Flag Environmental Solutions

CENE 486C Canyon City Mill Team
4/28/23

Presented By:

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Project Introduction

Purpose:

- Preliminary Assessment / Site Investigation Report
- Arsenic (As) contamination
- Determine…
  - Risk to human and environmental health
  - If further remedial action is needed
- **Client**: Bureau of Land Management (Eric Zielske)

Figure 1: Geographical Location [1]

Project Site

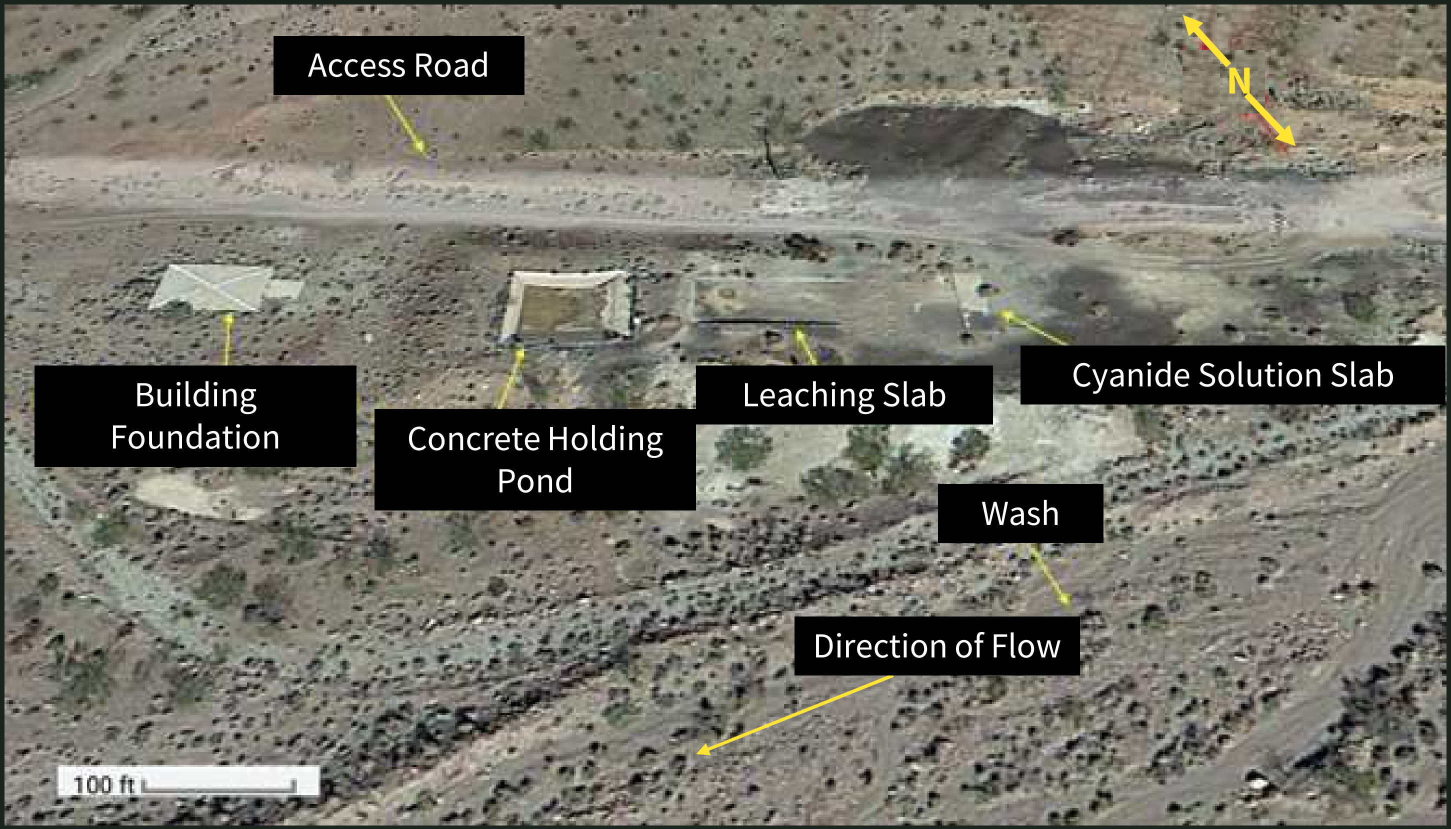

Figure 2: Aerial View of Project Site

Work Plan

- Work Plan
  - Sampling and Analysis Plan (SAP) and Health and Safety Plan (HASP)

- Original SAP included taking ~110 samples
  - 60+ grid samples
  - 30 transect samples in wash
  - Background and hotspots

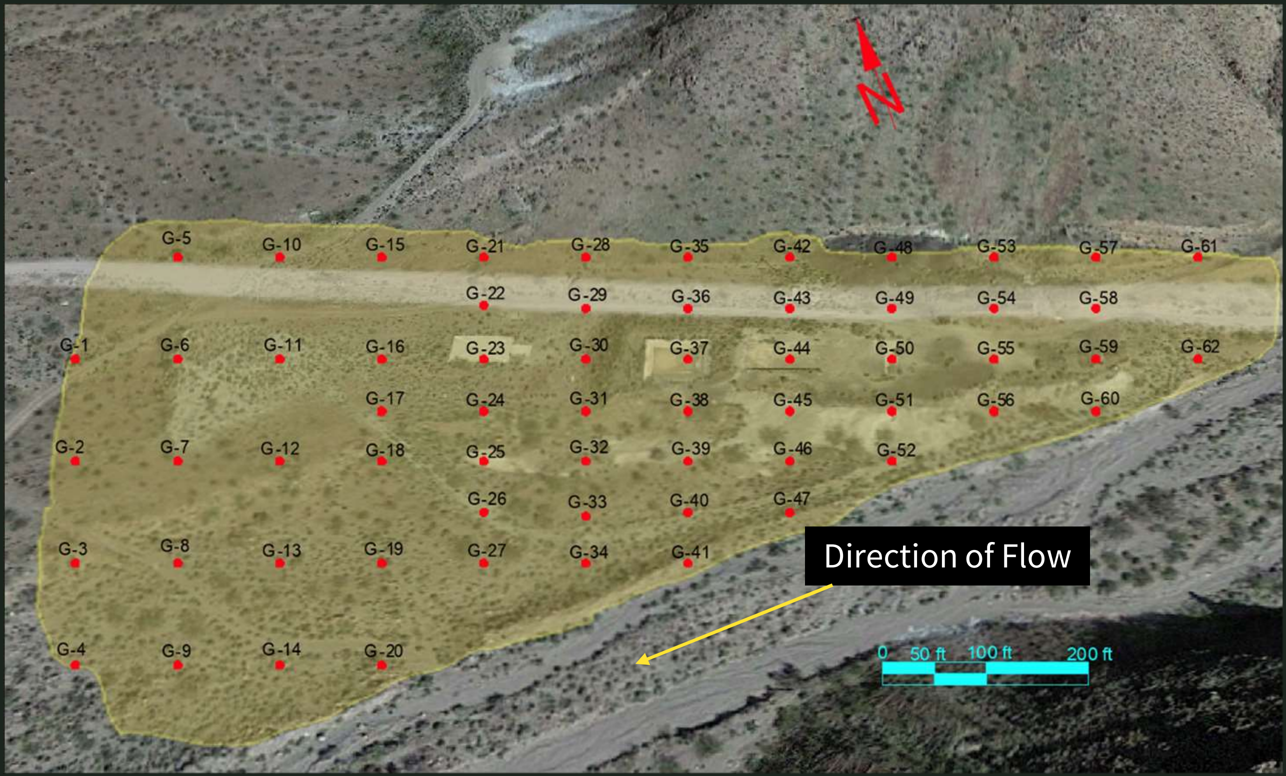

Figure 3: Original Grid Sampling Layout

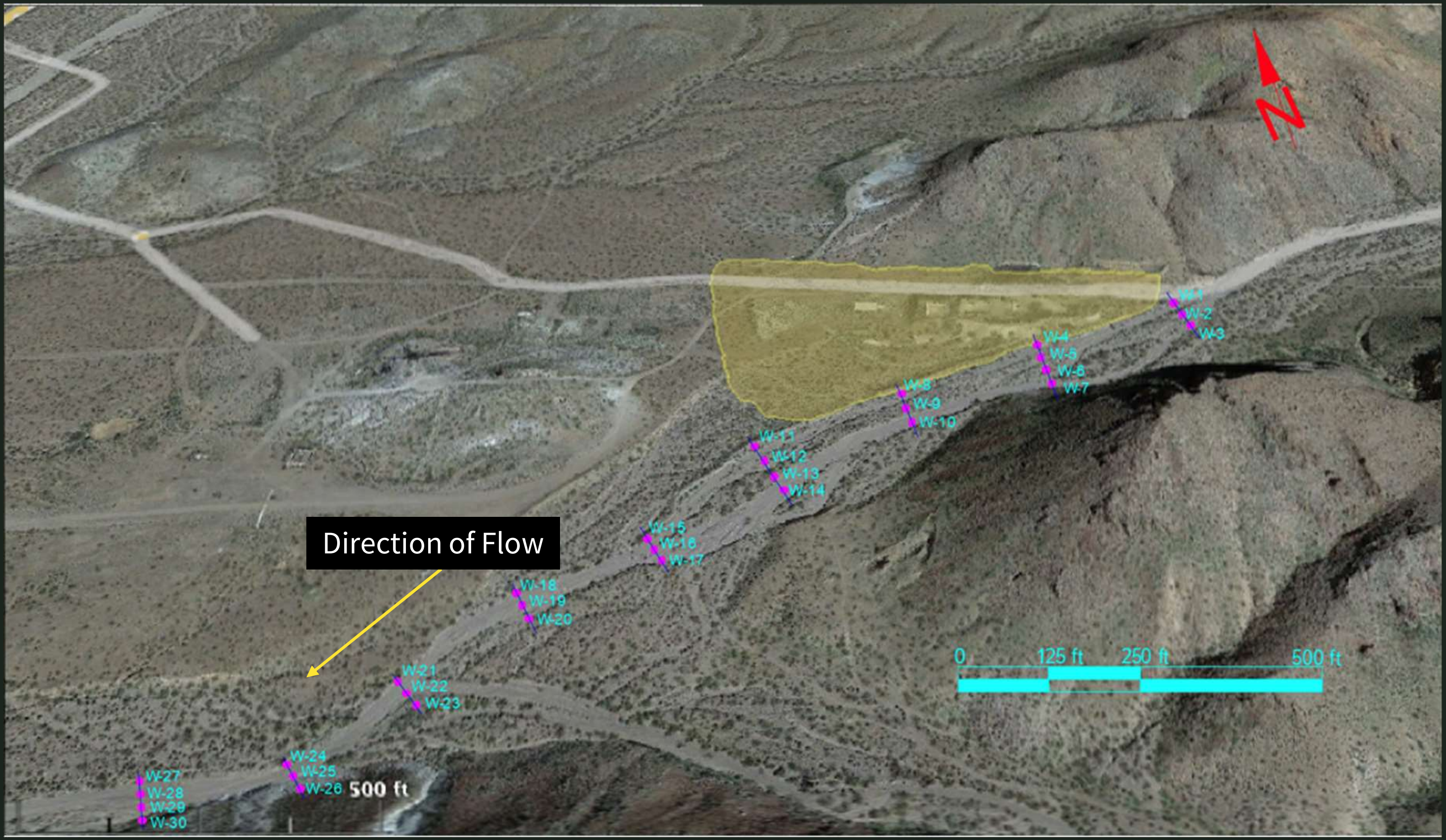

Figure 4: Original Transect Sampling Layout

Adjustment of Sampling and Analysis Plan (SAP)

- Site was difficult to access
- Client recommended Incremental Sampling Method (ISM)
  - Decision Units (DU)
  - Minimum 30 subsamples per DU
  - Statistically valid estimate of the mean concentration within the DU

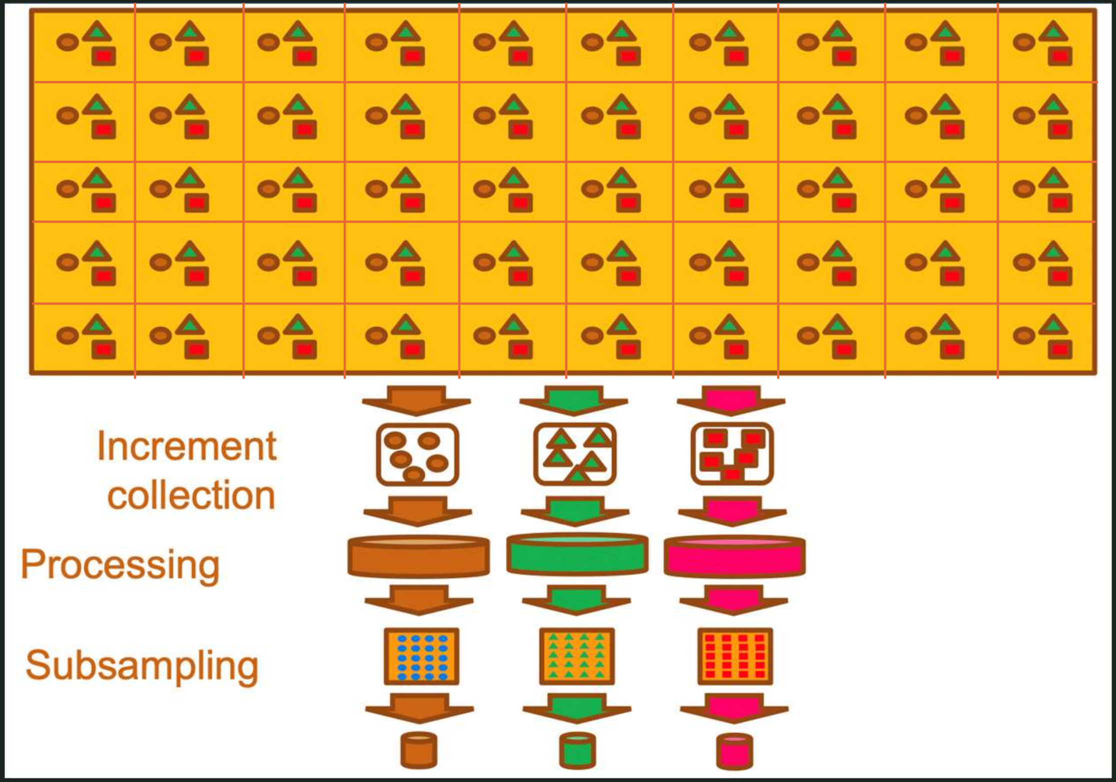

Figure 5: ISM [2]

Decision Units

Decision Unit 1

- Industrial Area

Decision Unit 2

- Vegetated Area

Decision Unit 3

- The Wash

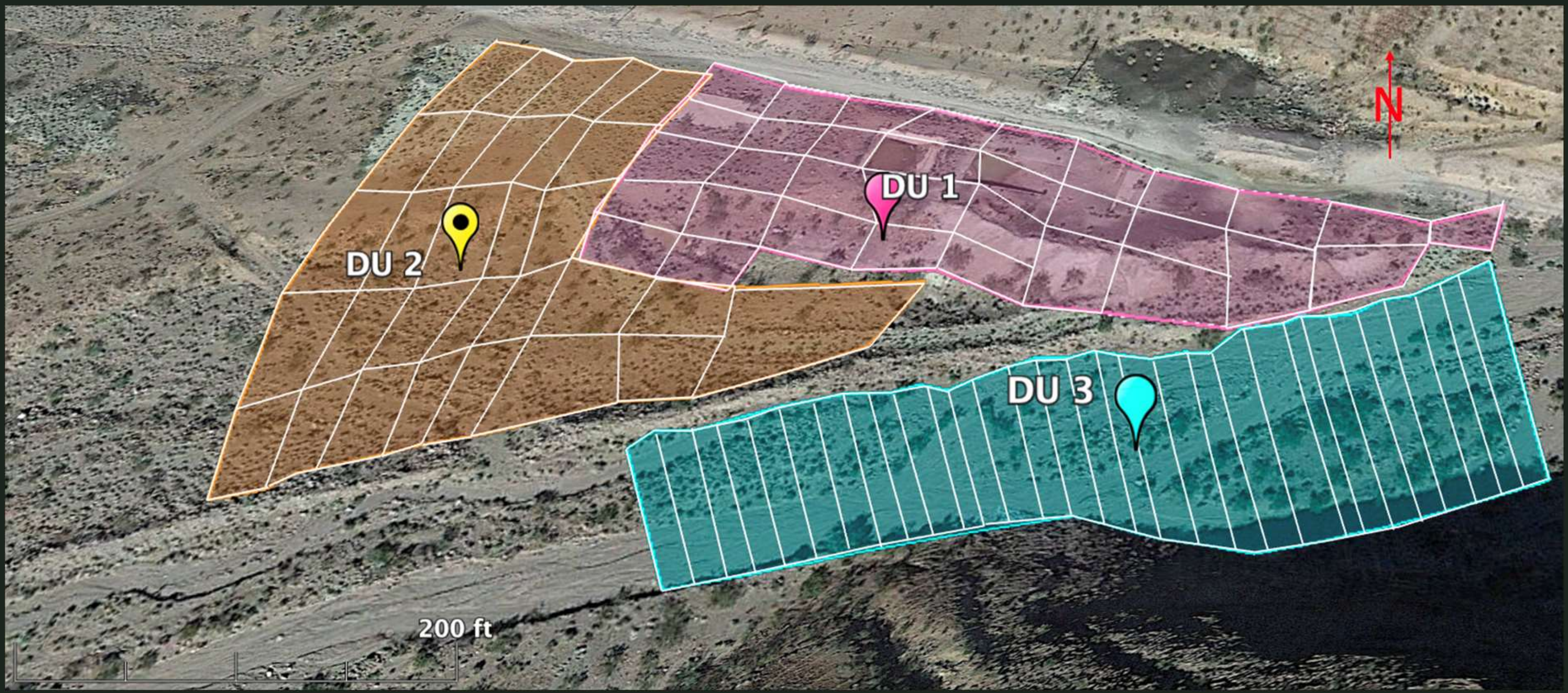

Figure 6: Decision Units

Site Investigation

- Conducted Jan. 20 – Jan. 21
- Team had difficulty reaching site
- Bags were labeled A-D
- 17 total soil samples taken
- Desert flora and fauna were observed

Figure 7: Driving Video
Video Credit: Evan Downs

Figure 8: Sampling Equipment
Photo Credit: Frankie Martinez

Site Investigation

Figure 9: Site Terrain
Photo Credit: Claire Griffiths

Figure 10: Tarantula Molt
Photo Credit: Claire Griffiths

Figure 11: Sampling Flag and Gridding Process
Photo Credit: Frankie Martinez

Site Investigation

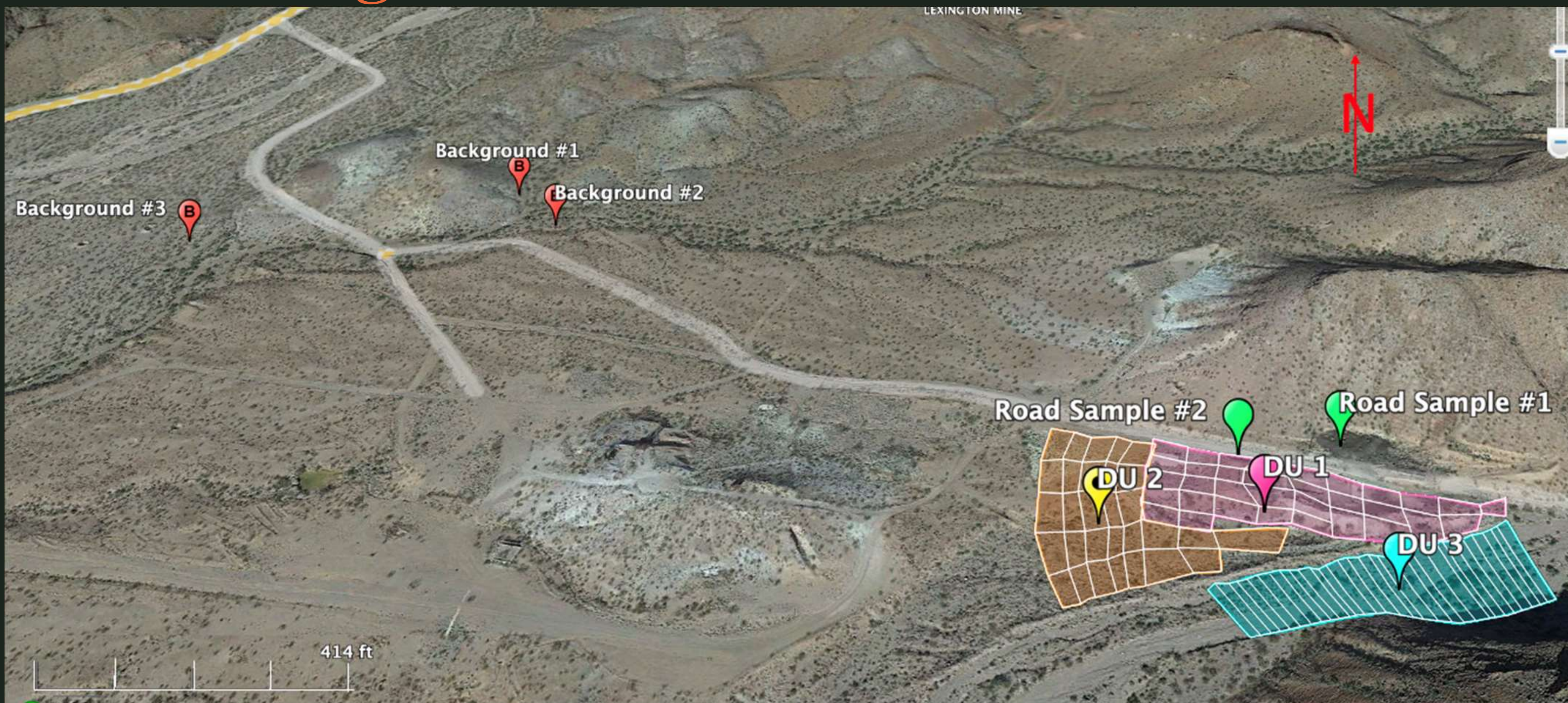

Figure 12: Location of Road and Background Samples

Sample Preparation

Drying

- Samples dried at 110°C for 17 hours

Figure 13: Samples in Oven
Photo Credit: Claire Griffiths

Soil Crushing

- Breaking up dried samples

Figure 14: Soil Crushing
Photo Credit: Frankie Martinez

Sieving

- #60 Sieve for 6 minutes
- Collected fines

Figure 15: Sieving Process
Photo Credit: Frankie Martinez

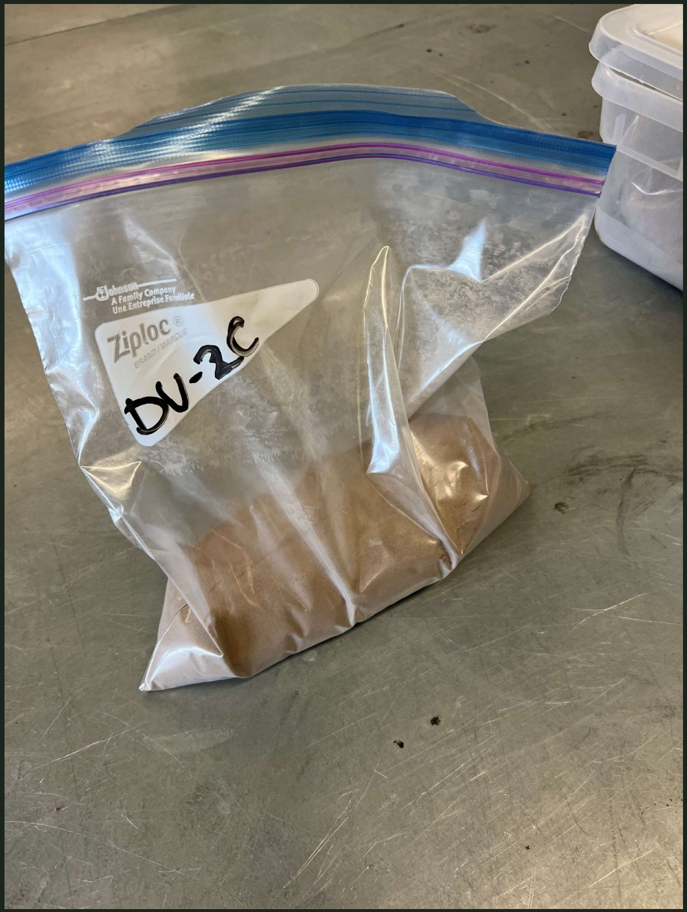

Figure 16: Bagged Fine material
Photo Credit: Evan Downs

Figure 17: Bagged Fine material
Photo Credit: Evan Downs

X-Ray Fluorescence (XRF) Analysis

- X-ray is emitted at the sample and electrons are displaced from their atomic orbital positions
- Energy released characteristic of a specific element
- Arsenic and lead X-ray lines are close in energy; cause interference due to overlapped spectrum
- Flame Atomic Absorption (FAA) and Inductively Coupled Plasma (ICP) used for confirmatory analysis
- FAA/ICP needed when lead to arsenic ratio >10:1

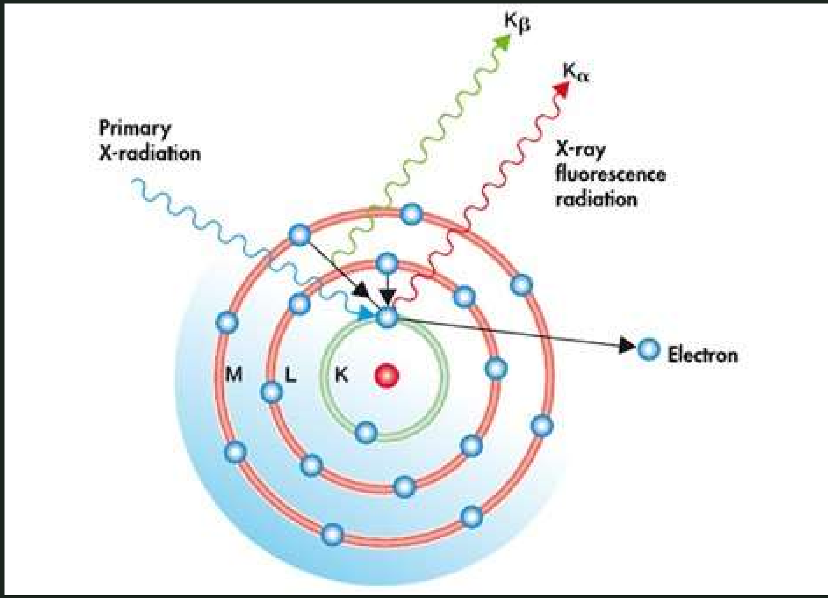

Figure 18: XRF Electron Displacement

X-Ray Fluorescence (XRF) Analysis

- 9 subsamples
- Concentrations were downloaded to an excel file
- Min and max values were removed, and averages found
- Confirmatory analysis (FAA/ICP) was not needed

Figure 19: XRF Analyzer
Photo Credit: Frankie Martinez

Figure 20: Sub Samples
Photo Credit: Frankie Martinez

Identify Human Health Contaminants of Concern

All XRF readings compared to the Arizona Non-Residential Soil Remediation Standards (AZ SRS) [2]

AZ Non- Residential SRS (ppm)	**10**
Sample ID	**As Concentration (ppm)**
B1	**12**
B2	**10**
B3	9
R1	**14**
R2	**16**
DU1 (N=4)	**76 +/- 20.36**
DU2 (N=4)	**17 +/- 5.03**
DU3 (N=4)	8 +/- 0.56

Table 1: Human Health COC- Arsenic

Ecological Contaminants of Concern

- Different EPA Ecological Soil Screening Levels (ECO-SSL) for plants, soil invertebrates, avian wildlife, and mammals
- Highest concentrations found in DU1

Element	Pb	As	Zn	Cu	Ni	Mn	V	Sb	Cd	Ag
ECO-SSL (ppm)										
Plants	120	18	160	70	38	220	N/A	N/A	32	560
Soil Invertebrates	1700	N/A	120	80	280	450	N/A	78	140	N/A
Avian	11	43	46	28	210	4300	26	N/A	0.77	4.2
Mammals	56	46	79	49	130	4000	280	0.27	0.26	14
Highest Elevated Concentration Found (ppm)	**376**	**100**	**2100**	**223**	**71**	**872**	**132**	**59**	**25**	**120**

Table 2: Ecological COCs

Slide 16

CAB1 Should I do this table or the next table?
Chloe Ann Blackhurst, 4/18/2023

FIM1 i think the next
Frankie Irene Martinez, 4/18/2023

Human Health Risk Assessment

Exposure Point Concentrations (EPCs)

50% EPC – Average Exposed Individual

- Arithmetic mean of replicate samples

95% EPC – Maximally Exposed Individual

- Calculated with following equation…

$$95\%\ EPC = \bar{X} + t_{(1-\alpha)(r-1)} \times \frac{S_{\bar{X}}}{\sqrt{r}}$$

Where:

$\bar{X}$ = arithmetic mean of all ISM samples in DU

t = $(1-\alpha)^{th}$ quantile of the t-distribution with (r-1) degrees of freedom (1.645)

$S_{\bar{X}}$ = standard deviation of all ISM samples in DU

r = number of ISM samples in DU

Table 3: EPCs

DU #	Arsenic 50% EPC (mg/kg)	Arsenic 95% EPC (mg/kg)
DU1	76	90
DU2	17	20
DU3	8	8

Exposure Assessment - Ingestion

- Used to calculate the intake dose via ingestion
- Residential exposure not required
- Adult worker exposure
  - 6-months total for site cleanup
- Recreational exposure for children and adults
  - 14 days/year
  - Age ranges:
    1. 0 to 6 years
    2. 6 to 12 years
    3. 12 to adulthood

Table 4: Worker Exposure [6] [7]

Worker Exposure Scenario	
Parameter	**Worker Ingestion**
Contact Rate (mg soil/day)	100
Exposure Frequency (hours/day)	8
Exposure Duration (days)	120
Average Body Weight (kg)	70
Averaging Time, Non-Carcinogen (year)	0.5
Averaging Time, Carcinogen (year)	70

Recreation Exposure Assessment - Ingestion

Table 5: Recreation Exposure [6] [7]

Recreational Exposure Scenario			
Parameter	**Child Ingestion (0 to 6 years)**	**Child Ingestion (6 to 12 years)**	**Adult Ingestion**
Contact Rate (mg/day)	200	100	100
Exposure Frequency (days)	14	14	14
Exposure Duration (years)	6	6	30
Average Body Weight (kg)	18	31	70
Averaging Time, Non-Carcinogen (year)	6	6	30
Averaging Time, Carcinogen (year)	70	70	70

Intake Doses

- Calculated for worker and recreation exposure scenarios
- Calculated for both 50% and 95% EPCS

Calculation

$$I = \frac{C \cdot CR \cdot EF \cdot ED}{BW \cdot AT}$$

Where:

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

C = Concentration at exposure point (mg/kg)

CR = Contact Rate (kg/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (days)

Human Health Risk Calculation

Carcinogenic Risk

$$Risk = I_c \cdot SF$$

Where:

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

SF = Slope Factor $(mg/(kg\text{-}day))^{-1}$

Elevated Risk if >10E-6

Non-Carcinogenic Risk

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

Where:

HI = Hazard Index (unitless)

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

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

Elevated Risk if >1

Human Health Risk – Carcinogenic

Table 6: 50% EPC Carcinogenic Risk

Risk	DU#1	Average of all DUs
Worker Exposure Scenario	7.65E-07	3.38E-07
Recreational Exposure Scenario (Child 0-6 years)	8.33E-06	3.68E-06
Recreational Exposure Scenario (Child 6-12 years)	1.61E-06	8.02E-07
Recreational Exposure Scenario (Adult)	5.35E-06	2.23E-06

Table 7: 95% EPC Carcinogenic Risk

Risk	DU#1	Average of all DUs
Worker Exposure Scenario	9.12E-07	4.00E-07
Recreational Exposure Scenario (Child 0-6 years)	9.93E-06	4.36E-06
Recreational Exposure Scenario (Child 6-12 years)	1.92E-06	9.45E-07
Recreational Exposure Scenario (Adult)	6.38E-06	2.64E-06

Human Health Risk – Non-Carcinogenic

Table 8: 50% Non-Carcinogenic Risk

Risk	DU#1	Average
Worker Exposure Scenario	0.241	0.107
Recreational Exposure Scenario (Child 0-6 years)	0.216	0.096
Recreational Exposure Scenario (Child 6-12 years)	0.063	0.028
Recreational Exposure Scenario (Adult)	0.028	0.012

Table 9: 95% Non-Carcinogenic Risk

Risk	DU#1	Average
Worker Exposure Scenario	0.288	0.126
Recreational Exposure Scenario (Child 0-6 years)	0.257	0.113
Recreational Exposure Scenario (Child 6-12 years)	0.075	0.033
Recreational Exposure Scenario (Adult)	0.033	0.015

Ecological Risk Assessment

Eco COCs Spatial Exceedances

Table 10: Ecological COCs

	Road	DU1	DU2	DU3		Road	DU1	DU2	DU3
Plants	Pb	Pb	Pb	Pb	**Avian**	Pb	Pb	Pb	Pb
	As	As	As	As		As	As	As	As
	Zn	Zn	Zn	Zn		Zn	Zn	Zn	Zn
	Cu	Cu	Cu	Cu		Cu	Cu	Cu	Cu
	Ni	Ni	Ni	Ni		Ni	Ni	Ni	Ni
	Mn	Mn	Mn	Mn		Mn	Mn	Mn	Mn
	Sb	Sb	Sb	Sb		Sb	Sb	Sb	Sb
	Cd	Cd	Cd	Cd		Cd	Cd	Cd	Cd
	Ag	Ag	Ag	Ag		Ag	Ag	Ag	Ag
Soil Invertebrates	Pb	Pb	Pb	Pb	**Mammalian**	Pb	Pb	Pb	Pb
	As	As	As	As		As	As	As	As
	Zn	Zn	Zn	Zn		Zn	Zn	Zn	Zn
	Cu	Cu	Cu	Cu		Cu	Cu	Cu	Cu
	Ni	Ni	Ni	Ni		Ni	Ni	Ni	Ni
	Mn	Mn	Mn	Mn		Mn	Mn	Mn	Mn
	Sb	Sb	Sb	Sb		Sb	Sb	Sb	Sb
	Cd	Cd	Cd	Cd		Cd	Cd	Cd	Cd
	Ag	Ag	Ag	Ag		Ag	Ag	Ag	Ag

Exceeds ECO-SSL and >120% of Background levels

Exceeds ECO-SSL and >1000% of Background levels

Plant ECO-SSL

Native Vegetation of the Mojave Desert Region:

- Yucca
- Cactus
- Shrubs
- Wildflowers

Figure 21: Vegetation On-Site
Photo Credit: Chloe Blackhurst

Table 11: Plant ECO-SSL

COC	ECO-SSL	Highest (ppm)
Lead	120	376
Arsenic	18	100
Zinc	160	2101
Copper	70	223
Nickel	38	70
Manganese	220	872

Common Effects of Toxicity in Plants:

- Limited biomass production
- Imbalanced mineral nutrition
- DNA damage
- Reduced root growth
- Overall degradation

Soil Invertebrate ECO-SSL

Soil Invertebrates of the Mojave Desert Region:

- Arachnids: tarantulas, scorpions
- Worms

Table 12: Invertebrate ECO-SSL

COC	ECO-SSL	Highest (ppm)
Zinc	120	2101
Copper	80	223
Manganese	450	872

Common affects:

- Reduced survival rates
- Slowed growth rates
- Developmental abnormalities

Figure 22: Giant Desert Hairy Scorpion

Avian Wildlife ECO-SSL

Endangered Avian Wildlife in the Mojave Desert Region:
- California condor
- Southwestern Willow Flycatcher

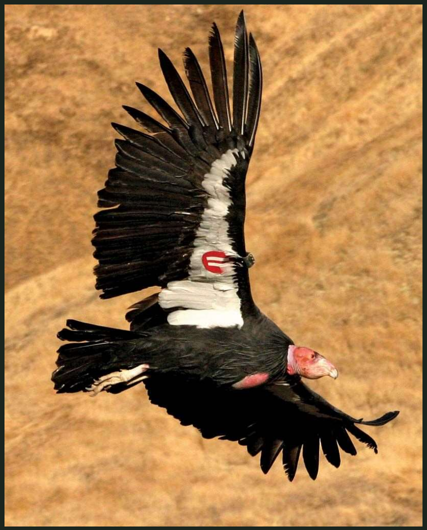

Figure 23: California Condor [2]

Figure 24: Southwestern Willow Flycatcher [3]

Table 13: Avian ECO-SSL

COC	ECO-SSL	Highest (ppm)
Lead	11	376
Arsenic	43	100
Zinc	46	2101
Copper	28	223
Vanadium	7.8	132
Cadmium	0.77	25
Silver	4.2	120

Effects on Avian Wildlife:
- Decreased body weight
- Gizzard and pancreatic lesions
- Biochemical changes
- Locomotor disturbances

Mammalian Wildlife ECO-SSL

Mammals of the Mojave Desert Region:
- Jack rabbits
- Burros
- Mule Deer
- Javalina

Figure 25: Jack Rabbit [4]

Figure 26: Burro On-Site
Photo Credit: Claire Griffiths

Table 14: Mammalian ECO-SSL

COC	ECO-SSL	Highest (ppm)
Lead	56	376
Arsenic	46	100
Zinc	79	2101
Copper	49	223
Antimony	0.27	132
Cadmium	0.36	25
Silver	14	120

Effects on Mammalian Wildlife:
- Impaired reproductive capacity
- Impaired immune function
- Cardiovascular collapse
- Behavioral issues such as anxiety
- Chronic poisoning - death

Migration Pathways

Particulate Matter (PM) Air Suspension

- Wind coming from northeast may carry alluvial material and PM
- PM would travel southwest into wash

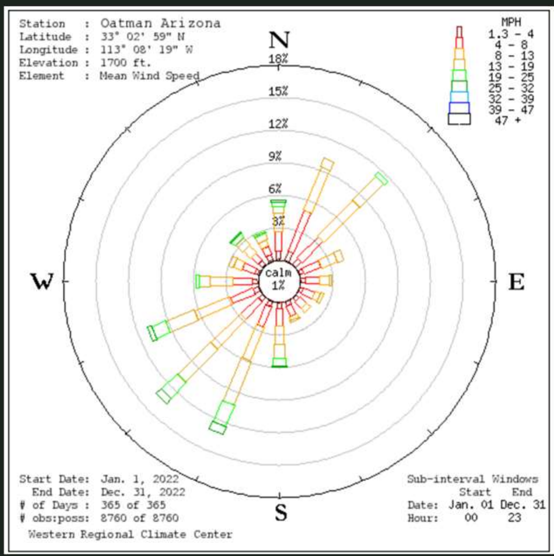

Figure 27: Wind Rose for Oatman [5]

Overland Flow

- Surface runoff/erosion- steep surrounding slopes and steep slopes on site
- Wash capable of carrying sediment offsite

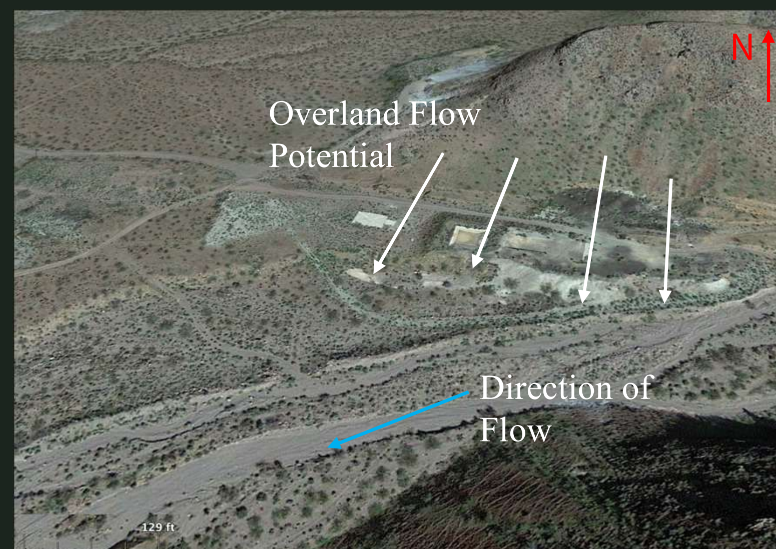

Figure 28: Overland Flow Pathways on Site

Remediation Options

Remediation Alternatives

Alternative #1: No Action	
Alternative #2: Phytoremediation	Bioremediation process that uses plants to uptake contaminants and restores the native vegetation
Alternative #3: Institutional Controls	Fencing and signage around DU1 to restrict access to the site
Alternative #4: Excavation	Removing the top layer of soil then treating/disposing of the soil ex-situ
Alternative #5: Phytoremediation and Institutional Controls	

Remediation Decision Matrix

Table 15: Remediation Decision Matrix

Remediation Alternatives						
Criteria	**Weight**	**No Action**	**Phytoremediation**	**Institutional Controls**	**Excavation**	**Phytoremediation and Institutional Controls**
Ecological Effectiveness	0.25	1	3	1	3	3
Human Health Effectiveness	0.15	1	2	3	3	3
Cost	0.35	3	2	3	1	2
Implementability	0.25	3	2	2	1	2
Total	1	2.2	2.25	2.25	1.8	2.4

3 = ideal, 2 = average, 1 = poor

Recommended Remedy

Phytoremediation with Institutional Controls

- Phytoremediation: short grasses (Deer Grass) and Yellow Pygmy Sunflowers are recommended
  - Both Native Plants, uptake arsenic from soil, habitable in Oatman
- Institutional Controls: fencing and signage around DU1
  - DU1 contains highest contamination and historical site structures

Figure 29: Deer Grass [8]

Figure 30: Yellow Pygmy Sunflower

Project Impacts

Societal Impacts

- Loss of public land
- Remediating would improve aesthetic value
- Developing land for recreational use promotes public health

Environmental Impacts

- Leaving contamination untouched would expose endangered/threatened species
- Remediating would…
  - Increase vegetation/food source
  - Restore to background levels

Economic Impact

- Remediation expenses
- Possible medical expenses from exposure
- Cost of project decreased due to change in sampling method

Questions?

References

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[2] "California condor," *Oregon Wild*. [Online]. Available: https://oregonwild.org/wildlife/california-condor. [Accessed: 16-Mar-2023].

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[5] WRCC, "Oatman Wind Rose," *Oatman Arizona*. [Online]. Available: https://raws.dri.edu/cgi-bin/rawMAIN.pl?azAOAT. [Accessed: 10-Mar-2023].

[6] United States Environmental Protection Agency , "Update for Chapter 5 of the Exposure Factors Handbook," EPA, September 2017. [Online]. Available: https://www.epa.gov/sites/default/files/2018-01/documents/efh-chapter05_2017.pdf. [Accessed 17 March 2023].

[7] United States Environmental Protection Agency, "Exposure Factors Handbook," EPA, September 2011. [Online]. Available: https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=526169. [Accessed 17 March 2023].