Preliminary Assessment, Site Investigation, and Remediation at Dragon Mine

CENE 486

Draft 4, Version 1

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List of Abbreviations

ALM – Adult Lead Model

ASTM – American Society for Testing and Materials

ATV – All Terrain Vehicle

AUF – Area Use Factor

AZ – Arizona

AZSRS – Arizona Soil Remediation Standards

BG – Background

BLM – Bureau of Land Management

CENE – Civil and Environmental Engineering

COC – Contaminant of Concern

DU – Decision Unit

ECOTOX – Ecological Toxicity

EPA – Environnemental Protection Agency

EPC – Exposure Point Concentration

GPS – Global Positioning System

HASP – Health and Safety Plan

HH – Human Health

HS-# – Hot Spot-#

ICP-OES – Inductively Coupled Plasma Optical Emission Spectroscopy

IEUBK – Integrated Exposure Uptake Bio-kinetic

IRIS – Integrated Risk Information System

ISM – Incremental Sampling Methodology

LOD – Limit of Detection

NAU – Northern Arizona University

NHANES - National Health and Nutrient Examination

PA – Preliminary Assessment

PC – Picture Credit

PPE – Personal Protective Equipment

ppm – Parts Per Million

QA – Quality Assurance

QC – Quality Control

RAGS – Risk Assessment for Superfund

RAO – Remedial Action Objective

RPD – Relative Percent Difference

RfD – Reference Dose

SAP – Sampling and Analysis Plan

SF – Slope Factor

SI – Site Investigation

SRL – Soil Remediation Levels

XRF – X-ray Fluorescence

Acknowledgements

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The team would also like to thank our technical advisor Dr. Bridget Bero for all the guidance provided throughout the technical work and site visit.

1.0 Project Introduction

1.1 Project Purpose

The Preliminary Assessment (PA), Site Investigation (SI), and Remediation at Dragon Mine is being conducted to provide the necessary technical information to identify the contaminants of concern (COCs), complete a Human Health (HH) and Ecological Risk Assessment associated with the COCs, and to identify remediation options to enable future development at the Dragon Mine site.

1.2 Project Location

The Dragon Mine is an abandoned mine and milling site located in the south half of Section 23, Township 7 North, Range 4 West, Gila and Salt River Meridian, about 5.7 miles southeast of Wickenburg, in Maricopa County, Arizona. Dragon Mine contained vein deposits that were mined primarily for gold, silver, and vanadium between the late 1800's and 1942. Figure 1-1 shows the location of the site within the state of Arizona and in relation to the City of Wickenburg.

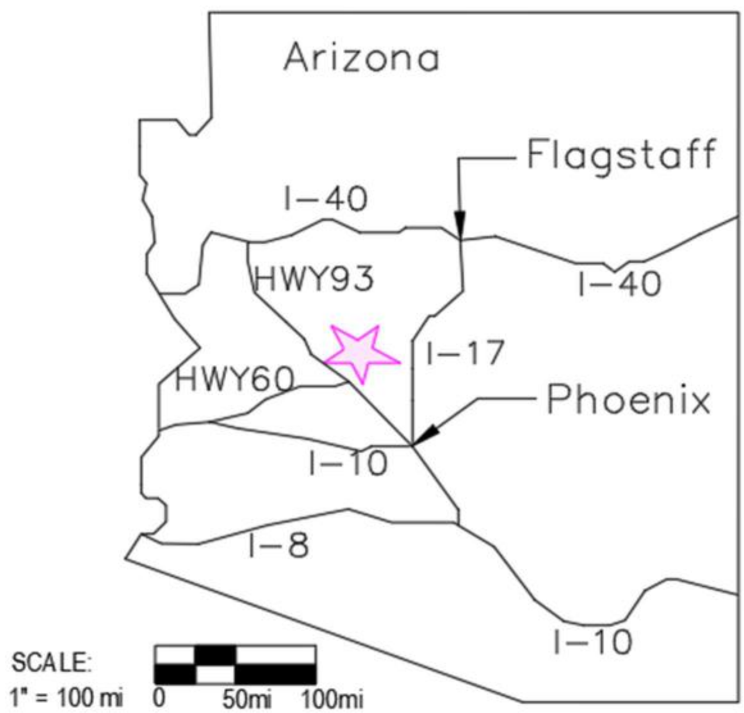

Figure 1-1. Location Map

Dragon Mine is located near the North by Northwest border of Maricopa County. Figure 1-2 shows the location of the Dragon Mine site within Maricopa Country.

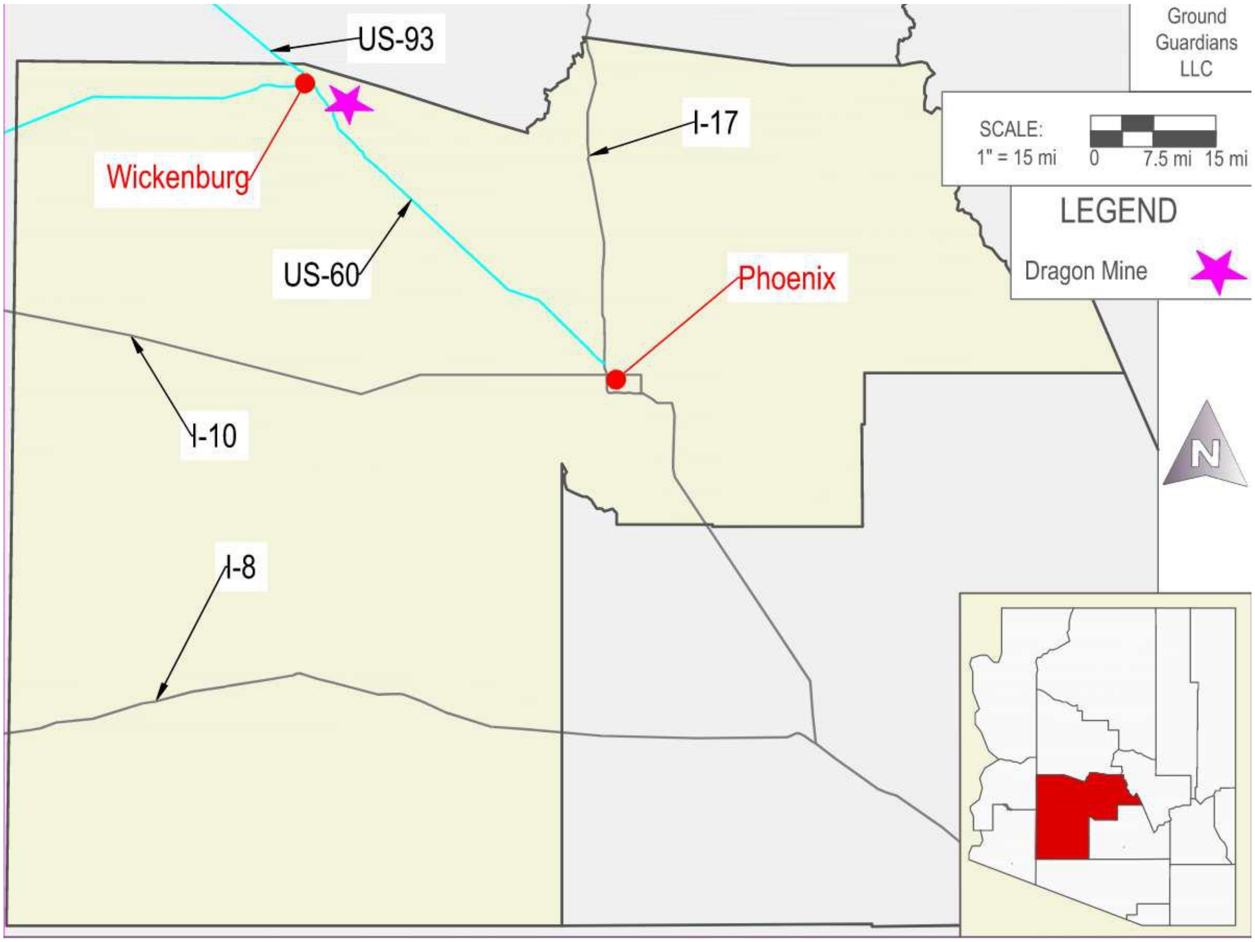

Figure 1-2. Maricopa County Location Map

Figure 1-3 shows the location of the Dragon Mine relative to the city of Wickenburg, AZ and site access roads. Two separate access routes are shown in red. The northern route was used to enter the site by turning off U.S Highway 60, onto W. San Domingo Peak Trail, that lead to San Domingo Wash which served as the remainder of the access route. The land surrounding the site is owned by the Bureau of Land Management (BLM).

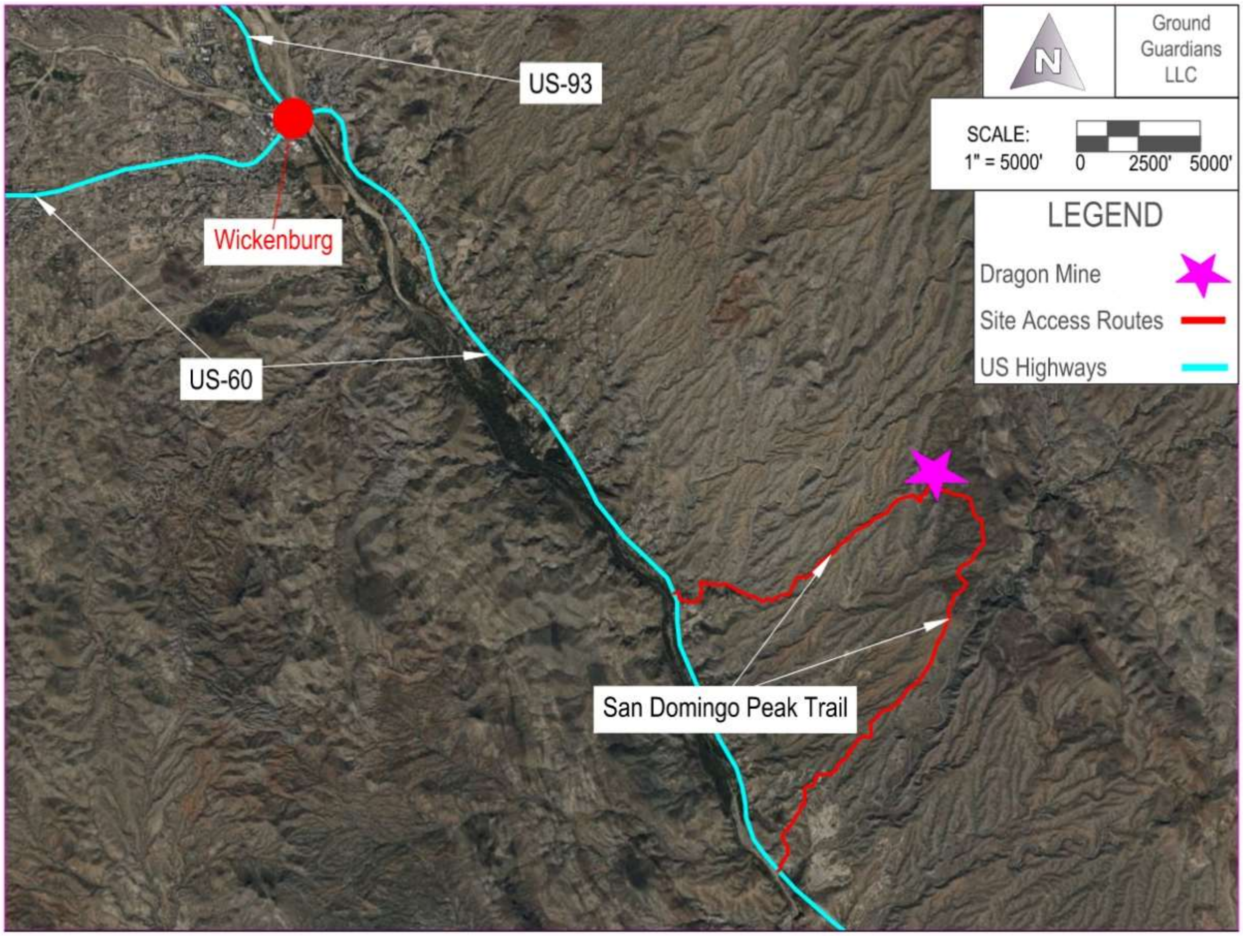

Figure 1-3. Vicinity Map

A more detailed visual is found in Appendix A Photo Log. A more detailed description of the site's features is found in Section 3.1 Site Features.

2.0 Work Plan

2.1 Lab Access

Ground Guardians obtained lab access to the Northern Arizona University (NAU) Civil and Environmental Engineering (CENE) Soils Laboratory from the NAU CENE lab manager on January 9, 2025. To obtain laboratory access for ex-situ sample analysis and sample storage, the team had discussions with the NAU CENE lab manager and developed a lab binder. This lab binder included a Sampling and Analysis Plan (SAP), a Health and Safety Plan (HASP), several team safety trainings, team emergency contact information, laboratory emergency contact information, the standard test methods and equipment to be used in the lab, an emergency response plan, chemical handling safety, and project activity logs. Prior to receiving lab access, the lab manager reviewed and signed laboratory safety agreement and usage forms with the team.

2.2 Sampling and Analysis Plan Preparation

A Sampling and Analysis Plan (SAP) was created to detail the sampling methods that Ground Guardians would perform during the SI. The SAP includes site DUs, and which sampling method will be performed, sample transportation and labeling guidelines, field documentation procedures, decontamination and Quality Assurance and Quality Control (QA/QC) procedures, laboratory analysis methods, and material disposal methods. The SAP also included maps of all 5 Decision Units (DUs) created by the team and details where each sample would be taken. The site boundary was chosen based on geographical features, like the wash and the area of white rocks to the northeast, as well as the lines of the dirt roads. DU boundaries were chosen based on physical features in the small areas, such as concrete foundations in DU3 and the waste rock in DU4. The original SAP estimated 50-59 surface samples to be taken: 25 grid samples, 20 transect, 4 Incremental Sampling Methodology (ISM), 3 backgrounds and 7 potential hotspots. To view changes made to the original SAP during the SI, see Section 3.2 below. To view the original SAP in its entirety, see Appendix B SAP.

See Figure 2-1 below for the original sampling map.

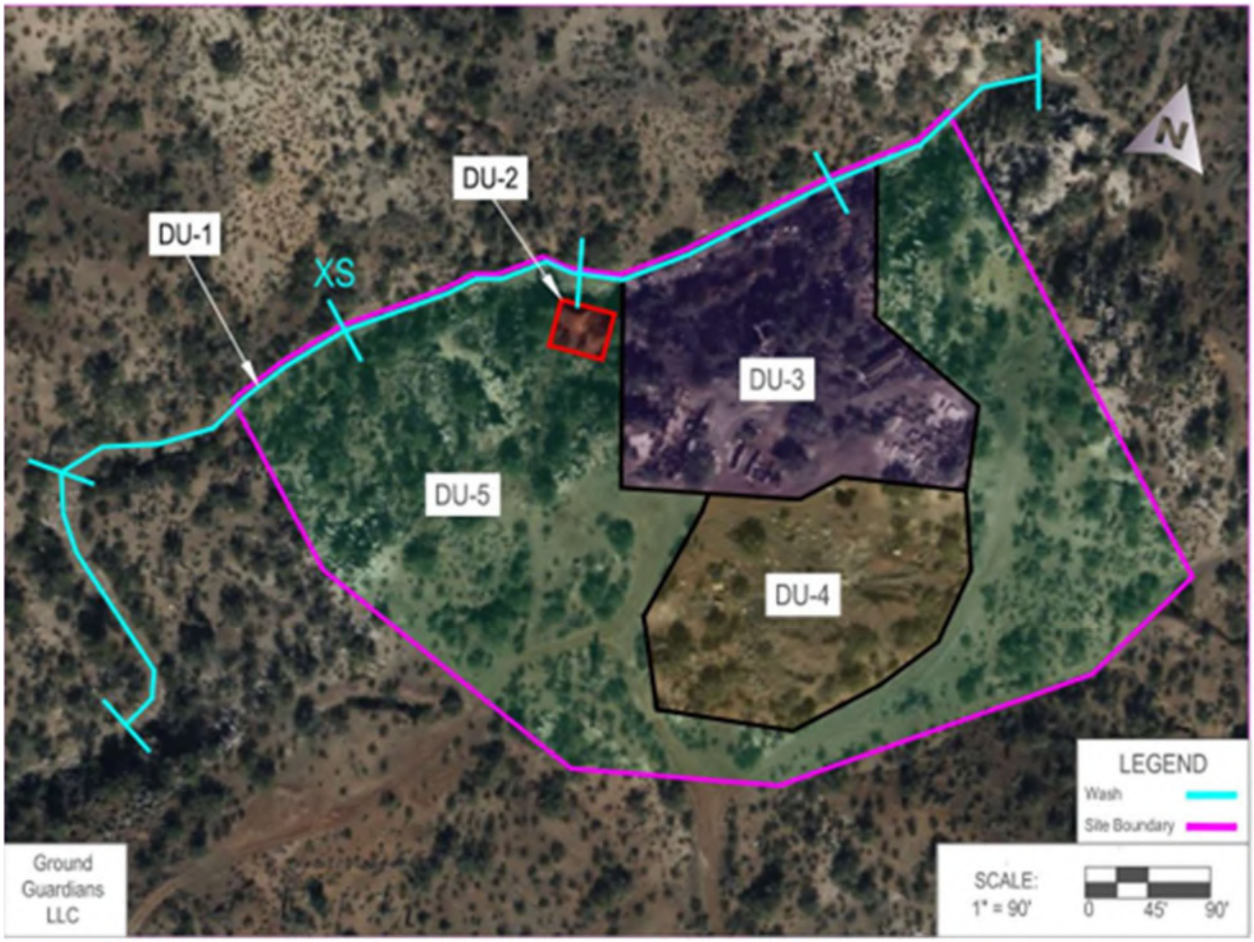

Figure 2-1. Original Sampling Map

2.3 Health and Safety Plan Preparation

To obtain lab access, Ground Guardians prepared a Health and safety Plan (HASP) as a component of the lab binder. The plan required each team member to complete X-Ray Fluorescence (XRF) safety training, power tool safety training, chemical hygiene safety training, and hazard communication training. All potential field and laboratory hazards were identified, and mitigation strategies were provided. Appropriate Personal Protective Equipment (PPE), decontamination procedures, and manual labor operating procedures were provided. Each team member provided an emergency contact and Bowie Ching was designated as the project Health and Safety Officer. The Health and Safety Officer oversees the safety of the team during the SI and during lab work. In the event of an emergency during the SI or in the lab, two separate maps were created to identify the shortest path to the nearest hospital. A complete emergency contact list was also created with the proper authorities in Flagstaff and Wickenburg. To view the original HASP in its entirety, see Appendix C HASP.

3.0 Site Investigation

The Dragon Mine site investigation occurred on January 17, 2025. The weather conditions at the site were optimal for sampling with little wind and sunny skies. Photos, videos and field notes were documented throughout the investigation.

3.1 Site Features

There are several dilapidated concrete foundations. There are two open mine shafts with fences around them shown as yellow dots. There is an adit at the site with a broken fence around it. There are red tailings that spill into the surrounding wash. The wash has a steep drop from the site, about 50 feet in elevation loss.

Figure 3-1 shows the pertinent site features of the site boundary, outlined in magenta.

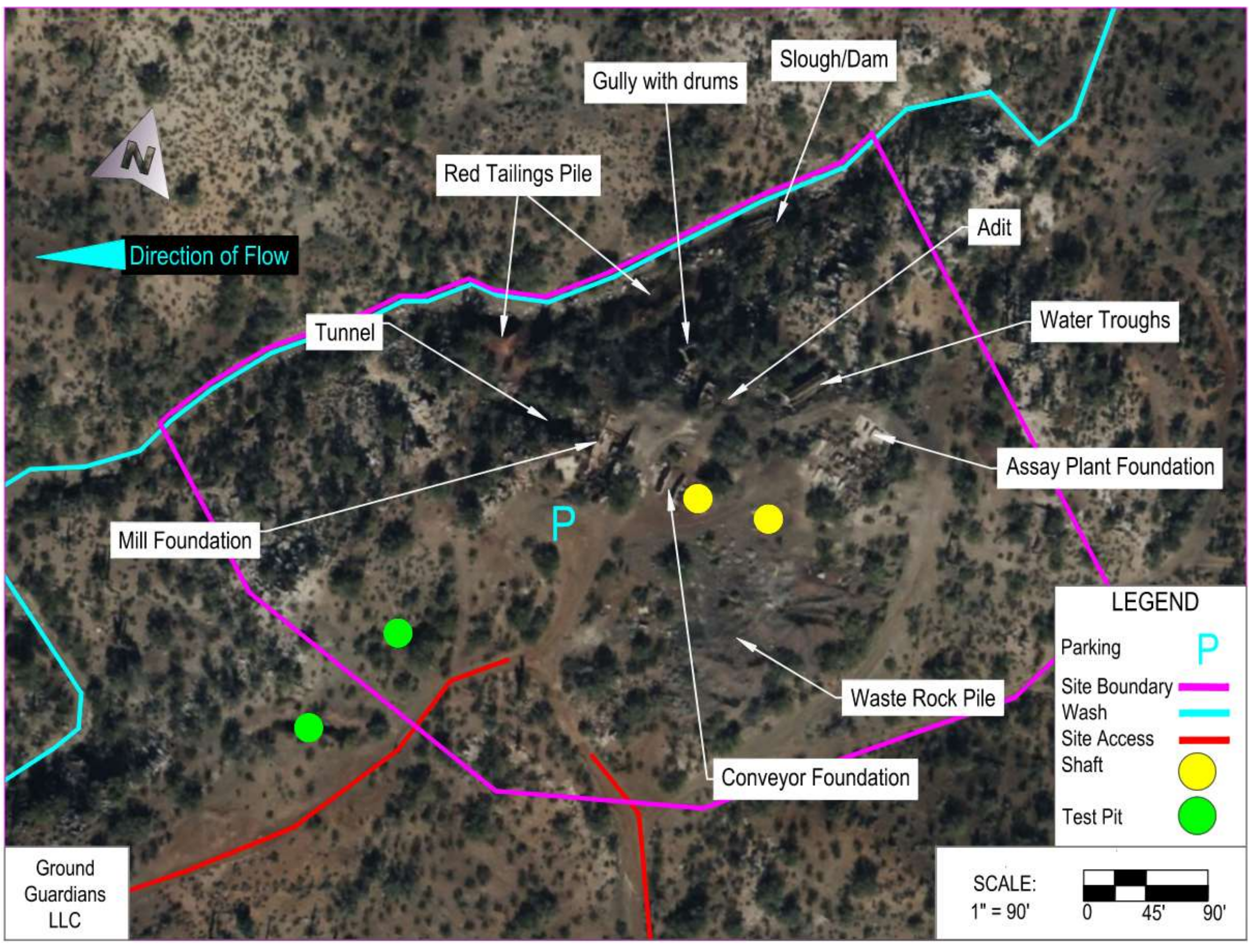

Figure 3-1. Site Features [1]

The Dragon Mine has steep elevation changes throughout the site boundary. These steep changes in terrain are shown in Figure 3-2.

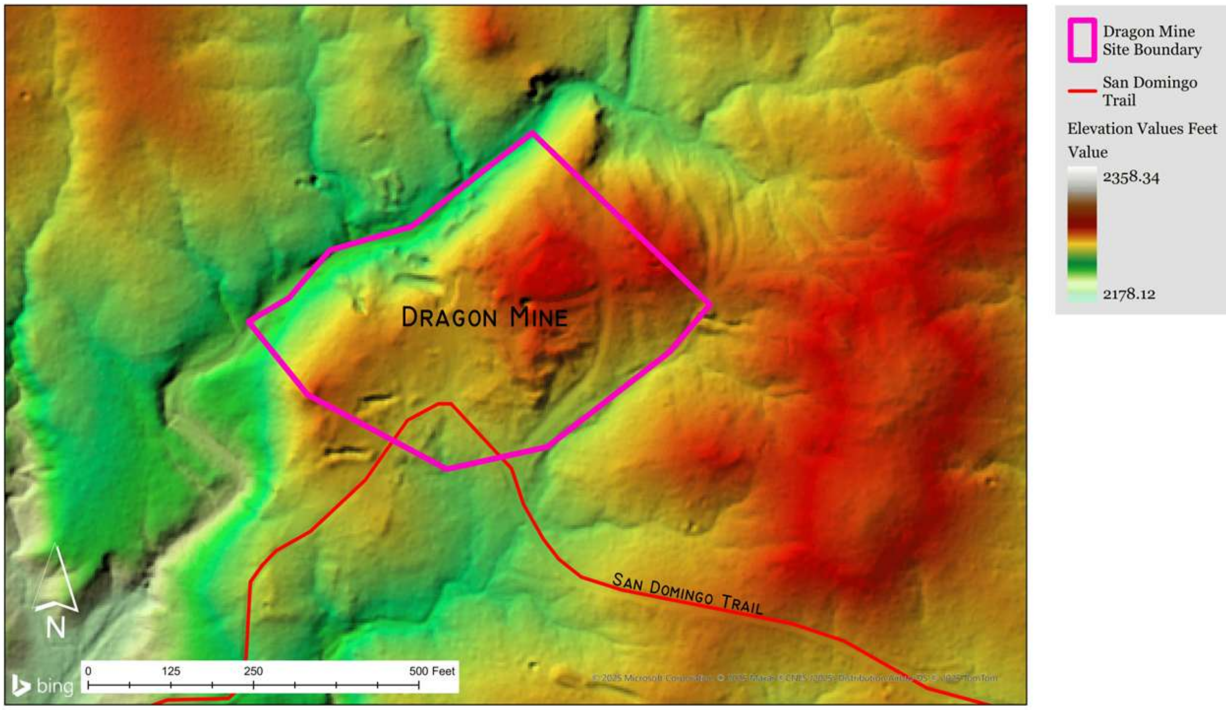

Figure 3-2. Elevation Map of Area Around Dragon Mine [2]

Figure 3-3 shows one of the mine shafts at the site. The shaft is fenced off with barb wire and a warning label on it.

Figure 3-3. Mine Shaft (PC: Jorja)

Figure 3-4 shows the adit with a broken fence at the site.

Figure 3-4. Adit (PC: Jorja)

The flora observed at the site include Paula Verde Trees, Saguaros, Fishhook Barrel Cactus, Mesquite Tree, Greece Wood Tree, dryland moss and typical grasses. The plant life did not appear to be distressed. Flora in the background areas included the same species as the site plus Chollas and Ocotillo which were not present at the mine.

The fauna observed at the site includes quail, rabbits, lizards, and people. Donkey and coyote feces were found throughout the site as well. Figure 3-5 shows donkey feces next to a sample in DU4.

Figure 3-5. Donkey Feces (PC: Jorja)

Throughout the site investigation evidence of recreation at the site was observed. Debris strewn throughout the site including barrels, old grills, scrap wood, etc. Several of the debris on site and signage on fences had bullet holes in them. See Figure 3-6 for bullet holes in an old grill.

Figure 3-6. Bullet Riddled Grill (PC: Jorja)

In addition to material evidence of recreational activities, several people traveled through the site during the site investigation. 15-20 people drove through or stopped at the site on all-terrain vehicles (ATVs). Three people stopped at the site to eat lunch, and two walked around the site to observe the mine. See additional photos of the site in Appendix A.

3.2 Deviations from SAP

Upon arriving at the Dragon Mine changes to the SAP were made based on the existing conditions described in section 3.1. The hills at the site led the team to change some of the decision units to have more natural boundaries. DU2 was on a steep hill leading into the wash so this DU was replaced by 5 hot spot samples. Cross sections of DU1 that sat along DU3 and DU5 were shortened from 200 ft apart to 100 ft apart. This decision was made by the senior engineer to ensure samples are representative of each area. DU5 was significantly changed to help the team sample more effectively, this included removing subsections that were blocked by debris or steep hillsides. This decision was made by the teams technical advisor.

The total number of samples was 51, including 3 background, 5 hot spot, 4 ISM, 20 transect, and 19 grid samples. Figure 3-7 shows the updated summary map of DUs with boundaries for each DU in black.

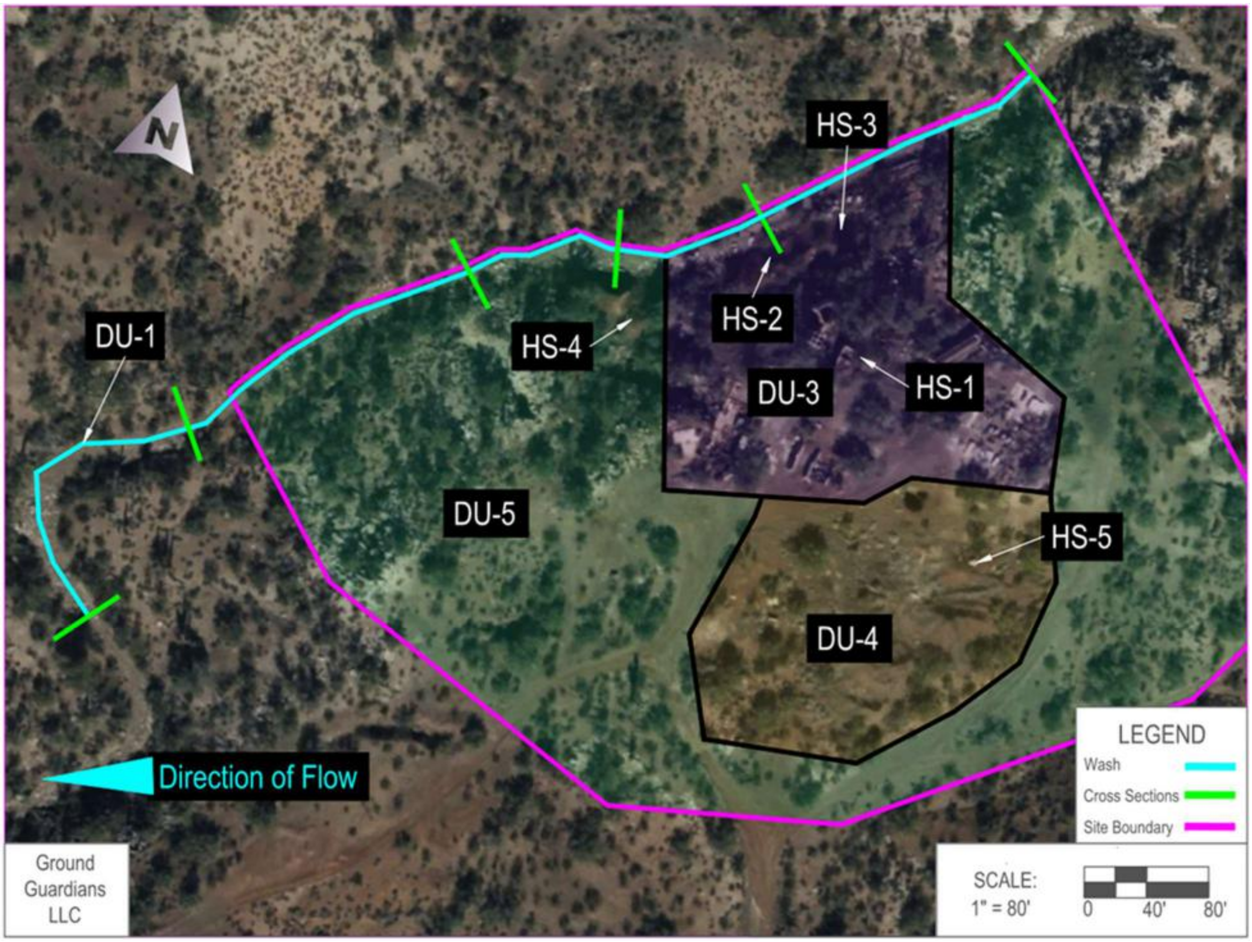

Figure 3-7. Updated Decision Unit Summary Map [3]

Figure 3-8 shows the location for background samples collected, in reference to the Dragon Mine. With assistance from the technical advisor, background sample locations were collected in areas that were not disturbed by vehicles or operations at the site. The samples were taken far enough away from the site that contaminant migration due to wind was unlikely.

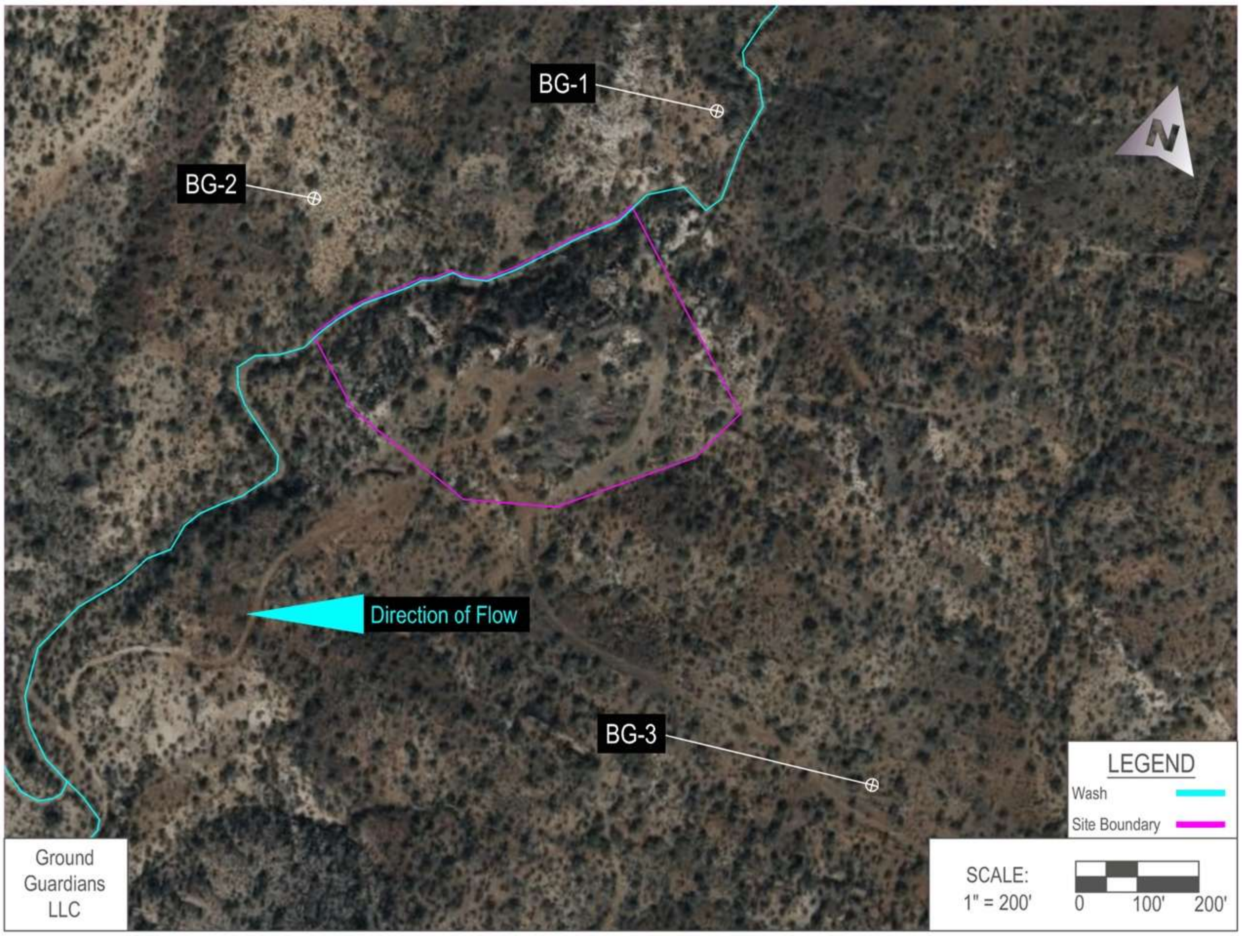

Figure 3-8. Background Sample Map [4]

Figure 3-9 shows the sampling locations for DU1. The location of each sample was captured with a Global Positioning Device (GPS) device.

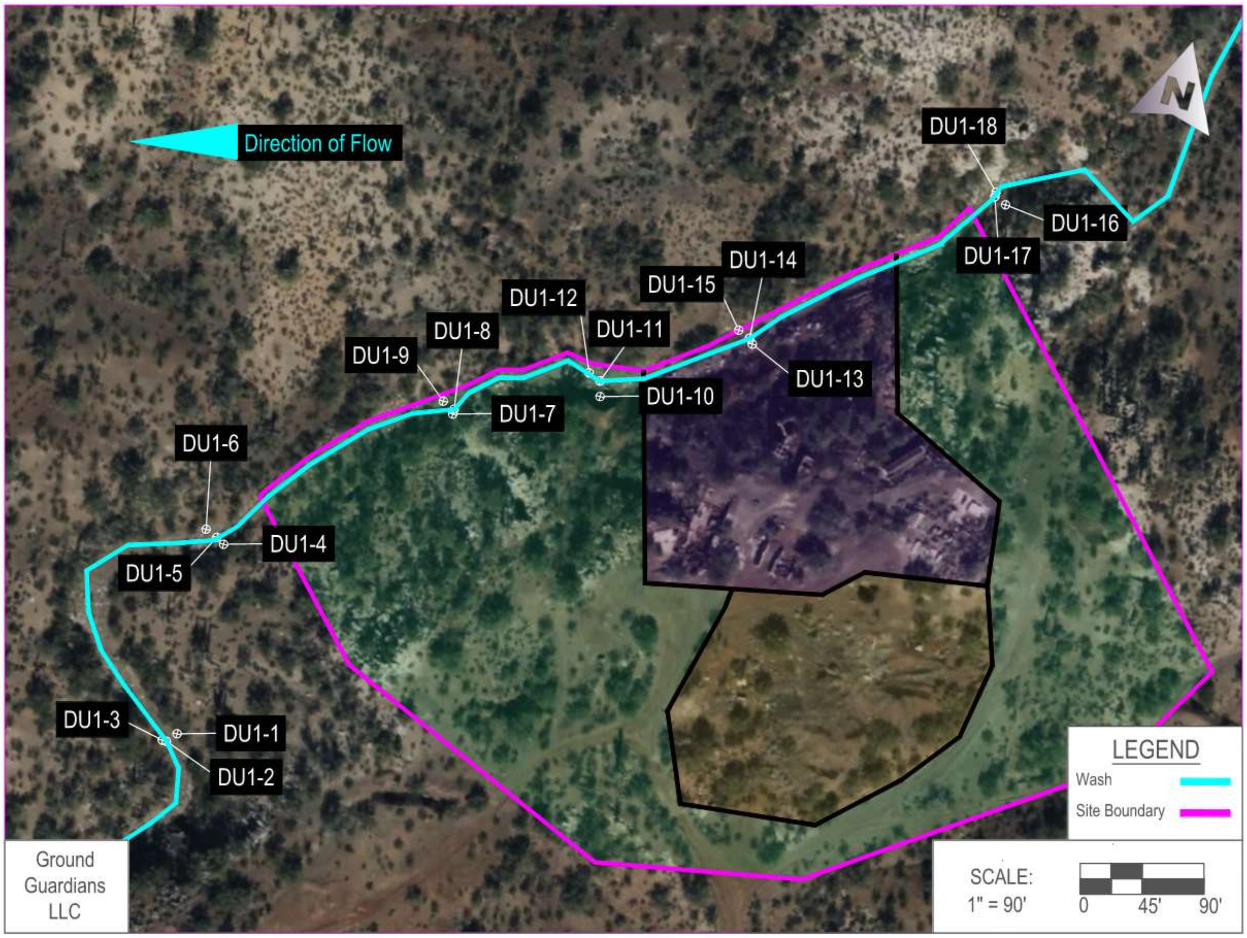

Figure 3-9. DU1 Sampling Location Map [5]

Figure 3-10 shows the sampling locations for DU3. The location of each sample was captured with a GPS device.

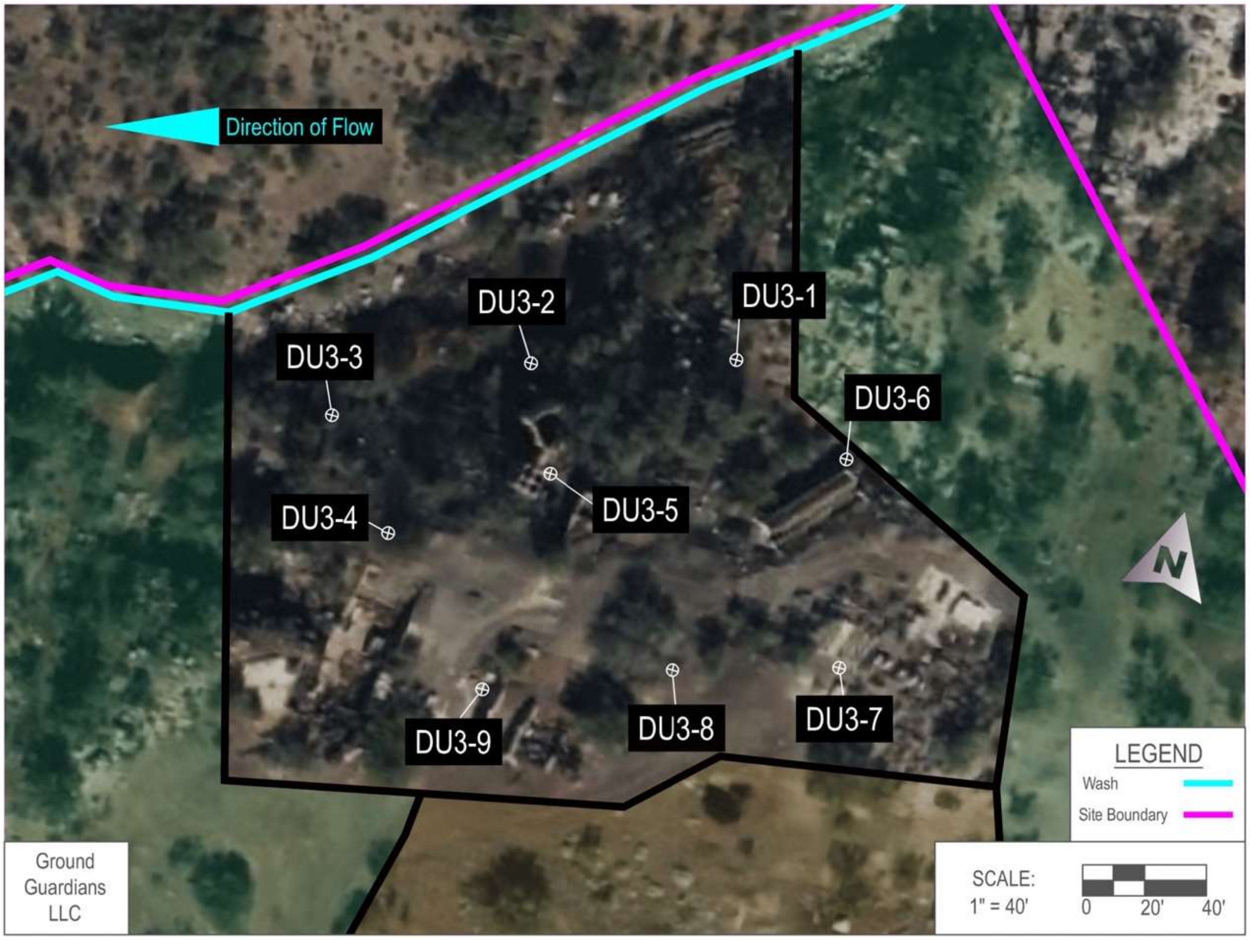

Figure 3-10. DU3 Sampling Location Map [6]

Figure 3-11 shows the sampling locations for DU4. The location of each sample was captured with a GPS device. Sample DU4-3 was later determined to be an accidental hot spot due to the extremely high concentrations of contaminants.

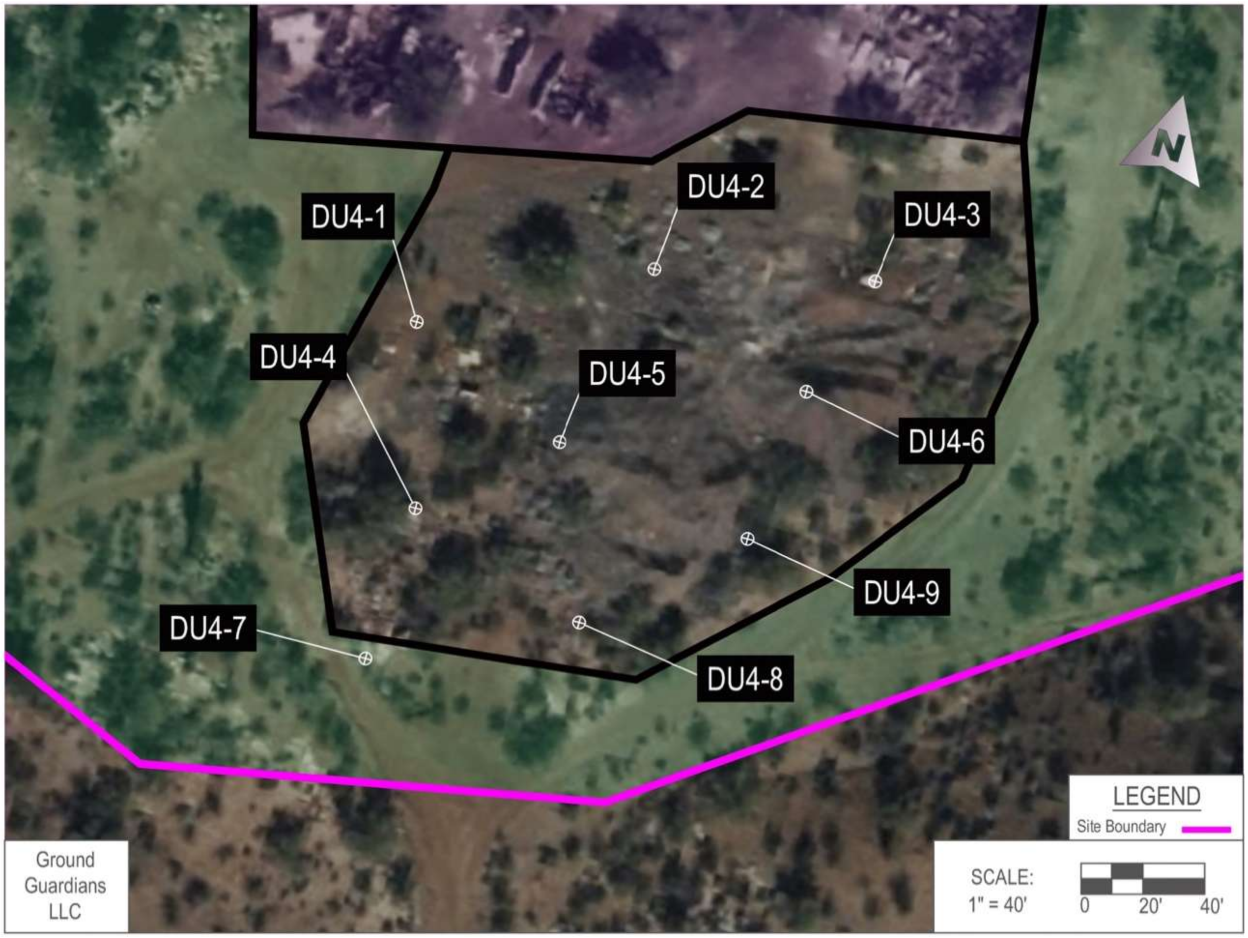

Figure 3-11. DU4 Sampling Map [7]

Due to the size and homogeneity of DU5, the incremental sampling methodology was used. Figure 3-12 shows the sampling locations for DU5. At each of the 30 labeled sample locations, 4 separate sub-samples – labeled A, B, C, and D – of roughly 2 tablespoons were taken within 3 feet of the label. All 30 of the A samples were combined, as were all the B samples, C samples, and D samples to create a total of 4 samples. Since there were so many sub-samples, which were then composited, collecting in-situ XRF data for this DU did not make sense.

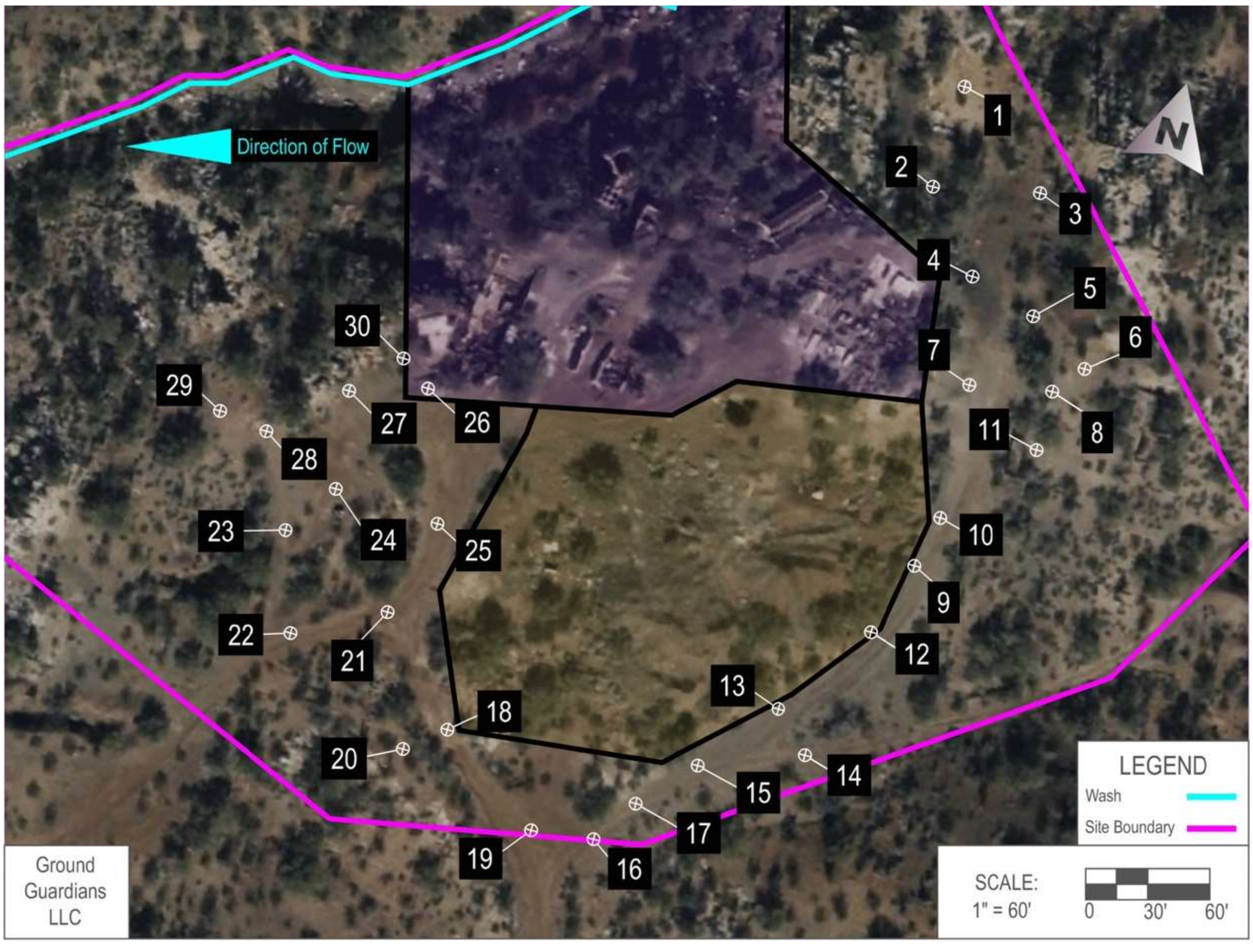

Figure 3-12. New DU5 Sampling Map [8]

3.3 Sample Collection

51 surface samples were collected at the site, 3 background samples were collected off site. Flags were placed at each sampling location, spaced out about 40-60 feet using a tape measure. GPS locations of each sample location were collected. Each sample was taken within a five-foot radius of the flags. The vegetation was cleared away and each sample was taken one to three inches below the surface. Trowels were used to collect the sample and put into gallon size Hefty Zip-Lock bags with its corresponding label. The labeling scheme is the decision unit number and the corresponding sample number.

Table 3-1 below displays the Arizona Department of Environmental Quality Soil Remediation Levels (SRLs).

Table 3-1. Arizona Department of Environmental Quality SRLs [9]

Element	Pb	As
Residential Limit (ppm)	400	10
Non-Residential (ppm)	800	10

3.4 In-Situ XRF Analysis

XRF analysis uses X-rays to determine the concentration of certain metals within the soil. The XRF device shoots high energy X-rays into the soil which interacts with the different atoms within the soil. When the X-rays interact with the atoms, an electron from the inner orbital shell of the atom gets knocked out of place. An electron from an outer orbital shell replaces the missing electron from the inner shell which causes the emission of a fluoresced X-ray with specific energy levels based on the atom. The XRF device captures the emitted X-rays from the soil and determines the concentration of metals based on the magnitude of the fluoresced X-rays.

Figure 3-13 shows the XRF device being used to take an in-situ soil sample.

Figure 3-13. In-Situ XRF Analysis (PC: Andres)

At each sample location an in-situ XRF reading was collected and stored on the device. The XRF device was wrapped in a Zip-Lock bag and put directly to the ground at each sample location. The device reads the soil contents for 90 seconds. The contaminants of concern found with the in-situ testing include lead and arsenic. Table 3-2 shows the contaminants of concern with their reading at each sample location. Cells highlighted in red indicate that the reading is over non-residential limits, yellow indicates that the reading is over residential limits. The XRF device calculates a Limit of Detection (LOD) when taking a reading. If the measured concentration is below the calculated limit, the device outputs a reading of the calculated LOD. Samples with a <LOD reading were adjusted to half the calculated LOD.

Table 3-2. In-Situ XRF Results

SAMPLE ID	Pb	As
DU-1-1	107.48	9.14
DU-1-2	65.66	3.8
DU-1-2-D	54.24	3.74
DU-1-3	80.78	14.855
DU-1-4	36.32	10.76
DU-1-5	98.44	12.55
DU-1-6	45.35	4.065
DU-1-7	64.77	6.865
DU-1-8	20.03	8.77
DU-1-9	41.86	10.22
DU-1-10	236.43	16.94
DU-1-11	32.35	9.59
DU-1-11-D	30.11	7.02
DU-1-12	33.17	6.16
DU-1-13	2428.42	23.81
DU-1-14	18.36	2.94
DU-1-15	23.18	7.54
DU-1-16	26.72	8.41
DU-1-17	24.15	10.03
DU-1-18	31.26	7.31
BG-1	14.53	3.8
BG-2	14.71	2.135
BG-3	24.91	4.61

SAMPLE ID	Pb	As
DU-3-1	70.04	6.6
DU-3-2	517.05	9.18
DU-3-3	325.89	8.425
DU-3-3-D	256.4	14.05
DU-3-4	1283.02	17.24
DU-3-5	138.31	7.105
DU-3-6	8.575	38.59
DU3-7	36.23	3.715
DU-3-8	65.14	9.62
DU-3-9	829.33	13.415
DU-4-1	141.18	9.21
DU-4-2	5786.47	92.26
DU-4-4	78.24	4.415
DU-4-5	395.76	9.945
DU-4-5-D	252.78	7.78
DU-4-6	62.03	5.425
DU-4-7	1094.88	18.255
DU-4-8	35.67	7.81
DU-4-9	362.52	26.38
HS-1	357.19	7.435
HS-2	8806.63	40.745
HS-3	1749.16	27.975
HS-4	8054.66	32.28
HS-5	7070.89	88.95

According to the Environmental Protection Agency (EPA) the arsenic levels should be accurate until lead exceeds 5000ppm. Lead and Arsenic can overlap in XRF measurements because of their similar secondary X-ray emissions. Higher concentrations of lead result in lower accuracy regarding arsenic readings [9].

After looking at the XRF data, sample DU-4-3 was changed to a hotspot sample, HS-5, because it had exponentially higher concentrations than other samples in DU-4.

See Figures 3-14 and 3-15 for contaminant distribution summary maps.

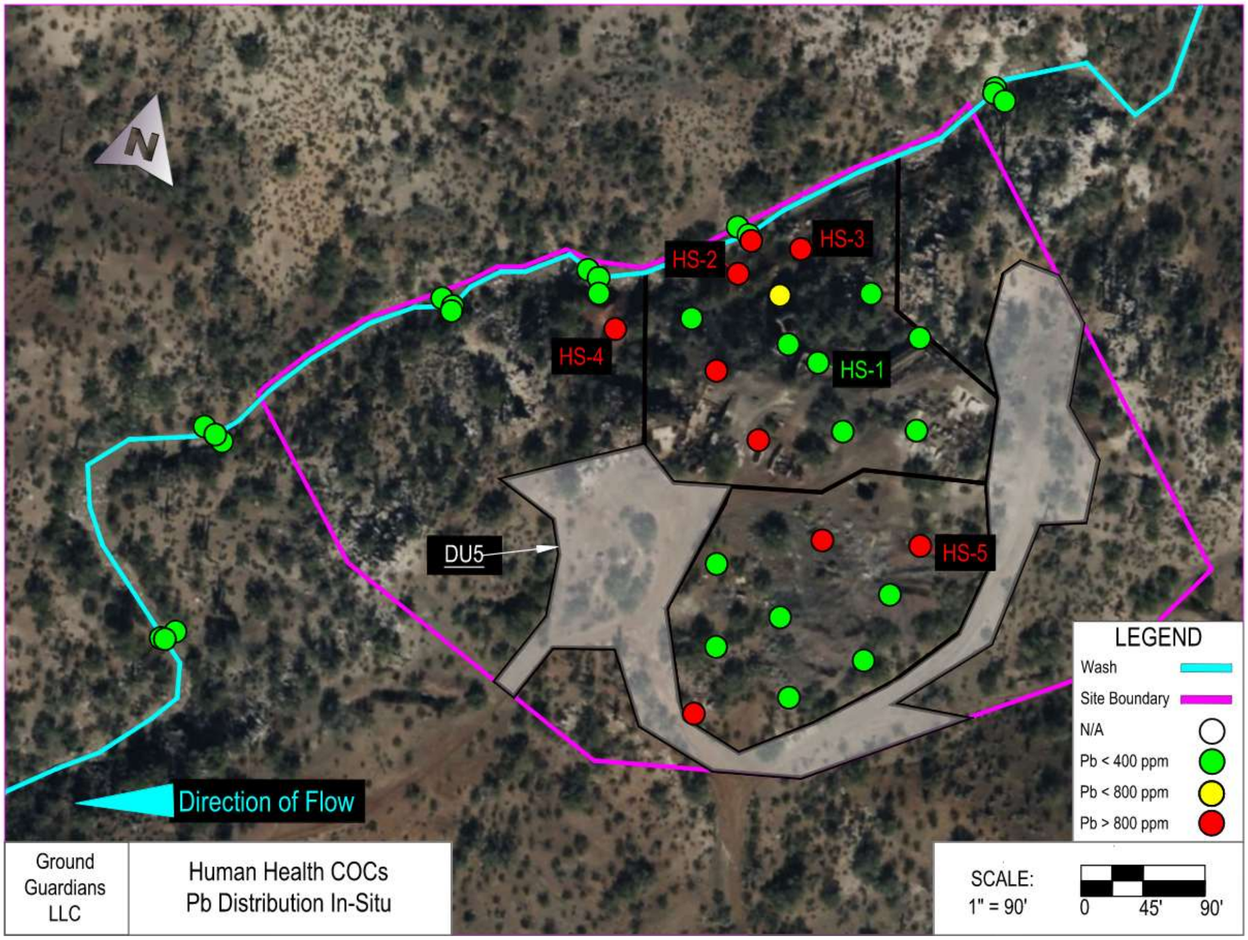

Figure 3-14. In-Situ Pb Contaminant Distribution Map [8]

Figure 3-14 details whether or not samples exceed the Arizona residential limit for lead in soil of 400 mg/kg (ppm) shown in yellow, or the non-residential limit of 800 ppm shown in red, determined from in-situ XRF analysis.

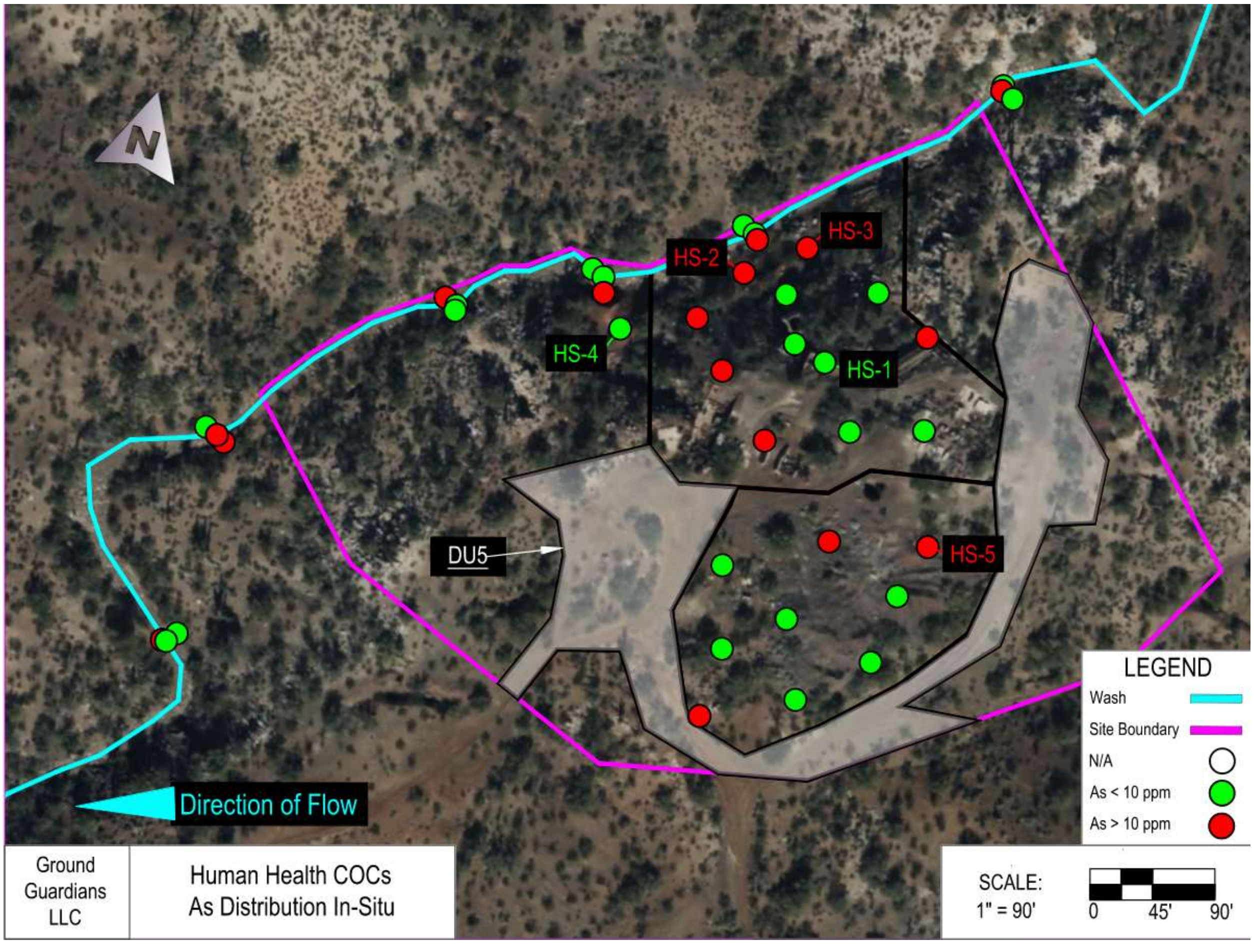

Figure 3-15. In-Situ As Contaminant Distribution Map [8]

Figure 3-15 details whether or not samples exceed the Arizona limit (both residential and non-residential) for arsenic in soil of 10 mg/kg (ppm), determined from in-situ XRF analysis.

3.5 Sampling QA/QC

To ensure samples were tracked, each sample was documented where it was stored. Plastic bins were used to store the samples and prior to leaving the site they were checked to account for each sample. A clean trowel was used for each sample and cleaned before being used again. Fresh nitrile gloves were worn for each sample to ensure no cross contamination.

4.0 Laboratory Analysis

The laboratory space used was shared with multiple groups, so equipment needed to be set up and put away each time the space was used. Equipment used in the lab was stored in designated cabinets while not in use. A folding table was set up as the main area of work within the lab.

4.1 Drying

The American Society for Testing and Materials (ASTM) Method D2216-19: Standard Test Methods for Laboratory Determination of Moisture Content of Soil and Rock by Mass was followed to dry the samples and test for moisture content of the first sample [10]. XRF testing requires a moisture content of less than 10 percent. Eight samples were put into the drying oven at 220 degrees Fahrenheit for 24 hours to determine the initial moisture content the samples were collected with. The samples are put into troughs to dry within the oven. Eight troughs can fit comfortably on the bottom of the oven. Transfer of the soil between the sample bags and the troughs is done outside to avoid cross contamination due to dust. Troughs are labeled with the accompanying sample label.

Figure 4-1 shows the troughs with sample being placed into the oven to dry.

Figure 4-1. Soil Drying (PC: Jorja)

4.2 Sieving

ASTM Method D6913: Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis was used to sieve the soil samples [11]. The testing deviated from this method by omitting the specified particle distribution because it was unnecessary for the intended analysis. The sieve shaker used was set up outside the laboratory to prevent cross contamination due to dust. Transfer of dry samples from troughs to the sieve stack was done outside as well. Four sieves were used to separate the fines needed for XRF testing, any sample caught in the sieves were considered overs and were disposed. The four sieves used were #4, 10, 20, and 60. Samples were put on the sieve shaker for 6 minutes. The sample that passes through the #60 sieve was transferred to a clean gallon sized plastic bag with the accompanying sample label.

Figure 4-2 shows Bowie Ching adjusting the sieve shaker before using it on a sample.

Figure 4-2. Sieving (PC: Andres)

4.3 Laboratory XRF Analysis

EPA Method 6200: Field Portable X-Ray Fluorescence Spectrometry for the determination of Elemental Concentrations in Soil and Sediment was used to do XRF testing [12]. XRF testing was done inside on a folding table. Nine clean sample cups were filled with the same sieved sample and covered with XRF thin film. These cups were then put into the XRF test stand and scanned for 90 seconds each. The sample label changed slightly, adding a number 1-9 at the end for each cup (e.g. DU3-2-5 for the fifth cup scanned for sample DU3-2). The XRF device had its own sample numbering which was recorded to pair our sample labels with the XRF sample numbers for data analysis.

Figure 4-3 shows Zachary Kauranen filling XRF sample cups prior to ex-situ analysis.

Figure 4-3. Zack Filling XRF Cups (PC: Jorja)

Figure 4-4 shows the XRF setup used to perform ex-situ analysis.

Figure 4-4. XRF Setup (PC: Jorja)

4.4 Laboratory XRF QA/QC

Laboratory procedures that had the potential to create dust were completed outside, clean gloves were worn when working with samples, and equipment was cleaned after each use to prevent cross contamination. Cleaning of equipment was done outside using compressed air and water. When cleaning sieves, a wire brush was used to remove any stuck rocks within the mesh. Equipment was initially dried inside using paper towels before being dried using compressed air.

5.0 Data Analysis

5.1 XRF In-situ vs Ex-situ Analysis

Statistical analysis was performed on the XRF data from the ex-situ laboratory analysis to the in-situ analysis performed during the site investigation to determine the relationships between XRF in the field and the dried/sieved laboratory samples. Arsenic outliers were identified and removed by the technical advisor for the project, Dr. Bridget Bero. The outliers included all samples that were 2 standard deviations away from the mean for either in-situ readings or ex-situ readings.

Figure 5-1 below displays the correlation between in-situ and ex-situ lead readings.

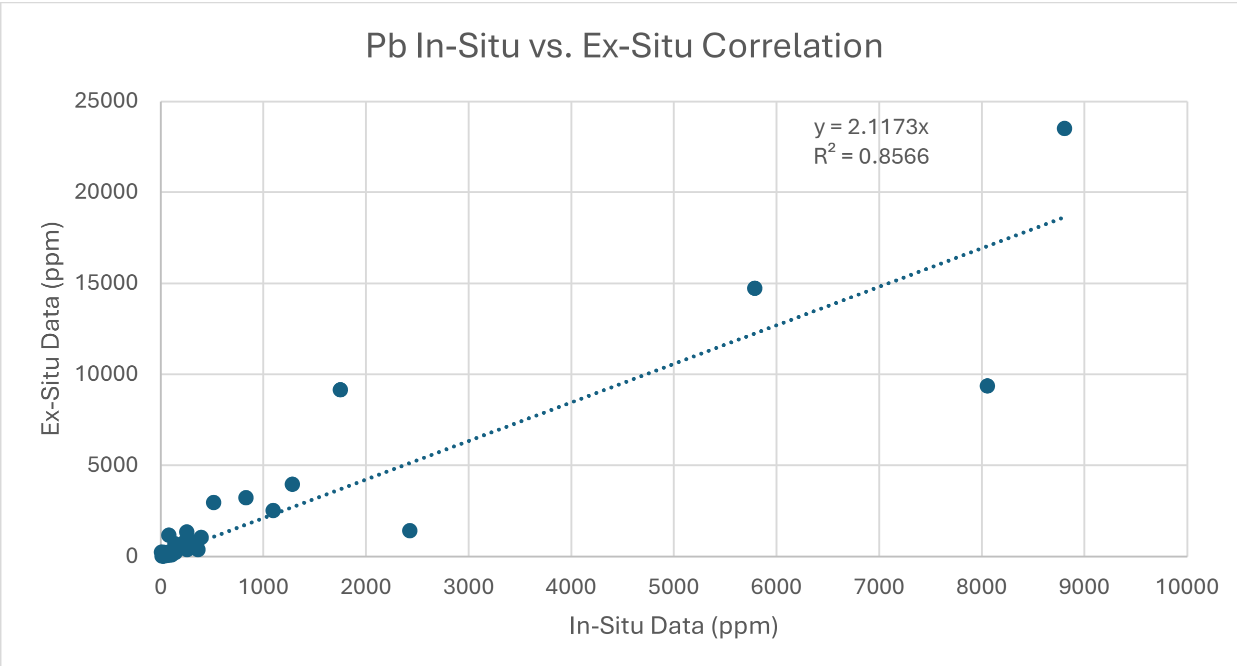

Figure 5-1. Pb In-Situ vs. Ex-Situ

The slope of the best fit line indicates that the ex-situ lead readings were typically 2.12 times larger than the in-situ lead readings.

Figure 5-2 below displays the correlation between in-situ and ex-situ arsenic readings.

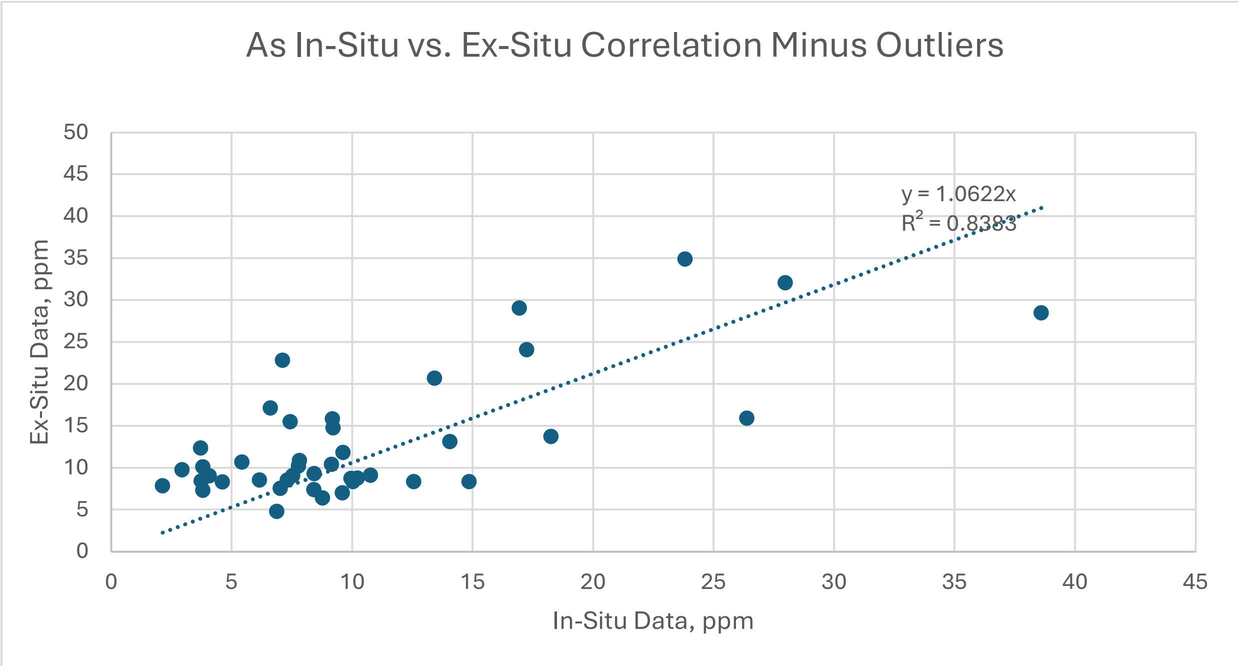

Figure 5-2. As In-Situ vs. Ex-Situ

The slope indicates that ex-situ arsenic readings were typically 1.30 times higher than the in-situ arsenic readings. Ex-situ lead and arsenic readings were likely bigger because the rocks and larger particulate matter have been sieved out leaving silt and clay particles also known as fines. The fines left over after sieving were expected to have higher concentrations of As and Pb due to the ability of metals to sorb to clay surfaces.

5.2 Corrected Arsenic Concentrations

During the XRF data analysis it was determined that the Dragon Mine has high lead levels. This indicated that the arsenic values must be corrected. Lead and arsenic can overlap in XRF measurements because of their similar XRF energy readings. According to EPA Method 6200: “Arsenic concentrations cannot be efficiently calculated for samples with Pb:As ratios of 10:1 or more.” [12] The highest Pb:As ratio discovered from the XRF sample data was 400:1, requiring that the arsenic concentration be corrected. This correction was only done for ex-situ XRF samples because the ex-situ data has much higher concentrations of lead contained in the fines after the sieving process.

The 2021-2022 Northern Arizona BLM capstone team sent their soil samples to Western Technologies who performed an Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) test providing data on the corrected arsenic values. A correlation curve determined by the 2023-2024 Northern Arizona University BLM capstone team was used to calculate the corrected arsenic concentrations [13]. Equation 5-1 is the correlation equation used.

Equation 5-1. Arsenic Correction

$$y = -8 \times 10^{-5}x^2 + 0.9132x$$

Where:

y = Corrected Arsenic Value (ICP)

x = Recorded Arsenic Value (XRF)

Table 5-1 displays the recorded and corrected values for arsenic in decision unit 3.

Table 5-1: DU3 Arsenic Correction

SAMPLE ID	Units	As (XRF)	As (ICP)
DU3-1	ppm	17.17	15.66
DU3-2	ppm	15.87	14.47
DU3-3	ppm	9.33	8.51
DU3-3-D	ppm	13.17	12.01
DU3-4	ppm	24.1	21.96
DU3-5	ppm	22.87	20.84
DU3-6	ppm	28.52	25.98
DU3-7	ppm	12.39	11.30
DU3-8	ppm	11.84	10.80
DU3-9	ppm	20.72	18.89

The corrected values for arsenic from the ICP-OES correlation curve were then used to continue with the rest of the data analysis.

5.3 Identification of Human Health and Ecological COCs

Results of XRF laboratory analysis were compared to the Arizona Soil Remediation Standards (AZSRS) to determine the HH COCs. The HH COCs determined were Pb and As. Ecological COCs were determined by referencing the EPA's Environmental Toxicity (ECOTOX) database. The team determined that the ecological COCs include Pb, Se, As, Zn, Cu, Ni, Co, Mn, Cr, and V. See Tables 5-2 and 5-3 for the HH SRLs and Ecological SRLs respectively.

Table 5-2. HH SRLs

AZ SRLs	Res	Non-Res
Pb	400	800
As	10	10

Table 5-3. Ecological SRLs

ECO Limits	Plants	Soil Invertebrates	Avian	Mammalian
Pb	120	1700	11	56
Se	0.52	4.1	1.2	0.63
As	18		43	46
Zn	160	120	46	79
Cu	70	80	28	49
Ni	38	280	210	130
Co	13		120	230
Mn	220	450	4300	4000
Cr			26	34
V			7.8	280

See HH COC tables and Ecological COC tables in Appendix D.

5.4 Data Distributions

Histograms were created for each DU to determine if the data was normally distributed or log normally distributed. It was determined that each DU was log normally distributed except for DU 5 which was normally distributed because it was collected using ISM. Some distributions do not look normally distributed after being transformed, this is likely due to the small sampling sizes. This suggests those results may have a higher degree of uncertainty.

Figures 5-3 through 5-8 display the log normal distribution of both lead and arsenic in decision units 1, 3, and 4.

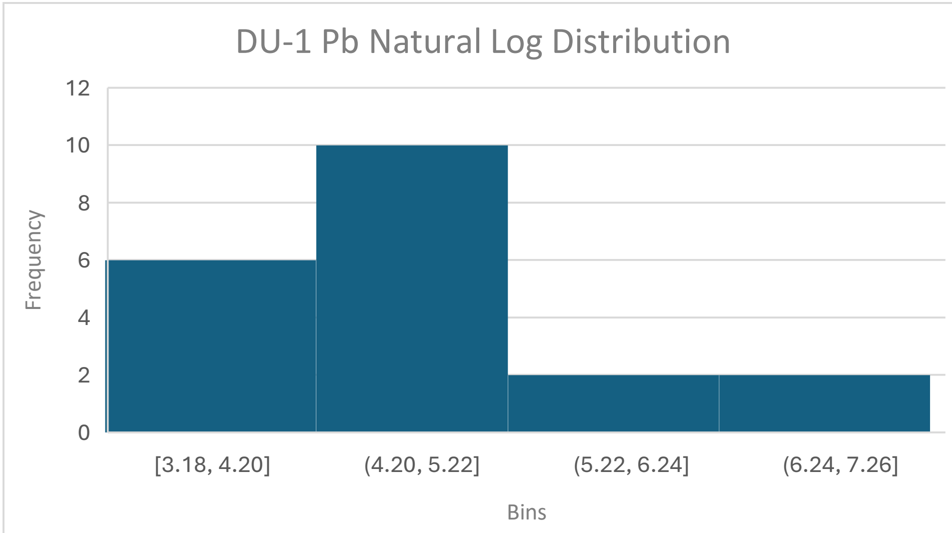

Figure 5-3. DU-1 Lead Distribution

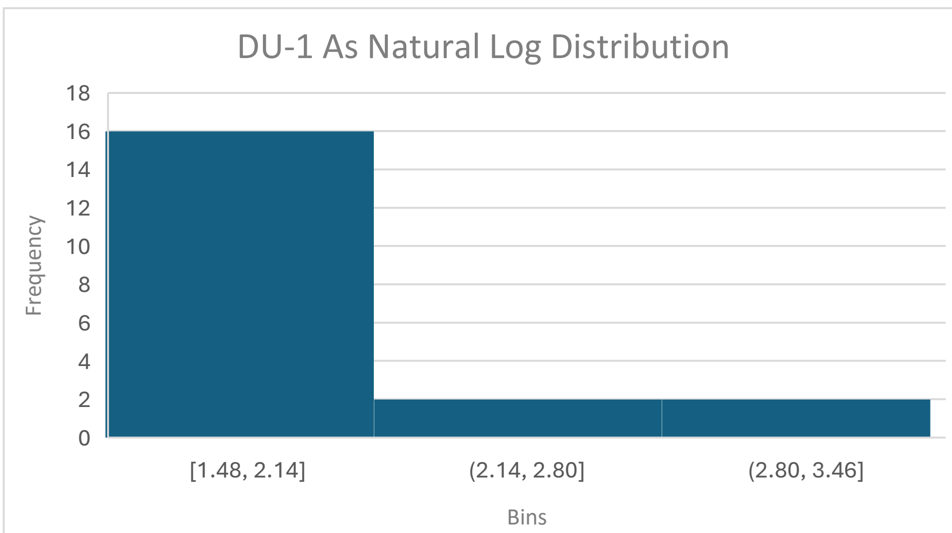

Figure 5-4. DU-1 Arsenic Distribution

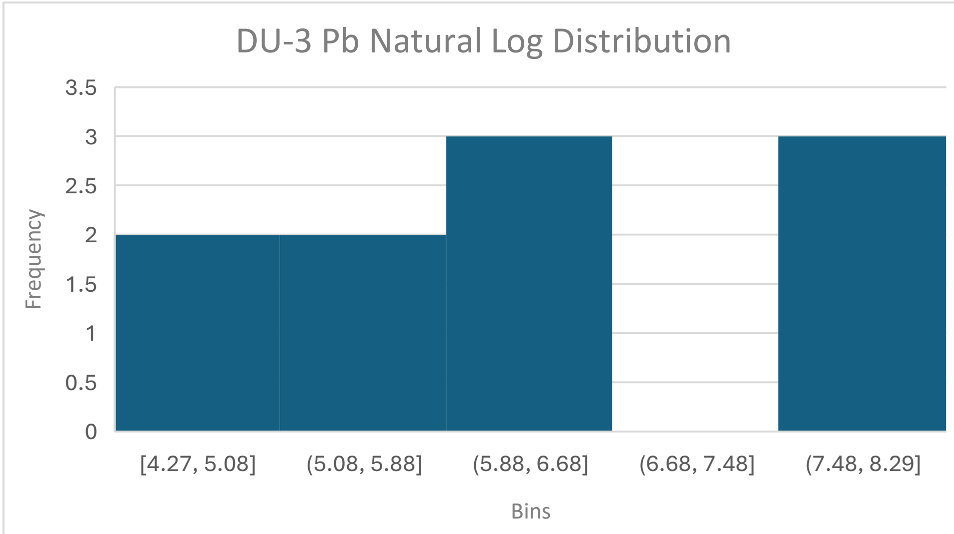

Figure 5-5. DU-3 Lead Distribution

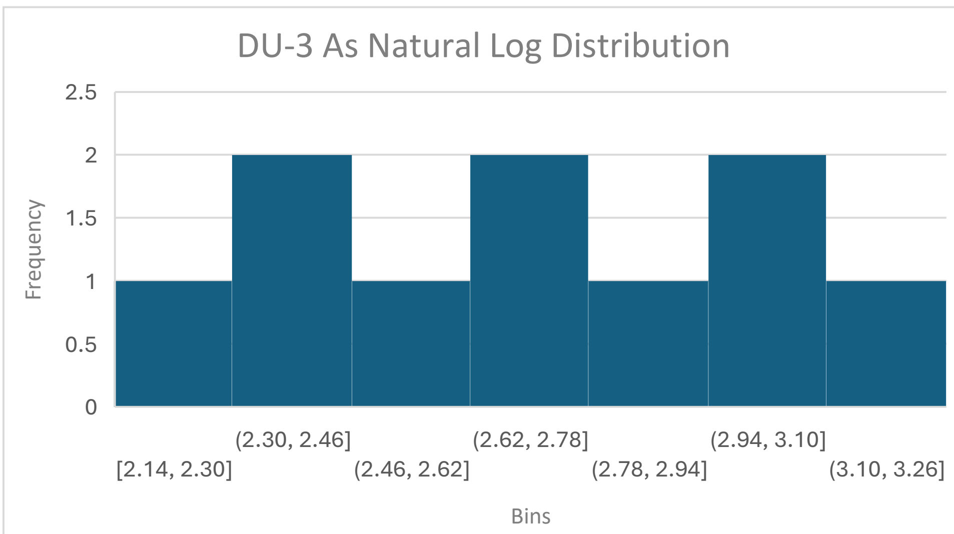

Figure 5-6. DU-3 Arsenic Distribution

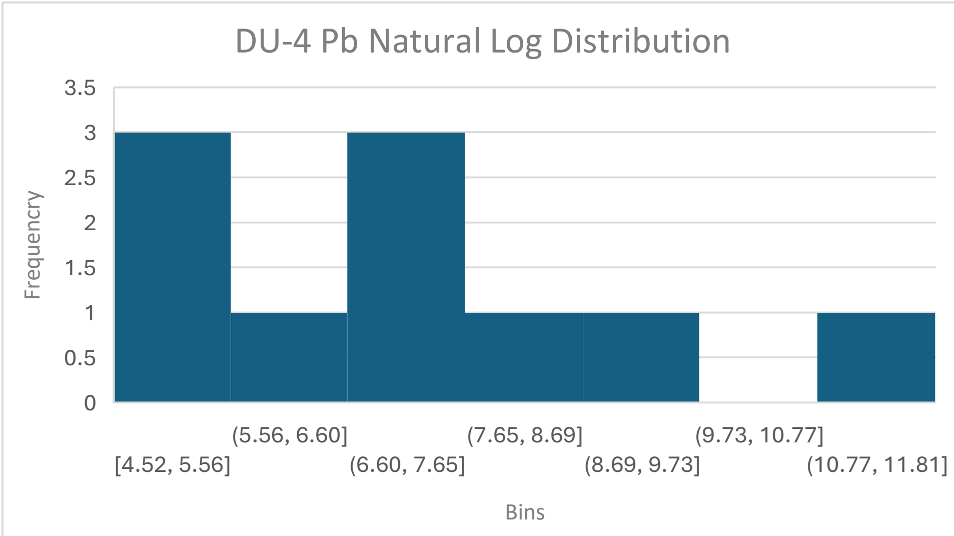

Figure 5-7. DU-4 Lead Distribution

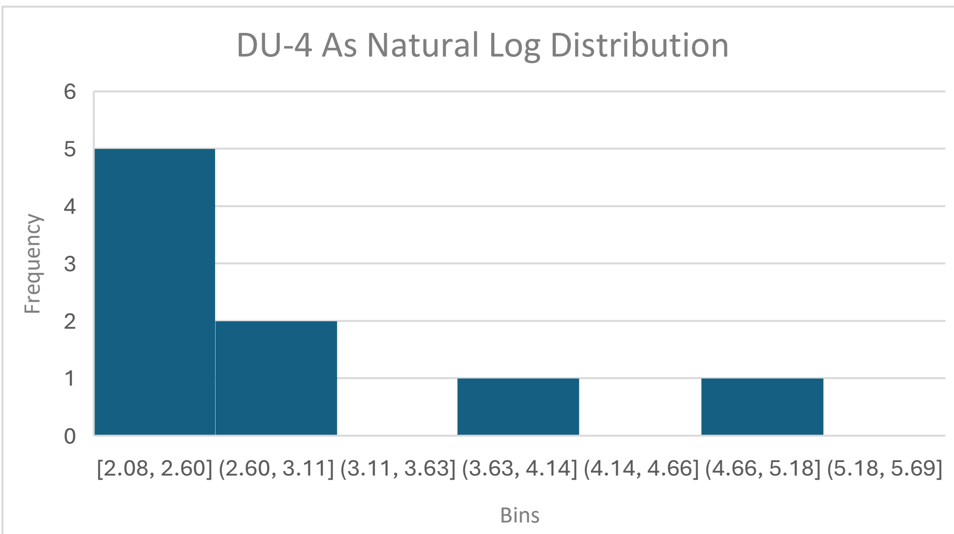

Figure 5-8. DU-4 Arsenic Distribution

5.5 QA/QC Analysis

Analysis of quality control samples was performed to evaluate precision of soil concentration data. Four duplicate samples were collected at the site. According to Appendix B of the SAP, the Relative Percent Difference (RPD) must be below 50% [14]. The RPD was calculated using Equation 5-2 below.

Equation 5-2. Relative Percent Difference

$$RPD = |S_i - S_d| \left(\frac{(S_i + S_d)}{2} \right) * 100\%$$

Where:

RPD = Relative Percent Difference

S_i = Original Sample Concentration

S_d = Duplicate Sample Concentration

Table 5-4 below displays the results of the duplicate analysis.

Table 5-4. Duplicate Analysis Results

Sample ID	Corrected As Initial (ppm)	Corrected As Duplicate (ppm)	As RPD (%)	Pb Initial (ppm)	Pb Duplicate (ppm)	Pb RPD (%)
DU-1-2	7.35	8.45	13.90	102.75	73.94	32.61
DU-1-11	7.05	7.57	7.07	227.45	159.17	35.32
DU-3-3	9.33	13.17	34.13	532.97	383.66	32.58
DU-4-5	8.77	13.17	40.11	1052.59	1348.6	24.66

All RPD values are below 50% which indicates that the sampling procedures were of good quality.

5.6 Identification of Exposure Point Concentrations for all COCs

Statistical analysis was performed on the COC datasets to determine the distribution of the data to calculate the 50% and 95% Exposure Point Concentrations (EPCs) for each COC. DUs 1, 3, and 4 were determined to be log distributed, so the log data will be used to calculate the EPCs. DU 5 was normally distributed so the original data will be used to calculate the EPCs. The 50% EPC for DUs 1, 3, and 4 was calculated by finding the geometric mean, Equation 5-3 below shows the geometric mean equation.

Equation 5-3. Geometric Mean Equation

$$50\%EPC = \sqrt[n]{(X_1 * X_2 *\ldots* X_n}$$

Where:

EPC = Exposure Point Concentration

X = Lead or Arsenic Readings

n = Number of Readings

The 50% EPC for DU 5 was determined by finding the arithmetic mean of the data set. Equation 5-4 shows the arithmetic mean equation.

Equation 5-4. Arithmetic Mean Equation

$$50\%EPC = \frac{X_1 + X_2 + \ldots + X_n}{n}$$

Where:

EPC = Exposure Point Concentration

X = Lead or Arsenic Readings

n = Number of Readings

The 95% EPC for DU 5 was found by taking the 50% EPC and adding 2 standard deviations because it is normally distributed. The 95% EPCs for DU 1, DU 3, and DU 4 were determined using Equation 5-5, the Cox equation, displayed below.

Equation 5-5. Cox Equation

$$95\%EPC = 50\%EPC + \frac{S^2}{2} + 1.645\sqrt{\frac{S^2}{n} + \frac{S^4}{2(n-1)}}$$

Where:

EPC = Exposure Point Concentration

S= Standard Deviation

n = Number of Samples

See the 50% and 95% EPCs in Tables 5-5 and 5-6 below.

Table 5-5. Lead EPCs

Lead	50% EPC (mg/kg)	95% EPC (mg/kg)
DU-1	98.37	266.55
DU-3	556.52	4246.07
DU-4	711.18	10906.7
DU-5	262.54	308.81

Table 5-6. Arsenic EPCs

Arsenic	50% EPC (mg/kg)	95% EPC (mg/kg)
DU-1	8.47	11.19
DU-3	15.15	19.62
DU-4	16.57	46.15
DU-5	6.47	8.85

6.0 Contaminant Pathways

6.1 Contaminant Distribution Maps

6.1.1 Human Health Contaminants of Concern

Human Health COCs were determined using Arizona SRLs shown in Table 5-2. Figure 6-1 displays the Pb HH summary ex-situ contaminant distribution map with sample locations colored based on contamination.

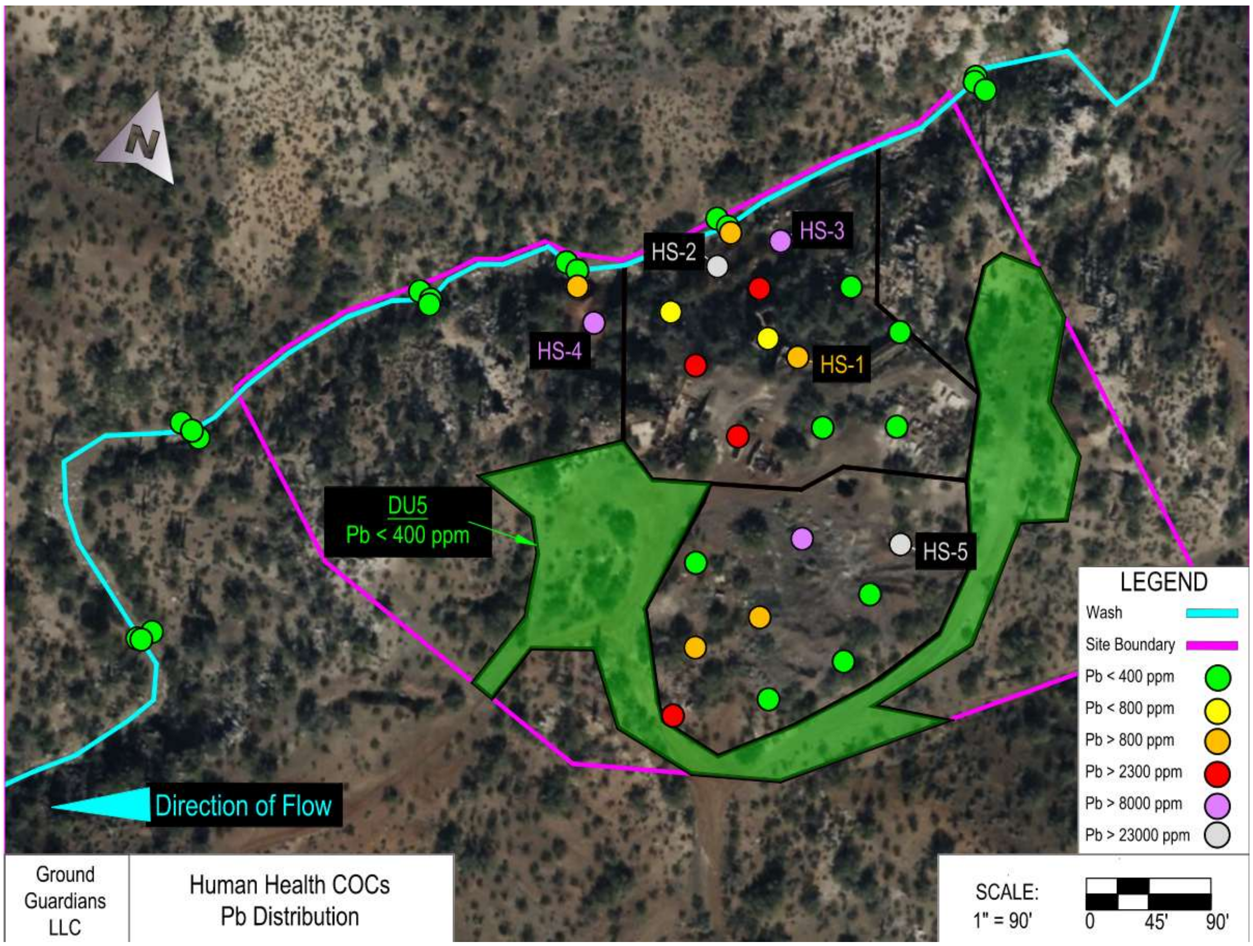

Figure 6-1. Summary Lead Ex-Situ Contaminant Distribution Map

Figure 6-2 displays the As HH summary ex-situ contaminant distribution map with sample locations colored based on contamination.

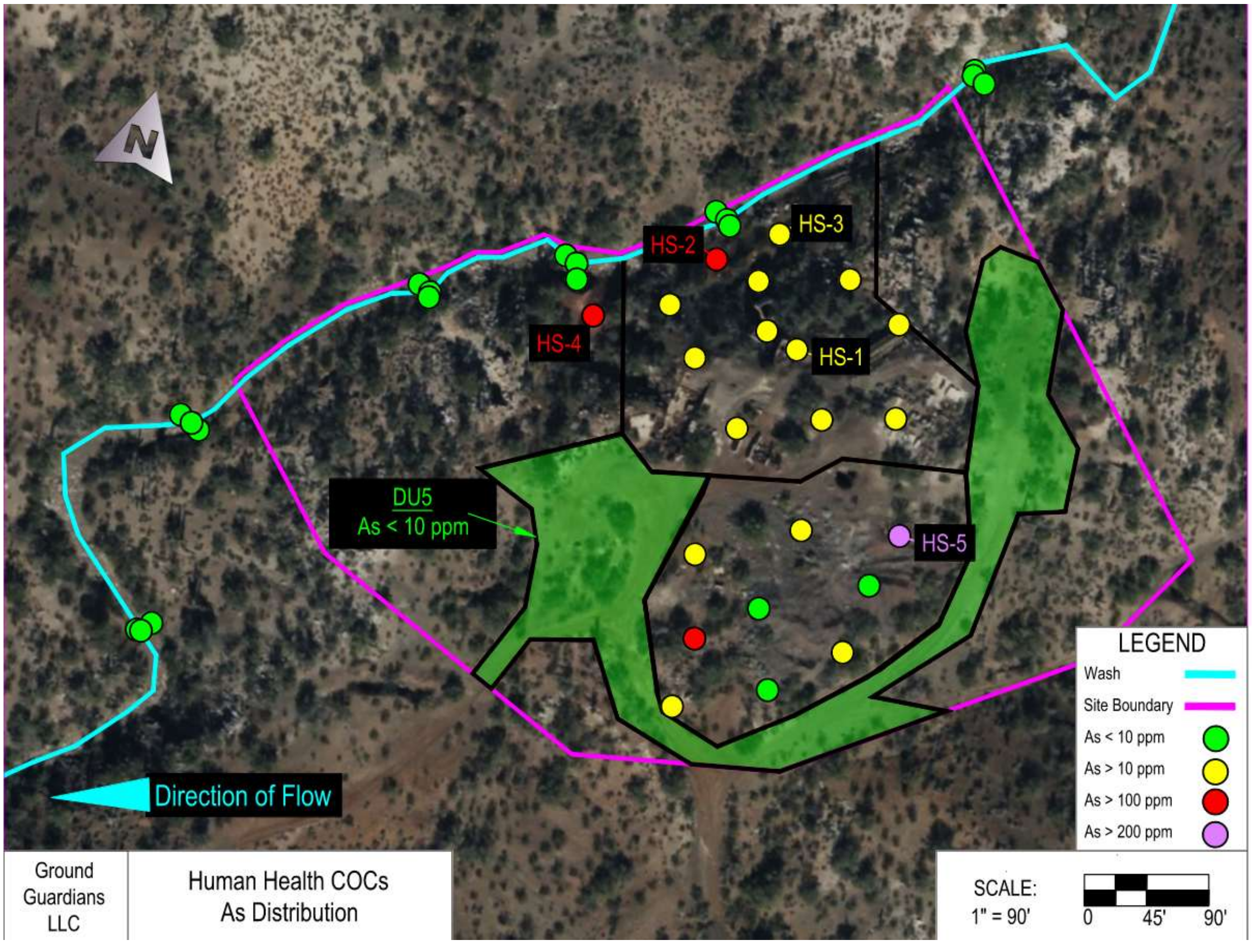

Figure 6-2. Summary As Ex-Situ Contaminant Distribution Map

Figure 6-3 displays the Pb HH DU-1 ex-situ contaminant distribution map with sample locations colored based on contamination.

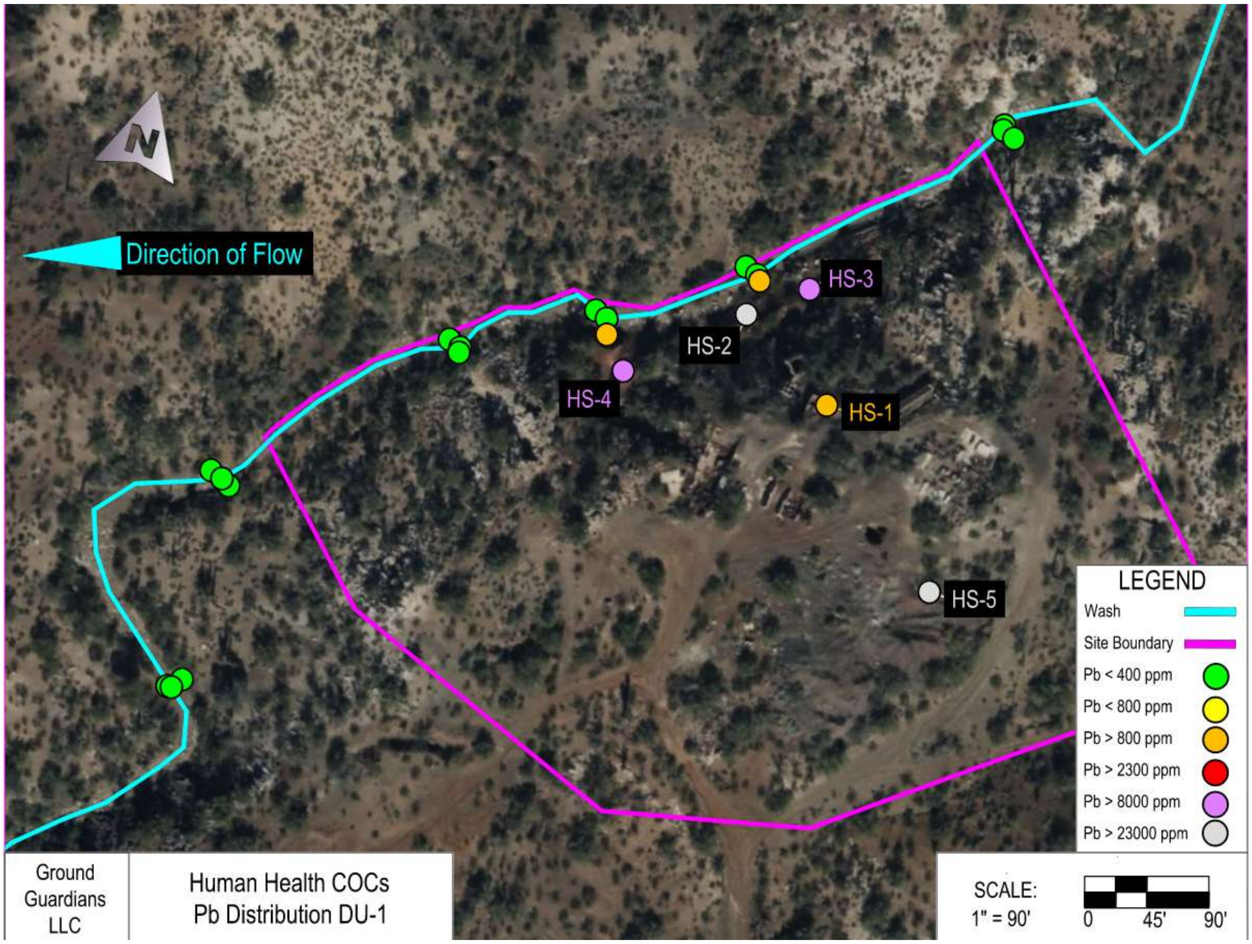

Figure 6-3. DU-1 Lead Ex-Situ Contaminant Distribution Map [5]

Figure 6-4 displays the As HH DU-1 ex-situ contaminant distribution map with sample locations colored based on contamination.

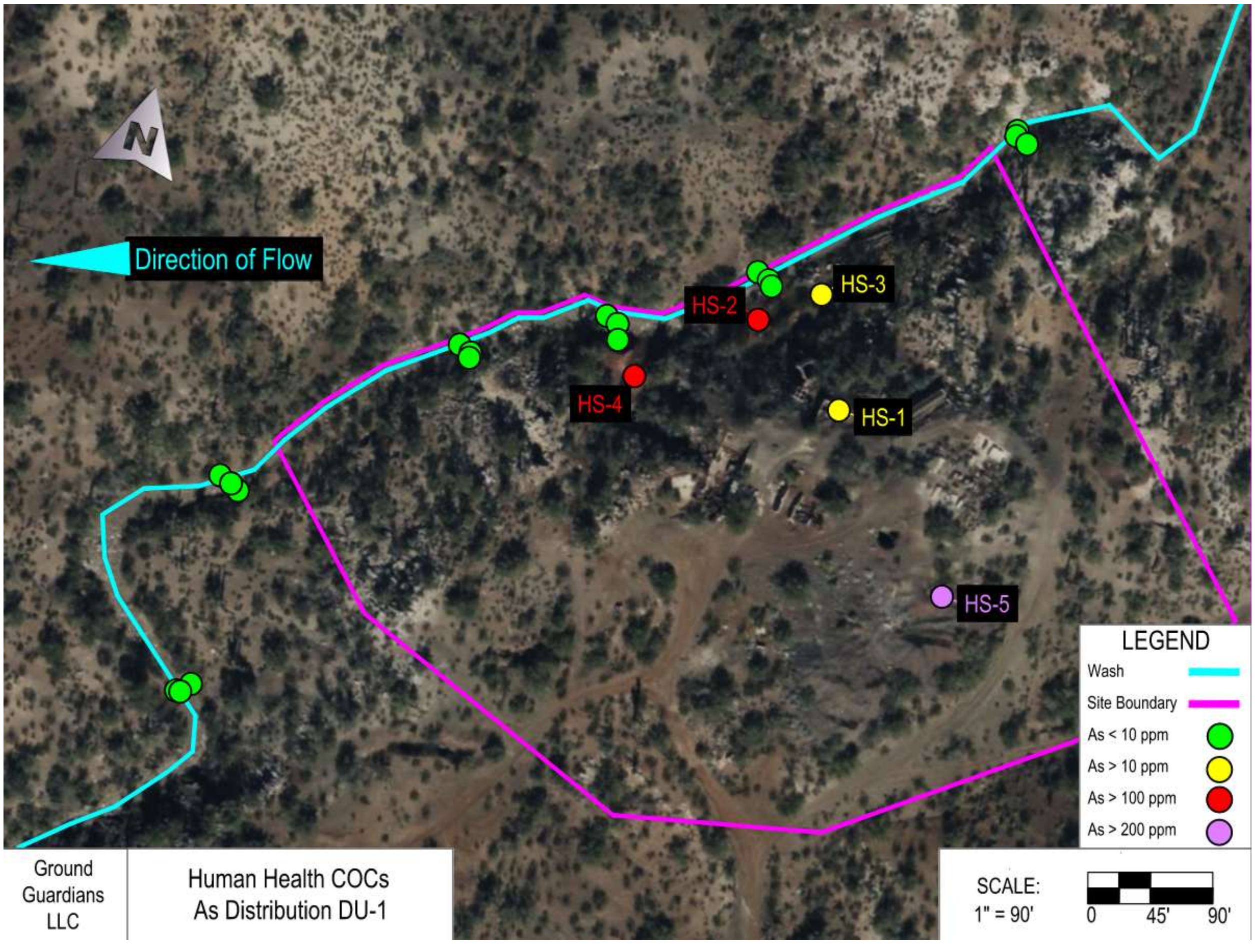

Figure 6-4. DU-1 Arsenic Ex-Situ Contaminant Distribution Map [15]

Figure 6-5 displays the Pb HH DU-3 and hot spot ex-situ contaminant distribution map with sample locations colored based on contamination.

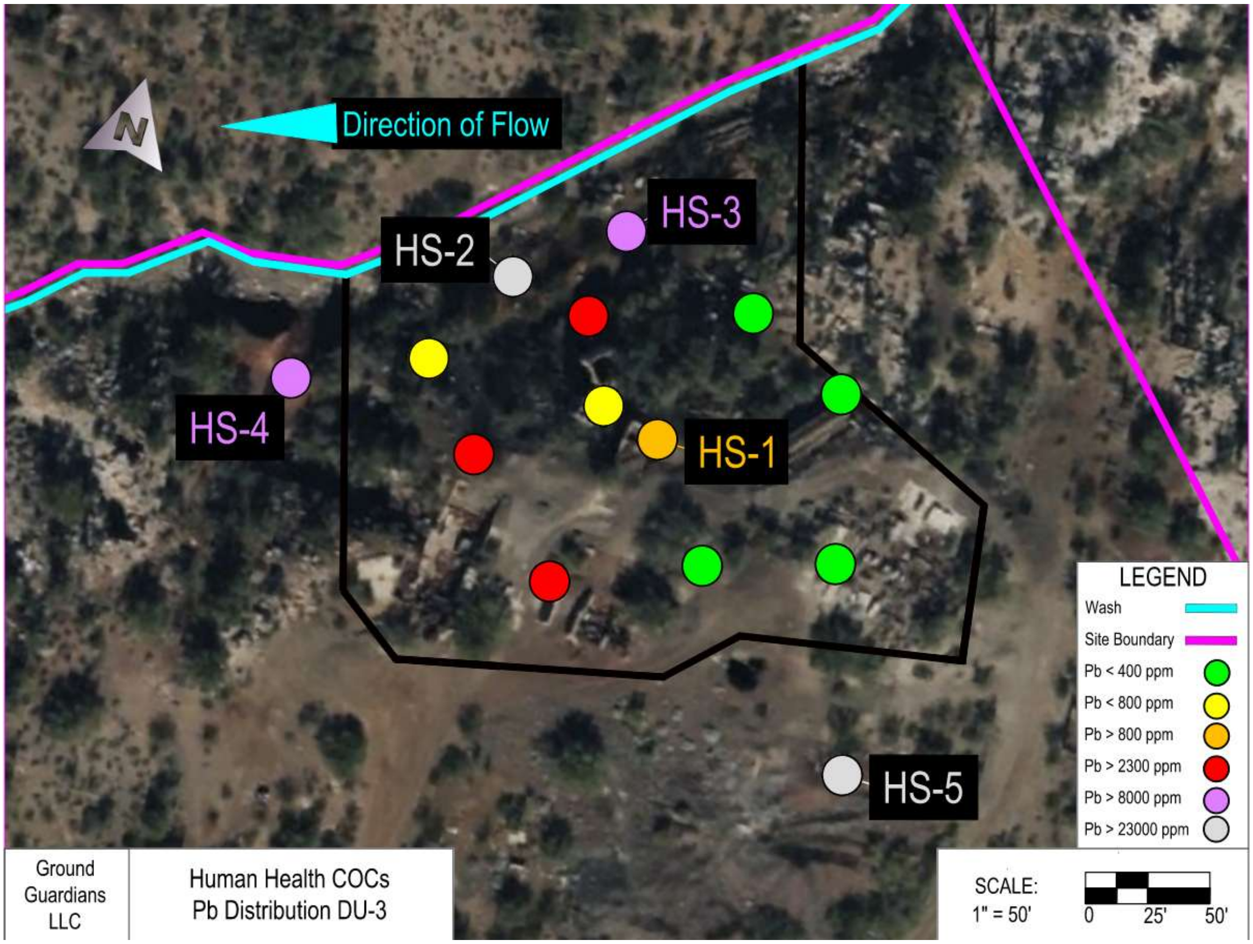

Figure 6-5. DU-3/HS Lead Ex-Situ Contaminant Distribution Map

Figure 6-6 displays the As HH DU-3 and hot spot ex-situ contaminant distribution map with sample locations colored based on contamination.

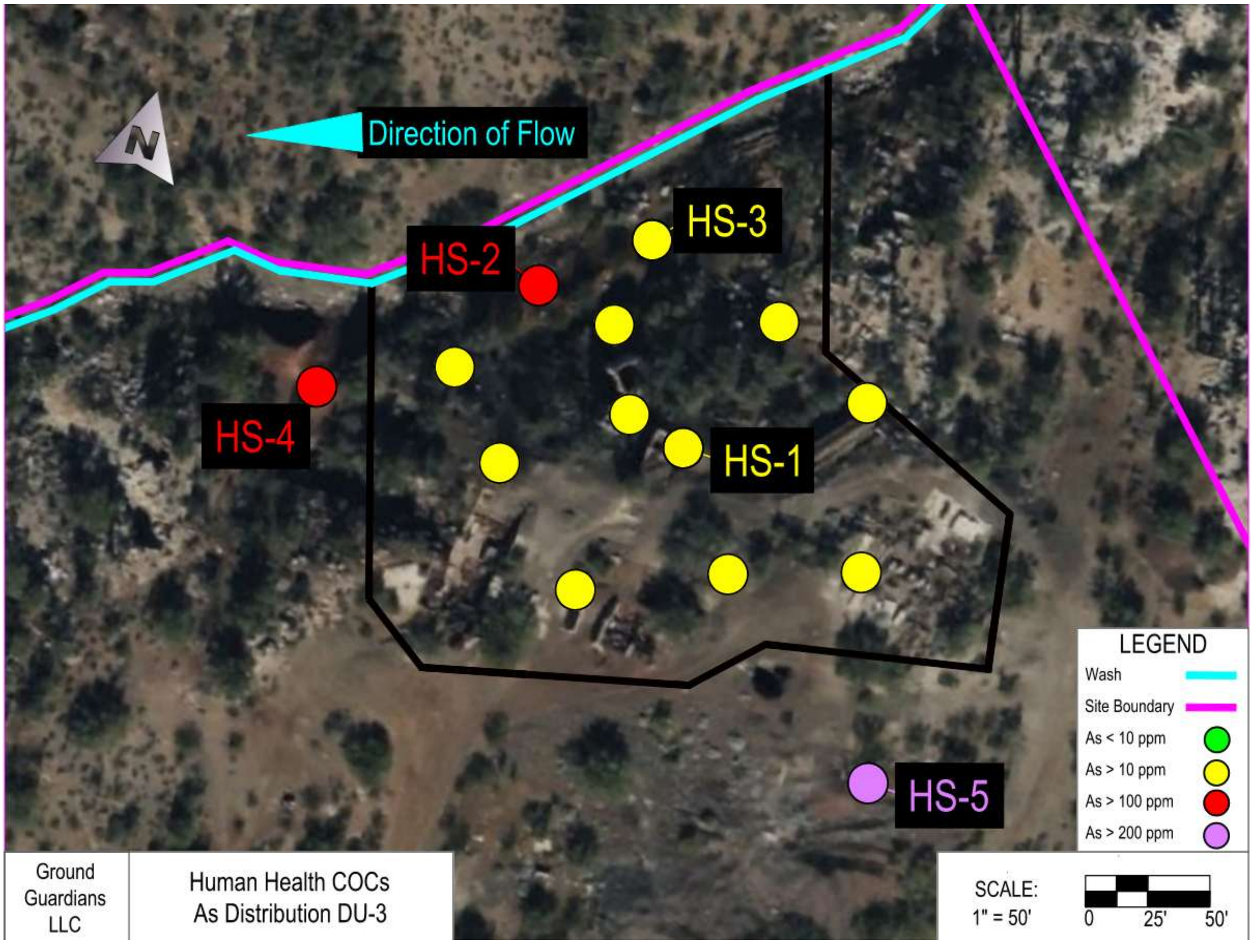

Figure 6-6. DU-3/HS Arsenic Ex-Situ Contaminant Distribution Map

Figure 6-7 displays the Pb HH DU-4 ex-situ contaminant distribution map with sample locations colored based on contamination. HS-5 does not represent the conditions of contamination for DU-4. The satellite imagery of the area suggests the location of HS-5 is more disturbed than the remainder of DU-4. The unusually high concentration is believed to be from a bullet fragment or tailings material. It is evident that the site is a common shooting area for recreational visitors and is possible that fragments of lead bullets were collected in the HS-5 sample.

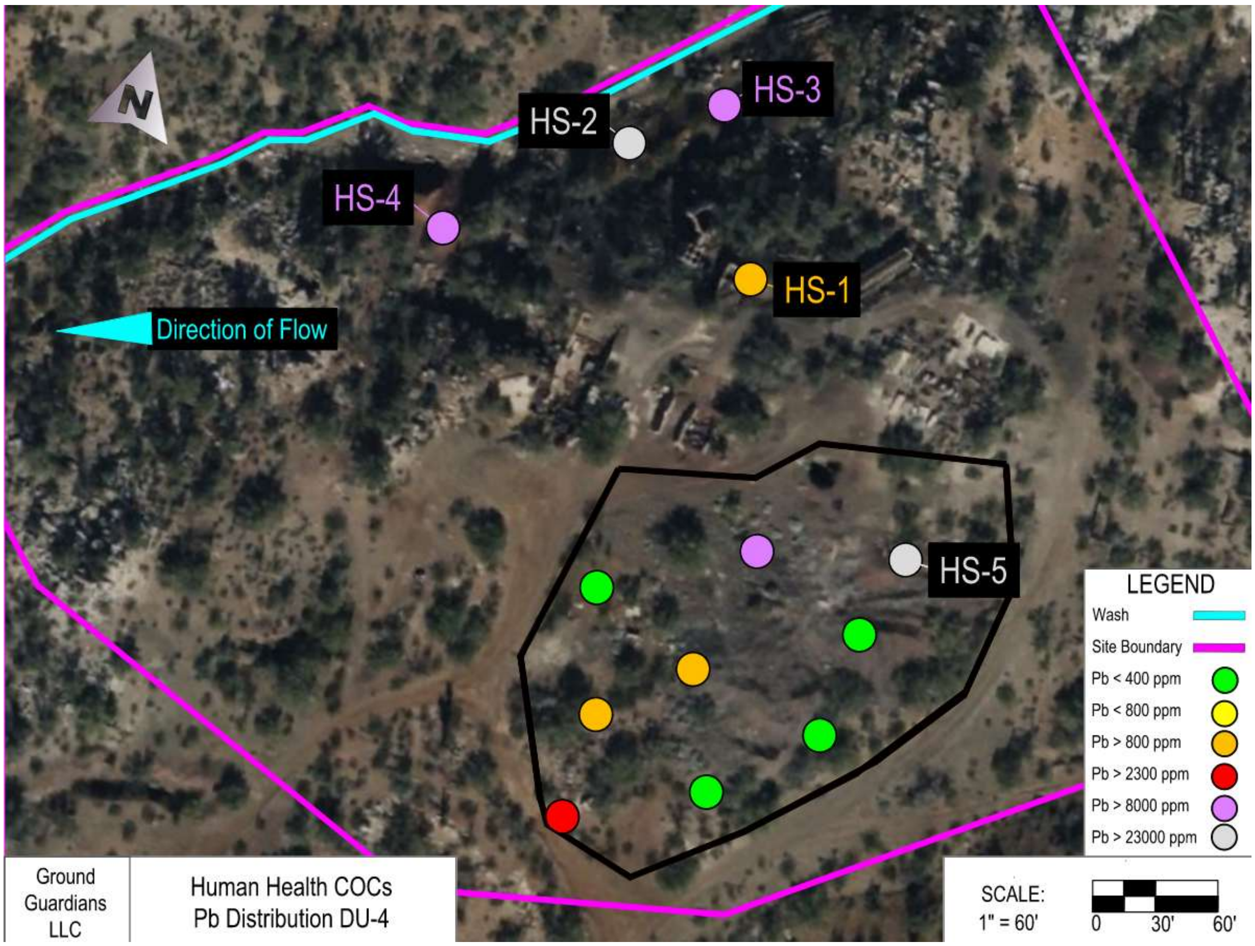

Figure 6-7. DU-4 Lead Ex-Situ Contaminant Distribution Map

Figure 6-8 displays the As HH DU-4 ex-situ contaminant distribution map with sample locations colored based on contamination.

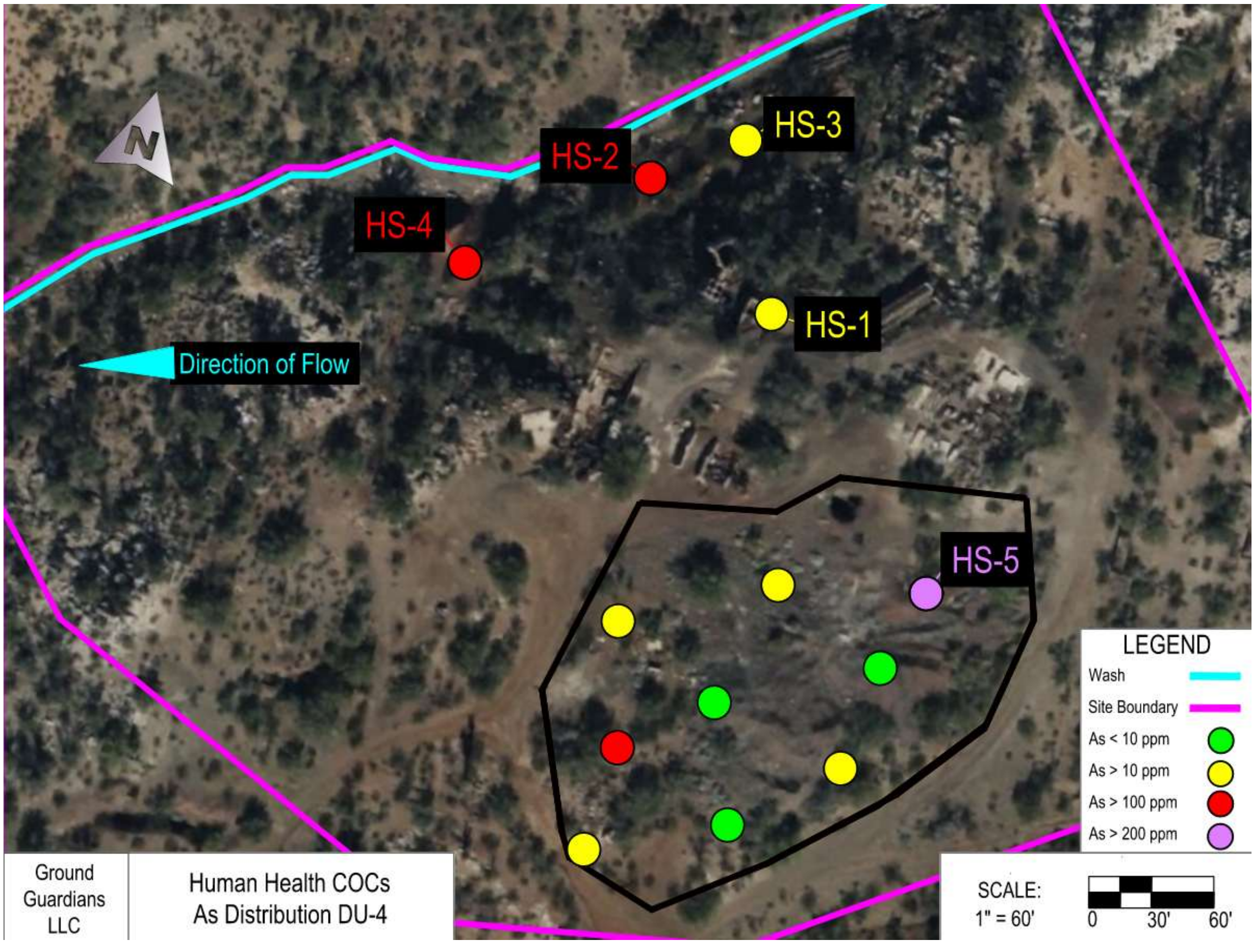

Figure 6-8. DU-4 Arsenic Ex-Situ Contaminant Distribution Map

Figure 6-9 displays the Pb HH DU-5 ex-situ contaminant distribution map with sample locations colored based on contamination.

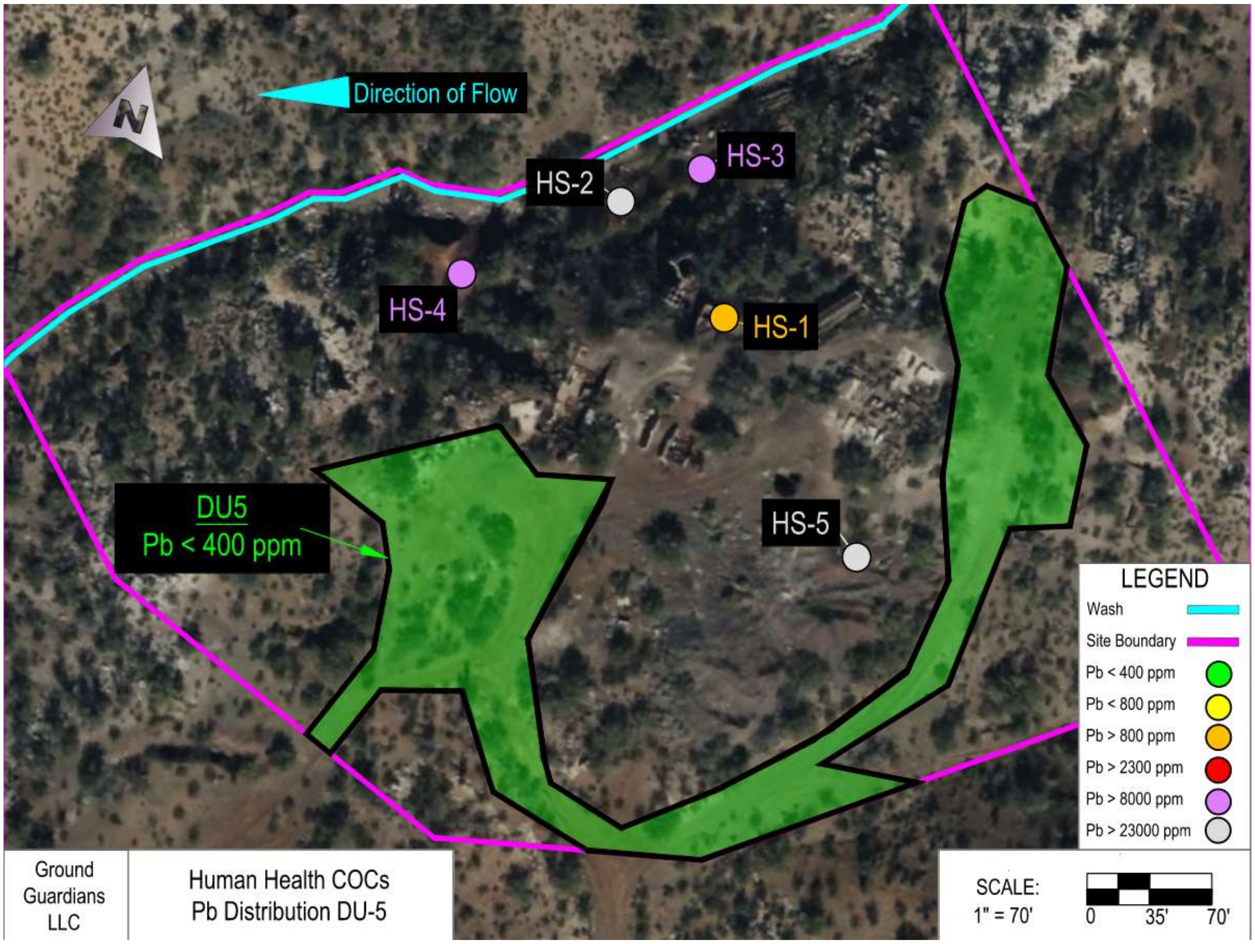

Figure 6-9. DU-5 Lead Ex-Situ Contaminant Distribution Map

Figure 6-10 displays the As HH DU-5 ex-situ contaminant distribution map with sample locations colored based on contamination.

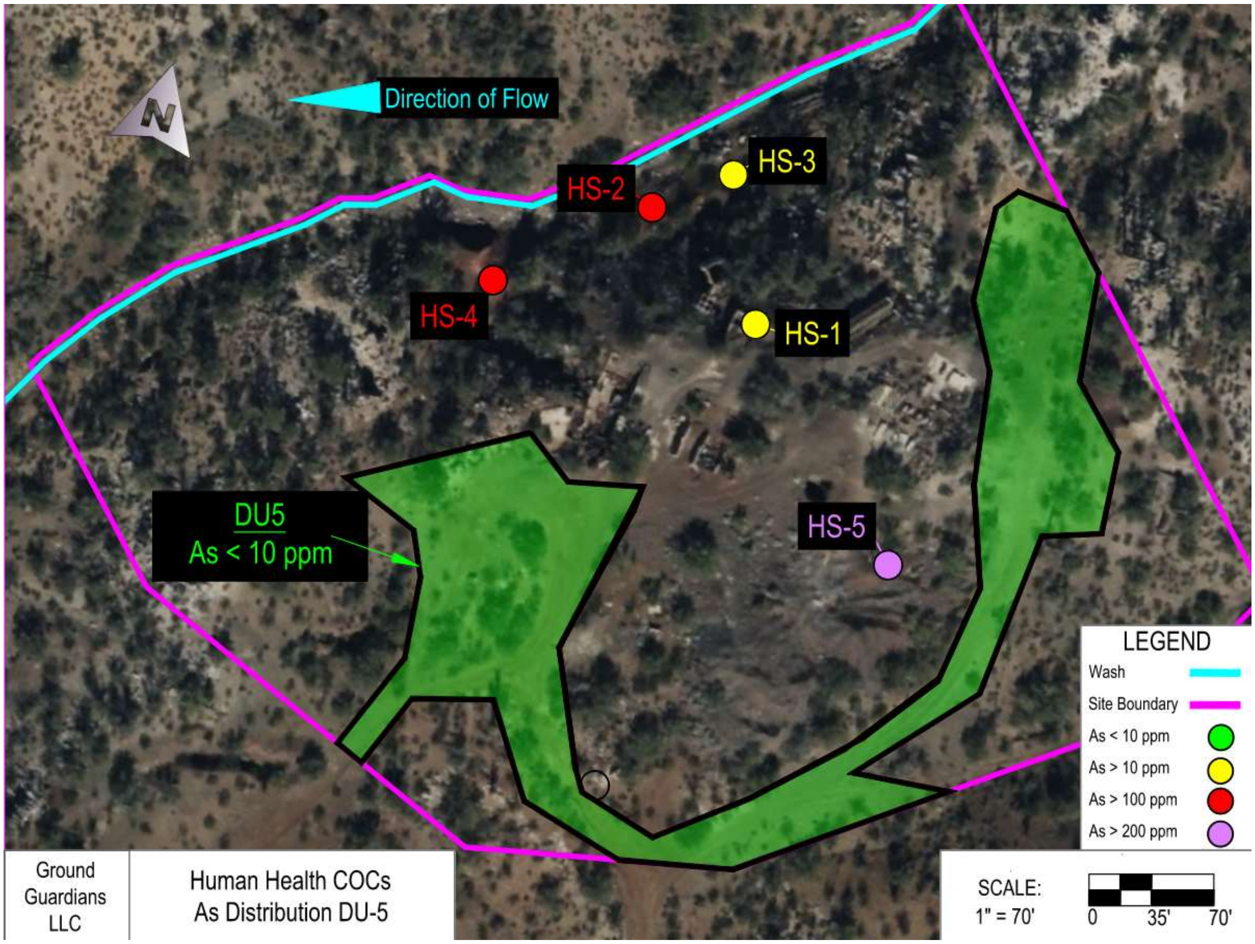

Figure 6-10. DU-5 Arsenic Ex-Situ Contaminant Distribution Map

Figure 6-11 displays the Pb HH BG ex-situ contaminant distribution map with sample locations colored based on contamination.

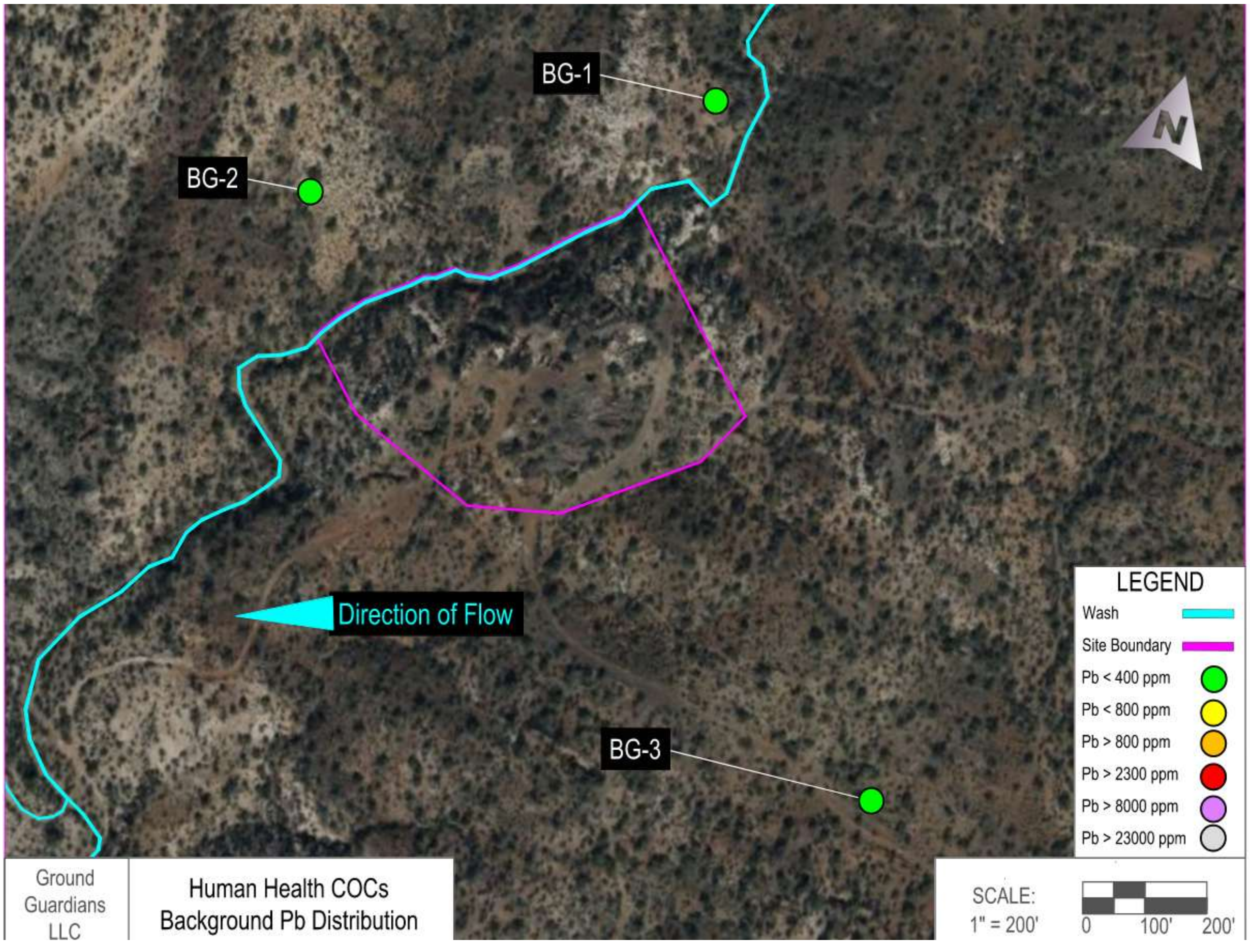

Figure 6-11. BG Lead Ex-Situ Contaminant Distribution Map

Figure 6-12 displays the As HH BG ex-situ contaminant distribution map with sample locations colored based on contamination.

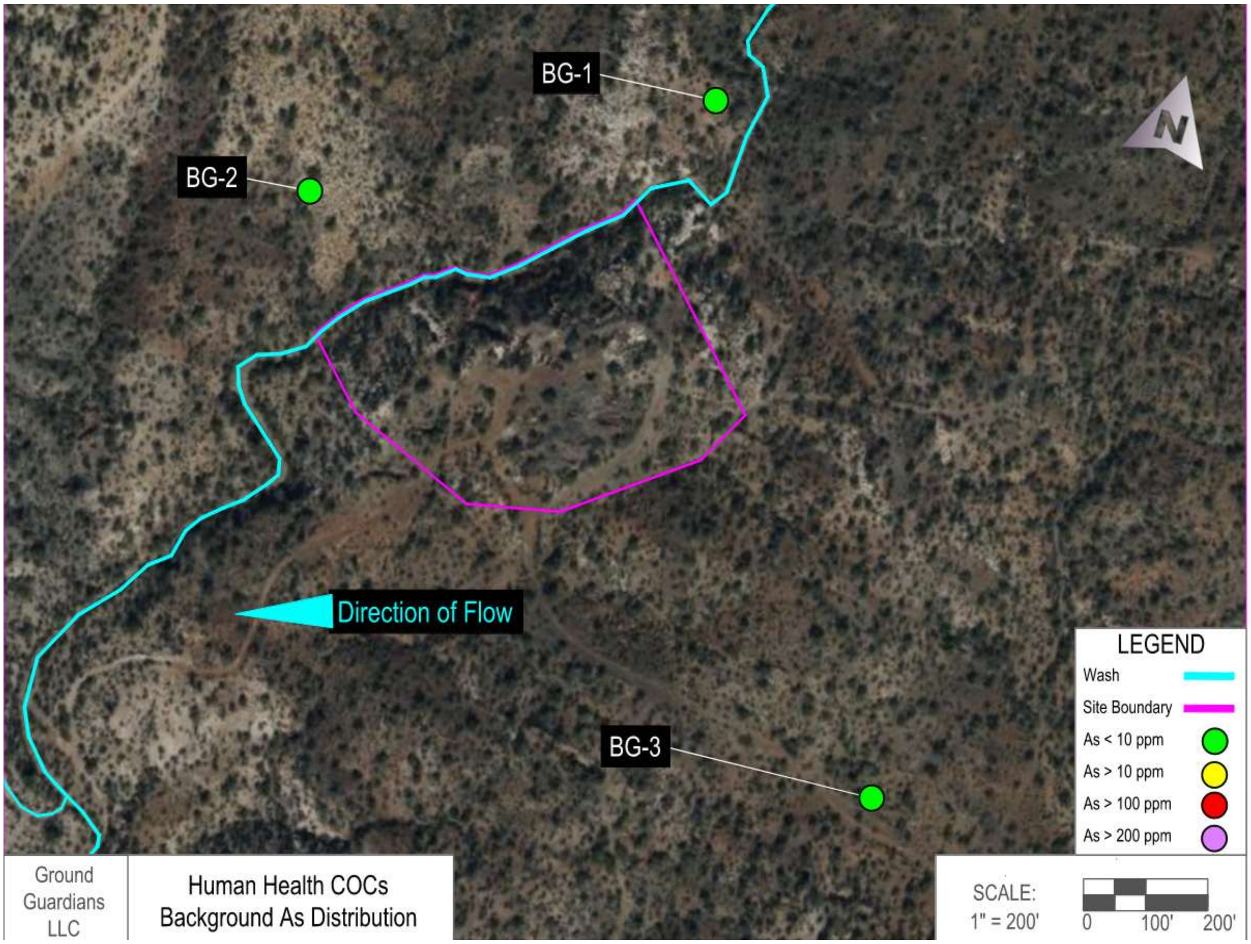

Figure 6-12. BG Arsenic Ex-Situ Contaminant Distribution Map

According to the HH contaminant distribution maps DU-3 and all the HS samples are significantly contaminated above the AZ non-residential SRLs for both Pb and As. A majority of DU-4 is also contaminated with As and Pb above the AZ non-residential SRLs. While DU-1 is not contaminated currently, the maps suggest the contaminants from DU-3 may migrate into the wash over time. Remedial action is needed to address site conditions for future occupational purposes and to prevent further contaminant migration into the wash.

6.1.2 Ecological Contaminants of Concern

Ecological COCs were determined using Arizona SRLs shown in Table 5-2. Figure 6-13 displays the Pb Ecological summary ex-situ contaminant distribution map with sample locations colored based on contamination.

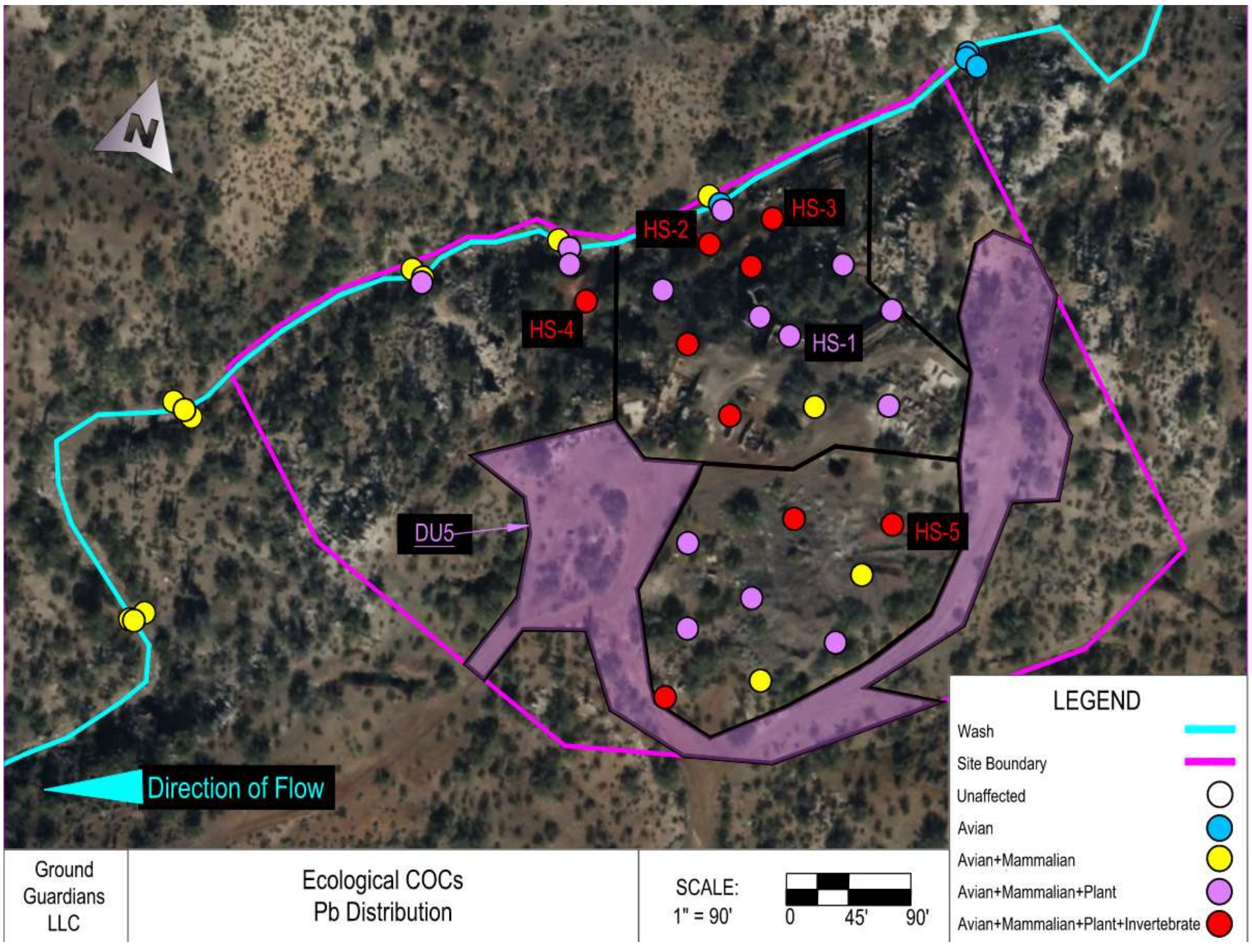

Figure 6-13. Lead Ecological Contaminant Distribution Map

Figure 6-14 displays the As Ecological summary ex-situ contaminant distribution map with sample locations colored based on contamination.

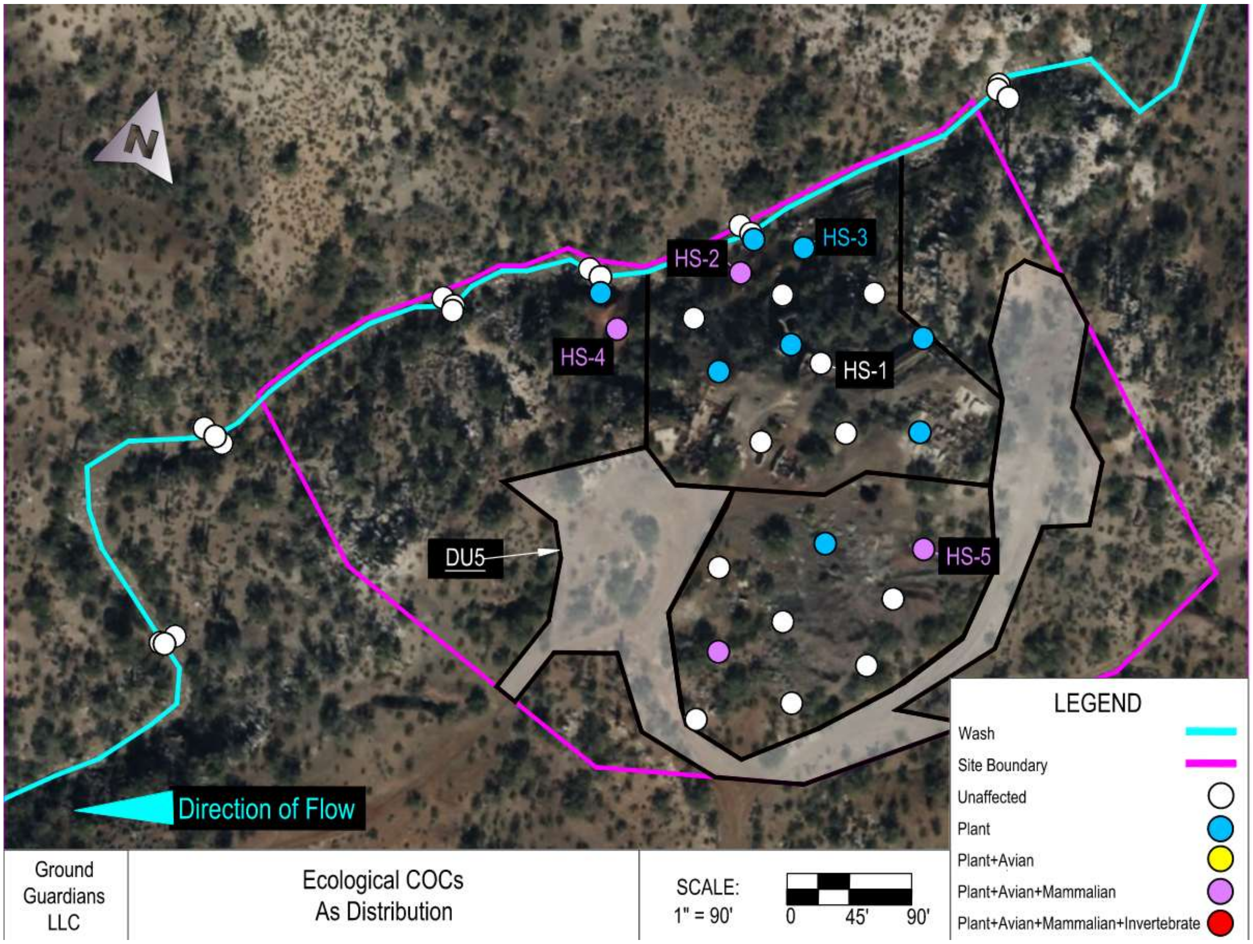

Figure 6-14. Arsenic Ecological Contaminant Distribution Map

According to the ecological contaminant distribution maps, Pb is a much more significant concern for all ecological species on site as compared to As. Ecological contaminant migration of Pb is also significantly worse as compared to HH Pb contaminant migration down the wash. Remedial action to address HH contamination will also address the concerns of ecological contamination. DU-3, DU-4, and all HS samples will need to be addressed. See all other ecological contaminant maps in Appendix E.

6.1.1 Conceptual Site Model

Figure 6-15 shows the conceptual site model of the Dragon Mine site. The model displays the sources of contamination and the pathways that COCs could reach humans, plants, and wildlife.

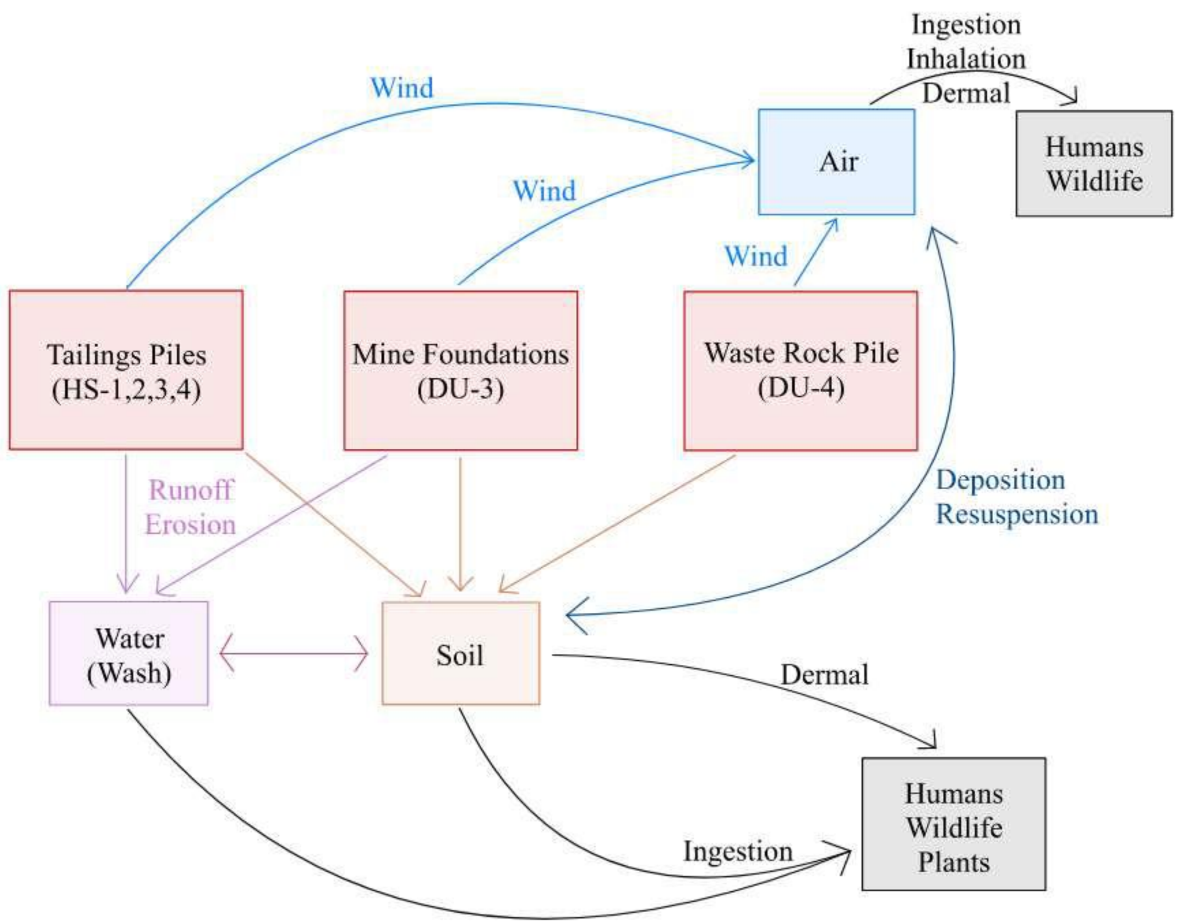

Figure 6-15. Conceptual Site Model

7.0 Human Health Risk Assessment

7.1 Human Health Exposure Assessment

The HH risk assessment for this site includes ingestion and dermal exposure to contaminated soils.

Using 50% EPCs, average exposure scenarios were determined. 95% EPCs were used to calculate the worst-case exposure scenarios. The exposure scenarios provide the intake doses for arsenic and lead for both ingestion and dermal contact. Arsenic requires both carcinogenic and non-carcinogenic intakes.

Worker exposure scenarios and recreational exposure scenarios were completed for both ingestion and dermal contact. A residential exposure scenario was not completed because there are no residences near the site.

7.1.1 Worker Exposure Scenario

The worker exposure scenario is based on people working at the site for remediation efforts. The remediation time is estimated to be 1 year, with 8-hour days, 5 days a week, for 50 weeks per year. Remediation work is assumed to be primarily done on DU-3 and DU-4 because those are the areas with the highest concentrations of COCs.

Table 7-1 shows the ingestion exposure parameters for the worker exposure scenario.

Table 7-1. Worker Exposure Parameters – Ingestion

Worker Exposure Scenario Parameters - Ingestion	
Contact Rate (mg soil/ day)	100
Exposure Frequency (hours/day)	8
Exposure Duration (days)	250
Average Body Weight (kg) [16]	70
Averaging Time, Non-Carcinogenic (days) [16]	250
Averaging Time, Carcinogenic (year) [16]	70

Equation 7-1 was used to determine the daily intake dose of arsenic for an ingestion exposure scenario.

Equation 7-1. Intake Dose

$$I = \frac{(C \cdot CR \cdot EF \cdot ED)}{BW \cdot AT \cdot \frac{24\,hours}{day}} \cdot 10^{-6}$$

Where:

I = Intake (mg COC/kg of body weight-day))

C = Concentration at Exposure Point (EPC in mg COC/kg soil)

CR = Contact Rate (mg soil/day)

EF = Exposure Frequency (hours/day)

ED = Exposure Duration (days)

BW = Body Weight (kg)

AT = Averaging Time (days)

Table 7-2 shows the calculated daily arsenic ingestion intake doses for workers in DU-3 and DU-4.

Table 7-2. Worker Scenario Arsenic Ingestion Intake Doses

Worker Exposure Scenario – Arsenic Ingestion				
	Carcinogenic		Non-Carcinogenic	
	50% EPC Intake Dose (mg/(kg-day))	95% EPC Intake Dose (mg/(kg-day))	50% EPC Intake Dose (mg/(kg-day))	95% EPC Intake Dose (mg/(kg-day))
DU-3	9.79E-08	1.27E-07	6.85E-06	8.88E-06
DU-4	1.07E-07	2.98E-07	7.50E-06	2.09E-05

The EPA document *Risk Assessment Guidance for Superfund* (RAGS) Part E "Guidance for Dermal Risk Assessment" was used to determine the area of skin exposed. The skin exposed includes the head, neck, hands and arms only [17]. RAGS also recommends a general dust adherence of 0.2 mg dust/cm^2 for adult workers [17]. An absorption factor of 4 percent (.04) will be used because it is the default point estimate for dermal uptake of arsenic [18]. The exposure frequency represents the number of times a day workers get "dirty". It is assumed workers have 3 breaks each workday and return to work on 4 events. When they go back to work, they are re-exposed.

Table 7-3 shows the dermal exposure parameters for the worker exposure scenario.

Table 7-3. Worker Dermal Exposure Parameters

Worker Exposure Scenario Parameters - Dermal	
Skin Exposed (cm^2) [17]	2500
Dust Adherence (mg dust/cm^2) [17]	0.2
Absorption Factor (unitless) [18]	0.03
Exposure Frequency (events/day)	4
Exposure Duration (days)	250
Average Body Weight (kg) [16]	70
Averaging Time, Non-Carcinogenic (days) [16]	250
Averaging Time, Carcinogenic (year) [16]	70

The parameters from Table 7-3 were used with Equation 7-2 to calculate the daily arsenic dermal intake doses for workers in DU-3 and DU-4.

Equation 7-2. Arsenic Daily Intake Doses

$$I = \frac{(C \cdot S \cdot DA \cdot AF \cdot EF \cdot ED)}{BW \cdot AT} \cdot 10^{-6}$$

Where:

I = Intake (mg COC/kg of body weight-day))

C = Concentration at Exposure Point (EPC) (mg COC/kg soil)

S = Skin Exposed (cm^2)

DA = Dust Adherence (mg dust/cm^2)

AF = Absorption Factor (unitless)

EF = Exposure Frequency (events/day)

ED = Exposure Duration (days)

BW = Body Weight (kg)

AT = Averaging Time (days)

Table 7-4 shows the calculated daily arsenic dermal intake doses for workers in DU-3 and DU-4.

Table 7-4. Worker Scenario Arsenic Dermal Intake Doses

Worker Exposure Scenario – Arsenic Dermal				
	Carcinogenic		Non-Carcinogenic	
	50% EPC Intake Dose (mg/(kg-day))	95% EPC Intake Dose (mg/(kg-day))	50% EPC Intake Dose (mg/(kg-day))	95% EPC Intake Dose (mg/(kg-day))
DU-3	1.35E-07	1.76E-07	1.38E-05	1.79E-05
DU-4	1.48E-07	4.13E-07	1.52E-05	4.22E-05

7.1.2 Recreational All-Terrain-Vehicle Exposure Scenario

All-Terrain-Vehicle (ATV) exposure was selected as the recreational exposure scenario due to their abundance during the site investigation. There were 5 visiting ATVs and 1 dirt bike observed in total during the entire SI. The ATVs were observed driving on the roads at the site through DU-5. Visitors on the ATVs were observed walking around the site between DU-3 and DU-4. Some visitors even stopped to eat lunch.

Table 7-5 shows the ingestion exposure parameters for the ATV exposure scenario.

Table 7-5. Recreational Scenario Ingestion Exposure Parameters

Recreational ATV Exposure Scenario - Ingestion		
Parameter	**Child (6-12)**	**Adult**
Contact Rate (mg soil/day) [16]	100	100
Exposure Frequency (hours/day)	5	6
Exposure Duration (days)	6	8
Average Body Weight (kg) [17]	31.8	70
Averaging Time, Non-Carcinogen (year)	6	30
Averaging Time, Carcinogenic (year) [16]	70	70
Absorption Factor [17]	0.95	0.95

Table 7-6 shows the calculated daily arsenic ingestion intake doses for ATV users in DU-3 and DU-4.

Table 7-6. Recreational Scenario Arsenic Ingestion Intake Doses

Recreational ATV Exposure Scenario – Arsenic Ingestion				
	Carcinogenic		**Non-Carcinogenic**	
	50% EPC Intake Dose (mg/(kg-day))	**95% EPC Intake Dose (mg/(kg-day))**	**50% EPC Intake Dose (mg/(kg-day))**	**95% EPC Intake Dose (mg/(kg-day))**
Child 6-12 Years Old				
DU-3	1.33E-08	1.72E-08	1.55E-07	2.01E-07
DU-4	1.45E-08	4.05E-08	1.70E-07	4.72E-07
Adult				
DU-3	4.83E-08	6.25E-08	1.13E-07	1.46E-07
DU-4	5.28E-08	1.47E-07	1.23E-07	3.43E-07

Recreational ATV use at the Dragon Mine may lead to dermal exposure as riders interact with contaminated soil and dust containing residual heavy metals. Heavy metals like lead and arsenic are common in abandoned mine landscapes. ATV tires disturb the terrain, aerosolizing soil particles, which settle onto exposed skin. Direct contact may also occur during dismounts or falls. Dermal absorption is enhanced by sweat or by prolonged contact without washing the soil away.

Table 7-7 shows the dermal exposure parameters for the ATV exposure scenario for both children and adults. It is assumed children younger than 6 years do not use ATVs.

Table 7-7. Recreational Scenario Dermal Exposure Parameters

Recreational ATV Exposure Scenario - Dermal		
Parameter	**Child (6-12)**	**Adult**
Skin Exposed (cm^2)	774.5	5293
Dust Adherance (mg dust/cm^2)	0.164	0.2
Absorption Factor	0.3	0.032
Exposure Frequency (events/day)	4	4
Exposure Duration (days/year)	6	8
Exposure Duration (years)	6	30
Average Body Weight (kg)	31.8	70
Averaging Time, Non-Carcinogen (year)	6	30
Averaging Time, Carcinogenic (year) [16]	70	70

Table 7-8 shows the calculated daily arsenic dermal intake doses for ATV users in DU-3 and DU-4.

Table 7-8. Recreational Scenario Arsenic Ingestion Intake Doses

Recreational ATV Exposure Scenario – Arsenic Dermal				
	Carcinogenic		**Non-Carcinogenic**	
	50% EPC Intake Dose (mg/(kg-day))	**95% EPC Intake Dose (mg/(kg-day))**	**50% EPC Intake Dose (mg/(kg-day))**	**95% EPC Intake Dose (mg/(kg-day))**
Child 6-12 Years Old				
DU-3	1.70E-08	2.21E-08	1.99E-07	2.58E-07
DU-4	1.87E-08	5.20E-08	2.18E-07	6.06E-07
Adult				
DU-3	2.75E-07	3.57E-07	6.43E-07	8.33E-07
DU-4	3.01E-07	8.39E-07	7.03E-07	1.96E-06

7.2 Human Health Arsenic Toxicity Assessment

Integrated Risk Information System (IRIS) from the EPA contains toxicity data for arsenic. Slope factors (SF) are used for carcinogenic risk calculations. SF is the risk of developing cancer due to oral ingestion per unit of intake dose. Reference dose (RfD) values are used to calculate non-carcinogenic risk. The RfD is the lowest dose able to be ingested prior to toxic effects being observed.

Possible carcinogenic effects from arsenic include lung, bladder and skin cancer [19]. Non-carcinogenic effects include cardiovascular diseases, hypertension, respiratory, neurological, liver/kidney disorders, type 2 diabetes and mental disorders [20]. Table 7-9 shows the slope factor and reference dose for arsenic. These values are used for both ingestion and dermal exposure calculations [21].

Table 7-9. Slope Factor and Reference Dose for Arsenic [https://www.epa.gov/iris]

COC	Slope Factor $(mg/kg\text{-}day)^{-1}$ (Carcinogenic)	Reference Dose (mg/kg-day) (Noncarcinogenic)
Arsenic	31.7	6E-5

7.3 Risk Calculations

7.3.1 Arsenic Risk

Arsenic has both carcinogenic and noncarcinogenic risk so two different calculations are needed. Carcinogenic and noncarcinogenic risk was calculated for each exposure scenario, for both 50% and 95% EPCs.

Equation 7-3 was used to calculate carcinogenic risk for arsenic.

Equation 7-3. Carcinogenic Risk

$$Risk = I_c \cdot SF$$

Where:

Ic = Carcinogenic Intake Dose (mg/(kg of body weight-day)

SF = Slope Factor (mg/(kg-day))^-1

Equation 7-4 was used to calculate non-carcinogenic risk for arsenic.

Equation 7-4. Non-Carcinogenic Risk

$$HI = \frac{I_N}{RfD}$$

Where:

HI = Hazard Index (unitless)

IN = Non-Carcinogenic Intake Dose (mg/kg of body weight-day))

RfD = Reference Dose (mg/(kg-day))

Table 7-10 shows the arsenic ingestion risk results for both carcinogenic and non-carcinogenic risk. The values highlighted in red indicate a significant increased risk.

Table 7-10. Arsenic Ingestion Carcinogenic and Non-Carcinogenic Risk Results

Arsenic Ingestion Risk					
Risk Scenario	**DU**	**Carcinogenic Risk (1E-6)**		**Non-Carcinogenic Hazard Index**	
		50% EPC	**95% EPC**	**50% EPC**	**95% EPC**
Worker Exposure Scenario	DU-3	3.103	4.020	0.114	0.148
	DU-4	3.395	9.455	0.125	0.348
Recreational ATV Exposure Scenario (Adult)	DU-3	1.530	1.983	0.002	0.002
	DU-4	1.674	4.663	0.002	0.006
Recreational ATV Exposure Scenario (Children 6-12))	DU-3	0.421	0.546	0.003	0.003
	DU-4	0.461	1.283	0.003	0.008

There is significant carcinogenic risk from arsenic ingestion to workers and adult-recreational ATV users. There is no increased non-carcinogenic risk from arsenic ingestion for anyone at the site.

Table 7-11 shows the arsenic dermal risk results for both carcinogenic and non-carcinogenic risk. The values highlighted in red indicate a significant increased risk.

Table 7-11. Arsenic Dermal Carcinogenic and Non-Carcinogenic Risk Results

Arsenic Dermal Risk					
Risk Scenario	DU	Carcinogenic Risk (1E-6)		Non-Carcinogenic Hazard Index	
		50% EPC	95% EPC	50% EPC	95% EPC
Worker Exposure Scenario	DU-3	4.295	5.565	0.231	0.299
	DU-4	4.699	13.089	0.253	0.703
Recreational ATV Exposure Scenario (Adult)	DU-3	8.730	11.311	0.011	0.014
	DU-4	9.552	26.604	0.012	0.033
Recreational ATV Exposure Scenario (Children 6-12))	DU-3	0.540	0.700	0.003	0.004
	DU-4	0.591	1.647	0.004	0.010

There is significant carcinogenic risk from dermal contact with arsenic to workers adult-recreational ATV users. There is no increased non-carcinogenic risk from dermal contact with arsenic for anyone at the site.

Inhalation risk is not depicted because no air quality data is available at the site. Inhalation may be a risk due to suspended particulate matter from occupational efforts and ATV use.

7.3.2 Lead Risk

Lead risk was calculated using the Integrated Exposure Uptake Biokinetic (IEUBK) model for children and the Adult Lead Model (ALM) for adults. The IEUBK model simulates human exposure, intake, and uptake of lead, and estimates blood lead concentrations under different exposure scenarios [23]. The ALM is used to assess lead exposure in adults and their potential fetuses in occupational settings. It predicts blood lead concentrations based on exposure levels [23]. The ALM is based on various animal studies that examine how lead (Pb) interacts with the body. These findings are informed by reference values from the National Health and Nutrition Examination Survey (NHANES) conducted between 2009 and 2014.

Tables 7-12 and 7-13 shows the lead risk to workers based on average and maximum exposure. Cells highlighted in red indicate increased risk. Adults are considered at increased risk if their blood lead level exceeds 5 µg/dL. There is also an increased risk to a fetus if the probability of fetal blood lead (PbB) exceeds 5%.

Table 7-12. Pb Risk to Average and Maximum Exposed Worker

Average Worker Scenario		
DU	**Geomean PbB (µg/dL)**	**Probability fetal PbB exceeds target (%)**
DU-3	2.4	8.0
DU-4	2.9	13.9
Max Worker Scenario		
DU	**Geomean PbB (µg/dL)**	**Probability fetal PbB exceeds target (%)**
DU-3	14.6	94.9
DU-4	36.5	99.9

Table 7-13. Pb Risk to Average and Maximum Exposed Recreational Adult

Average Worker Scenario		
DU	**Geomean PbB (µg/dL)**	**Probability fetal PbB exceeds target (%)**
DU-3	0.6	0.01
DU-4	0.7	0.01
Max Worker Scenario		
DU	**Geomean PbB (µg/dL)**	**Probability fetal PbB exceeds target (%)**
DU-3	0.9	0.1
DU-4	1.5	1.2

Tables 7-12 and 7-13 indicate that lead exposure is a concern at the site for both average and maximum worker exposure scenarios. There is a high probability that blood lead concentrations will exceed the target level of concern, 5 µg/dL. It is also likely that the blood lead level in the potential fetuses of both average and maximum exposed workers will exceed 5 µg/dL. In contrast, the risk of lead exposure for recreational ATV users is negligible for both average and maximum exposure scenarios, as their blood lead levels are unlikely to exceed 5 µg/dL. The probability that a potential fetus of a recreational user will have a blood lead level above the target is less than 1%. Full ALM model inputs and results are provided in Appendix F.

The IEUBK model is used to evaluate residential exposure scenarios so the EPCs were adjusted to reflect non-daily exposure.

Equation 7-5 is used to calculate the adjusted EPC values. Table 7-14 shows the adjusted EPC values used for the IEUBK model.

Equation 7-5. Adjusted EPCs

$$Adjusted\ EPC = \frac{EPC * EF * ED}{24\frac{hr}{d} * \frac{365d}{yr}}$$

Where:

EPC = Original EPC Value (mg Pb/kg Pb)

EF = Exposure Frequency (hours/day)

ED = Exposure Duration (days/year)

Table 7-14. Adjusted EPC Values

	DU3		DU4	
	50%	**95%**	**50%**	**95%**
Original EPC	556.52	4246.07	711.18	10906.70
Adjusted EPC	1.91	14.54	2.44	37.35

Table 7-15 shows the results of the IEUBK model for the average exposure for a child-recreational ATV user.

Table 7-15. Child ATV 50% EPC

Child ATV 50% EPC		
Decision Unit	**Age Range (years)**	**Blood Pb (µg/dL)**
DU3	6 to 7	1.0
DU4	6 to 7	1.0

Table 7-16 shows the results of the IEUBK model for the maximum exposure for a child-recreational ATV user.

Table 7-16. Child ATV 95% EPC

Child ATV 95% EPC		
Decision Unit	**Age Range (years)**	**Blood Pb (µg/dL)**
DU3	6 to 7	1.0
DU4	6 to 7	1.1

Tables 7-17 and 7-18 show the average and maximum exposure lead blood levels for 6–7-year-old child-recreational ATV user. The distribution curves for the lead blood levels can be found in IEUBK Models in Appendix F.

Table 7-17. DU3 Lead Blood Levels

DU 3 Lead Blood Levels		
	Average Exposure	**Max Exposure**
Limit	5 μg/dl	5 μg/dl
GEOMEAN	0.991	1.039
% Above Limit	0.029	0.042

Table 7-18. DU4 Lead Blood Levels

DU 4 Lead Blood Levels		
	Average Exposure	**Max Exposure**
Limit	5 μg/dl	5 μg/dl
GEOMEAN	0.993	1.126
% Above Limit	0.029	0.076

Tables 7-15, 7-16, 7-17, and 7-18 show that there is not significant risk posed to children using the site for ATV recreation because it is below 5µg/dL blood-lead concentration.

This section determined that there is a significant risk posed to people due to lead that are working at the site. Recreational visitors, adults, and children do not experience significant risk from lead exposure at the site.

8.0 Ecological Risk Assessment

A qualitative risk assessment was completed to determine the risk to wildlife due to contamination at the site.

8.1 Species of Concern

While at the site, species observed at the site include quail, rabbits, lizards. Evidence of donkeys and coyotes were also present. Flora that was observed at the site include Paula Verde trees, Saguaros, Fishhook Barrel Cacti, Mesquite trees, Greece Wood trees, and typical grasses.

Based on research about endangered species in Arizona known to be near Wickenburg the species of concern are the Mexican Grey Wolf, California least tern, and Yellow Billed Cuckoo [22].

8.2 Ecological COCs

The EPA ecological screening levels were used to determine the ecological COCs for plants, soil invertebrates, avian wildlife and mammals.

Table 8-1. Ecological Screening Levels

ECO Limits	Plants	Soil Invertebrates	Avian	Mammalian
Pb	120	1700	11	56
Se	0.52	4.1	1.2	0.63
As	18		43	46
Zn	160	120	46	79
Cu	70	80	28	49
Ni	38	280	210	130
Co	13		120	230
Mn	220	450	4300	4000
Cr			26	34
V			7.8	280

See Appendix D, Table D-4 for a comprehensive table of samples that exceed Ecological screening levels. The Ecological COCs were determined to be Pb, Se, As, Zn, Cu, Ni, Co, Mn, Cr, and V.

Table 8-2 is to be used as a legend for Table 8-3. Table 8-3 below shows the risk to each species compared to the ecological SRLs and background levels present for each contaminant. A blank area indicates that the area is below ecological SRLs. Darker coloration indicates a higher risk in that decision unit compared to the background levels. Averages of sample areas and backgrounds were used for simplicity.

Table 8-2. Ecological Contamination Compared to Background Levels Legend

Below Eco Limit
Above Eco Limit
Above Eco Limit + 150% BG
Above Eco Limit + 1000% BG

Table 8-3. Ecological Contamination Compared to Background Levels

Chemical	Pb	Se	As	Zn	Cu	Ni	Co	Mn	Cr	V	Pb	Se	As	Zn	Cu	Ni	Co	Mn	Cr	V
Sample Group	**Plants**										**Avian**									
DU-1																				
DU-3																				
DU-4																				
DU-5																				
HS-1																				
HS-2																				
HS-3																				
HS-4																				
HS-5																				
Sample Group	**Mammalian**										**Invertebrate**									
DU-1																				
DU-3																				
DU-4																				
DU-5																				
HS-1																				
HS-2																				
HS-3																				
HS-4																				
HS-5																				

Table 8-3 indicates that Pb, As, and Zn in DU4, and the hotspots are risks to the wildlife at the site. Area use factors will not be used because the site is small enough to assume mammal and avian species do not spend extended time at the site. Plants and invertebrates are always present at the site and will be considered when deciding remediation design.

8.3 Ecological Risk

The effects of exposure to each COC were researched. Tables 8-4 through 8-7 show the health effects of exposure for plants, invertebrates, avians, and mammals.

Table 8-4. Plant Health Effects for Pertinent Ecological COCs

Plant	
Element	**Health Effects for Plants**
Pb	Inhibits growth, reduces photosynthesis, interferes with cell division and respiration, reduces water uptake, accelerates abscission and pigmentation, and also reduces other essential functions for energy. [23]
Se	A beneficial element. Will cause stunted growth and nutrient deficiencies in plants with low tolerance to selenium toxicity. Younger plants are more susceptible to this toxicity as compared to mature plants. [24]
As	Disrupts the viability of root cells, hinders transport of essential micronutrients, and inhibits photosynthesis and other biochemical, physiological, and morphological processes. [25] [26]
Zn	An essential trace element. In excess, zinc may cause iron deficiency or the yellowing of leaves. [27]
Cu	Generally, an essential element. Important for oxidation, photosynthesis, and protein and carbohydrate metabolism. May impact nitrogen fixation, valence electron changes, and the cell wall metabolism. Different species are affected differently. [28]
Ni	An essential trace element. Essential for healthy growth and metabolic processes. In excess, nickel reduces seed germination, growth, biomass accumulation and overall production of the plant. Nickel toxicity causes chlorosis and inhibits physiological processes like photosynthesis and transpiration. [29] [30]
Co	A beneficial element. Cobalt is a component of several enzymes and proteins that participate in plant metabolism. In excess, cobalt will cause morphological problems, reduce photosynthetic efficiency and nutrient uptake, and may cause iron deficiency. [31] [32]
Mn	An essential trace element. Participates in the oxygen system of photosynthesis and the photosynthetic electron transport system. Manganese toxicity is characterized by iron chlorosis or the abnormal coloring of leaves. [33]
Cr	It is uncertain if chromium is an essential element for plant nutrition. Chromium toxicity is characterized by reduced seed germination, growth, and yield. Also inhibits physiological processes like photosynthesis. [34] [35]

Plant (Continued)	
Element	**Health Effects for Plants**
V	Reduced plant biomass, alterations to enzymatic activities, decreased nutrient absorption, inhibits chlorophyll and protein production, impairs cell wall formation, and causes cell apoptosis. [36]

Table 8-5. Invertebrate Health Effects for Pertinent Ecological COCs

Invertebrate	
Element	**Health Effects for Invertebrates**
Pb	Affects synthesis of heme, altering urinary or blood concentration of enzymes and intermediates. [23]
Se	Acute effects include abnormal posture and movement, watery diarrhea, labored respiration, abdominal pain, prostration, and death. [24]
Zn	Zinc salts adversely affect tissues, interfere with metabolism of other ions such as copper, calcium, and iron, and inhibit erythrocyte production and formation. [27]
Cu	Nausea, vomiting, epigastric pain, dizziness, jaundice, and general debility. [28]
Mn	High levels may produce neurotoxic responses such as hypoactivity, nervousness, tremors, and ataxia. [33]

Table 8-6. Avian Health Effects for Pertinent Ecological COCs

Avian	
Element	**Health Effects for Avians**
Pb	Encephalopathy and gastrointestinal malfunction occur. Lead poisoning causes anxiety, manic behavior, and disturbances to movement [23].
Se	High levels of ingestion of Se can cause abnormal movement, diarrhea, pain, and death. Chronic Exposure can also lead to alkali disease and blind staggers [24].
As	Blood loss and diarrhea, dehydration, weakness, depression and cardiovascular issues [37].
Zn	Toxicity occurs form prolonged exposure. Causes passive regurgitation, lethargy, weight loss, and neurologic signs [38].
Cu	Weight loss, tissue damage, microbial disturbances, unbalance intestinal function [39].
Ni	Weight loss, liver function impairment, kidney issues, weakened bone marrow [40].
Co	Increases red blood cell count, cardiomyopathy, and disrupts male reproductive systems [41].
Mn	Liver damage, decreased growth, nervousness, tremors, ataxia, and hypoactivity [33].
Cr	Decreases hatchability, decreases glucose levels, and decreases vitamins [42].

Avian (Continued)	
Element	**Health Effects for Avians**
V	Weight loss, liver and kidney disturbances, intestinal hemorrhages, blood chemistry changes, and hepatic oxidative stress [43].

Table 8-7. Mammalian Health Effects for Pertinent Ecological COCs

Mammalian	
Element	**Health Effects for Mammalians**
Pb	Interferes with synthesis of heme (hemoglobin), altering blood content, lowered immune system, fetal death, neurological damage, gastrointestinal malfunction, loss of coordination and strength [44]
Se	Acute effects of abnormal posture, watery diarrhea, labored breath, and death. Excessive doses can cause chronic effects of alkali disease, blind staggers, adverse reproductive and developmental effects. [24]
As	Affects the capillaries in cardiovascular and gastrointestinal systems, blood loss diarrhea, dehydration, weakness, depression, cardiovascular collapse. [21]
Zn	Vomiting, diarrhea, slower growth rate, and loss of coordination [45]
Cu	Increase cell permeability, fever, increased heart rate, hypotension, inadequate urination, coma, cardiovascular collapse, death. [28]
Ni	Increased risk of lung and nasal cancers, reproductive and developmental effects. [29]
Co	Increased red blood cell count, growth inhibition, male reproductive defects [41]
Mn	Neurotoxic responses such as hypoactivity, nervousness, tremors, and ataxia. Other reported effects include liver damage and decreased growth. [33]
Cr	Digestive tract ingestion and inflammation, kidney and liver damage, internal tissue damage, tumor development [46]
V	Respiratory issues, decreased red blood cell counts, increased blood pressure, neurological effects [47]

Pb is evidently harmful towards all ecological species and As is harmful towards all species except soil invertebrates. Plants are unable to move away from the site and soil invertebrates currently on site will likely remain on site. Area use factors (AUFs) were not used because ecological risk was not calculated quantitatively. Ecological risk was calculated qualitatively by comparing ecological contamination to background samples. The ecological contaminant distribution maps support the idea that the primary areas of concern are DU-3, DU-4, and all hotspot samples. There is a small mammalian and avian health concern seen with Pb migrating down the wash. However, remediating these areas of concern will eliminate ecological concerns.

9.0 Remedial Action

From the contaminant distribution maps and risk assessments that have been completed, it is known that the problem areas on the Dragon Mine site are DU-3, DU-4, and the hot spot areas. Hot spots and DU-4 are a risk to both human and ecological health while DU-3 is only a risk to HH. Remediation will be focused on those target areas.

9.1 Remedial Action Objectives

Remedial Action Objectives (RAOs) are goals created to assist in developing remediation alternatives. The COCs for HH are As and Pb, and the ecological contaminants of concern are Pb, Se, As, Zn, Cu, Ni, Co, Mn, Cr, and V according to the risk assessment. The RAOs for the Dragon Mine are as follows:

1. Limit contaminated soil from tailings/hotspots migrating into the Wash.
2. Mitigate HH risk by reducing lead and arsenic concentrations in DU-3, DU-4, and in hot spot areas to below nonresidential SRLs or to background levels.
3. Reduce risk to wildlife from contaminant exposure in DU-4 and hotspot areas.

These RAOs were used to develop and evaluate the remedial action alternatives.

9.2 Alternative Selection

Many technologies were researched to meet the remediation action objectives for the Dragon Mine. Some of these technologies include excavation, soil washing, capping, and solidification. Alternatives were created using a combination of technologies to clean up the site with various combinations. All alternatives were designed to meet the RAOs that were created in Section 9.1.

9.2.1 Introductions of Alternatives

Excavation involves the physical removal of contaminated soil or mine tailings from the site for disposal or treatment. This typically involves trucks, excavators, and other heavy machinery. Depending on the amount of soil removed, soil would be replaced as well. Soil washing involves excavation as well, first removing the contaminated soil to an off-site location. There the soil is washed using water or chemical solutions to extract contaminants from the soil, separating clean soil fractions for reuse while concentrating pollutants for disposal. Clean soil will be replaced to fill whatever was excavated. Capping for this project would use 18” of bentonite clay to cover the contaminated soil surface. This is done to limit the migration of surface soil and reduce infiltration. Solidification would use large mixing machines to stir a concrete mixture into the contaminated soil. Mixing required excavation first to break up the soil. The concrete binds the contaminants within a stable matrix to prevent leaching and erosion.

Alternatives were only evaluated if they met each RAO. No action, and institutional controls (fences and signs) would not meet the RAOs. The alternatives that were evaluated are as follows:

1. Excavate HS, DU-3, and DU-4 to onsite repository.
2. Excavate HS to onsite repository; excavate/soil wash/ replace DU-4; in-situ solidification of DU-3.
3. Excavate HS to DU-3 and solidify; excavate/soil wash/ replace DU-4.
4. Excavate HS to DU-3 and cap; excavate/soil wash/replace DU-4 + retaining wall.

Alternatives 1 and 2 include creating an onsite repository which would be located outside of the site boundary in a test pit, but still on BLM land. Once all disposed soil is in the repository, it will be capped. The alternatives that excavate and soil wash DU4 will use soil wash solution that is effective for soil contaminated with heavy metals. Alternatives that include solidification will use a Portland cement solution that is 10% of the soils volume.

9.2.2 Selection of Alternative

Each alternative was scored based on the decision matrix shown in Table 9-1. The categories are effectiveness of the alternative to complete RAOs, ease of implementation, and cost. Each category is scored on a scale of --/-/+/++, with -- being the least implementable or most costly when scaled to others, - being moderately hard to implement on site or second most costly when scaled to other options, + being moderately easily implementable or having the second cheapest cost when scaled to the others, and ++ being the best solution scaled to the others.

Table 9-1. Decision Matrix

Option #	Remedial Action	Effectiveness	Implementability	Cost	Total
1	Excavate HS, DU3, & DU4 to onsite repository	++	+	-	++
2	Excavate HS to onsite repository; excavate/soil wash/ replace DU4; in-situ solidification of DU3	+	--	--	---
3	Excavate HS to DU3 and solidify; excavate/soil wash/ replace DU4.	+	-	+	+
4	Excavate HS to DU3 and cap + retaining wall; excavate/soil wash/replace DU4	+	+	++	++++

Excavation of the hot spots to DU-3 and capping DU-3 with a retaining wall preventing erosion into the wash, and the full excavation, soil washing, and replacing of soil in DU-4 was determined to be the best remediation option. This is due to being the most cost-effective plan when compared to the other possible solutions, meeting the remedial action objectives, and being one of the easier plans to implement on site. Comparing alternative 2 to alternative 4, excavating the HS to DU-3 instead of a repository would reduce travel distance and contact time. Capping DU-3 is more accessible given the site features compared to solidifying and is why alternative 4 beats alternative 3 for implementability. Soil washing is better for DU-4 because it can treat soil contaminated with metals such as lead or arsenic and is especially effective for gravelly soil.

9.3 Design

Alternative 4 was selected for design. This alternative includes excavating hotspot areas and relocating the contaminated soil to Decision Unit (DU) 3, capping DU 3, constructing a retaining wall between DU 3 and the wash, and excavating, soil washing, and replacing the soil in DU 4. The average excavation depth in the tailings piles is 20 feet, while the average excavation depth in DU 4 is 10 feet. Approximately 270,000 cubic feet of soil will be moved from the tailings to DU 3. The cap on DU 3 will cover approximately 28,700 square feet and consist of an 18-inch-thick layer of bentonite clay. The retaining wall, made of concrete, will be 208 feet long, 2 feet high, and 1 foot wide. About 65,000 cubic feet of soil will be processed through soil washing. Area and volume breakdowns for each decision unit are provided in Appendix G.

Figure 9-1 below shows how the implementation design map.

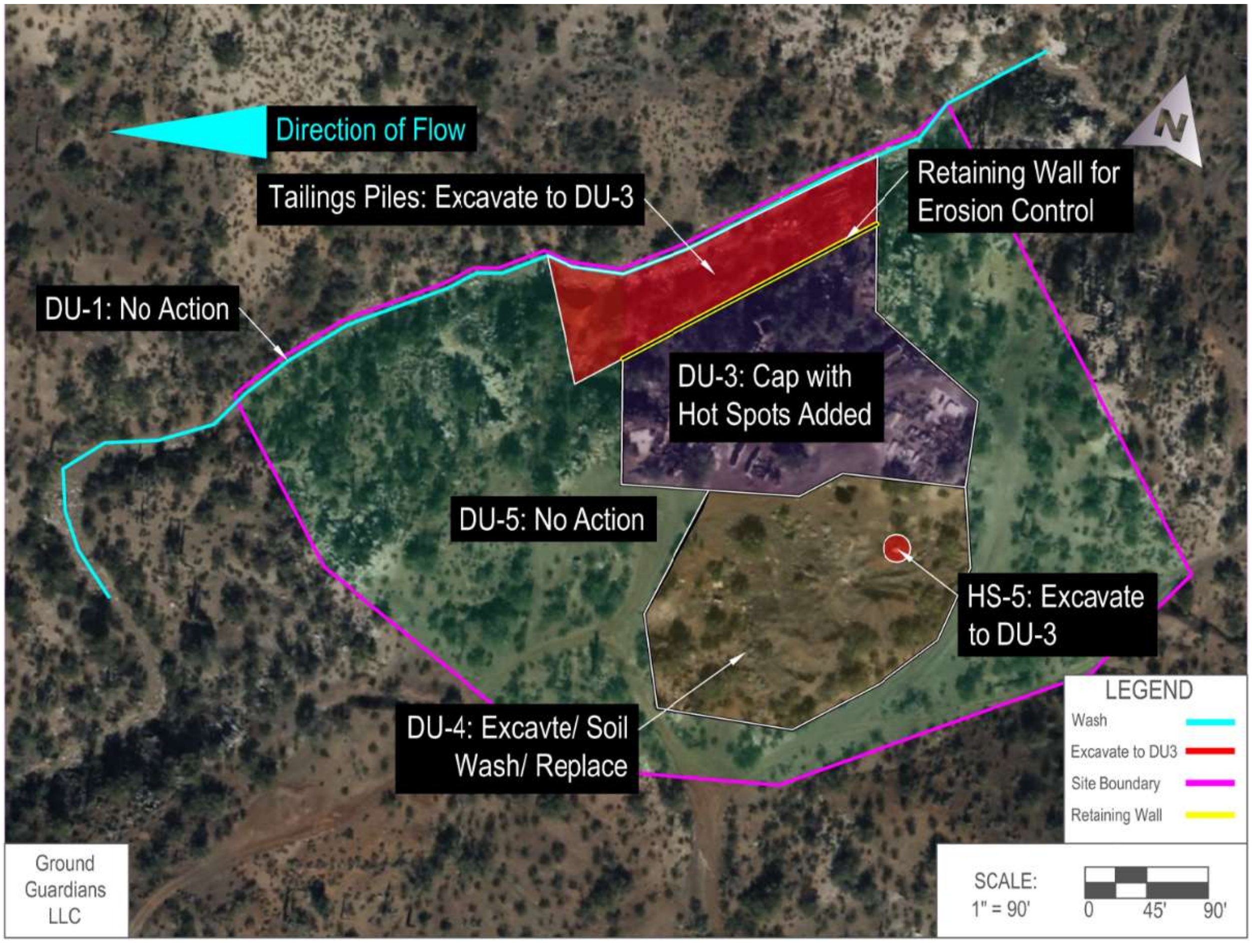

Figure 9-1. Final Proposed Design

9.4 Implementation Cost

Costs were estimated using online material pricing and area calculations performed in AutoCAD. Excavation costs were based on the volume of soil to be removed. This alternative requires approximately 550,800 cubic feet of soil to be excavated, with an estimated excavation cost of $15 per cubic yard [50]. Assumptions include an average depth of 20 feet for hotspot areas and 10 feet for DU 4. Labor costs assume a remediation crew of eight workers completing the project within one year, each earning an annual salary of $75,000 including benefits. The bentonite clay cap is not expected to require routine maintenance.

The cost of implementation breakdown is shown in Table 9-2 below.

Table 9-2. Alternative 4 Cost Estimate Breakdown

Alternative 4 Cost Estimate Breakdown	
Institutional controls	$4,000
Site changes/ road making	$75,000
Excavation cost	$2,811,800
Soil washing cost	$200,000
Capping cost	$674,800
Retaining wall cost	$9,736
Labor cost	$600,000
Total cost	$4,375,336

10.0 Impacts Analysis

The short-term and long-term social, economic, and environmental impacts were evaluated for the project when fully considering the impacts remediation or no remediation will have on Dragon Mine.

The Dragon Mine contains high concentrations of lead and arsenic, which pose risks to HH. Several other metals present at the site are also harmful to local wildlife. The site is frequently used for recreational purposes, so mitigating risks to HH is essential. Endangered species are likely to inhabit areas near the mine, and various plants and invertebrates are consistently present at the site. Therefore, remediation is necessary to reduce risks to wildlife.

Ongoing contamination has the potential to impact the health and increase medical costs for individuals who use the site. Users of the non-remediated site may also track contaminated soil back to town, homes, and hotels. Remediation will result in temporary, additional funding to the area such as jobs, housing, and shopping. However, remediation efforts may temporarily disrupt local businesses in Wickenburg that rely on tourism, particularly from visitors seeking hiking trails and ATV routes that will be affected by construction.

Remediating the site will protect both humans and wildlife from dangerous exposure to heavy metals. It will also prevent the spread of contamination via runoff and wind, which can affect surrounding soil and surface water. Remediation will make the site more accessible for a wider range of recreational activities and could generate local jobs during the construction phase. Additionally, remediation may allow local businesses to increase promotion of safe outdoor activities such as using ATV's and hiking.

During remediation, however, there will be health risks for workers on site. Wildlife may face temporary displacement due to construction activities. Remediation will also be costly, reducing other work BLM could choose to complete with limited funding.

11.0 Summary of Engineering Work

The estimated schedule displayed on a Gantt chart can be found in Appendix H. The actual schedule can also be found in Appendix H. The team stayed on schedule throughout the duration of the project. The actual start date of October 17, 2024, and the actual end date of May 6, 2025, are the exact dates the team anticipated the project would start and end. The dates of completion for tasks 3 through 11 differ slightly compared to the estimated schedule because of the removal of subcontracting. This placed the team slightly ahead of schedule for all remaining tasks and the actual Gantt chart critical path ended up following the project deliverable deadlines. All tasks were still completed sequentially, as expected.

12.0 Summary of Engineering Cost

12.1 Staffing Hours

The team completed the project in significantly less time than expected and this resulted in lower staffing costs. The fast completion is due to a shorter site investigation, shorter than expected laboratory work, and the removal of subcontracting. A comparison between the estimated and actual staffing hours can be seen in Table 12-1. Refer to Appendix I for a detailed table of projected and actual hours for major tasks, for each staff position.

Table 12-1. Staffing Hours

	Senior Engineer	Engineer	Lab Technician	Total
Estimated Hours	117	405	272	794
Actual Hours	65.75	350.75	192.75	609.25

The lab technician and the senior engineer worked significantly less hours than expected due to a shorter site investigation, shorter lab work and fewer project management tasks. The working engineer reported slightly more hours than expected. This is because the team failed to consider the time spent completing and submitting project deliverables.

12.2 Estimated Cost

The total estimated cost for the proposed project at Dragon Mine was $105,342. The cost for personnel salary was accounted for along with the cost of travel to Dragon Mine and the cost of lodging and meals for the two-day, one night duration of the SI. The cost of supplies during the SI, as well as the cost of lab access and required laboratory devices were accounted for. The detailed breakdown of cost can be seen in Table 12-2.

Table 12-2. Estimated Cost of Engineering Services

Estimated Project Cost Summary					
Subsection	**Classification**	**Qty**	**Rate**	**Unit**	**Cost**
Personnel	Senior Engineer	117	$300	$/hr	$37,800
	Engineer	405	$135	$/hr	$52,785
	Lab Technician	272	$35	$/hr	$6,020
				Total Personnel	**$99,295**
Travel	NAU Mileage Rate	300	$0.40	$/mile	$120
	Rental: NAU Suburban	2 days	$65	$/day	$130
	Hotel 1 Night	4	$100	$/room	$400
	PerDiem; 4 persons	2 days	$30	$/day-person	$240
				Total Travel	**$890**
Supplies	Ziplock gallon freezer bags, 120 ct	1	$16	$/pack	$16
	Trowel	4	$10	EA	$40
	Rental: GPS device	2 days	$120	$/device-day	$240
	Soap	1	$6	$/bottle	$6
	Marker flags, 50 pack	2	$7	$/pack	$14
	Plastic bins, 2 pack	2	$57	$/pack	$114
	5 gal buckets	4	$7	EA	$28
	Water, 12 pack	2	$4	$/pack	$8
	Paper towels, 2 pack	1	$7	$/pack	$7
	Sharpie, 5 pack	1	$5	$/pack	$5
	Nitrile gloves, 1000 pack	1	$45	$/pack	$45
	Trash bags, 74 pack	1	$20	$/pack	$20
	Clipboards, 6 pack	1	$12	$/pack	$12
	Logbooks	2	$5	EA	$10
	Measuring tape	4	$20	EA	$80
	Scrub brushes	4	$3	EA	$12
	Rental: NAU Soils Lab	20 days	$100	$/day	$2,000
	Rental: XRF Device	5 days	$300	$/day	$1,500
				Total Supplies	**$4,157**
Subcontract	Western Technologies	10	$100	$/sample	$1,000
Total Cost					**$105,342**

12.3 Actual Cost

The actual cost of engineering services differed slightly from the original estimate. Changes to cost occurred due to personnel hours, not needing to subcontract to Western Technologies, and unexpected material donations. The actual cost for the engineering services used for the Dragon mine PA/SI was $81,759. Table 12-3 shows the actual cost detailed breakdown.

Table 12-3. Actual Cost of Engineering Services

Actual Project Cost Summary					
Subsection	**Classification**	**Qty**	**Rate**	**Unit**	**Cost**
Personnel	Senior Engineer	65.75	$300	$/hr	$19,725
	Engineer	350.75	$135	$/hr	$47,351
	Lab Technician	192.75	$35	$/hr	$6,746
	Total Personnel				**$73,823**
Travel	NAU Mileage Rate	300	$0.40	$/mile	$120
	Rental: NAU Suburban	2 days	$65	$/day	$130
	Hotel 1 Night	5	$100	$/room	$500
	PerDiem; 5 persons	2 days	$30	$/day-person	$300
	Total Travel				**$1,050**
Supplies	Ziplock Gallon Freezer Bags, 120 ct	1	$16	$/pack	$16
	Trowel	8	$10	EA	$80
	Rental: 2 GPS devices	2 days	$120	$/device-day	$480
	Soap	1	$6	$/bottle	$6
	Plastic Bins, 2 pack	2	$57	$/pack	$114
	Water, 12 pack	2	$4	$/pack	$8
	Sharpie, 5 pack	1	$5	$/pack	$5
	Nitrile Gloves, 1000 pack	3	$45	$/pack	$135
	Trash Bags, 74 pack	1	$20	$/pack	$20
	Logbooks	2	$5	EA	$10
	Scrub Brushes	4	$3	EA	$12
	Rental: NAU Soils Lab	24 days	$100	$/day	$2,400
	Rental: XRF Device	12 days	$300	$/day	$3,600
	Total Supplies				**$6,886**
Total Cost					**$81,759**

13.0 Conclusion

The Ground Guardians completed a preliminary assessment and site investigation at the Dragon Mine Site. The preliminary assessment included making a sampling analysis plan, and a health and safety plan. The site investigation included taking 51 samples using transect, grid and integrated sampling methods. The samples were processed in the lab by drying and sieving. Then X-ray fluorescence testing was used on each sample to determine the concentrations of metals present in the soil. Using the data found in in-situ and ex-situ testing, contaminants of concern for human and ecological health were determined. Human health risks were calculated quantitatively, and ecological risks were determined qualitatively. Based on risks to human and ecological health DU-3, DU-4, and all 5 hot spot areas were determined to need remediation.

Remediation designs were determined based on their ability to limit migration of contaminants and mitigate human and ecological health risks. The 4 leading designs were then evaluated based on effectiveness, implementability, and cost. The remedial action the Ground Guardians propose to do at the Dragon Mine site is to Excavate all 5 hot spot areas to DU-3 and cap with a retaining wall; excavate, soil wash, and replace DU-4. The estimated cost of the remediation is 4.4 million dollars and is estimated to take 1 year to complete.

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15.0 APPENDICES

Appendix A: Photo Log

Figure A - 1: In-situ XRF (PC: Andres)

Figure A - 2: Sample Collection (PC: Andres)

Figure A - 3: Background Sample Collection (PC: Andres)

Figure A - 4: Background Sample Collection (PC: Zack)

Figure A - 5: Waste Rock Pile (PC: Jorja)

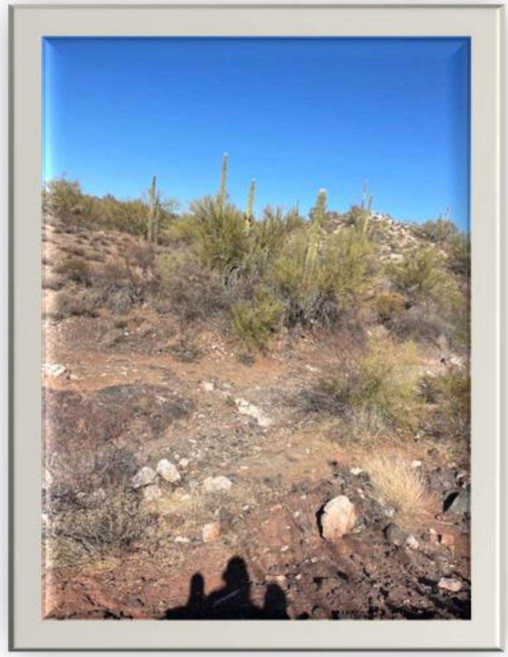

Figure A - 6: Background Area (PC: Jorja)

Figure A - 7: Red Tailings Pile (PC: Bowie)

Figure A - 8: Background Area (PC: Zack)

Figure A - 9: Scrap Metal Barrels (PC: Jorja)

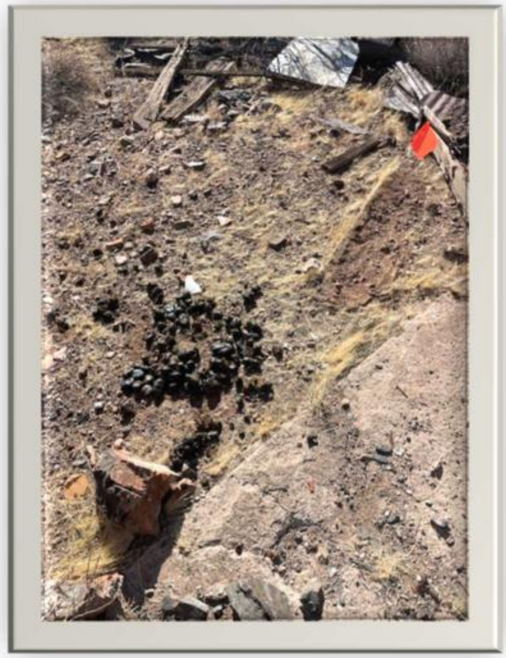

Figure A - 10: Donkey Feces (PC: Jorja)

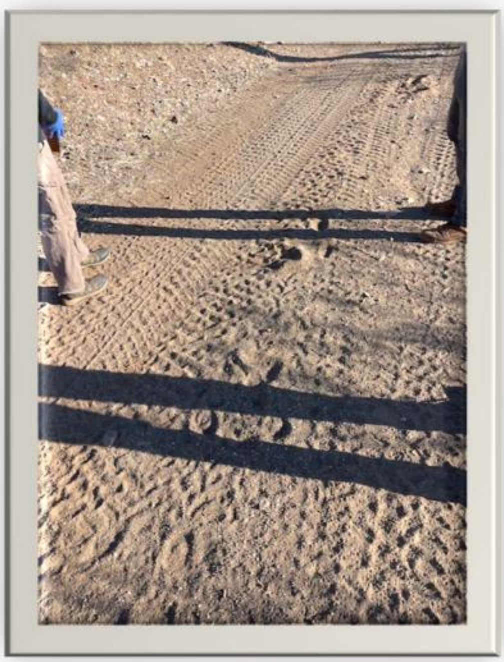

Figure A - 11: ATV Tracks (PC: Jorja)

Figure A - 12: Scrap Metal Stove (PC: Jorja)

Figure A - 14: Team Photo (PC: Jorja)

Figure A - 13: PA With Maps (PC: Jorja)

Figure A - 15: PA (PC: Jorja)

Figure A - 16: PA (PC: Jorja)

Figure A - 17: Mine Shaft (PC: Andres)

Figure A - 18: Mine Shaft (PC: Andres)

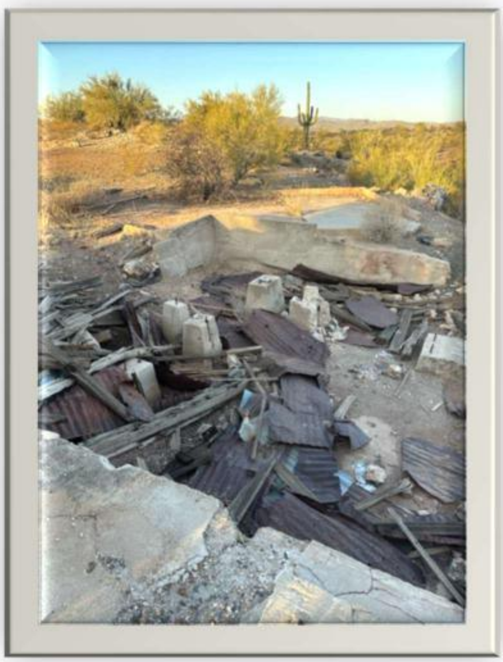

Figure A - 19: Concrete Foundation (PC: Andres)

Figure A - 20: Concrete Foundation (PC: Andres)

Figure A - 22: Pedestrian On Site (PC: Bowie)

Figure A - 21: Birds Nest In Cacti (PC: Bowie)

Figure A - 23: Wash On Site (PC: Bowie)

Figure A - 24: Red Tailings Pile Near Wash (PC: Bowie)

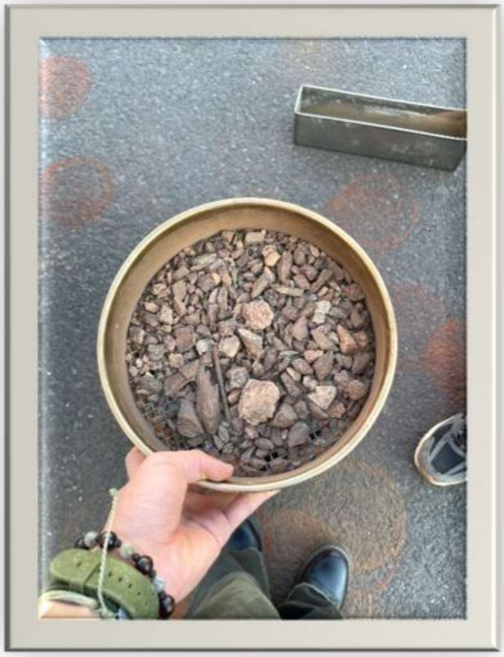

Figure A - 25: Nail In Overs Bucket (PC: Bowie)

Figure A - 26: Andres Breaking Up Clumps of Soil (PC: Bowie)

Figure A - 27: Bowie Air Cleaning Trough (PC Jorja)

Figure A - 28: Bowie XRF Ex-situ (PC Jorja)

Figure A - 29: Chain Of Custody Log (PC Jorja)

Figure A - 30: Separating Fines (PC Jorja)

Figure A - 31: BLM Capstone Cabinet (PC Jorja)

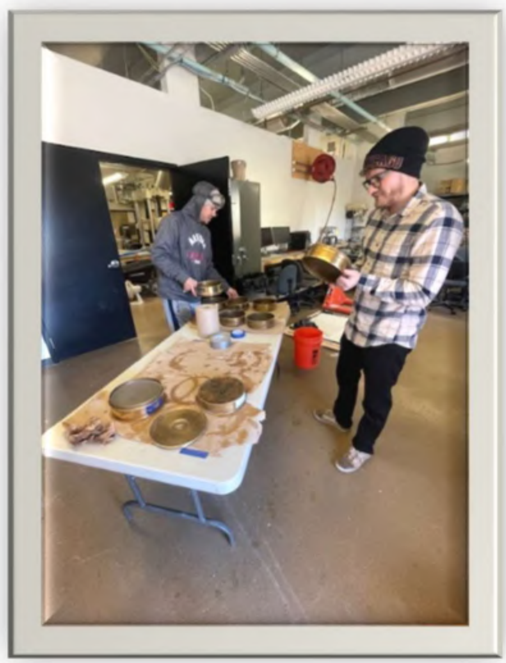

Figure A - 32: Sieve Drying Station (PC Jorja)

Figure A - 33: Samples Drying In Oven (PC Jorja)

Figure A - 34: Sample In Trough (PC Jorja)

Figure A - 35: Zack Loading XRF Cups (PC Jorja)

Figure A - 36: XRF Station Setup (PC Jorja)

Appendix B: Sampling and Analysis Plan (SAP)

1.0 Introduction

1.1 Responsible Agency

Ground Guardians LLC will conduct this Sampling and Analysis Plan (SAP) under the guidance of the BLM Arizona State Office and the BLM-Hassayampa Field Office.

1.2 Project Organization

All personnel involved in the SAP activities, including roles and responsibilities, are listed in Table B-1-1.

Table B-1-1. Personnel Contact Table

Title/Responsiblity	Name	Phone Number
Technical Advisor	Dr. Bridget Bero, P.E.	(928) 607-2516
Staff Engineer, Health and Safety Officer	Bowie Ching	(808) 294-4169
Staff Engineer, QA/QC Officer	Andres Garcia Rico	(623) 326-9139
Staff Engineer	Zachary Kauranen	(224) 938-2903
Staff Engineer	Jorja Whitcher	(605) 877-6660
Client, P.E.	Eric Zielske, P.E.	(602) 653-6283

1.3 Sampling Overview

A combination of sampling methodologies will be performed including transect, grid, and incremental sampling methodology (ISM). A total of 53 samples will be collected including up to 7 hotspot samples and 3 background samples. Core sampling will not be performed.

2.0 Project Data Quality Objectives and QA/QC Methods

2.1 Project Objectives

The Dragon mine site and the immediate surrounding area will have a site investigation completed to identify all the contaminants of concern (COCs). The distribution and migration paths of COCs will be determined through soil sampling. Information gathered from the site investigation and soil sampling will be used to estimate the environmental and human health concerns. Remediation efforts will be determined based on the COCs and extents of contamination.

2.2 Data Quality Objectives

The Data Quality Objectives (DQOs) process is used by the EPA to help users decide what type, quality, and quantity of data will be sufficient for environmental decision making [48]. DQOs for this project are used to define Quality Assurance (QA) procedures for collecting and analyzing contamination data. Examples of these objectives are that background samples need to be taken at undisturbed locations, equipment decontamination must occur after each sample is taken, and duplicates are to be taken a few inches away from the original sample. The DQO for this project is to obtain data sufficient for screening-level decision making at the site.

2.3 Quality Assurance and Control

The purpose of QA and QC in the field and the laboratory is to ensure that the data collected accurately represents the existing conditions to support the project objectives. Use of the QA/QC protocols will maintain accuracy and precision of the data sets. Field and laboratory QC samples will be used and are described in this section. Chain of Custody documents will be used to keep track of the samples and have physical documentation of sample movements. All samples will have a Chain of Custody document. Details on the Chain of Custody documents are in Section 3.5.3.

2.3.1 Field QA/QC

For each type of sampling (transect, grid, etc.) an initial sample location will be identified using GPS. The remaining sample locations will be determined using a compass and measuring tape. All sampling locations will be flagged including backgrounds, duplicates, and hotspots. After collecting each sample, the GPS location and a picture of the location and sample will be taken and logged in the Field Notebook.

Duplicate samples will be taken as field quality control samples to evaluate precision during sampling every 9 samples, and decision units with less than 9 samples will have 1 duplicate. Decision units with ISM sampling will not have any duplicates taken. All field QC samples will be noted in the Field Notebook. Duplicate samples will be obtained within one foot of the original sample.

The QA/QC officer will keep a sample checklist for sample control to assure that all required samples are collected and stored. Samples will be properly labeled according to the sample naming scheme in Section 3.2.5.

The samples will be stored according to Section 3.3 and 3.5. Equipment decontamination will follow the procedure defined in Section 3.4.

In-situ XRF testing will be done using the hand-held XRF device. Readings will be taken for 90 seconds within 2” of the surface soil sample location. The XRF device has an internal calibration that occurs every time the device is turned on. This internal calibration will be logged in the Field Notebook.

2.3.2 Lab QA/QC

Samples will be tracked and documented in a lab notebook during drying and sieving. When in the drying ovens, each sample will go into its own sample dish with its corresponding label written in China pencil. After drying, the sample will remain in their labeled drying dish until put into the sieve tower. Sieve towers with sample in them will be labeled with a piece of tape that has the corresponding sample label on it. After sieving, material passing the smallest sieve will be placed in a new Ziploc bag and labeled with the original sample number plus an “S” (for “sieved”) Table B-2-1 shows an example of the information in lab notebook to keep track of the dried/sieved samples.

Table B-2-1. Lab Notebook Table Example

Sample	Date Dried	Date Sieved
DU1-1		
DU1-2		

XRF analysis in the lab will be performed on the sieved samples using an XRF device. The device will be maintained and used in accordance with the manufacturer's instructions, EPA Method 6200, and the LSASD Operating Procedure for Equipment Inventory and Management (LSASDPROC-1009) [49]. When powered on, the XRF machine performs an internal calibration. Additional calibration will be performed using the National Institute of Standards and Technology (NIST) standards and blanks, found in the XRF kit.

XRF calibration using the standards will be performed prior to the site visit and upon return; results will be documented in the Field Notebook. For the laboratory work, these checks will be performed each day upon startup, after 4 hours of analysis, and when the XRF machine batteries are changed.

Calibration check values must be within 20% of known values of standards and blanks [50]. Calibration checks conducted in the lab will be documented in the Laboratory Notebooks.

Nine sub samples from each sample will be tested with the XRF device [50]. For each element, the highest and lowest values found will be disregarded and the rest of the readings will be averaged. All XRF tested soil will be returned to their sample bag and retained throughout the length of the project.

2.3.3 Cross Contamination

2.3.3.1 Field Prevention

The following precautions will be taken while collecting samples:

- Sampling equipment will be decontaminated between each sample by washing with soap and rinsing.

- New gloves will be put on before collecting a sample and gloves will be discarded after decontaminating sampling equipment.
- No sampling staff will touch the inside of the sampling bag.
- Sample bags are only open while the sample is being put inside the bag.
- Sample bags that are damaged are to be double bagged.

2.3.3.2 Laboratory Prevention

The following precautions will be taken while analyzing samples:

- Drying containers, sieves, and XRF cups will be decontaminated between uses by washing with soap and rinsing. Sieves will be dried with compressed air.
- All analysis equipment and surfaces will be cleaned between uses.
- New gloves will be used when handling any new samples, gloves are to be removed after decontamination.
- Sieving will be done outdoors to prevent further contamination of surfaces.

2.4 Data Quality Indicators

Data Quality Indicators (DQIs) are used to evaluate the quality of the data and ensure that the values of the data determined are what they are. These indicators are defined in terms of PARCCS (precision, accuracy, representativeness, completeness, comparability, and sensitivity). Specific indicators to ensure data validity for each of the DQIs can be found below.

2.4.1 Precision

Precision is the degree of agreement between similar samples and their measurements found [51]. Field duplicates will be collected every 9 samples. To evaluate the precision of a sample and its duplicate, the relative percent difference will be calculated. See Equation B-2-1 below for the relative percent difference.

Equation B-2-1. Relative Percent Difference

$$RPD = \frac{|S_i - S_d|}{((S_i + S_d)/2)} * 100\%$$

Where:

RPD = Relative Percent Difference

S_i = Original Sample Concentration

S_d = Duplicate Sample Concentration

The allowable RPD per the DQI is 40% based on the expected errors for the amount of samples [14].

2.4.2 Accuracy

Accuracy is how closely an experimental measurement matches the actual value. Previous experience with XRF testing indicates that lead (Pb) data are reliable. Arsenic (As) levels may be inaccurate, particularly when Pb levels are high, due to an overlap of As and Pb frequencies. To ensure accurate data is analyzed, 10 samples will be sent to a subcontracted laboratory for ICP/FAA testing. Results will be correlated and the XRF As reading will be adjusted as necessary to ensure accuracy.

2.4.3 Representativeness

The accuracy and precision of a data set is referred to as representativeness [51]. It will be up to the QA/QC officer to ensure that every sample collected at the site represents the area's current conditions. The sampling plan outlined in Section 3.1 is subject to change based on unforeseen changes that may come up at the site visit. Any changes to the sampling plan will be approved by the technical advisor, Dr. Bero, or the client, Eric Zielske, while on site.

2.4.4 Completeness

Completeness refers to the proportion of valid data collected compared to the amount originally expected [51]. Factors that reduce completeness include not collecting intended samples, sample loss, equipment malfunctions or technical errors. To assure completeness is achieved, QA/QC procedures will be followed.

The typical target for completeness is between 75% and 90% [51], with a DQI of 85% for this project.

2.4.5 Comparability

Comparability refers to how well one data set can be related to another identical set of data [51]. Comparability does not apply to this project because data sets will not be identical.

2.4.6 Sensitivity

Sensitivity is represented as the method detection limits (MDL) or the lowest concentration that can be reliably detected. XRF, ICP, and FAA data will receive an MDL. When a sample receives a non-detect measurement, then the sample will be recorded as half of the MDL.

2.5 Data Review, Validation, and Management

The data collected will be analyzed by the QA/QC officer to determine if the DQIs are satisfied. Data found to be inappropriate will be flagged and removed from the dataset. All remaining data will adhere to the EPA “National Functional Guidelines for Inorganic

Superfund Methods Data Review" [52]. Unaccepted data will be noted in the project report along with a summary of the quality review.

Microsoft Teams will be used to store and backup all data files as excel spreadsheets. The XRF data will be exported as an excel spreadsheet from the XRF machine to a computer. One team member along with the QA/QC Officer will obtain all data.

3.0 Field Sampling Protocols

3.1 Soil Sampling

Between 50 to 57 soil samples will be collected at the Dragon Mine site (18 transect samples, 25 grid samples, 4 ISM samples, 3 background samples, and up to 7 hotspots).

The site will be split into 5 decision units (DU) shown in Table B-3-1.

Table B-3-1. Sampling Plan Breakup

Decision Unit	Area	Sampling Type	Number of Samples (Duplicates)	Color
1	Wash	Transect	18(2)	Cyan
2	Red Tailings Pile	Grid	4(1)	Red
3	Production Area	Grid	9(1)	Purple
4	Waste Rock Pile	Grid	9(1)	Yellow
5	Roads	ISM	4	Green

A map showing the decision units is shown in Figure B-3-1 below.

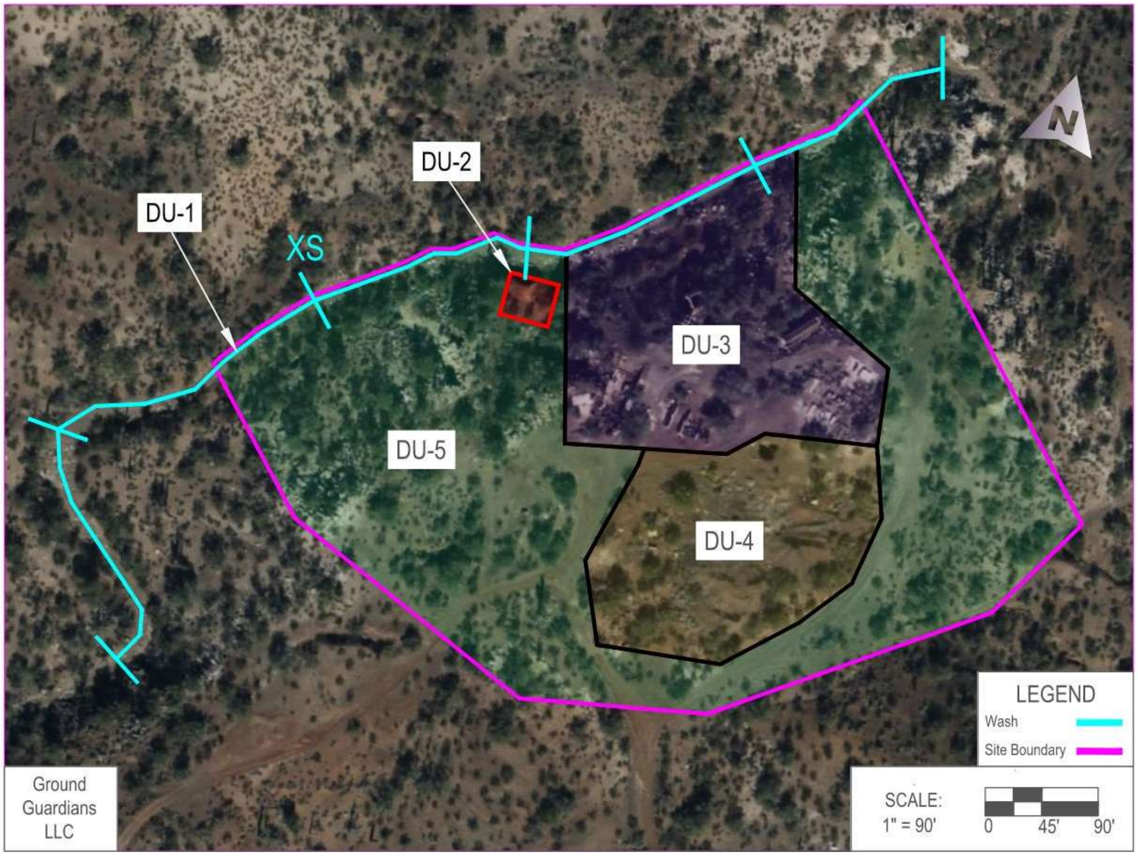

Figure B-3-1. Decision Units

Decision unit 1 will have 18 transect samples taken at both overbanks and the thalweg. DU 2 will be grid sampling with 4 samples and 1 duplicate. DU 3 will have 9 grid samples with 1 duplicate. DU4 will have 9 grid samples and 1 duplicate. DU 5 will be ISM sampling with 4 homogenized samples.

Figure B-3-2 shows the specific locations of the samples taken in decision unit 1.

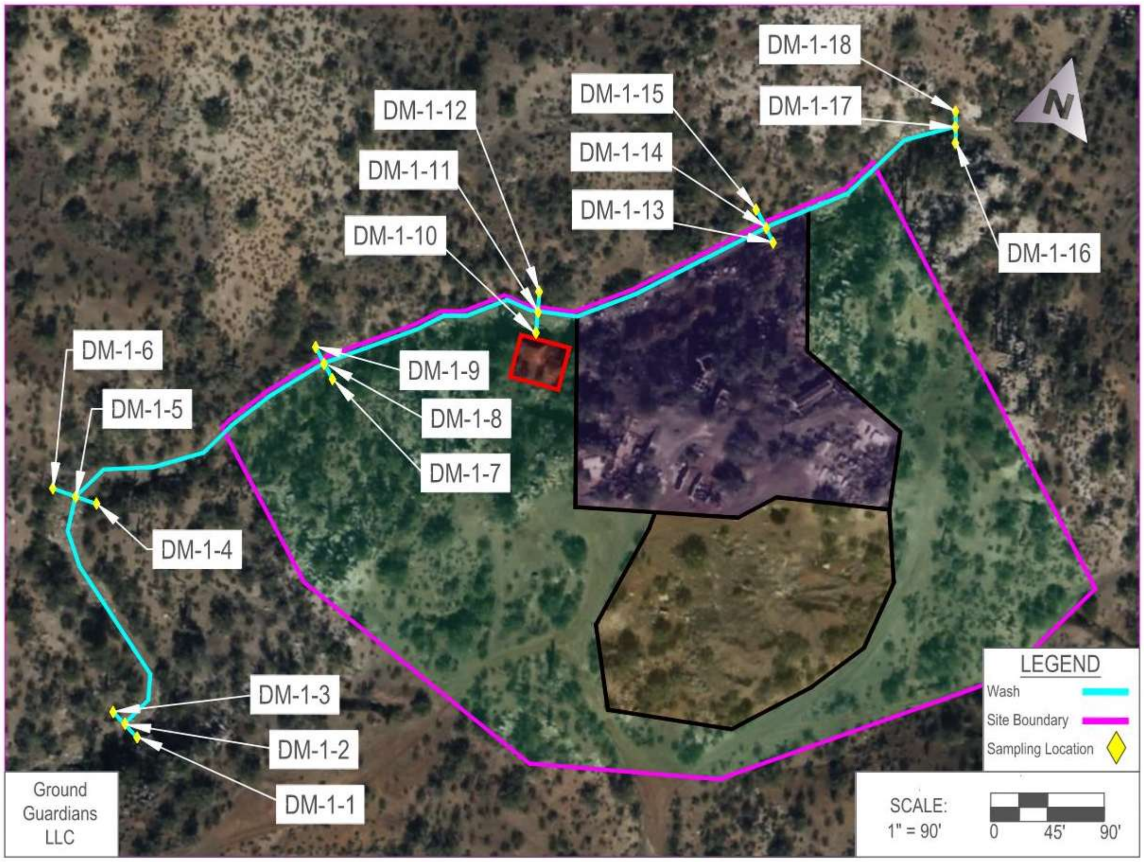

Figure B-3-2. Decision Unit 1 Sampling Plan

Figure B-3-3 shows the 4 sampling locations that will be taken in decision unit 2. Samples will be taken in the center of each grid.

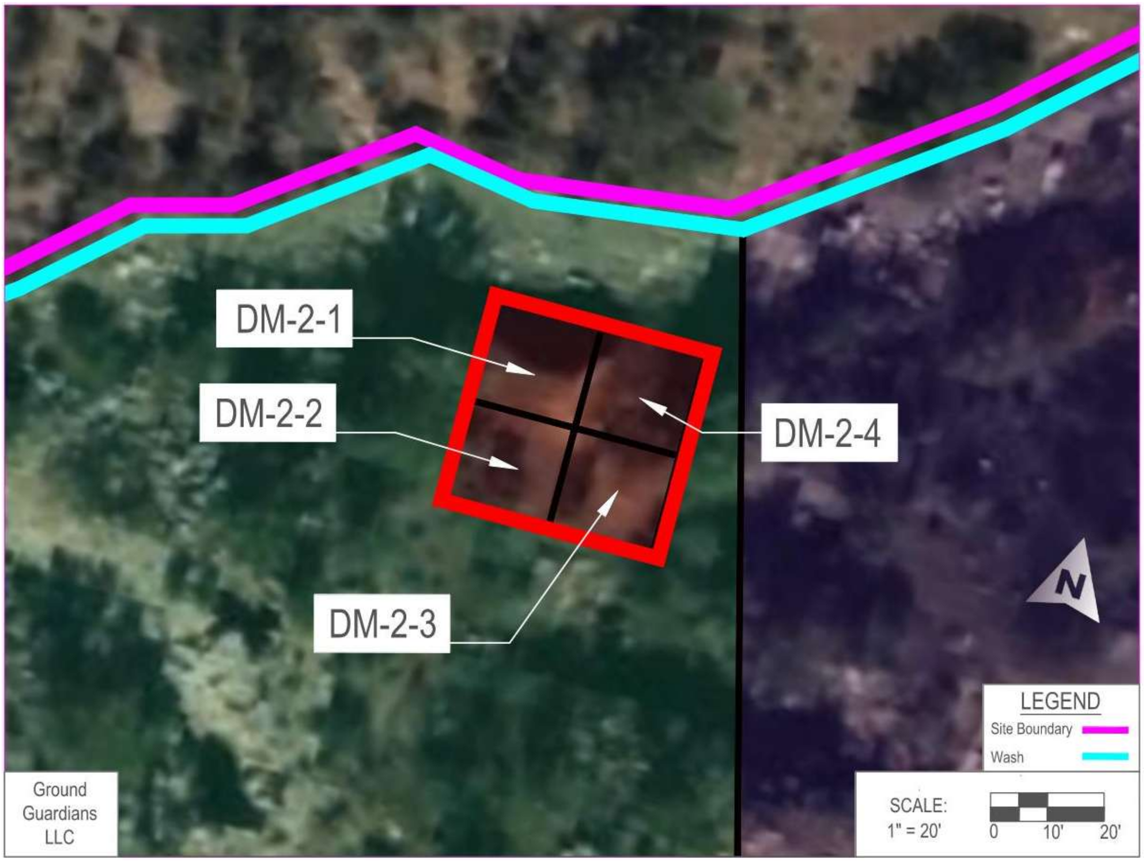

Figure B-3-3. Decision Unit 2 Sampling Plan

Figure B-3-4 shows the 9 sampling locations from decision unit 3. Samples will be taken in the center of each grid.

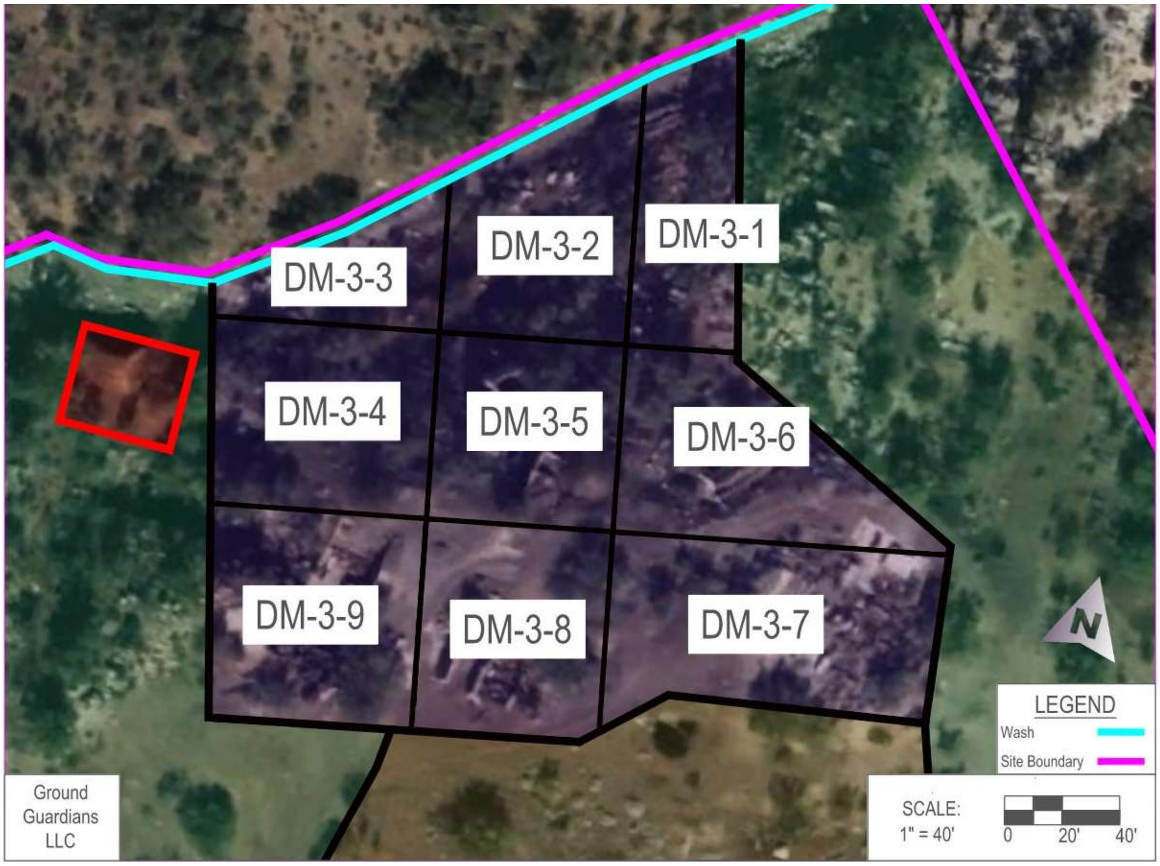

Figure B-3-4. Decision Unit 3 Sampling Plan

Figure B-3-5 shows the 9 sampling locations from decision unit 4. Samples will be taken in the center of each grid.

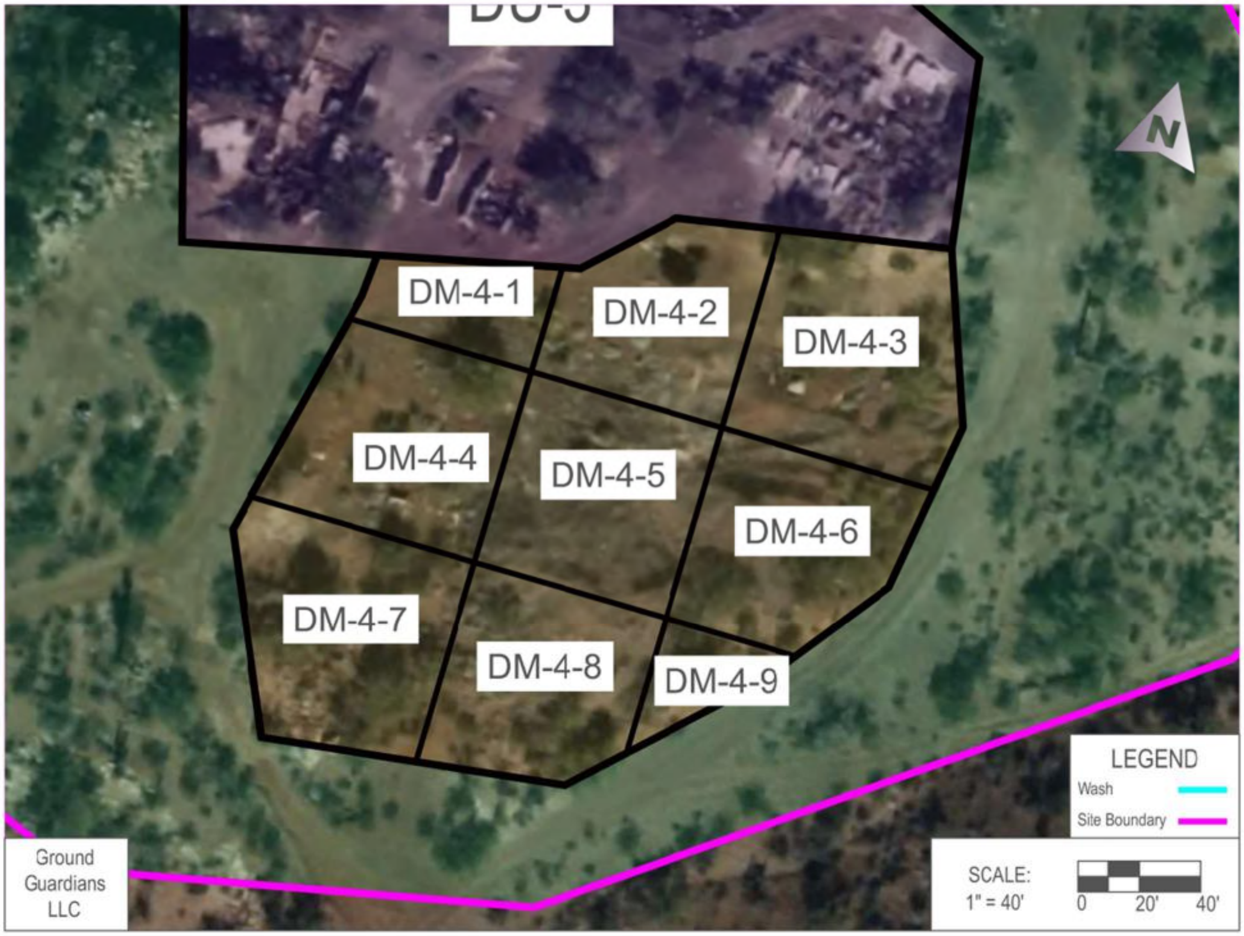

Figure B-3-5. Decision Unit 4 Sampling Plan

Figure B-3-6 shows the incremental sampling plan for DU5. The area will be divided into 34 units of similar size; four small surface soil samples will be taken from each grid and homogenized, creating four duplicates of the DU.

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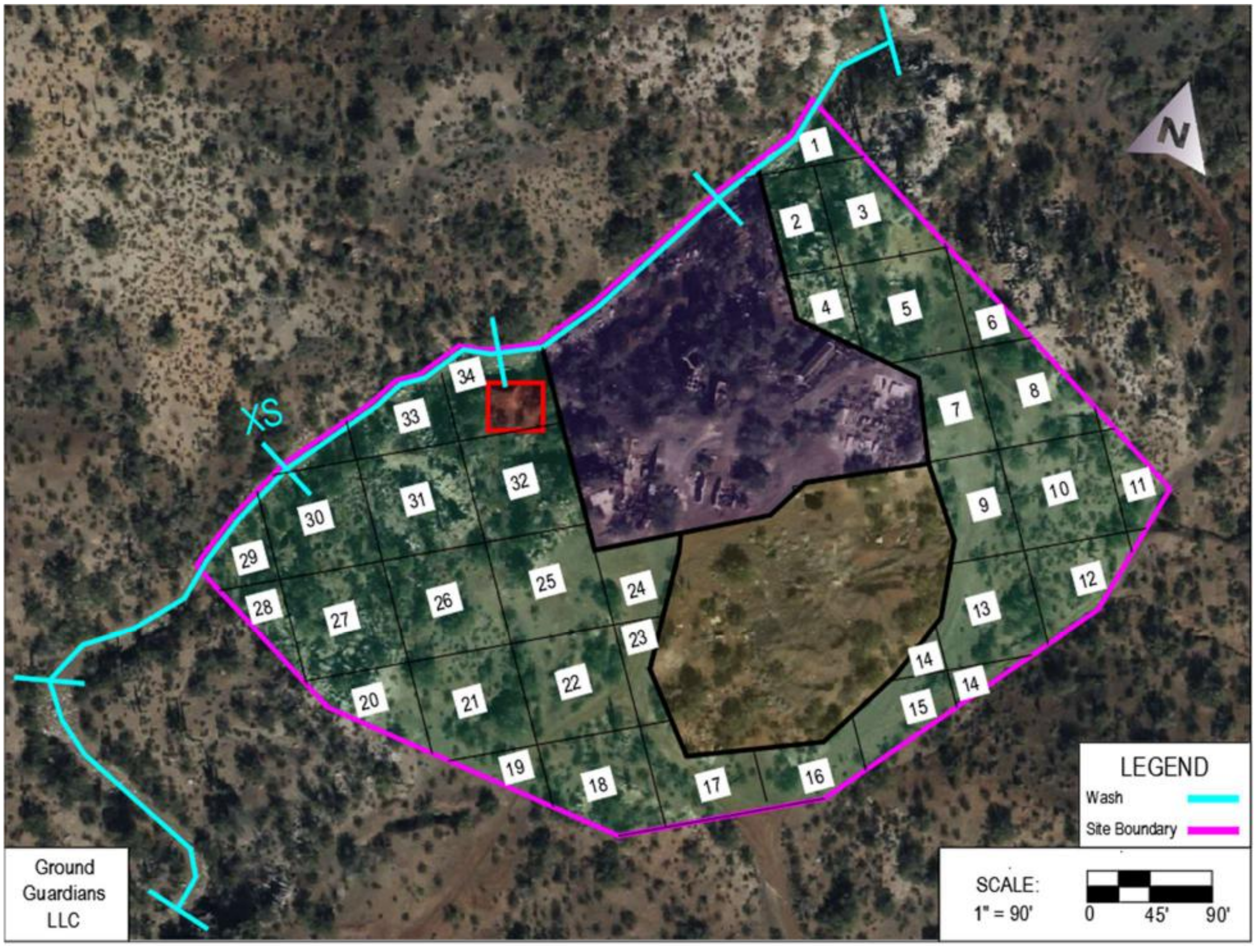


Figure B-3-6. Decision Unit 5 Sampling Plan

Decision units in the maps will be updated after the site investigation to show the actual sampling areas.

3.2 Soil Collection

Surface soil samples will be collected after vegetation, rocks, gravel or other surface litter has been removed using a trowel. A clean stainless-steel trowel will be used to collect the surface sample 0-3 inches below the existing soil surface. The sample will be placed into a gallon sized heavy-duty Ziploc bag and labeled as outlined in Section 3.4. An in-situ XRF reading will be taken at the sample locations after surface litter is removed if there is no precipitation.

3.2.1 Background Samples

Three background samples will be collected as surface samples as described in section 3.2. The location of the background samples will be determined on site, choosing areas without disturbances. The samples are meant to show the true characteristics of the native soil without effects from the site. Wind migration of contaminants will be considered in selecting background sample locations.

3.2.2 Hot Spot Samples

Up to 7 hot-spot samples are allotted to be collected in areas where visual determination indicates the likelihood of high contamination. These samples will be collected as surface samples as described in Section 3.2.

3.2.3 Field Equipment and Calibration

Equipment needed for soil samples includes an XRF device, stainless-steel trowel, heavy-duty gallon sized Ziploc bags, 5-gallon buckets, marking flags, measuring tapes, and a handheld GPS. Field notebooks with writing utensils, and cell-phone cameras in Ziplock bags will be used for documentation. Sampling equipment will be cleaned after each sample is taken using wash water, dish soap, and a scrub brush, see Section 3.6.

The X-Ray Fluorescence (XRF) device will be used to take in-situ measurements at each surface sample location. The device performs an internal calibration each time it is turned on.

3.2.4 Sample Containers

Containers used for the samples will be new heavy-duty gallon sized freezer Ziplock Bags. Once each sample is collected the bags will be transported to the vehicle, logged by the QA Officer into the Field Notebook and the Chain of Custody forms, and placed into large plastic bins for storage and transport. Completed Chain of Custody forms will be placed in each full bin, and the bin will be sealed with the Custody Seal (see Section 3.5.3.1).

3.2.5 Sample Labeling

The samples will be labeled according to the protocol shown in Table B-3-2 below.

Table B-3-2. Sample Labeling Convention

Locator	Sample ID #	Duplicate Sample ID
DU1 (wash)	DU1-1,2,3…18	DU1-(orig#)-D
DU2 (tailings)	DU2-1…9	DU2-(orig#)-D
DU3 (production area)	DU3-1…9	DU3-(orig#)-D
DU4 (waste rock)	DU4-1…9	DU4-(orig#)-D
DU5 (roads)	DU5-1…4	(none)
Background	B-1...3	B-(orig#)-D
Hot Spots	HS-1…7	HS-(orig#)-D

See Section 2.3.2 above for additional sample labeling once laboratory testing begins.

3.3 Sample Preservation, Packaging, and Shipping

Sample preservation is not required for soil samples being tested by XRF. The samples will be transported from the site to NAU in sealed bins.

If samples are tested at subcontracted laboratories, two team members will deliver the samples. Five grams of each sample will be placed into glass vials placed in Styrofoam shipping containers for transport. The samples will be kept at standard conditions when transported. Chain of Custody documents will accompany all sample transfer.

3.4 Equipment Decontamination Procedures

Trowels will be decontaminated after each sample is taken in the field as described in Section 3.2.3. Decontamination is necessary to ensure that each sample is representative of its sampling location. Decontaminated trowels will be stored in a clean 5-gallon bucket.

3.5 Documentation

3.5.1 Field Notes and Logbooks

Each team member will keep a logbook documenting work performed in the field. Information will include project name, location, team member name, and any other pertinent information; all information will be written in ink. All observations and deviations from the Work Plan will be documented. In-situ XRF results and information on each sample including sampler name, date/time, sample location, sample ID, sampling method, description of sample, and if it has a duplicate sample. Maps, sketches and notes on weather conditions, terrain, and flora and fauna observed will be included in logbooks. Page numbers will be noted out of total pages in the logbook.

CENE Laboratory Project Activity Log sheets will be used to in addition to laboratory logbooks. The Project Activity Log sheets include team member names, date and start/end times of each activity, description of activity, and project name. The activities taking place in the lab include sample preparation, sample analyses, and equipment checks. When conducting analysis, the laboratory logbooks will include student name, date and time of analysis, test method and specific procedure details, sample IDs. The instrument name and serial number, calibration records, ID of preparation equipment, units, measurement results, and disposal and decontamination procedures used will be recorded once at the beginning of analysis.

3.5.2 Photographs

Cellphones kept in Ziplock bags will be used to photograph and document the site conditions. Each sample, flora and fauna, and any interesting site conditions such as disturbed soil or tailings piles will be photographed. The photos will be compiled into a Photo Log and stored on the shared drive as described in Section 2.5 above.

3.5.3 Chain of Custody

The samples obtained will be tracked from their collection, handling and transport, analysis, and disposal. To track sample movement a Chain of Custody Form will be used. The form includes who is in possession of each sample and its location, and each time the sample changes custody. See Figure B-3-7 for chain of custody form to be used.

Chain of Custody Record Ground Guardians Dragon Mine PA/SI			
Date of Transfer: Sample Type: Name of Person Relinquishing: Signature of Person Relinquishing: Name of Person Accepting: Signature of Person Accepting Date of Transfer:		Sample ID#s: *Add lines based on number of samples.*	

Figure B-3-7. Chain of Custody Form

The Chain of Custody form is to remain with the sample(s) at all times. The forms will be generated each time samples are worked with, and each change of custody will be recorded. Both people relinquishing and accepting the sample must sign the form.

3.5.3.1 Custody Seals

A Chain of Custody Seal will be used on the lid of every container with samples. Each time a container is opened in the laboratory, the date will be recorded, and the broken seal will be stored with the logbook. A new seal will be placed when samples are returned to the bin, with revised Chain of Custody forms as needed. Chain of Custody forms will be revised as needed; any revisions will be dated and initialed by the user. The Custody Seal is shown below in Figure B-3-8.

Chain of Custody Seal
Ground Guardians

Site Name: ______________________________________

Bin #: _____________________ Sample Type: ____

Date Sealed: _______________ Sealed By: ____

Date Opened:_______________Opened By:____

Figure B-3-8. Chain of Custody Seal

4.0 Laboratory Analysis

4.1 Sample Drying

To remove moisture and homogenize the soil, samples will be dried according to ASTM Method D2216 [53]. After drying, the soil will be prepared for sieving. If soils are clumped, they will be broken up with a pestle to ensure an accurate sieving. The entirety of the sample will be dried and placed in a new Ziploc freezer bag. After drying, the sample will retain its original sample ID# with "dried" being written after the sample ID.

4.2 Sample Sieving

Heavy metals such as arsenic and lead tend to adsorb to finer soil particles. Thus, finer and more homogenous soil is desired for XRF analysis. Soil sieving will be performed according to ASTM Method D6913 [54]. Multiple sieve sizes will be used during the test, the smallest being the #60 sieve with a pore size of less than 250 µm. Sieve #60 was chosen acknowledging ASTM Method 6200 which states heavy metals are often found in the finer soil material. A decision to sieve further than Sieve #60 would result in an insufficient amount of remaining sample. Samples will be sieved in their entirety and returned to its Ziploc bag; the bag will then have "S" written on it to show that the sample has been processed and is ready for XRF analysis. Once an entire sample is sieved, the sieves will be washed with soap, rinsed and dried using compressed air to prepare for the next sample. Any material not passing the #60 sieve will be appropriately discarded as solid waste.

4.3 XRF

XRF analysis will be performed in accordance with EPA Method 6200 [55]. Each sample will be further divided into nine different polyethylene XRF sample cups. Each sub-sample will undergo XRF analysis for 90 seconds, resulting in nine unique measurements for each sample. All data will be downloaded into a spreadsheet. The maximum and minimum value for each element within a sample will be excluded and the remaining data will be averaged to provide a reading for each element. Table B-4-1 shows the detection limits for potential

COC's for the NITON XL3t 600 XRF device, as well as AZ SRLs [56]. Any samples that return a non-detect will be assigned a numerical value of half the detection limit for that element.

Table B-4-1. COC Detection Limits and AZ SRLs [57]

Contaminant	Detection Limit (mg/kg)	Residential (mg/kg)		Non-Residential (mg/kg)
		Carcinogenic (10^{-5} Risk)	Non-Carcinogenic	
		Soil Remediation Levels		
Antimony	30	-	31	410
Arsenic	11	10	10	10
Lead	13	-	400	800
Molybdenum	15	-	390	5,100
Vanadium	70	-	78	1,000

4.4 Acid Digestion, FAA, and ICP Confirmation Testing

The presence of lead at high concentrations is known to cause inaccurate readings of arsenic concentrations using the XRF device. Acid digestion will be performed in accordance with EPA Method 3050B by an external laboratory to confirm the team's arsenic analysis. Subsequently, Flame Atomic Absorption (FAA) and Inductively Coupled Plasma (ICP) testing will be performed by the external laboratory for additional confirmation of chemical concentration. The FAA and ICP test will follow EPA methods 7000B, and 6010B, respectively [58] [59] [60].

5.0 Disposal of Residual Materials

5.1 Field Disposal

The water used to wash and rinse the sampling equipment will be poured directly onto soil at the site. The water will not pose a threat to human health, and contaminant migration should not be an issue. Gloves, paper towels, and flags used during sampling will be collected into a trash bag and disposed of as solid waste at Northern Arizona University.

5.2 Lab Disposal

Previous TCLP testing of BLM Capstone project soils (Pilgrim Mine, Magma Mine) that had higher levels of lead and arsenic than the Dragon Mine Site indicated that the soils are not considered hazardous waste. Soil waste will either be retained for further use as an educational material or will be disposed of as solid waste.

Appendix C: Health and Safety Plan (HASP)

1.0 Job Name and Location

A Preliminary Assessment and Site Investigation of the Dragon mine will be conducted. The site is located about 5.7 miles southeast of Wickenburg, Arizona in Maricopa County.

2.0 Safety & Health Administration

The project Health and Safety Officer, Bowie Ching, is responsible for overseeing safety for the team during the field and lab work portions of this project. The Health and Safety Officer will provide safety guidelines for fieldwork and ensure members are compliant.

3.0 Hazard Assessment & Required PPE

The soil, air, surface water, groundwater, and foliage at the Dragon mine may contain harmful contaminants. The field sampling team will prepare for potential hazards by following proper procedures and wearing protective clothing.

Personal Protective Equipment (PPE) for field sampling includes long pants and sleeves, closed-toed shoes, a brimmed hat, nitrile gloves, a face mask, and sunglasses. PPE for laboratory work includes a lab coat, closed-toe shoes, long hair tied back, goggles, and nitrile gloves.

3.1 Field Hazards

Table C-3-1 shows the potential hazards that may be encountered doing the field site investigation. The hazard, the level of risk and recommended mitigations are also shown.

Table C-3-1. Field Hazards

Hazard	Level of Risk	Mitigation Strategy
Physical		
Sun exposure	Low	Wear sunscreen and proper attire; drink water frequently; take breaks in shaded areas.
Temperature exposure	Low	Wear clothing based on weather forecasts; wear several layers for different temperatures.
Inclement weather	Moderate	Monitor weather forecasts, bring appropriate and extra clothing, postpone field work if necessary.
Falls/ scrapes	Low	Tread carefully, particular care t aken on inclines; wear sturdy shoes.
Chemical		
Dermal exposure to COC’s	Low	Wear gloves, long sleeve shirts and long pants.

Ingestion exposure to COC’s	Low	Wash hands after field work especially before lunch break, wear dust mask if windy.
Inhalation expsure to COC’s	Moderate	Wear a dust mask over nose and mouth if windy.
Biological		
Contact with dangerous animals	Low	Be aware of surroundings; do not approach any animal/insect and follow proper first aid if bitten/stung.
Contact with hazardous plants	Low	Be aware of surroundings and watch steps carefully.
Radiological		
X-Ray Exposure	Low	Use XRF machine at arm’s length, leaning forward to keep instrument away from torso.

3.2 Laboratory Hazards

Table C-3-2 shows the potential hazards that may be encountered in the laboratory during soil testing. The level of risk and recommended mitigations are provided for each hazard.

Table C-3-2. Laboratory Hazards

Hazard	Level of Risk	Mitigation Strategy
Physical		
Burns	Low	Wear special gloves when using drying ovens.
Cuts	Low	Use caution when handling glassware, dispose of broken glass in proper container.
Fire	Low	Use a fire extinguisher and call 911.
Chemical		
Dermal exposure to COC’s	Moderate	Wear gloves, long sleeves and pants, closed toed shoes and a lab coat.
Ingestion exposure to COC’s	Moderate	Wear gloves when handling soil and wash hands often.
Inhalation expsure to COC’s	Moderate	Work outdoors or under fume hoods when testing and handling toxic chemicals. Wear dusk mask if appropriate.
Biological		

None	N/A	N/A
Radiological		
X-Ray Exposure	Low	Only use XRF machine in proper apparatus.

4.0 Training Requirements

4.1 NAU Lab Safety

All GG LLC personnel are required to complete NAU's Chemical Hygiene Training prior to any lab sample analysis. Training completion certificates will be provided by all GG LLC personnel in the lab binder.

4.2 XRF Training

All GG LLC personnel have been trained in use of the XRF device to ensure proficient and correct use of the instrument prior to sample analysis. Additionally, all GG LLC personnel will read the XRF training and operating manual.

5.0 Site Control & Operating Procedures

The site control and operating procedures at Dragon Mine will follow the Occupational Safety and Health Administration (OSHA) 1910 General Industry Subpart H: Guidelines for Hazardous Waste. These guidelines require the inclusion of a site map, site work zones, the use of a buddy system, site communications, emergency response and procedures and safe work practices. These operating procedures are detailed in the following sections. All lab work requires a minimum of two people. Working alone in the lab is prohibited [61].

6.0 Decontamination Procedures

Decontamination for field and laboratory samples will be done following the OSHA standards for hazardous waste decontamination. Procedures will detail the number and layout of decontamination stations, decontamination equipment needed, appropriate decontamination methods, procedures to prevent contamination of clean area, methods and procedures to minimize contamination of workers when taking off PPE, and the methods for disposing of articles that are not completely decontaminated [62]. The details for the procedure have been split into three categories to address field and laboratory decontamination as well as disposal of any contaminated articles.

6.1 Field

Prevention of contamination while in the field shall be done through minimization of contact with waste [62]. The following prevention measures will be taken:

- Do not walk through areas of obvious contamination or touch potentially hazardous substances.

- Protect monitoring and sampling instruments with bags leaving holes for sample ports and sensors.
- Wear disposable outer garments and use disposable equipment where appropriate.
- Cover equipment and tools with coating that can be removed during decontamination.

Articles used as outer wear for both workers and equipment will be removed and consolidated in a disposable plastic bag prior to entering the vehicle used for transport. Care should be taken to prevent contamination of the interior of the vehicle

6.2 Laboratory

A designated space within the laboratory will be used for storage and testing of any potentially hazardous materials. The NAU Chemical Hygiene Plan details the handling and decontamination methods to be followed within the designated space [63]. The following methods will be followed:

- Breakable containers will be stored in a tray.
- When leaving the designated area, all PPE is to be removed and stored in a labeled container. All hands and forearms are to be washed thoroughly.
- Equipment must be decontaminated before leaving the designated area.
- A wet mop will be used to decontaminate surfaces. Do not dry sweep.

6.3 Waste Disposal

NAU Environmental Health & Safety (EHS) will handle the disposal of all hazardous materials. Containers holding any hazardous materials must be triple rinsed and made unusable before discarded. If the container is unable to be made unusable, it must be marked with a completed “EMPTY” label [63]. No hazardous waste is expected in this project.

7.0 Emergency Response Procedures

All personnel at Dragon Mine during the SI will carry a cellphone on their persons if emergency medical services are needed. Phone numbers and physical addresses for emergency response services are listed later in this section. First aid supplies will be provided for all personnel during the SI and during lab analysis. All first aid supplies will be inspected prior to the SI and items will be replaced as needed.

7.1 Closest Medical Facility

The closest medical facility to Dragon Mine is the Wickenburg Community Hospital, less than 10 miles or less than 25 minutes from the site. This facility offers a full-service emergency department that is open 24 hours per day, 7 days a week.

Address: 520 Rose Ln, Wickenburg, AZ 85390

Phone: (928) 684-5421

Figure C-7-1 below shows the path from Dragon Mine to the Wickenburg Community Hospital.

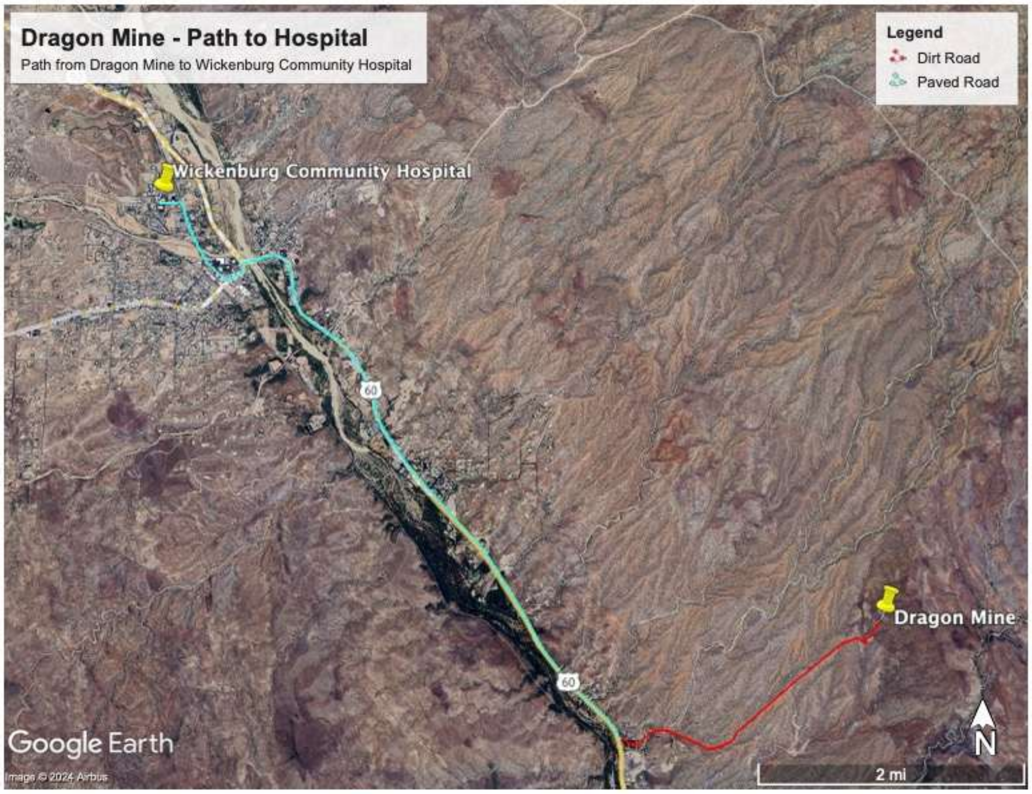


Figure C-7-1. Path from Mine to Nearest Hospital Path from Dragon Mine to Nearest Hospital

The closest medical facility to the lab, where sample analysis will be performed, is the Flagstaff Medical Center, about 3 miles or 10 minutes away from the lab. Flagstaff Medical Center offers a full-service emergency department that is open 24 hours per day, 7 days a week.

Address: 1200 N. Beaver Street, Flagstaff, Arizona

Phone Number: (928) 773-2113

Figure C-7-2 below shows the path from NAU Engineering Building to the Flagstaff Medical Center.

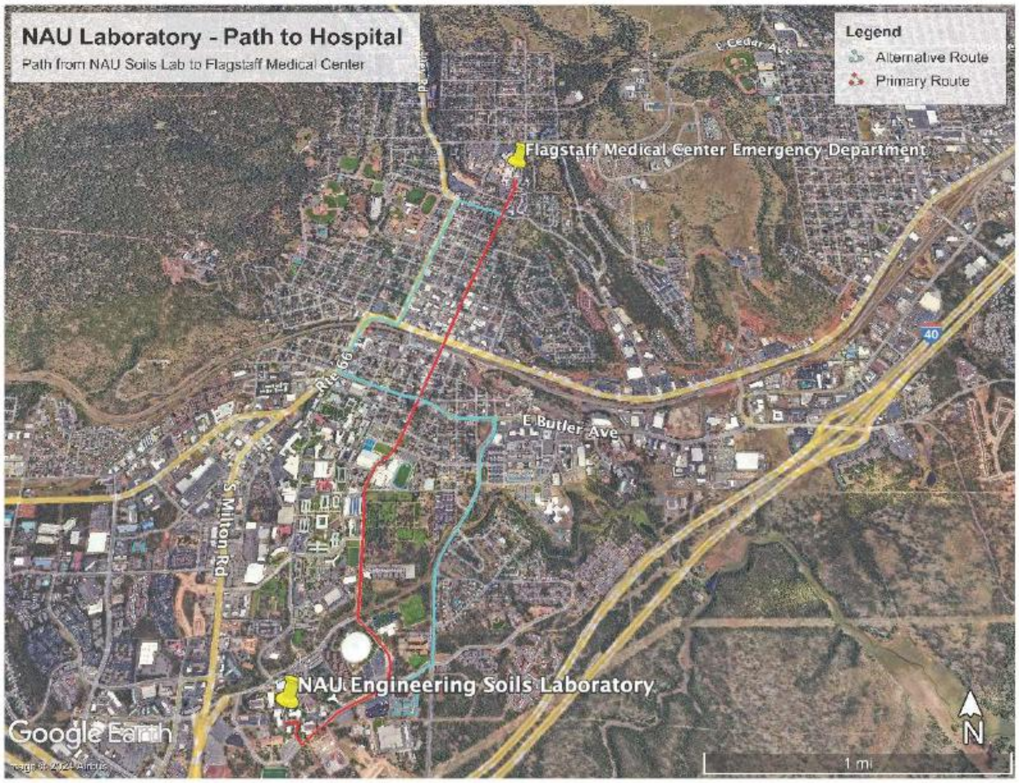


Figure C-7-2. Path from NAU CENE Soils Lab to Nearest Hospital

7.2 Emergency Contact List

In case of an emergency, use the following list to contact the proper authorities and aid services:

Table C-7-1. Emergency Contacts Information. Project Emergency Contact List

Emergency Contact	Phone Number	Address
Wickenburg Community Hospital	(928) 684-5421	520 Rose Ln, Wickenburg, AZ 85390
Wickenburg Police Department	(928) 684-5411	1980 W Wickenburg Way, Wickenburg, AZ 85390
Flagstaff Medical Center	(928) 773-2113	1200 N. Beaver Street, Flagstaff, Arizona
NAU Engineering Department	(928) 523-2704	2112 S Huffer Ln Flagstaff, AZ 86011
BLM Arizona State Office	(602) 417-9223	One North Central Ave, Ste. 800 Phoenix, Arizona 85004
Eric Zielske	(602) 533-6283	-
National Poison Control Center	800-222-1222	-

Personal emergency contacts for all site visit personnel are listed in Table C-7-2 below.

Table C-7-2. Personnel Emergency Contact Information List

Name	Phone Number	Emergency Contact	Relationship	Contact's Phone Number
Dr. Bridget Bero	(928) 607-2516	Charles Beadles	Spouse	(928) 607-8688
Bowie Ching	(808) 294-4169	Steven Ashbaugh	Friend	(480) 688-3869
Andres Garcia Rico	(623) 326-9139	Evelyn Garcia Rico	Mother	(623) 396-8866
Zachary Kauranen	(224) 938-2903	Mary Ann Gorge	Mother	(847) 946-1664
Jorja Whitcher	(605) 877-6660	Kristi Erdman	Mother	(605) 390-4722

Appendix D: HH and ECO COCs Tables

Table D-1 HH COCs Legend

Legend
Under Res
Above Res, Under Non-Res
Above Non-Res
Above Res + Non-Res
Very Above Non-Res

Table D-2. HH COCs

SAMPLE ID	Units	Pb	As
DU1-1	ppm	2.32	1.98
DU1-2	ppm	2.28	2.02
DU1-2-D	ppm	2.92	1.98
DU1-3	ppm	3.09	2.05
DU1-4	ppm	3.30	2.03
DU1-5	ppm	2.22	2.04
DU1-6	ppm	2.36	2.02
DU1-7	ppm	2.25	2.01
DU1-8	ppm	2.70	1.96
DU1-9	ppm	2.21	1.96
DU1-10	ppm	2.62	2.51
DU1-11	ppm	2.25	2.01
DU1-11-D	ppm	2.61	2.05
DU1-12	ppm	2.97	2.01
DU1-13	ppm	4.90	2.18
DU1-14	ppm	2.26	2.04
DU1-15	ppm	2.24	2.02
DU1-16	ppm	2.16	1.92
DU1-17	ppm	2.64	2.06
DU1-18	ppm	3.69	1.97
SAMPLE ID	Units	Pb	As
DU3-1	ppm	137.42	15.66

DU3-2	ppm	2969.71	14.47
DU3-3	ppm	532.97	8.51
DU3-3-D	ppm	383.66	12.01
DU3-4	ppm	3967.28	21.96
DU3-5	ppm	692.07	20.84
DU3-6	ppm	245.89	25.98
DU3-7	ppm	218.06	11.30
DU3-8	ppm	71.82	10.80
DU3-9	ppm	3229.51	18.89
SAMPLE ID	Units	Pb	As
DU4-1	ppm	230.26	13.48
DU4-2	ppm	14729.67	39.05
DU4-3	ppm	134271.16	296.98
DU4-4	ppm	1178.05	135.17
DU4-5-D	ppm	1348.60	9.35
DU4-5	ppm	1052.59	8.00
DU4-6	ppm	92.70	9.77
DU4-7	ppm	2520.55	12.55
DU4-8	ppm	92.20	9.94
DU4-9	ppm	380.91	14.53
SAMPLE ID	Units	Pb	As
DU5-1	ppm	272.00	7.68
DU5-2	ppm	226.08	5.54
DU5-3	ppm	258.87	4.92
DU5-4	ppm	293.22	7.72
SAMPLE ID	Units	Pb	As
HS-1	ppm	817.24	14.14
HS-2	ppm	23505.39	146.09
HS-3	ppm	9164.15	29.24
HS-4	ppm	9367.51	139.95
SAMPLE ID	Units	Pb	As
BG-1	ppm	25.86	9.26
BG-2	ppm	24.18	7.19
BG-3	ppm	32.72	7.60

Table D-3 Ecological COCs Legend

Legend:
plants + soil invertebrates
plants
all
soil invertebrates + avian + mammalian
plants + avian
plants + avian + mammalian
avian + mammalian

Table D-4. Ecological COCs

SAMPLE ID	Units	Pb	Se	As	Zn	Cu	Ni	Co	Mn	Cr	V
DU1-1	ppm	92.56	2.31	10.44	184.59	69.46	73.48	102.83	1626.99	45.84	182.17
DU1-2	ppm	102.75	1.44	7.35	169.50	77.77	64.82	179.56	1646.93	50.33	188.56
DU1-2-D	ppm	73.94	1.38	8.45	158.94	68.74	59.10	118.44	1366.94	51.61	159.55
DU1-3	ppm	74.77	1.36	8.36	152.91	67.93	59.52	61.03	1205.28	42.72	160.40
DU1-4	ppm	108.22	1.52	9.13	170.84	71.55	54.98	90.49	1332.67	47.68	158.00
DU1-5	ppm	82.79	2.03	8.38	166.48	74.10	60.02	162.11	1345.48	53.15	167.15
DU1-6	ppm	73.35	1.33	9.06	158.91	63.86	62.14	89.90	1304.34	50.39	171.58
DU1-7	ppm	227.09	1.39	4.84	217.81	65.91	66.55	68.33	1552.61	41.58	183.49
DU1-8	ppm	63.23	1.67	6.43	172.13	65.19	66.66	94.52	1652.55	38.23	187.60
DU1-9	ppm	73.66	1.35	8.80	164.97	59.03	62.14	93.06	1428.92	49.75	178.04
DU1-10	ppm	809.94	1.79	29.07	621.02	137.63	92.42	94.87	4014.72	83.06	265.65
DU1-11	ppm	227.45	1.38	7.05	218.24	68.33	54.99	104.67	1346.78	45.35	167.36
DU1-11-D	ppm	159.17	1.60	7.57	186.43	61.90	61.21	156.12	1384.63	45.90	169.47
DU1-12	ppm	108.55	1.36	8.57	177.31	56.25	60.48	101.17	1461.41	48.22	185.19
DU1-13	ppm	1420.15	1.83	34.93	977.23	152.76	63.54	75.94	1644.68	48.14	243.71
DU1-14	ppm	39.54	1.38	9.79	152.35	61.85	54.47	261.54	1532.29	50.76	185.72
DU1-15	ppm	56.34	1.35	9.12	154.69	51.80	53.17	101.76	1429.52	43.17	169.98
DU1-16	ppm	25.28	1.32	7.43	131.98	49.86	61.76	74.75	1366.43	42.90	175.51
DU1-17	ppm	32.01	1.65	8.37	156.17	54.94	59.97	232.54	1557.37	54.91	183.43
DU1-18	ppm	24.15	1.30	8.57	137.94	48.98	60.42	62.65	1337.82	47.61	155.20
SAMPLE ID	Units	Pb	Se	As	Zn	Cu	Ni	Co	Mn	Cr	V
DU3-1	ppm	137.42	1.41	15.66	322.47	136.20	75.54	147.18	1670.49	80.13	201.62
DU3-2	ppm	2969.71	2.30	14.47	1511.75	269.93	72.19	90.77	2834.81	89.64	281.72
DU3-3	ppm	532.97	1.71	8.51	607.14	118.75	70.49	99.41	2649.98	47.07	315.63

DU3-3-D	ppm	383.66	1.65	12.01	432.23	98.92	72.84	98.50	2563.30	38.43	332.48
DU3-4	ppm	3967.28	2.59	21.96	2235.79	287.85	90.53	95.34	2822.82	92.39	554.07
DU3-5	ppm	692.07	1.68	20.84	1007.05	122.13	71.35	88.20	1637.20	47.89	418.46
DU3-6	ppm	245.89	2.34	25.98	353.22	107.06	26.07	267.58	3079.58	46.94	67.05
DU3-7	ppm	218.06	1.41	11.30	496.19	67.06	32.05	63.26	1063.89	55.54	109.04
DU3-8	ppm	71.82	1.59	10.80	249.64	52.87	46.39	96.06	1357.99	87.61	116.85
DU3-9	ppm	3229.51	2.54	18.89	2041.98	345.30	47.28	106.86	2188.64	37.19	332.03
SAMPLE ID	Units	Pb	Se	As	Zn	Cu	Ni	Co	Mn	Cr	V
DU4-1	ppm	230.26	1.58	13.48	388.62	131.61	59.72	81.90	1695.42	49.02	196.86
DU4-2	ppm	14729.67	5.07	39.05	7640.14	944.05	81.75	141.45	4395.02	71.57	974.53
DU4-3	ppm	134271.16	24.61	296.98	14773.81	1363.69	50.21	379.14	6198.74	252.92	4542.50
DU4-4	ppm	1178.05	2.13	135.17	319.09	62.25	52.89	97.11	1073.91	47.58	422.07
DU4-5-D	ppm	1348.60	2.81	9.35	767.74	190.70	84.93	71.94	2602.54	88.31	229.19
DU4-5	ppm	1052.59	2.39	8.00	707.32	177.32	81.21	81.99	2575.77	84.91	189.13
DU4-6	ppm	92.70	2.47	9.77	271.36	199.20	100.98	94.73	2803.44	87.99	277.15
DU4-7	ppm	2520.55	2.06	12.55	1545.21	98.95	63.15	110.79	1568.38	71.91	268.23
DU4-8	ppm	92.20	1.61	9.94	244.20	70.54	58.59	65.87	1512.33	43.33	180.47
DU4-9	ppm	380.91	1.50	14.53	382.11	110.49	71.25	70.53	1639.09	75.87	183.33
SAMPLE ID	ppm	Pb	Se	As	Zn	Cu	Ni	Co	Mn	Cr	V
DU5-1	ppm	272.00	1.46	7.68	315.58	85.64	74.84	71.48	1590.66	76.10	194.54
DU5-2	ppm	226.08	1.44	5.54	298.27	81.64	64.91	94.91	1523.61	68.11	172.93
DU5-3	ppm	258.87	1.44	4.92	267.36	75.07	65.52	68.12	1478.45	64.30	171.34
DU5-4	ppm	293.22	1.45	7.72	327.71	94.82	74.46	68.01	1476.32	67.63	179.92
SAMPLE ID	Units	Pb	Se	As	Zn	Cu	Ni	Co	Mn	Cr	V
HS-1	ppm	817.24	1.73	14.14	1152.49	139.74	66.44	110.42	1780.49	52.92	421.78
HS-2	ppm	23505.39	6.99	146.09	7212.07	1597.84	74.05	200.11	3557.30	59.22	929.49
HS-3	ppm	9164.15	3.89	29.24	5345.07	562.21	73.86	134.29	3192.05	41.37	545.20
HS-4	ppm	9367.51	3.98	139.95	3804.16	737.42	68.29	129.89	2044.02	64.64	515.55
SAMPLE ID	Units	Pb	Se	As	Zn	Cu	Ni	Co	Mn	Cr	V
BG-1	ppm	25.86	1.66	9.26	145.38	61.19	60.27	279.80	1422.43	50.61	207.20
BG-2	ppm	24.18	1.28	7.19	94.81	74.28	57.41	165.02	696.32	41.34	93.76
BG-3	ppm	32.72	1.78	7.60	175.58	74.86	72.37	179.26	1500.45	88.07	209.58

Appendix E: ECO COCs Maps

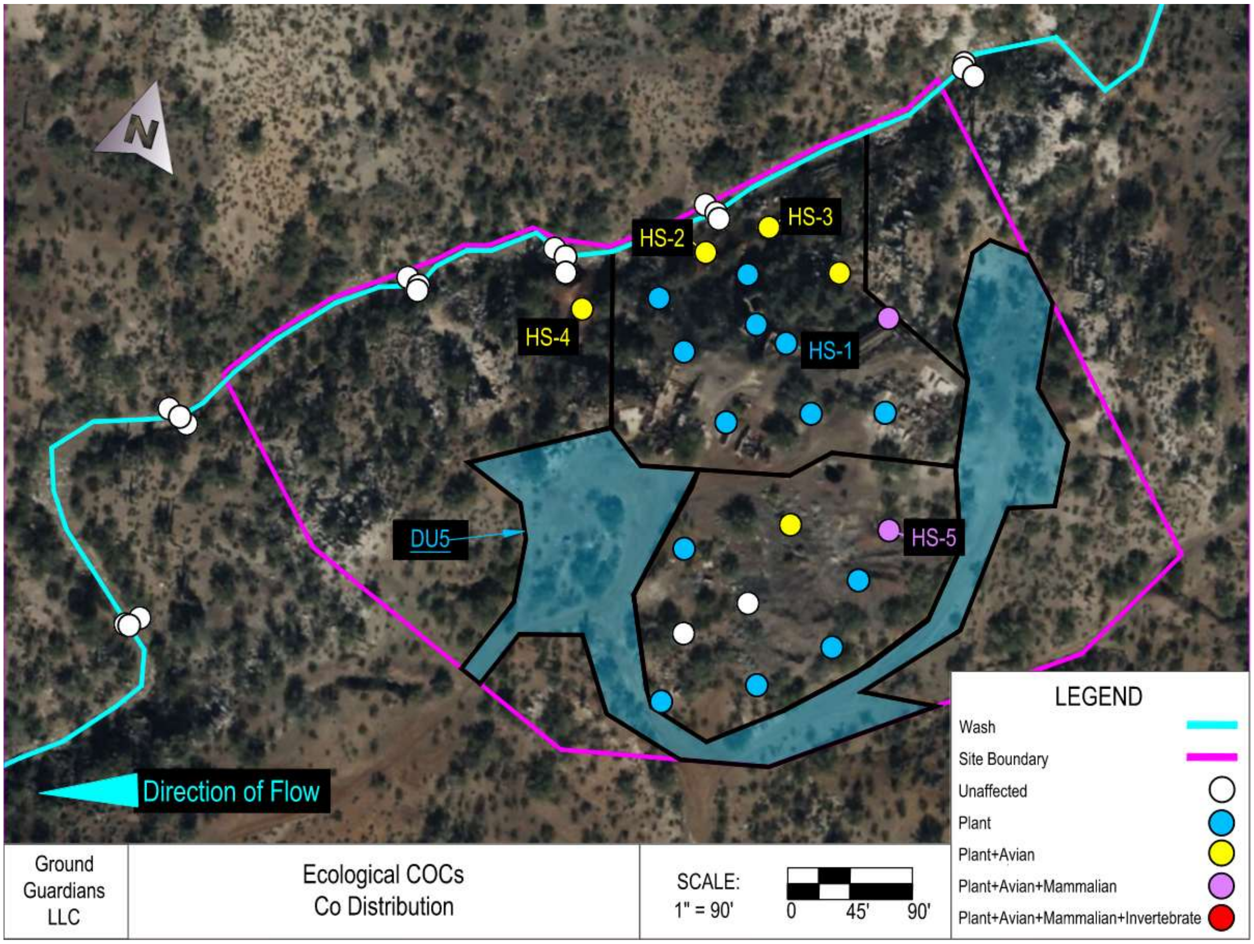


Figure E-1. Co Ecological Distribution Map

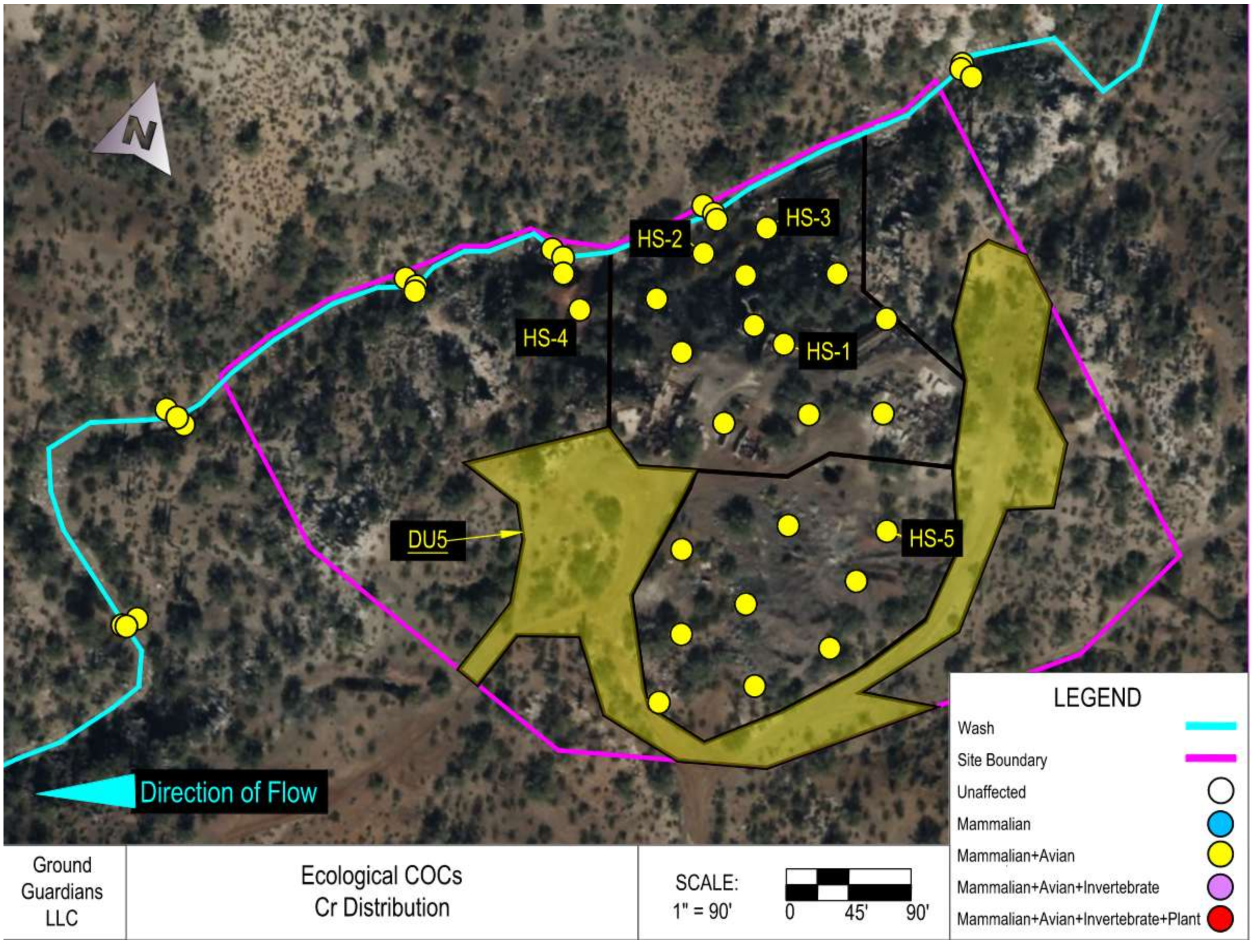


Figure E-2. Cr III Ecological Distribution Map

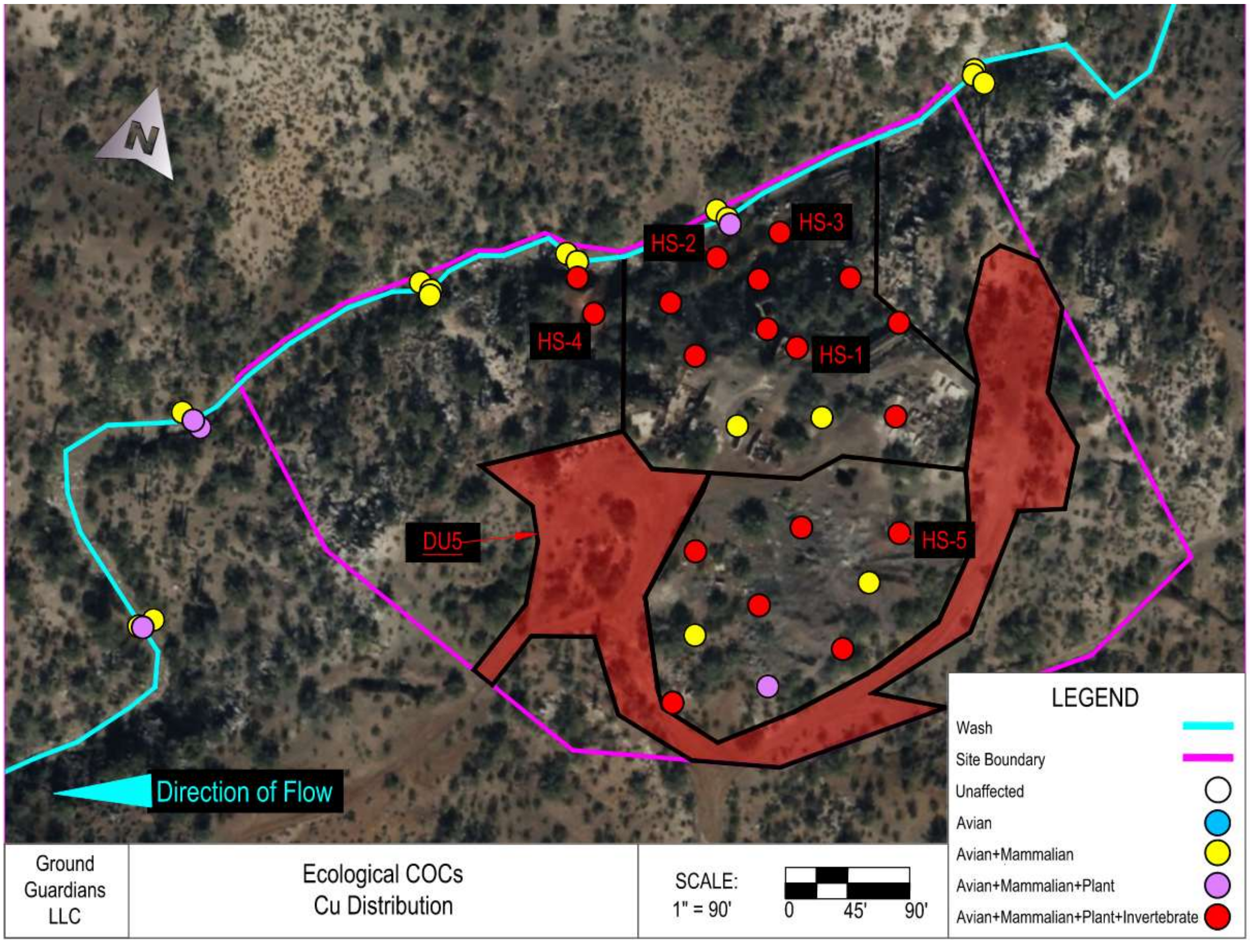


Figure E-3. Cu Ecological Distribution Map

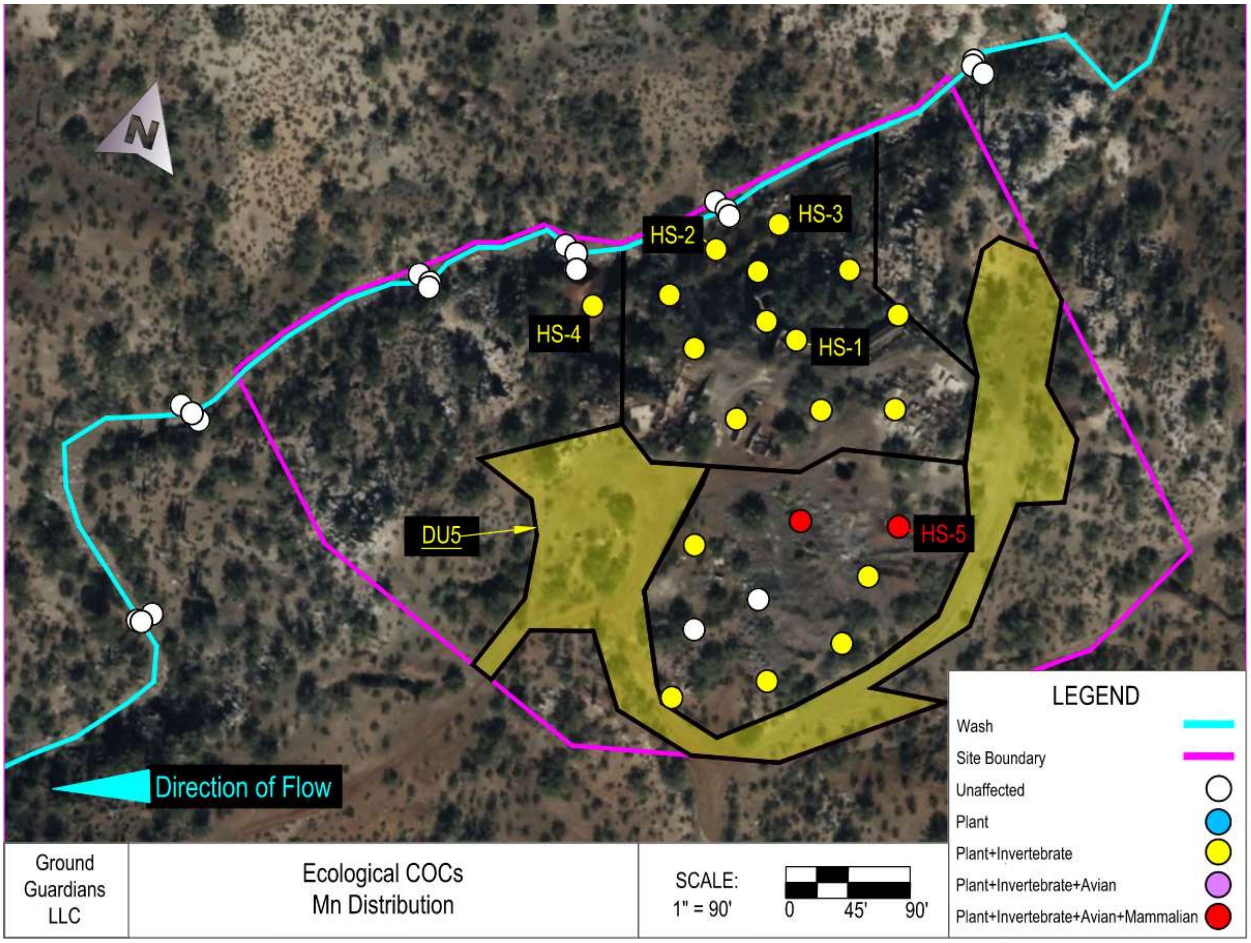


Figure E-4. Mn Ecological Distribution Map

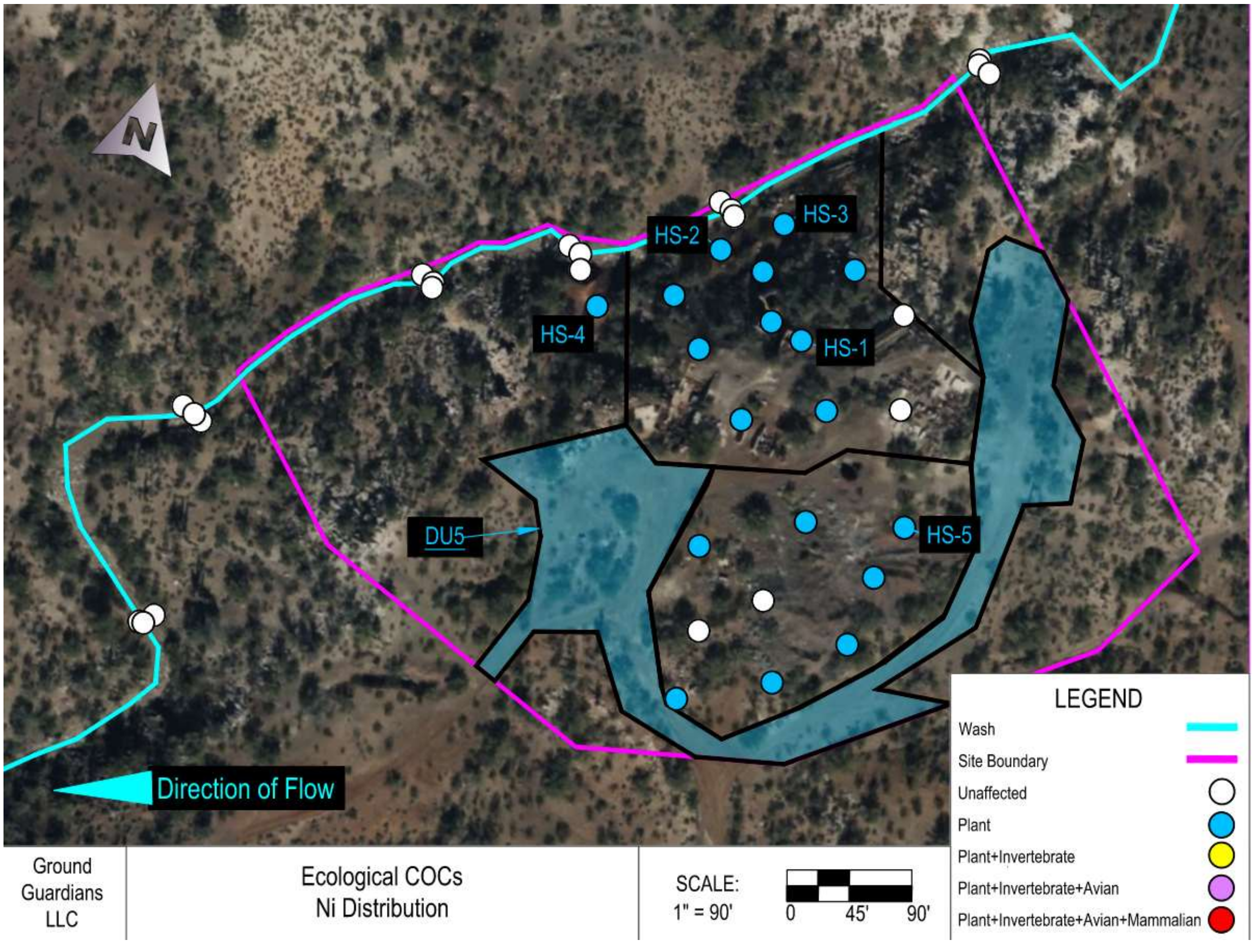


Figure E-5. Ni Ecological Distribution Map

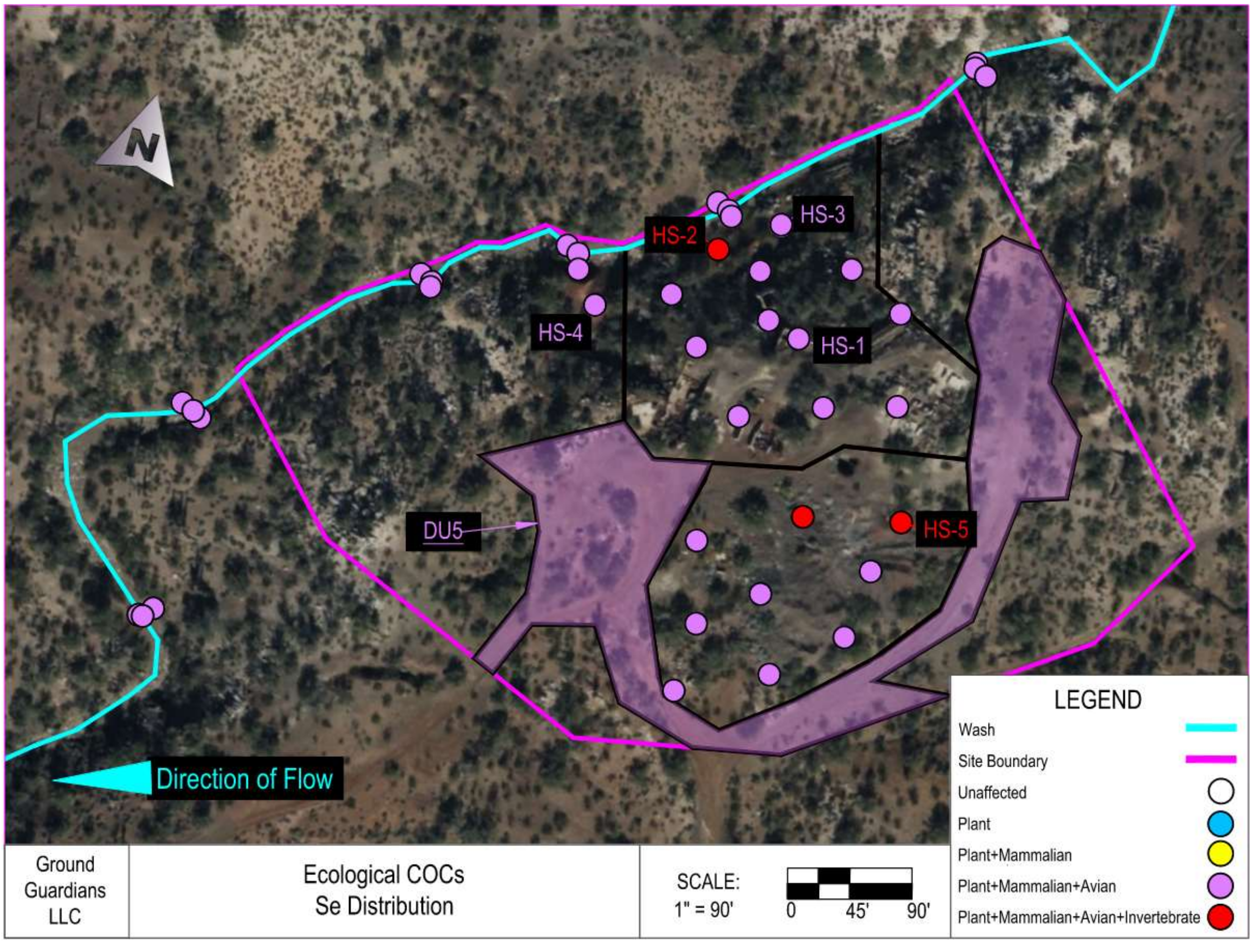


Figure E-6. Se Ecological Distribution Map

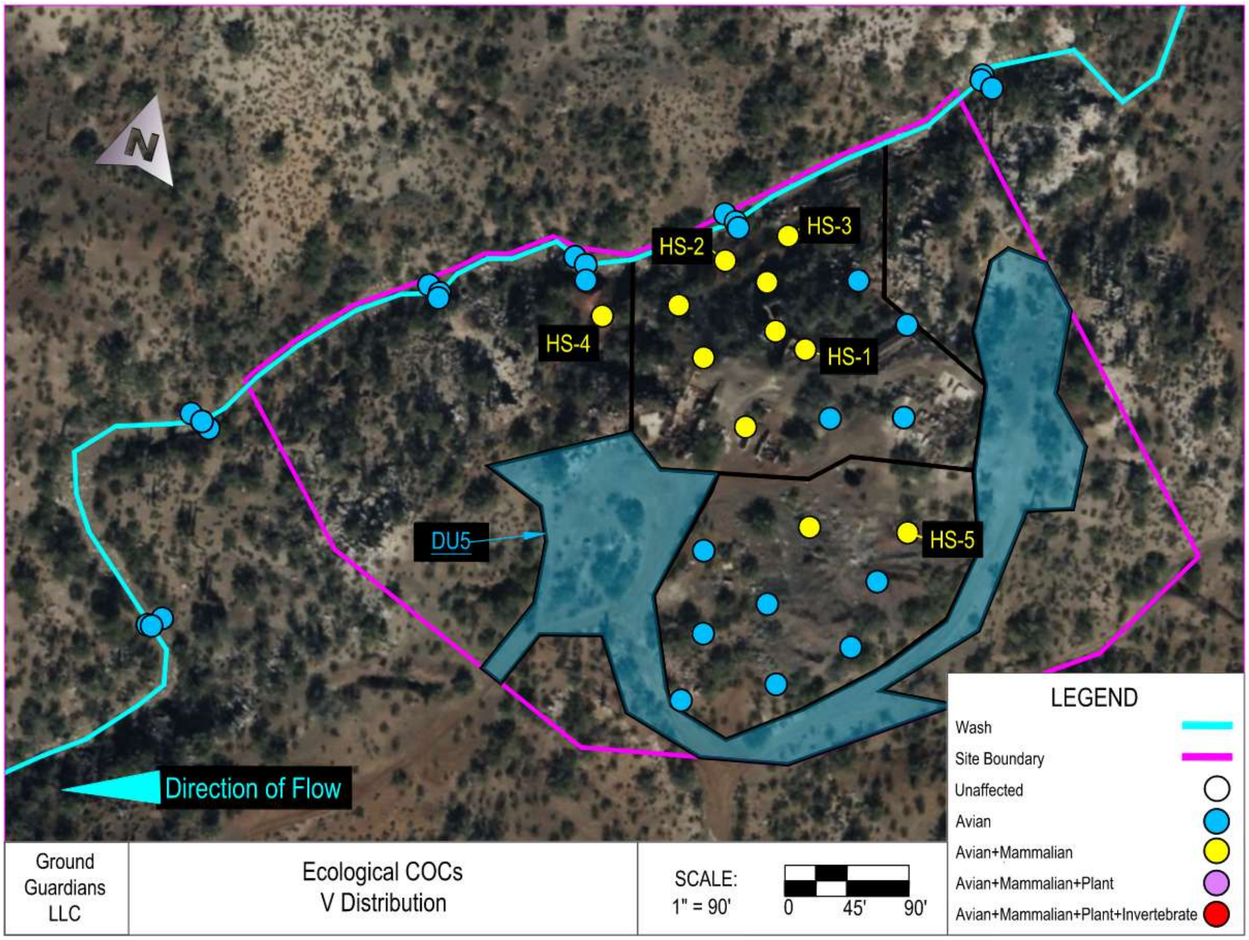


Figure E-7. V Ecological Distribution Map

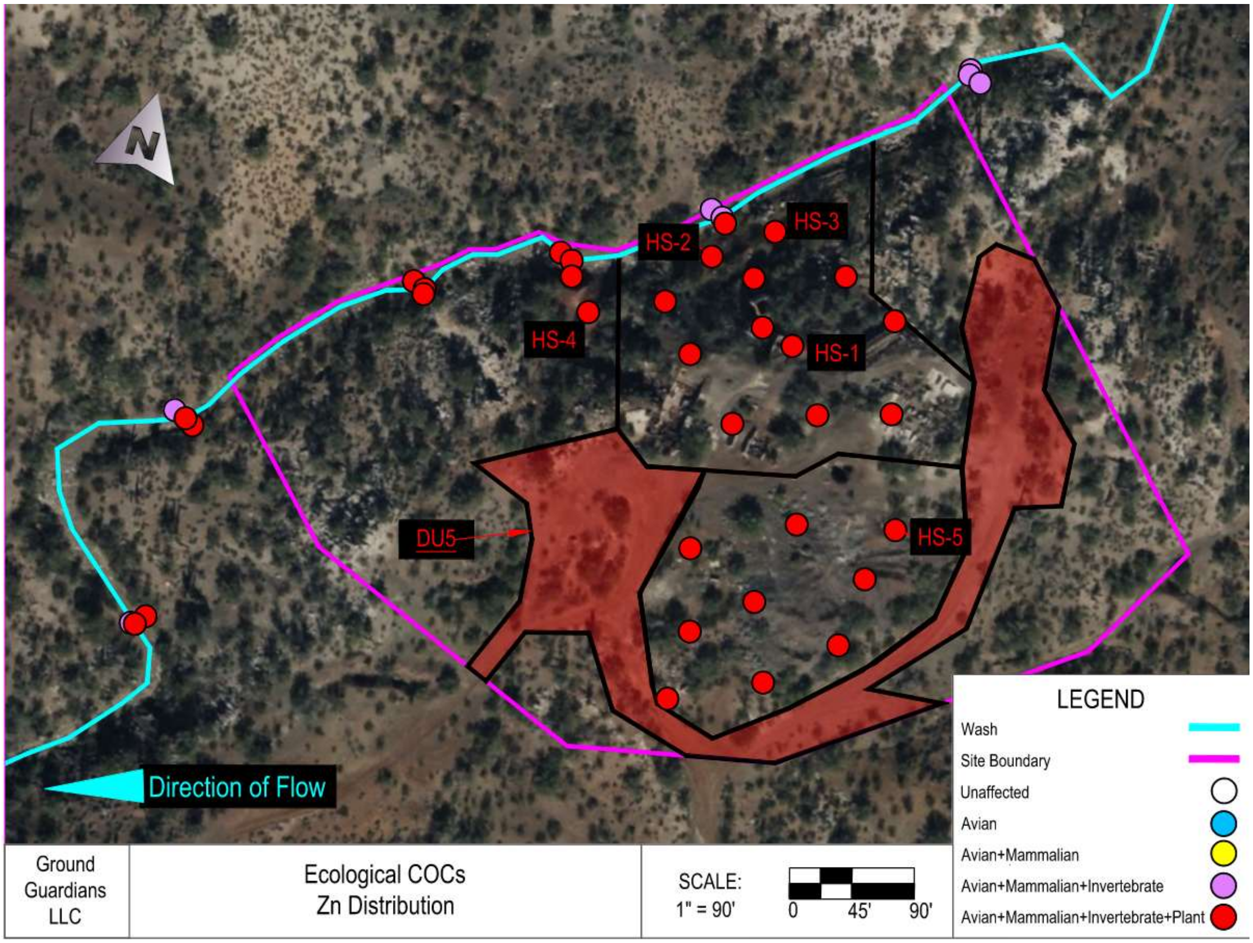


Figure E-8. Zn Ecological Distribution Map

Appendix F: Lead Risk Models

Adult Lead Models

Table F-1 Adult Lead Model DU3 Output for Average Worker Exposure

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 2009-2014
PbS	Soil lead concentration	µg/g or ppm	556.52
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--
K_{SD}	Mass fraction of soil in dust	--	--
$AF_{S, D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S, D}$	Exposure frequency (same for soil and dust)	days/yr	250
$AT_{S, D}$	Averaging time (same for soil and dust)	days/yr	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	2.4
$PbB_{fetal, 0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	5.8
PbB_t	Target PbB level of concern (e.g., 2-8 ug/dL)	µg/dL	5.0
$P(PbB_{fetal} > PbB_t)$	Probability that fetal PbB exceeds target PbB, assuming lognormal distribution	%	8.0%

Table F-2 Adult Lead Model DU3 Output for Maximum Worker Exposure

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 2009-2014
PbS	Soil lead concentration	µg/g or ppm	4246.07
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--
K_{SD}	Mass fraction of soil in dust	--	--
$AF_{S, D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S, D}$	Exposure frequency (same for soil and dust)	days/yr	250
$AT_{S, D}$	Averaging time (same for soil and dust)	days/yr	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	14.6
$PbB_{fetal, 0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	34.5
PbB_t	Target PbB level of concern (e.g., 2-8 ug/dL)	µg/dL	5.0
$P(PbB_{fetal} > PbB_t)$	Probability that fetal PbB exceeds target PbB, assuming lognormal distribution	%	94.9%

Table F-3 Adult Lead Model DU4 Output for Average Worker Exposure

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 2009-2014
PbS	Soil lead concentration	µg/g or ppm	711.18
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--
K_{SD}	Mass fraction of soil in dust	--	--
$AF_{S, D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S, D}$	Exposure frequency (same for soil and dust)	days/yr	250
$AT_{S, D}$	Averaging time (same for soil and dust)	days/yr	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	2.9
$PbB_{fetal, 0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	7.0
PbB_t	Target PbB level of concern (e.g., 2-8 ug/dL)	µg/dL	5.0
$P(PbB_{fetal} > PbB_t)$	Probability that fetal PbB exceeds target PbB, assuming lognormal distribution	%	13.9%

Table F-4 Adult Lead Model DU4 Output for Maximum Worker Exposure

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 2009-2014
PbS	Soil lead concentration	µg/g or ppm	10906.70
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--
K_{SD}	Mass fraction of soil in dust	--	--
$AF_{S,\ D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S,\ D}$	Exposure frequency (same for soil and dust)	days/yr	250
$AT_{S,\ D}$	Averaging time (same for soil and dust)	days/yr	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	36.5
$PbB_{fetal,\ 0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	86.3
PbB_t	Target PbB level of concern (e.g., 2-8 ug/dL)	µg/dL	5.0
$P(PbB_{\mathbf{fetal}} > PbB_t)$	Probability that fetal PbB exceeds target PbB, assuming lognormal distribution	%	99.9%

Table F-5 Adult Lead Model DU3 Output for Average Recreation Exposure

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 2009-2014
PbS	Soil lead concentration	µg/g or ppm	556.52
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--
K_{SD}	Mass fraction of soil in dust	--	--
$AF_{S, D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S, D}$	Exposure frequency (same for soil and dust)	days/yr	6
$AT_{S, D}$	Averaging time (same for soil and dust)	days/yr	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	0.6
$PbB_{fetal, 0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	1.5
PbB_t	Target PbB level of concern (e.g., 2-8 ug/dL)	µg/dL	5.0
$P(PbB_{fetal} > PbB_t)$	Probability that fetal PbB exceeds target PbB, assuming lognormal distribution	%	0.01%

Table F-6 Adult Lead Model DU3 Output for Maximum Recreation Exposure

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 2009-2014
PbS	Soil lead concentration	µg/g or ppm	4246.07
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--
K_{SD}	Mass fraction of soil in dust	--	--
$AF_{S, D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S, D}$	Exposure frequency (same for soil and dust)	days/yr	6
$AT_{S, D}$	Averaging time (same for soil and dust)	days/yr	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	0.9
$PbB_{fetal, 0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	2.2
PbB_t	Target PbB level of concern (e.g., 2-8 ug/dL)	µg/dL	5.0
$P(PbB_{fetal} > PbB_t)$	Probability that fetal PbB exceeds target PbB, assuming lognormal distribution	%	0.1%

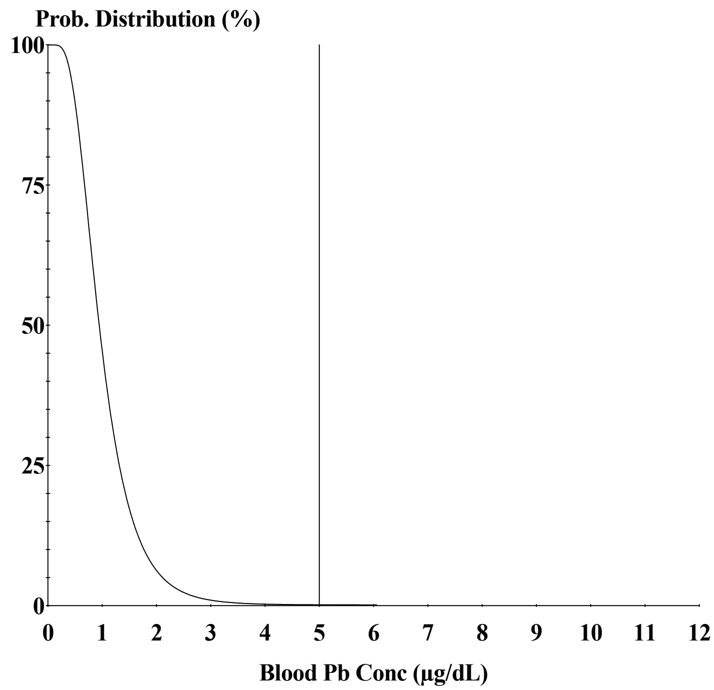
Table F-7 Adult Lead Model DU4 Output for Average Recreation Exposure

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 2009-2014
PbS	Soil lead concentration	µg/g or ppm	711.18
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--
K_{SD}	Mass fraction of soil in dust	--	--
$AF_{S, D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S, D}$	Exposure frequency (same for soil and dust)	days/yr	6
$AT_{S, D}$	Averaging time (same for soil and dust)	days/yr	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	0.7
$PbB_{fetal, 0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	1.6
PbB_t	Target PbB level of concern (e.g., 2-8 ug/dL)	µg/dL	5.0
$P(PbB_{fetal} > PbB_t)$	Probability that fetal PbB exceeds target PbB, assuming lognormal distribution	%	0.01%

Table F-8 Adult Lead Model DU4 Output for Maximum Recreation Exposure

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 2009-2014
PbS	Soil lead concentration	µg/g or ppm	10906.70
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--
K_{SD}	Mass fraction of soil in dust	--	--
$AF_{S,\,D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S,\,D}$	Exposure frequency (same for soil and dust)	days/yr	6
$AT_{S,\,D}$	Averaging time (same for soil and dust)	days/yr	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	1.5
$PbB_{fetal,\,0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	3.5
PbB_t	Target PbB level of concern (e.g., 2-8 ug/dL)	µg/dL	5.0
$P(PbB_{fetal} > PbB_t)$	Probability that fetal PbB exceeds target PbB, assuming lognormal distribution	%	1.2%

IEUBK Models

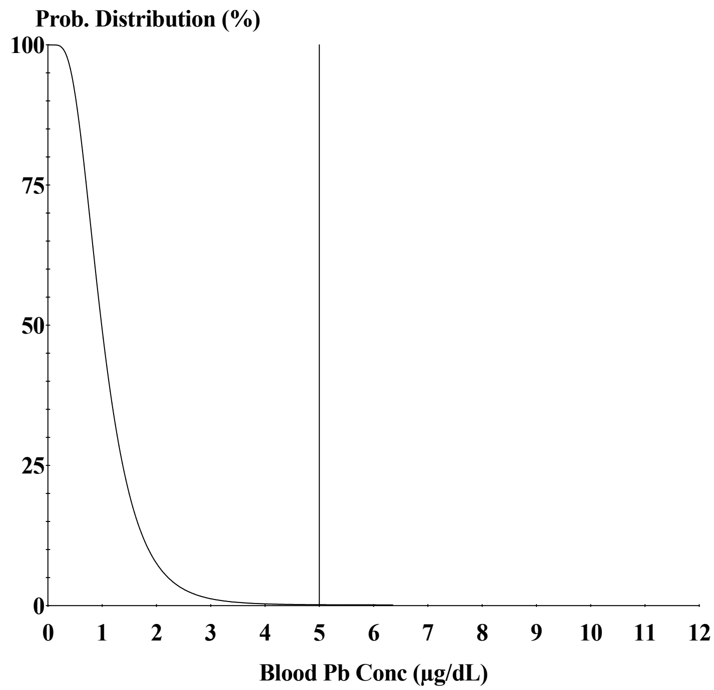


Cutoff = 5.000 µg/dl
Geo Mean = 0.991
GSD = 1.600
% Above = 0.029

Age Range = 72 to 84 months

Run Mode = Research

These IEUBK Model results are valid as long as they were produced with an official, unmodified version of the IEUBK Model w
While IEUBK Model output is generally written with three digits to the right of the decimal point, the true precision of the outpu



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Geo Mean = 1.039
GSD = 1.600
% Above = 0.042

Age Range = 72 to 84 months

Run Mode = Research

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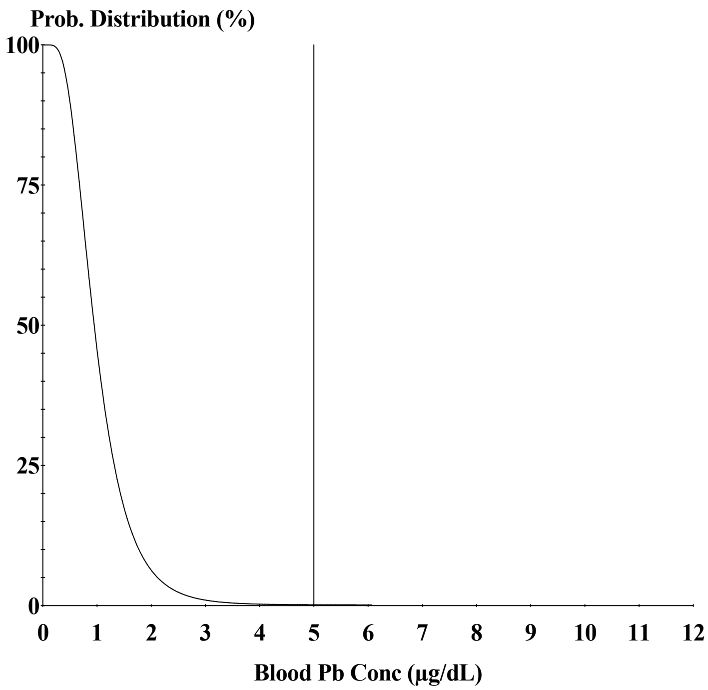
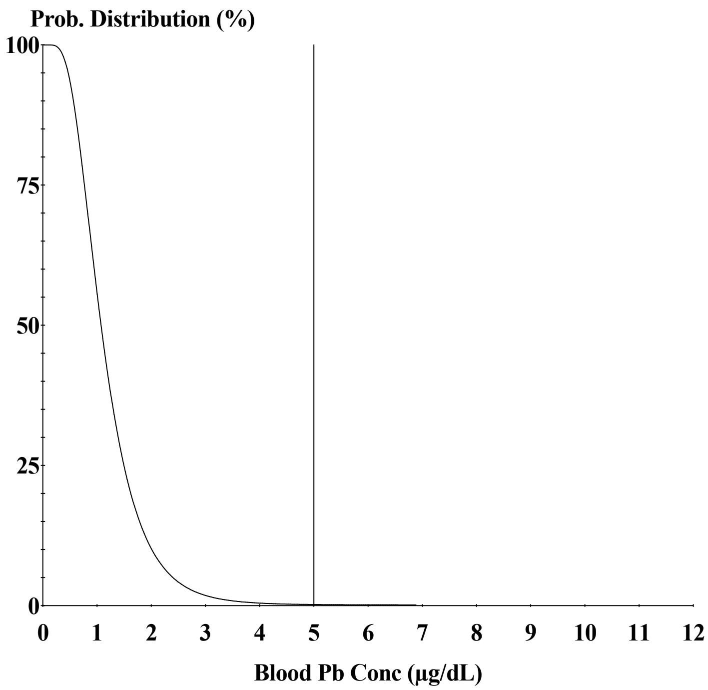


Cutoff = 5.000 µg/dl
Geo Mean = 0.993
GSD = 1.600
% Above = 0.029

Age Range = 72 to 84 months

Run Mode = Research

These IEUBK Model results are valid as long as they were produced with an official, unmodified version of the IEUBK Model w
While IEUBK Model output is generally written with three digits to the right of the decimal point, the true precision of the outpu



Cutoff = 5.000 µg/dl
Geo Mean = 1.126
GSD = 1.600
% Above = 0.076

Age Range = 72 to 84 months

Run Mode = Research

These IEUBK Model results are valid as long as they were produced with an official, unmodified version of the IEUBK Model w
While IEUBK Model output is generally written with three digits to the right of the decimal point, the true precision of the outpu

Appendix G: Excavation Areas:

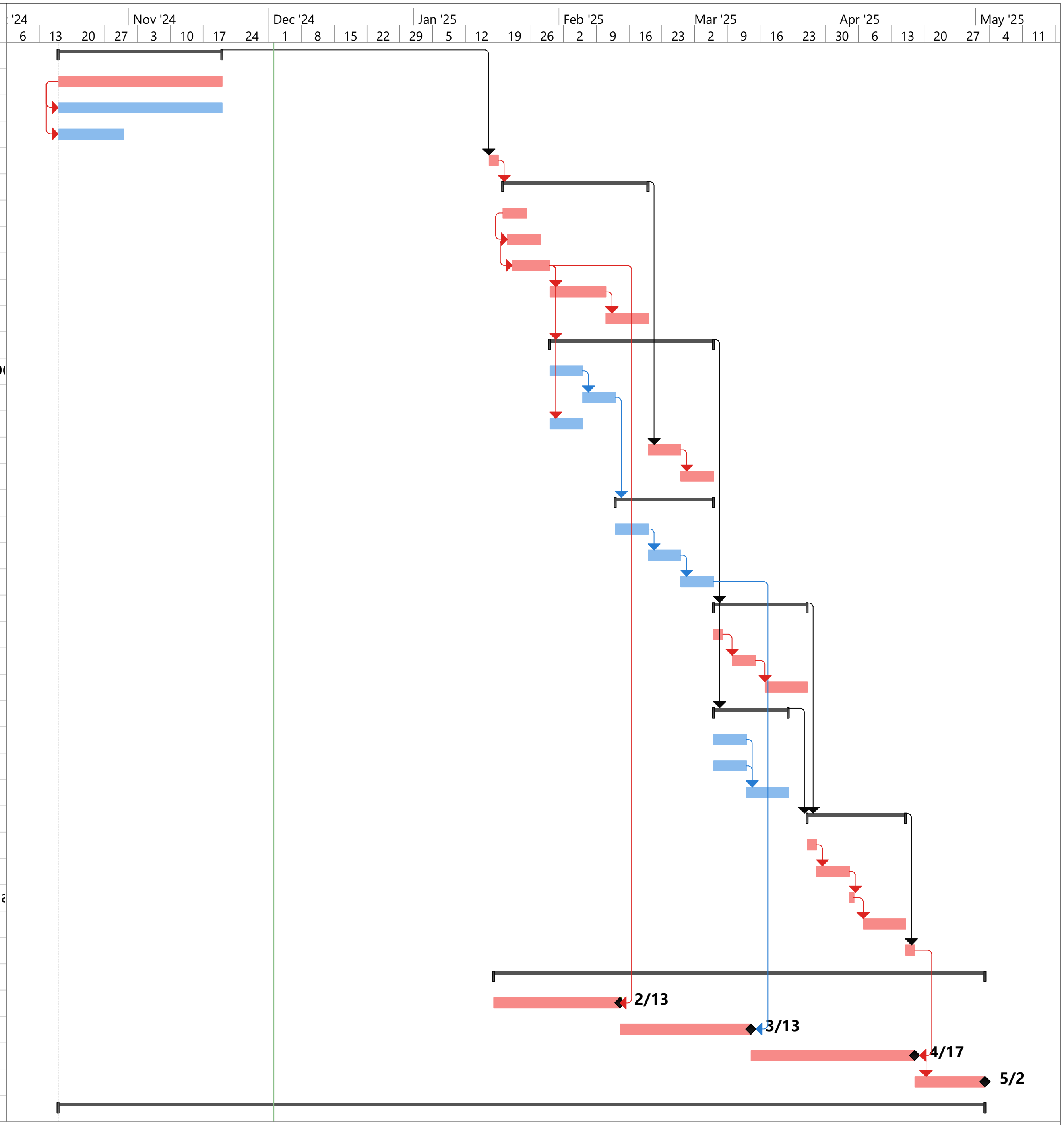
Table G-1. Excavation Areas Breakdown

DU	Surface Area (ft^2)	Average Depth (ft)	Volume (ft^3)	Excavation Cost (4$/ft^3)
3	42200	2	84400	$337,600.00
4	32540	2	65080	$260,320.00
WRP	7500	10	75000	$300,000.00
HS1	510	2	1020	$4,080.00
HS2	1200	20	24000	$96,000.00
HS3	700	10	7000	$28,000.00
HS4	1270	20	25400	$101,600.00
HS5	190	2	380	$1,520.00
3 W/O HS	39790	2	79580	$318,320.00
4 W/O HS	8390	2	16780	$67,120.00
4W/O HS/WR	32350	2	64700	$258,800.00
Tailings hills	13500	20	270000	$1,080,000.00

Appendix H: Gantt Charts:

Estimated Schedule

ID	Task Name
1	**Task 1.0 Work Plan**
2	Task 1.1 Sampling and Analysis Plan
3	Task 1.2 Health and Safety Plan
4	Task 1.3 Lab Binder/ Lab Access
5	**Task 2.0 Site Investigation**
6	**Task 3.0 Laboratory Analysis**
7	Task 3.1 Sample Drying
8	Task 3.2 Sample Sieving
9	Task 3.3 XRF Testing
10	Task 3.4 Acid Digestion
11	Task 3.5 FAA/ICP
12	**Task 4.0 Data Analysis**
13	Task 4.1 Identification of Human Health and Ecological COC
14	Task 4.2 Identify EPCs for all COCs
15	Task 4.3 XRF in-situ vs ex-situ Analysis
16	Task 4.4 XRF ex-situ vs FAA/ICP Analysis
17	Task 4.5 QA/QC Analysis
18	**Task 5.0 Contaminant Pathways**
19	Task 5.1 Maps of Contaminant Distribution
20	Task 5.2 Migration Pathways
21	Task 5.3 Site Conceptual Model
22	**Task 6.0 Human Health Risk Assessment**
23	Task 6.1 Toxicity Assessment
24	Task 6.2 Exposure Assessment
25	Task 6.3 Risk Characterization
26	**Task 7.0 Ecological Risk Assessment**
27	Task 7.1 Potentially at-risk Species
28	Task 7.2 Identify Area Use Factors
29	Task 7.3 Determination of Ecological Risk
30	**Task 8.0 Remedial Actions**
31	Task 8.1 Remedial Action Objectives
32	Task 8.2 Develop Alternatives
33	Task 8.3 Evaluate Alternatives and Select Preferred Alterna
34	Task 8.4 Design of Preferred Alternative
35	**Task 9.0 Project Impacts**
36	**Task 10.0 Project Deliverables**
37	Task 10.1 30% Deliverable
38	Task 10.2 60% Deliverable
39	Task 10.3 90% Deliverable
40	Task 10.4 Final Deliverable
41	**Task 11.0 Project Management**



ID	Task Name
1	**Task 1.0 Work Plan**
2	Task 1.1 Sampling and Analysis Plan
3	Task 1.2 Health and Safety Plan
4	Task 1.3 Lab Binder/ Lab Access
5	**Task 2.0 Site Investigation**
6	**Task 3.0 Laboratory Analysis**
7	Task 3.1 Sample Drying
8	Task 3.2 Sample Sieving
9	Task 3.3 XRF Testing
10	**Task 4.0 Data Analysis**
11	Task 4.1 Identification of Human Health and Ecological CO
12	Task 4.2 Identify EPCs for all COCs
13	Task 4.3 XRF in-situ vs ex-situ Analysis
14	Task 4.4 XRF ex-situ vs FAA/ICP Analysis
15	Task 4.5 QA/QC Analysis
16	**Task 5.0 Contaminant Pathways**
17	Task 5.1 Maps of Contaminant Distribution
18	Task 5.2 Migration Pathways
19	Task 5.3 Site Conceptual Model
20	**Task 6.0 Human Health Risk Assessment**
21	Task 6.1 Toxicity Assessment
22	Task 6.2 Exposure Assessment
23	Task 6.3 Risk Characterization
24	**Task 7.0 Ecological Risk Assessment**
25	Task 7.1 Potentially at-risk Species
26	Task 7.2 Identify Area Use Factors
27	Task 7.3 Determination of Ecological Risk
28	**Task 8.0 Remedial Actions**
29	Task 8.1 Remedial Action Objectives
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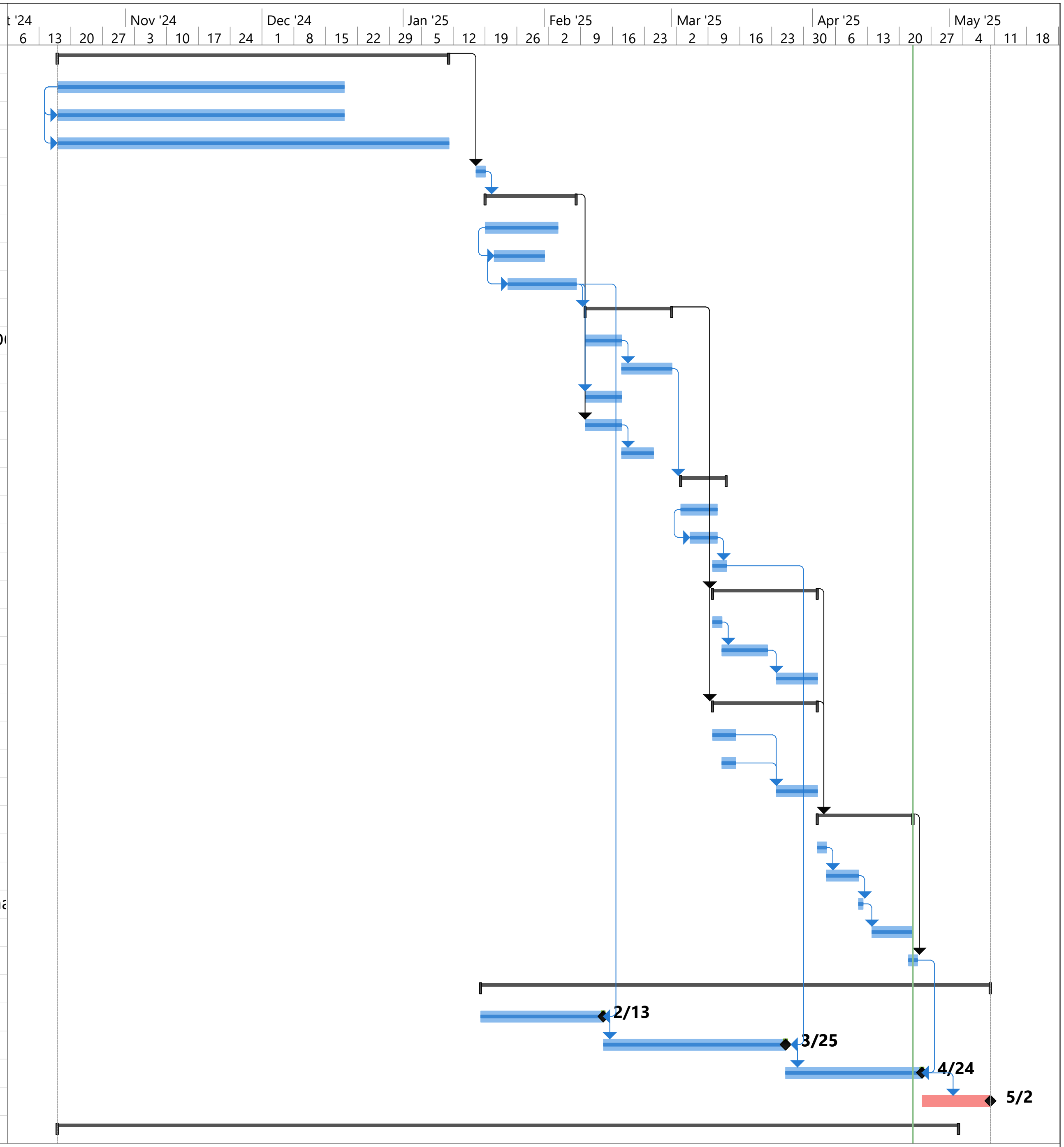

Appendix I: Detailed Staffing Hours

Table I-1. Staffing Hours Breakdown

Task	Proposed Hours			Actual Hours		
	SENG	ENG	Tech	SENG	ENG	Tech
Task 1.0 Work Plan	10	50	15	10	72	3
Task 2.0 Site Investigation	25	50	50	3	36	36
Task 3.0 Laboratory Analysis	0	8	172	0	0	120
Task 4.0 Data Analysis	6	50	5	2.5	26	0
Task 5.0 Contaminant Pathways	4	21	0	0.5	30	0
Task 6.0 Human Health Risk Assessment	2	38	0	2.5	16	0
Task 7.0 Ecological Risk Assessment	6	40	0	1.5	20.5	0
Task 8.0 Remedial Actions	13	46	0	1.5	18.5	0
Task 9.0 Project Impacts	1	3	0	1	1	0
Task 10.0 Project Deliverables	8	32	0	13.25	62.8	0
Task 11.0 Project Management	42	67	30	32.25	78	33.8
Total Hours	117	405	272	68	361	193