Harquahala Mine PA/SI

CENE 486

Client: Bureau of Land Management

Prepared by:

VIPERIDAE TECH

Sierra Binney, Bohao Liu, Jack Priniski, Elda Silva

05/03/2024

Introduction

Fig. 1: Site location in Arizona. [1]

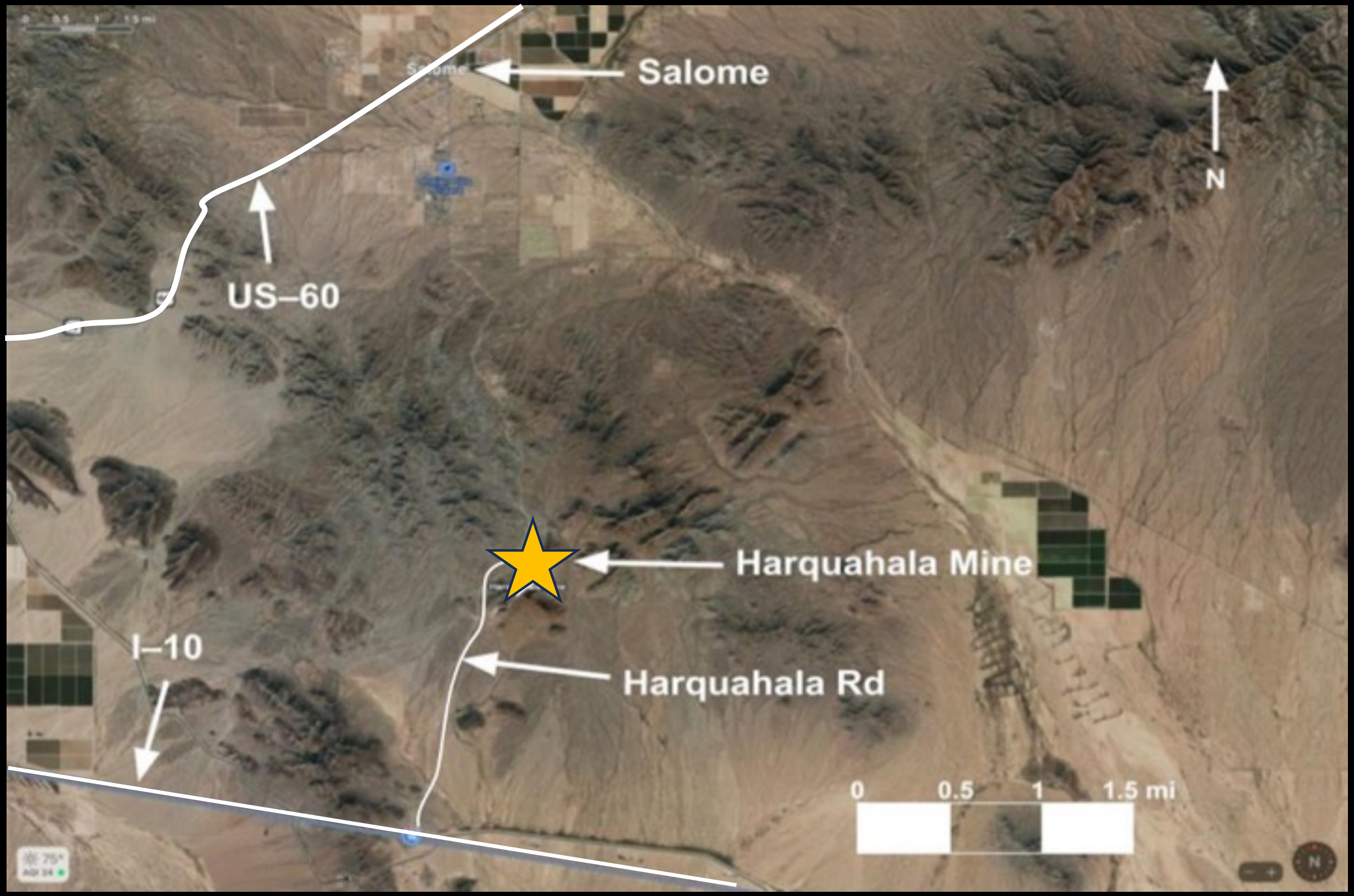

Fig. 2: Site with reference to US-60 and I-10. [2]

Introduction

- Preliminary assessment: identify & evaluate areas of possible contamination to determine human health and ecological risks
- Site investigation: sampling and ecological survey
- Harquahala Mine has been mined for silver & gold since 1888
- Site is currently in operation under Bonanza Mining Company

Fig. 3: Private mine practices kicking up dirt. Photo: SB

Site Background

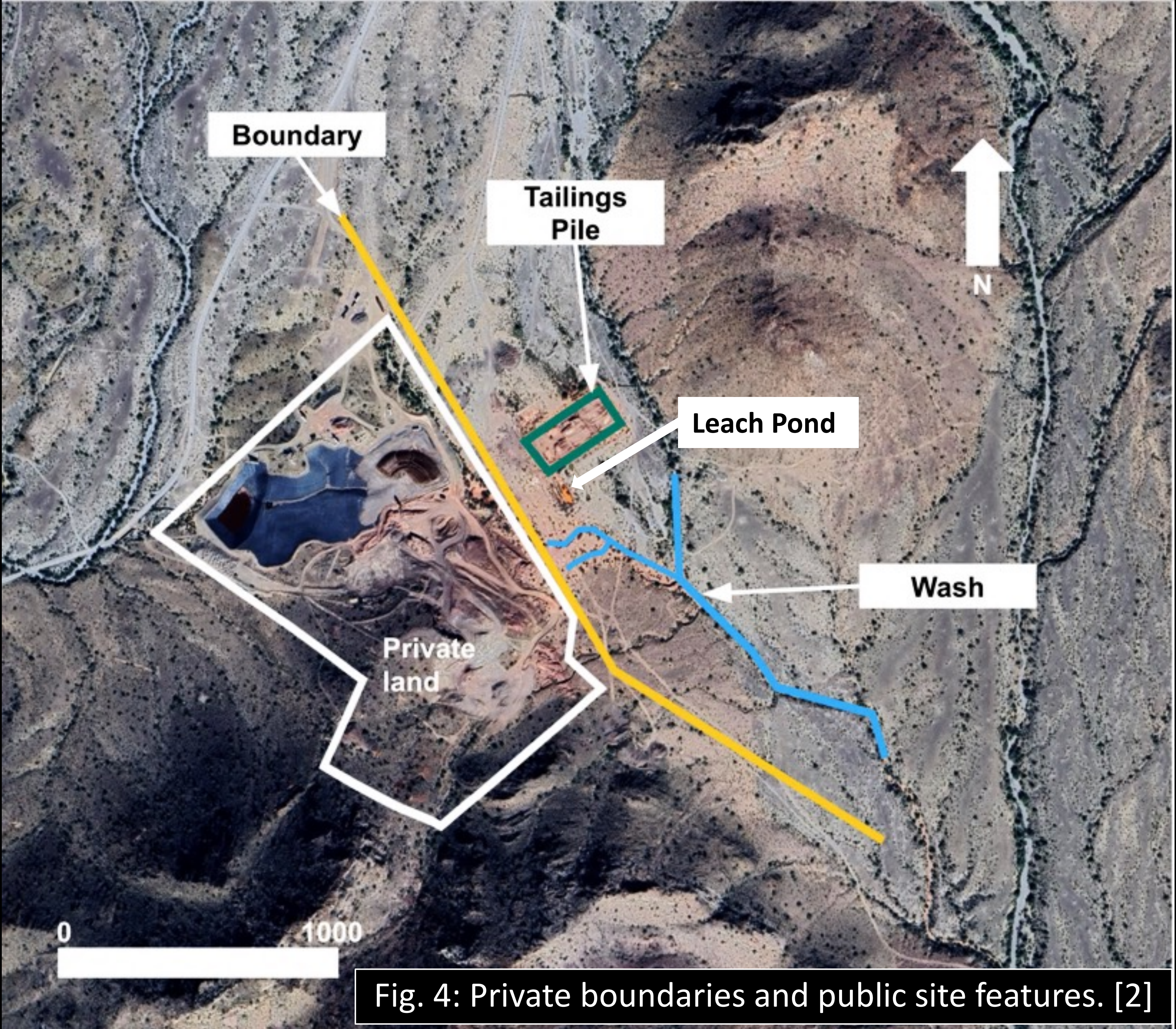

Fig. 4: Private boundaries and public site features. [2]

- Sampling & Analysis Plan (Work Plan) prepared before site visit, changed during visit
- No fences for private land area
- Tailings pile on BLM land is 45,000 ft^2 and 20 ft tall
- 1,800 ft of wash highlighted

Project Background - Conditions in 2018

Table 1: Site conditions in 2018. [3]

Contaminant	Lead	Arsenic
AZ Non-residential standard (ppm)	**800**	**10**
HARQ-1	3467	<LOD
HARQ-2	1228	56
HARQ-3	2519	196
HARQ-4	2517	133
HARQ-5	2522	160
HARQ-6	1764	82
HARQ-7	4578	356
HARQ-9	693	<LOD
HARQ-10	1885	99

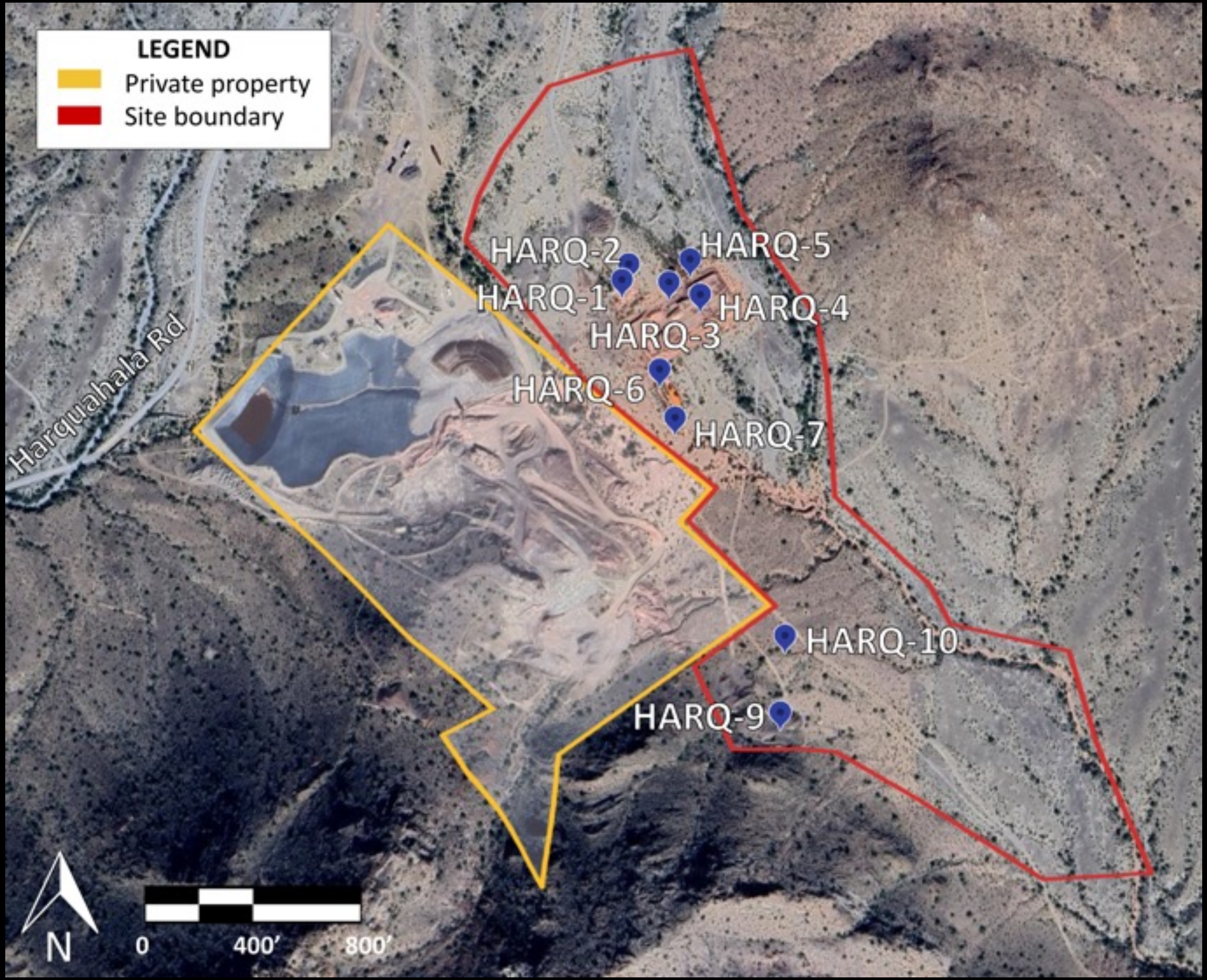

Fig. 5: Sample locations from 2018. [2] [3]

Site Visit 1/19-1/20

Fig. 6: Mine (top) and tailings pile (center). Photo: JP

Site Visit 1/19-1/20

Fig. 7: Potential leach pond by tailings. Photo: JP

Fig. 8: Impacted wash south of mine. Photo: SB

Floodplain impact discovered

Fig. 9: Apparent downstream impact from mine (top). Photo: JP

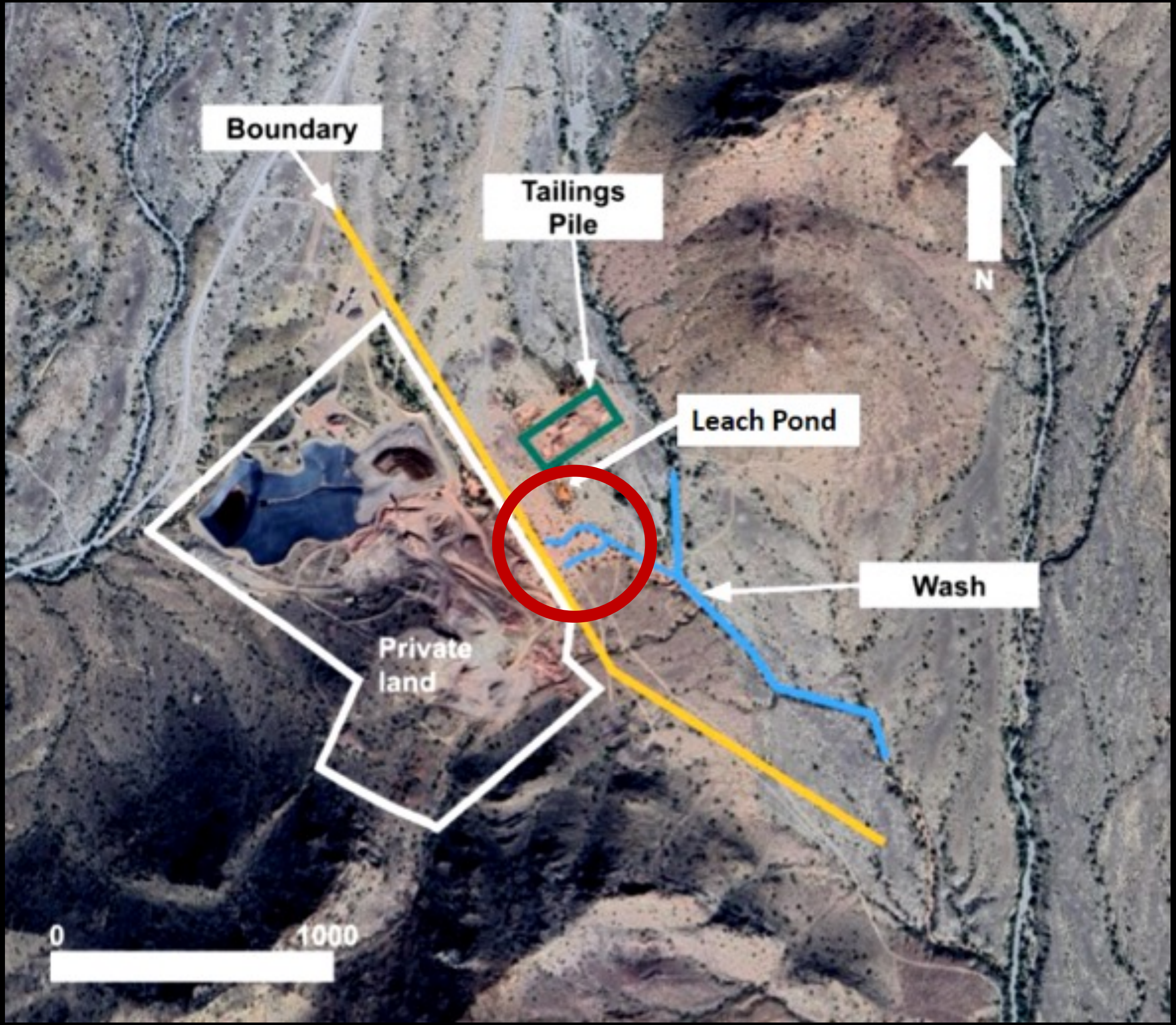

Fig. 10: Site layout, with Fig. 9 region circled in red. [2]

Soil Sampling 01/2024

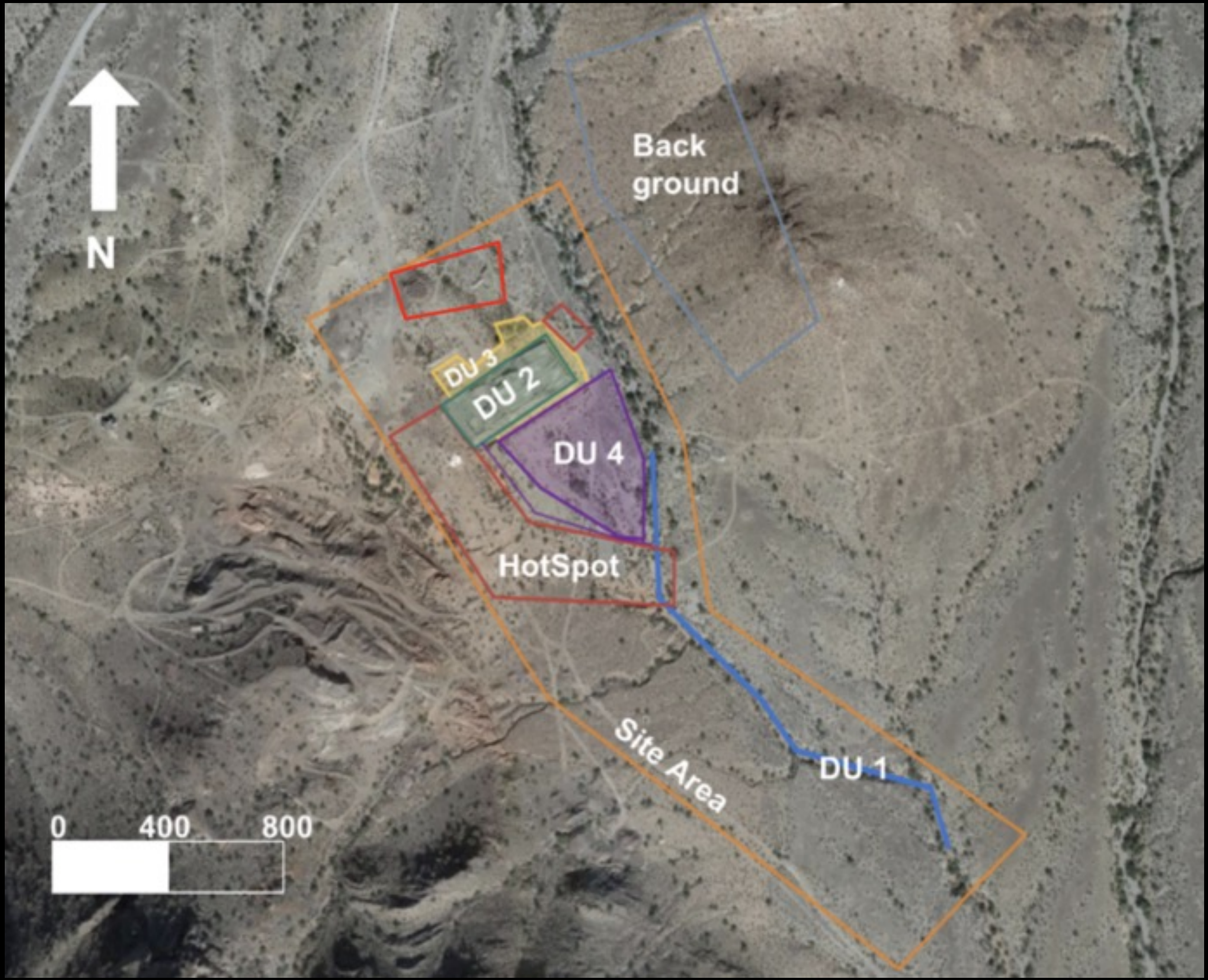

Fig. 11: Summary of site decision units (DU). [2]

Table 2: Sampling methods and amounts per type.
(ISM = Incremental Sampling Method)

Decision Unit & Sampling Type	Samples Collected / # of Duplicates
1: Transect down wash	18 / 3
2: Random on tailings pile	6 / 2
3: ISM surrounding tailings pile	4
4: ISM south of tailings pile	4
Hot spots	9 / 1
Background	3 / 1

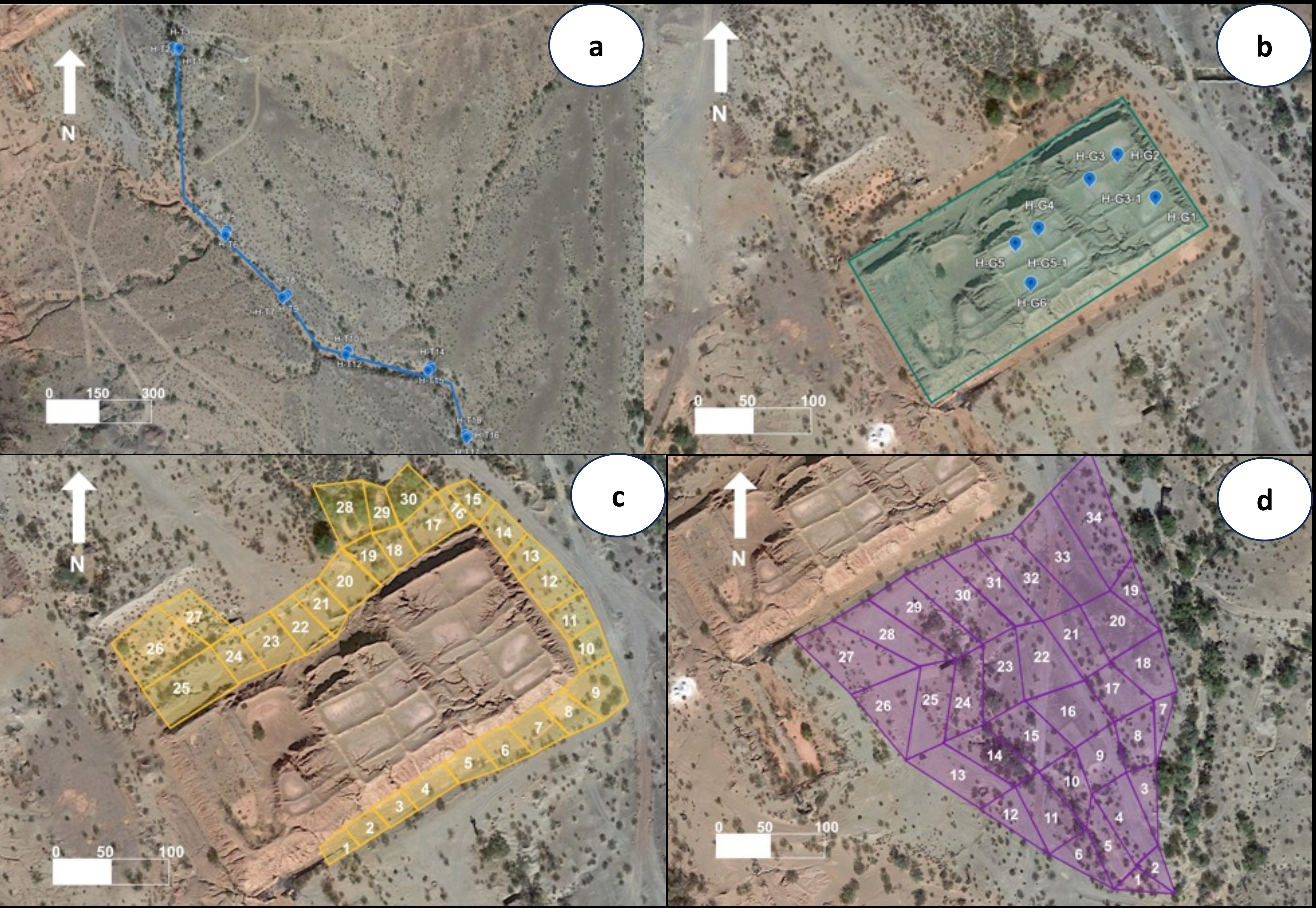

Fig. 12: Sampling sections and types. [2]

Fig. 12a: Transect sampling along the wash **(DU-1)**.

Fig. 12b: Random sampling on tailings pile **(DU-2)**.

Fig. 12c: Incremental Sampling Method (ISM) surrounding DU-2 **(DU-3)**.

Fig. 12d: ISM south of tailings pile **(DU-4)**.

Sample Analysis

In-lab soil analysis included:

- Drying in oven
- Sieving to 250 µm particle size
- X-ray fluorescence (XRF) for 9 sub-samples of each sample

Fig. 13: Sample drying. Photo: ES

Fig. 14: Sample sieving. Photo: SB

Fig. 15: XRF preparation. Photo: JP

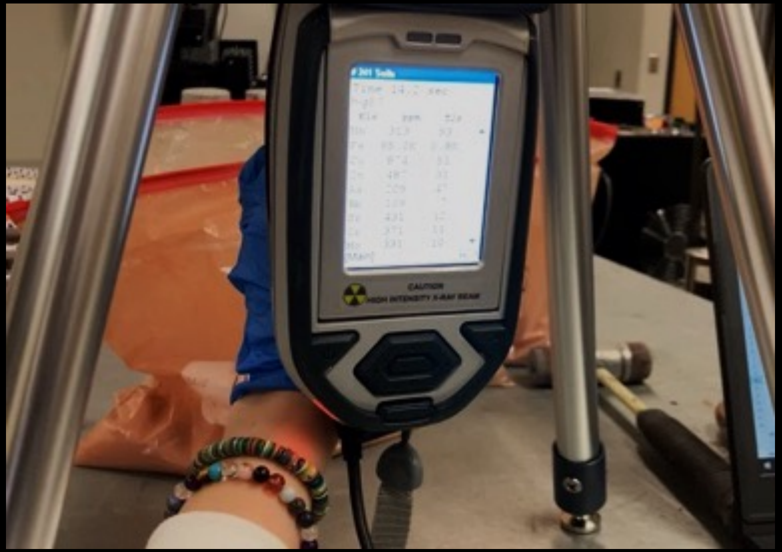

Fig. 16: XRF reading. Photo: SB

Precision Analysis

Equation 1: Precision.

$$\%RPD = \frac{2|O_i - D_i|}{(O_i - D_i)} \bullet 100\%$$

% RPD < 50% meets the criteria for data quality

Where:

%RPD - Relative percent difference for the compound *i*

O_i - Value of compound *i* in the original sample

D_i - Value of compound *i* in the duplicate sample

Table 3: Precision analysis results.

Sample ID	As original (ppm)	As duplicate (ppm)	As RPD	Pb original (ppm)	Pb duplicate (ppm)	Pb RPD
H-T6	42.90	35.5	19%	775.4	738.8	5%
H-T11	66.40	51.9	25%	1437.7	1612.4	11%
H-T18	50.40	44.30	13%	1037.3	914.5	13%
H-G5	171.40	160.50	7%	2936.9	2764.4	6%
H-HS7	82.00	74.90	9%	963.9	985.9	2%
H-BG2	10.30	9.90	4%	32.7	29.3	11%

Sample Analysis Results

Table 4: Summary of human health contaminants of concern (COCs) found onsite.

Minimum and Maximum Values of Human COCs by Section				
Human COCs	**Arsenic (ppm)**		**Lead (ppm)**	
AZSRS (Res/Non-res)	10/10		400/800	
Section	Min	Max	Min	Max
DU-1 (Wash)	11	81	79	2006
DU-2 (Tailings)	171	269	2937	4705
DU-3 (Around tailings)	91	125	1811	2288
DU-4 (South of tailings)	24	46	379	844
Hotspots	7	217	30	3846
Background	9	11	29.3	39.1

Spatial Distribution Map of Arsenic

Non-residential standard

10 ppm

Minimum concentration

11.0 ppm

Maximum concentration

268.5 ppm

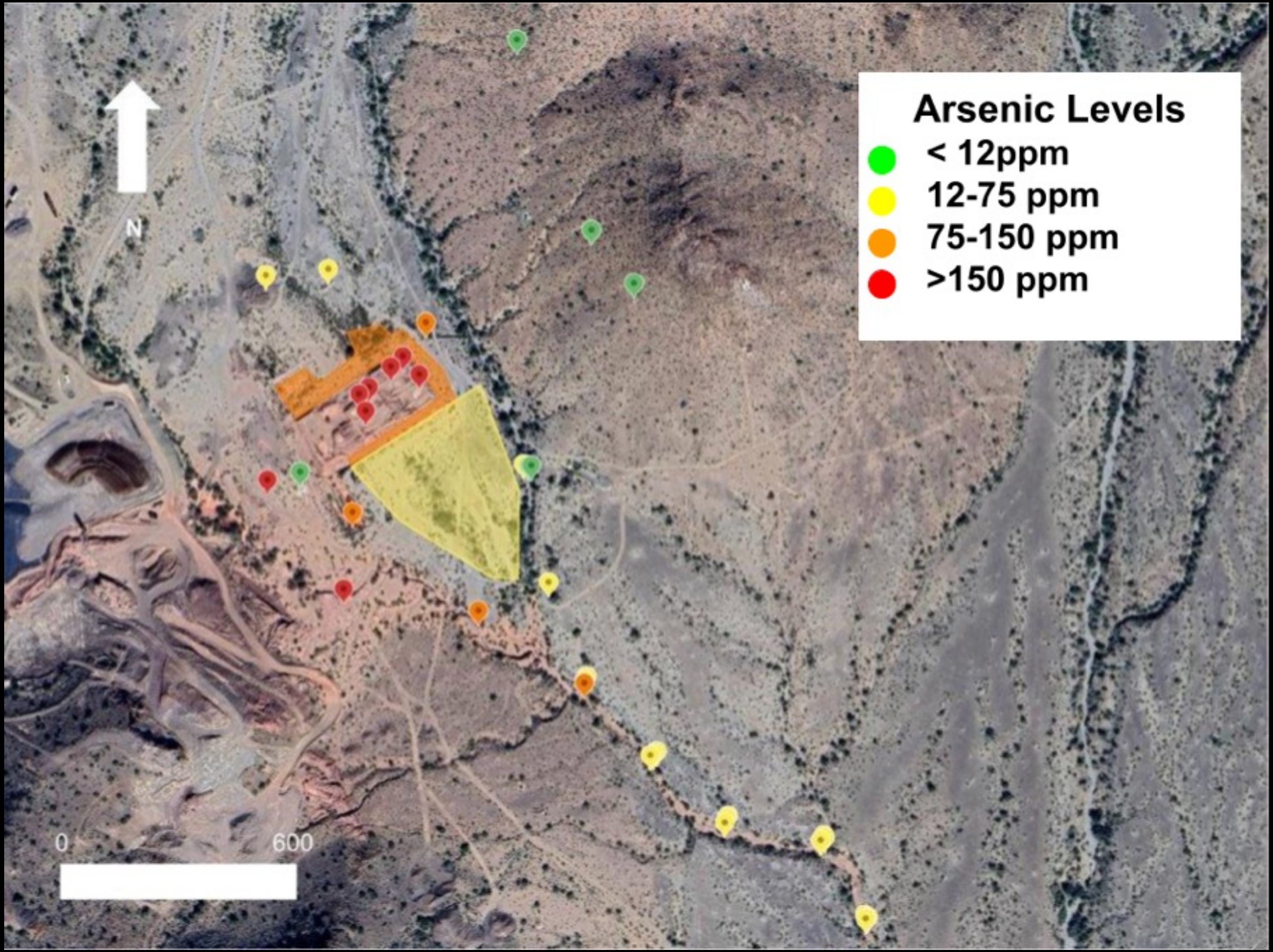

Fig. 17: Arsenic contamination distribution map. [2]

Spatial Distribution Map of Lead

Non-residential standard

800 ppm

Minimum concentration

78.8 ppm

Maximum concentration

4704.8 ppm

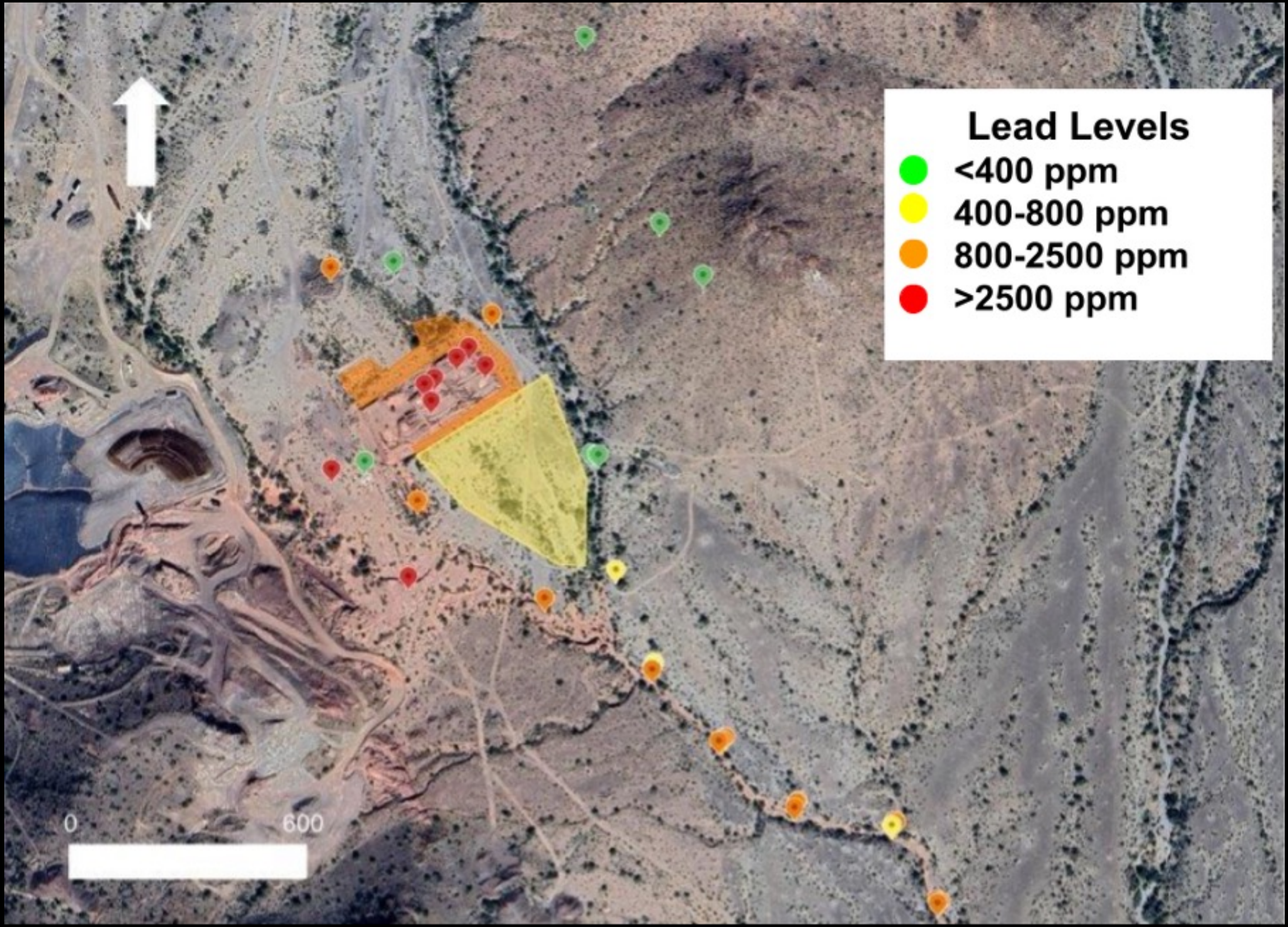

Fig. 18: Lead contamination distribution map

Exposure Point Concentrations (EPCs)

Table 5: Arsenic EPCs in mg/kg, or ppm.

Arsenic	50% (mg/kg)	95% (mg/kg)
DU-1 (wash)	49	61
DU-2 (tailings)	196	227
DU-3	109	142
DU-4	30	51

Table 6: Lead EPCs in mg/kg, or ppm.

Lead	50% (mg/kg)	95% (mg/kg)
DU-1 (wash)	1125	1356
DU-2 (tailings)	3353	3915
DU-3	2042	2503
DU-4	544	959

50% EPC: Average exposure concentration

95% EPC: Maximum exposure concentration

Evidence of Recreation Onsite

Fig. 19: ATVs driving to the tailings pile. Photo: JP

Fig. 20: Campsite next to tailings. Photo: SB

Exposure Scenarios

Incidental Ingestion & Dermal Exposures

- **Worker:** 40 hours/week, 50 weeks/year, 3 years , Adult only
- **Recreational camping:** 2 weeks/year, Ages 0-6, 6-12, & Adult
- **Recreational ATV:** 40 hours/year, Ages 0-6, 6-12, & Adult

Fig. 21: Soil on tailing pile. Photo: SB

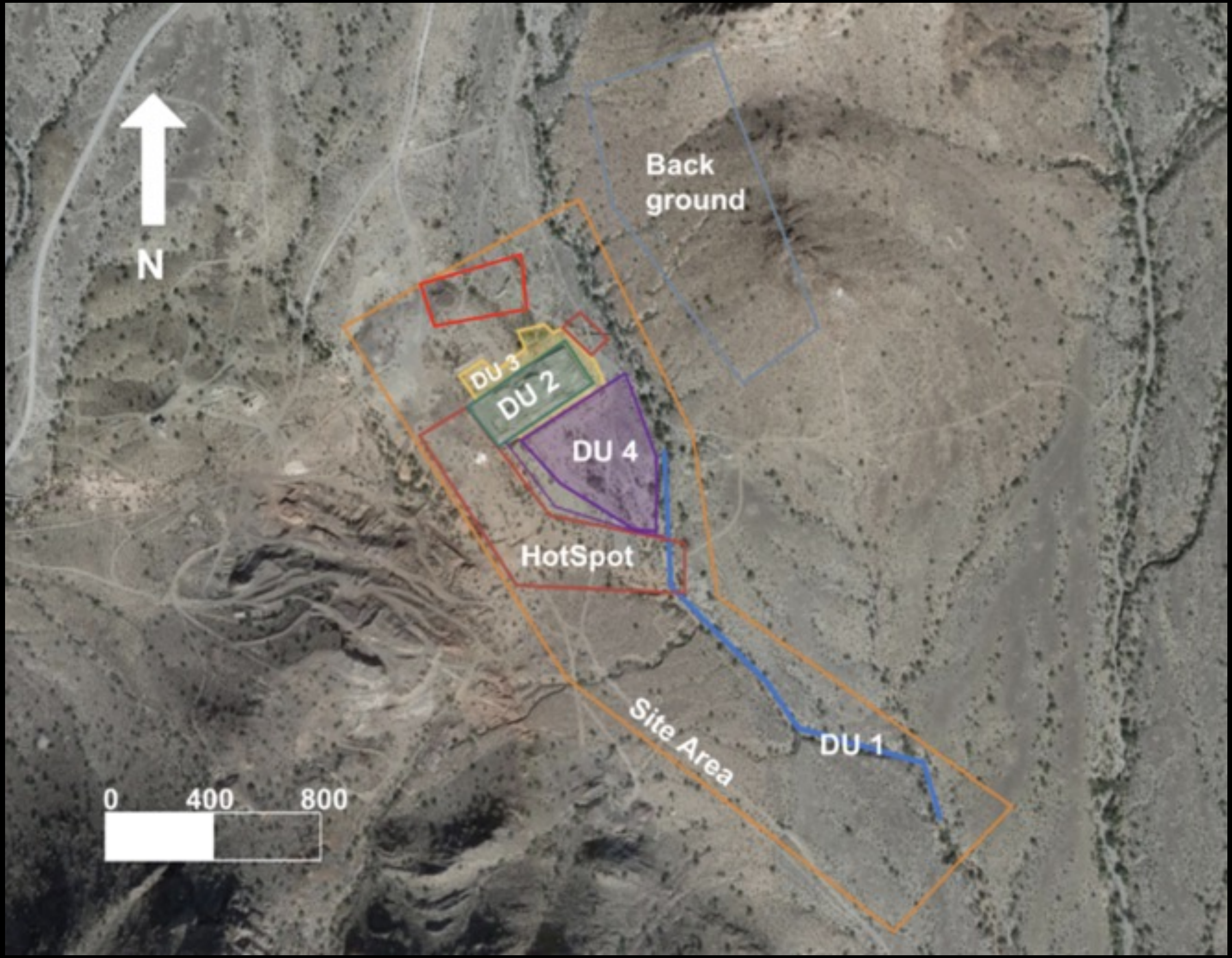

Fig. 22: Site layout and decision units. [2]

Exposure Scenarios, cont.

Incidental Ingestion

- Contact rate (mg soil/day)
  - Adult: 100 mg/day
  - Child: 200 mg/day
- Exposure frequency (hr/day)
- Exposure duration (days)
- Average body weight (kg)

Dermal

- Skin exposed (cm^2)
- Dust adherence (mg dust/cm^2)
- Absorption factor
- Exposure frequency (events/day)
  - Worker and Camping: 4 events
  - ATV: 2 events
- Average body weight (kg)

Fig. 23: ATVs kicking up dust. [4]

Characterization of Risk (Arsenic)

Table 7: Health risk from arsenic ingestion at each scenario.

ARSENIC INGESTION RISK				
Risk Scenario	Carcinogenic Risk (E-06)		Non-Carcinogenic Hazard Index	
	50% EPC	95% EPC	50% EPC	95% EPC
Worker Exposure Scenario	4.12	4.77	0.21	0.25
Recreational Camping Exposure Scenario (Child 0-6 years)	1.65	2.81	0.04	0.07
Recreational Camping Exposure Scenario (Child 6-12 years)	0.48	0.82	0.01	0.02
Recreational Camping Exposure Scenario (Adult)	1.06	1.81	0.01	0.01
Recreational ATV Exposure Scenario (Child 0-6 years)	0.71	0.93	0.02	0.03
Recreational ATV Exposure Scenario (Child 6-12 years)	0.21	0.27	0.01	0.007
Recreational ATV Exposure Scenario (Adult)	0.46	0.60	0.002	0.003

Table 8: Health risk from arsenic on skin at each scenario.

ARSENIC DERMAL RISK				
Risk Scenario	Carcinogenic Risk (E-06)		Non-Carcinogenic Hazard Index	
	50% EPC	95% EPC	50% EPC	95% EPC
Worker Exposure Scenario	10.44	12.08	0.54	0.63
Recreational Camping Exposure Scenario (Child 0-6 years)	5.92	10.08	0.15	0.26
Recreational Camping Exposure Scenario (Child 6-12 years)	3.68	6.27	0.10	0.16
Recreational Camping Exposure Scenario (Adult)	0.90	1.53	0.01	0.01
Recreational ATV Exposure Scenario (Child 0-6 years)	15.32	19.96	0.40	0.52
Recreational ATV Exposure Scenario (Child 6-12 years)	9.53	12.42	0.25	0.322
Recreational ATV Exposure Scenario (Adult)	2.32	3.03	0.01	0.02

Elevated carcinogenic risk $>10^{-6}$

Elevated non-carcinogenic hazard index >1

Lead Risk

Environmental Protection Agency lead models:

- Integrated Exposure Uptake Biokinetic Model (IEUBK) for ages 0 – 7
- Adult Lead Model (ALM) for adolescents & adults
- Heightened risk: blood lead content > 5 µg/dL

Table 9: IEUBK model results. [5]

Blood lead concentration (µg/dL)				
Exposure Scenario	**Camping**		**ATV**	
Age	50% EPC	95% EPC	50% EPC	95% EPC
0.5-1	1.1	1.3	1.0	1.0
1-2	1.3	1.5	1.2	1.3
2-3	1.2	1.4	1.2	1.2
3-4	1.2	1.3	1.1	1.1
4-5	1.2	1.2	1.1	1.1
5-6	1.1	1.2	1.1	1.1
6-7	1.1	1.1	1.0	1.0

Table 10: ALM results. [5]

Exposure Scenario	**Probability that fetal blood lead content exceeds 5 µg/dL (%)**		**Blood lead concentration of adult (µg/dL)**	
	50% EPC	95% EPC	50% EPC	95% EPC
Worker	89.54%	93.41%	11.6	13.5
Camping	0.02%	0.04%	0.7	0.8
ATV	0.01%	0.01%	0.6	0.7

Arsenic and Lead Health Effects

Arsenic

<u>Carcinogenic</u>

- Skin cancer
- Bladder cancer
- Lung cancer

<u>Non-Carcinogenic</u>

- Vascular complications
- Abdominal pain
- Heart attacks

Lead, "probable human carcinogen"

- Lower fertility/ fetal complications and death
- Damage to nervous system
- Anemia
- Kidney and brain damage
- Stomach & abdominal complications
- Stunted growth

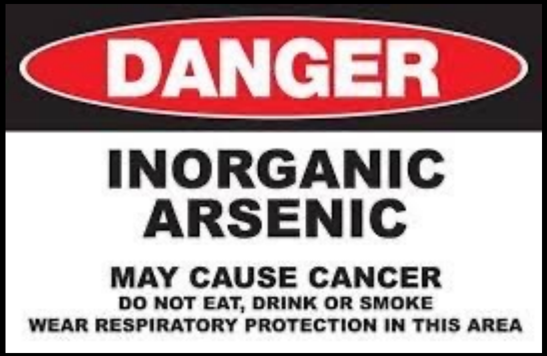

Fig. 24: Arsenic danger sign. [6]

Fig. 25: Lead danger sign. [6]

Ecological Risk Assessment

Fig. 26: Plant diversity onsite. Photo: JP

Fig. 27: Many animal tracks in wash. Photo: SB

Table 13: Species identified for this site.

Scientific Names	Common Name (* = endangered)
Invertebrates	
Euproserpinus wiesti	Prairie Sphinx Moth*
Aphonopelma chalcodes	Western Desert Tarantula
Avian Wildlife	
Toxostoma bendirei	Bendire's Thrasher*
Athene cunicularia	Burrowing Owl
Mammalian Wildlife	
Canis latrans	Coyote
Gopherus agassizii	Desert tortoise*
Plants	
Purshia subintegra	Arizona Cliff-rose*
Carnegiea gigantea	Saguaro

Table 11: Identification of ecological COCs. [7]

Contaminant	Range of levels found (ppm)	EPA Ecological Soil Screening Levels			
		Plant	Invertebrate	Avian	Mammal
Arsenic	7 – 270	18	NA	43	46
Cobalt	20 – 310	13	NA	120	230
Chromium (III)	20 – 40	NA	NA	26	34
Copper	30 – 1330	70	80	28	49
Manganese	120 – 1290	220	450	4300	4000
Nickel	20 – 80	38	280	210	130
Lead	30 – 4700	120	1700	11	56
Selenium	3 – 260	0.52	4.1	1.2	0.63
Vanadium	2 – 110	NA	NA	7.8	280
Zinc	30 - 1090	160	120	46	79

Potential Remediation Alternatives

Remedial Action Objectives (RAOs):

- **Eliminate migration of contaminants** in public land.
- **Reduce direct contact** with contaminated soil/water on public land.
- **Reduce COCs concentrations** in DU-1, DU-2, & DU-3 TO **Arizona non-residential soil remediation standards.**

Alternatives:

1. **No Action**
2. **Fence, Sign, & Monitor**
3. **Excavate to Hazardous Waste Landfill**
4. **Excavate to Private Mine**
5. **Capping**
6. **Solidification/Stabilization**

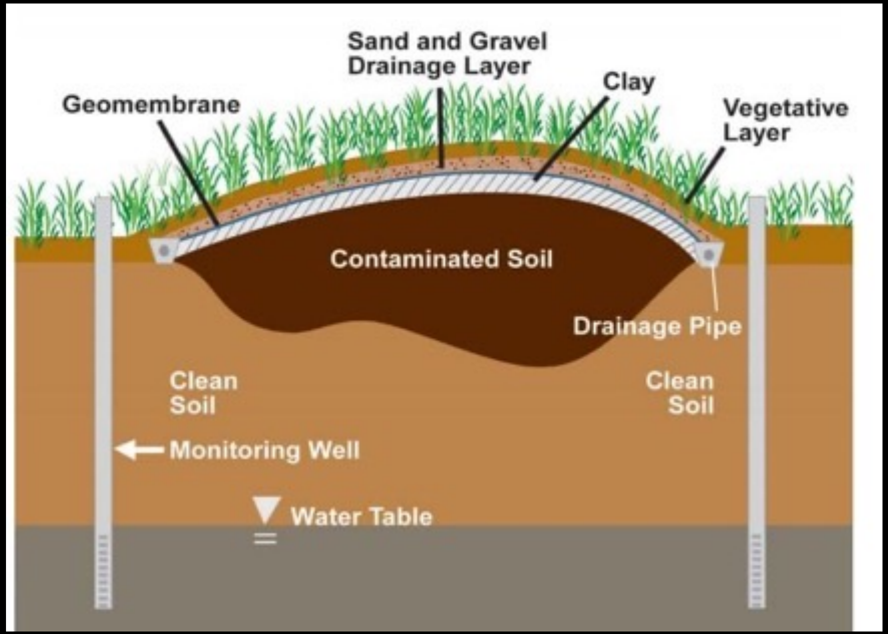

Fig. 28: Example of engineered cap. [8]

Decision Matrix

Table 12: Decision sub-matrix of alternatives meeting all Remedial Action Objectives (RAOs).

Option	Remedial Option	Cost (-/+/0)	Implementability (-/+/0)	Effectiveness (-/+/0)	Total
3c	Full excavation and off-site disposal at hazardous waste landfill.	- -	- -	+ +	- -
4b	Full excavation and move to private land repository and berm to be processed.	0	0	+ +	+ +
5b	Excavate hot spot area & wash, move to tailings pile; cap tailings pile in place.	+	-	+	+
5c	Excavate hot spot area & wash, move to private land repository and berm. Cap tailings pile.	+	-	+	+
6b	Excavate hot spot area & wash to tailings pile; solidify in place and cover with native soil.	-	-	+	-

Selected Alternative

Excavation of contamination to Private Mine to be processed by Bonanza Mining Co. for metals.

Table 13: Cost breakdown for remedial action.

Excavation	
Volume of soil (ft^3)	4,455,804
Unit Price	$4.00
Total Excavation Cost	**$17,823,216**
Berm	
Perimeter (ft)	3,000
Height (ft)	2.5
Width (ft)	4.0
Volume of soil (ft^3)	30,000
Volume of soil (CY)	1,100
Unit Price	$8.00
Total Cost of Berm Construction	**$8,890**
Total Cost of Remediation	**$17,832,106**

Fig. 29: Remedial action sketch. [2]

Impacts

Table 14: Breakdown of project impacts.

	NO ACTION	REMEDIAL ACTION
Environmental	- Risk for plant and wildlife health	+ Long-term plant and wildlife health - May destroy habitats in the process
Economic	- Healthcare cost from treating disease + Tax dollars not being spent	+ Creating jobs - Decreased tourism to Salome - Cost of remediation comes from government (taxes)
Social	- Exposing unknowing visitors to permanent health effects	+ Increased awareness about the dangers of contamination in Arizona Deserts

References

[1] Maps for Design. *Powerpoint Map of Arizona*. [Online]. [Accessed September 2023]. Accessible at: www.mapsfordesign.com

[2] Google Earth, *Harquahala Mine*. [Online]. [Accessed September 2023]. Accessible at: earth.google.com/web

[3] B. B. R. F. D. H. V. Beresford, "Harquahala Mine," 2018.

[4] UTV Driver. *Best Used UTVs*. [Online]. [Accessed May 2024]. Accessible at: https://www.utvdriver.com/best-used-utvs/

[5] United States Environmental Protection Agency, "Lead at Superfund Sites: Software and Users' Manuals," US EPA, 23 October 2023. [Online]. Available: https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals. [Accessed April 2024].

[6] Safety Emporium, [Online]. [Accessed February 2024]. Accessible at: https://www.safetyemporium.com/z-2665s .

[7] EPA, "Ecological Soil Screening Level," United States Environmental Protection Agency, [Online]. Available: https://www.epa.gov/chemical-research/ecological-soil-screening-level. [Accessed 24 April 2024].

[8] Anderson Engineering, "Site Remediation: Conventional Technologies for Pollution Treatment“, [Online]. Available: https://www.andersoneng.com/site-remediation-conventional-technologies-for-pollution-treatment/ [Accessed April 2024].

Questions?