Cedar Creek Technical Report

CEDAR CREEK ASSOCIATES, INC.
5586 Overhill Dr. Fort Collins, Colorado 80526 (970) 223-0775

To: Stantec
From: CEDAR CREEK ASSOCIATES, Inc.
Date: October 4, 2018
Subject: St. Anthony Mine Materials Characterization

1.0 Introduction

Cedar Creek Associates, Inc. (Cedar Creek) was contracted by Stantec to complete a materials characterization study pertaining to the suitability of several Borrow Areas, Topsoil Piles, and Waste Piles for use as growth media in the reclamation of the St. Anthony Mine Site in Cibola County, New Mexico. This technical report serves to summarize observations made during field surveys and sample collection which took place from March 26th through April 17th and subsequent laboratory analysis.

Previous mining activities have resulted in unvegetated piles at the St. Anthony mine site. Limited topsoil salvage and stockpiling occurred during historic mining activities. However, in order to achieve successful reclamation of the St. Anthony Mine Site, in accordance with New Mexico Mining and Minerals Division (NMMMD) – Closeout Plan Guidelines, sufficient volumes of topsoil and/or alternate growth media are required. The Waste Piles, Topsoil Piles, and Borrow Areas were observed and sampled to determine whether materials comprising each facility exhibit suitable chemical and physical characteristics for use as a reclamation planting media (seedbed/surface material) or rooting media (subsurface material).

To optimize the required thickness of suitable growth media, numerous local soil-vegetation systems were also observed. These observations help inform the required thickness of cover materials to support the establishment of a self-sustaining vegetation community.

2.0 General Methodology

2.1 Field Sampling Preparation

Prior to the field surveys, available site-specific soils and geologic data were gathered. Publicly available data from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soil surveys were reviewed to identify major soils that dominate the project area. Soil characteristics of each identified NRCS soil type along with corresponding mapping, both within and adjacent to the project area, were on hand during the field evaluation. In addition, agronomic analytical laboratory results from previous soil sampling efforts detailed in the 2007 Materials Characterization Report (MWH, 2007) were also reviewed and on hand during field evaluation. Various aerial imagery, geologic maps, and topographic maps were acquired to aid the field surveys.

2.2 Bore-Hole Sampling and Cataloging

A drilling program to characterize materials encountered throughout the various mine facilities and potential Borrow Areas was conducted by Stantec. Drilling locations and drilling methodologies were pre-determined by Stantec. Selected drilling sites were randomly distributed throughout each of the mine facilities and represented each facility adequately. Cedar Creek was onsite during drilling to observe materials excavated from the boreholes and to describe and characterize the properties and features of the materials encountered. Samples were collected throughout the drilling process for laboratory analysis of agronomic properties of the various material types encountered.

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2.2.1 Sample Collection Methodology

A hollow stem rotary auger (with and without a core sampler) and a modified California sampler were the primary methods used to extract, observe, and sample soils. Numerous sample locations were selected for material core extraction, where more detailed observations of soil properties could be recorded. On all borehole locations, regardless of whether cores were extracted, cuttings brought up through the auger bit were continually inspected, observations recorded, and occasionally collected for laboratory analysis.

Observations pertaining to the properties and features of soil and geologic materials were recorded. Field characterizations generally followed NRCS soil description protocols and terminology in version 3 of the Field Book for Describing and Sampling Soils. NRCS pedon descriptions focused on features such as color, texture, structure, pedon concentrations, consistence, roots and pores, chemical response, coarse fragments, and any other features that were encountered and deemed potentially pertinent for informing revegetation success.

Soil and geologic materials were sampled by a combination of systematic and targeted sampling approaches. Professional judgement was required in deciding which materials would be sampled and tested for agronomic analysis to adequately characterize the site. Efforts were made to sample all material types, with several duplicates of material types. Samples selected for laboratory analysis came from either:

1. Fixed interval composite samples from intact soil cores.

2. Horizon sampling from intact soil cores.

3. Bulk composite samples from both rotary cuttings and cores.

4. Targeted samples of materials with unique or extreme properties or features.

On the Waste Piles and Topsoil Piles, soil and alluvial materials were often mixed with geologic materials as a result of the excavation, transport, and placement during previous mining activities. When materials were mixed, soil sampling defaulted to fixed interval composite sampling.

When intact core samples were extracted with materials in distinct layers (i.e., not mixed), horizon sampling techniques could be utilized to test the properties of the individual soil and geologic material types. This was the most common sampling approach in undisturbed, native Borrow Areas, but occasionally occurred on both Waste Piles and Topsoil Piles.

When intact cores were not extracted or were heavily disturbed and partially intact, bulk composite samples were instead utilized. This method was the least preferred, and was only utilized where necessary.

When unique or extreme variants of a material type were encountered (i.e., unweathered shale, coal, pure white saline sandstone), targeted sampling methods were utilized, to identify the bounds in which soil properties and features could vary within the various distinct geologic materials onsite.

2.3 Laboratory Analyses

Laboratory analyses consisted of numerous tests pertaining to the agronomic properties of the soils and geologic materials. The parameters tested, along with the methods and suitability criteria, are found below in Table 1. Methods and suitability criteria either meet or exceed the Soil and Topsoil Suitability Ratings within Attachment 1 of the NMMMD Closeout Plan Guidelines.

Table 1 St. Anthony Mine - Materials Characterization - 2018			
Soil Laboratory Results - Suitability Criteria			
Paramater	**Method**	**Acceptable Average Values**	**Units**
pH (paste)	ASTM D4972 - 13	6 - 8.3	N/A
Electrical Conductivity	4F1a1a1*	< 3 < 6	mmhos/cm
Organic Matter	Walkley-Black	< 10	% of Total Soil
NO_3-N	4D6*	> 0.1+	ppm
Phosphorus (P)	4D6*	> 1+	ppm
Potassium (K)	4D6*	> 20+	ppm
Zinc (Zn)	4D6*	> 0.25+	ppm
Iron (Fe)	4D6*	> 1.0+	ppm
Manganese (Mn)	4D6*	> 0.1+	ppm
Copper (Cu)	4D6*	> 0.1+	ppm
Calcium (Ca)	EPA Method 3050B	Addressed as SAR	ppm
Magnesium (Mg)	EPA Method 3050B	Addressed as SAR	ppm
Sodium (Na)	EPA Method 3050B	Addressed as SAR	ppm
Texture by hydrometer	ASTM D422-63(2007)e2	No Textural Extremes	% Size Fraction
Sodium Adsorption Ratio	EPA Method 3050B	< 15	N/A

* Soil Survey 2014 as Reference + Values Can Be Increased Through OM Additions

* EC > 6 excludes use as surficial growth media unless mixed. EC between 3-6 requires special consideration in the reclamation plan.

Additionally, textural extremes (very poorly graded or well sorted materials) should be avoided for use in reclamation. Due to the extremely arid climate and challenging soil chemistry, the range of suitable textural classifications is more restrictive than typical for rangeland systems in the arid west. Below is a textural classification triangle highlighting unsuitable textural designations.

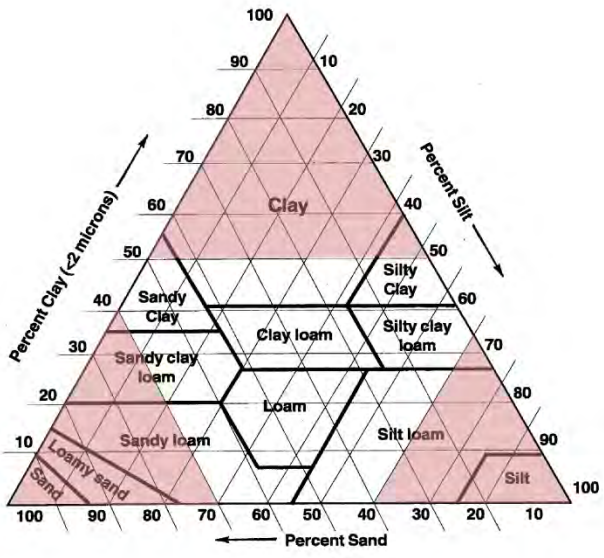

Figure 1: – Soil texture triangle, with unsuitable textural classes highlighted in red.

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2.4 Additional Field Observations

Undisturbed soil-vegetation systems with comparable parent and geologic materials to the projected reclamation systems were targeted for observation, primarily to approximate cover thicknesses needed to support undisturbed plant communities. The depth of topsoil overlying geologic materials, particularly in thinner, lower-quality (productivity) soil systems, were specifically observed and noted. Observations were made contrasting areas that are currently supporting vegetation with unvegetated areas across the site. Emphasis was placed on geomorphic features most comparable to the eventual revegetation communities. Also, successful vegetation species were observed and recorded to assist in the compilation of a site-specific seed mix for inclusion in the reclamation plan.

3.0 Results

Any exceedances of the acceptable ranges for each parameter in Table 1 are denoted in red for easy identification within the tables in Section 3.0. Similarly, moderate or marginally elevated laboratory results below the suitability thresholds defined in Table 1 are denoted in orange. The degree of suitability for any parameter exists on a continuum, and moderate or marginal exceedances of most parameters may still require additional consideration in reclamation planning and design.

3.1 Boreholes

The predetermined sampling approach for the growth media characterization efforts was organized primarily by facility, under the assumption that materials in each pile would be consistent throughout. In reality, several piles contained varying combinations of unique geologic materials, randomly structured (layered and deposited) and often mixed. While conducting the field efforts, and after reviewing laboratory data specifically targeting representative samples of each material type, it became apparent that assessing the reclamation potential of any pile would be wholly dependent upon the material types eventually exposed at the surface of each pile.

The success of any direct revegetation efforts or reclamation of placed cover materials will be directly linked to the properties of the underlying geologic material types. Because the piles include somewhat random mixtures of numerous, individual types of geologic materials, it is inappropriate to discuss reclamation potential by facility, and more suitable to discuss reclamation potential by material type.

The features and properties of soil and geologic materials encountered across the property can be easily differentiated and summarized by color. Section 3.0 presents data as it was sampled, by facility. The discussion section (Section 4.0) will transition to discuss the reclamation potential of pertinent facilities by color coded material types, as it more useful for reclamation planning, design, and implementation.

3.1.1 South Borrow

Ten samples from three boreholes were analyzed from the South Borrow. Overall, field observations indicated that native soils in the South Borrow are relatively uniform, productive soils. The South Borrow is comprised of a small alluvial fan, with a slope alluvium and colluvium influence, exhibiting moderately deep soils with some deeper and shallower areas. Salinity, measured as electrical conductivity (EC), was slightly elevated in four samples, moderately elevated in three samples, and strongly elevated in one sample (above suitability threshold). The pH in one sample was slightly acidic. Two samples exhibited moderate elevations of sodium, measured as the Sodium Adsorption Ratio (SAR). Eight samples exhibited moderately

high proportions of sand, while two samples were very high in sand (above suitability threshold). Otherwise, all agronomic parameters of individual samples were within the suitability criteria.

Table 2 St. Anthony Mine - Soil and Geologic Materials Characterization

South Borrow

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	Paste pH	Paste EC mmhos/cm	Lime Estimate	% Organic Matter	ppm NO_3-N	ppm P	ppm K	ppm Zn	ppm Fe	ppm Mn	ppm Cu
R2608	BS-1	1	5	8.1	0.4	very high	1.3	0.35	1.89	128.20	1.43	3.14	1.08	4.97
R2609	BS-1	5	10	8.0	5.7	very high	0.8	1.10	3.24	98.96	0.22	7.88	1.80	1.29
R2610	BS-1	0	10	7.7	2.7	very high	0.9	3.90	1.68	107.20	0.83	3.52	2.06	2.89
R2611	BS-1	10	20	7.7	2.9	high	0.8	4.10	1.26	81.03	0.16	3.37	0.78	0.66
R2612	BS-1	20	21	6.5	3.5	low	0.7	0.51	1.51	64.30	0.53	22.98	1.38	1.86
R2613	BS-3	0	5	7.5	2.8	high	0.9	1.40	2.00	134.20	0.10	3.08	1.10	0.64
R2614	BS-3	5	10	7.6	3.2	high	0.7	1.70	2.01	81.88	0.09	3.19	1.40	0.73
R2615	BS-3	10	15	7.7	2.7	high	0.6	1.20	1.69	62.19	0.10	5.25	1.42	0.56
R2616	BS-6	0	10	7.9	1.0	high	0.8	0.32	1.68	114.70	0.07	3.31	1.43	0.50
R2618	BS-6	10	20	7.9	6.1	high	0.5	1.50	1.57	45.85	0.07	1.97	0.58	0.37

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L Ca	meq/L Mg	meq/L Na	meq/L K	SAR	% Sand	% Silt	% Clay	Texture
R2608	BS-1	1	5	3.0	0.7	1.3	0.2	1.62	60	22	18	Sandy Loam
R2609	BS-1	5	10	33.4	0.5	34.4	29.7	4.02	60	16	24	Sandy Clay Loam
R2610	BS-1	0	10	32.5	1.6	4.3	1.1	0.80	58	24	18	Sandy Loam
R2611	BS-1	10	20	29.5	1.0	5.5	2.6	0.98	60	18	22	Sandy Clay Loam
R2612	BS-1	20	21	25.8	1.5	8.7	4.2	1.41	74	8	18	Sandy Loam
R2613	BS-3	0	5	28.8	2.0	4.4	1.0	0.85	56	22	22	Sandy Clay Loam
R2614	BS-3	5	10	32.2	1.2	4.3	1.5	0.78	64	18	18	Sandy Loam
R2615	BS-3	10	15	30.1	0.7	5.4	1.6	0.96	68	16	16	Sandy Loam
R2616	BS-6	0	10	6.0	0.9	2.3	1.0	1.27	72	10	18	Sandy Loam
R2618	BS-6	10	20	40.1	0.5	32.1	18.5	3.75	62	20	18	Sandy Loam

*= Below Reporting Limits

+ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

+ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.2 West Borrow

Four bulk composite samples from four boreholes were analyzed from the West Borrow. Overall, it was noted that native soils in the West Borrow are relatively uniform, productive soils. The West Borrow is a large alluvial fan and fan plane, with very deep soils. Salinity was slightly elevated in two samples, and strongly elevated (above the suitability threshold) in one sample. Otherwise, all other agronomic parameters were within the suitability criteria. When averaged, assuming mixing will occur through excavation, transport, and placement/grading, all parameters are within the suitability criteria.

Table 3 St. Anthony Mine - Soil and Geologic Materials Characterization														
West Borrow														
				Paste				ppm						
Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	pH	EC mmhos/cm	Lime Estimate	% Organic Matter	NO_3-N	P	K	Zn	Fe	Mn	Cu
R2829	BW-1	0	35	8.0	7.3	very high	0.7	1.50	1.40	138.90	0.15	5.90	1.70	1.60
R2830	BW-2	0	20	8.3	2.0	very high	0.6	0.79	1.50	130.30	0.12	2.80	0.86	1.50
R2831	BW-3	0	15	8.4	1.1	very high	0.6	0.29	1.80	106.00	0.14	2.80	1.20	1.50
R2832	BW-4	0	20	7.9	3.5	medium	0.6	8.60	1.10	153.50	0.11	2.40	0.91	1.20
Average				8.1	3.5	very high	0.6	2.80	1.45	132.18	0.13	3.48	1.17	1.45

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L				SAR	%			Texture
				Ca	Mg	Na	K		Sand	Silt	Clay	
R2829	BW-1	0	35	3.1	0.2	2.8	4.7	0.80	49	20	31	Sandy Clay Loam
R2830	BW-2	0	20	4.6	1.2	6.1	7.6	1.50	42	28	30	Clay Loam
R2831	BW-3	0	15	2.4	0.9	3.8	3.3	1.40	40	27	33	Clay Loam
R2832	BW-4	0	20	27.4	2.4	7	3.4	1.00	49	22	29	Sandy Clay Loam
Average				9.4	1.2	4.9	4.8	1.18	45	24	31	Clay Loam

*= Below Reporting Limits

+ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

+ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.3 Lobo Tract Borrow

Seventeen samples from seven boreholes were analyzed from the Lobo Tract Borrow. Overall, observations note that native soils in the Lobo Tract Borrow are somewhat variable (salinity), productive soils. The Lobo Tract Borrow is located in a wide valley bottom flood plain. Flowing surface water was observed in the region, with evaporative salt deposits consistently lining the waterway, and along the flood bank of the alluvial features. Salinity was slightly elevated in eleven samples, and moderately elevated in two samples. One sample exhibited a moderate level of sodium, while three samples were slightly elevated. Five samples exhibited moderately high proportions of sand, while two samples were very high in sand (above the suitability threshold). Four samples were high in clay, while three samples were moderately high in clay. Otherwise, all other agronomic parameters were within the suitability criteria. When averaged, assuming mixing will occur through excavation, transport, and placement/grading), all parameters are within the suitability criteria.

Table 4 St. Anthony Mine - Soil and Geologic Materials Characterization
Lobo Tract Borrow

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	Paste pH	Paste EC mmhos/cm	Lime Estimate	% Organic Matter	ppm NO_3-N	ppm P	ppm K	ppm Zn	ppm Fe	ppm Mn	ppm Cu
R2593	L1-1	0	5	8.0	0.6	very high	1.0	4.60	7.12	99.26	1.09	4.03	2.88	1.86
R2597	L1-1	5	6	8.1	1.7	very high	1.3	1.80	1.78	262.30	0.35	12.49	2.53	4.73
R2594	L1-1	7.5	10	7.6	3.1	very high	0.9	4.50	3.56	125.20	0.19	4.28	0.38	2.56
R2595	L1-1	10	15	7.8	1.4	very high	0.8	8.50	2.75	119.20	0.29	4.07	0.53	1.72
R2596	L1-1	15	20	8.0	1.0	very high	0.7	8.00	2.36	80.77	0.20	4.70	0.51	3.40
R2591	L1-4	0	10	7.5	2.5	high	1.5	5.20	3.21	217.50	0.47	9.51	1.66	3.54
R2592	L1-4	13	20	7.7	2.4	high	0.2	2.20	4.36	31.42	0.67	4.81	0.38	3.67
R2598	L1-5	0	5	7.6	4.4	very high	1.0	3.80	1.59	249.40	0.27	8.71	0.59	3.33
R2599	L1-5	7.5	10	7.5	4.5	very high	1.2	18.80	2.56	274.60	0.45	9.69	0.47	3.88
R2600	L1-5	15	20	7.7	3.2	high	0.4	2.60	2.89	56.14	0.18	2.06	0.19	0.56
R2601	L2-1	0	20	7.7	5.0	very high	0.7	0.35	2.27	151.10	2.35	5.34	2.57	8.02
R2604	L2-5	0	10	7.5	3.5	high	1.2	12.00	2.25	330.70	2.27	8.61	3.55	7.73
R2605	L2-5	10	20	7.5	3.3	high	1.7	17.10	2.05	290.10	1.59	12.21	4.87	5.72
R2602	L2-6	7	10	7.6	5.1	very high	1.1	5.50	2.51	214.20	0.43	9.90	0.50	3.29
R2603	L2-6	11	13	7.6	3.9	very high	1.0	3.40	2.51	178.00	0.32	9.42	0.53	3.02
R2606	L2-7	0	10	7.6	2.9	very high	1.2	4.90	2.64	188.80	1.39	4.84	2.27	6.29
R2607	L2-7	10	20	7.7	3.6	very high	1.0	0.30	1.60	105.30	1.64	5.64	2.64	6.22
Average				7.7	3.1	very high	1.0	6.09	2.82	174.94	0.83	7.08	1.59	4.09

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L Ca	meq/L Mg	meq/L Na	meq/L K	SAR	% Sand	% Silt	% Clay	Texture
R2593	L1-1	0	5	0.3	0.0	0.1	0.0	0.33	64	18	18	Sandy Loam
R2597	L1-1	5	6	8.3	0.9	5.3	4.8	1.42	34	22	44	Clay
R2594	L1-1	7.5	10	22.6	0.9	6.4	5.0	1.20	46	22	32	Sandy Clay Loam
R2595	L1-1	10	15	9.1	0.5	2.9	4.0	0.88	48	20	32	Sandy Clay Loam
R2596	L1-1	15	20	5.5	0.3	2.0	3.4	0.77	60	19	21	Sandy Clay Loam
R2591	L1-4	0	10	127.0	6.1	48.7	56.3	3.58	32	30	38	Clay Loam
R2592	L1-4	13	20	36.4	3.9	15.7	7.9	3.34	84	10	6	Loamy Sand
R2598	L1-5	0	5	27.0	1.9	6.4	12.3	1.09	32	24	44	Clay
R2599	L1-5	7.5	10	27.0	1.5	5.8	13.8	1.00	16	28	56	Clay
R2600	L1-5	15	20	20.0	0.4	5.7	8.4	1.07	74	12	14	Sandy Loam
R2601	L2-1	0	20	30.4	2.0	18.6	16.9	2.64	62	20	18	Sandy Loam
R2604	L2-5	0	10	30.2	2.1	4.6	6.0	0.83	28	28	44	Clay
R2605	L2-5	10	20	25.3	1.6	5.0	8.8	0.92	24	22	54	Clay
R2602	L2-6	7	10	37.8	1.1	16.6	14.7	2.38	26	20	54	Clay
R2603	L2-6	11	13	21.6	0.6	7.2	10.8	1.24	14	22	64	Clay
R2606	L2-7	0	10	19.7	2.5	7.1	3.7	1.39	60	19	21	Sandy Clay Loam
R2607	L2-7	10	20	24.4	1.2	8.0	9.1	1.33	52	26	22	Sandy Clay Loam
Average				27.8	1.6	9.8	10.9	1.50	44	21	34	Clay Loam

*= Below Reporting Limits

+ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

+ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.4 Waste Piles 1, 2, 3, 4 and 7

Ten samples from nine boreholes were analyzed from Waste Piles 1, 2, 3, 4, and 7. Overall, it was noted that various geologic materials encountered between the piles were consistent, but with extensive variability within each pile. The piles contained a random mixture of saline sandstone, carbonaceous sandstone, shale, and coal. Significant yet variable coarse fragment contents were observed, ranging from gravels to boulders. Salinity was slightly elevated in two samples, moderately elevated in three samples, strongly elevated in two samples (above suitability threshold), and extremely elevated in one sample (specifically targeted for testing due to suspected high salt content). Four samples exhibited moderate levels of sodium, while one sample exhibited a moderately high level of sodium. Four samples exhibited moderately high proportions of sand, while four samples were very high in sand (above suitability threshold). One sample was slightly acidic, one sample was moderately acidic, and two samples were

extremely acidic. One Sample was high in clay. Otherwise, all other agronomic parameters were within the suitability criteria.

Table 5 St. Anthony Mine - Soil and Geologic Materials Characterization
Waste Piles 1, 2, 3, 4, and 7

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	Paste pH	Paste EC mmhos/cm	Lime Estimate	% Organic Matter	ppm NO_3-N	ppm P	ppm K	ppm Zn	ppm Fe	ppm Mn	ppm Cu
R2586	P1-2	60	65	4.2	9.8	low	1.2	0.08	2.93	88.38	6.36	187.20	32.90	3.92
R2587	P2-1	25	30	4.2	4.6	low	1.1	<0.1	4.14	136.80	2.29	153.30	15.69	4.99
R2590	P3-2	0	45	8.4	1.9	very high	0.4	3.70	3.46	52.50	0.90	6.01	1.00	1.27
R2588	P3-4	0	25	6.2	2.5	low	0.4	0.39	2.10	34.31	0.86	11.72	1.30	3.80
R2589	P3-4	35	40	5.8	4.1	low	0.7	<0.1	4.13	50.71	0.51	44.53	4.90	2.04
R2585	P4 (white sand)	0	1	8.2	42.1	low	0.8	60.40	1.43	94.48	0.32	5.15	0.20	0.77
R2833	P4-5	0	1	7.9	10.7	high	0.9	0.07	2.30	44.70	3.70	61.00	27.60	1.60
R2834	P4-7	0	1	6.9	1.3	low	0.2	0.30	1.60	66.70	0.23	6.70	4.10	0.42
R2835	P4-9	0	1	7.5	3.6	medium	0.4	<0.1	2.00	19.90	0.20	2.70	1.10	0.54
R2836	P7-1	0	1	7.6	4.8	high	0.4	0.07	1.00	68.50	0.16	5.00	0.97	1.00

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L Ca	meq/L Mg	meq/L Na	meq/L K	SAR	% Sand	% Silt	% Clay	Texture
R2586	P1-2	60	65	219.8	37.8	105.9	51.3	4.70	66	10	24	Sandy Clay Loam
R2587	P2-1	25	30	201.6	13.1	54.7	9.6	3.68	58	12	30	Sandy Clay Loam
R2590	P3-2	0	45	236.8	16.1	46.6	55.7	2.88	78	8	14	Sandy Loam
R2588	P3-4	0	25	249.5	33.6	81.5	65.0	4.17	76	10	14	Sandy Loam
R2589	P3-4	35	40	9.0	10.6	2.4	169.6	0.22	76	8	16	Sandy Loam
R2585	P4 (white sand)	0	1	18.3	7.1	84.5	451.8	3.96	76	10	14	Sandy Loam
R2833	P4-5	0	1	18.8	1.8	17.2	0.9	1.40	42	9	49	Clay
R2834	P4-7	0	1	6.1	2.0	1.8	5.2	0.50	55	29	16	Sandy Loam
R2835	P4-9	0	1	17.4	1.7	7.2	16.4	1.00	53	22	25	Sandy Clay Loam
R2836	P7-1	0	1	21.6	1.2	9.3	16.6	1.10	39	32	29	Clay Loam

Note: Averages Exclude Sample P4 (white sand)

*= Below Reporting Limits

+ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

+ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.5 North and South Topsoil Piles

One sample from one borehole was analyzed from the North Topsoil Pile. Overall, it was noted that the stockpiled native soils in the North Topsoil Pile were consistent, productive soils. The origin of the topsoil is unknown, but observations suggest that the North Topsoil Pile has not been visibly mixed with geologic materials, and is uniform. Sampling was constrained by the proximity of the North Topsoil Pile to the pit wall, and complicated by signs of cracking and instability adjacent to the North Topsoil Pile. Due to the small size of the North Topsoil Pile, a lone sample was deemed representative of the entire pile. The lone sample exhibited a high proportion of sand (above threshold values). Otherwise, all other agronomic parameters were within the suitability criteria.

Five samples from three boreholes were analyzed from the South Topsoil Pile. Overall, it was noted that soils in the South Topsoil Pile were extensively mixed with crushed, unweathered geologic materials. The origin of the material is unknown. Salinity was slightly elevated in two samples, moderately elevated in two samples, and strongly elevated in one sample (above suitability threshold). Three samples exhibited moderately high proportions of sand, while two samples were high in sand (above suitability threshold). One sample each was slightly acidic, moderately acidic, and strongly acidic. Otherwise, all other agronomic parameters were within the suitability criteria.

Table 6 St. Anthony Mine - Soil and Geologic Materials Characterization
North and South Topsoil Piles

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	Paste pH	Paste EC mmhos/cm	Lime Estimate	% Organic Matter	ppm NO_3-N	ppm P	ppm K	ppm Zn	ppm Fe	ppm Mn	ppm Cu
R2619	TN-2	0	25	8.0	1.0	high	0.8	17.90	1.58	98.18	0.07	2.13	0.64	0.59
R2620	TS-2	20	30	5.2	6.3	low	0.6	1.50	4.24	57.54	1.80	69.82	5.85	1.98
R2621	TS-3	0	10	6.9	3.5	low	1.0	0.40	1.59	147.20	1.09	5.80	2.15	3.26
R2622	TS-3	25	30	5.9	5.7	low	0.7	1.70	2.08	90.85	4.81	37.79	7.39	13.22
R2623	TS-4	0	10	7.1	3.8	high	0.6	0.28	1.61	87.64	1.53	5.08	1.88	4.79
R2624	TS-4	10	20	7.2	4.6	high	1.0	3.80	2.10	72.99	1.80	14.67	2.13	6.30

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L Ca	meq/L Mg	meq/L Na	meq/L K	SAR	% Sand	% Silt	% Clay	Texture
R2619	TN-2	0	25	4.9	0.8	3.1	1.6	1.62	72	12	16	Sandy Loam
R2620	TS-2	20	30	23.8	2.1	12.9	4.0	1.63	74	12	14	Sandy Loam
R2621	TS-3	0	10	27.6	2.6	6.5	6.0	1.14	62	16	22	Sandy Clay Loam
R2622	TS-3	25	30	22.3	2.0	11.9	7.1	1.61	68	6	26	Sandy Clay Loam
R2623	TS-4	0	10	25.1	1.3	8.3	5.7	1.37	70	8	22	Sandy Clay Loam
R2624	TS-4	10	20	26.6	1.6	9.4	7.0	1.51	68	11	21	Sandy Clay Loam

*= Below Reporting Limits

+ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

+ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.6 Topsoil / Overburden Pile

Twenty-seven samples from five boreholes were analyzed from the Topsoil/Overburden Pile. Overall, it was noted that soils in the Topsoil/Overburden Pile were somewhat variable, productive soils. Black shale fragments are consistently interspersed throughout the pile, along with precipitated gypsum ($CaSO_4$) crystals approximately 1-2 inches in length. Extensive erosion features, including piping, rills, and gullies were observed from the surface of the Topsoil/Overburden Pile. The origin of materials located within the Topsoil/Overburden Pile is unknown, but it is likely a mix of topsoil, alluvium, and slightly weathered shale. Salinity was slightly elevated in seventeen samples, and moderately elevated in ten samples. Thirteen samples exhibited moderately high proportions of sand, while one sample was high in sand (above suitability threshold). One sample was high in clay, while two samples were moderately high in clay. The Topsoil/Overburden Pile was somewhat well mixed, and average values should approximately represent on the ground conditions at any point across the pile.

Cedar Creek Associates, Inc.
5586 Overhill Dr. Fort Collins, Colorado 80526 (970) 223-0775

Table 7 St. Anthony Mine - Soil and Geologic Materials Characterization

Topsoil / Overburden Pile

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	Paste pH	Paste EC mmhos/cm	Lime Estimate	% Organic Matter	ppm NO_3-N	ppm P	ppm K	ppm Zn	ppm Fe	ppm Mn	ppm Cu
R2559	T/O-1	0	25	7.5	3.6	very high	0.8	6.00	1.86	134.50	0.31	10.03	2.36	1.70
R2560	T/O-1	25	50	7.4	3.8	very high	0.7	6.30	1.69	145.60	0.45	14.50	3.09	1.90
R2561	T/O-1	70	90	7.8	2.7	very high	0.8	3.00	2.19	109.10	1.45	4.36	1.94	6.49
R2576	T/O-2	0	20	7.8	4.6	very high	0.7	4.80	1.53	215.60	0.18	13.12	3.83	2.14
R2625	T/O (shale)	-	-	7.6	3.2	high	1.0	2.50	0.86	218.50	0.12	5.34	0.79	0.91
R2562	T/O-3	0	5	7.7	3.6	very high	0.8	0.42	2.23	109.90	0.19	4.14	0.54	1.23
R2563	T/O-3	5	10	7.6	3.9	very high	0.6	4.70	1.64	125.00	0.18	4.94	0.49	1.25
R2564	T/O-3	10	15	7.6	4.0	very high	0.7	6.00	1.18	107.10	0.19	6.76	0.42	1.68
R2565	T/O-3	15	20	7.6	4.0	very high	0.8	9.60	1.94	135.00	0.30	8.62	0.83	1.19
R2566	T/O-3	20	25	7.7	2.4	high	0.8	3.20	2.38	118.90	0.15	6.08	0.83	1.35
R2567	T/O-3	25	30	7.8	3.2	high	0.8	3.20	2.06	85.70	0.18	3.27	0.30	1.66
R2568	T/O-3	30	35	7.6	3.5	very high	0.7	4.90	1.53	117.80	0.23	10.08	2.10	1.38
R2569	T/O-3	35	40	7.7	4.0	very high	0.7	5.80	1.79	112.90	3.60	9.76	1.54	1.48
R2570	T/O-3	40	45	7.6	3.6	very high	0.9	7.10	0.74	115.40	0.56	11.59	2.69	4.76
R2571	T/O-3	50	55	7.8	4.1	very high	0.7	9.20	2.30	117.90	0.23	10.69	1.20	2.05
R2572	T/O-3	55	60	7.7	4.6	very high	0.7	9.40	1.48	123.90	0.29	8.48	1.43	1.49
R2573	T/O-3	65	70	7.8	4.6	very high	0.7	1.30	1.74	115.00	0.19	29.15	5.03	1.79
R2574	T/O-3	70	75	7.7	3.8	high	0.7	4.70	1.62	108.70	0.19	15.45	2.12	0.90
R2575	T/O-3	75	80	8.0	2.1	high	0.7	30.50	2.95	131.70	0.18	14.33	1.08	1.41
R2577	T/O-4	0	10	7.7	2.7	very high	0.8	3.60	1.51	168.70	0.20	10.11	2.88	1.13
R2578	T/O-4	30	40	7.8	4.1	very high	0.8	8.60	1.88	148.40	1.16	8.99	2.93	5.22
R2579	T/O-5	0	5	7.8	4.0	high	0.7	7.50	2.30	101.20	0.10	2.91	0.49	0.87
R2580	T/O-5	5	10	7.8	3.7	high	0.7	13.50	2.53	102.50	0.13	3.81	0.67	0.61
R2581	T/O-5	10	15	7.8	4.1	high	0.7	4.20	2.56	112.30	0.15	4.53	0.46	1.16
R2582	T/O-5	15	20	7.9	3.9	very high	0.6	4.70	2.06	104.90	0.20	6.65	1.24	2.88
R2583	T/O-5	20	25	7.8	2.8	very high	0.7	3.90	2.99	101.10	0.11	5.41	0.68	1.23
R2584	T/O-5	25	29	7.9	3.7	very high	0.9	7.40	2.11	118.50	0.28	9.58	1.15	2.19
Average				7.7	3.6	very high	0.7	6.52	1.91	126.14	0.43	8.99	1.60	1.93

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L Ca	meq/L Mg	meq/L Na	meq/L K	SAR	% Sand	% Silt	% Clay	Texture
R2559	T/O-1	0	25	25.0	13.3	7.9	0.6	1.80	36	34	30	Clay Loam
R2560	T/O-1	25	50	24.6	13.4	9.0	0.6	2.07	40	30	30	Clay Loam
R2561	T/O-1	70	90	12.5	12.4	6.7	0.4	1.90	60	20	21	Sandy Clay Loam
R2576	T/O-2	0	20	27.3	2.1	8.5	9.4	1.32	36	24	40	Clay
R2625	T/O (shale)	0	1	28.7	1.8	4.8	0.4	0.90	16	34	50	Clay
R2562	T/O-3	0	5	24.6	0.9	7.0	7.7	1.20	52	26	22	Sandy Clay Loam
R2563	T/O-3	5	10	24.9	0.9	8.0	8.4	1.33	46	24	30	Sandy Clay Loam
R2564	T/O-3	10	15	25.9	1.1	8.2	9.8	1.34	34	30	36	Clay Loam
R2565	T/O-3	15	20	25.9	1.2	7.9	7.5	1.32	44	26	30	Clay Loam
R2566	T/O-3	20	25	11.8	0.8	5.8	6.7	1.38	58	20	22	Sandy Clay Loam
R2567	T/O-3	25	30	18.0	0.6	7.9	9.8	1.42	56	20	24	Sandy Clay Loam
R2568	T/O-3	30	35	26.4	1.4	7.7	9.2	1.28	40	28	32	Clay Loam
R2569	T/O-3	35	40	25.4	1.2	8.0	9.3	1.32	42	28	30	Clay Loam
R2570	T/O-3	40	45	25.3	1.6	7.9	8.3	1.31	36	30	34	Clay Loam
R2571	T/O-3	50	55	23.1	1.5	8.8	7.0	1.46	64	12	24	Sandy Clay Loam
R2572	T/O-3	55	60	29.8	1.4	8.5	8.1	1.33	48	24	28	Sandy Clay Loam
R2573	T/O-3	65	70	27.3	1.7	8.5	10.3	1.32	48	26	26	Sandy Clay Loam
R2574	T/O-3	70	75	23.6	1.2	7.9	6.8	1.35	54	24	22	Sandy Clay Loam
R2575	T/O-3	75	80	14.1	2.1	4.5	1.4	1.31	70	18	12	Sandy Loam
R2577	T/O-4	0	10	26.2	4.7	8.2	10.8	1.29	32	28	40	Clay
R2578	T/O-4	30	40	24.8	1.8	8.3	6.8	1.37	58	20	22	Sandy Clay Loam
R2579	T/O-5	0	5	25.0	1.5	8.3	9.1	1.36	56	20	24	Sandy Clay Loam
R2580	T/O-5	5	10	21.9	3.1	8.1	6.7	1.44	64	16	21	Sandy Clay Loam
R2581	T/O-5	10	15	25.3	1.3	9.0	8.6	1.42	60	16	24	Sandy Clay Loam
R2582	T/O-5	15	20	22.7	1.2	8.6	7.3	1.43	58	20	22	Sandy Clay Loam
R2583	T/O-5	20	25	24.0	0.7	7.7	7.8	1.32	64	12	24	Sandy Clay Loam
R2584	T/O-5	25	29	25.6	1.4	7.2	6.1	1.28	60	20	21	Sandy Clay Loam
Average				23.7	2.8	7.7	6.8	1.39	49	23	27	Sandy Clay Loam

*= Below Reporting Limits

+ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

+ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.2 Additional Soil-Vegetation System Observations

Both disturbed and undisturbed areas within the project area were observed, specifically to obtain information on locally successful vegetation species and the corresponding edaphic systems.

3.2.1 Disturbed Soil Systems

The extent to which disturbed systems were supporting vegetation (both seeded and volunteer) varied greatly across the project area. Areas with visible salt deposits and salt crusts (such as several Waste Piles) were supporting little to no vegetation. Areas with approximately 6 to 8 inches of disturbed topsoil overlying visibly salty geologic materials supported diminutive and sparse vegetation.

Slope angle largely influenced vegetation. Because of how the dump facilities were constructed, materials are either generally flat to gently sloping or approaching angle of repose. Little to no vegetation was observed growing on angle of repose slopes, even when materials seemed suitable for use in reclamation (topsoil/alluvial materials). Only on flat areas (less than 10% slopes) were suitable patches of vegetation observed.

3.2.2 Native (Undisturbed) Soil Systems

Native soils in the region vary greatly, particularly in depth and age. Deeper and older alluvial soils in the main drainage channels and alluvial fans are not particularly useful when attempting to estimate the required depth of cover materials on reclamation and were excluded. Therefore, small pockets of residually weathering topsoil with shaley and sandy geologic parent materials were targeted as a proxy to estimate cover requirements.

Native systems observed supporting vegetation sufficient to minimize erosion ranged in depth from 1-4 feet. Vegetation was noticeably diminished in areas with 12-18 inch topsoil depths and mostly productive in areas with topsoil greater than 2 feet. Deeply incised rills and gullies were visible in these native areas, even on relatively shallow slopes (less than 20%) with no topographic variation to concentrate overland flow; demonstrating the high potential for erosion in local soil and geologic systems.

4.0 Technical Discussion

4.1 General Overview

Soils in the project area generally have elevated levels of salt and high proportions of sand. Targeted sampling of unique or unadulterated geologic materials (such as Sample R2585 - Table 5; EC=42.1) provides the bounds for which conditions could be encountered within the reclaimed system. Material types (and corresponding suitability as a top/sub soil) have distinctive colors in the field:

- Brown materials (soils and alluviums) are typically slightly saline and have some potential to exhibit textural extremes, but are most often within all suitability criteria. These materials are most suited to serve as a reclamation planting media.
- White materials (weathered or crushed sandstone) are typically very saline, and inappropriate for use as a rooting media. These materials should be buried if possible (a minimum of 4 feet), to avoid the upward mobilization of soluble salts and contamination of overlying rooting media.
- Grey materials (shale and weathered carbonaceous sand, silt, and clay stone) are typically slightly to moderately elevated in salts, occasionally display low pH's, and exhibit high

erosivity. These materials should be avoided for use as a planting media, but will act sufficiently as a subsoil rooting media.

- Black materials (coal, shale, and carbonaceous sandstone) are typically elevated in salts, exhibit unsuitably low pH's for native arid western vegetation, and are moderately to highly erosive. These materials should be avoided for use as a planting media, but will act sufficiently as a subsoil rooting media.

Reclamation will be challenging, and a variety of best management practices should be implemented to ensure reclamation success. Observations suggest that at a minimum, 2 feet of suitable cover material should be utilized for reclamation, preferably deeper (especially if reclaiming the white saline sandstone encountered within Waste Piles 1, 2, 3, 4, and 7). Observations also suggest that best management practices will need to be used to control erosion, even on shallow slopes.

4.2 Findings from Field and Laboratory Analysis

4.2.1 Waste Piles 1, 2, 3, 4, and 7

Field observations indicated that these Waste Piles consist of large quantities of saline sandstone (white materials), shale, coal, and carbonaceous sandstone (black materials), and shale (grey materials). Laboratory results from Waste Piles 1, 2, 3, 4, and 7 demonstrated that these piles are comprised of materials that exhibit unsuitable subsoil / rooting media conditions. The potential for moderate to exceptionally high salinity, and slight to extreme acidity is possible.

Sodium levels have the potential to be elevated. Samples from this sampling effort suggest that sodium elevations correspond with elevated salinity, balancing the salt to sodium ratio and diminishing the negative effects of sodium presence. Agronomic samples from the 2007 MWH Materials Characterization Report exhibited SAR values up to 19.1 in Non-Economical Material Storage Areas, Shaft Area Ponds, and Mine Dump and Shaft Pads.

Sampling results from 2018 characterization efforts indicate that the upper and middle portions of these piles are not suitable growth media; Yet drilling logs from previous sampling efforts indicate that brown alluvial materials or soils may comprise the lower portions of Pile 4 (although no sampling was conducted to these depths during the 2018 efforts). The lower portions of Pile 4 may be suitable for use as a reclamation growth media or for direct revegetation, but sampling should be conducted if the lower portions of Pile 4 are to be used as a revegetation planting media.

4.2.2 South Topsoil Pile

The South Topsoil Pile is comprised more of crushed carbonaceous sandstone (black materials) and shale (black and grey materials), than topsoil (brown materials). This Pile exhibited laboratory results approaching thresholds for salinity, along with slightly to strongly acidic pH's, in addition to high proportions of sand (relative to other potential Borrow Areas). This pile should be considered the least desirable of the identified potential sources for use as a reclamation planting media. It would be suitable for use as a rooting media.

4.2.3 Topsoil / Overburden Pile

The Topsoil/Overburden Pile is likely comprised of mostly topsoil, but with a considerable shale component (grey and black materials) mixed throughout, with occasional concentrated pockets of weathering shale. Laboratory testing parameters were comparable to other potential sources of growth media, yet extensive erosion features were observed on the pile (8-10 foot deep gullies). This is likely due

to the poor consolidation and the erosive nature of the shale material. This pile would be more suited for use on flatter reclamation surfaces (less than 10% slopes) or as a subsoil.

4.2.4 Borrow South, Borrow West, Lobo Tract Borrow, and North Topsoil Pile

Borrow South, Borrow West, Lobo Tract Borrow, and North Topsoil Pile can all be considered comparable in quality for use as a reclamation growth media. Each Pile exhibits at least one or more samples with elevated salinity or sand content, but when averaged are suitable for use as a cover material / planting material. Averaging of laboratory values are applicable for these locations, because they are predominantly undisturbed systems that can be definitively characterized, and will be significantly mixed through salvage, transportation, final placement, and grading.

4.3 Addressing Reclamation Challenges

4.3.1 Erosion

The erosive nature of locally available growth media, due to elevated sand content, will require best management practices to stabilize the reclamation surface. The proportion of sand found in most soils across the project area will result in poorly structured and non-cohesive soils, especially following disturbance from earth moving and reclamation activities. In addition to direct erosion control measures (i.e., mulching, hydro-seeding, wood chip waddles, etc.), an effort should be made to adjust slope length and minimize steepness wherever possible. By considering the erosive nature of available materials, conservative planning and design will increase the likelihood of a favorable reclamation outcome on the project.

4.3.2 Salinity

The moderate salinity consistently found throughout local soils will exacerbate drought stress, particularly during the critical period of germination and establishment. There is no impact threshold with salinity; impacts exist on a continuum, meaning any increase in salinity is a direct increase is plant-water stress. Deeper soil systems have the potential to capture and store more plant available water, increasing the likelihood of a successful reclamation effort.

Relatively deeper soils will also limit the upward migration of soluble salts from underlying salty and acidic geologic materials, such as the white sandstone, black coal, and grey shale. Erosion control efforts, such as mulching, contouring, waddles, etc., will provide additional benefits in mitigating salinity by aiding in soil moisture retention through limiting surface evaporation and facilitating greater infiltration.

4.3.3 Acidity

The slight to extreme acidic conditions (in black and dark grey materials) encountered on Borrow South, South Topsoil Pile, and Piles 1, 2, and 3, are challenging to overcome in arid rangeland reclamation systems. Native arid western vegetation is not adapted for acidic soil conditions and will likely result in diminutive vegetation or a lack of germination. Acidity was localized to areas with black materials (coals, shales, and carbonaceous sandstones). The degree and extent of acidity can be managed by ensuring any black materials are buried at least 2 feet below adequate cover materials, or excluded from salvage.

5.0 Summary

Local soils and site conditions present significant hurdles to overcome when considering reclamation planning and design. Industry best management practices and conservative reclamation planning will be crucial when attempting to establish vegetation and stabilize reclaimed slopes. Any adversity in climatic conditions will exacerbate these challenges. Expectations for reclamation timelines and overall potential should be tempered, as even favorable weather coupled with conservative best management practices may likely be insufficient to ensure site-wide reclamation success. Reseeding and regrading of erosive areas will likely be required at some point during the liability period.

Table 8 provides a ranking of the relative suitability of Borrow Areas for use as growth media, the recommended minimum thickness, and the soil and geologic material types noted in each location.

Table 8 St. Anthony Mine - Materials Characterization - 2018

Growth Media Borrow Source Summary

Potential Growth Media Borrow Source	Rank by Preference	Placement Suitability	Recommended Minimum Thickness	Material Types Observed
North Topsoil Pile	1	Cover / Planting Media	24 inches	Topsoil
West Borrow	2	Cover / Planting Media	24 inches	Topsoil Alluvium
Lobo Tract	3	Cover / Planting Media	24 inches	Topsoil Alluvium
Borrow South	4	Cover / Planting Media	24 inches	Topsoil Alluvium
Topsoil / Overburden Pile	5	Cover / Planting Media (on < 10% slopes) Subsoil / Rooting Media	24-36 inches	Topsoil Alluvium Shale Coal Gypsum Precipitates
South Topsoil Pile	6	Subsoil / Rooting Media	N / A	Topsoil Alluvium White Saline Sandstone Black Carbonaceous Sandstones Shale Coal

The information gathered through field efforts and laboratory testing will be utilized to update the existing reclamation plan to reflect site conditions and developing site-specific strategies for achieving successful revegetation and slope stabilization.

6.0 References

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