A.A.C.	Arizona Administrative Code
ABP	Acid-Base Potential
ADEQ	Arizona Department of Environmental Quality
AGP	Acid Generating Potential
AMD	Acid Mine Drainage
AMSL	Above Mean Sea Level
ANP	Acid Neutralizing Potential
AOC	Administrative Order on Consent
AOI	Area of Interest
AOIs	Areas of Interest
APPL	Agricultural & Priority Pollutants Laboratory, Inc.
ARAR	Applicable or Relevant and Appropriate Requirement
ARARs	Applicable or Relevant and Appropriate Requirements
ARS	Arizona Revised Statutes
As	Arsenic
As(III)	Arsenic III or Arsenite
As (V)	Arsenic V or Arsenate (inorganic arsenic)
A&We	Aquatic and Wildlife Ephemeral SWQS
AWQS	Aquifer Water Quality Standard
AWQSs	Aquifer Water Quality Standards
bgs	Below ground surface
BHHRA	Baseline Human Health Risk Assessment
BS	Background Soils AOI
$CaCO_3$	Calcium Carbonate
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	Chemical or Compound of Concern
COCs	Chemicals or Compounds of Concern (may be capitalized as COCS)
COPC	Chemical or Compound of Potential Concern
COPCs	Chemicals or Compounds of Potential Concern
CSM	Conceptual Site Model
DMA	Del Mar Analytical
DQO	Data Quality Objective
DQOs	Data Quality Objectives
DSS	Downstream Streambed Sediments AOI
Dynamac	Dynamac Corporation
EE/CA	Engineering Evaluation/Cost Analysis
EPA	United States Environmental Protection Agency
ERA	Ecological Risk Assessment
^{o}F	Degrees in Fahrenheit
GEAE	General Electric Aircraft Engines
GPL	Groundwater Protection Limit (Arizona)
GPS	Global Positioning System
Hg	Mercury
HgS	Mercury Sulfide or Cinnabar
HHERA	Human Health and Ecological Risk Assessment
MACTEC	MACTEC Engineering & Consulting, Inc.
MIT	Massachusetts Institute of Technology
µg/g	Micrograms per Gram or Parts per Million (equivalent to mg/kg)
µg/L	Micrograms per Liter or Parts per Billion

mg/kg	Milligrams per kilogram or Parts per Million
mg/L	Milligrams per Liter or Parts per Million
NCP	National Contingency Plan
NE1/4	Northeast Quarter
NFA	No Further Action
No.	Number
NRSRL	Non-Residential Soil Remediation Level
NTC	Non-Time Critical
NW1/4	Northwest Quarter
PA	Preliminary Assessment
PA/SI	Preliminary Assessment/Site Investigation
PBC	Partial Body Contact SWQS
PCSM	Preliminary Conceptual Site Model
PF	Particulate Fallout AOI
ppb	parts-per-billion
ppm	parts-per-million
QA/QC	Quality Assurance/Quality Control
R	Total Metals Concentration/SPLP Result
R9E	Range 9 East
RAO	Removal Action Objective
RB	Retort Building AOI
RBCs	Risk-Based Concentrations
REA	Registered Environmental Assessor (California)
R.G.	Registered Geologist
RSRL	Residential Soil Remediation Level (Arizona)
RT	Retort Tailings AOI
SAP	Sampling and Analysis Plan
SPLP	Synthetic Precipitation Leaching Procedure
SRL	Soil Remediation Level (Arizona)
SRLs	Soil Remediation Levels (Arizona)
SWQS	Surface Water Quality Standard (Arizona)
SWQSs	Surface Water Quality Standards (Arizona)
SWSS	Surface Water Sampling Station
T17N	Township 17 North
TPH	Total Petroleum Hydrocarbons
UNC	United Nuclear Corporation
USDA	United States Department of Agriculture
USS	Upstream Streambed Sediments AOI
WRCC	Western Region Climate Center

EXECUTIVE SUMMARY

The Pine Mountain Mine site ("Site") is a former cinnabar mine and retort (mercury ore processing structure) that is located within the boundaries of the Tonto National Forest, Maricopa County, Arizona. The mine and/or associated retort were periodically operated from the late 1930's to 1970. The Site is located in a normally dry tributary of the East Fork of Sycamore Creek. Retort tailings and waste rock were historically deposited in the tributary. Historical records indicate that at least 33,000 tons of retort tailings were produced by the Pine Mountain Mine.

The mine and retort were operated for decades over various periods of time from the 1930s to 1970. However, a subsidiary of United Nuclear Corporation (UNC) historically only operated the Site for a period of approximately 20 months from October 8, 1965 until May 30, 1967. During this time period, approximately 8,546 short tons of ore were mined and processed. In September 1970, a thunderstorm referred to as the Labor Day Storm dropped more than eight inches of rain in less than 24 hours in the vicinity of the Site. Based on aerial photographs of the Site before and after the storm, an unknown quantity of the retort tailings were eroded during the storm and deposited downstream of the Site. A survey conducted by the United States Forest Service (Forest Service) in 2002 indicated that the retort tailings pile and downstream deposits, which extend approximately 0.25 miles downstream of the current retort tailings pile, constituted approximately 7,800 cubic yards of material. A Preliminary Assessment/Site Investigation (PA/SI) performed for the Forest Service in 2001 concluded that the retort tailings contain total mercury concentrations in excess of background concentrations established by the Forest Service, and that the retort tailings represented a potential risk to human health and the environment. Therefore, the Forest Service requested that UNC perform an EE/CA to evaluate a possible removal action for the retort tailings.

Mercury and arsenic were identified as contaminants of potential concern (COPCs) for the baseline human health risk assessment (BHHRA) and ecological risk assessment (ERA), based upon the Forest Service's Preliminary Assessment (Dynamac, 2001) and experience with risk assessment for metals. Since these metals are naturally occurring, exist in different forms, and possess speciation-dependent toxicity factors, data were gathered to address the site-specific characteristics of these metals, including background and speciation data. In addition, the

conceptual site model (CSM) identified the inhalation of mercury vapor in the retort building as a potential exposure pathway that required investigation.

The EE/CA investigation involved eight Areas of Interest (AOIs) that are listed below.

- Area BS - background soil
- Area PF - potential retort stack particulate fallout area
- Area RB - soil around the retort
- Area RT - retort tailings deposit
- Area USS – upstream or background streambed sediments
- Area DSS - downstream streambed sediments
- Surface water quality

The assessment of potential human health impacts was performed using the exposure assumptions used by ADEQ and EPA in developing risk-based soil cleanup levels, with the exception of those assumptions that were based on the site-specific receptors and conditions as recognized by the Bureau of Land Management for recreational receptors (BLM, Risk Management Criteria for Metals at BLM Mining Sites, 2004). The concentration of the various mercury species were compared to the species-specific soil criteria to evaluate potential hazards associated with the recreational scenario. The investigation and risk analysis led to the following findings:

- Arsenic was eliminated as a COPC based on its consistency with background concentrations. Therefore, mercury was retained as the single COPC for human health and ecological evaluation.

- The analyses of the mercury species present in soil/sediment from the Site confirmed that more than 80 percent of the mercury present in soil/sediment was in the non-mobile (non-extractable) form consistent with mercuric sulfide (cinnabar) rather than the more toxic and mobile organic (e.g., methyl mercury) or inorganic (e.g., mercuric chloride) mercury species. Organomercurials (methyl mercury) were present in the lowest concentration of any of the mercury species (less than 1% of total mercury).

- Based on the mercury speciation data and on generally accepted peer reviewed research, the conditions required for the formation of toxic species of mercury are not present at the Site. Also, mercury concentrations found at the Site are not present at levels that could significantly affect the flora and fauna in the area.

- None of the analytical soil/sediment results for mercury from any AOI exceeded the species-specific, recreational soil criteria.

- Mercury vapor (elemental) concentrations did not exceed the health-based elemental mercury air criterion for the recreational receptor.

Based on the maximum concentrations of methyl mercury or mercuric chloride in soil/sediment or elemental mercury vapor in the retort building, recreational visitors to the Site would not be subject to unacceptable risk.

Potential chemical-specific, location-specific, and action-specific applicable or relevant and appropriate requirements (ARARs) were reviewed and evaluated. Site-specific ARARs were identified and were used to evaluate removal action alternatives for the Site.

The applicable factors described in 40 CFR § 300.415(b)(2) of the National Contingency Plan (NCP) that were used to develop the removal action objectives (RAOs) for the Site, are listed as follows:

RT/DSS: Reduce potential exposure to human populations, animals, or the food chain to mercury species present in the retort tailings and downstream sediments. Reduce the potential for contaminant migration to surface water or groundwater.

RB: Reduce potential exposure to human populations, animals, or the food chain to mercury species present in the soils surrounding the retort building. Reduce the potential for contaminant migration to surface water or groundwater.

Based on the RAOs, a total of eight overall removal action alternatives were identified and evaluated as follows:

- Alternative 1 – No Action
- Alternative 2 – No Action for DSS/RT AOI and limit access.
- Alternative 3 – No Action for DSS/RT AOI and remove soils around retort building.
- Alternative 4 – No Action for DSS/RT AOI, demolish retort building to concrete slab, and limited soil removal around retort building.
- Alternative 5 – No Action for DSS/RT AOI, complete removal of retort building, and limited soil removal around retort building.
- Alternative 6 – In-place closure for RT AOI, on-site consolidation for DSS AOI, complete removal of retort building, and limited soil removal around retort building.
- Alternative 7 – On-site consolidation for DSS/RT AOI, complete removal of retort building, and limited soil removal around retort building.

- Alternative 8 – Complete removal and off-site disposal for DSS/RT AOI, complete removal of retort building, and limited soil removal around retort building.

Each alternative was evaluated in terms of effectiveness, implementability, and cost. Based on the evaluation, Alternative 1 is the recommended removal action alternative for the Site.

1.0 INTRODUCTION

This report presents the results of an Engineering Evaluation/Cost Analysis (EE/CA) for the Pine Mountain Mine located in Maricopa County, Arizona (Site). The Site is a former cinnabar mine that includes a former ore beneficiation facility, referred to as a retort, and a deposit of retort tailings. Cinnabar, or mercury sulfide, is a primary ore of mercury. The operation involved removing ore from a nearby open pit and underground shaft, crushing the ore, and then separating the mercury from the ore in the retort. The processed mercury was recovered in containers referred to as flasks. The retort tailings were then deposited near the retort.

The Site is located on land administered by the United States Department of Agriculture (USDA), Forest Service (Forest Service) and is within the boundaries of the Tonto National Forest, Mesa Ranger District. As the lead regulatory agency under the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), the Forest Service requested an EE/CA to further evaluate the Site, including the potential for releases of heavy metals, most notably mercury and arsenic, from the retort and retort tailings. This EE/CA Report has been prepared in accordance with and in a manner consistent with the following documents:

- *Administrative Order on Consent for Engineering Evaluation/Cost Analysis* (AOC), effective date of October 3, 2003
- *"Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA, PB93-963402, 9360.0-32, EPA540-R-93-057, Environmental Protection Agency, August 1993"* (EPA, 1993)
- *Work Plan for Engineering Evaluation/Cost Analysis, Pine Mountain Mine Site, Tonto National Forest, Mesa Ranger District, Maricopa County, Arizona* dated January 9, 2004
- The National Contingency Plan, 40 C.F.R. Part 3400 *et seq*
- *Addendum to Sampling and Analysis Plan*, dated August 30, 2006

Pursuant the AOC, UNC agreed to conduct an EE/CA for the Site. UNC retained MACTEC Engineering and Consulting, Inc. (MACTEC) to conduct and prepare the EE/CA for the Site.

The EE/CA identifies the objectives of the removal action and analyzes the various alternatives that may be used to satisfy these objectives for cost, effectiveness, and implementability. The removal action objectives include preventing or abating the threat of actual or potential releases of the inorganic chemicals such as mercury at concentrations which pose an unacceptable risk to

human health or to the environment. The appropriateness of a removal can be determined by considering the following factors set forth in 40 CFR 300.415(b)(2) of the NCP:

1. Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants
2. Actual or potential contamination of drinking water supplies or sensitive ecosystems
3. Hazardous substances in drums, barrels, tanks, or other bulk storage containers that may pose a threat of a release
4. High levels of hazardous substances, pollutants, or contaminants in soils at or near the surface that may migrate or be released
5. Weather conditions that may cause hazardous substances, pollutants, or contaminants to migrate or to be released
6. Threat of fire or explosion
7. Availability of other appropriate Federal or State response mechanisms to respond to the release
8. Other situations or factors that may pose threats to public health, welfare, or the environment

The EE/CA provides the technical foundation upon which the Action Memorandum selects a removal action for the Site that is consistent with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) (EPA, 1990).

Based on the review of the PA/SI, two areas require additional evaluation: the retort tailings pile and the retort building. Based upon the data collected and evaluated for the Site, the removal action alternatives evaluated under this EE/CA range from No Action to removal of the retort tailings, building and/or soil that have been impacted by mining operations.

The EE/CA involved the following tasks:

- Review of existing data
- Development of a preliminary conceptual site model (PCSM) based on existing data
- Identification of data gaps

- Development of a Work Plan and Sampling and Analysis Plan (SAP) to collect additional data necessary to perform the EE/CA
- Completion of data gap sampling
- Analysis of the new data
- Modification of the CSM based on additional data
- Preparation of a site specific Human Health and Ecological Risk Assessment (HHERA)
- Development and evaluation of removal action alternatives based on the HHERA and the NCP
- Analyzing the removal action alternatives for their effectiveness, implementability and cost consistent with the NCP and EPA guidance, and recommending a preferred alternative to the Forest Service

2.0 SITE CHARACTERIZATION

2.1 SITE DESCRIPTION AND BACKGROUND

The Pine Mountain Mine is located in the Northwest Quarter (NW1/4) of Section 4, and the Northeast Quarter (NE1/4) of Section 5, of Township 17 North (T17N), Range 9 East (R9E), Gila and Salt River Base and Meridian, Maricopa County, Arizona. The subject site is further located at approximately 33° 58' 44" North Latitude and approximately 111° 26' 55" West Longitude. The Site is located at an elevation of approximately 5,200 feet above mean sea level (AMSL). The Site lies within the boundaries of the Tonto National Forest on land administered by the Forest Service, and is under the jurisdiction of the Mesa Ranger District. Figure 1 shows the location of the Site, and photographs of the Site are included in Appendix A.

The Site is a former cinnabar (mercury sulfide) mine. Cinnabar was discovered in the area in 1911. By 1913, mercury mining, milling, and retort operations began in the area, which became known as the Mazatzal Mercury Mining District. The peak periods of mining occurred during World Wars I and II and during the post-World War II atomic energy program. Several other cinnabar mines operated in the area, including the Sunflower and Mercuria Mines. There are currently no active cinnabar mining or mercury milling operations in the area.

At the Site, ore was mined from nearby workings, crushed, and then mercury was separated from the ore in a facility referred to as a retort. A retort is a furnace where the cinnabar is burned or roasted at a temperature of 600°F to 700°F to vaporize mercury from the cinnabar. Lime was typically added to the ore prior to roasting to remove sulfur. The mercury vapor was then condensed by air or water cooling to form liquid mercury. According to the archeologist's report that is included in the Dynamac report (Dynamac, 2001), prospecting at the Site started in 1925 with 10 claims. However, mercury production did not begin until the late 1930's or early 1940's with the construction of retorts. In 1942, a furnace plant (e.g., mercury retort) was installed. The production rate was 50 to 70, 76-pound flasks per month with 216 flasks (16,416 pounds) of mercury reportedly produced in 1943. Due to falling prices, the Pine Mountain Mine was reportedly shut down from 1945 to 1955. In 1954, the mill was revamped, and mining and production were restarted. Approximately 130 flasks (9,880 pounds) of mercury were produced during 1955. The operation was then shut down in December 1955. In 1959, the mining operations were started up again and continued until 1963. During that time, the ore from the

Site was processed at the Rattler Mill. In 1963, the Pine Mountain Retort was repaired, with only a few flasks of mercury produced. In 1964, it was estimated that 25,000 tons of retort tailings were present on the Site. In July 1965, the mill was retorting 35 to 40 tons of ore per day, which corresponded to 1.5 to 2 flasks per day of mercury recovered (Dynamic, 2001).

Harpoon Inc. (Harpoon), a wholly-owned subsidiary of UNC, leased the Site for approximately 20 months from October 8, 1965 until May 30, 1967. During this time Harpoon mined and processed approximately 8,546 short tons of ore. Harpoon left the Site by June 1967, and no mining activities were reported from 1968 through June 1969. In October 1969, Dixilyn Corporation performed sampling and exploration activities. In February 1970, Dixilyn concluded activities and left the Site. No mining activities have occurred on the Site since 1970, with the exception of minor mineral specimen collection that was conducted in August 1980.

2.1.1 Structures and Topography

The Site sits on the western slope of the Mazatzal Mountains, a fault-block mountain range that extends for approximately 35 miles across Central Arizona. Mountain peaks along the range are generally greater than 5,800 feet in elevation with several peaks exceeding 7,000 feet in elevation, namely Four Peaks (located 25 miles to the south), Mt. Ord (located 10 miles to the south), and Greens Peak (located 10 miles to the north). The prominent peak located above the Site is Pine Butte, which has an elevation of slightly over 6,400 feet. The Site is located in a normally dry drainage that is a tributary of the East Fork of Sycamore Creek (see photographs in Appendix A). As shown on Figure 1 (topographic map) and in Photographs 2, 13, 15, and 16, the terrain is extremely steep and rugged, with thick brush, cactus, desert vegetation, small pine trees, and riparian trees such as cottonwoods and sycamores. Access to the Site is limited to a minimally maintained Forest Service gravel road. Two-wheel drive vehicles with high clearance can enter the area to within approximately 0.75 miles of the Site. A rough gravel road provides four-wheel drive access for the remaining 0.75 miles. A site and vicinity plan is included as Figure 2.

Remnants of mining and milling in the area consist of a small open pit (located approximately 200 yards upslope of the retort), closed underground workings with associated shafts and adits, several concrete foundations, retort tailings (Photographs 8, 13, 14), minor debris from houses, vehicles, pipes, mine rail, and the mill-retort building. The retort is housed in a wooden and

metal building whose condition is structurally unsound. The building houses a rotary kiln and condenser. A fallen smokestack is located along the hillside immediately adjacent to the retort. The base of the retort is designed to allow the discharge of retort tailings into carts, which were then deposited into the adjacent drainage. The retort tailings at one time filled the drainage. However, over time the retort tailings have been eroded by storm water runoff flowing through the drainage, and a portion of the retort tailings have been transported down-drainage and deposited along the drainage line.

2.1.2 Geology

The Site is located on the west side of a mountain range identified as the Mazatzal Mountains, a range that extends from the Four Peaks Wilderness in a north-northwesterly direction for approximately 35 miles, and is located within the Central Highlands Physiographic Province. The Central Highlands are a diagonal band of fault-bound mountains and valleys that separate the Basin and Range Province to the south from the Colorado Plateau to the north. The Central Highlands (also termed the "Transition Zone" in the geologic literature) are characterized by fault-bounded, sediment-filled valleys and basins surrounded by rugged mountains, comprised primarily of granitic, metamorphic, and volcanic rocks. The Mazatzal Mining District is situated on the north limb of a major syncline and is coextensive with an irregular Proterozoic felsic sill of the Pine Mountain porphyry.

The rocks at the Site are part of the Alder Formation or Alder Group of the Precambrian Yavapai Series. A majority of the rock outcrops observed in the vicinity of the Site consist of schist and platy phyllite. Wruke characterized the occurrence of mercury in the Mazatzal Mining District as cinnabar, which is found in shaly tuff and sandstone of the Alder Formation (Wruke, 1983). The Alder Group is subdivided into six formations, from youngest to oldest; crystalline tuffs, the West Fork Formation, the Horse Camp Formation, the Cornucopia Formation, the East Fork Formation, the Oneida Formation, and the Telephone Canyon Formation (Nations and Stump, 1983). Cinnabar is disseminated in a phyllite host rock and is concentrated along prominent foliation planes. Phyllite is described as a metamorphosed argillaceous (clay mineral) rock intermediate in metamorphic grade between slate and schist. The mica crystals in phyllite impart a silky sheen to the surface of the cleavage (Wruke, 1983, as quoted in Dynamac, 2001). The foliation planes are the result of considerable deformation that allowed hydrothermal solutions to

alter the phyllites under high temperature conditions. This hydrothermal alteration is attributed to Tertiary igneous activity.

J.N Faick described the ore body at the nearby Ord Mine, which provides a general description of the ore bodies present in the Mazatzal Mining District, as follows: "The ore occurred in phyllites and schists as narrow, lenticular bodies that strike east-northeast, stand nearly vertical, and rake steeply west. The ore is of two different types: the most abundant type is composed of very fine-grained cinnabar disseminated in whitish sericitized phyllite or schist; and the other type is composed of coarser-grained cinnabar embedded in quartz siderite veins. A little cinnabar occurs in the conglomerate in the upper workings in ore zone B. Ore zone B, which has been the most productive, is typical of Ord deposits. This zone consists of a group of closely spaced small ore bodies, each separated by a fault gouge, barren schist, or mineralized host rocks of submarginal grade. Individual ore bodies in zone B range from about 15-150 feet in strike length and generally from 2 to about 8 feet in width; however, disseminated ore of relatively low grade attains exceptional widths as great as 20 or 25 feet in a few places above the 200-foot level (J.N. Faick, 1958, as quoted in Dynamac, 2001)."

2.1.3 Surface Water

The Mazatzal Mountains form a hydrologic divide which is often referred to as the Mazatzal divide. Surface water on the east side of the divide flows into the Tonto Basin, which further drains south to the Salt River. A majority of the surface water on the west side of the divide flows west toward the Verde River. The Site is located on the west side of the Mazatzal Mountains, near the top of the divide. The prominent peak located northeast of the Site is identified on the topographic map (Reno Pass Quadrangle) as Pine Butte. The Site sits in a drainage basin that is an unnamed dry tributary of the East Fork of Sycamore Creek. This is further referred to in this report as the East Sycamore Drainage Basin.

The unnamed tributary is normally dry. Water flows only during brief, heavy rainfall events, or following long duration, high quantity precipitation events. Snow pack is also a possibility during winter months, and rapid melt-off due to warm storms can also result in runoff. The East Fork of Sycamore Creek eventually joins the West Fork of Sycamore Creek southwest of the Site, forming Sycamore Creek. The West Fork of Sycamore Creek and upper portions of Sycamore

Creek are spring fed and often have water year-round. Due to drought conditions, surface water is currently scarce in Sycamore Creek.

On August 5, 2003, MACTEC installed two automated surface water sampling stations at the Site (see Figure 2 for locations). Due to access limitations, and with the approval of the Forest Service, the sampling stations were removed on October 8, 2004. Surface Water Sampling Station No. 1 (SWSS-1) was located upstream of the retort building and was equipped with a rain gauge. Between August 5, 2003 and August 5, 2004, water flow was recorded at SWSS-2 following precipitation events in September 2003, January 2004, February 2004, March 2004, April 2004, and July 2004. The sampling stations were adjusted to collect samples when the water depth in the channel is one-inch or greater. Samples were not collected on the dates water flow was recorded because the water flow was not sufficient enough for a sample to be collected. MACTEC personnel visited the Site following major precipitation events, and water flow was not observed in the stream following these events. Section 2.1.7.1 discusses the precipitation events in greater detail.

2.1.4 Groundwater

The presence of intermittent springs in the area, particularly a spring located upstream of the Site (identified in this report as the Mine Spring), indicates that limited groundwater occurs in the area. While crystalline bedrock is not known to be water bearing, water may be contained within the fractures in the bedrock. During long duration, low intensity precipitation events, referred to as “soaking rainfall”, or during snowmelt events, water will infiltrate into the subsurface strata. However, as soon as the storm passes and sunlight warms the soil, a majority of the water in the soil is extracted by evaporation. Plants also remove water via transpiration. Remaining water will tend to flow downhill through the strata toward the adjacent basins. As indicated by the presence of springs, sediment filled fractures in the bedrock act as water collection points that transmit water. A spring forms where this water surfaces. Other than these occasional fractures, a regional aquifer is not present below the Site.

2.1.5 Surrounding Land Use and Populations

The Site is surrounded by undeveloped and uninhabited land of the Tonto National Forest. Typical of the arid mountains of Central Arizona, the Mazatzal Mountains are a recreational area that draw diverse visitors including hunters, hikers, off-highway vehicles, campers, and rock

collectors. Therefore, land use is limited occupancy recreational. The only vehicular access to the Site is via a dirt and gravel Forest Service road, approximately 15 miles long, from Arizona Highway 87. The closest town to the Site is Sunflower, which is located approximately 10 miles south along Arizona Highway 87. The population of this town is small. There is no town center and the populace resides in low density, multi-acre homesteads and ranches. Maricopa County has an estimated population of more than 3.5 million people and includes the Phoenix Metropolitan Area, which is located approximately 45 miles to the south of the Site.

2.1.6 Sensitive Ecosystems

An ecological risk assessment was conducted by SWCA Consultants, Inc. (SWCA) under subcontract to MACTEC. The results of the SWCA ecological risk assessment, which includes identification of sensitive ecosystems, are discussed in detail in Section 3.2.

2.1.7 Meteorology

The nearest official weather station that provides meteorological data representative of the Site is located in Payson, Arizona, approximately 35 miles north of the Site. Climatic data from 1941 to 2000 were reviewed at the Western Regional Climatic Center website (http://www.wrcc.dri.edu) for the Payson weather station 026323. The climate at the Site is described as semi-arid.

2.1.7.1 Rainfall/Snowfall

A majority of the precipitation at the Site, and throughout most of Arizona, falls during two seasons: the summer monsoon, which occurs from late July through late September, and during the winter from late November through early March. Sporadic thunderstorms that are characterized by high intensity, short duration rainfall can occur at the Site anytime during the year. However, these types of storms are most prevalent during the summer monsoon when moisture originating from the Gulf of Mexico or Gulf of California encounters hot air rising off the desert floors. The heaviest rainfall often occurs in the mountainous areas, resulting in heavy runoff referred to as flash floods. During the winter “wet” season, precipitation is often characterized as low intensity, longer duration, referred to as a “soaking rain” or as snowfall. The Site is at an elevation where snow will occasionally fall. However, accumulations during a given storm are typically less than one foot and snow does not often remain on the ground for more than a few days. Mean monthly precipitation for the Payson weather station ranged from 0.4 inches

during June to 3.3 inches during August with an annual mean average of approximately 21.59 inches. The one day maximum rainfall occurred in September 1970 during an event called the Labor Day Storm. These data are consistent with data collected at the confluence of East and West Sycamore Creeks from 1945 to 1972 (Sellers, 1974). Mean annual rainfall at that site was 20.4 inches. Mean monthly precipitation ranged from 0.3 inches in June to 3.3 inches in August. The greatest daily precipitation was 8.0 inches in September 1970 during the Labor Day Storm.

On August 5, 2003, MACTEC installed two automated surface water sampling stations at the Site (see Figure 2 for locations). Surface Water Sampling Station No. 1 (SWSS-1) is located upstream of the retort building and is equipped with a rain gauge. Since August 5, 2003, the maximum daily rainfall reported was 2.94 inches on February 23, 2004 inches and the cumulative amount of precipitation recorded between September 1, 2003 and August 5, 2004 was 10.14 inches.

2.1.7.2 Temperature Ranges

Winter temperatures at the Payson weather station range from 25 to 55 degrees Fahrenheit (^{o}F), averaging 40.1^{o}F. Summer temperatures average 72.6^{o}F, ranging from 55°F to 90°F.

2.1.7.3 Wind Conditions

The Site is located in a deep V-shaped drainage of the Mazatzal Mountains. These V-shaped drainages tend to funnel winds up or down the drainage depending on the time of day or weather conditions. A phenomenon referred to as “canyon winds” occurs, which result from convective currents. During the daylight hours, particularly during the afternoon when maximum heating of the valley or desert floor occurs, heated air will move up the valleys, creating a predominant up-valley wind direction. The opposite occurs during the nighttime when heavier chilled air above moves down-valley, creating a down-valley wind direction. Wind directions can also be affected by storm fronts that typically move from the west and by collapsing thunderstorms that create downdrafts and micro-bursts.

2.2 PREVIOUS INVESTIGATIONS

2.2.1 Regulatory Involvement

In September 1999, the Forest Service retained Dynamac Corporation (Dynamac) to perform a Preliminary Assessment (PA) of the Mazatzal Mercury Mining District. Dynamac reported its findings in the *Final Removal Preliminary Assessment Report* dated September 28, 2001. The PA included the Pine Mountain Mine. Samples that Dynamac collected at the Pine Mountain Mine are summarized below.

- Collection and analysis of background samples. A total of five soil/sediment samples were collected from the entire 30 square mile area to evaluate background conditions.
- Collection of a total of six primary soil/sediment samples from the retort tailings and areas down-drainage from the retort tailings. Three additional samples identified as duplicates and replicates were also collected.
- Collection of two soil/sediment samples from the air shed.
- Collection of two ore samples.
- Collection of one waste rock sample.
- Collection of one sediment sample from the East Fork of Sycamore Creek, immediately down-drainage from the Site.
- Collection of a water sample from the spring located up-drainage from the Site. Due to apparent cross-contamination of the sample, the mercury concentration reported for the sample was considered invalid.

2.2.2 Source, Nature, and Extent of Contamination

The PA was focused on the retort and the retort tailings deposits. Samples of the waste rock and ore were also collected. Dynamac compared their soil/sediment sample analytical data to the Arizona Department of Environmental Quality (ADEQ) 1997 SRLs as promulgated by A.A.C. R18-7-205. Soil and sediment samples were analyzed for total mercury, which did not have listed 1997 SRLs. However, some of the samples were detected with total mercury in excess of the 1997 RSRL of 6.7 mg/kg for elemental mercury.

Arsenic exceeded the 1997 RSRL/NRSRL of 10 mg/kg. However, the toxicity of arsenic is also based on the species that is present, and background concentrations are an important consideration when evaluating arsenic as a COPC.

The two areas that contained mercury and arsenic are the retort tailings, which includes downstream bank and sediment deposits, and around the retort. The approximate locations of the retort, identified as Area RB, and retort tailings pile, identified as Area RT, are shown on Figure 2. A portion of the retort tailings have also been washed downstream of the retort tailings pile and have been deposited on the drainage banks. Therefore, the retort tailings deposit extends for a short distance downstream of the Site.

Dynamac collected one sample on the ridge to the west of the retort and one sample near the top of the fallen smokestack to evaluate what was termed "air shed". This sampling was apparently intended to evaluate potential impacts to the surrounding soil from retort smokestack emissions. Dynamac concluded that due to the smokestack being protected from high winds by the surrounding hills, emissions would have less chance to mix with air, and thus would be carried a shorter distance. Based on these results, the stack emissions had a limited effect on the soils in the air shed. Regardless of this conclusion, the Forest Service was still concerned about potential soil impacts in the area caused by stack emissions. Therefore, the soil sampling program in the background soils area (Area BS) and particulate fallout area (Area PF) was intended to further assess soil impacts from stack emissions (see Section 2.5).

2.2.3 Quantity, Volume, Size, or Magnitude of the COPCs

According to records referenced in the Dynamac report and production information obtained from UNC, at least 33,000 tons of retort tailings may have been produced by the Pine Mountain Mine and deposited in the retort tailings pile. This includes the approximately 25,000 tons that were reported in 1965 and the approximate 8,500 tons of ore that were processed by Harpoon. According to aerial photographs available at the Forest Service, the retort tailings pile apparently still filled the drainage during the mid-1960's. Current observations and a survey conducted by the Forest Service show that a portion of the retort tailings pile has been eroded and deposited downstream.

The Forest Service performed a survey of the retort tailings in 2002, including the downstream deposits. The survey map is included in Appendix B. The Forest Service estimated that the retort tailings pile and downstream retort tailings deposits constitute approximately 7,800 cubic yards of material.

2.3 SAMPLING PROGRAM AND RESULTS

The EE/CA investigation involved eight Areas of Interest (AOIs) listed as follows:

- Area BS - background soil
- Area PF - potential retort stack particulate fallout area
- Area RB - soil around the retort
- Area RT - retort tailings deposit
- Area USS – upstream or background streambed sediments
- Area DSS - downstream streambed sediments
- Surface water quality

Figure 2 shows the locations and boundaries of the AOIs. Soil sampling and analytical requirements were performed in accordance with the SAP dated January 9, 2004 (MACTEC, January 9, 2004). The soil and sediment samples were analyzed by Del Mar Analytical (DMA) for total mercury and arsenic using EPA Method 7471 and 6010, respectively. Soil sample collection field forms are included in Appendix C. The DMA reports, including chain-of-custody and Quality Assurance/Quality Control (QA/QC) report, are attached as Appendix D. Brooks Rand analyzed split soil samples for mercury and arsenic species using EPA Methods 3200 and 1632, respectively and four retort tailings samples for acid-base accounting and SPLP mercury. The Brooks Rand analytical report, including chain-of-custody and QA/QC documents, is included in Appendix E. Quality by Design (QBD), under contract to MACTEC, performed an EPA Level 3 QA/QC verification of the analytical data. The QBD Data Verification Reports are attached as Appendix H. According to QBD, the data are acceptable for use and the analyses were generally within the requirements of the referenced methods. Specific data qualifiers and discussion are provided in the QBD Data Verification Reports that are attached in Appendix H.

In addition, mercury air monitoring was conducted on the retort building on October 27, 2006 for the presence of a vapor hazard. It was performed in accordance with the August 30, 2006 Addendum to Sampling and Analysis Plan, Engineering Evaluation/Cost Analysis, Pine Mountain Mine Site, Tonto National Forest, Mesa Ranger District, Maricopa County, Arizona.

2.3.1 Speciation of Mercury in Soil and Sediment

Mercury occurs in the environment and exists in several forms. These forms can be grouped into three basic types, as discussed below:

- Elemental mercury is a shiny, silver-white metal that is a liquid at room temperature. Elemental mercury is also referred to as non-extractable, semi-mobile mercury. Metallic mercury is the elemental or pure form of mercury (e.g., it is not combined with other elements).

- Inorganic mercury – these are compounds that form when mercury combines with elements such as chlorine, sulfur, or oxygen. Mercuric sulfide (cinnabar ore) is also referred to as non-extractable, non-mobile mercury due to its extremely low solubility (log Ksp of approximately -52.4). Other mercury compounds of chlorine and oxygen are also called mercuric salts and are referred to as inorganic, extractable and mobile mercury.

- Organic mercury - when mercury combines with carbon, the compounds formed are called "organic" mercury compounds or organo-mercurials. There are a potentially large number of organic mercury compounds. However, by far the most common organic mercury compound in the environment is methyl mercury (also known as mono-methyl mercury).

The most common natural forms of mercury found in the environment are metallic mercury, cinnabar, mercuric ion typically reported as mercuric chloride, and methyl mercury. The environmental mobility and toxicity of mercury in a soil profile depend on its form. Organic mercury species, such as methyl mercury, are at least an order of magnitude more soluble than inorganic mercury species, and thus are more readily bio-accumulated and more toxic. Soluble inorganic mercury species such as mercury chloride are more easily transported by natural process than the other inorganic mercury species and serve as the substrate for mercury methylation processes. The environmental conditions that favor methyl mercury production include low pH (acidic) conditions, high levels of organic matter, and anoxic conditions which are often associated with swamps and wetlands as well as ponds and lakes. These conditions are not present at or anywhere close to the Site.

Methyl mercury is the most abundant form of organic mercury and is formed from a variety of biotic and abiotic processes. Most methyl mercury production results as a metabolic byproduct of sulfur-reducing bacteria (Carroll, 2000). Sulfate-reducing bacteria only exist in anaerobic conditions. Conditions such as those found in the vicinity of the Site are well oxygenated and sulfate-reducing bacteria cannot survive and thrive. Consequently, sulfate-reducing bacteria and

the formation of methyl mercury are limited to those environments typically found in the anoxic channel bottoms and backwater habitats of large, less energetic, streams, ponds, and lakes (Gilmore and Henry 1991, Marilainen 1995, Watras et al. 1995, all cited in Carroll 2000). Finally, the rate at which sulfate-reducing bacteria produce methyl mercury is affected by pH. Therefore, weathering of cinnabar (e.g., oxidizing the sulfide through sulfite to sulfate, with the Hg^{+2} being reduced to elemental mercury and subsequently being methylated), is not a favored reaction within sediments having a neutral pH, such as those that are present within the surface waters near the Site (Harsh and Doner 1981). The streams in the vicinity of the Site are ephemeral. Conditions enabling the formation of methyl mercury are essentially lacking in the vicinity of the Site. Based on the nature of the Site, there is a prominence of cinnabar that has essentially no water solubility (4.5×10^{-24} mol/L), and is likely to remain fixed in soil.

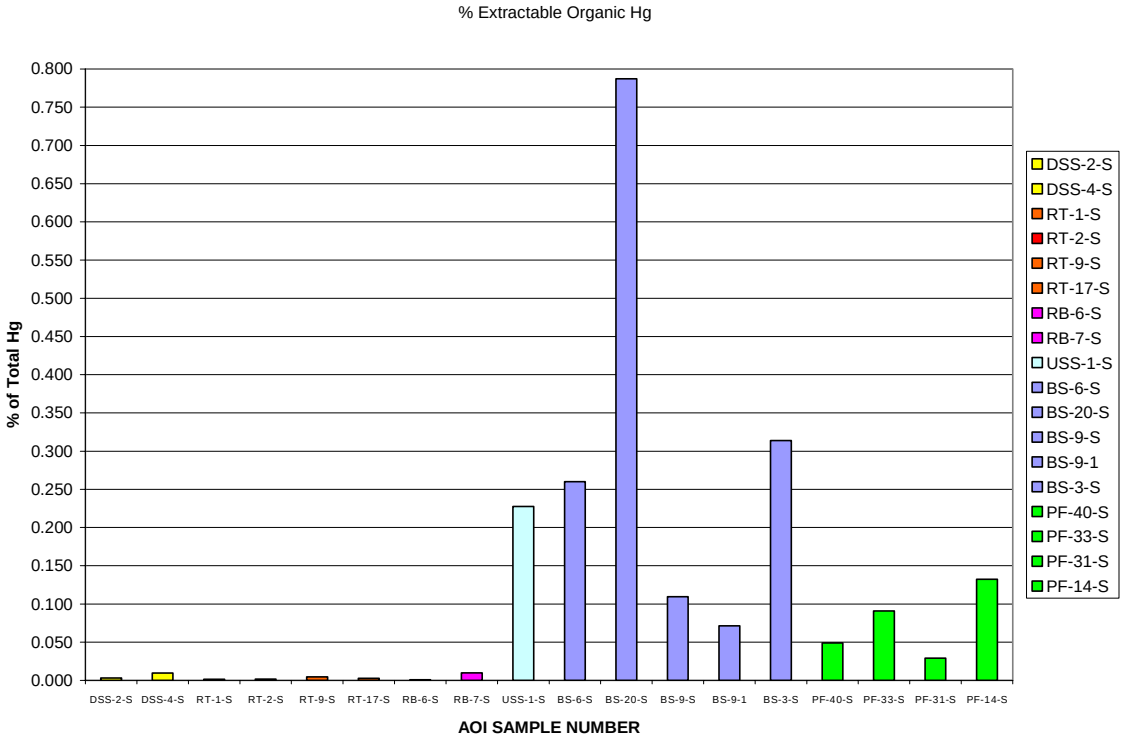
Soluble or "extractable" organomercury species (e.g., methyl mercury) and extractable inorganic species (e.g., mercuric chloride), that could contribute potential mercury toxicity in the soils, should be absent or present in relatively small amounts in the soil/sediment from the AOIs when compared to the other forms of mercury. Other mercury species that fall into the "semi-mobile" category, such as elemental mercury, are less toxic than extractable mercury species and would only be a concern for indoor vapor formation (e.g., in the Retort Building). The majority of the total mercury present in soil/sediment should be the "non-mobile" mercury species, such as cinnabar. Cinnabar is chemically stable in the soil for geologic time periods and is characterized as the least toxic of all mercury species. The differences in physical properties of the major mercury species was the basis for EPA's analytical method for mercury (e.g., EPA Method 3200) that was performed by Brooks Rand on soil/sediment from the AOIs. The following table provides descriptions for each of the mercury species.

Operationally-Defined Mercury Fractions		**Individual Mercury Species**
Total Mercury		All mercury containing species
Extractable Mercury	Extractable Organic Mercury (methyl mercury)	CH_3HgCl, CH_3CH_2HgCl
	Extractable Inorganic Mercury (mercuric chloride, mercury oxides, and bivalent mercury complexes)	$HgCl_2$, $Hg(OH)_2$, $Hg(NO_3)_2$, $HgSO_4$ HgO, Hg_2^+ complexes[a]
Non-extractable Mercury	Semi-mobile Mercury (includes elemental mercury)	Hg0 & Hg0-M[b] Hg_2^+ complexes[a], Hg_2Cl_2 (minor)
	Non-mobile Mercury	HgS (cinnabar), HgSe

a. Certain inorganic mercury complexes may be present as extractable or non-extractable fractions.
b. This represents a mercury-metal amalgam.

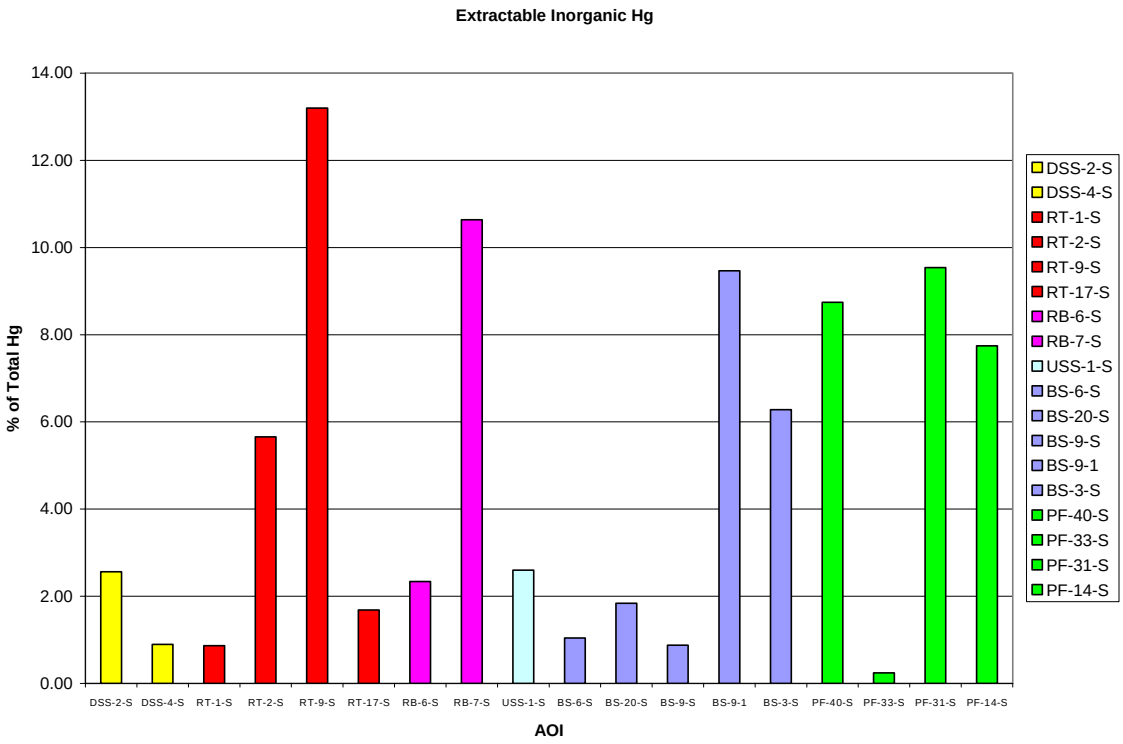
During the EE/CA study, 100 soil/sediment samples were collected and analyzed for mercury by Del Mar Analytical (DMA). In addition to the total mercury concentration (EPA Method 7471), extractable and non-extractable mercury concentrations were determined using EPA's analytical method for differentiating environmentally relevant forms of mercury (EPA Method 3200) in a subset of soil samples containing the highest total mercury content. These same samples were further analyzed for total leachable mercury using the synthetic precipitation leaching procedure (SPLP, EPA Method 1312) to determine the potential impact to ground and surface waters (Sections 3.1.2 and 3.1.3).

The results of the mercury analyses are presented and evaluated in Tables 1 through 4 and in Bar Graphs 1-3 below. The most soluble and toxic form of mercury, which is methyl mercury, comprised an insignificant portion of the total mercury in soil/sediment from the Site (see Bar Graphs 1-3 below). The methyl mercury component ranged from 0.001% to 0.132% by weight of the total mercury concentrations within the soils in the Site AOIs compared to 0.071% to 0.787% by weight for the upstream sediment and background soil samples (Bar Graph 1).



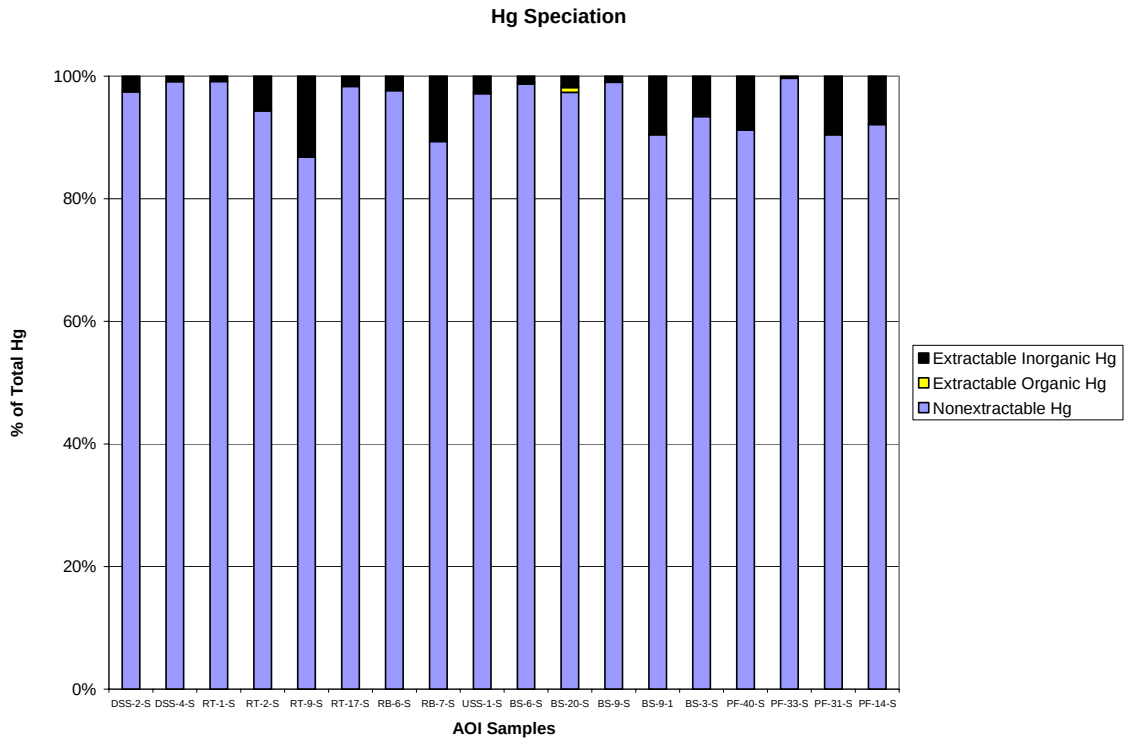
BAR GRAPH 1

For the mercuric chloride component, the AOI soil data contained 0.24% to 13.20% by weight of the total mercury of the Site AOIs compared to 0.87% to 9.47% by weight for upstream sediment and background soils samples (Bar Graph 2).



BAR GRAPH 2

As shown in Bar Graph 3 below, the majority of the total mercury in all the samples is in the form of cinnabar.



BAR GRAPH 3

The mercury analytical results for each AOI are discussed in detail in the following subsections.

2.3.1.1 Background Conditions – BS Area

The background sampling area, identified as Area BS, is shown on Figure 2. During the on-site meeting on August 4, 2003, the Forest Service stated that tailings were reportedly deposited on the access road in the past. This was also stated in the archeologist's report that is attached to the Dynamac Report. Therefore, the background soil sampling area was located upslope of the road. Due to the known presence of other mining operations not associated with the Site, the background soil sampling area was entirely located within the drainage basin that includes the Site and did not extend to adjacent drainage basins. A sampling grid was established, as described in detail in the SAP, and 20 sampling cells were randomly selected for sampling. The background sampling locations were accepted by the Forest Service.

The sampling grid and sample locations for Area BS are shown on Figure 3. Table 1 includes the sample Global Positioning System (GPS) coordinates, date of collection, and date of analysis. Samples were collected from each location at the surface and at approximately one foot deep.

With the exception of samples BS-20 and BS-31, the samples were collected near the GPS coordinates presented in the SAP. Sample locations BS-20 and BS-31 had to be moved slightly due to the presence of steep terrain or cliffs.

The total mercury concentrations in background soils are shown in Table 1. Mercury speciation data are shown in Table 2 and are further evaluated in Bar Graphs 1-3 (Section 2.3.1) and Table 3. None of the samples contained total mercury in excess of the most stringent mercury screening level of 6.5 mg/kg (ADEQ 1997 RSRL for methyl mercury). The total mercury concentrations ranged from 0.025 mg/kg to 4.6 mg/kg. Additionally, the samples do not contain total mercury in excess of the minimum GPL of 12 mg/kg.

2.3.1.2 Particulate Fallout Area (Area PF)

Area PF is bound on the northeast and southwest by surface water sampling stations SWSS No. 1 and SWSS No. 2, respectively (Figure 2). This AOI does not include the streambed, Pit No. 1, the retort building area, or the retort tailings deposit. This AOI was established to evaluate if emissions from the retort stack have impacted surface soils in this area.

The sampling grid and locations for Area PF are shown on Figure 4. Twenty sampling locations were randomly selected from the grid. Table 1 includes the sample GPS coordinates, date of collection, and date of analysis. The samples were collected near the GPS coordinates presented in the SAP.

The soil samples were analyzed by DMA for total mercury using EPA Method 7471. The four samples that contained the highest total mercury concentrations were further analyzed by Brooks Rand for extractable and non-extractable mercury species using EPA Method 3200.

The total mercury concentrations are shown in Table 1. The total mercury concentrations ranged from 0.12 mg/kg to 82 mg/kg. Samples PF-14-S, PF-31-S, PF-33-S, and PF-40-S contained total mercury in excess of the most stringent (methyl mercury) ADEQ 1997 RSRL and EPA Region 9 residential PRG mercury screening level of 6.5 and 6.1 mg/kg, respectively. However, only one sample was detected with total mercury in excess of the methyl mercury NRSRL or nonresidential EPA Region 9 PRG (PF-31-S). Samples PF-31-S and PF-40-S contained total mercury in excess of the minimum GPL of 12 mg/kg. Samples PF-31-S and PF-40-S, which

contain 82 and 37 mg/kg of total mercury, respectively, were collected upslope of the former open pit.

Samples PF-14-S, PF-31-S, PF-33-S, and PF-40-S were detected with the highest total mercury concentrations and were analyzed for mercury species. The analytical results are shown in Table 2 and are further evaluated in Bar Graphs 1-3 (Section 2.3.1) and Table 3. The analytical results indicated the concentrations of mercuric chloride and methyl mercury in the samples do not exceed the ADEQ 1997 RSRL and EPA Region 9 residential PRGs for mercuric chloride as well as methyl mercury. The concentrations of total extractable mercury were relatively low, ranging from 0.011 ug/g (mg/kg) in sample PF-33-S to 3.946 mg/kg in sample PF-31-S. As shown in Bar Graphs 1-3 (Section 2.3.1) and Table 3, mercuric chloride and methyl mercury constituted less than 10 percent by weight of the total mercury detected, with the primary species being the mercuric chloride. Methyl mercury constitutes less than 0.2 percent by weight of the total mercury detected.

As shown in Bar Graphs 1-3 (Section 2.3.1) and Table 3, the Area PF samples contain predominantly cinnabar ranging from 90.43% to 99.67% by weight of the total mercury detected. Samples PF-31-S and PF-40-S, which were collected near ore outcrops and had the highest total mercury concentrations, contained predominantly cinnabar. However, samples PF-14-S and PF-33-S, which had the lowest detectable total mercury concentrations of the four speciated samples, contained more elemental mercury than cinnabar. This is similar to the trend observed in the Area BS samples.

2.3.1.3 Retort Building (Area RB)

The retort building area, which is identified as Area RB, includes soils around the retort building and the fallen retort stack. A total of 10 soil samples were collected from this area and analyzed for total mercury using EPA Method 7471.

The sample locations for Area RB are shown on Figure 5. Samples RB-1-S were collected around the retort building, sample RB-6-S was collected from a crack in the concrete on the east side of the retort building and near the concentrator/condenser pipes, and samples RB-7-S through RB-10-S were collected along the fallen stack with RB-7-S collected within one-foot of the base and RB-10-S collected within one foot of the top. Table 1 includes the sample GPS coordinates, date of collection, and date of analysis.

The soil samples were analyzed by DMA for total mercury using EPA Method 7471. The two samples that contained the highest total mercury concentrations were further analyzed by Brooks Rand for extractable and non-extractable mercury species using EPA Method 3200.

The total mercury concentrations are shown in Table 1. The total mercury concentrations range from 57 mg/kg in sample RB-9-S to 8,400 mg/kg in sample RB-7-S. Sample RB-7-S was collected near the base of the fallen retort stack. All 10 samples contained total mercury in excess of the most stringent mercury (methyl mercury) ADEQ 1997 RSRL and EPA Region 9 residential screening level of 6.5 mg/kg and 6.1 mg/kg, respectively and the minimum GPL of 12 mg/kg. Four samples exceeded the ADEQ 1997 NRSRL, including RB-6-S and RB-7-S.

Samples RB-6-S and RB-7-S were detected with the highest total mercury concentrations and were analyzed for mercury species. The analytical results are shown in Table 2 and are further evaluated in Bar Graphs 1-3 (Section 2.3.1) and Table 3. There is a slight difference in the total mercury concentrations reported by DMA and by Brooks Rand. The samples that were submitted to DMA for total mercury analysis and to Brooks Rand for mercury speciation were split samples. The difference in total mercury concentrations may represent heterogeneity in the sample.

The analytical results indicated the concentrations of methyl mercury in the samples did not exceed the AQEQ 1997 RSRLs or EPA Region 9 residential PRG for methyl mercury of 6.5 and 6.1 mg/kg, respectively. The concentrations of methyl mercury constitute less than 0.01 percent by weight of the total mercury detected and are considered negligible.

The concentrations of mercuric chloride in samples RB-7-S and RB-6-S exceed the 1997 ADEQ RSRL and NRSRL and EPA residential and nonresidential PRGs for mercuric chloride. This area requires further site-specific evaluation in the human health risk assessment (Section 3.0). As shown in Histograms 1-3 (Section 2.3.1) and Table 3, the Area RB samples contained predominantly non-extractable mercury species, mainly cinnabar, ranging from 89.35% to 97.66% by weight of the total mercury detected.

2.3.1.4 Retort Tailings (Area RT)

The retort tailings AOI, which is identified as Area RT, is limited to the large retort tailings deposit that extends from the retort to the streambed. A total of 20 samples were collected along the base of the retort tailings deposit and from retort tailings deposited on the channel bed and

banks between the tailings pile and SWSS-2 (16 samples from the retort tailings pile and 4 samples along the streambed).

The sample locations for Area RT are shown on Figure 6. The 20 sampling locations were identified in the field. Samples RT-1-S through RT-16-S were collected along the base of the retort tailings pile and samples RT-17-S through RT-20-S were collected along the stream banks downstream of the retort tailings deposit. Table 1 includes the sample GPS coordinates, date of collection, and date of analysis.

The soil samples were analyzed by DMA for total mercury using EPA Method 7471. The four samples containing the highest total mercury concentrations were further analyzed by Brooks Rand for extractable and non-extractable mercury species using EPA Method 3200.

The total mercury concentrations are shown in Table 1. The total mercury concentrations ranged from 9.3 mg/kg in sample RT-10-S to 1,300 mg/kg in sample RT-1-S. All 20 samples contained total mercury in excess of the most stringent mercury (methyl mercury) ADEQ 1997 RSRL and EPA Region 9 residential screening level of 6.5 mg/kg and 6.1 mg/kg, respectively. However, only two samples exceeded the ADEQ 1997 NRSRL, including RT-1-S and RT-2-S. Samples RT-1-S and RT-2-S, in which the highest total mercury concentrations were detected, were collected from what appeared to be piles of ore or waste rock near the northernmost end of the retort tailings deposit. With the exception of samples RT-10-S and RT-13-S, the total mercury concentrations in the samples also exceeded the minimum GPL of 12 mg/kg.

Samples RT-1-S, RT-2-S, RT-9-S, and RT-17-S had the highest total mercury concentrations detected. Therefore, these samples were analyzed for mercury species. The analytical results are shown in Table 2 and are further evaluated in Bar Graphs 1-3 (Section 2.3.1) and Table 3. There is a slight difference in the total mercury concentrations reported by DMA and by Brooks Rand. The samples that were submitted to DMA for total mercury analysis and to Brooks Rand for mercury speciation were split samples. The difference in total mercury concentrations represents heterogeneity in the sample.

The analytical results indicated the concentrations of methyl mercury in the samples do not exceed the 1997 ADEQ RSRL and EPA Region 9 residential PRG for methyl mercury of 6.5 and

6.1 mg/kg, respectively. The concentrations of methyl mercury constituted less than 0.005% by weight of the total mercury detected and are considered negligible.

With the exception of sample RT-2-S, the concentrations of mercuric chloride in the samples did not exceed the 1997 RSRL and EPA Region 9 residential PRG for mercuric chloride of 23 mg/kg. Sample RT-2-S contained 33.54 mg/kg of mercuric chloride, which was slightly above the 1997 RSRL of 23 mg/kg. However, this concentration is well below the 1997 NRSRL and EPA Region 9 nonresidential PRG for mercuric chloride of 510 and 310 mg/kg, respectively.

As shown in Bar Graphs 1-3 (Section 2.3.1) and Table 3, the Area RT samples contained predominantly non-extractable mercury species, mainly cinnabar, ranging from 86.80% to 99.13% by weight of the total mercury detected.

2.3.1.5 Streambed Sediment Samples

The streambed sediment sampling area is divided into two sub-areas, downstream of the Site and background. The sub-areas, identified as USS for upstream and DSS for downstream, are shown on Figure 2. Area DSS included the streambed from the base of the retort tailings pile to a point slightly downstream of SWSS No. 2. Area USS included the streambed upstream of the access road to the discernable head of the drainage, as shown on Figure 2. A sampling grid was established for each sub-area and four background sample and six downstream sample locations were randomly selected.

The samples were analyzed for total mercury using EPA Method 7471. One of the background samples and two of the downstream samples were also analyzed for mercury species using EPA Method 3200.

2.3.1.5.1 Upstream Streambed Sediment Samples (Area USS)

The Area USS sample locations are shown on Figure 7. The four Area USS samples were collected near the GPS coordinates presented in the SAP with minor adjustment to fall within the streambed. Table 1 includes the sample GPS coordinates, date of collection, and date of analysis. The following subsections discuss the analytical results.

The soil samples were analyzed by DMA for total mercury using EPA Method 7471. The sample containing the highest total mercury concentrations was further analyzed by Brooks Rand for extractable and non-extractable mercury species using EPA Method 3200.

The total mercury concentrations are shown in Table 1. The total mercury concentrations ranged from 0.17 mg/kg in sample USS-2-S to 0.26 mg/kg in sample USS-4-S. None of the four Area USS samples contained total mercury in excess of the most stringent (methyl mercury) ADEQ 1997 RSRL and EPA Region 9 residential PRG mercury screening level of 6.5 and 6.1 mg/kg, respectively or the minimum GPL of 12 mg/kg. The total mercury concentrations reported in the Area USS samples were equivalent to the total mercury concentrations reported in the Area BS samples.

The total mercury concentrations in the four Area USS samples did not vary much, ranging from 0.17 mg/kg to 0.26 mg/kg. Though sample USS-4-S contained the highest total mercury concentration of the four Area USS samples, sample USS-1-S was selected for mercury speciation because it contained a much higher total arsenic concentration than the other three samples. The analytical results are shown in Table 2 and are further evaluated in Bar Graphs 1-3 (Section 2.3.1) and Table 3. There was a slight difference in the total mercury concentrations reported by DMA and by Brooks Rand. The samples that were submitted to DMA for total mercury analysis and to Brooks Rand for mercury speciation were split samples. The difference in total mercury concentrations represented heterogeneity in the sample.

The analytical results indicated the concentration of methyl mercury in the sample did not exceed the ADEQ 1997 RSRL and EPA Region 9 residential PRG for methyl mercury of 6.5 and 6.1 mg/kg, respectively. The concentration of methyl mercury constituted 0.227% by weight of the total mercury detected and is considered negligible. The concentration of mercuric chloride in the sample also did not exceed the ADEQ 1997 RSRL and EPA Region 9 residential PRG for methyl mercury of 23 mg/kg. As shown in Table 3, the mercuric chloride fraction represented 2.60% by weight of the total mercury detected. Additionally, sample USS-1-S contained 97.17% by weight of non-extractable mercury species, which was primarily elemental mercury. This is similar to the mercury speciation results for the Area BS samples.

2.3.1.5.2 Downstream Streambed Sediment Samples (Area DSS)

The Area DSS sample locations are shown on Figure 7. The six Area DSS samples were collected near the GPS coordinates presented in the SAP with minor adjustment to fall within the streambed. Table 1 includes the sample GPS coordinates, date of collection, and date of analysis. The Area DSS samples were collected from deposits of retort tailings in the streambed. The following subsections discuss the analytical results.

The soil samples were analyzed by DMA for total mercury using EPA Method 7471. The two samples that contained the highest total mercury concentrations were further analyzed by Brooks Rand for extractable and non-extractable mercury species using EPA Method 3200.

The total mercury concentrations are shown in Table 1. The total mercury concentrations ranged from 39 mg/kg in sample DSS-3-S to 160 mg/kg in sample DSS-2-S. The six Area DSS samples contained total mercury in excess of the most stringent (methyl mercury) ADEQ 1997 RSRL and EPA Region 9 residential PRG mercury screening level of 6.5 and 6.1 mg/kg, respectively and the minimum GPL of 12 mg/kg. However, only two samples exceeded the ADEQ 1997 NRSRL and EPA Region 9 nonresidential PRG for methyl mercury. The total mercury concentrations reported in the Area DSS samples were similar to the total mercury concentrations reported in the Area RT samples. Therefore, the area DSS samples were generally characteristic of the retort tailings.

Samples DSS-2-S and DSS-4-S were detected with the highest total mercury concentrations and were analyzed for mercury species. The analytical results are shown in Table 2 and are further evaluated in Bar Graphs 1-3 (Section 2.3.1) and Table 3. There was a slight difference in the total mercury concentrations reported by DMA and by Brooks Rand. The samples that were submitted to DMA for total mercury analysis and to Brooks Rand for mercury speciation were split samples. The difference in total mercury concentrations represented heterogeneity in the sample.

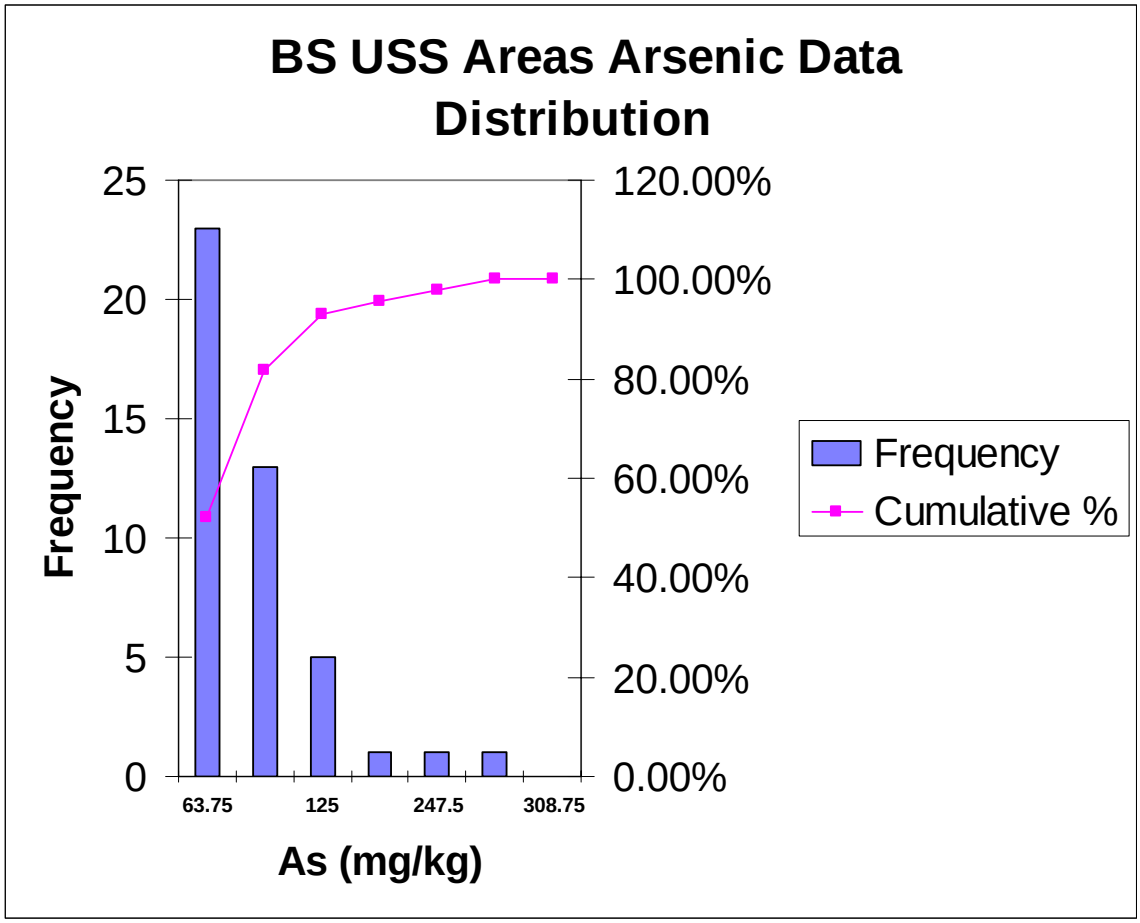
The analytical results indicated the concentrations of methyl mercury in the samples did not exceed the ADEQ 1997 RSRL or EPA Region 9 residential PRG for methyl mercury of 6.5 and 6.1 mg/kg, respectively. The concentrations of methyl mercury constituted less than 0.009% by weight of the total mercury detected and are negligible.

The concentrations of mercuric chloride in the samples did not exceed the ADEQ 1997 RSRL and EPA Region 9 residential PRG for mercuric chloride of 23 mg/kg. As shown in Bar Graphs 1-3 (Section 2.3.1) and Table 3, the mercuric chloride fraction represented between 0.89% and 2.56% by weight of the total mercury detected. Applying this range, it is unlikely that the other four samples collected from Area DSS contained mercuric chloride above the soil cleanup criteria of 23 mg/kg. As shown in Bar Graphs 1-3 (Section 2.3.1) and Table 3, the Area DSS samples contained predominantly non-extractable mercury species, mainly cinnabar, ranging from 97.43% to 99.10% by weight of the total mercury detected. The mercury speciation results for the Area DSS samples were similar to those for the Area RT samples. However, the speciation results indicated the Area DSS samples contained a greater percentage of cinnabar.

2.3.2 Arsenic in Soil and Sediment

2.3.2.1 Background Conditions – BS and USS Areas

The arsenic concentrations in the Area BS samples were variable ranging up to 370 mg/kg (Table 1). Many sample results exceeded the arsenic ADEQ 1997 RSRL/NRSRL of 10 mg/kg (default background). The total arsenic concentration in sample BS-9-1 of 370 mg/kg exceeded the ADEQ's minimum Groundwater Protection Level (GPL) of 290 mg/kg. Histogram 1 presents the distribution of the background data (BS and USS areas).



HISTOGRAM 1

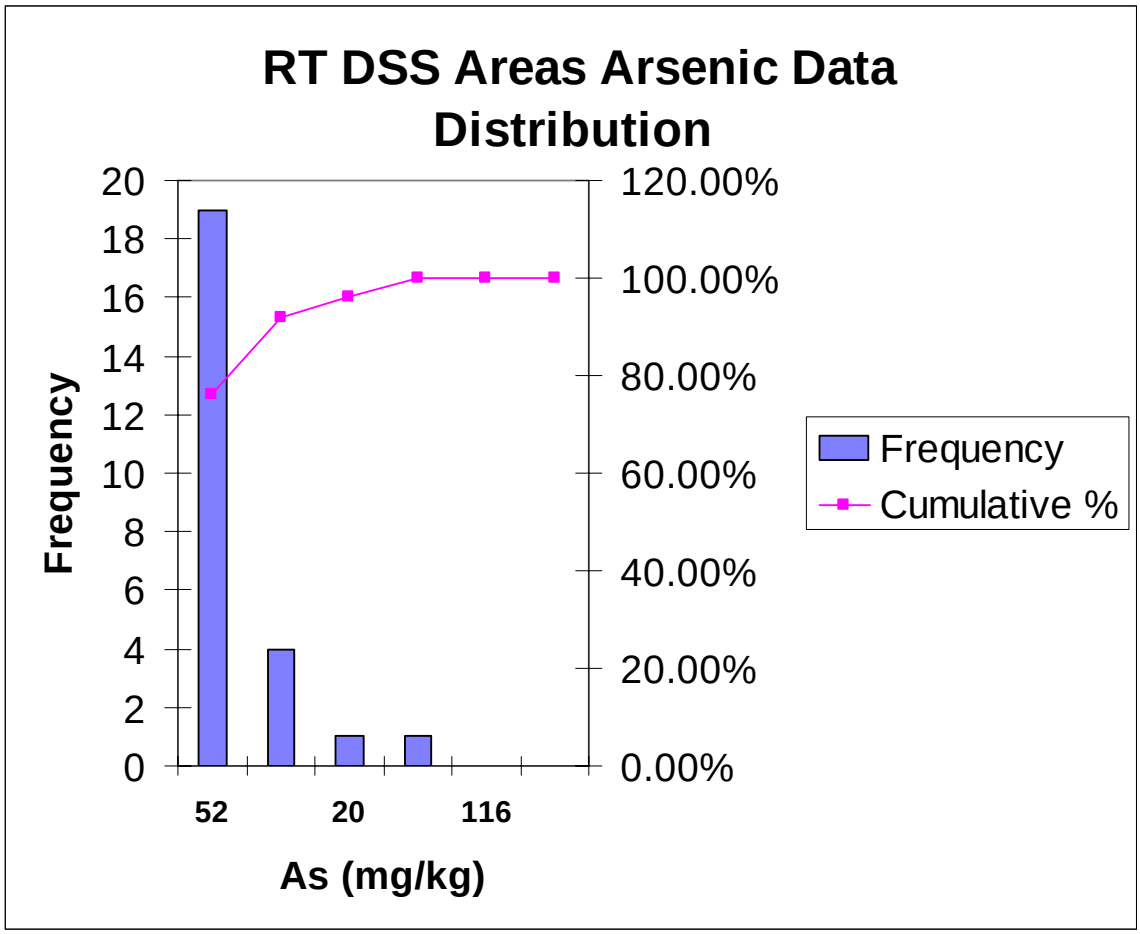
While background concentration is inherently represented by a distribution of concentrations, arithmetic mean or confidence levels thereof do not represent the range of values that may be within that distribution. Nonetheless, the upper confidence level of the background dataset was calculated using EPA ProUCL consistent with ADEQ guidelines. Based on the distribution of data, ProUCL identified the data as nonparametric and recommended the 99% Chebyshev (Mean, Sd) UCL as the appropriate upper confidence value (154 mg/kg). The 99% Chebyshev UCL site-specific natural background arsenic concentration of 142.4 mg/kg was compared to the soil/sediment results from AOIs to determine if additional evaluation was warranted.

2.3.2.2 Retort Tailings (RT) and Downstream Sediment (DSS) Areas

For comparison to background conditions, nonparametric statistics applied to the arsenic concentration distribution for RT and DSS and the UCL was 54.5 mg/kg (modified T UCL-

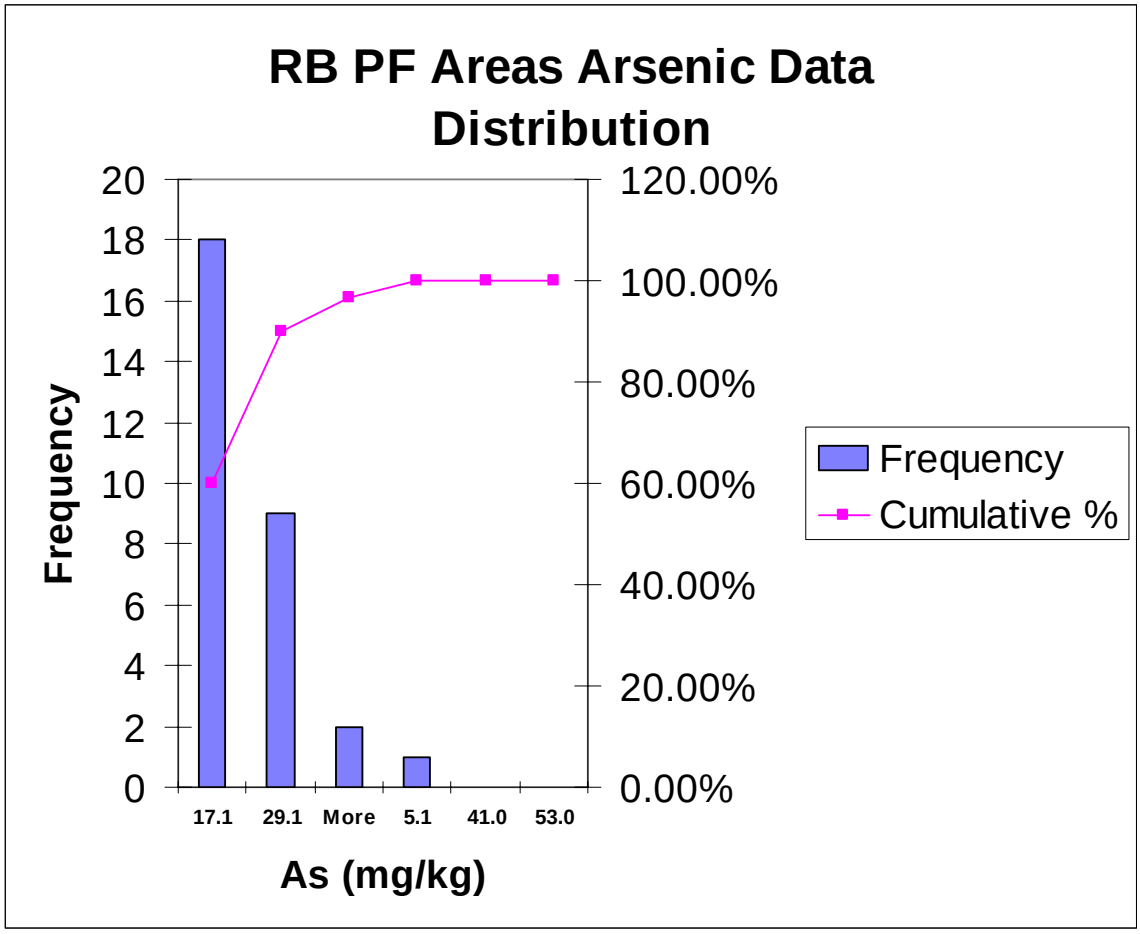
adjusted for skewedness). A histogram of the Site AOI data is presented in Histogram 2 below. Based on the nonparametric statistical test (Wilcoxon/Mann-Whitney U Test), the RT DSS area arsenic concentrations are statistically different at the 95% confidence level (lower concentrations) than Area BS USS.

HISTOGRAM 2



2.3.2.3 Retort Building (RB) and Particulate Fallout (PF) Areas

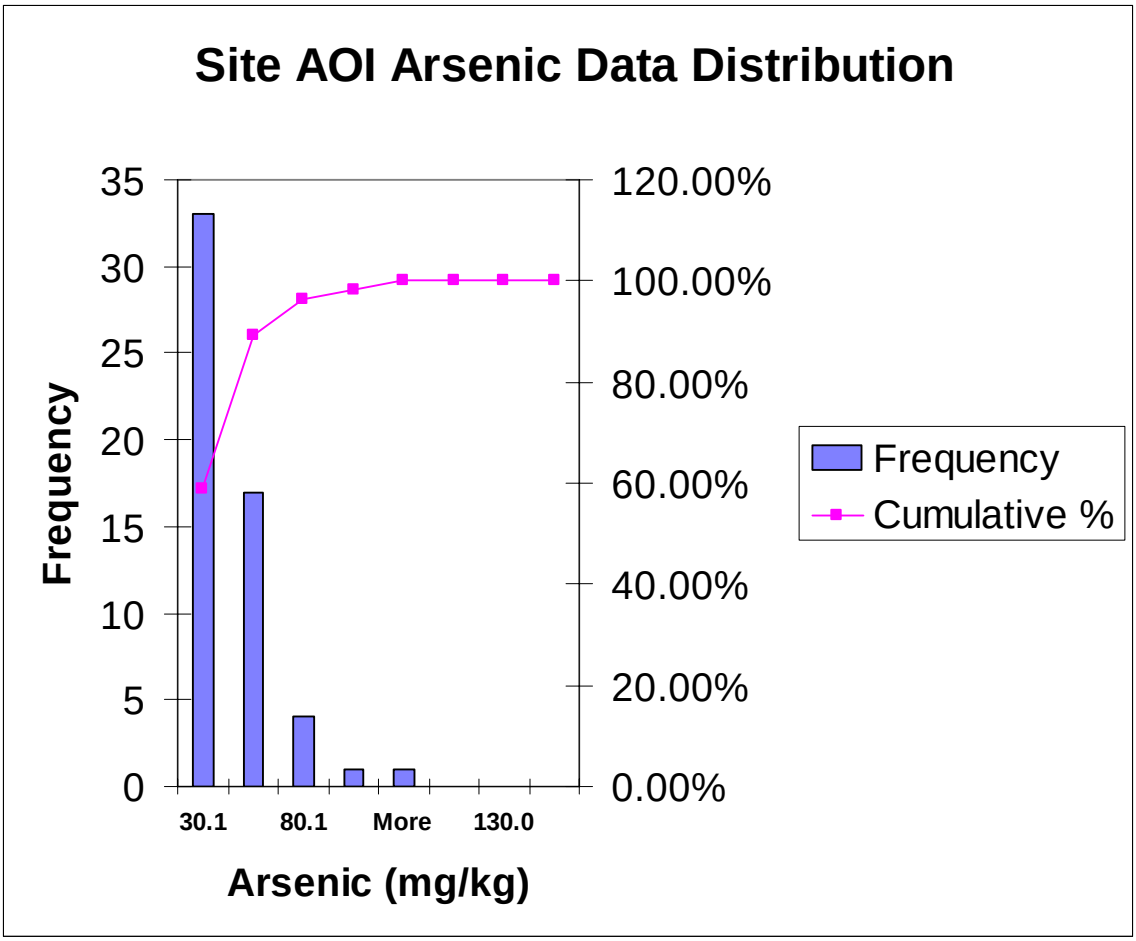
For comparison to background conditions, nonparametric statistics were found to apply to the arsenic concentrations for RB and PF and the UCL was 28.2 mg/kg (95% Chebyshev (mean sd) UCL). A histogram of the Site AOI data is presented in Histogram 3 below. Based on the nonparametric statistical test (Wilcoxon/Mann-Whitney U Test), the RB PF area arsenic concentrations are not statistically different than Area BS USS.



HISTOGRAM 3

2.3.2.4 RT, DSS, RB, and PF Areas

For comparison to background conditions, the arsenic concentrations for RT, DSS, RB and PF were statistically described as being a gamma distribution and the UCL was 34.8 mg/kg (approximate Gamma UCL). A histogram of the Site AOI data is presented in Histogram 4 below. Based on the nonparametric statistical test (Wilcoxon/Mann-Whitney U Test), the RT, USS, RB PF area arsenic concentrations are not statistically different than Area BS USS, but are statistically different (lower in concentration) from the BS/USS area samples.



HISTOGRAM 4

The statistical summary table presented below shows that the Site data demonstrate statistically significant differences from the background dataset, with the Site data being described by lower UCLs and less variance than the background dataset. Nonetheless, according to EPA's risk assessment guidance on background, arsenic was not eliminated as a COPC, but rather retained for human health risk evaluation.

Statistical Summary of Arsenic Soil/Sediment Results from AOIs

AOI	Distribution	UCL As (mg/kg)	Wilcoxon, Mann-Whitney U Test
USS BS	Nonparametric (0.05)	**142.4** - 99% Chebyshev (Mean.Sd) UCL	N/A
RT DSS	Nonparametric (0.05)	**54.5** – modified T UCL (adjusted for skewness)	Statistically different (0.05) from BS USS
RB PF	Nonparametric (0.05)	**28.2 –** 95% Chebyshev (Mean.Sd) UCL	Not statistically different (0.05) from BS USS; Statistically different from RT DSS
RT DSS RB PF	Gamma distribution (0.05)	**34.8** – Approximate Gamma UCl	Statistically different (0.05) from USS BS

2.3.3 Other Metals in Soil and Sediment

2.3.3.1 Particulate Fallout Area (Area PF)

Surface samples PF-07-S, PF-22-S, PF-25-S, and PF-44-S were analyzed for antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc using EPA Method 6010. The analytical results are summarized in Table 1. The samples did not contain concentrations of antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, or zinc above their respective 1997 RSRLs.

2.3.3.2 Retort Building (Area RB)

Surface samples RB-1-S, RB-4-S, RB-6-S, and RB-8-S were analyzed for antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc using EPA Method 6010. The analytical results are summarized in Table 1. The samples did not contain concentrations of antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, or zinc above their 1997 RSRLs.

2.3.3.3 Retort Tailings (Area RT)

Surface samples RT-4-S, RT-8-S, RT-12-S, and RT-16-S were analyzed for antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc using EPA Method 6010. The analytical results are summarized in Table 1. The samples did not contain concentrations of antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, or zinc above their respective 1997 RSRLs.

2.3.3.4 Streambed Sediment Samples

Upstream surface sample USS-1-S was analyzed for antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc using EPA Method 6010. The analytical results are summarized in Table 1. This sample did not contain concentrations of antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc above their respective 1997 RSRLs.

Downstream surface samples DSS-3-S and DSS-5-S were analyzed for antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc using EPA Method 6010. The analytical results are summarized in Table 1. These samples did not contain concentrations of antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc above their respective 1997 RSRLs.

2.3.4 Acid-Base Accounting

Retort tailings samples RT-1-S, RT-12-S, RT-13-S, and RT-20-S were analyzed by STL Laboratories, under subcontract to Brooks Rand, for acid-base accounting. Acid-base accounting measures the potential for mining processed materials to generate acids, which could mobilize heavy metals. The acid-base potential (ABP) of a material is measured in tons of calcium carbonate ($CaCO_3$) per 10,000 tons of material. The analysis calculates the acid generating potential (AGP) and the acid neutralizing potential (ANP), both of which are also expressed in tons of $CaCO_3$ per 10,000 tons of material. The AGP is subtracted from the ANP, which yields the ABP. A positive number indicates the material has a greater acid neutralizing potential, hence the material is determined to not be acid generating. A negative number indicates that the material has an acid generating potential, specifically the material generates more acid than it can auto-neutralize. As shown in Table 6, the retort tailings samples have high ANPs and relatively low AGPs, resulting in strongly positive ABPs. Therefore, the retort tailings are not acid generating.

2.3.5 Migration to Water Resources

2.3.5.1 Groundwater

The sampling program included evaluating the potential for mercury to migrate to water resources. Two methods have been developed to evaluate the potential for metals to leach to

groundwater and/or surface water, the Toxicity Characteristic Leaching Procedure (TCLP) and the Synthetic Precipitation Leaching Procedure (SPLP). The TCLP methodology was developed by EPA to simulate conditions in an anaerobic landfill. It is intended to represent worst-case leaching conditions in a municipal landfill where organic wastes are commingled. However, soils and metal production mill tailings are not compatible with the municipal landfill model that was used to develop TCLP. The SPLP was developed by the EPA in the late 1980's to better simulate leaching in the environment.

SPLP is identical to the TCLP with regards to the sample processing and extraction process. The difference exists in the extraction fluid used. The TCLP fluids are highly buffered and mildly acidic using acetic acid. The SPLP method uses an extraction fluid based on the physical location of the site to be characterized (east or west of the Mississippi River). The SPLP typically is utilized to more closely simulate groundwater leaching effects in the environment than the TCLP.

The samples from each AOI that were analyzed for mercury species were analyzed for leachable mercury using the SPLP method. The SPLP extract is analyzed for total metals. It should be noted that only the extractable species should be present in the SPLP extract. Therefore, for mercury, the SPLP extract should only contain methyl mercury and mercuric chloride. However, suspended or sorbed non-extractable species may be present in the extract. To confirm this, Brooks Rand, LLC (Brooks Rand) obtained SPLP extracts from the four retort tailings samples containing the highest total mercury concentrations and speciated the mercury using EPA Method 3200.

Samples PF-14-S, PF-31-S, PF-33-S, PF-40-S, RB-6-S, RB-7-S, RT-1-S, RT-2-S, RT-9-S, RT-17-S, USS-1-S, DSS-2-S and DSS-4-S were analyzed for total leachable mercury using EPA Method 1312, the SPLP. The SPLP results are shown in Table 2.

The standard SPLP extract is analyzed for total mercury. The SPLP extraction fluid has a pH of approximately 5.0 to approximate the pH of rainfall, which is higher than the pH of the extraction fluid used to obtain the extract for the mercury speciation analysis. MACTEC hypothesized that if the SPLP extraction fluid was used to obtain an extract, the SPLP extract should contain lower concentrations of extractable mercury species than the extract that was obtained during the original mercury speciation of the retort tailings samples. Therefore, MACTEC requested that Brooks Rand obtain SPLP extracts for samples RT-1-S, RT-2-S, RT-9-S, and RT-17-S and

analyze the SPLP extracts for the extractable mercury species using EPA Method 3200. MACTEC requested that the data be reported in mg/L, which represents the dissolved concentration of mercury. The results are shown in Table 4.

As shown in Table 4, the concentrations of total extractable mercury in the SPLP extracts for samples RT-1-S, RT-2-S, RT-9-S, and RT-17-S were relatively low, ranging from 0.000178 mg/L to 0.00209 mg/L. Mercuric chloride constitutes a majority of the extractable mercury detected, with methyl mercury concentrations being negligible. Sample RT-2-S, which also contained the highest concentrations of extractable mercury, had the highest concentration of extractable mercury in the SPLP extract, which is 0.00209 mg/L.

The SPLP data was then used to calculate site-specific Groundwater Protection Levels (GPLs). The Arizona GPLs were developed in 1996 as a first level of screening for groundwater protection. The minimum GPLs for metals are those minimum metals concentrations that are protective of groundwater quality. The minimum GPLs for metals, which are listed in Table 1, are worst-case because of the assumption that all metal leaches to groundwater regardless of the depth to groundwater (ADEQ, 1996).

As indicated previously and in Table 1, some of the total mercury concentrations exceeded the ADEQ GPL for mercury. Site-specific characteristics were used to calculate site-specific GPLs using the following equation (ADEQ, 1996).

$$X_s = (292.9)RC_w$$

Where: X_s = ***alternate GPL***
R = ***total metals concentration/SPLP result***
C_w = ***Arizona Aquifer Water Quality Standard (AWQS)***
292.9 = constant

Total and SPLP mercury data were collected for selected soil/sediment samples. The Arizona AWQS for mercury is 0.002 milligrams per liter (mg/L). Site-specific GPLs were calculated for the samples that were analyzed using the SPLP and are shown in Table 2.

As discussed previously, the mercury in soil/sediment samples in the AOIs is not mobile as evidenced by the speciation data (Table 2). The highest concentrations of total and extractable

mercury are present in the RB AOI (retort building), specifically sample locations RB-6-S and RB-7-S. SPLP results for total mercury in the extract demonstrate a greater potential for these samples to leach mercury. The site-specific GPLs for samples RB-6-S and RB-7-S are calculated to be 2,774 to 3,748 mg/kg. Only sample RB-7-S was detected with mercury above the calculated site-specific GPL for that sample. Therefore, there is a potential for the mercury in sample RB-7-S to leach to groundwater at concentrations exceeding the AWQS of 0.002 mg/l. However, one sample in ten is considered too insignificant for soils from the RB AOI to be considered a potential threat to groundwater quality.

Potable groundwater use is not a complete exposure pathway. A widespread aquifer does not exist below the Site and the nearest well is located more than ten miles from the Site. However, the presence of springs indicates that there is limited local groundwater in the area. Water originating from precipitation infiltrates into the underlying strata. However, a majority of the water in the soil is extracted by evapo-transpiration. The little remaining water will flow downhill through the strata toward the surrounding basins. Flowing groundwater will occasionally encounter sediment filled fractures (faults, joints, cracks) in the bedrock, which can act as collection points for water. These groundwater pathways can then continue to transmit water to the adjoining basins. A spring is formed when these water filled fractures intersect the surface. Water samples collected from the Mine Spring and Horse Camp Spring did not contain laboratory detectable concentrations of dissolved and total mercury (see Section 2.4.6).

In summary, the retort tailings and soils at the Site will not cause mercury concentrations in groundwater to rise above the AWQSs. Therefore, mercury is eliminated as a COPC to groundwater. This, combined with the fact that groundwater is not used at or in the immediate vicinity of the subject site, makes the groundwater exposure pathways incomplete as shown on the CSM provided in Figure 8.

2.3.5.2 Surface Water

The Site is located in a normally dry tributary of the East Fork of Sycamore Creek. The presence of deposits of retort tailings downstream of the Site indicates that flash flood type runoff events have occurred at the Site in the past. According to available meteorological records, these events are rare, and much of the downstream retort tailings deposits may have been transported downstream during a single historical event, the 1970 Labor Day Storm.

Surface water sampling stations SWSS No. 1 and SWSS No. 2 were installed at the Site on August 5, 2003. Due to access limitations resulting from the Willow Fire, and with the approval of the Forest Service, the sampling stations were removed on October 8, 2004. These stations were installed to sample possible runoff events during the Arizona summer monsoon and during the winter wet season. Arizona was in a midst of a prolonged drought when the investigation took place. Though precipitation amounts since August 2003 were still below normal, 2003 was the wettest year of the previous five years.

The amount of runoff that occurs is a factor of the size of the drainage area, the soil type, the presence of vegetation, the rainfall intensity, and the water holding capacity of the soil prior to the event. Runoff events in Arizona typically occur during torrential, short-term thunderstorms where the rainfall intensity is greater than the soil infiltration rate, which is a factor of soil type and existing moisture content. During the 2003-2004 monitoring period, a precipitation event capable of producing runoff in the drainage basin that encompasses the Site did not occur, and runoff samples were not collected. Therefore, surface water analytical data are not available to evaluate COPCs and the surface water exposure pathway for direct contact. Instead, the Synthetic Precipitation Leaching Procedure (SPLP) data were used to evaluate COPCs and the surface water exposure pathway.

The SPLP data was compared to the applicable mercury SWQSs in Tables 2 and 4. Some limited extent areas around the retort building contain soil/sediment that may produce leachate containing mercury above the SWQSs (Table 2). The area of impact represents a fraction of a percent of the total drainage basin area. The nearest water impoundment area to the Pine Mountain Mine is the Granite Reef Diversion Dam on the Salt River, which is located approximately 50 miles away. The vast majority of the mercury at the site is in the form of cinnabar and thus is not extractable from the matrix. The small fraction of extractable mercury present would not likely be substantive surface water runoff. However in the unlikely event any soluble mercury species enters the surface waters from the Pine Mountain Mine, they would be attenuated during the course of the approximately 50 mile distance to Granite Reef. Sediment transport in these streams is primarily under flash flood conditions, which represents a high energy, well oxygenated environment. Since these water bodies are well oxygenated, sulfur-reducing bacteria that are capable of forming methyl mercury are limited in this environment and, if present, are typically found in the anoxic channel bottoms and backwater habitats that are not known to be present downstream from the Site.

2.3.6 Spring Samples

On January 14, 2004, water samples were collected from the spring located near the Pine Mountain Mine, identified as the Mine Spring on Figure 2, and from the Horse Camp Spring along the East Fork of Sycamore Creek. Field sampling forms are included in Appendix F. The samples were analyzed for total arsenic, mercury, antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc, collectively referred to as the priority pollutant metals, for comparison to the partial body contact surface water quality standard (PBC SWQS). Of these metals, mercury, arsenic, cadmium, copper, lead, nickel, silver, and zinc have Aquatic Life and Wildlife ephemeral stream (A&We) standards, which are dissolved metal concentrations. Therefore, the samples were also analyzed for dissolved mercury, arsenic, cadmium, copper, lead, nickel, silver, and zinc. The samples were analyzed by DMA for total and dissolved metals using the EPA Method 200 series. The DMA analytical report, including chain-of-custody document and QA/QC data, is included in Appendix G.

The total metals analytical results are summarized in Table 5. The total metals analysis is an unfiltered analysis and takes into account both dissolved and non-dissolved metals in the sample. For mercury and arsenic, the total concentration is inclusive of the extractable and non-extractable species.

Total arsenic, mercury, antimony, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc were not reported above laboratory detection limits. With the exception of total lead, the detection limits are below the PBC SWQSs.

The analytical results for dissolved mercury, arsenic, cadmium, copper, lead, nickel, silver, and zinc are summarized in Table 6. The dissolved metals analysis is performed on a filtered sample, thus eliminating non-dissolved metals. For mercury and arsenic, the dissolved concentration should represent only the extractable mercury and arsenic species. Calculation of the sample-specific A&We standards for cadmium, copper, lead, nickel, silver, and zinc requires the hardness of the water. Therefore, the hardness as calcium carbonate ($CaCO_3$) is also provided in Table 6. As shown in Table 6, dissolved mercury, arsenic, cadmium, copper, lead, nickel, silver, and zinc were not reported above laboratory detection limits. Half the detection limit was used to calculate the sample specific A&We standards. As shown in Table 6, the laboratory detection limits are

below the A&We standards, indicating that there is no unacceptable risk to aquatic life or wildlife.

2.3.7 Mercury Vapor in Retort Building

Elemental mercury volatilization and accumulation in enclosed spaces provide another potential threat. Metallic or elemental mercury is liquid at room temperature and subject to volatilization creating a vapor that may pose an inhalation risk to receptors visiting the retort building. Therefore, a principal study question was, "does the mercury present in the retort building present a hazard that is considered an imminent and substantial endangerment to the public health or welfare or the environment"?

To identify if a mercury vapor hazard exists, real-time monitoring was conducted using an OhioLumex Zeeman Portable Mercury Vapor Analyzer, Model RA-915+. The Lumex RA-915+ has an ultra low detection limit of 0.002 micrograms per cubic meter (ug/m3), which is sufficiently sensitive to detect the low concentrations associated with the EPA Region 9 PRG for mercury vapor in ambient air (0.31 ug/m3). Federal EPA approved the Lumex RA-915+ Zeeman mercury analyzer protocol for final clearance and assessment sampling of mercury.

Real time mercury monitoring was conducted at five locations within the Retort Building targeting potential mercury vapor source areas. The proposed locations are provided in the floor plan (Figure 9). The floor plan identifies the key features of the retort building including those features that may represent a mercury vapor source. An outside location (upwind) was identified at the time of the site investigation and monitored similar to the indoor locations to characterize background conditions. Readings were taken at both three and six feet above the floor to simulate breathing zones and identify potential vapor source area concentration gradients. Mercury readings were taken twice at each monitoring location. Real-time monitoring results from in and outside the Retort Building were numbered sequentially and recorded. The letters "L" and "H" were used to indicate the three and six foot samples, respectively. The real time sampling results for elemental mercury are provided in Table 7. Based on the results of the real-time monitoring, fixed-based monitoring was not required to develop time-weighted averages.

A number of the sample results exceeded the mercury ambient air criterion of 310 ng/m^3 (EPA Region 9) that applies to continuous exposure to mercury vapor, e.g., residential. Therefore, this exposure pathway required site-specific evaluation (Section 3.0).

2.4 CONCEPTUAL SITE EXPOSURE MODEL

2.4.1 Pathways and Components

Mercury and arsenic were identified as COPCs for the baseline human health risk assessment (BHHRA) based on the Forest Service's Preliminary Assessment (Dynamac, 2001). Because the mercury is naturally occurring, exists in different forms and possesses speciation-dependent toxicity factors, data were gathered to address the site-specific characteristics of these metals, including background and speciation data.

For exposures to mercury in soil, the two important species are inorganic and organic soluble (extractable) forms. There is a three-fold difference in toxicity criteria (reference dose) between the inorganic and organic forms. The difference is due to the ability of methyl mercury to pass blood brain barriers. No toxicity factors have been developed for non-extractable inorganic mercury since it is not readily bio-available. In addition, a potential for volatilization of mercury from materials in the retort building was identified as a potentially completed exposure pathway that required investigation. Naturally occurring background arsenic concentrations in soil and sediment were considered for arsenic.

The conceptual site exposure model (CSM) for the Pine Mountain Mine describes the possible exposure pathways from mercury mining operation residuals (retort tailings). The COPCs are arsenic and mercury. The exposure pathways (Figure 8) include the following:

- Direct contact with soils/sediment containing the COPCs (ingestion, inhalation and dermal exposure routes)
- Volatilization and enclosed space accumulation of mercury vapor in retort building
- Meteoric leaching of COPCs in soil to groundwater with subsequent discharge to surface water
- Surface runoff of COPCs in soil to surface water and sediments

Based on current and reasonably anticipated future land use, as well as the remote location of the subject site in the Tonto National Forest, standard residential or occupational/commercial exposure scenarios to human receptors are not reasonable or appropriate for the Site. Therefore, exposure scenarios related to recreational visitors, Forest Service personnel, or much less frequent visits by firefighters were considered. The recreational receptor is the most sensitive of these receptors since their activities are associated with higher exposure potential (BLM, 2002). Because the Site use has not been designated for occupancy or residential use, ADEQ SRLs and EPA Region 9 Preliminary Remedial Goals (PRGs) are useful for screening purposes, but not for establishing removal action goals.

Mercury vapor monitoring was conducted in the retort building to quantify the presence and magnitude of any vapor hazards. The monitoring was performed in accordance with the Addendum to the Sampling and Analysis Plan (MACTEC, August 30, 2006). Real time mercury monitoring was conducted at five locations within the Retort Building targeting potential mercury vapor source areas. A number of the sample results exceeded the mercury ambient air criterion of 310 ng/m^3 (EPA Region 9) that applies to continuous exposure to mercury vapor (e.g., residential). Additional evaluation was required because the concentrations exceeded the screening criterion.

The potential for mercury leaching to groundwater/surface water and domestic use was evaluated by using synthetic precipitation leaching procedure (SPLP) data. In addition, the mercury speciation data was used to differentiate between the mobile, semi-mobile, and non-mobile components of the COPCs within soil/sediment at the Site.

A widespread aquifer does not exist below the Site and the nearest well, the Cross F Ranch, is located more than ten miles from the Site. According to Arizona Administrative Code (A.A.C.) R18-16-405 (I), a well that is located one-quarter mile up-gradient, one-half mile cross-gradient, and one-mile down-gradient of the boundaries of an identified groundwater impact is presumed threatened. No such well is located in the vicinity of the Site. The Cross F Ranch was not included in the exposure assessment because it is located more than one mile from the Site. Therefore, the potable use of groundwater in the area is considered an incomplete exposure pathway.

Water originating from precipitation infiltrates into the underlying strata. However, the predominant natural mechanism by which water is removed from the soil is by evapo-transpiration. The little remaining water will flow downhill through the strata toward the surrounding basins. Flowing groundwater will occasionally encounter fractures (faults, joints, cracks) in the bedrock, which can act as collection points for water. A spring is formed when these water-filled fractures are exposed at the ground surface. Water samples collected from the Mine Spring and Horse Camp Spring did not contain detectable concentrations of dissolved or total mercury (see Section 2.3.6).

Sycamore Creek joins the Verde River about 40 stream miles from the Site. The Verde River joins the Salt River approximately 8 miles from that point of confluence. The Salt River flows downstream about 3 miles to the Granite Reef Diversion Dam, where the water is diverted to a series of canals that deliver water to the Phoenix Metro area. The vast majority of mercury present at the Site is insoluble in the form of cinnabar and does not present a risk or hazard. Any of soluble mercury species that enters the surface waters from the small fraction of extractable mercury at the Pine Mountain Mine would be attenuated during the course of the approximately 50 miles to get to Granite Reef. Since these water bodies are well oxygenated, sulfur-reducing bacteria that are capable of forming methyl mercury are limited in this environment and, if present, are typically found in the anoxic channel bottoms and backwater habitats that are not known to be present downstream from the Site. Therefore, the small area of potential impact in conjunction with the volume of water from a runoff event will not impact surface water above the SWQSs.

2.4.2 Background Concentrations

Background soil quality is an important consideration because the Site is located in an area of mercury-bearing rocks and regional mining. Concentrations of mercury or arsenic may be attributable to background conditions rather than to mining activities. The Sampling and Analysis Plan (SAP) presented the hypothesis that the background soils contain mercury primarily in the form of cinnabar. It is likely that mercury concentrations are present in the background soils at similar or higher concentrations than those in the retort tailings, because mercury has been removed and is therefore depleted in the retort tailings. Arsenic is volatile in the oxide form and is released during the roasting process. Therefore, there was a possibility that emissions from the retort stack may have impacted soils in the vicinity of the Site. To

differentiate between a "true" background sample and a sample that has anthropogenic mercury and arsenic originating from the stack, MACTEC proposed a combination of sample location, vertical profiling, and mercury and arsenic speciation.

2.4.3 Regulatory Criteria

In 1997, the Arizona Department of Environmental Quality (ADEQ) promulgated three mercury soil remediation levels (SRLs) for residential and nonresidential land use: mercuric chloride (CAS # 7487-94-7), elemental mercury (CAS # 7439-97-6) and methyl mercury (CAS # 22967-92-6). Currently, the 1997 SRLs are slated for revisions and ADEQ has limited the proposed SRLs for mercury to those for methyl mercury and "mercury and compounds" consistent with EPA Region 9. According to ADEQ, because elemental mercury exists as a liquid/vapor state, Region 9 EPA does not include it for soil. Simply stated, all inorganic mercury compounds, regardless of solubility in soil/water environments, are listed under the proposed SRL for "mercury and compounds".

EPA Region 9 has established Preliminary Remedial Goals for different mercury species including two for soil: mercury and compounds (CAS # 7487-94-7 based on mercuric chloride) and methyl mercury (CAS # 22967-92-6). The two mercury soil PRGs are directed to the most mobile (extractable) and toxic mercury species that may be present in soil. For exposures to mercury in soil, the two important species are inorganic and organic soluble (extractable) forms. There is a three-fold difference between the toxicity criteria (reference dose) between the inorganic and organic forms. The difference is due to the ability of methyl mercury to pass blood brain barriers.

No soil PRG for elemental mercury was established because elemental mercury is a liquid/vapor at room temperature and the available toxicity criteria is based on breathing air containing elemental mercury vapor. This PRG for elemental mercury in air was identified for comparison to the real time mercury vapor monitoring results from the Retort Building and was not used in evaluating exposures associated with soil. A number of the air sample results exceeded the mercury ambient air criterion of 310 ng/m^3 (EPA Region 9) that applies to continuous exposure to mercury vapor(e.g., a residential exposure scenario). Therefore, this exposure pathway required site-specific evaluation to determine an appropriate risk-based concentration based on the recreational exposure scenario.

Based on screening the total mercury concentrations against the most stringent of the 1997 SRLs and EPA Region 9 PRGs, a number of sample results exceeded the most stringent soil criterion across the Site. Additional screening was performed comparing the mercury speciation data to the species-specific SRL or PRG based on non-residential land use. Based on this evaluation, two areas required further evaluation for potential risk to human health: the retort building (Area RB) and retort tailings (Area RT). In addition, the exposures that would be experienced by receptors frequenting Area RB and RT are not compatible with the default non-residential (industrial/commercial worker) scenario. Thus, a site-specific evaluation is needed to assess hazards from direct contact with soils/sediment in these areas.