Final Design Report

Vulture Mine Site
Maricopa County, Arizona

May 2015

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Abbreviations

BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
PA/SI	Preliminary Assessment / Site Inspection
QA/QC	Quality Assurance / Quality Control
SAP	Sampling and Analysis
XRF	X-Ray Fluorescence
FAAS	Flame Atomic Absorption Spectroscopy
ALM	Adult Lead Model

Acknowledgements

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Bureau of Land Management

- Dr. Bill Harris, P.E., for the opportunity to work with BLM and providing feedback on Gold Member Inc.'s proposal and work plan for the Vulture Mine site.

- Matt Plis, for guiding and accompanying Gold Member Inc. in the field on the sampling days and also for assisting in creating and implementing the Vulture Mine Work Plan.

1.0 Project Description

The purpose of this project is to examine and assess the risks that accompany the migration of mine tailings produced from the Vulture Mine. This mine is located in Wickenburg, Arizona, northwest of Phoenix (see figure 1.1). The main objective for examining and assessing the risks of the Vulture Mine tailings is to produce a preliminary assessment and site inspection (PA/SI) report. The PA/SI will meet the requirements of the Comprehensive Environmental Response and Liability Act (CERCLA), and will help the Bureau of Land Management (BLM) determine if they should proceed with further CERCLA actions to pursue the responsible party or begin a remedial investigation.

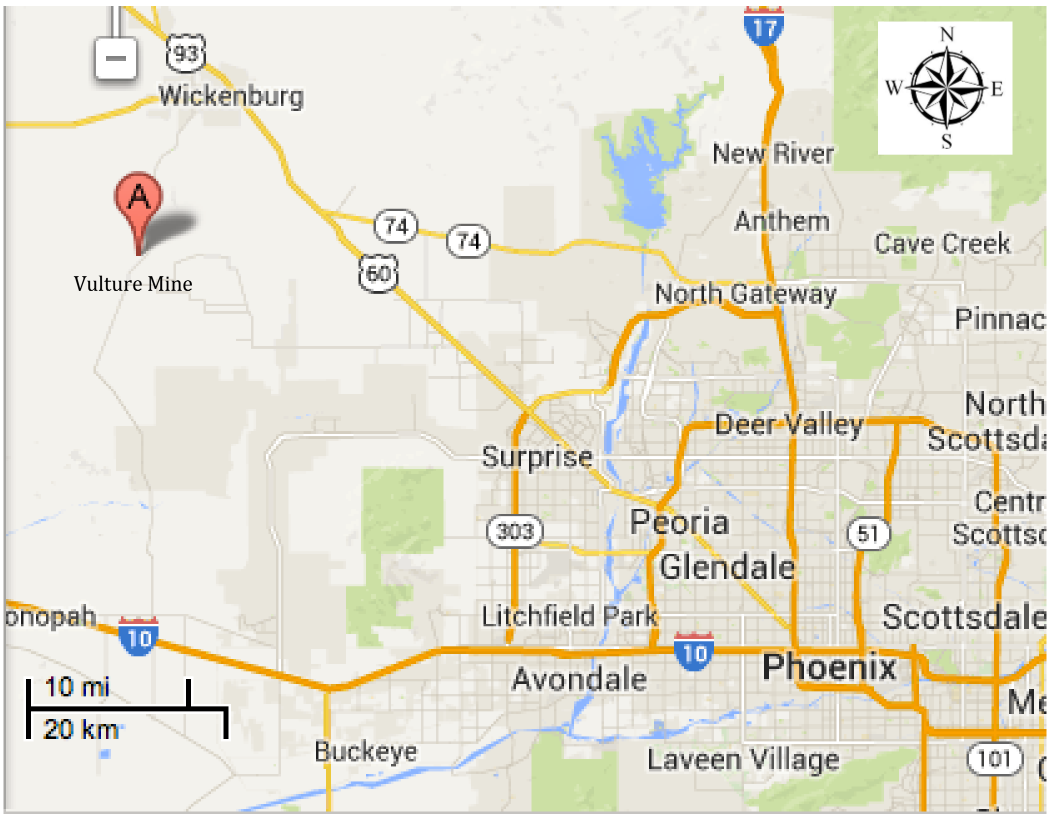

Figure 1.1 Point A on this map is the location of Vulture Mine with respect to Wickenburg and Phoenix [1]

1.1 Background Information

Henry Wickenburg discovered Vulture Mine in 1863. Between 1866 and 1931, Vulture Mine became the largest gold mine in Arizona, has had multiple owners, and was operated by eight different companies [2]. The property consists of amalgamation mills, a campsite, a cyanide leaching plant, and a concentrating plant. This site was mainly mined using open-cut methods and the mine ore was treated using cyanide leaching and flotation [2]. In 1935 hard-rock mining was discontinued and the cyanide leaching plant and concentrating plant were taken over by D. R. Finlayson and A. B. Peach respectively [2]. Mine tailings from the first operations were washed into a nearby channel south of the mine. Today, there is an estimated several thousand tons of mine tailings that still exist in the wash and may present metal contaminant levels that could be of concern. Mine tailings are the waste effluent from processing ore.

Vulture Mine, the mill facilities, and the first 1/3 of a mile of the wash south of the mine, are on private land. The sampling plan for the PA/SI is for public lands only, which is easy to identify, because the private landowners have clearly marked the boundaries of their property. BLM's records show there is no current mining activity on the public lands understudy, so there were no conflicts regarding mining claims at the site.

1.2 Existing Conditions

The site's known primary contaminants of concerns (COC) are lead and copper. Other COC's that are known are arsenic, antimony, molybdenum, and vanadium. The mine tailings from the site migrated into a wash south of the mine through rain and flooding events. The tailings have been identified from one mile to a mile and a quarter from the cyanide leaching plant. The mine is located on private land and is currently vacant. The wash south of the mine, where there appears to be thousands of tons of mine tailings, is on public land. The Vulture mine is located in an arid climate and has a Sonoran Desert landscape. There is little vegetation and may be home to threatened species such as the desert tortoise, mountain plover, and the California leaf-nosed bat [3]. The various types of vegetation found in the Sonoran Desert include palo verde, mesquite, desert ironwood trees, cat claw, chollas, and saguaro cacti. The red boundary lines shown Figure 1.2 represent the location of the Vulture mine with respect to the surrounding land.

Figure 1.2 Google Earth image of the Vulture mine [3]

2.0 Background

For this project, Gold Member Inc. has researched the following topics:

- CERCLA
- X-ray fluorescence technology
- Ecological risk assessment
- Human health risk assessment
- Deliverables and communication

2.1 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), better known as Superfund, was enacted in 1980 to tax chemical and petroleum industries. This tax money is then placed into a trust fund that goes towards cleanup and remedial actions for abandoned or uncontrolled hazardous waste sites [4]. CERCLA also provides a process for how a hazardous waste site will be cleaned up. This process includes the following 10 steps [5]:

1) Discovery
2) Preliminary Assessment/Site Inspection
3) National Priority List (NPL)
4) Remedial Investigation
5) Feasibility Study
6) Proposed Plan
7) Remedy Selection
8) Remedy Design/Action
9) Operation & Maintenance Monitoring
10) Deletion from NPL

2.1.1 Discovery

Discovery is the first step in the CERCLA process. It entails an inspection from the Federal Agency Hazardous Waste Compliance Docket (FAHWCD), who will then determine if a site presents any potential risk to human or ecological health. The FAHWCD will provide a means to make this information available to the public [5].

2.1.2 Preliminary Assessment/Site Inspection (PA/SI)

A preliminary assessment/site inspection (PA/SI) is conducted in order to further classify a hazardous waste site and to identify Contaminants of Concern (COC). A PA/SI is a sampling analysis of either soil or water, or both, and from testing results, determines if the site needs further CERCLA action.

2.1.3 National Priorities List (NPL)

The third step of the CERCLA process is the National Priority List. This step entails the use of the Hazard Ranking System (HRS) to score and evaluate the risks a site poses to human and environmental health. If a site scores a 28.5 or higher, the site then qualifies for placement on the NPL [5]. However, our client, the Bureau of Land Management, is a federal agency, has primacy for cleanup, and does not place their sites on the NPL.

2.1.4 Remedial Investigation (RI)

A Remedial Investigation provides health and ecological risk assessment, and site characterization. This is done after soil and water samples have been taken so that it can be determined what types of hazardous wastes are present, their contamination levels, and if the hazardous wastes are migrating to where human health and the environment could be at risk [5]. Before the remedial investigation and feasibility study begin, Remedial Action Objectives (RAO's) are determined. RAO's are descriptions of what a CERCLA cleanup would accomplish [5]. RAO's are needed because they structure the investigation and clearly state the goals that need to be achieved.

2.1.5 Feasibility Study (FS)

"The feasibility study determines the best technology for cleaning up a site" [5]. This step of the CERCLA process is a cost benefit analysis, which will go into detail to determine whether a proposed cleanup action is practical and achievable.

2.1.6 Proposed Plan

A proposed plan includes the rational and reason of a preferred remedial alternative compared to other remediation alternatives. This plan describes all of the alternatives and the criteria that were used to determine which alternative would be the best choice for that specific project and which meet the RAO's that were specified. A proposed plan is available for public comment [5].

2.1.7 Remedy Selection

In this section, the Record of Decision (ROD) is documented. The ROD includes which remedial actions will take place and how these remedial actions will be carried out. This document acts as a legal certification that a remedy was chosen following CERCLA requirements and the National Contingency Plan (NCP) [5].

2.1.8 Remedy Design/Action

After a remedial alternative has been selected, a remedy design is developed specific to that option that complies with environmental standards [5].

2.1.9 Operations & Maintenance Monitoring

Once a remedy has been implemented, operation and maintenance monitoring will be performed to observe the effectiveness of the remedial action. Further sampling will be done as routine checkups to make sure the sites contaminants are either being contained or kept below acceptable contaminant levels. Once operation and maintenance monitoring show positive results, the site may be fit to begin site closure [5].

2.1.10 Deletion from NPL

The last step of the CERCLA process is determining whether a site can be removed from the NPL after it has fulfilled all of the ROD requirements or remedial objectives [5]. A final document called the Close Out Report (COR) must be completed before a site can be taken off of the NPL. This document states how the chosen remedy fulfilled and satisfied each of the requirements listed in the ROD [5].

2.2 CERCLA Guidance

The CERCLA guidance for preliminary assessment (PA) includes determining the information required for the evaluation of the site and how to obtain this information [6]. The structure of the PA includes an introduction, conducting the PA investigation, site evaluation and scoring, reporting requirements, and reviews.

The CERCLA guidance for site inspection (SI) will help in reviewing and evaluating available information, planning an effective sampling strategy for acquiring analytical data, and preparing required reports and work products [7].

2.3 CERCLA Deliverables

The elements of the following three plans will follow EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* [10]. Three different plans are required under CERCLA including the Work Plan, Health and Safety Plan, and Sampling and Analysis Plan.

The Work Plan includes both the Health and Safety Plan and the Sampling and Analysis Plan. The Work Plan is attached to this report as appendix A. The Work Plan will detail the project objectives, project management, site background information, and the project schedule and deliverables. Within the Health and Safety Plan, procedures are detailed in case of emergencies. There is also a list of animals and plants that can be encountered during fieldwork. The Sampling and Analysis Plan consists of all the protocols, procedures, and quality assurance and control that need to be followed throughout the duration of field sampling.

2.4 X-Ray Fluorescence (XRF)

This project used an X-ray fluorescence (XRF) portable hand-held device, made by Olympus DELTA series, for on- and off-site screening. An XRF device has the ability to determine the makeup of elements including metals, rocks, ore, painted surface, and plastic [8]. This technology also has the ability to analyze up to forty different elements in one reading. The elements Gold Member Inc. screened were arsenic, antimony, lead, copper, vanadium, and molybdenum.

The science behind this technology depends on fundamental principles that involve the use of x-rays and electron beams (wavelengths). When an atom is exposed to radiation, their internal energy changes from a ground state to an excited state. When the energy of radiation becomes enough to dislodge a tightly held inner electron, an atom then becomes unstable and an electron from the outer cloud replaces the dislodged electron [8]. This process produces a release of stored energy due to the decreased binding energy of the inner electron orbital and is considered to be a form of radiation called fluorescent radiation. Fluorescence is common, but because incident radiation is used, it is considered X-ray fluorescent. This energy, or fluoresced energy, can then be measured. The K_α and K_β x-rays measure the change in energy between the L shell and K shell, and the M shell and K shell respectively. These energy differences are proportional to the concentration of the element or contaminate of concern. Each individual element has its own specific energy based on its orbital shells. Figure 2.1 shows a simple diagram of what happens when x-ray radiation hits an electron.

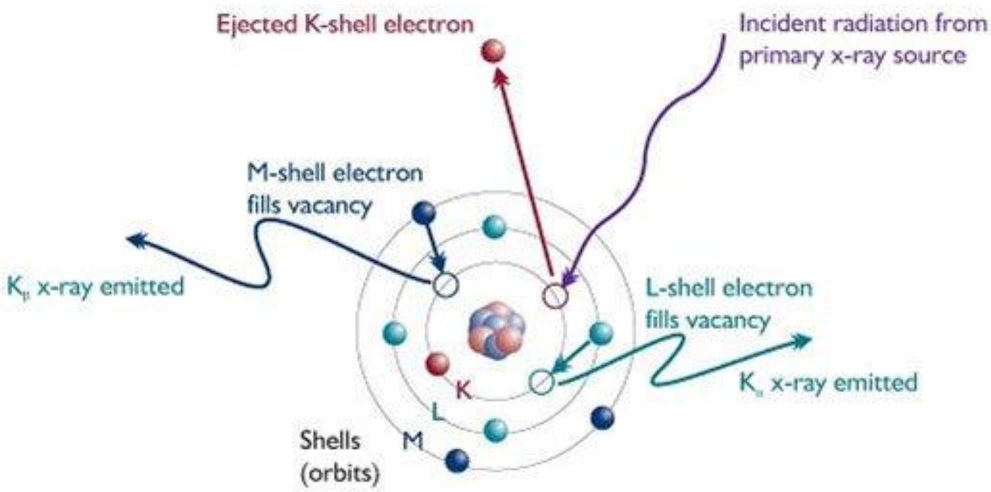

Figure 2.1 Fluorescence [13]

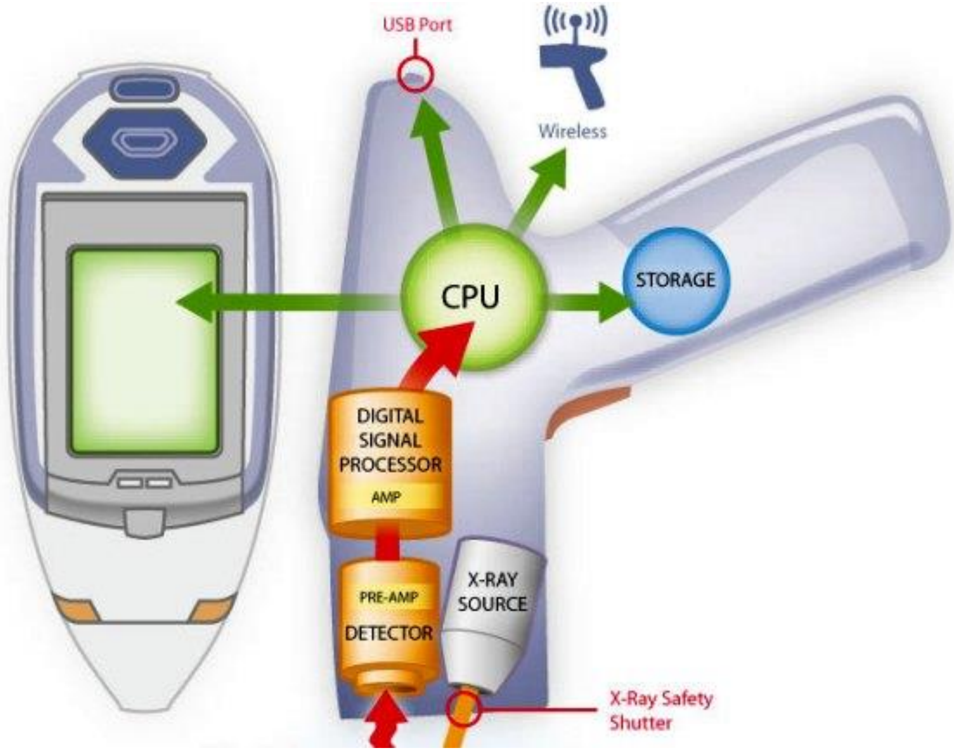

Figure 2.2 Handheld XRF Device Components. [14]

Figure 2.2 is presenting all of the components within an XRF handheld device. X-rays are produced by an x-ray generator, which pushes electric current through a filament, therefore, causing electrons to be released. A high voltage (20-100kV) is then used to make these electrons hit an anode. Once the electrons hit the anode, a broad x-ray continuum is discharged [22]. This device measures the fluoresced energy through a Si-PIN detector or a silicone drift detector. The detector then transmits this data to a specialized filter (three-beam kV-filter) that can detect metals. Once the metals have been distinguished, the information is sent to the viewing screen and immediately saved and stored in a data center that can be accessed on command or at a later time [27].

2.5 Ecological Risk Assessment

Ecological risk assessments are carried out in order to estimate the potential ecological risks that can occur from the contaminants of concern (COC's) identified at the specific site. This risk assessment focuses on plants and wildlife found near the Vulture Mine. There are four different stages that make up this risk assessment process.

2.5.1 Characterization of Baseline Ecology

The first stage for the ecological risk assessment is evaluating the ecosystem at the site along with the ecology in order to provide a summary of the system's diversity. Based upon the findings, indicator species will be selected. Indicator species are chosen because they are important to the ecology of the site. This can include dominant species population, sensitive species, or endangered species [15]. The Vulture mine is located in an arid climate in the Sonoran Desert. There are various plants that are found in the Sonoran Desert, which includes, palo verdes, mesquite, desert ironwood trees, catclaw, chollas, and saguaro cacti. The saguaro cacti are not endangered, however the cacti are protected by the United States government. An endangered plant that could be found at the site is the pima pineapple cacti [29]. Endangered species that may be located in close proximity to the Vulture Mine includes the sonoran desert tortoise, mountain plover, and the California leaf-nosed bat [16]. Figures 2.3 through 2.9 are images of the endanger plants and animals that could be encountered at the site. The location of residence of the sonoran desert tortoise, the mountain plover, and the California leaf-nosed bat are shown on the maps below. The diamond on the figures 2.7 through 2.9 represents Wickenburg, Arizona.

Figure 2.3 An image of the pima pineapple cactus [30]

Figure 2.4 An image of a Sonoran desert tortoise [31]

Figure 2.5 An image of the mountain plover [32]

Figure 2.6 An image of the California leaf-nosed bat [33]

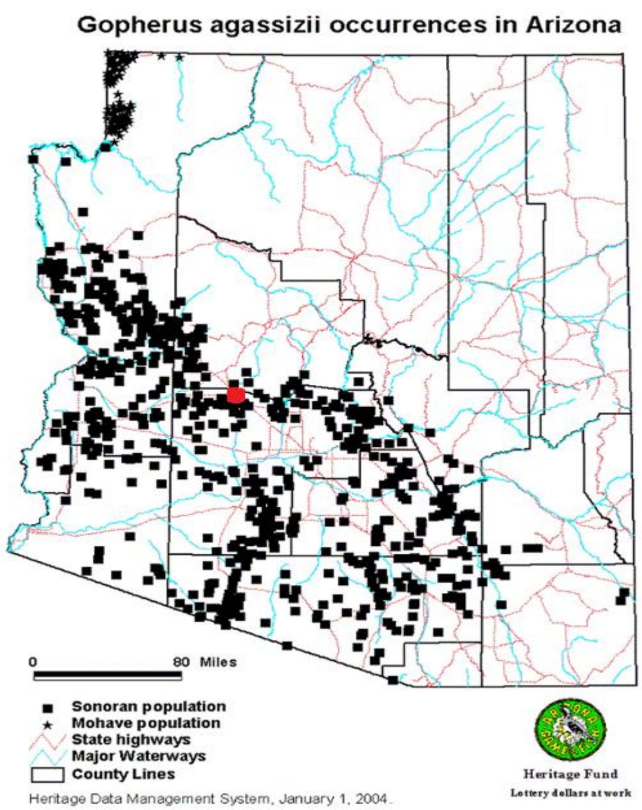

Figure 2.7 The location of residence of the Sonoran desert tortoise [17]

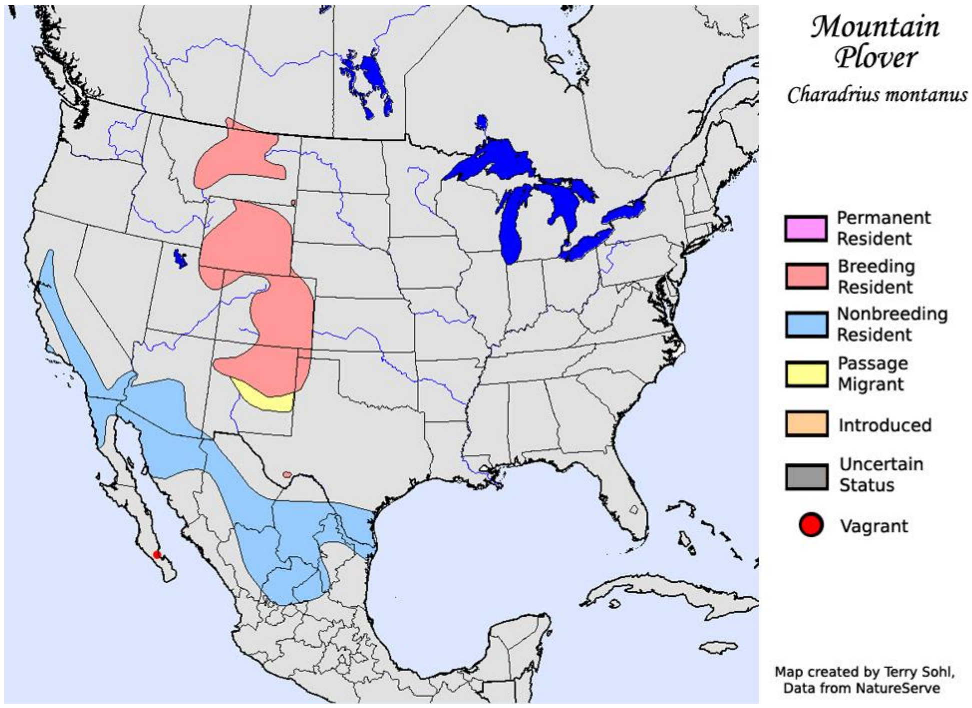

Figure 2.8 The location of residence of the mountain plover [23]

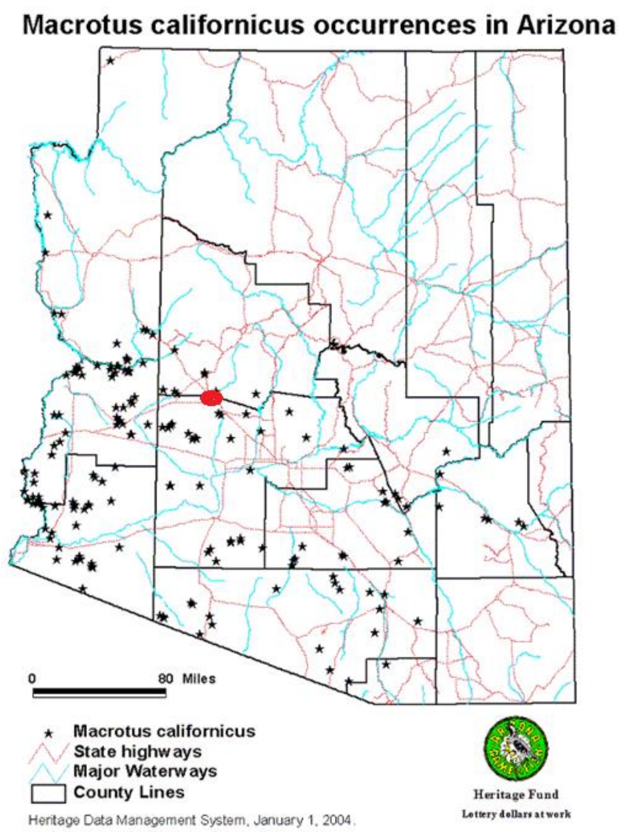

Figure 2.9 The location of residence of the California leaf-nosed bat [17]

The maps above indicate that the sonoran desert tortoise, mountain plover, and the California leaf-nosed bat all reside in locations near the mine. The sonoran desert tortoise can be found in the flat plains of the site. The mountain plover nests on the ground, and could be encountered while walking the site. The California leaf-nosed bat finds shelter in the mountain range in close proximity to the site.

2.5.2 Ecological Toxicity Assessment

The objective of ecotoxicology is to protect the diverse species, both plants and wildlife, in the environment. This stage focuses on identify potential harmful effects resulting from the COC's on the site.

2.5.3 Ecological Exposure Assessment

This stage entails estimating the concentration, frequency, and length of the species contaminant exposure, and consists of the exposure pathways and the exposure point concentration. The exposure pathways include ingestion and direct contact of the contaminated water or soil. Potential exposure scenarios, which happen within or near the site, are developed [15]. The concentrations of the COC's in the soil are required to assess the potential exposure scenarios.

2.5.4 Ecological Risk Characterization

The final step of the ecology risk assessment uses the information determined in the above three stages to estimate the risk regarding the site. The risk characterization includes both qualitative and quantitative risk estimates. This section includes two important parts, which include the risk estimation and risk description. The risk estimation is found by using the exposure and exposure-effect profile and assessing any associated uncertainties. The risk description provides any information that is needed to interpret the results [24]. The single end point exposure and effect comparison can also be determined in the risk characterization. Quantity exposures, or the quotient, can be identified by using the ratio of the exposure concentration divided by the effects of concentration. The quotient can be divided by the toxicity endpoint to determine the chemical stressor [24].

2.6 Human Health Risk Assessment

Human health risk assessments are carried out in order to estimate the potential human health risks that can occur from the COC's identified at the site. There are four different stages that make up this risk assessment process. Research is required to collect the following information: site history, land use, contaminant levels in media, and the potentially affected population.

2.6.1 Hazard Identification

The first stage of this risk assessment is to examine all the contaminants that are identified at the site, and determine the contaminants that maybe a cause for concern.

2.6.2 Exposure Assessment

This stage includes the process of assessing the exposure to the COC's. Information about the sources involving the contaminants at the site is needed in order to effectively evaluate the possible human contact that may occur [15]. Exposure pathways include inhalation, oral, and dermal. Possible exposure pathways include inhalation and ingestion of the contaminated soil. This could occur by the production of dust from the soil sediments and a person may inhale the dust containing the COC's. Ingestion can occur if small children or adults inadvertently or deliberately consume the soil or water. This information will assist in developing potential exposure scenarios for the Vulture Mine site. Possible exposure scenarios include an adult site worker and an adult recreational user. The worker scenario includes anyone who would be working on the site in the present or future. This includes any personal that might perform remedial actions in the future or if the site is used for other purposes. The recreation use scenario includes anyone who may use the site for leisure activities such as hiking or biking. This exposure scenario can be better developed after a site visit is conducted and observations are made. Short and long-term exposures to the contaminants must also be considered.

2.6.3 Toxicity Assessment

This stage identifies the toxicity of the COC's. The COC's are characterized into carcinogens or non-carcinogens. The models used to calculate the risks for carcinogens and non-carcinogens differ from one another. The non-carcinogenic risks are categorized using a hazard index. The hazard index is a ratio of the chronic daily intake of non-carcinogen (I_N) to the reference concentration (RfC). A hazard index for each COC's found on the site must be calculated [15]. A slope factor is used to calculate the risks for carcinogens. The slope factors are used to estimate the risk of cancer that the exposures of possible carcinogenic substances contain. The slope factors refers to the upper bound, which is the 95% confident level of the cancer risk that has a lifetime exposure to the carcinogenic substance [25].

2.6.4 Risk Characterization

The final stage of the human health risk assessment is to use the information found above in order to estimate the risk associated with the site. Carcinogenic risk is calculated by multiplying the slope factor by intake. Approximations for both the carcinogenic and non-carcinogenic risks for all the exposure scenarios and the three pathways are required. This includes average and maximum exposure estimation. If the hazard index is found to be less then 1 the toxicity is unlikely to be significant, and if the hazard index is greater then 1 there is concern for potential toxicity. The hazard index is a sum off all the non-carcinogenic

COC's. It is important to identify the effects and target organs for the COC's as each chemical is different [25]. There is no reference dose or factor of safety for lead, thus a biokinetic model must be used. A biokinetic model establishes allowable clean up levels for a specific site in which lead is a COC [17]. The biokinetic model measures the exposure of a substance such as lead using site-specific information to determine the distribution of the containment throughout the body. There are numerous components for this model that include: exposure, uptake, biokinetic, and variability. Uptake is determined by multiplying the intake by the absorption factor. The biokinetic model creates an estimate for the sites transfer of lead. There are two different models that can be used. The first is the Adult Lead Model (ALM), which focuses on adults, and the biokinetic model, which focuses on children. The ALM can be adjusted by the number of days an adult is at the site while the biokinetic model assumes that the child lives on site for an entire year. The final step of this process produces a credible distribution concentration of the lead for the site [28].

3.0 Testing and Analysis

Gold Member Inc. has performed tests on the soil samples collected from the site. The tests included an initial X-ray Fluorescent (XRF) approach for analysis of the contaminants of concern and a Flame Atomic Absorption Spectroscopy (FAAS) test for quality assurance and quality control. The sampling and analysis plan mentions these different tests that helped determine the concentrations of contaminants. The results found during analysis determined the actual concentrations of the samples collected and correlations were made using the XRF results. The purpose of the testing was to determine if further action should be done at the site.

3.1 Deviations from the Sampling and Analysis Plan

Gold Member Inc. had originally planned to take approximately 200 soil samples at the Vulture Mine site. The team under estimated the time each soil sample would take to collect. The first 20 samples took roughly 4 hours to bag and sieve. In order to be able to collect the required number of samples, it was decided by Technical Advisor, Bridget Bero, and confirmed by BLM's Project Manager, Matt Plis, that sieving offsite at the laboratory would be done due to the time limit. Therefore, more soil per sample was collected in the gallon bags and brought back to the laboratory to sieve. Gold Member Inc. collected 104 samples total during the two days of sampling. The sampling took place on February 11-12, 2015. This includes samples collected from the grid, hot spots, and background samples. The SAP originally had 8 background samples being collected but due to the decrease of samples collected, only 4 backgrounds were taken. Figure 3.1 displays the grid the team created for the SAP and figure 3.2 is a map with points representing where the team sampled while in the field. The reason for changing plans when the team was on the site was due to time restrictions, unnecessary sampling, and Matt Plis wanted to take samples at areas with high tailing collections that were not on the map from the SAP.

Figures 3.1 and 3.2 show the difference in the SAP proposed grid compared to the actual locations samples were collected. BLM Project Manager, Matt Plis, wanted to focus on the areas just north of Whispering Ranch Road, shown in Figure 3.1, and the south end of the wash close to residential property. Gridding in these areas were in accordance with the SAP. Samples were not collected on a grid south of the road or the northern most part of the wash. Three points were sampled 50 feet apart for 1/3 and 2/3 of the way down the wash south of the road and in the upper northern region of the wash in order to collect samples throughout the entire site. Refer to appendix B for team field notes.

XRF screening was originally going to be done during field sampling at both random and hot spots. Due to time restraints the team was unable to take any XRF screenings in the field and all the soil samples collected were screened back at the lab.

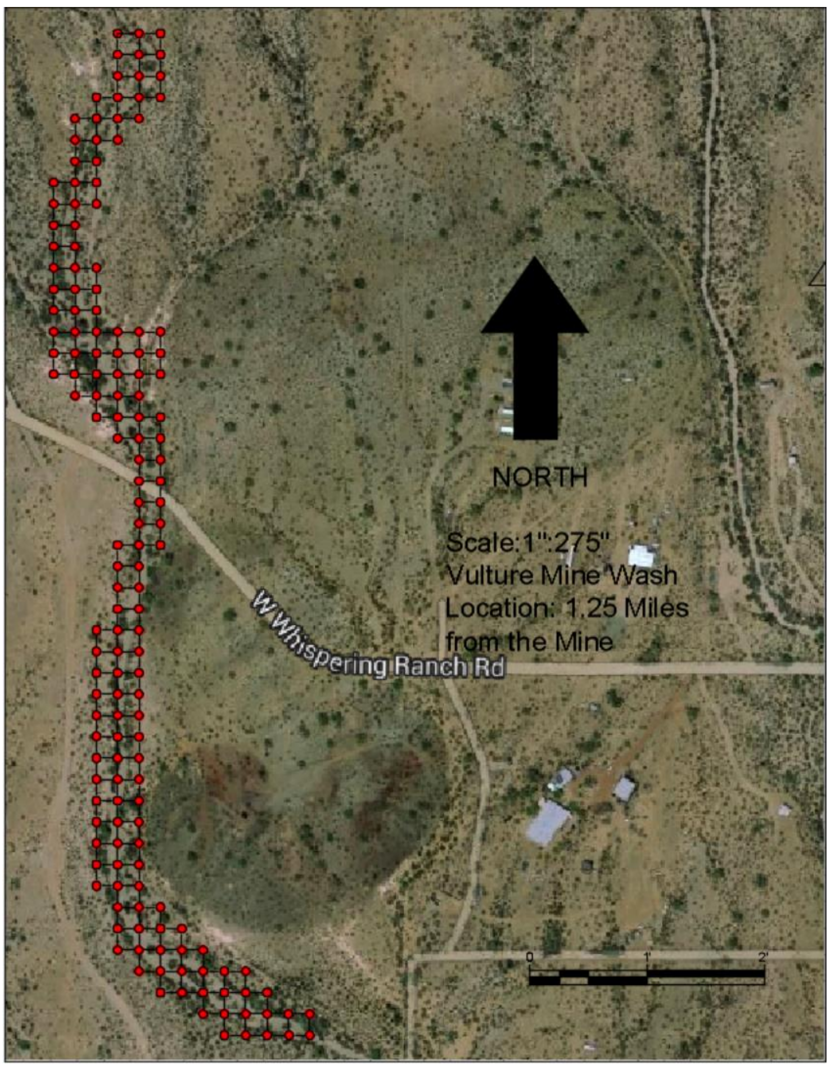

Figure 3.1 The proposed grid from Gold Member Inc.'s Sampling and Analysis Plan

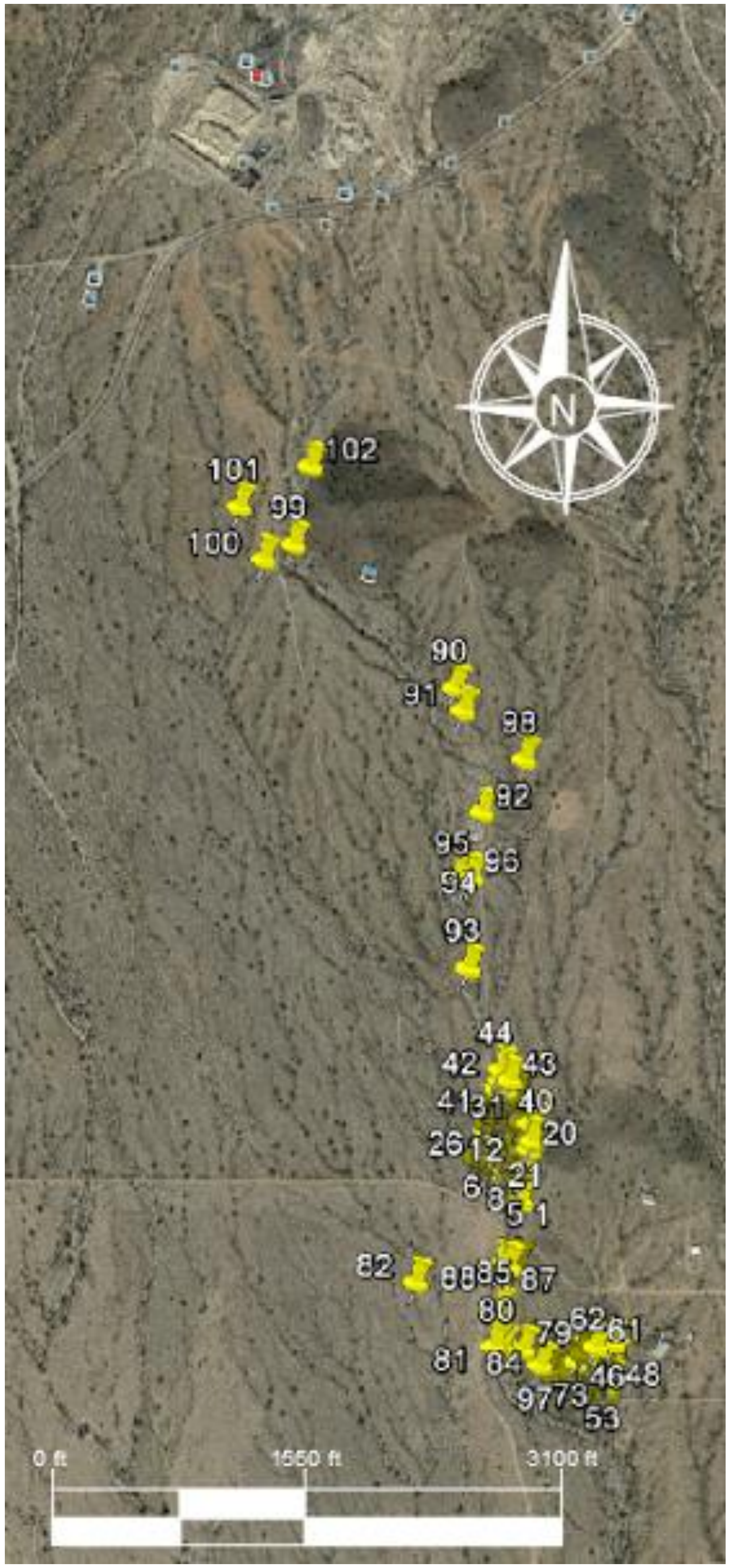

Figure 3.2 A map representing the locations of soil samples collected from the site

4.0 Results

Gold Member Inc. determined the concentrations of approximately 20% of the soil samples collected through laboratory testing. In order to determine the results, Gold Member Inc. created a correlation using the results of FAAS and XRF data. From the correlation graphs, concentration maps were created to show the concentrations of each sample and where the samples are located in respect to the mine.

4.1 Data Correlations

Correlations are necessary as it indicates whether the XRF data is valid. The FAAS was able to determine the concentrations of copper and lead. The other four elements, arsenic, antimony, vanadium, and molybdenum, tested on the XRF were not readily available for use on the FAAS. These two elements were used to make a correlation from the XRF data. Any FAAS concentrations that were not within 40% of the XRF data was not used for the correlation, which came out to be around 20% of the samples from FAAS concentrations. The reason for not including them in the correlation was due to potentially bad readings from the FAAS. Figure 4.1 and 4.2 show the FAAS results compared to the XRF results to create a correlation.

A linear trend line produced a correlation equation for comparing the data to each other. This equation was used to determine what the concentrations would have been for all the samples if they were going to be run through a FAAS. The R^2 value represents the validity of the correlation. The closer the R-value is to 1.0, the more accurate the correlation. Taking the square root of the R^2 value represents the sufficiency of the data. Anything above a 0.9 indicates a decision can be made off of the results from the data correlations. The lead and copper graphs shows that a linear correlation can be applied and get sufficient results.

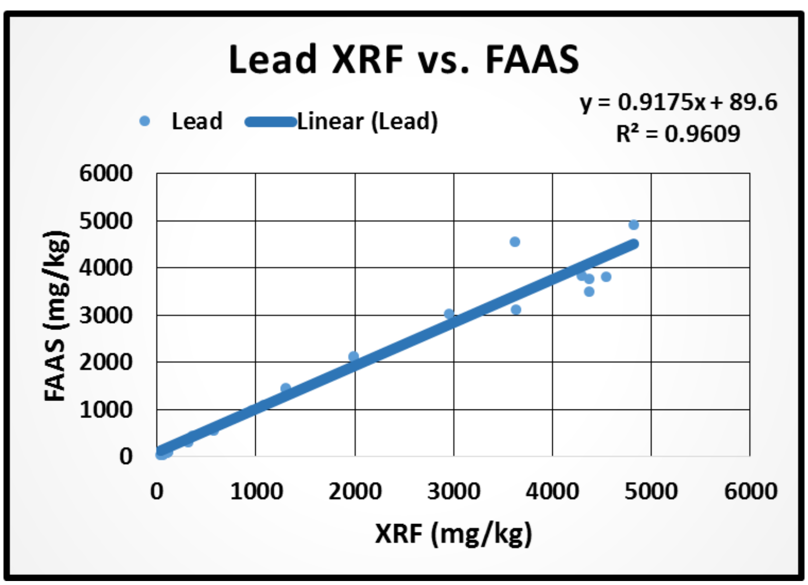

Figure 4.1 Lead Correlation

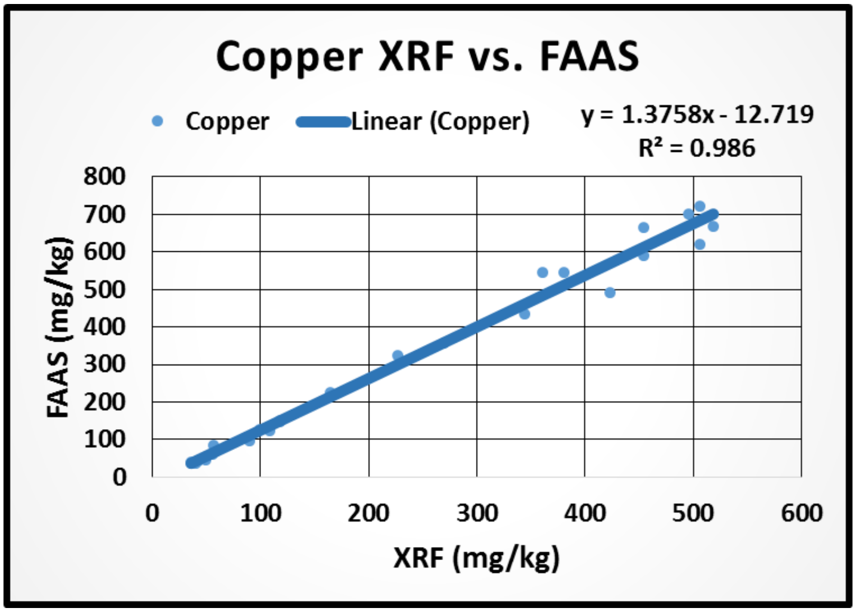

Figure 4.2 Copper Correlation

4.2 Concentration Mapping of Lead

After the correlations were made for each COC, a map of the entire site was made. Gold Member Inc. decided to create a visual map of the lead distribution as oppose to copper, because lead was the contaminant of the most concern at the site due to the alarmingly high levels found. The following concentration maps show the layout of the concentrations spread throughout the wash starting south of the private property line of Vulture Mine and west of the residential property line.

Figure 4.3 shows eight hotspots along the wash, a cross section and two background samples. Taking samples at the hotspots showed that all groupings of mine tailings have a very high concentration of lead. A line at the top of the photo indicates the Vulture Mine property. The background samples provided the concentrations of metals naturally occurring in the soil.

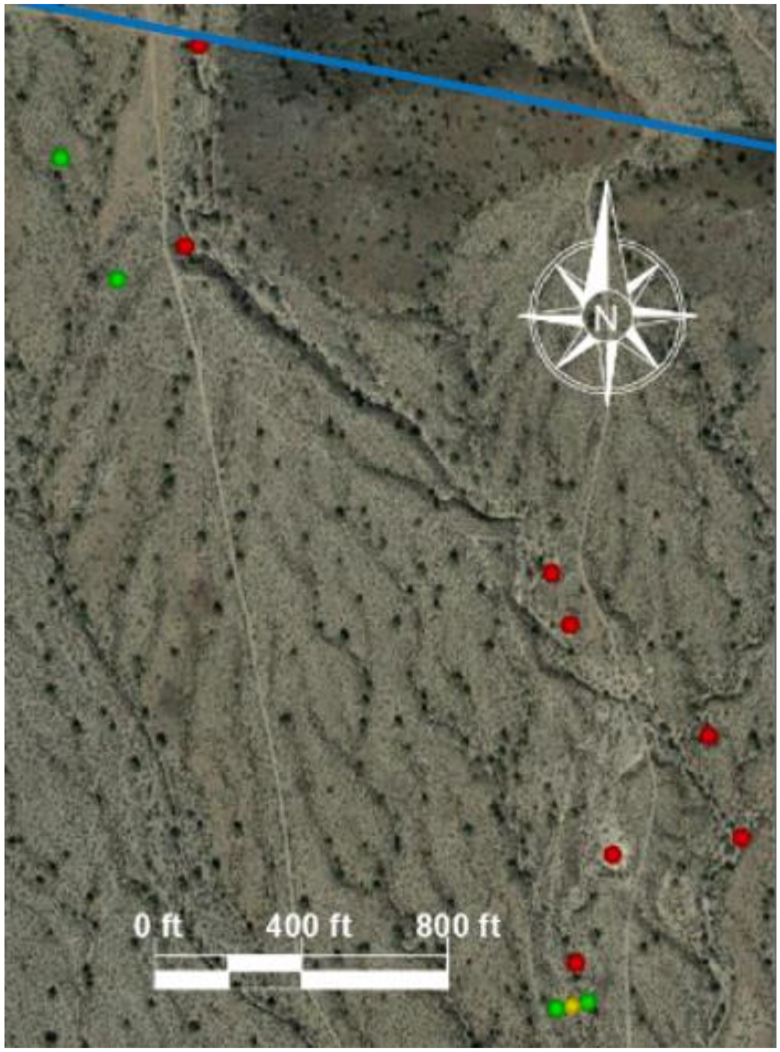

Figure 4.3 North end of wash

The center of the wash is shown in Figure 4.4. This area merged three washes into one. The highest concentrations of lead in this area were at the point of where all washes joined. Samples were taken on the banks of the wash to see how the land was affected in terms of lead.

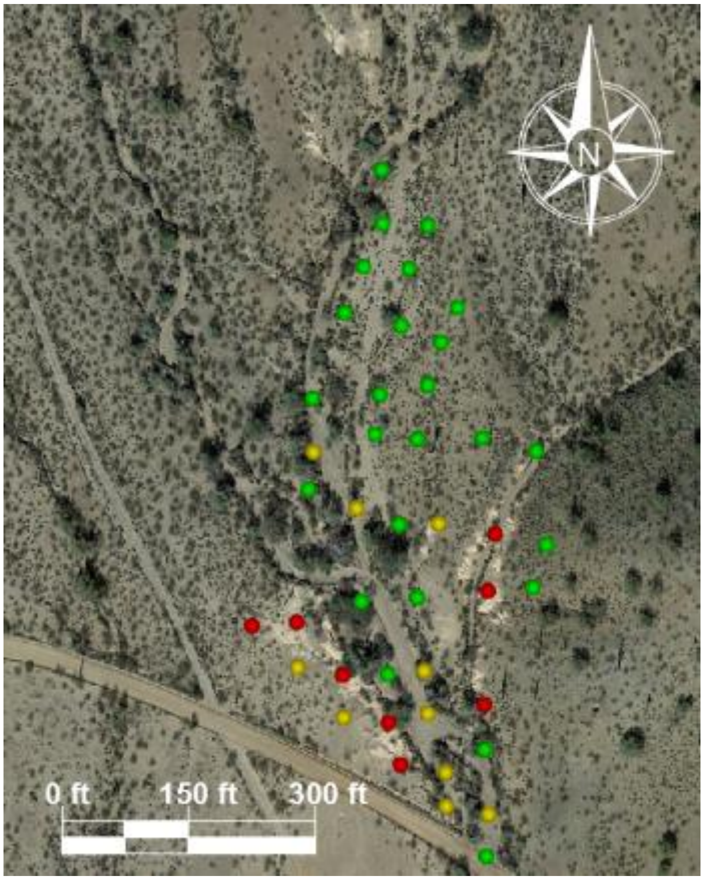

Figure 4.4 Central area of wash

The last section of sampling was near the residential property shown in Figure 4.5. The line right of the samples represents the residential property. This area shows the most diverse concentrations ranging from low concentrations to high concentrations. The map shows a number of high lead concentrations that are not in the wash, but on the banks. This could have been due to large flooding events in the past. There is also another cross section and two more background samples.

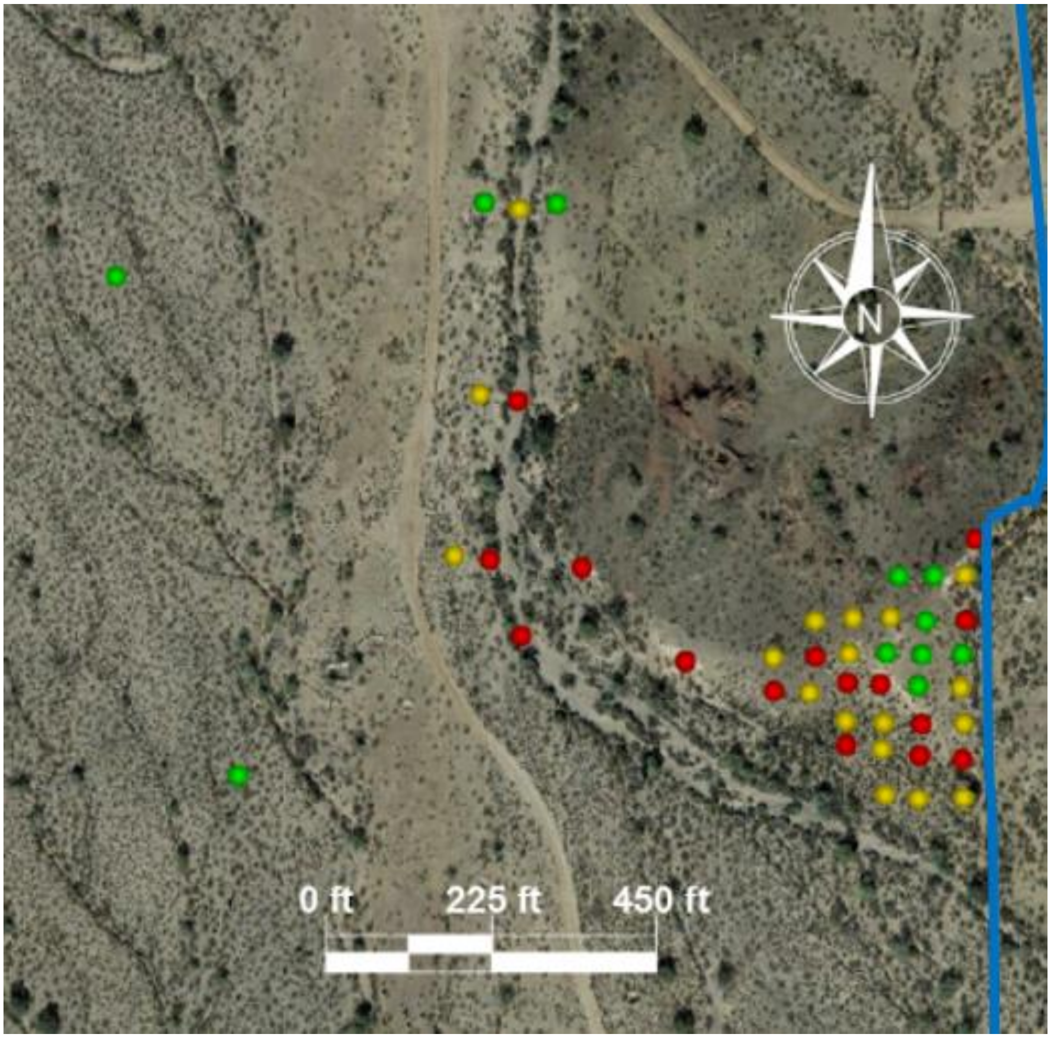

Figure 4.5 South end of wash

Figure 4.6 shows the entire range of the wash where the soil samples were taken. The Vulture Mine is indicated by the star. High concentration of lead occur throughout the entire length of the wash.

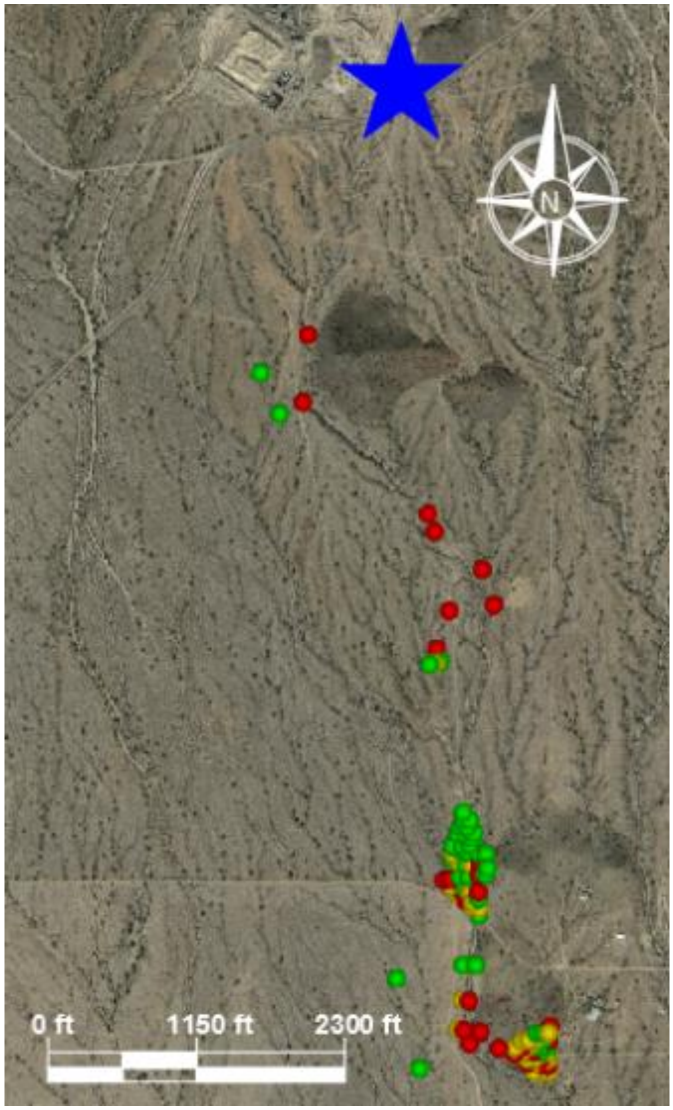

Figure 4.6 Extent of sampling (north to south)

4.3 Arizona Soil Remediation Levels

Using the XRF handheld device, Gold Member Inc. screened for six different contaminants at the Vulture Mine site. The six contaminants include: Copper, Lead, Molybdenum, Vanadium, Antimony, and Arsenic. Table 4.1 shows the residential and non-residential soil remediation levels for Arizona. The table also displays the number of samples screened using the XRF handheld device that exceeded these levels.

Table 4.1 Arizona Soil Remediation Levels

Arizona Soil Remediation Levels			
Contaminant	Residential Non-carcinogen (mg/kg)	Non-Residential Non-carcinogen (mg/kg)	# of Samples Over Residential Remediation Level (Out of 102 Samples Taken)
Copper and Compounds	3,100	41,000	0
Lead	400	800	67
Molybdenum	390	5,100	0
Vanadium and Compounds	78	1,000	42
Antimony and Compounds	31	410	3
Arsenic	10	10	24

The Flame Atomic Absorption Spectroscopy (FAAS) test was used for approximately 20% of the samples collected using the Environmental Analysis Laboratory at NAU. Only two of the six contaminants could be tested using the FAAS. The two contaminants for the Vulture Mine site that were tested were copper and lead. The concentrations of these contaminants are shown in Table 4.2 below.

Table 4.2 FAAS concentrations for the Vulture Mine Site

Vulture Mine Site		
Contaminant	Average (mg/kg)	90% Max (mg/kg)
Copper	132	443
Lead	1152	4277

Based upon the results from the XRF and the FAAS testing, copper was well below both the residential and non-residential soil remediation levels. The results show that the main COC for the Vulture Mine site is Lead. Lead greatly exceeded both the residential and non-residential soil remediation levels for the average and 90% max.

4.4 Exposure Scenarios

The two exposure scenarios that will be considered for risk assessments are the cases of an adult site worker and an adult recreational user. These scenarios will exhibit the exposure pathway of ingestion. Both of these scenarios are possible situations that could occur at the Vulture Mine site. To examine these risk, Gold Member Inc. used the Adult Lead Model (ALM) provided by the EPA. This model was run using the average lead concentration and 90% max lead concentrations that were found in the wash south of Vulture Mine. These concentrations are 1152 ppm and 4277 ppm respectively.

4.3.1. Adult Site Worker – Ingestion

To determine the receptor intakes in which a site worker is potentially exposed, some assumptions were made in order to produce a realistic situation. The assumptions made for a site worker are as follows:

- Exposure frequency: 87 days
- Averaging time: 365 days
- Soil Intake Rate (SIR): 100%
- Adult absorption fraction: 0.3

4.3.2. Adult Recreational User – Ingestion

To determine the receptor intakes in which a recreational user is potentially exposed, some assumptions were made in order to produce a realistic situation. The assumptions made for a recreational user are as follows:

- Exposure frequency: 5 days/year
- Averaging time: 365 days/year
- Soil Intake Rate (SIR): 100%
- Adult absorption fraction: 0.3

After these numbers were entered into the ALM, the results concluded that there is little to no risk for an adult site worker and adult recreational user when exposed to the average lead concentration found in the wash south of Vulture Mine. These values are reported in tables 4.3 and 4.4. However, when Gold Member Inc. ran that ALM with the 90% max lead concentration, the risk to the adult site worker exceeded the recommended/target blood lead level of 10 micrograms per deciliter by 3 micrograms per deciliter, as shown in table 4.4.

Table 4.3 Average Lead Concentration – Adult Site Worker

Calculations of Blood Level Concentrations: Adult Worker		
Cases	Units	GSDi and PbBo from Analysis of NHANES III
Target PbB level of concern	ug/dL	10
PbB of adult worker, geometric mean	ug/dL	4.8
95th percentile PbB among fetuses of adult workers	ug/dL	14.6
Probability of fetal PbB > adult PbB	%	12.9

Table 4.4 Average Lead Concentration – Adult Recreational User

Calculations of Blood Level Concentrations: Adult Recreational User		
Cases	Units	GSDi and PbBo from Analysis of NHANES III
Target PbB level of concern	ug/dL	10
PbB of adult recreational user, geometric mean	ug/dL	1.7
95th percentile PbB among fetuses of adult recreational user	ug/dL	5.2
Probability of fetal PbB > adult PbB	%	0.6

Table 4.5 90% Max Lead Concentration – Adult Site Worker

Calculations of Blood Level Concentrations: Adult Worker		
Cases	Units	GSDi and PbBo from Analysis of NHANES III
Target PbB level of concern	ug/dL	10
PbB of adult worker, geometric mean	ug/dL	13.7
95th percentile PbB among fetuses of adult workers	ug/dL	41.9
Probability of fetal PbB > adult PbB	%	61.2

Table 4.6 90% Max Concentration – Adult Recreational User

Calculations of Blood Level Concentrations: Adult Recreational User		
Cases	Units	GSDi and PbBo from Analysis of NHANES III
Target PbB level of concern	ug/dL	10
PbB of adult recreational user, geometric mean	ug/dL	2.2
95th percentile PbB among fetuses of adult recreational user	ug/dL	6.7
Probability of fetal PbB > adult PbB	%	1.5

4.5 Ecological Risk Assessment

Mammals and reptiles such as the sonoran desert tortoise found at the Vulture Mine Site have the potential risk associated with the high lead level concentrations. The sonoran desert tortoise was chosen because it is an endangered animal that lives in the vicinity of the site. Little quantitative data is available for reptilians. Integrated risk information system (IRIS) has conducted studies on the effects of lead on animals. Rats were tested and there is clear evidence that lead has harmful effects on animals. Rats ingested lead salts, and the rats that were fed high doses showed signs of carcinogenic responses such as tumors. IRIS was confident with their results that ingesting lead is harmful to the rat. No tests were done for inhalation. The sonoran desert tortoise along with other small mammals could potentially have negative side effects because of the large amounts of lead found at the site based upon the experiments conducted by IRIS.

A leaching test was conducted for the Vulture Mine site and the lead found within the mine tailings will not percolate with rainwater. This shows that the mammals and reptiles at the site would be mainly at risk if it ingested the soil, which could occur if dust particles are on the plants that it is consuming. The Desert Tortoise has a long lifespan, which means that a large amount of lead could be consumed though out its entire life. With the Desert Tortoise being an endangered species it is important to take all precautions to protect this reptile.

4.6 Hours Worked and Projected Project Costs

Gold Member Inc. has dedicated over 450 hours to this project. These hours include tasks such as writing reports, fieldwork, lab work, data correlations, and meetings. Table 4.7 provides a break down of Gold Member Inc. roles and how many hours were spent in each position. This table also provides estimates of the projected position cost and site visit expenses.

Table 4. 7 Personal Costs and Site Expenses

Personnel Cost		
Position	**Hours**	**Cost**
Senior Engineer	93	$ 9,300
Environmental Engineer	160	$ 8,263
Lab Technician	128	$ 3,590
External Help	72	$ 1,900
Total	453	**$ 23,053**
Site Visit Expenses		
Item		**Cost**
Transportation	$0.56/mile	$ 201.6
Hotel	$90/room	$ 270
Food	$8/meal	$ 160
	Total	**$ 631.6**
Total Cost of Project		
$23,684.60		

Gold Member Inc. has also projected the costs of lab work. In table 4.8 the costs for each laboratory test are broken down. A student discount was also provided to Gold Member Inc. for participating in all laboratory work and analysis.

Table 4.8 Laboratory Costs

Laboratory Costs for Metal Extractions			
Metal Extractions	**$/Sample**	**# of Samples**	**Cost**
Synthetic Leaching	4	28	$ 112
Microwave Digest	7.5	33	$ 247.5
		Total	**$ 359.5**
Laboratory Costs for FAA Testing			
FAA Testing	**$/Sample**	**# of Samples**	**Cost**
Synthetic Leaching	16	28	$ 448
Microwave Digest	15.5	33	$ 511.5
		Total	**$ 959.5**

Table 4.9 Student Discount

Student Discount		
Discount	**M.E.+FAA Cost**	**Total**
75%	$ 1,319.00	**$ 329.75**

5.0 Conclusion

The wash south of Vulture Mine contains an estimated several thousand tons of mine tailings left behind from previous mining activities. The exposure scenarios have identified potential risks that accompany the migration of mine tailings, which can occur through intense rainstorms and have the possibility to impact nearby residents. According to the correlations between XRF and laboratory data, Gold Member Inc. recommends the Bureau of Land Management to take further action at this site that will eventually lead to remedial action.

6.0 References

[1] Google Maps: The Vulture Mine – Wickenburg, AZ. Available: [https://maps.google.com/maps?output=classic&dg=brw]

[2] Metzger, O. H. (1938, February). *Gold Mining and Milling in the Wickenburg Area, Maricopa and Yavapai Counties, Ariz.* United States Department of the Interior- Bureau of Mines. Print.

[3] Google Earth: The Vulture Mine- Wickenburg, AZ. Available: [https://www.google.com/earth/] Date Accessed: December 2, 2014

[4] (2011, December). *Environmental Protection Agency* [Online]. Available: [http://www.epa.gov/superfund/policy/cercla.htm] Date Accessed: November 2, 2014.

[5] (2005, January). *NAVFAC Environmental: CERCLA Process* [Online]. Available: [http://www.navfac.navy.mil/products_and_services/ev/products_and_services/env_restoration/installation_map/navfac_atlantic/midlant/cherry_point/resource_conservation_recovery_act/cercla_process.html] Date Accessed: November 3, 2014.

[6] (1991, September). *Guidance for Conducting Preliminary Assessments Under CERCLA* [Online]. Available: [http://www.epa.gov/superfund/sites/npl/hrsres/pa/paguidance.pdf] Date Accessed: November 3, 2014.

[7] (1992, September). *Guidance for Conducting Site Inspections Under CERCLA* [Online]. Available: [http://www.epa.gov/superfund/sites/npl/hrsres/si/siguidance.pdf] Date Accessed: November 3, 2014

[8] (2013, December). *Geochemical Instrumentation and Analysis* [Online]. Available: [http://serc.carleton.edu/research_education/geochemsheets/techniques/XRF.html] Date Accessed: November 3, 2014.

[9] J.C. Evans, M.D. LaGrega, P.L. *Buckingham. Hazardous Waste Management*. Long Grove, IL: Wavland Press, Inc., 2012.

[10] (1988, October*). Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* [Online]. Available: [http://www.epa.gov/superfund/policy/remedy/pdfs/540g-89004-s.pdf] Date Accessed: November 2, 2014.

[11] B.J. Mason. (1992, July). Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies [Online]. Available: [http://www.epa.gov/OUST/cat/mason.pdf] Date Accessed: November 1, 2014.

[12] (2014). The Environmental Analysis Laboratory (EAL) [Online]. Available:

[http://nau.edu/Research/Services-Facilities/Labs-Facilities/CPAL/Environmental-Analysis-Lab/] Date Accessed: November 1, 2014.

[13] (2012, August). *Portable XRF arrives at the Alaska State Museum* [Online]. Available: [http://museumbulletin.wordpress.com/2012/08/08/alaska-state-museums-bulletin-55/] Date Accessed: November 30, 2014.

[14] (2013, November). *How XRF Works* [Online]. Available: [http://www.nachi.org/xrf-chinese-drywall.htm] Date Accessed: November 3, 2014.

[15] J.C. Evans, M.D. LaGrega, P.L. *Buckingham. Hazardous Waste Management*. Long Grove, IL: Wavland Press, Inc., 2012.

[16] P. Yamnik. (2011). Biological Review Technical Report Forepaugh industrial Rail Park [online]. Available: [http://www.wredp.com/tiger/biological.pdf] Date Accessed: November 2, 2014.

[17] T. A. Lewandowski, "Comparison of IEUBK model predictions and actual blood lead values at a former battery recycling site," *Environmental Geochemistry and Health* , vol. 16, no. 3-4, pp. 217-222, 1994.

[18] (2013). Managing Today for Wildlife Tomorrow [Online]. Available: [http://www.gf.state.az.us/w_c/edits/hdms_abstracts_mammals.shtml] Date Accessed: November 3, 2014.

[19] (1988, October*). Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* [Online]. Available: [http://www.epa.gov/superfund/policy/remedy/pdfs/540g-89004-s.pdf] Date Accessed: November 1, 2014.

[20] B.J. Mason. (1992, July). Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies [Online]. Available: [http://www.epa.gov/OUST/cat/mason.pdf] Date Accessed: November 2, 2014.

[21] (2014). The Environmental Analysis Laboratory (EAL) [Online]. Available: [http://nau.edu/Research/Services-Facilities/Labs-Facilities/CPAL/Environmental-Analysis-Lab/] Date Accessed: November 3, 2014.

[22] (2014). *X-Ray Generators- The Basics* [Online]. Available: [http://www.horiba.com/us/en/scientific/products/x-ray-fluorescence-analysis/tutorial/x-ray-generators-—-the-basics/] Date Accessed: November 30, 2014.

[23] (2012,July). Mountain Plover [Online]. Available: [http://www.sdakotabirds.com/species/mountain_plover_info.htm] Date Accessed: November 26, 2014

[24] (2014, October). Integrated Risk Information System (IRIS) [Online]. Available: [http://www.epa.gov/iris/help_ques.htm] Date Accessed: November 26, 2014

[25] (2013, May). Guidelines for Ecological Risk Assessment [Online]. Available: [http://www.epa.gov/raf/publications/guidelines-ecological-risk-assessment.htm] Date Accessed: November 29, 2014

[26] (2009, May). Arizona Administration Code [Online]. Available: [file://Downloads/ADEQ_SRLs_18-07_August%202014%20(2).pdf] Date Accessed: December 1, 2014

[27] (2014, May). DELTA Handheld XRF for Environmental Inspection [Print]. OLYMPUS. January 21, 2015.

[28] Training on the IEUBK Model, Adult Lead Methodology, and Recent Lead Risk Assessment Update. [Online].Available: [http://www.epa.gov/superfund/lead/products/training.pdf] Date Accessed: January 24, 2015

[29] (2001, December). Arizona Game and Fish Department Heritage Data Management System. [Online]. Available: [http://www.azgfd.gov/pdfs/w_c/hdms/Plants/Coryscro.fo.pdf] Date Accessed January 24, 2015

[30] (2010, January). Bloom Day Pineapple Cactus. [Online]. Available [https://ironwing.wordpress.com/2010/07/16/bloom-day-pima-pineapple-cactus/] Date Accessed: January 25, 2015

[31] (2014, July). Sonoran Desert Tortoise. [Online]. Available [http://www.fws.gov/southwest/es/arizona/Sonoran_Tort.htm] Date Accessed: January 25, 2014

[32] Mountain Plover Charadrius montanus. [Online]. Available [http://www.wildearthguardians.org/site/PageServer?pagename=species_birds_mountain_plover] Date Accessed: January 25, 2015

[33] North American Mammals. [Online]. Available [http://www.mnh.si.edu/mna/image_info.cfm?species_id=145] Date Accessed: January 25, 2015

7.0 Appendices