# Dragon Mine Preliminary Assessment, Site Investigation & Remediation

# Bureau of Land Management.
# Ground Guardians LLC.

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CENE 486

(05/02/2025)

# Introduction

**Purpose**:

Preliminary Assessment and Site Investigation to assess health risks and propose remedial action

**Client**:

Eric Zielske from the Bureau of Land Management

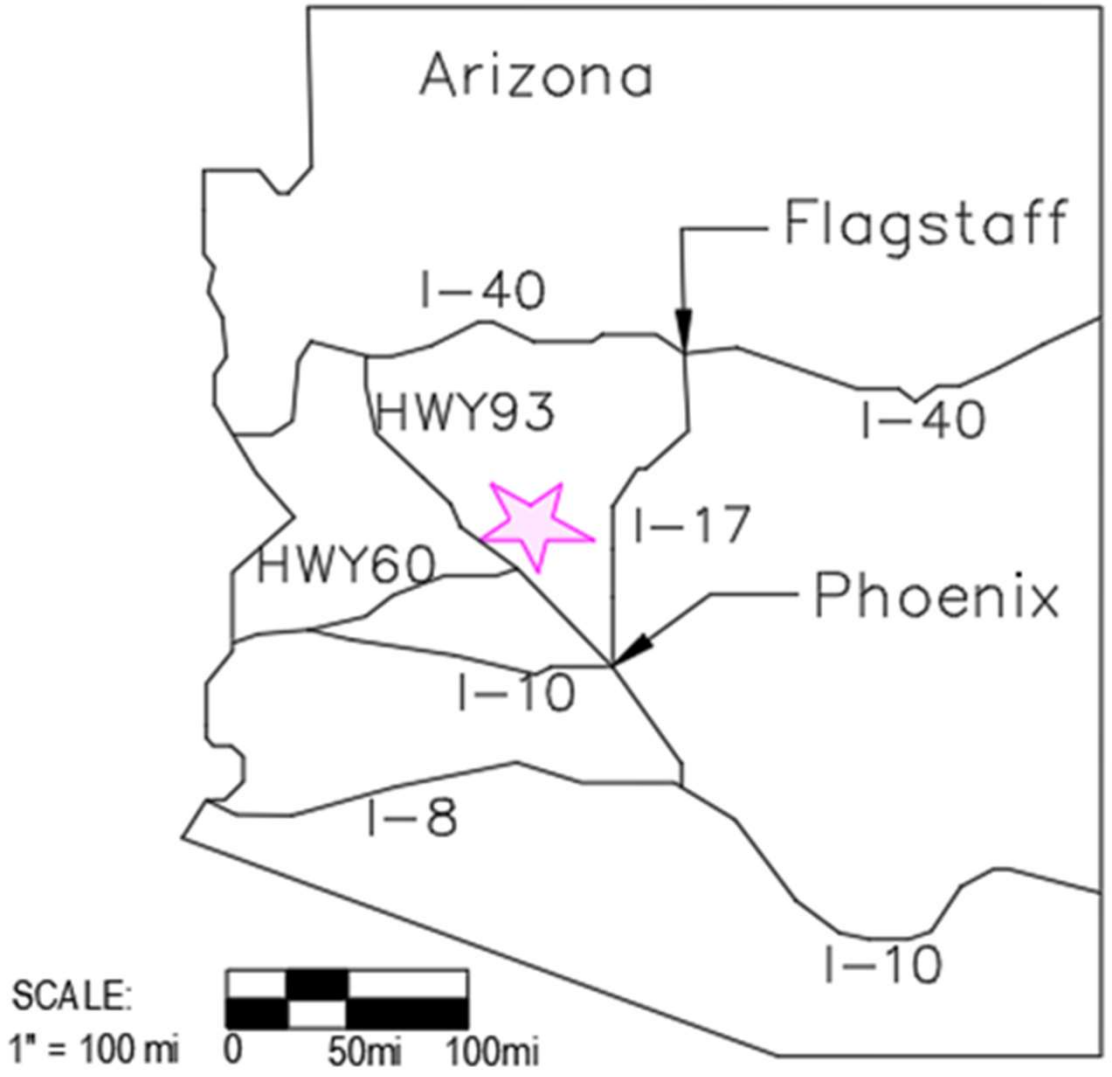



Figure 1. Location Map [1]

# Location Map

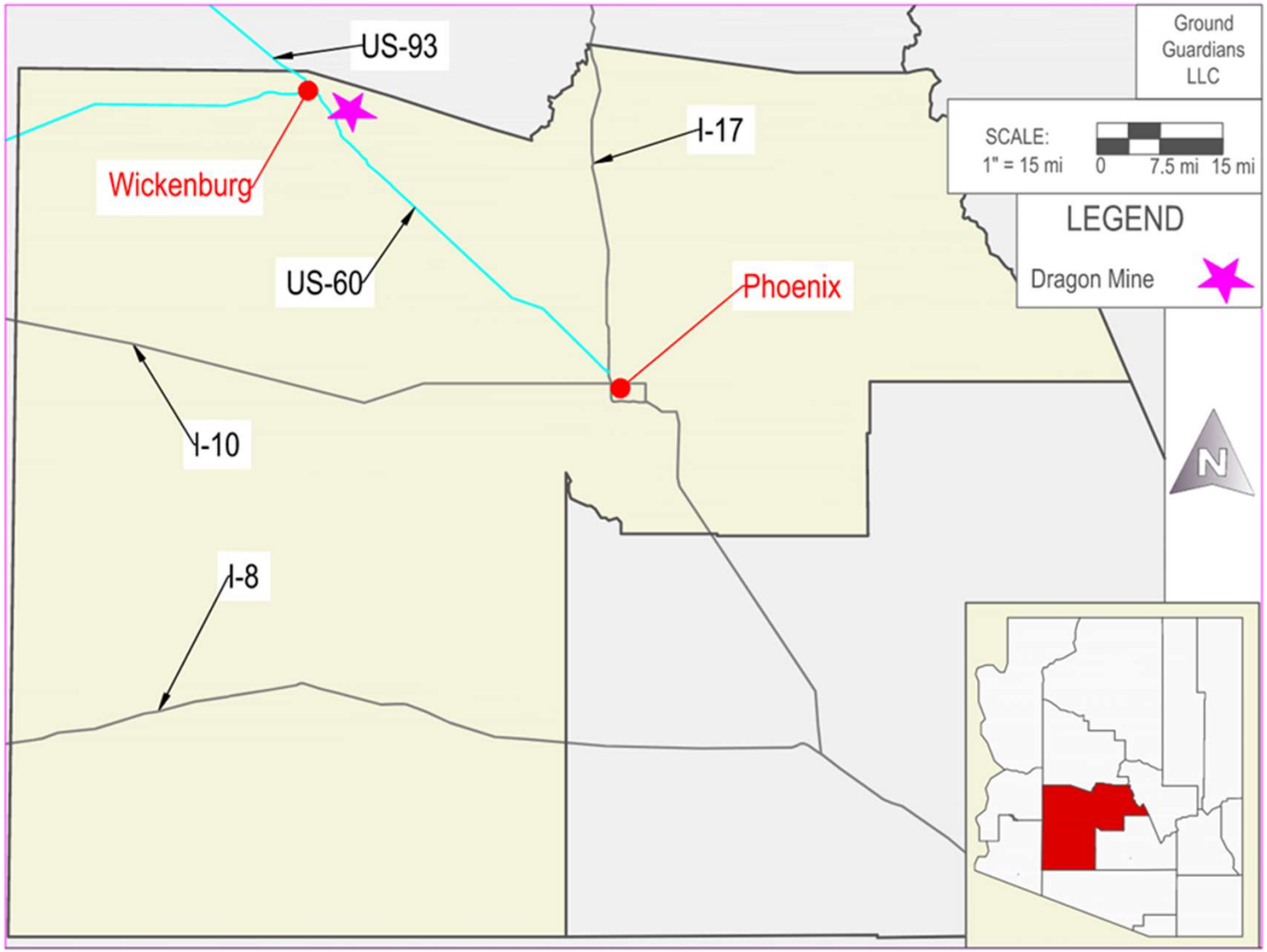



Figure 2: County Location Map [2]

# Vicinity Map

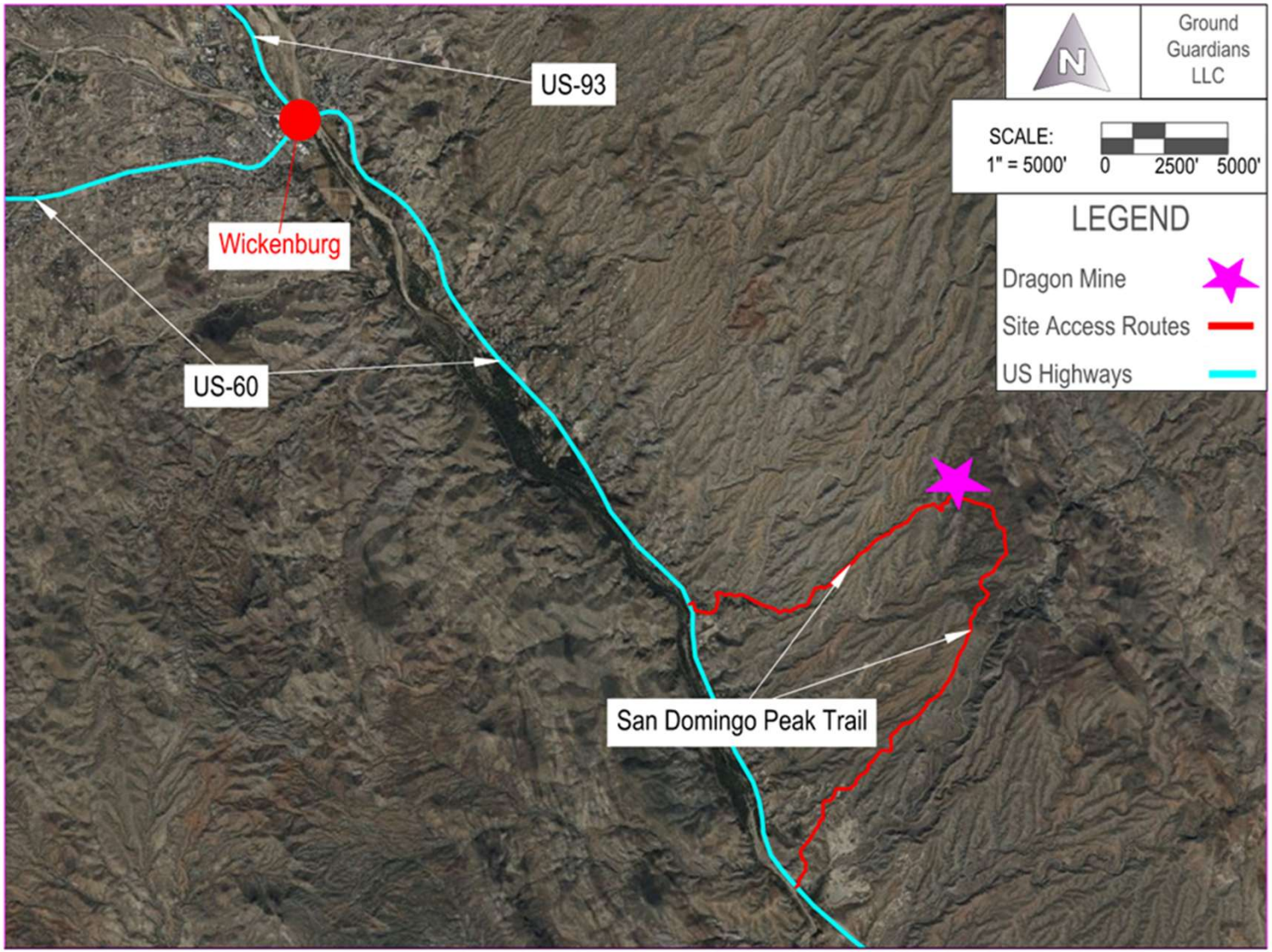



Figure 3: Vicinity Map [3]

# Work Plan

- Sampling and Analysis Plan (SAP)
- Health and Safety Plan (HASP)
- Lab Binder
- Decision Unit (DU)

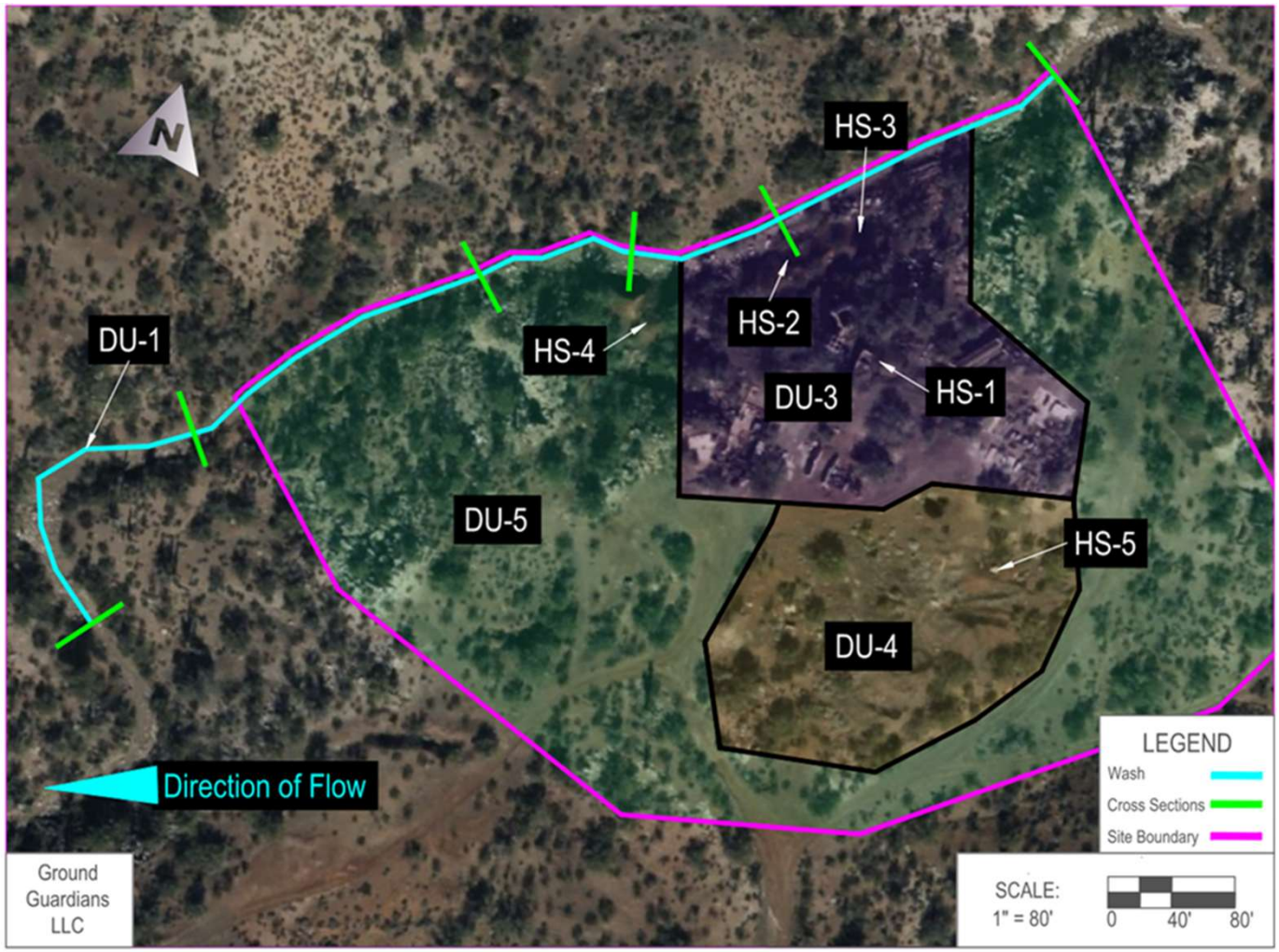



Figure 4. Sampling Plan Map [4]

# Site Investigation – Preliminary Assessment

Figure 5. Mine Shafts (PC Andres)

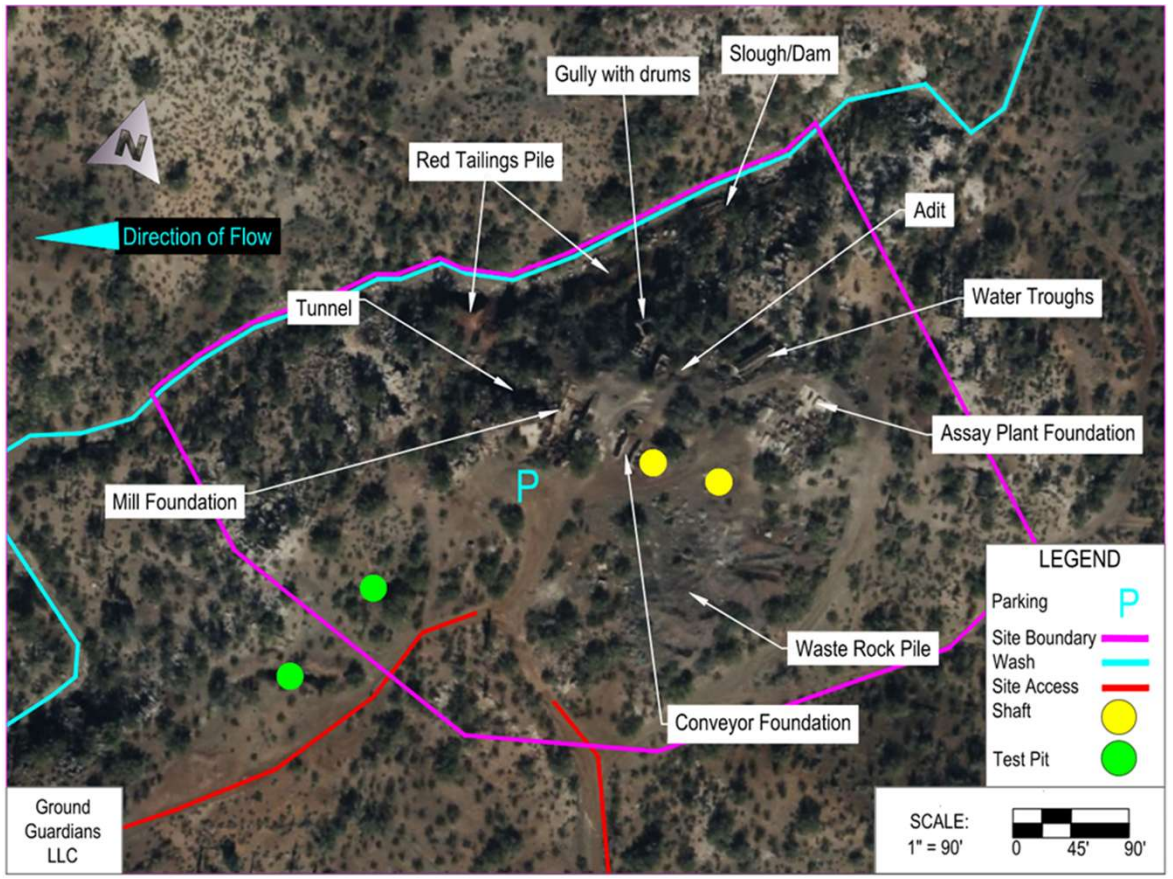



Figure 6. Site Features Map [5]

# Site Investigation – Sampling

Figure 7. XRF Test (PC Jorja)

Figure 8. Zack Collecting Sample (PC Jorja)

- 51 Samples Collected
  - Integrated Sampling Method (ISM)
  - Grid
  - Transect
- In-situ XRF - EPA Method 6200
- QA/QC

# Laboratory Work – Drying, Sieving, XRF

Figure 9. Dried Sample (PC Jorja)

Figure 10. Sieve Setup (PC Jorja)

Figure 11. XRF Setup (PC Jorja)

# XRF Analysis – As Correction & QA/QC

- XRF experiences interference reading As with high Pb concentrations
  - Interference causes higher As readings
- Used previous BLM team's correction equation

Equation 1: Arsenic Correction Equation

$$y = (-8E-05)x^2 + 0.9132x$$

- Duplicate Analysis using Relative Percent Difference Equation
  - Relative percent difference must be less than or equal to 40%.

Table 1: Duplicate Analysis RPD

| Sample ID | As RPD (%) | Pb RPD (%) |
|---|---|---|
| DU-1-2 | 13 | 32 |
| DU-1-11 | 7 | 35 |
| DU-3-3 | 34 | 32 |
| DU-4-5 | 40 | 24 |

Equation 2: Relative Percent Difference Equation

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

Where:
RPD = Relative Percent Difference
Si = Original Sample Concentration
Sd = Duplicate Sample Concentration

# Human Health Contaminants of Concern

- Averaged XRF measurements
- Arizona Soil Remediation Levels [7]
- Determined COCs
  - Lead
  - Arsenic
- DU4-3 is now Hot Spot 5
  - 130,000 ppm Pb

Table 2: Arizona SRLs [6]

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

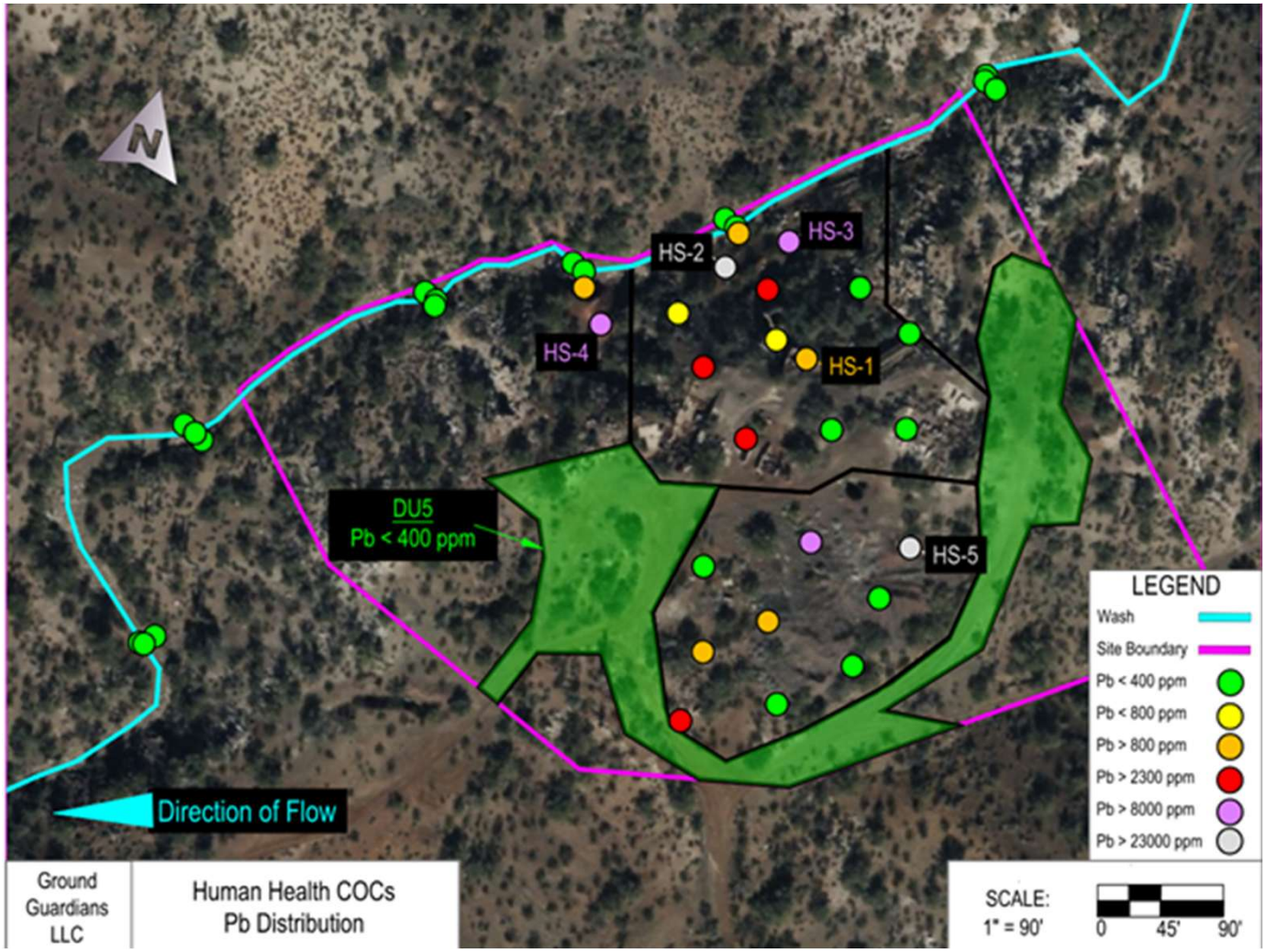



Figure 12: HH COCs Pb Distribution Map [6]

# Ecological Contaminants of Concern

- EPA Ecological Soil Screening Levels [8]
- Determined COCs
  - Lead
  - Selenium
  - Arsenic
  - Zinc
  - Copper
  - Nickel
  - Cobalt
  - Manganese
  - Chromium
  - Vanadium

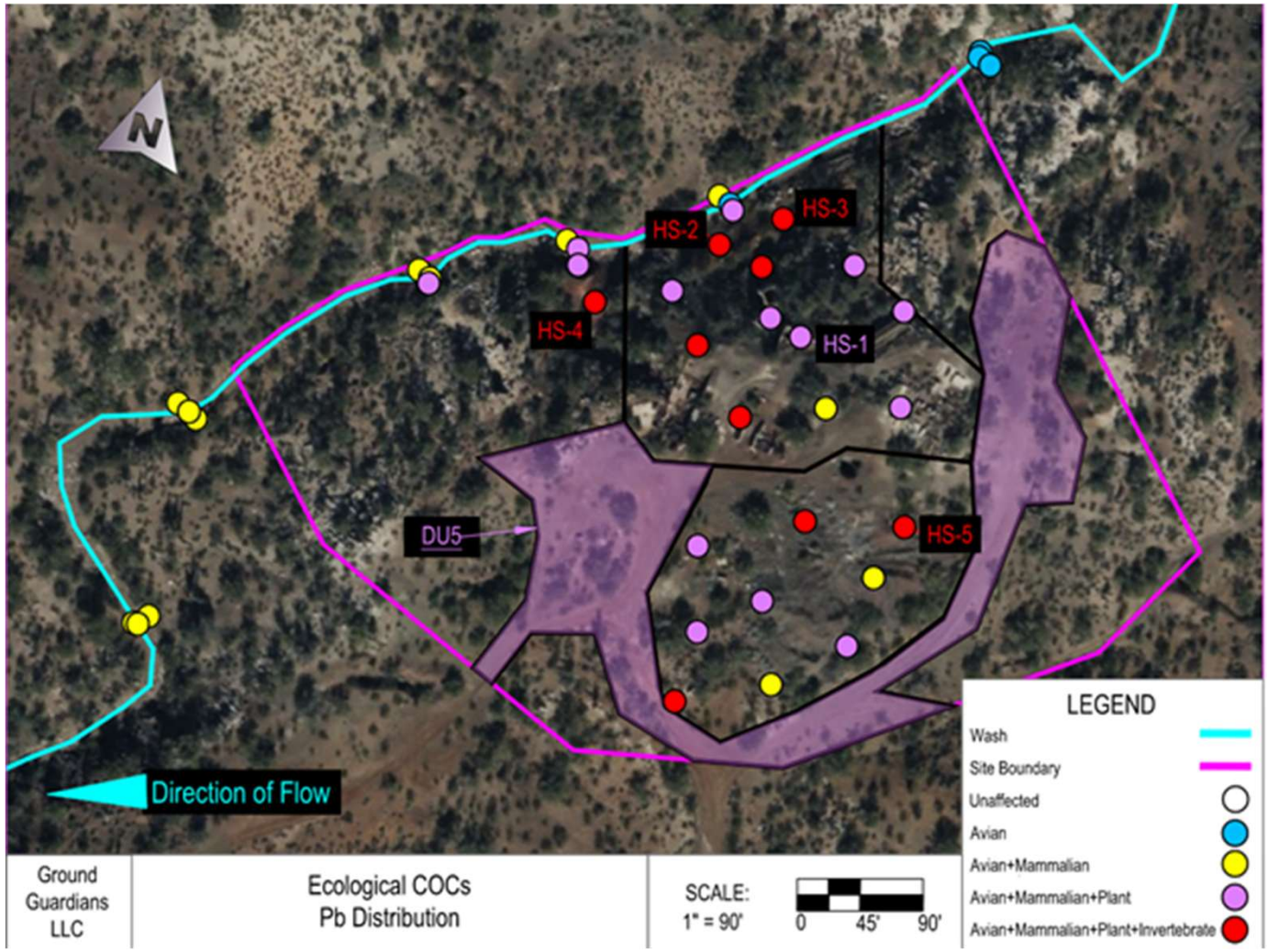



Figure 13: Eco COCs Pb Distribution Map [6]

# Exposure Point Concentrations – Grid & Transect Samples

*Equation 3: Geometric Mean*

$$GEOMEAN = \sqrt[n]{x_1 * x_2 * \cdots * x_n}$$

*Equation 4: Cox Equation*

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

Where:

n = Number of samples

S = Standard deviation

x = Sample measurement

Table 4: Grid & Transect EPCs

| Location | Lead | | Arsenic | |
|---|---|---|---|---|
| | 50% EPC | 95% EPC | 50% EPC | 95% EPC |
| DU 1 | 98.37 | 266.55 | 8.47 | 11.19 |
| DU 3 | 556.52 | 4,246.07 | 15.15 | 19.62 |
| DU 4 | 711.18 | 10,906.70 | 16.57 | 46.15 |

# Exposure Point Concentrations – ISM Samples

- 50% EPC determined using the Arithmetic Average of the sample data
- 95% EPC determined to be Two Standard Deviations from the Average

Table 5: ISM EPCs

| Location | Lead | | Arsenic | |
|---|---|---|---|---|
| | 50% EPC | 95% EPC | 50% EPC | 95% EPC |
| DU 5 | 262.54 | 308.81 | 6.47 | 8.85 |

# Conceptual Site Model

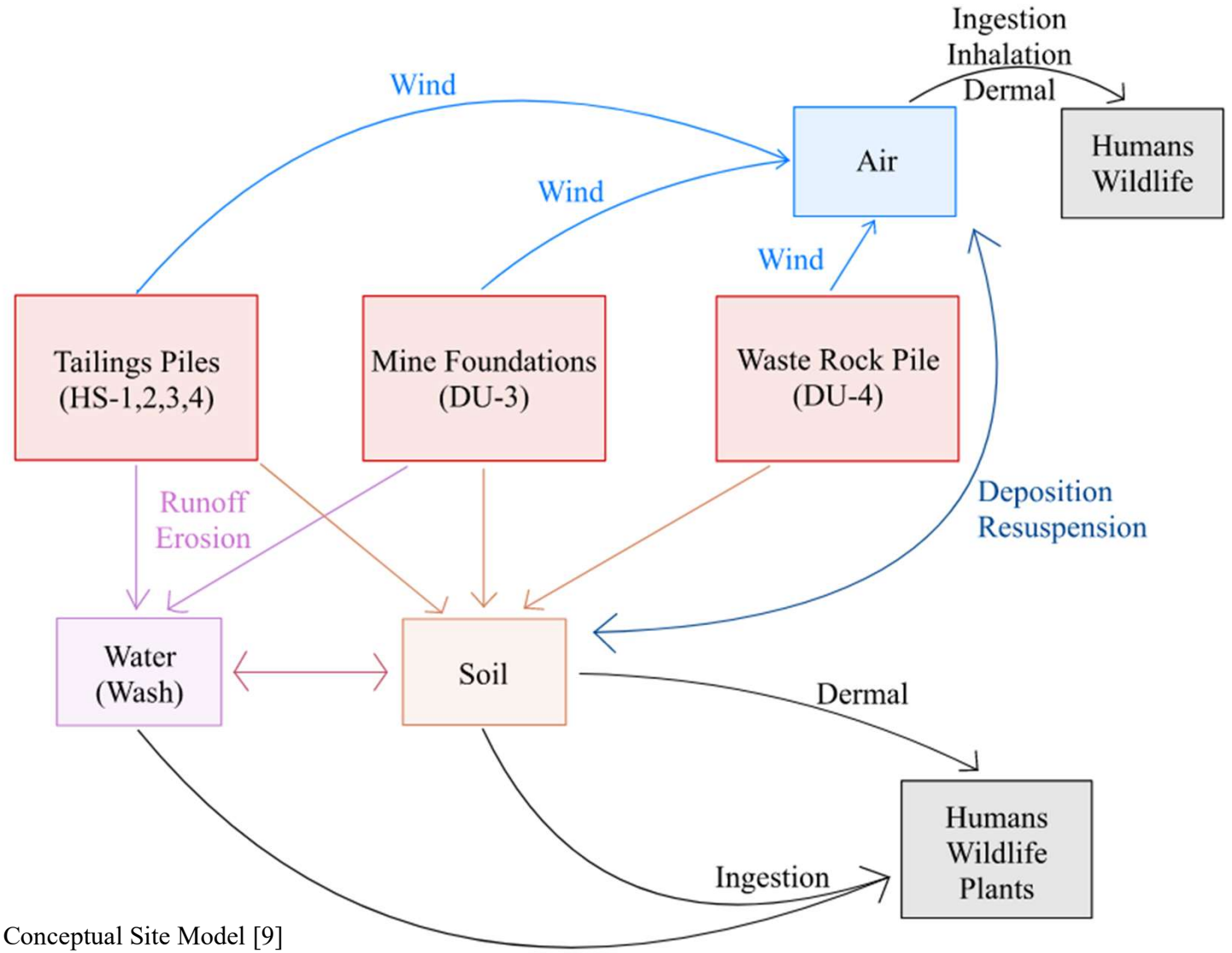



Figure 14: Conceptual Site Model [9]

# Exposure Scenarios

- Recreational ATV Use
  - Adults for 30 years
  - Children 6-12 for 6 years
- Remediation workers
  - Construction for 1 year
- Calculated intake doses for each scenario
  - Ingestion and Dermal
  - Carcinogenic and Non-Carcinogenic

*Equation 5: Ingestion intake dose equation* [10]

$$I = \frac{([\text{EPC}] \cdot CR \cdot EF \cdot ED)}{BW \cdot AT} \cdot 10^{-6}$$

*Table 6: Worker-ingestion exposure parameters*

| Worker Exposure Scenario Parameters - Ingestion | |
|---|---|
| Contact Rate [CR] (mg soil / day) | 100 |
| Exposure Frequency [EF] (hours/day) | 8 |
| Exposure Duration [ED] (days) | 250 |
| Average Body Weight [BW] (kg) | 70 |
| Averaging Time, Non-Carcinogenic [AT] (days) | 250 |
| Averaging Time, Carcinogenic [AT] (years) | 70 |

# Arsenic Risk

*Equation 6: Carcinogenic risk equation* [10]

$$Risk = I_c \cdot SF$$

*Equation 7: Noncarcinogenic risk equation* [10]

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

*Table 7: IRIS toxicity data*

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

*Table 8: Worker-ingestion exposure parameters*

| Arsenic Ingestion Risk | | | |
|---|---|---|---|
| Exposure Scenario | DU | Carcinogenic Risk (1E-6) | |
| | | 50% EPC | 95% EPC |
| Worker | DU3 | 3.103 | 4.020 |
| | DU4 | 3.395 | 9.455 |
| Recreational ATV (Adult) | DU3 | 1.530 | 1.983 |
| | DU4 | 1.674 | 4.663 |
| Recreational ATV (Children 6-12) | DU3 | 0.421 | 0.546 |
| | DU4 | 0.461 | 1.283 |

# Lead Risk

- PbB > 5 µg/dL is considered at risk for lead toxicity
- Probability of risk to fetus to be less than 5%

*Table 9: IEUBK results – maximum exposure*

| Child ATV 95% EPC | | |
|---|---|---|
| DU | Age Range (years) | Blood Pb (µg/dL) |
| DU3 | 6 to 7 | 1.0 |
| DU4 | 6 to 7 | 1.1 |

*Table 10: ALM results – worker exposure*

| PbB of adult worker (µg/dL) | | |
|---|---|---|
| DU | 95% EPC | 50% EPC |
| DU3 | 14.6 | 2.4 |
| DU4 | 36.5 | 2.9 |

*Table 11: ALM results – fetal risk*

| Probability of risk to fetus (%) | | |
|---|---|---|
| DU | 95% EPC | 50% EPC |
| DU3 | 94.9 | 8.0 |
| DU4 | 99.9 | 13.9 |

# Remedial Action Objectives

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

Problem Areas Based on Risk:

- ECO: DU4, Hot Spots
- HH: DU3, DU4, Hot Spots

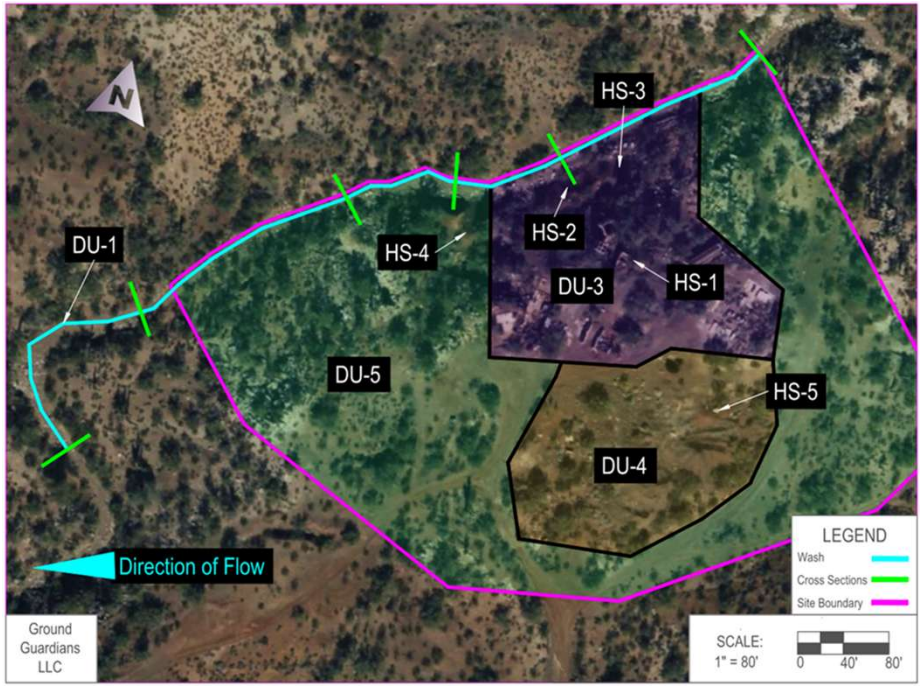


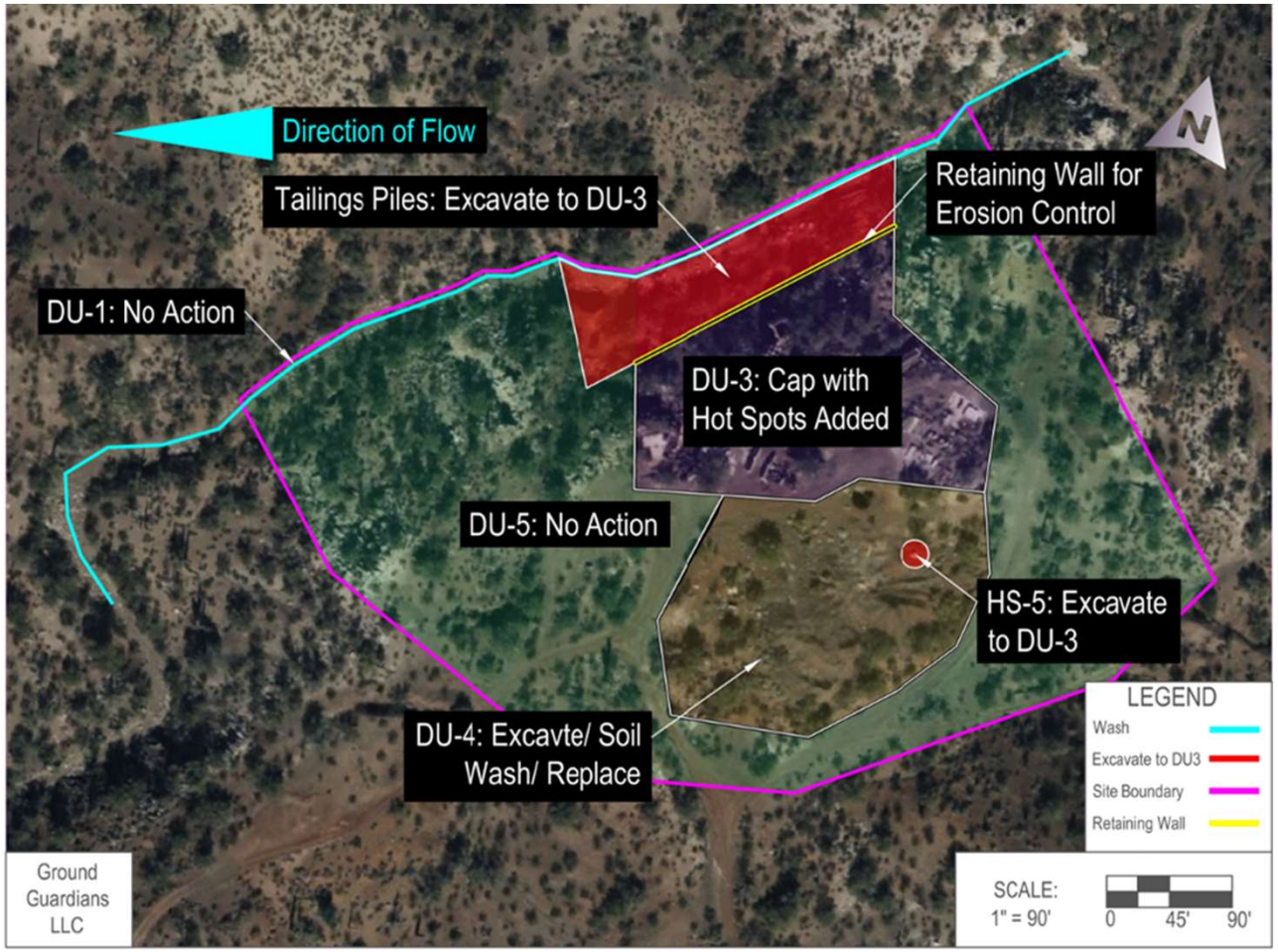

Figure 15. Sampling Plan Map [3]

# Remedial Action Decision Matrix

*Table 12: Remedial Action 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 w/ retaining wall; excavate/soil wash/replace DU4 | + | + | ++ | ++++ |

# Remedial Action Design




- 4.4 million dollars
- 1 year duration
- 18" bentonite clay cap
- Retaining wall

Figure 15: Remediation Design Map [11]

# Impacts

**No Remediation:**

- Continued risk to human health
- Continued risk to wildlife
- Possible migration of contaminants
- Increased medical costs for locals

**Yes Remediation:**

- Less risk to human health
- Less risk to wildlife
- Eliminates migration of contaminants
- Economic gain for local businesses
- Economic gain to workers
- Economic loss to BLM

# Conclusion

- The Ground Guardians determined that the Dragon Mine site is contaminated with heavy metals.
- Human Health COCs: lead and arsenic
- Ecological COCs: lead, selenium, arsenic, zinc, copper, nickel, cobalt, manganese, chromium, and vanadium
- Risk calculations were completed for the COCs based on the concentrations determined from laboratory testing.
- Remedial action limits migration and mitigates human and ecological health risk.

# Works Cited


[1] J. Whitcher, “Dragon Mine: Preliminary Assessment Location Map,” AUTOCAD, 2014

[2] A. G. Rico, “Dragon Mine: Preliminary Assessment Location Map,” AUTOCAD, 2014

[3] A. G. Rico, “Dragon Mine: Preliminary Assessment Vicinity Map,” AUTOCAD, 2014

[4] A. G. Rico, “Dragon Mine: Sampling Plan Map,” AUTOCAD, 2014

[5] A. G. Rico, “Dragon Mine: Site features Map,” AUTOCAD, 2014

[6] A. G. Rico, “Dragon Mine: Contaminant Distribution Maps,” AUTOCAD, 2014

[7] “Appendix A - Soil Remediation Levels (SRLs), Ariz. Admin. Code § tit. 18, ch. 7, art. 2, app A | Casetext Search + Citator,” *Casetext.com*, 2025. https://casetext.com/regulation/arizona-administrative-code/title-18-environmental-quality/chapter-7-department-of-environmental-quality-remedial-action/article-2-soil-remediation-standards/appendix-a-soil-remediation-levels-srls (accessed Mar. 22, 2025).

[8] “Ecological Soil Screening Level (Eco-SSL) Guidance and Documents | US EPA,” *US EPA*, Sep. 02, 2015. https://www.epa.gov/risk/ecological-soil-screening-level-eco-ssl-guidance-and-documents

[9] B. Ching, "Conceptual Site Model," GoodNotes2, 2025

[10] M. D. LaGrega, P. L. Buckingham and J. C. Evans, Hazardous Waste Management, Long Grove: Waveland Press, 2001

[11] J. Whitcher, “Dragon Mine: Remedial Design Map,” AUTOCAD, 2014


# QUESTIONS?