

Uranium Mine Soils and Spoils Characterization and 3D Modeling

1

Insights from an Abandoned Uranium Mine in Wyoming

Topics

1. Introduction
2. Material Classification
3. Field Screening
4. Soil Types
5. 3D Modeling of Soil Types & Unsuitable Materials
6. Volumes
7. Suitable Salvage Materials

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Introduction

Mined in the 60s and 70s

Initially reclaimed in the 90s

Uranium mine overburden and spoil

Material placed through undocumented backfill sequences

Large uncertainty in material Placement

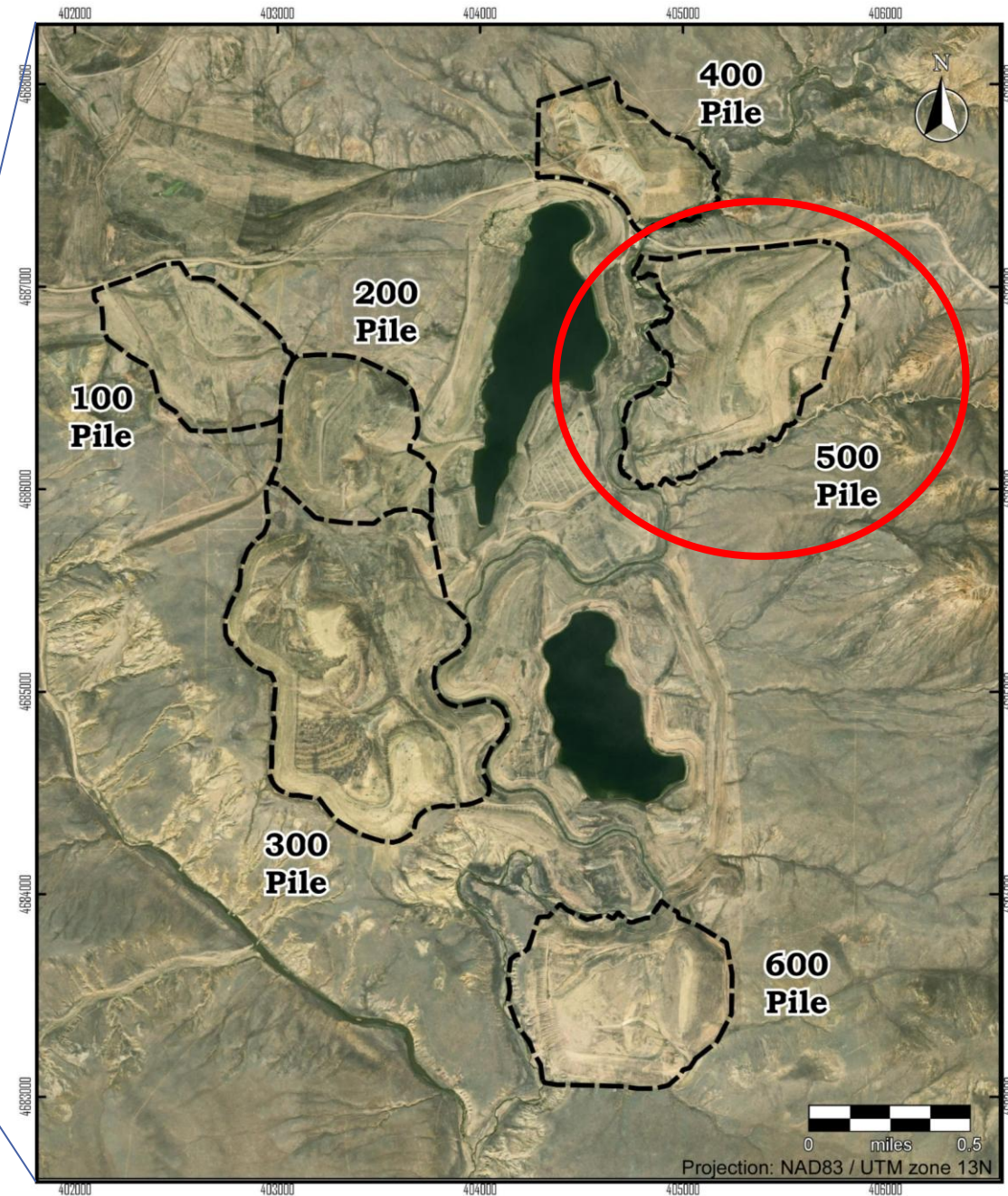
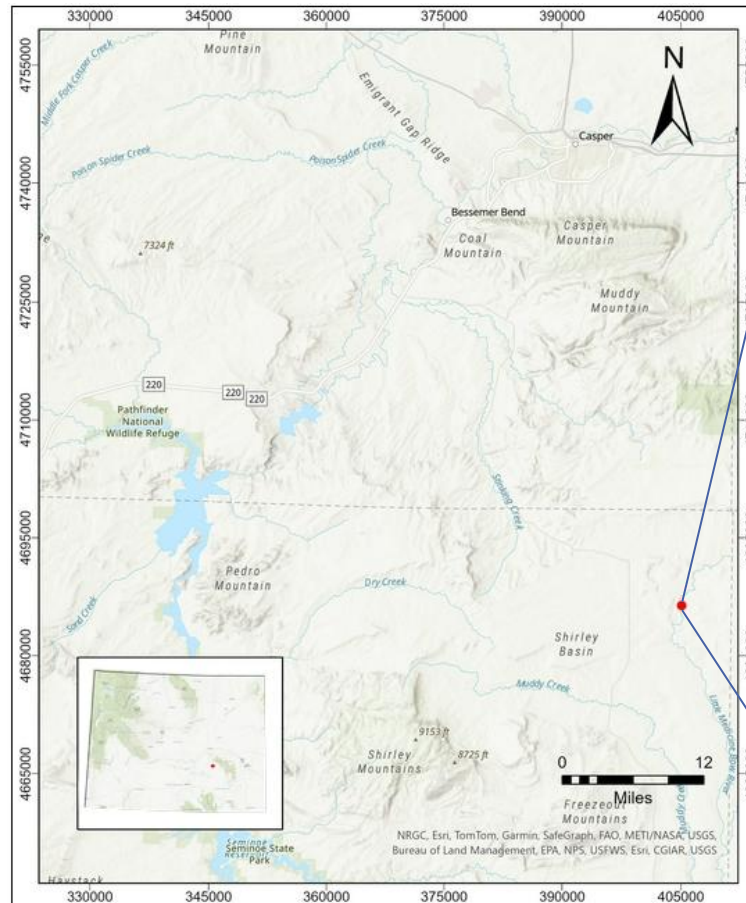
Most material is not suitable for plant growth

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Shirley Basin Location

Carbon County, WY

4



Material Classification

5

Field Screening Classification criteria

Parameter	Material Classification - Field			
	Suitable A	Suitable B	Fill	Unsuitable
pH	>5.5 <8.5	5.0 - 5.5 8.5 - 9.0	3.0 - 5.0 9.0 - 10.0	<3.0 >10.0
Ludlum model 19 measurement (MicroR/hr)	> 0	-	-	100
EC (mmhos/cm)	0-8	8-12	>12	-
Coarse Frag (% vol)	<25	25-35	>35	-
Texture **	L, Si, SiL, SL, CL, SiCL, SCL	S, C, LS, SC, SiC	-	-

** L = loam, Si = Silt, S = Sand, C = Clay, SiL = Silty Loam, SiCL = Silty Clay Loam, SL = Sandy Loam, SCL = Sandy Clay Loam, CL = Clay Loam, SC = Sandy Clay, SiC = Silty Clay, LS = Loamy Sand

Material Use by Soil Group and Depth

Material Classification	Salvage Depth (ft bgs)	Soil Groups
Coversoil	≤2	1 ; 2 ; 3
Suitable A	> 2	1 ; 2 ; 3
Suitable B	Any	Any
Fill	Any	Any
Unsuitable	Any	Any

Field Screening

Real time screening of exploration drilling

Separate distinct soil types for measurement

Core Logging

Texture ; Soil Type ; Color ; Recovery

pH / EC Measurements

Hannah Instruments handheld

Readings for each interval

Radiometrics

Ludlum Model 19

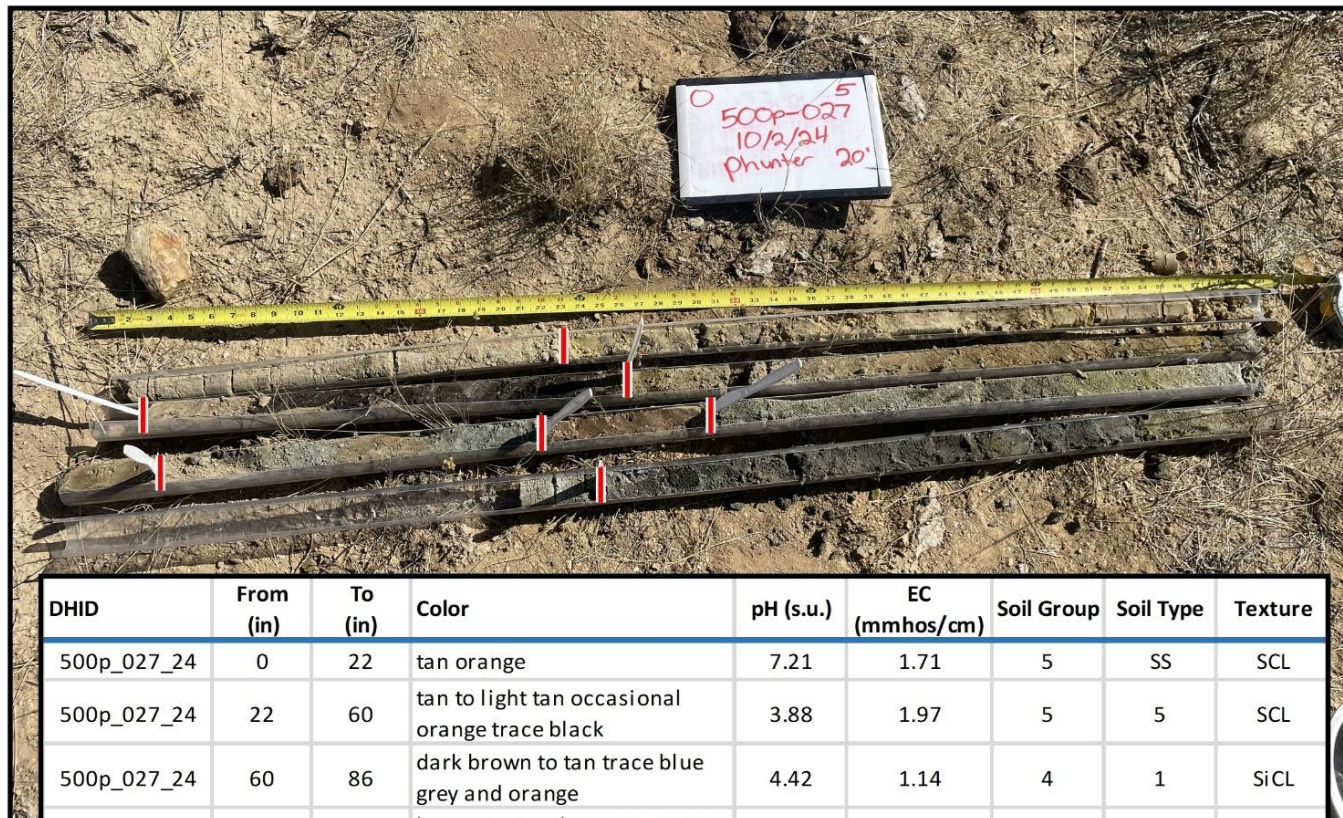
Measures MicroR / hr

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Field Screening

Example of a soil log



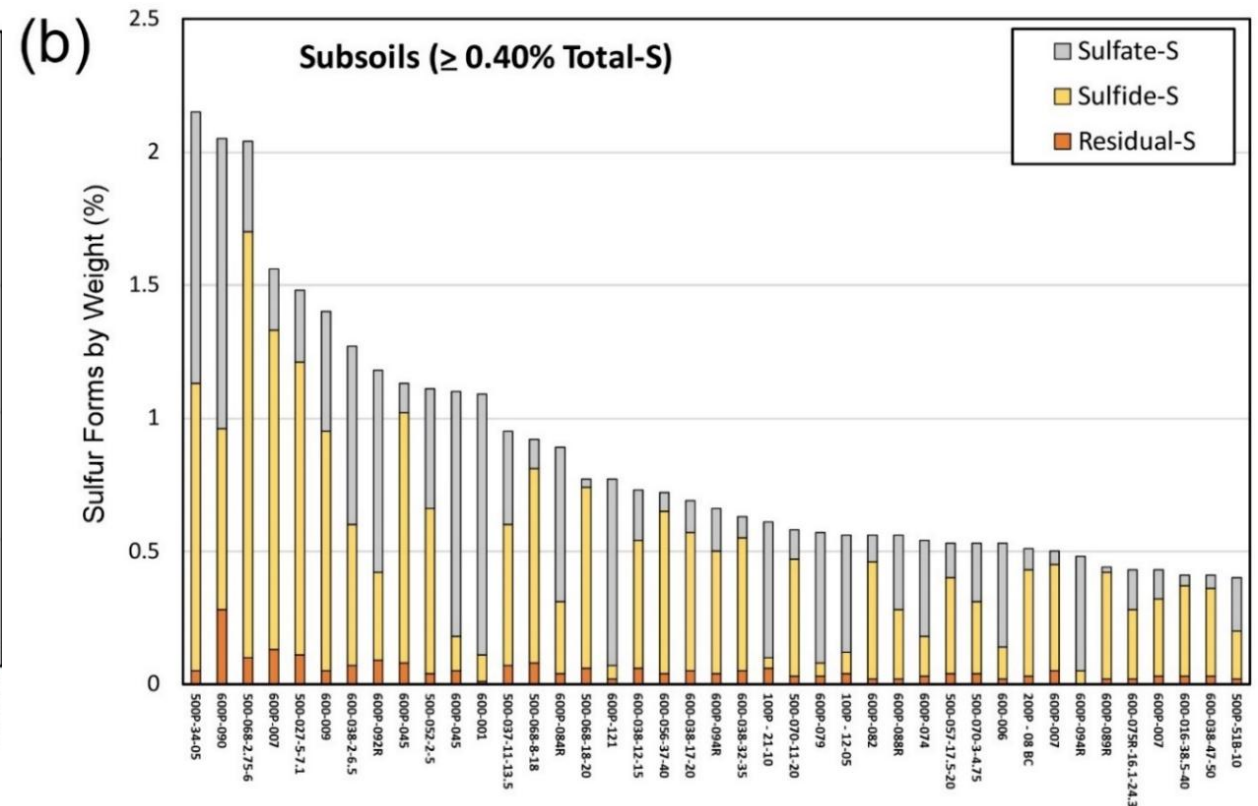
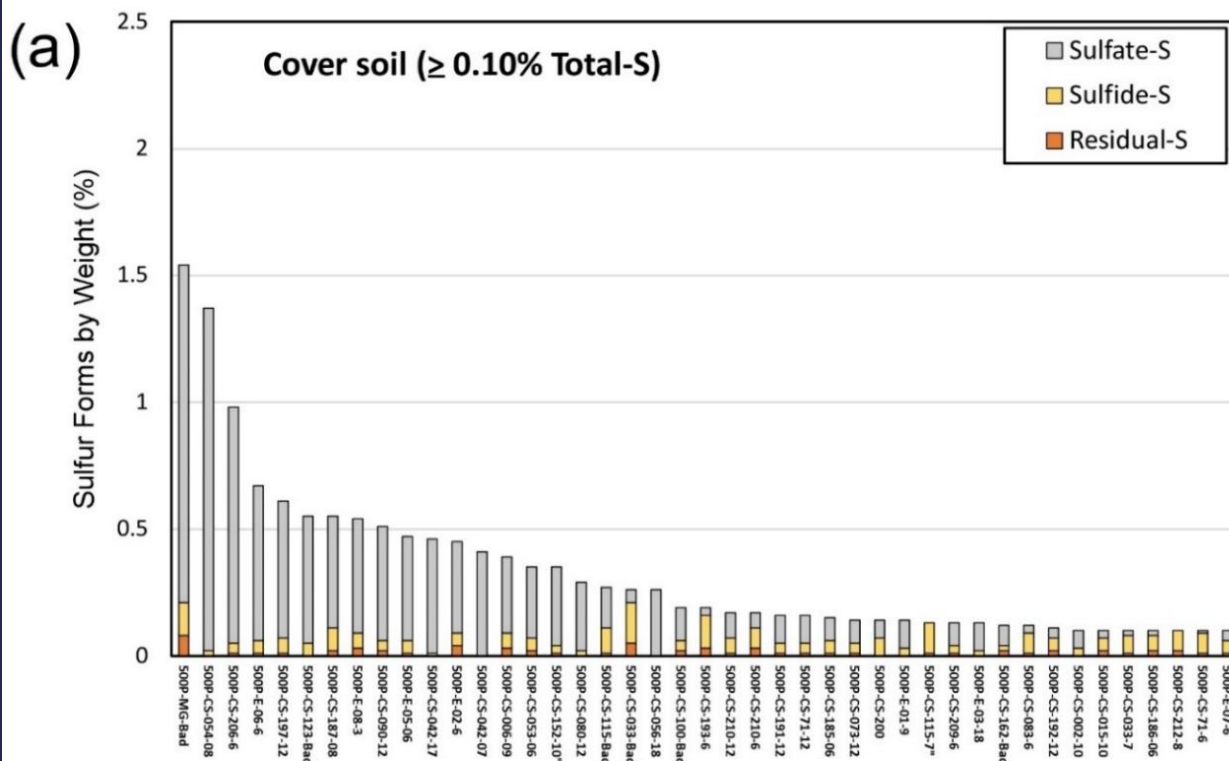
DHID	From (in)	To (in)	Color	pH (s.u.)	EC (mmhos/cm)	Soil Group	Soil Type	Texture
500p_027_24	0	22	tan orange	7.21	1.71	5	SS	SCL
500p_027_24	22	60	tan to light tan occasional orange trace black	3.88	1.97	5	5	SCL
500p_027_24	60	86	dark brown to tan trace blue grey and orange	4.42	1.14	4	1	SiCL
500p_027_24	86	125	brown to grey brown to orange brown to dak grey	7.08	1.09	1	3	SCL
500p_027_24	125	142	blue grey to brown to light brown	7.38	0.65	2	9	SCL
500p_027_24	142	150	brown trace orange	6.19	0.57	5	5	C
500p_027_24	150	216	light grey to dark grey to yellow grey	7.02	0.86	2	9	SCL
500p_027_24	216	240	dark grey to dark yellow grey	7.14	0.96	2	6	SCL



Soil Data

Total Sulfur in Selected Cover Soil (a) and Subsoil (b) Samples by Sulfur Form

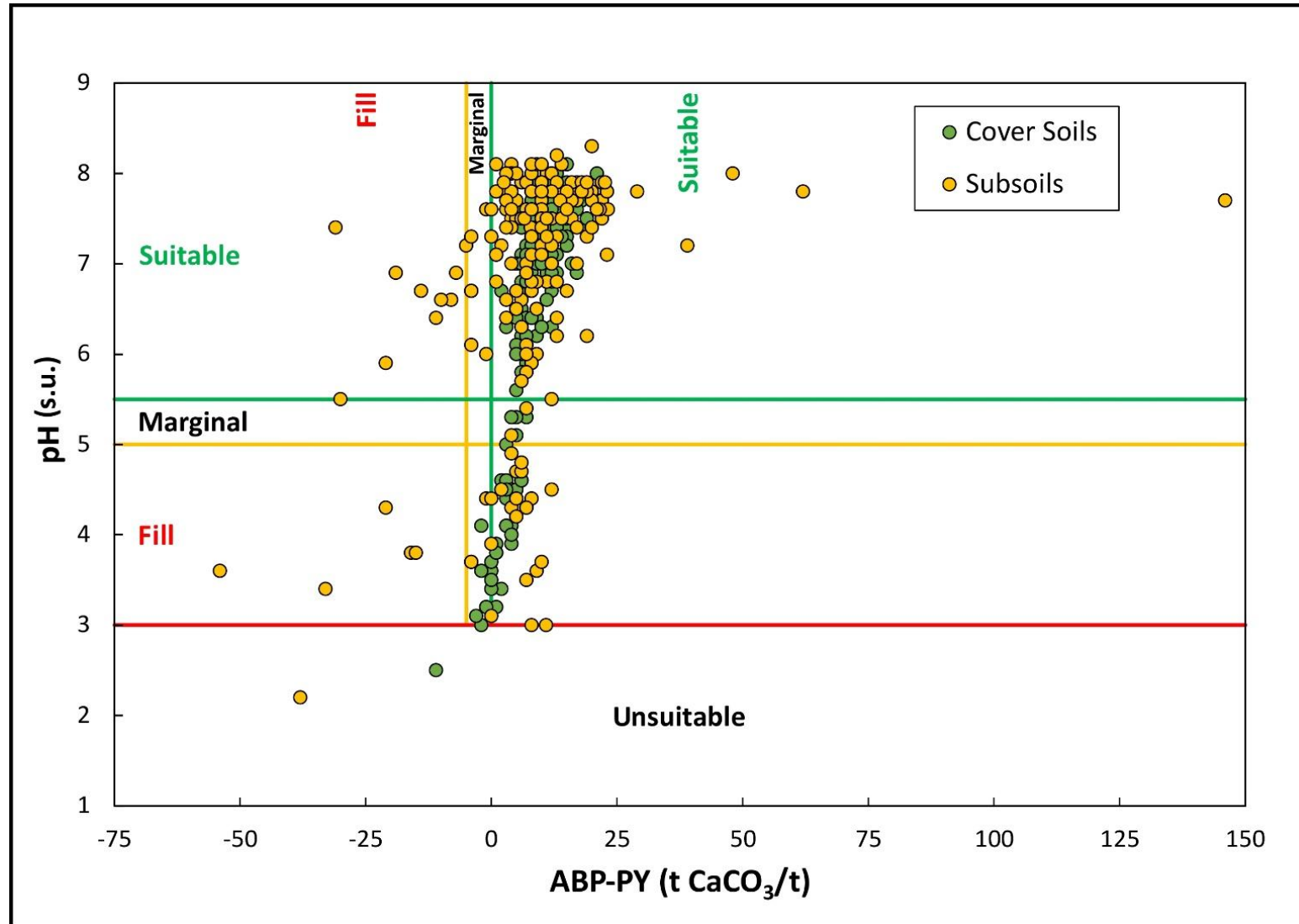
- Most sulfur in Cover soil is Sulfate sulfur
- Variable sulfate and sulfide in subsoils



Soil Data

All Cover Soil and Subsoil Samples Plotted as Pyritic Acid Based Potential (ABP-Py) vs pH

- Strong correlation between pH and ABP-Py in the subsoils
- Approximately 10% of sub soil samples had a higher classification from pH than ABP-Py
 - Risk of acidification if used as Suitable A or B material

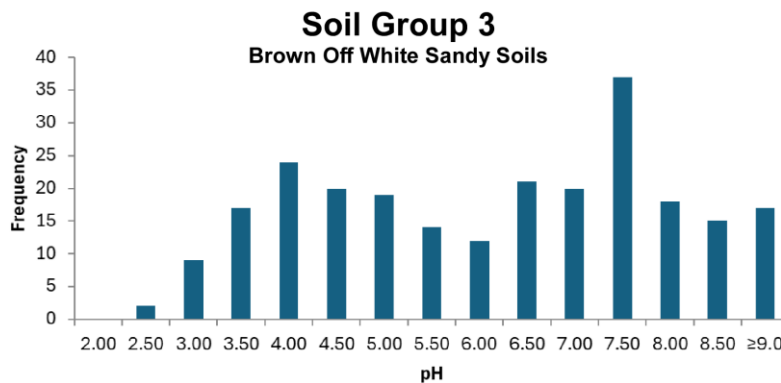
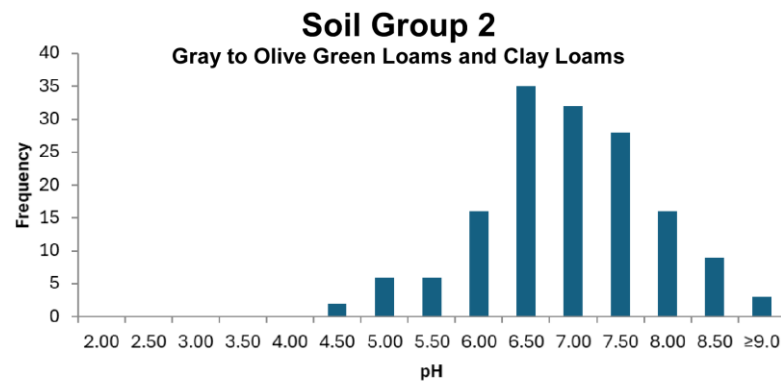
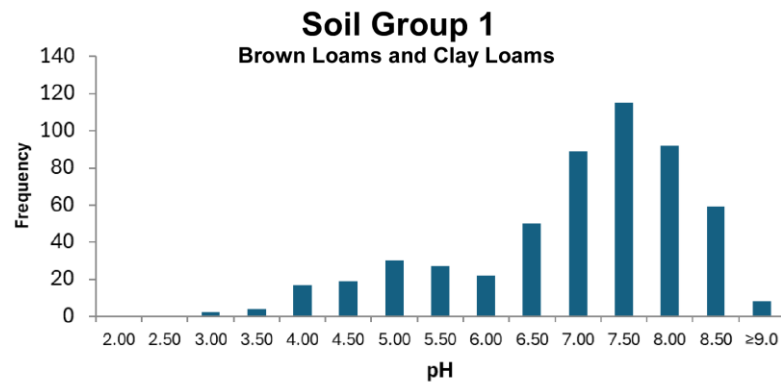


Soil Groups

- Most Suitable A and B soil is in Groups 1 and 2
- Group 3 is highly variable
- Groups 4 and 5 comprise most soil on site and are used for Fill
- Most Unsuitable comes from Group 5

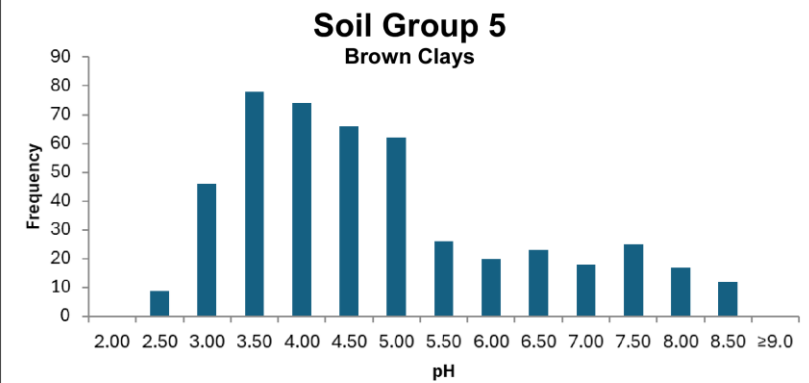
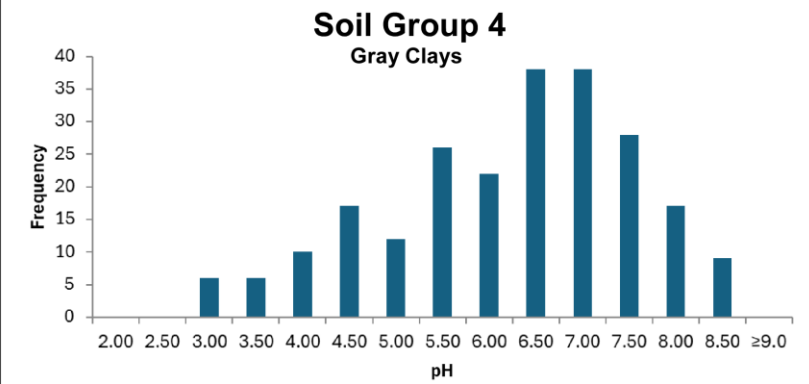
Five Soil Groups identified from all drilling

		Soil Groups				
		1	2	3	4	5
pH (s.u.)	Mean	6.7	6.7	5.9	6.0	4.6
	Max	9.0	8.9	9.4	8.5	8.4
	Min	2.8	4.3	2.5	2.5	2.3
	Std Dev	1.3	0.9	1.8	1.3	1.5
	Coeff Var	0.19	0.14	0.31	0.22	0.33
EC (mmhos/cm)	Mean	0.7	0.9	1.0	1.1	1.9
	Max	7.6	4.0	5.7	4.2	12.3
	Min	0.0	0.1	0.0	0.1	0.1
	Std Dev	0.9	0.8	0.9	0.9	1.5
	Coeff Var	1.16	0.93	0.90	0.78	0.76
Total Length (ft)		814	746	1097	1,352	1,906
Intervals		541	157	256	243	492



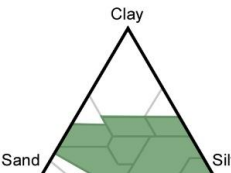
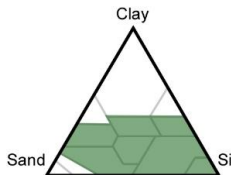
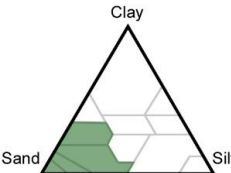
Soil Groups

pH Histograms



Soil Groups

Soil Group Summary

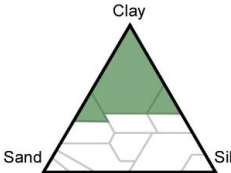
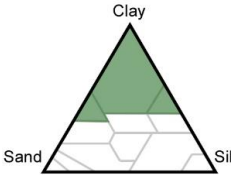
	Average pH	Common pH Range	Texture Range
Group 1 Cover Suitable A	6.7	5.5 to 8.0	 Loamy
Group 2 Cover Suitable A	6.7	5.8 to 7.6	 Loamy
Group 3 Any	5.9	4.1 to 7.7	 Sandy

Brown to Tan to Light Brown
Occasional Dark Brown to Orange to Red Brown

Light Grey to Dark Grey to Grey Brown to Grey Green
Occasional Olive Green to Black

Tan to Brown to Yellow Green Tan to Blue Grey
Occasional Orange to Black to Off White

Soil Group Summary

	Average pH	Common pH Range	Texture Range
Group 4 Suitable B Fill	6.0	4.6 to 7.3	 Clayey
Group 5 Suitable B Fill	4.6	3.1 to 6.1	 Clayey

Grey to Dark Grey to Blue Grey
Occasional Black to Brown to Light Grey to Red

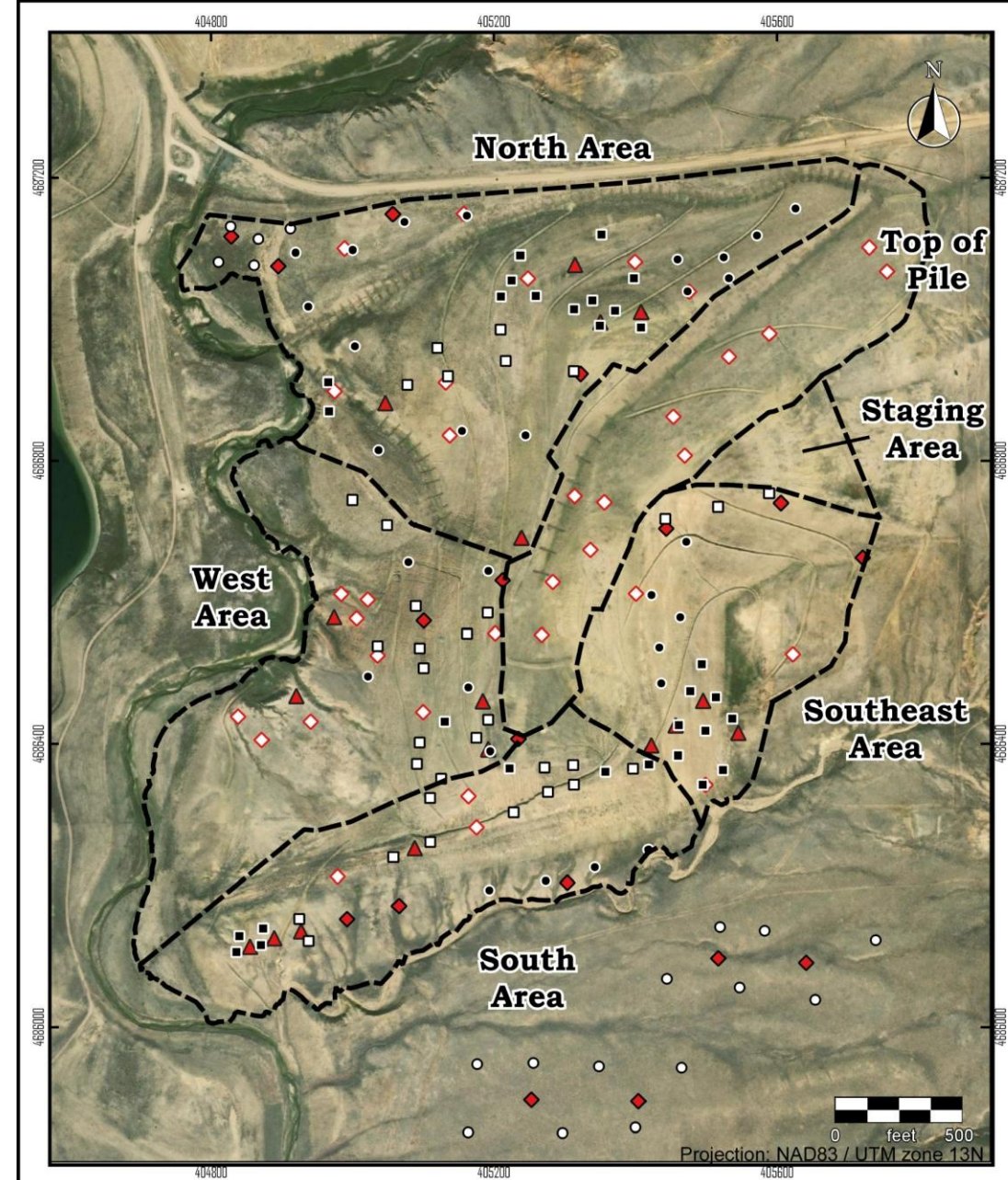
Tan to Brown to Dark Brown
Occasional Orange to Grey to Black

- Guide for construction management
- Quickly Identify Soil Groups in the Field

Modeling

- DH location map
- Logs to Model

Year	No. Drillholes	Depth (ft)	No. Lab Samples	No. Field Screening
2023	185	3429	292	2088
2024	315	5887	130	1692
Total	500	9316	422	3780



Shirley Basin 500 Pile
Drillhole Locations
Carbon County, WY

Legend

- 10' - 2023
- 15' - 2023
- 25' - 2023
- 45' - 2023

--- Grading Areas

- ◇ 10' & 15' - 2024
- ◆ 20' & 25' - 2024
- △ 30' & 35' - 2024
- ▲ 45' - 2024

Date: 6/12/2025

PREPARED BY:



PREPARED FOR:



Using Drillholes to build a model

- Import georeferenced drillhole locations
- Enter field screening data
 - Soil Group
 - pH / EC



Groups 1 and 2



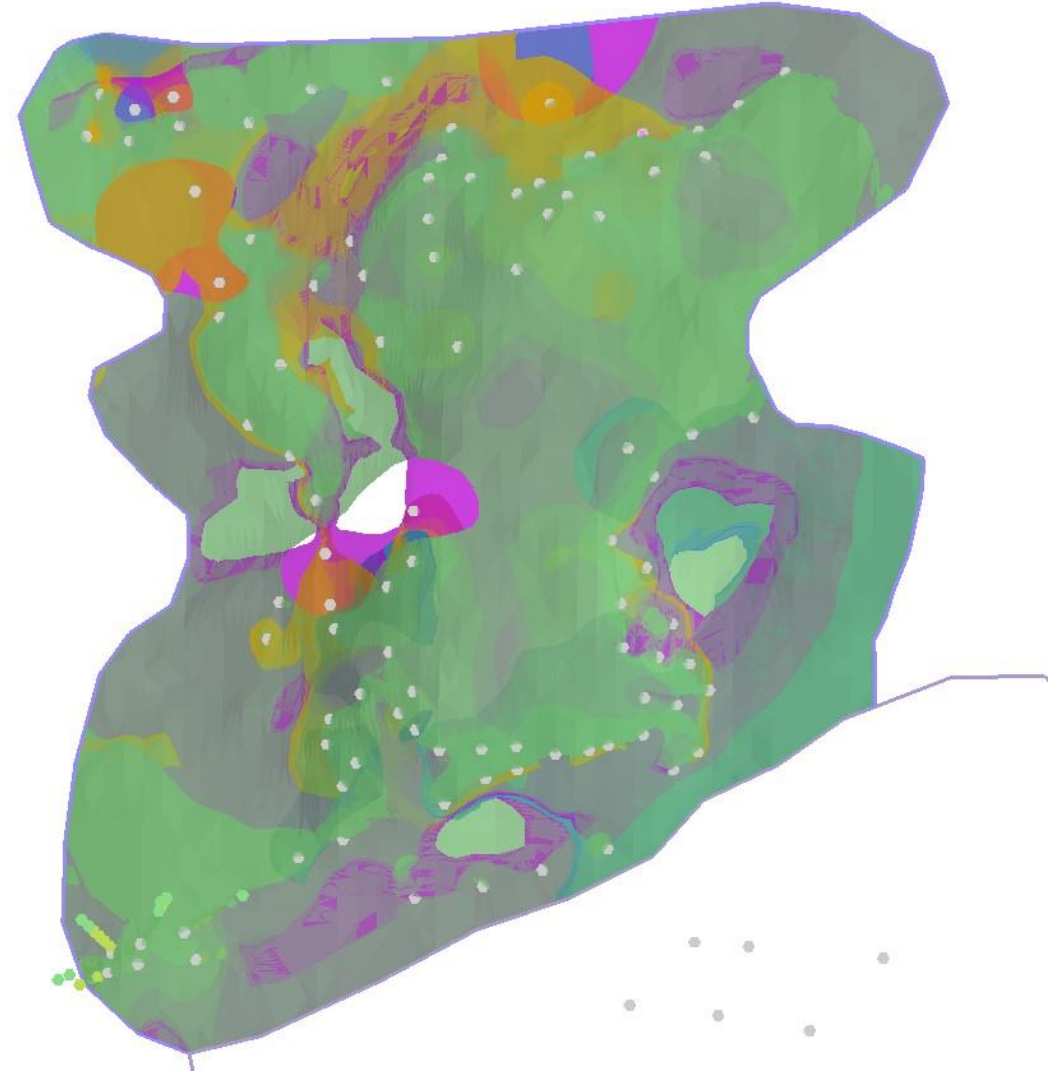
Group 3



Groups 4 and 5

Model data

- Create 3D correlations between data
- Create top and bottom surfaces for soil units
- Generate solids of soil units
- Review data to eliminate overlap
- Classify Material



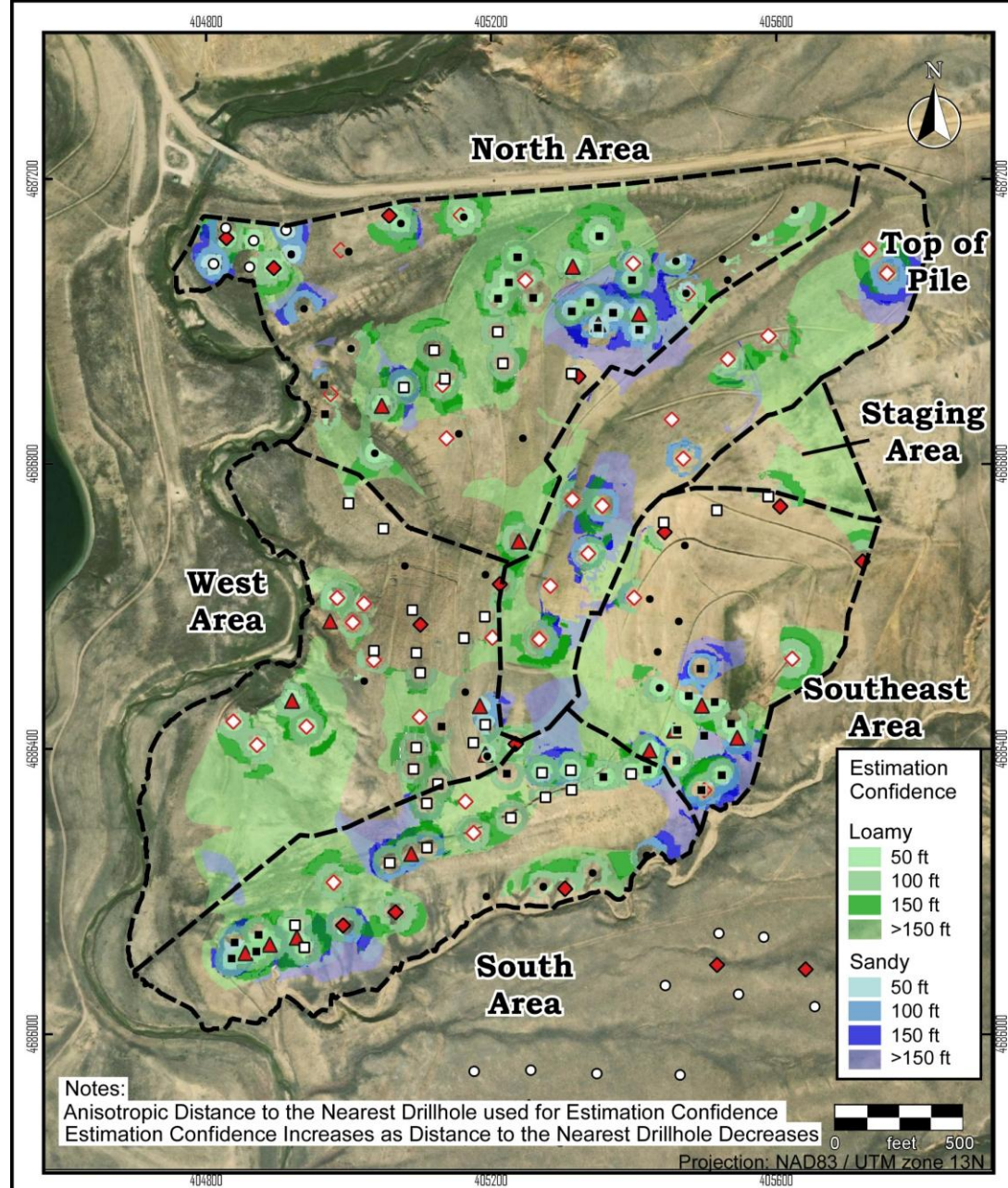
Suitable A

- Locations
- Based on Soil Group and pH
- Distribution by Estimation Confidence

Material Volume (K CY)†*

Area	Soil Type	Cover soil	Suitable A	Suitable B	Unsuitable
North	All	78.0	182.2	163.9	4.6
South	All	46.6	47.0	42.5	4.5
Southeast	All	31.4	19.8	112.2	12.1
Staging	All	13.6	0.0	0.0	0.0
Top of Pile	All	59.3	4.3	20.6	0.5
West	All	43.2	16.9	27.9	0.0
Total		272.1	270.2	367.1	21.7

Grand Total 909.4



Shirley Basin 500 Pile
Estimation Confidence
Suitable A Material
Carbon County, WY

Legend

- 10' - 2023
- 15' - 2023
- 25' - 2023
- 45' - 2023

Grading Areas

- ◆ 10' & 15' - 2024
- ◇ 20' & 25' - 2024
- ▲ 30' & 35' - 2024
- △ 45' - 2024

Date: 6/16/2025

PREPARED BY:
ROCKWELL Science

PREPARED FOR:
DEQ & HERRERA

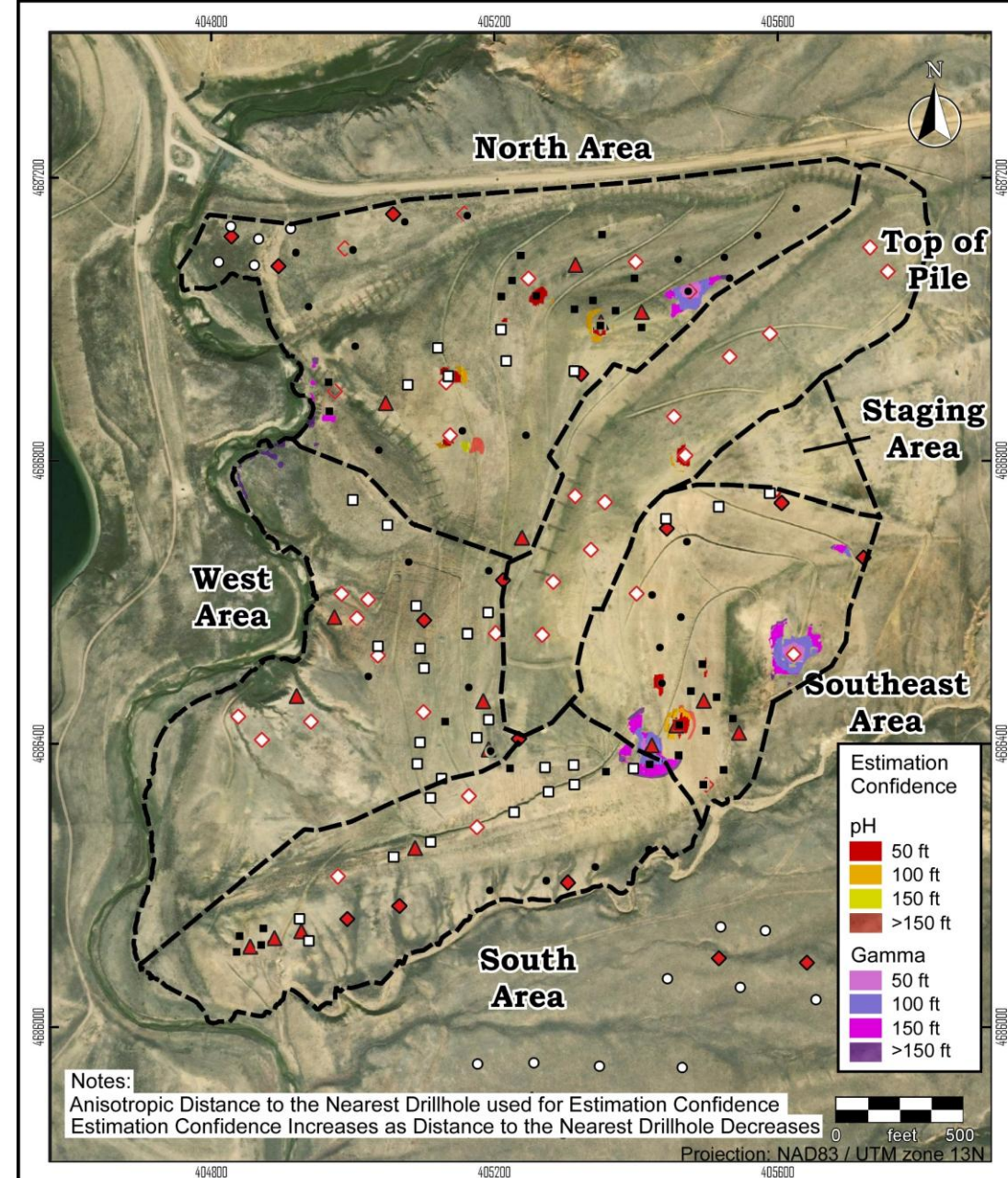
Unsuitable

- Locations
- Volumes from pH and Gamma models
- Distribution by Estimation Confidence

Unsuitable Material (CY)

Area	pH	Gamma
North	2,600	2,800
South	0	6,100
Southeast	5,200	7,800
Staging	0	0
Top of Pile	500	0
West	0	200
Total	8,300	16,900

Grand Total 25,200



Shirley Basin 500 Pile
Estimation Confidence
Unsuitable Material
Carbon County, WY

Legend

- 10' - 2023
- 15' - 2023
- 25' - 2023
- 45' - 2023

Grading Areas

- ◆ 10' & 15' - 2024
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Date: 6/16/2025

PREPARED BY:



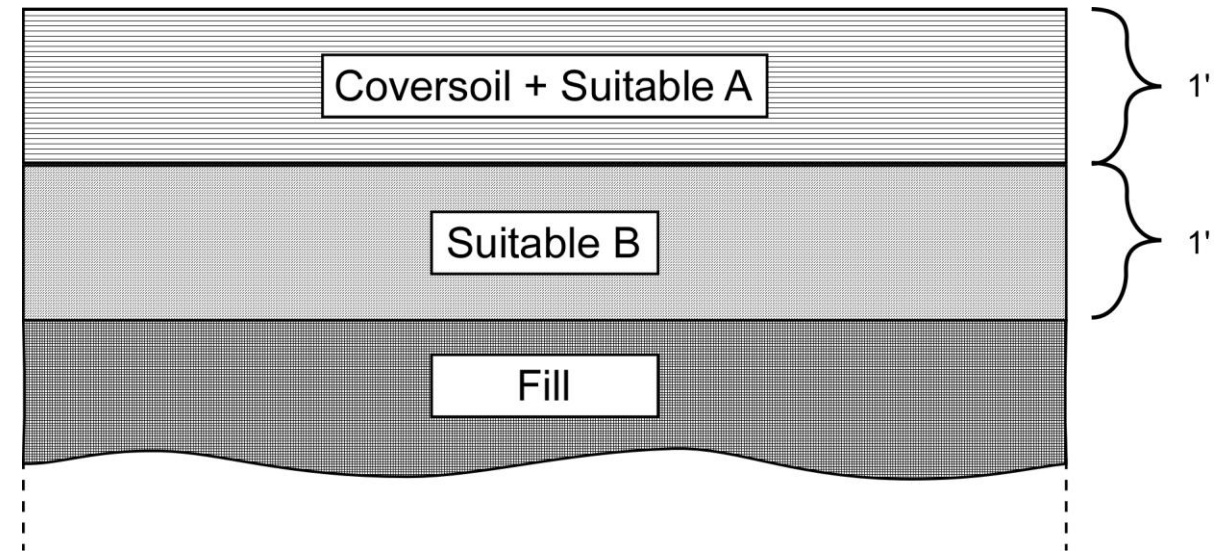
PREPARED FOR:



Cap Volumes

	Thickness (in)	Volume (K CY)
Cover soil	9	272
Suitable A	9	270
Suitable B	12	367

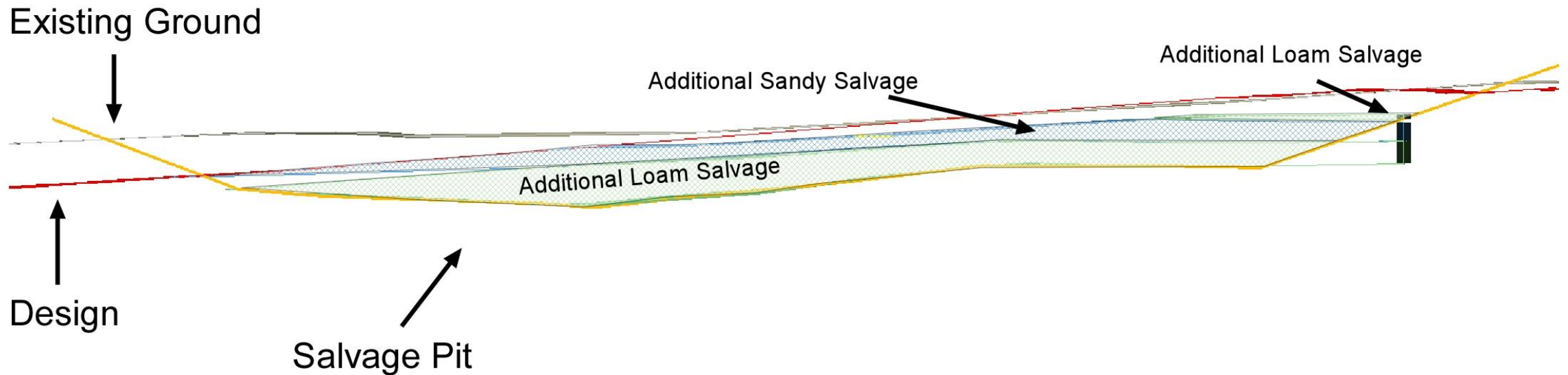
Target cap thicknesses



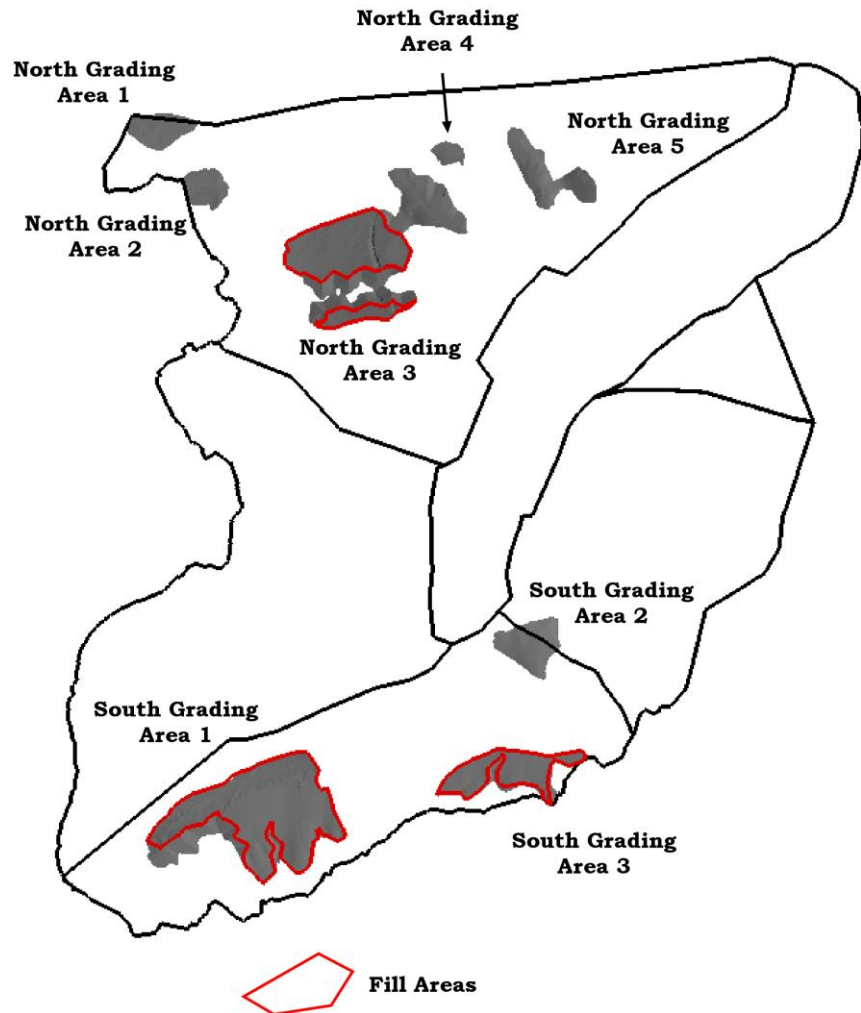
Salvageable Material

- ▶ High quality buried soil was found below cuts
- ▶ Salvage material can be harvested to supplement Suitable A during construction

Additional Loamy and Sandy Salvage Below Design



Volumes – Salvage



Area	Cut/Fill Zone	Total Volume (K CY)	Salvage Volume (K CY)	Cost
North Grading Area 1	Cut	6.1	4.5	\$ 18,448
North Grading Area 2	Cut	4.4	3.4	\$ 13,306
North Grading Area 3	Fill	48.9	25.5	\$ 146,840
North Grading Area 3	Cut	37.6	17.2	\$ 112,658
North Grading Area 4	Cut	1.8	1.8	\$ 5,454
North Grading Area 5	Cut	12.7	5.7	\$ 38,071
South Grading Area 1	Fill	71.4	64.4	\$ 214,282
South Grading Area 1	Cut	13.2	3.0	\$ 39,718
South Grading Area 2	Cut	13.3	6.0	\$ 40,043
South Grading Area 3	Fill	13.4	11.9	\$ 40,344
South Grading Area 3	Cut	2.2	0.9	\$ 6,571

Excavation Costs Estimated:

\$3 / cy

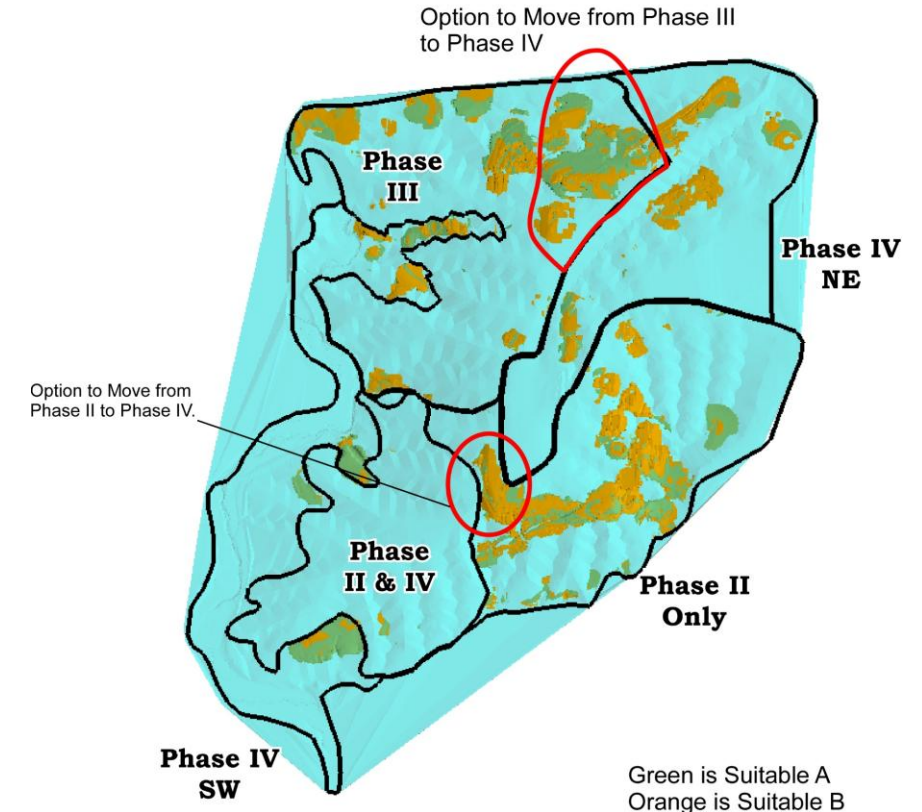
Phasing

- Determine proper phasing to ensure sufficient material
 - Some areas have very little Suitable A
 - Some areas are primarily Suitable B
- Save money through planning
 - Limit double handling of material
 - Limit stockpiling of material
- Avoid not having enough cover material in the first phase

Estimated Volumes by Phase (KCY)

Phase	Coversoil	Suitable A	Suitable B	Unsuitable
Phase II Only	48.9	55.9	195.9	21.2
Phase II and IV	36.2	0.6	0.3	0.0
Phase III	62.6	169.1	130.7	3.2
Phase IV - NE	77.2	5.2	35.8	0.6
Phase IV - SW	62.0	41.7	26.7	1.9
Total	287.0	272.5	389.4	26.9

Snip showing CUT for Final Design 500 Pile



**Volume (K CY)
for 1' Cover**

Volume (K CY) for 1' Cover	Acres
89.8	55.7
57.8	35.8
104.4	64.7
74.8	46.4
125.0	0.0
451.8	280.0



THANK YOU!

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SHIRLEY BASIN
TOUR BROCHURE



**KIROL APPLIED
ECOLOGICAL RESEARCH**

