MWH®

APPENDIX D

CEDAR CREEK ASSOCIATES, INC. REPORTS

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APPENDIX D1

VEGETATION CHARACTERIZATION AND BIOINTRUSION SURVEY

CEDAR CREEK ASSOCIATES, INC.

United Nuclear Corporation

Vegetation Characterization
and Biointrusion Surveys

<u>CHURCH ROCK MILL SITE</u>

JULY, 2014

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United Nuclear Corporation (UNC)

Church Rock Mill Site

VEGETATION CHARACTERIZATION AND BIOINTRUSION SURVEYS

1.0 INTRODUCTION

Cedar Creek Associates, Inc. (Cedar Creek) was contracted in 2013 to implement vegetation and bio-intrusion surveys in support of the proposed repository for United Nuclear Corporation's (UNC) Church Rock Mill Site (Mill Site). Analog sites were selected to provide an opportunity to quantitatively evaluate specific parameters of the successional communities expected to progressively inhabit the repository through the regulated 1,000 year timeline. For each projected community (ecological scenario), vegetation and biointrusion (both plant and animal) surveys were conducted October 19th-23rd 2013 by or under the direct supervision of Cedar Creek Ecologist (and Project Manager) Mr. Jesse H. Dillon.

Projected vegetative communities that are expected to inhabit the repository during the 1,000 year timeline were characterized by field sampling. Vegetation sampling procedures included metrics for (1) ground cover (canopy cover), (2) species richness or diversity, (3) vegetative production (biomass) and (4) woody plant density. Ground cover results were analyzed to present Leaf Area Index (LAI) for each projected community. Vegetative root density and depth were characterized through field sampling using excavated soil pits and were verified through literature research. Animal biointrusion evaluation determined the presence of burrowing animals and the potential for future colonization of the proposed repository, based on the local populations' existing habitat and the various scenarios for long-term vegetated cover and communities. Animal biointrusion sampling occurred as small mammal trapping and incidental wildlife observation transects.

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2.0 VEGETATION COMMUNITIES

Five vegetation communities exist in the vicinity of the Mill Site (Map 1).

Reclaimed	A previously disturbed ecosystem which has been revegetated through either natural or anthropogenic means.
Grassland	A native ecosystem which is characterized by deep soils and is physiognomically dominated by grasses.
Shrubland	A native ecosystem which is characterized by deep soils and is physiognomically dominated by shrubs.
Piñon Juniper	A native ecosystem which is characterized by thin soils and is physiognomically dominated by trees.
Disturbed Bottomland	A bottomland ecosystem which is characterized by deep soils and riparian vegetation. Riparian vegetation has elevated water requirements which are typically met with a water table close to the surface.

Through literature review, field investigation, and analysis, Cedar Creek has identified the following three vegetation communities that are projected to colonize the repository over the next 1,000 years: reclaimed (early-successional), grassland (mid-successional), and shrubland (late-successional or climax community). The Piñon Juniper community, which prefers thin soils, was eliminated as a potential ecological scenario on the repository because the soils profile (as currently proposed) can be considered a deep soil. The Disturbed Bottomland community was eliminated as a potential ecological scenario on the repository because of the elevated water requirement of the vegetation. The repository will be designed to shed any water that falls directly onto it, and with diversion channels to divert any water that flows toward it.

Though specific timeframes are very difficult to predict and are often affected by environmental conditions such as climate, and land management activities such as grazing, the projected communities are expected to inhabit the repository for the following timeframes:

- Reclaimed: 0 - 50 Years
- Grassland: 25 - 100 Years
- Shrubland: 50 - 1,000 Years

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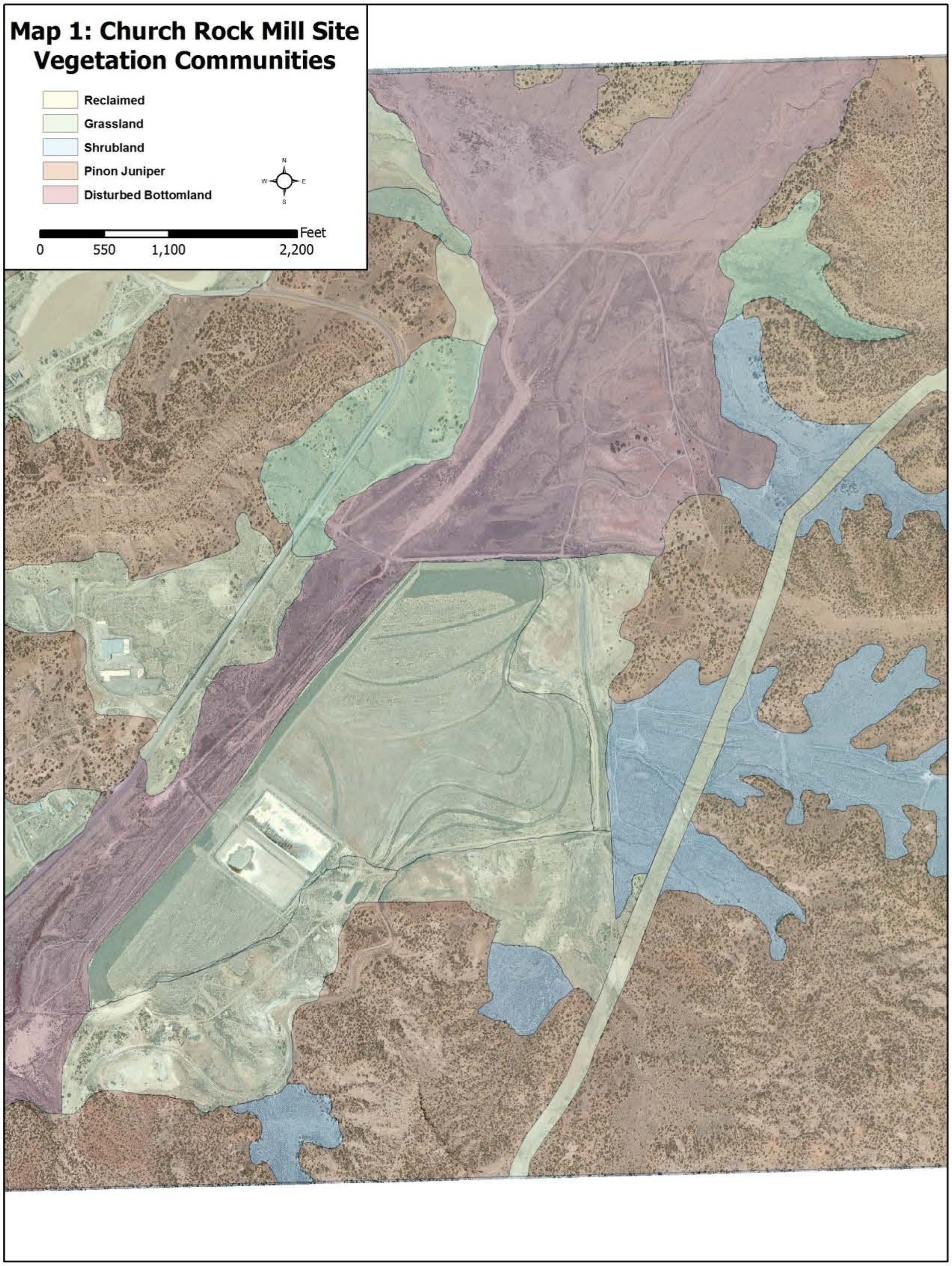
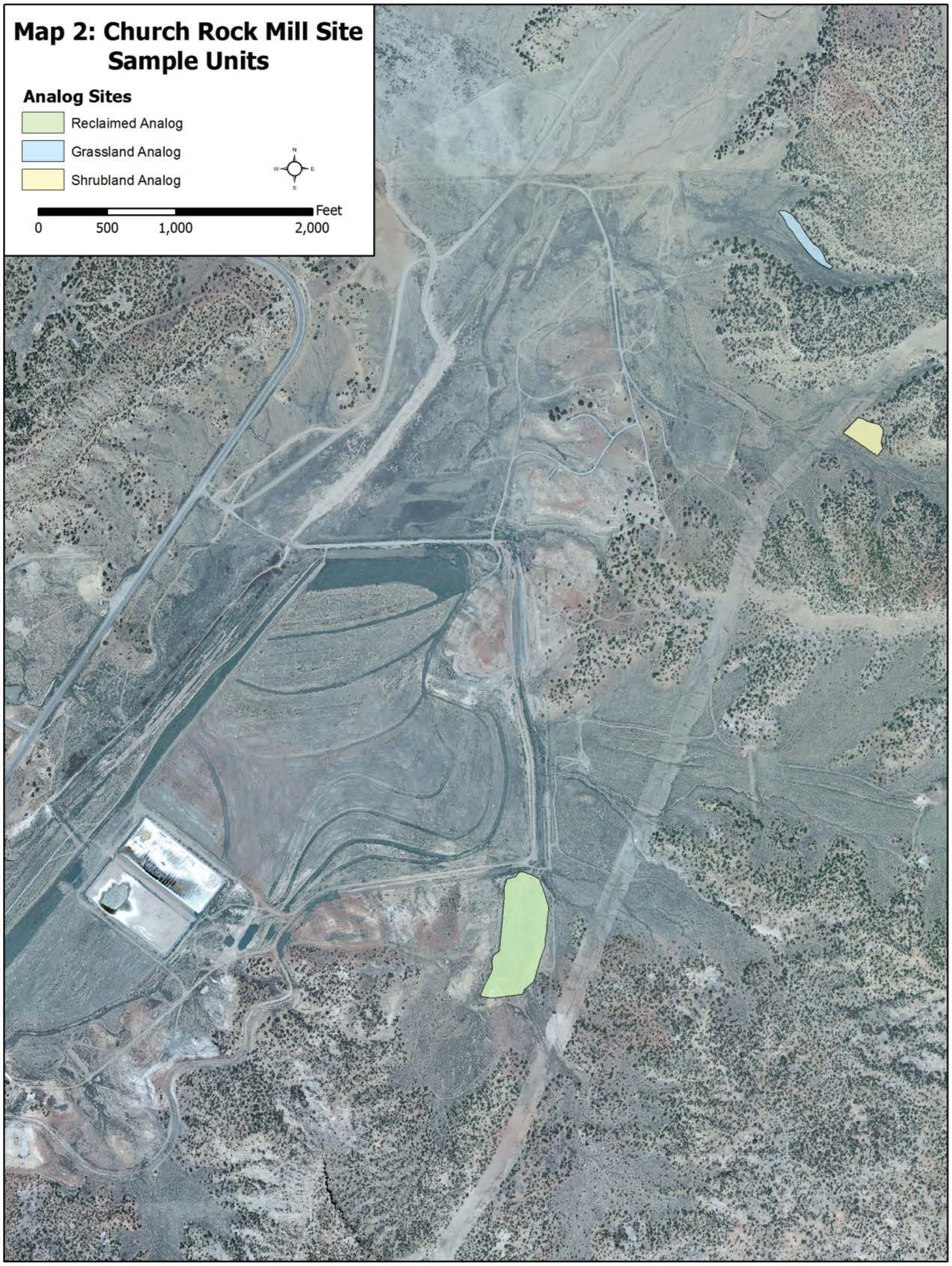
Analog Area Selection

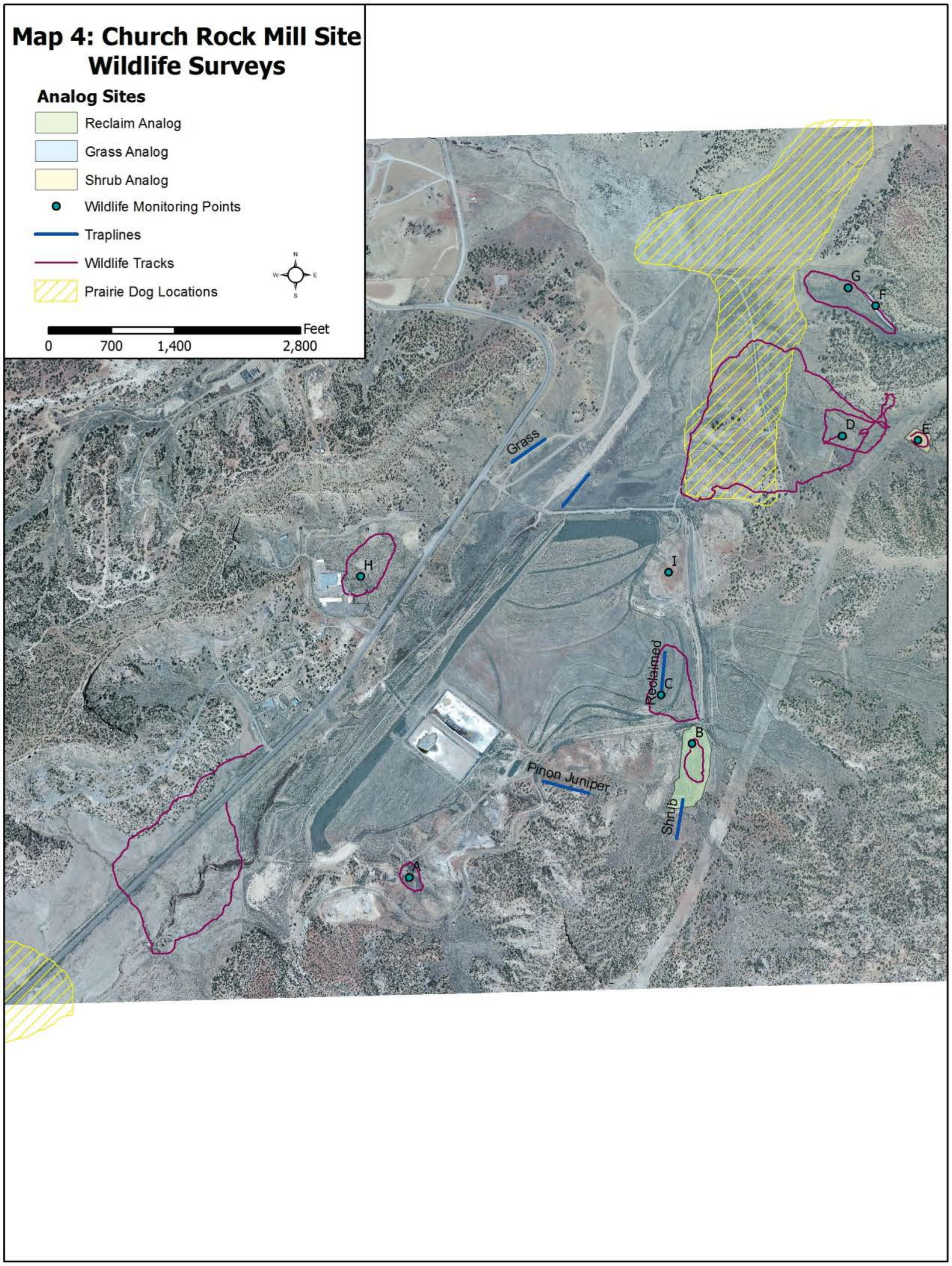
The grassland and shrubland analog area(s) to be used to characterize ecological scenarios for the repository cap will be selected from undisturbed areas in the vicinity of the project area. Preferred analog areas can be characterized as "ecologically and topographically similar" to the eventual rehabilitated landform and are based on three main considerations, as follows:

1. The analog area(s) is representative vegetation communities projected to inhabit the cap.
2. The analog area(s) occupy topography and aspects that are representative of the majority of reclaimed areas.
3. The analog area(s) exhibit similar physical soil conditions as reclaimed areas and therefore, should be an "approximate ecological equivalent".


Map 1: Church Rock Mill Site
Vegetation Communities
Reclaimed
Grassland
Shrubland
Pinon Juniper
Disturbed Bottomland
N
W
E
S
Feet
0
550
1,100
2,200


Map 2: Church Rock Mill Site
Sample Units
Analog Sites
Reclaimed Analog
Grassland Analog
Shrubland Analog
Feet
0
500
1,000
2,000


Map 3: Church Rock Mill Site
Soil Excavation Pits
Analog Sites
Reclaimed Analog
Grassland Analog
Shrubland Analog
Soil Excavations
Feet
0
500
1,000
2,000
1
2
2
1
2
1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Reclaim Analog
Grass Analog
Shrub Analog
Wildlife Monitoring Points
Traplines
Wildlife Tracks
Prairie Dog Locations
Feet
0
700
1,400
2,800
Grass
Reclaimed
Pinon Juniper
Shrub
A
B
C
D
E
F
G
H
I

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2.1 Reclaimed Community

The reclaimed community was characterized by sampling the Reclaimed Analog site. This site is located in a previous borrow source, that has been disturbed and was reclaimed, either naturally or anthropogenically, approximately twenty years ago (Map 2). The vegetation and biointrusion survey results are presented below. Discussions on all results can be found in Section 3.

2.1.1 Vegetation Survey Results

Vegetation was evaluated in the Reclaimed Analog using 15 co-located ground cover, production (current annual biomass), and woody plant density belts. Vegetation sampling results are presented on Table 1 with the raw data presented in the Baseline report (Cedar Creek, 2014). In general, the reclaimed community is characterized by early/mid seral species. This community displays the highest cover, production, species diversity, and woody plant density of the three projected communities. Bareground exposure, litter, and rock cover were 27.9%, 25.1%, and 1.2%, respectively.

Table 1 - Vegetation Parameters

Reclaimed Community

Ground Cover by Lifeform			
Grass	Forb	Shrub/Tree	**Total**
17.8%	12.6%	17.3%	**47.7%**
Ground Cover by Habit			
Perennial	Annual	Noxious	**Total**
36.6%	11.1%	0.0%	**47.7%**
Species Diversity			
Perennial	Annual	Noxious	**Total**
9	6	0	**15**
Dominant Species			
Artriplex canescens	16.9%		
Sporobolus cryptandrus	6.4%		
Achnatherum hymenoides	5.7%		
Symphyotrichum falcatum	4.2%		

Production by Lifeform (lbs per acre)		
Grass	Forb	Shrub/Tree
422.8	38.8	186.2
Total = 647.7 lbs per acre		
Production by Habit (lbs per acre)		
Perennial	Annual	Noxious
422.8	38.8	186.2
Total = 647.7 lbs per acre		
Woody Plant Density (stems per acre)		
Shrub	Succulent	Tree
2,061	0	0
Total = 2,061 stems per acre		

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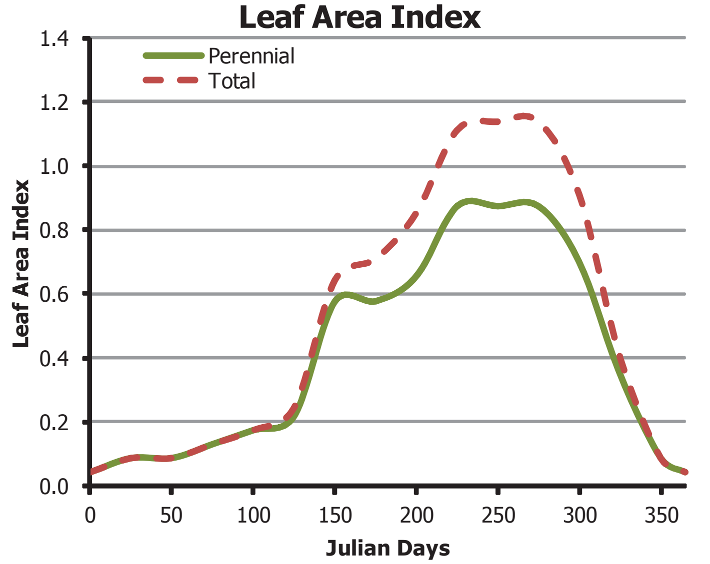
2.1.2 Leaf Area Index Results

Leaf area index was characterized with an indirect approach, using vegetative ground cover as a basis. Since surveys were conducted October 19th-23rd, leaf area index was quantified when approximately 80% of the peak potential. Results are presented on Table 2 and Chart 1. Data were extrapolated throughout the Julian calendar to account for plant dynamics.

Table 2 - Leaf Area Index

Reclaimed Community				Leaf Area Index
Grasses	Perennial	Native	Cool-Season	0.18
			Warm-Season	0.12
		Introduced		-
	Annual			0.13
Forbs	Perennial	Native		0.07
		Introduced		-
	Annual & Biennial Native & Introduced			0.08
Sub-shrubs				-
Shrubs				0.33
Total LAI				0.91
Perennial LAI				0.70

Chart 1 - Reclaimed Community Leaf Area Index



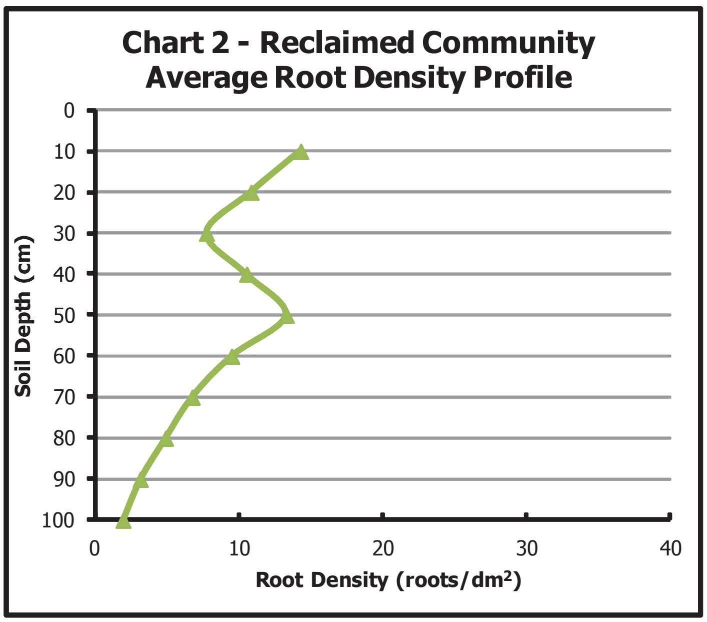
2.1.3 Biointrusion Results

Plant

Two soil pits were excavated to a depth of approximately 5 feet to evaluate root density in the reclaimed community (Map 3). Average results are presented on Table 1 and Chart 1. Root density was highest at the soil surface with a density of 14.3 roots/dm^2, and generally decreased with depth to 1.95 roots/dm^2 at 100cm depth, except for a slight increase between 30-50 cm depth. This increase is due to both physical restriction of the roots and perching of the water table on top of a carbonate accumulation horizon, stimulating opportunistic root growth. The upper 0.4 meters of the soil profile contained 50% of the roots. Roots were observed to 58 inches depth, but were very fine and few in number below a depth of 80 cm. No shrub taproots were observed to a depth greater than or near the bottom of the pit.

Table 3 Reclaimed Community Summary

Depth Interval (cm)	Average root density (roots/dm^2)	Average of Total Roots (%)	Cumulative Average Root Density (%)
0 - 10	14.3	18.91	18.91
10 - 20	10.85	12.22	31.13
20 - 30	7.75	7.99	39.12
30 - 40	10.55	12.62	51.75
40 - 50	13.3	16.06	67.80
50 - 60	9.5	11.44	79.24
60 - 70	6.75	8.50	87.74
70 - 80	4.9	6.23	93.98
80 - 90	3.15	3.67	97.65
90 - 100	1.95	2.35	100.00



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Animal

Trapping associated with the reclaimed community was conducted on the revegetated tailings facility to maximize the efficiency of the data (Map 4). Trapping located closer to the proposed location of the repository provides more accurate data for the small mammal potential on the repository while still representing the reclaimed community. As indicated on Table 4, trapping in the reclaimed community yielded 0 captures.

Table 4 - NECR - Wildlife Surveys

Small Mammal Trapping Results - Fall 2013

Surveys Occurred from 10/21/13 to 10/23/13

Sample Area (Plot No.)	Captures			
	DAY 1	DAY 2	DAY 3	TOTAL
Revegetated Tailings (Reclaimed)	0	0	0	0

2.2 Grassland Community

The grassland community was characterized by sampling the Grassland Analog site. This site is located immediately adjacent to the North Drainage Borrow (Map 2). The vegetation and biointrusion survey results are presented below. Discussions on all results can be found in Section 3.

2.2.1 Vegetation Survey Results

Vegetation was evaluated in the Grassland Analog using 15 co-located ground cover, production (current annual biomass), and woody plant density belts. Vegetation sampling results are presented on Table 5 and the raw data is presented in the Baseline report (Cedar Creek, 2014). In general, the Grassland community is characterized by mid/late seral species. This community displays the middle cover, production, and species diversity, and the lowest woody plant density of the projected communities. Bareground exposure, litter, and rock cover were 32.9%, 25.3%, and 6.7%, respectively.

Table 5 - Vegetation Parameters

Grassland Community

Ground Cover by Lifeform			
Grass	Forb	Shrub/Tree	**Total**
25.7%	3.4%	6.1%	**35.1%**
Ground Cover by Habit			
Perennial	Annual	Noxious	**Total**
31.7%	3.4%	0.0%	**35.1%**
Species Diversity			
Perennial	Annual	Noxious	**Total**
10	4	0	**14**
Dominant Species			
Bouteloua gracilis		24.5%	
Gutierrezia sarothrae		4.4%	
Salsola tragus		2.9%	
Chrysothamnus nauseosus		1.3%	

Production by Lifeform (lbs per acre)		
Grass	Forb	Shrub/Tree
288.5	6.0	57.3
Total = 351.8 lbs per acre		
Production by Habit (lbs per acre)		
Perennial	Annual	Noxious
345.8	6.0	0.0
Total = 351.8 lbs per acre		
Woody Plant Density (stems per acre)		
Shrub	Succulent	Tree
120	0	2
Total = 122 stems per acre		

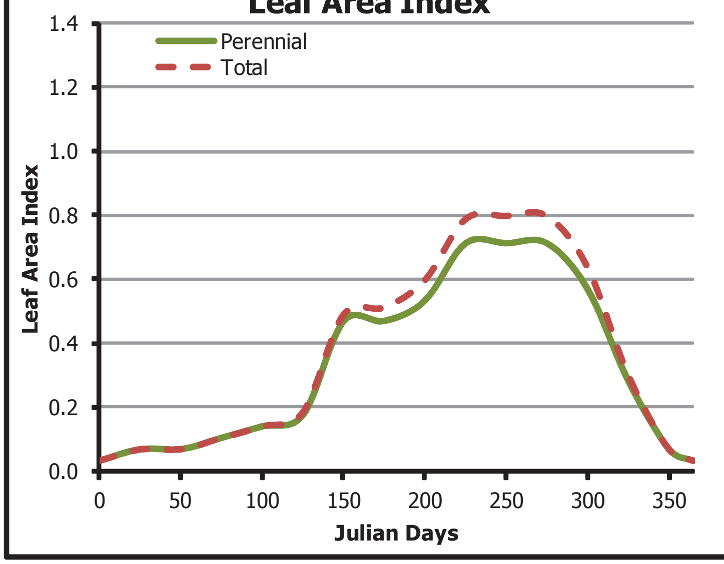
2.2.2 Leaf Area Index Results

Leaf area index was characterized with an indirect approach, using vegetative ground cover as a basis. Since surveys were conducted October 19th-23rd, leaf area index was quantified when approximately 80% of the peak potential. Results are presented on Table 6 and Chart 3. Data were extrapolated throughout the Julian calendar to account for plant dynamics.

Table 6 Leaf Area Index

Grassland Community				Leaf Area Index
Grasses	Perennial	Native	Cool-Season	0.00
			Warm-Season	0.44
		Introduced		-
	Annual			-
Forbs	Perennial	Native		-
		Introduced		-
	Annual & Biennial Native & Introduced			0.07
Sub-shrubs				0.10
Shrubs				0.03
Total LAI				0.64
Perennial LAI				0.57

Chart 3 - Grassland Community Leaf Area Index



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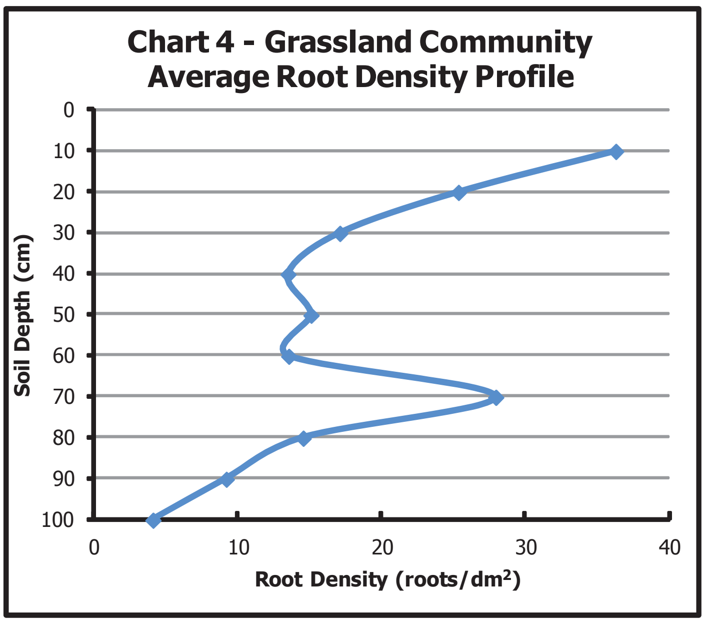
2.2.3 Biointrusion Results

Plant

Two soil pits were excavated to a depth of approximately 5 feet, to evaluate root density in the grassland community (Map 3). Average results are presented on Table 7 and Chart 4. Root density was highest at the soil surface with 36.25 roots/dm^2, and generally decreased with depth to 4.05 roots/dm^2 at 100cm depth, except for an increase between 60-80cm depth. This increase is due to both physical restriction of the roots and perching of the water table on top of a carbonate accumulation horizon at approximately 80 cm depth (see soil survey in Appendix D), stimulating opportunistic root growth. The upper 0.4 meters of the soil profile contained 50% of the roots. Roots were observed to 56 inches depth, but were very fine and few in number below a depth of 80 cm.

Table 7 Grassland Community Summary

Depth Interval (cm)	Average root density (roots/dm^2)	Average of Total Roots (%)	Cumulative Average Root Density (%)
0 - 10	36.25	20.02	20.02
10 - 20	25.3	14.04	34.06
20 - 30	17.05	9.60	43.66
30 - 40	13.45	7.62	51.28
40 - 50	15.05	8.68	59.96
50 - 60	13.5	7.65	67.61
60 - 70	27.9	16.07	83.68
70 - 80	14.5	8.53	92.21
80 - 90	9.15	5.37	97.59
90 - 100	4.05	2.41	100.00



Animal

Trapping associated with the grassland community was conducted on a grassland closer to the tailings facility to maximize the efficiency of the data (Map 4). Trapping located closer to the proposed location of the repository provides more accurate data for the small mammal potential on the repository while still representing the grassland community. As indicated on Table 8, trapping in the grassland community yielded 1 captured deer mouse.

Table 8 - NECR - Wildlife Surveys

Small Mammal Trapping Results - Fall 2013

Surveys Occurred from 10/21/13 to 10/23/13

Sample Area (Plot No.)	Captures			
	DAY 1	DAY 2	DAY 3	TOTAL
Grassland	0	0	Deer Mouse (*Peromyscus maniculatus*) - (1)	1

2.3 Shrubland Community

The shrubland community was characterized by sampling the Shrubland Analog site. This site is located across the buried pipeline to the east of the South Drainage Borrow (Map 2). The vegetation and biointrusion survey results are presented below. Discussions on all results can be found in Section 3.

2.3.1 Vegetation Survey Results

Vegetation was evaluated in the Shrubland Analog using 15 co-located ground cover, production (current annual biomass), and woody plant density belts. Vegetation sampling results are presented on the summary table and the raw data is presented in the Baseline report (Cedar Creek, 2014). In general, the Shrubland community is characterized by late seral species. This community displays the lowest cover, production, and species diversity, and the middle woody plant density of the projected communities. Bareground exposure, litter, and rock cover were 47.4%, 26.5%, and 1.3%, respectively.

Table 9 - Vegetation Parameters

Shrubland Community

Ground Cover by Lifeform			
Grass	Forb	Shrub/Tree	**Total**
8.9%	1.8%	14.1%	**24.8%**
Ground Cover by Habit			
Perennial	Annual	Noxious	**Total**
23.0%	1.8%	0.0%	**24.8%**
Species Diversity			
Perennial	Annual	Noxious	**Total**
7	2	0	**9**
Dominant Species			
Bouteloua gracilis	8.8%		
Artemisia tridentata	6.9%		
Gutierrezia sarothrae	6.7%		
Chenopodium album	1.2%		

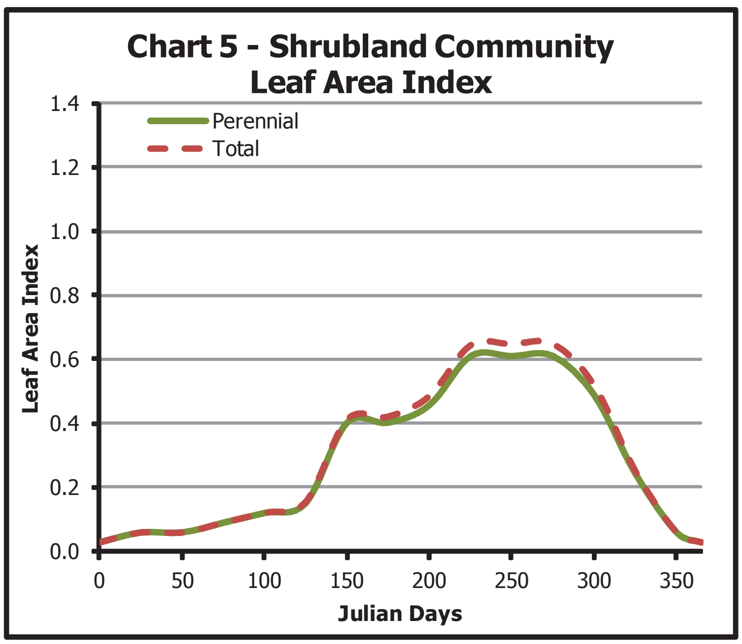
Production by Lifeform (lbs per acre)		
Grass	Forb	Shrub/Tree
74.1	1.3	149.9
Total = 225.3 lbs per acre		
Production by Habit (lbs per acre)		
Perennial	Annual	Noxious
223.6	1.7	0.0
Total = 225.3 lbs per acre		
Woody Plant Density (stems per acre)		
Shrub	Succulent	Tree
1,022	0	27
Total = 1,049 stems per acre		

2.3.2 Leaf Area Index Results

Leaf area index was characterized with an indirect approach, using vegetative ground cover as a basis. Since surveys were conducted October 19th-23rd, leaf area index was quantified when approximately 80% of the peak potential. Results are presented on Table 10 and Chart 5. Data were extrapolated throughout the Julian calendar to account for plant dynamics.

Table 10 Leaf Area Index

Shrubland Community				Leaf Area Index
Grasses	Perennial	Native	Cool-Season	0.00
			Warm-Season	0.15
		Introduced		-
	Annual			-
Forbs	Perennial	Native		-
		Introduced		-
	Annual & Biennial Native & Introduced			0.04
Sub-shrubs				0.17
Shrubs				0.16
Total LAI				0.52
Perennial LAI				0.49



2.3.3 Biointrusion Results

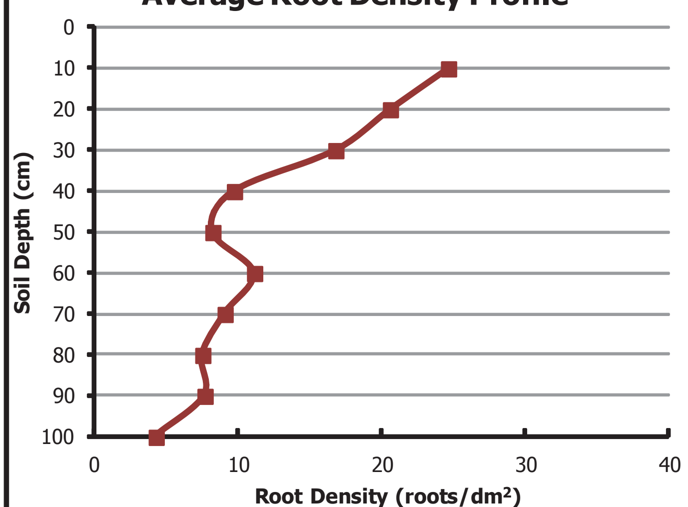
Plant

Two soil pits were excavated to a depth of approximately 61 inches to evaluate root density in the shrubland community (Map 3). Average results are presented on Table 11 and Chart 6. Root density was highest at the soil surface with 24.6 roots/dm^2, and generally decreased with depth to 4.25 roots/dm^2 at 100cm depth, except for an increase between 50-70cm depth. This increase is due to both physical restriction of the roots and perching of the water table atop of a carbonate accumulation horizon, stimulating opportunistic root growth. The upper 0.3 meters of the soil profile contained 50% of the roots. Roots were observed to 61 inches depth, the bottom of the pit, but were very fine and few in number. No shrub taproots were observed to a depth greater than or near the bottom of the pit.

Table 11 Shrubland Community Summary

Depth Interval (cm)	Average root density (roots/dm^2)	Average of Total Roots (%)	Cumulative Average Root Density (%)
0 - 10	24.6	20.45	20.45
10 - 20	20.55	17.28	37.72
20 - 30	16.75	14.01	51.73
30 - 40	9.7	8.10	59.83
40 - 50	8.2	6.81	66.65
50 - 60	11.1	9.38	76.02
60 - 70	9.05	7.67	83.70
70 - 80	7.5	6.35	90.05
80 - 90	7.65	6.40	96.45
90 - 100	4.25	3.55	100.00

Chart 6 - Shrubland Community Average Root Density Profile



Animal

Trapping associated with the shrubland community was conducted on a shrubland closer to the tailings facility to maximize the efficiency of the data (Map 4). Trapping located closer to the proposed location of the repository provides more accurate data for the small mammal potential on the repository while still representing the Shrubland community. As indicated on Table 12, trapping in the reclaimed community yielded 0 captures.

Table 12 - NECR - Wildlife Surveys

Small Mammal Trapping Results - Fall 2013

Surveys Occurred from 10/21/13 to 10/23/13

Sample Area (Plot No.)	Captures			
	DAY 1	DAY 2	DAY 3	TOTAL
Sagebrush Steppe (Shrubland)	0	0	0	0

3.0 DISCUSSION

3.1 Vegetation Communities

The identified vegetation communities that are projected to colonize and occupy the repository over the next 1000 years are 1) anthropogenic (reclaimed) (early to mid-successional); 2) grassland (mid-successional); and 3) shrubland (late-successional or climax community). The Piñon-Juniper Woodland community was eliminated as a potential final community for the repository because the soils profile (as currently proposed) can be considered a deep soil that is nonconductive to the establishment and persistence of woodland species. The depth of soil profile is important in when describing the vegetation in proximity to the Mill Site because species replacement is the driving factor for ecological succession among these three projected communities.

Young reclaimed communities in western New Mexico are characterized by a diversity of perennial shrubs and grasses along with an elevated population of annual/biennial weedy species (invaders). Typically, the vast majority of seeded species are perennial and can be generally considered mid-seral, whereas annual/biennial species are invading volunteers (that are almost always classified as early-seral). Vegetation data collected from the Reclaimed Analog area support this characterization. At the time of evaluation, dominant perennial species on the Reclaimed Analog were a short-lived shrub; fourwing saltbush (*Atriplex canescens*) and a diversity of grasses including sand dropseed (*Sporobolus cryptandrus*) and indian ricegrass (*Achnatherum hymenoides*), comprising 16.9%, 6.4%, and 5.7%, respectively. While an annual species, white prairie aster (*Symphyotrichum falcatum*) exhibited 4.2% ground cover.

Grassland communities in New Mexico are characterized by a more significant dominance by a reduced diversity of grasses as well as diminished shrub and annual/biennial weedy populations. Typically, the early diversity of perennial grasses is replaced by a single taxon or two of mid- to late-seral species that are best suited for the site-specific environs. Similarly, early-to mid-seral shrubs, which are generally short-lived, diminish as the grassland community matures. However, replacement of these taxa occurs at a very slow pace. The annual/biennial taxa drop out of the community structure due to competition with the perennial plants that have a competitive advantage for limited resources such as water and nutrients. By example, the dominant taxon from the Grassland Analog was the grass species, blue grama (*Bouteloua gracilis*) that comprised 24.5% ground cover at the time of the evaluation.

Shrubland communities in New Mexico are characterized by co-dominance of late seral grasses and overstory shrubs. Typically, species diversity is elevated, but with only a relatively few late seral species exhibiting dominance. Shrub replacement over many years has occurred with better-suited, longer-lived species. The dominant taxa on the Shrubland Analog were an understory grass, blue grama, and two overstory shrubs, big sagebrush (*Artemisia tridentata*) and broom snakeweed, comprising 8.8%, 6.9%, and 6.7% ground cover, respectively.

3.2 Vegetation Succession

The ecological succession among the projected repository cover communities is expected to follow this same sequence of reclaimed, grassland and shrubland. The reclaimed community is expected to be dominated by fourwing saltbush, a diversity of early/mid seral grasses species, and annual/biennial weedy species. The grassland community is expected to replace all early/mid grass species with blue grama dominance. Likewise, the fourwing saltbush, a short lived species, and annual/biennial weedy species are expected to die back and be replaced by blue grama and broom snakeweed. Finally, big sagebrush is expected to invade to form the shrubland community.

The timescale of the transition between communities is difficult to predict. Typically, these communities develop and transition as a result of or in association with land management and climatic factors. While the repository will be subject to the same climatic factors found in natural landscapes, the land management activities will be controlled during the lifetime of the repository. Ecosystems in the arid west have developed and progressed through succession with grazing from native and/or domestic grazers. Grazing is expected to be precluded from the repository by way of institutional controls. Therefore the impact of restricted land use on the progression of ecological communities is difficult to predict, since no examples exist to use as a basis. Succession is expected to progress through the communities sampled and described in this report and the best prognostication for timeframe is presented in the following ranges:

- Reclaimed Community: 0 - 50 years
- Grassland Community: 25 - 100 Years
- Shrubland Community: 50 - 1,000 Years

3.3 Leaf Area Index

Published LAI values for semi-arid plant communities are generally lacking in the professional literature and where they are presented, exhibited precision is low. Scurlock et al. (2001) reviewed worldwide historical leaf area studies and reported mean LAI values for deserts (1.31 ± 0.85), grasslands (2.5 ± 2.98), and shrublands (2.08 ± 1.58), all indicative of low precision around mean values. Ground cover methods (indirect measurement approach) employed by Clark and Seyfried (2001) in Idaho sagebrush communities found LAI values ranging from 0.03 to 1.1. Romig et al. (2006) collected leaf area measurements in native and reclaimed shrub-grassland communities in southwestern New Mexico. In the Romig study, leaf area indices were determined using digital image analysis of harvested leaves at the end of the growing season, a direct measurement approach. These data were used to estimate peak LAI and develop an annual LAI distribution. The average LAI ranged from 0.29 in reclaimed plant communities to 0.42 in native shrub-grasslands.

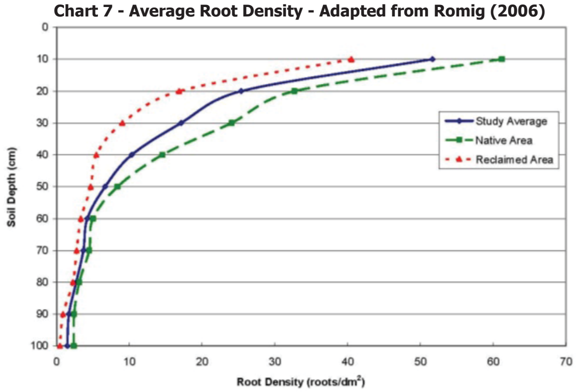
At the project area, peak LAI collected from associated analogs for each of the projected communities ranged from 0.65 to 1.1. The reclaimed community exhibited the highest peak LAI with 1.14 where perennial species account for 0.88 of this total and annual species account for the remaining 0.26. The grassland community exhibited the middle LAI value with 0.80 where perennial species account for 0.71 of the total and annual species account for 0.09. The shrubland community exhibited the lowest peak LAI with 0.65 where perennial species account for 0.61 of the total and annual species account for 0.04. These values were extrapolated to an annual LAI distribution following the form in Romig (2006). These results show that as the vegetation communities continue through ecological succession, the LAI decreases. This decrease is directly related to the fact that late seral species are better adapted to local environs and more efficient at capturing limited resources when compared with early/mid seral species. The site-specific results obtained by Cedar Creek differ from Romig (2006), but Romig does not provide information about the status (or composition) of the sampled reclaimed community, which could be underperforming and/or ecologically different from the reclaimed community in the NECR study. In addition, the sampled native community in Romig's study is dominated by black grama, as opposed to blue grama which is the dominant grass in the vicinity of NECR.

Including the annual plant contribution into any LAI analysis must occur with caution. Annual species exhibit a much more dynamic response to varied precipitation than perennial species. Annual species are opportunistic and can be dominant with elevated precipitation or completely absent in drought conditions. Therefore, LAI contribution from annual species is inappropriate for use in modeling long-term vegetative conditions due to their inconsistency on an annual basis.

3.4 Plant Biointrusion

Knowledge of the distribution of roots in unsaturated soils is important for predicting soil-water relations, but quantitative data are generally absent in scientific literature. Jackson et al. (1996) indicated that 83 percent of rootmass occurred in the upper 30 cm of soil in temperate grasslands compared to 53 percent in deserts. In a study in central New Mexico, semi-arid grassland had 63 percent of the root mass in the upper 25 cm (Peace et al., 2004). Romig et al. (2006) calculated root length density on reclaimed and native grassland / shrubland (see Chart 7). In contrast, data collected as part of the study at NECR is presented on Chart 8. Chart 9 also summarizes normalized root length density curves developed from a study in southwestern New Mexico (Romig et al., 2006), a study at Sandia National Labs in Albuquerque (Peace et al., 2004), and a study for agricultural crops (Ayers and Westcot, 1989). Once again, normalized root length density curves from the study at the Mill Site are presented on Chart 10. Root length density is a measurement attempting to quantify the density of roots (cm roots / cm soil) within a cross section of the soil profile. The data must be normalized to be properly incorporated as an input parameter in soil-water models, where the normalized root density provides a fraction of the maximum potential plant water uptake at specific depths within the profile.

Chart 7 - Average Root Density - Adapted from Romig (2006)



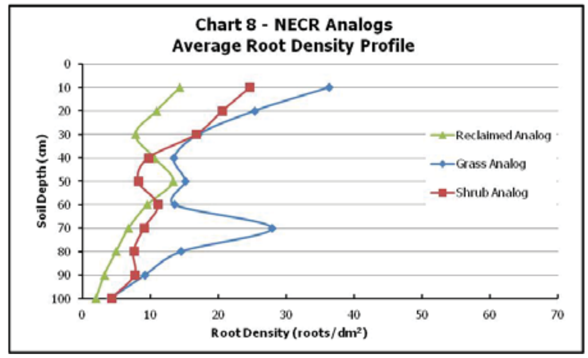
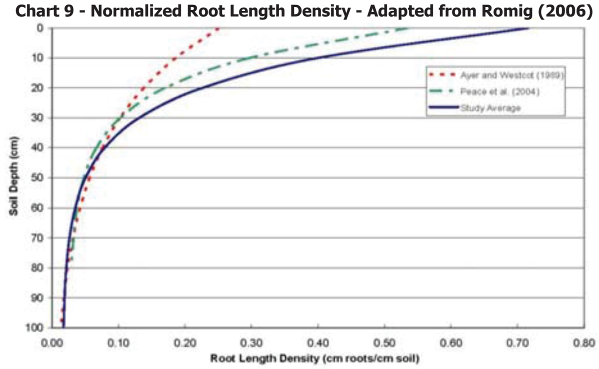
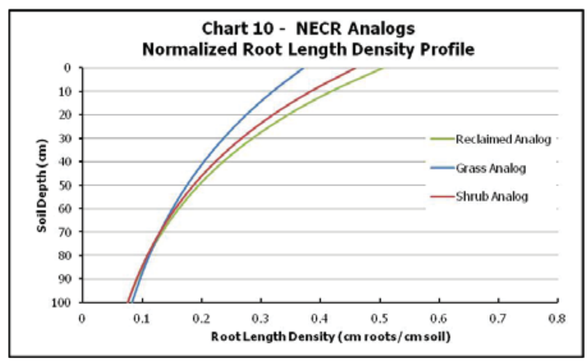


Chart 9 - Normalized Root Length Density - Adapted from Romig (2006)





The distinguishing characteristics of the Buckle soil (see soil Survey in Appendix D) are the increase of clay with depth, and the presence of a calcium carbonate accumulation forming a root restrictive layer at approximate depths of 60 cm, 80 cm, and 70 cm in the reclaimed, grassland, and shrubland communities evaluated. The presence of carbonates causes cementation of the soil, limiting the ability of plant roots and water to infiltrate deeper into the profile and causing roots to spread laterally, which explains the at-depth root increases observed in the field. This lateral spreading is due to both physical restriction of the roots and perching of the water table atop the carbonate-dominated horizon, stimulating opportunistic root growth. A soil survey is presented in Appendix D to support these observations.

An increase in root density at depth in the profile was observed in all three projected communities, but was very pronounced in the undisturbed native grass community. An increase in root density occurred in the Btk horizon, the transitional zone between clay and calcium carbonate dominating properties. The increase of roots at depth in the profile would not occur if the opportunity to harvest perched water did not exist, rather the plants' rooting energy would most likely be placed at or near the soil surface. The increased root density at depth in the native profiles has skewed root length density (RLD) for the sampled communities.

Site-specific root density data may not be initially appropriate for use with unsaturated flow modeling within the soil matrix of the repository cover because this "cemented" horizon restricting deep drainage will not exist, at least not for several decades/centuries. To accurately represent root distribution in freshly disturbed growth media, it may be appropriate to assume that total root biomass will remain similar, and that quantitatively distributing the root biomass measured in the Btk horizon throughout the upper 0.5-0.7m of the profile will represent more realistic plant biomass allocation in the absence of perched soil water overtop the calcium carbonate cemented hardpan.

The timeframe for formation of a carbonate horizon significant enough to affect subsurface flow (and subsequent root biomass allocations) in the repository cover will depend on climatic factors, the chemical and physical properties of harvest material resulting from the salvage depth and subsequent mixing of sourced surface and subsurface horizons, pedogenic processes such as loess deposition, and certain cap design features. The measured RLD, or a modified function that allocates slightly more root biomass in the upper 0.5m of the profile, will most likely be appropriate for the later successional periods of the repository when this carbonate layer becomes established. Other repository cover design features may have more immediate and significant impacts on soil water mechanics that will affect root growth and density.

In regard to root depth, literature tends to support the root depths detected in the NECR study (Romig et al. 2006, Lee and Lauenroth 1994). However, soil pits in the study at NECR did not detect shrub taproots at depth and both fourwing saltbush and big sagebrush have well-developed pronounced taproot and lateral root system with the greatest concentration of roots found within the uppermost 1.7 m of the soil profile. Based on studies of these taxa (Peace et al. 2004, Mozingo, 1987), the root system of fourwing saltbush may extend 2 to 6 m below the surface and the root system of big sagebrush may extend 1 to 4 m below the surface.

3.5 Animal Biointrusion

Table 13 - NECR - Wildlife Surveys				
Small Mammal Trapping Results - Fall 2013				
Surveys Occurred from 10/21/13 to 10/23/13				
Sample Area (Plot No.)	**Captures**			
	DAY 1	**DAY 2**	**DAY 3**	**TOTAL**
Piñon-Juniper Woodland	Piñon Mouse (*Peromyscus truei*) - (4)	Piñon Mouse (*Peromyscus truei*) - (3)	Piñon Mouse (*Peromyscus truei*) - (5)	12
Sagebrush Steppe (Shrubland)	0	0	0	0
Revegetated Tailings (Reclaimed)	0	0	0	0
Disturbed Bottomland	0	0	Deer Mouse (*Peromyscus maniculatus*) - (1)	1
Grassland	0	0	Deer Mouse (*Peromyscus maniculatus*) - (1)	1
Overall Trapping Success = (4+3+7)/300 = 4.67%				

Small mammal trapping was also implemented on Pinon Juniper and Disturbed Bottomland communities because of their close proximity to the proposed repository location. Table 13 exhibits the trapping results from the five small mammal traplines extended through project area habitats. As indicated in Table 13, trapping success was best within the Piñon-Juniper woodland type with 12 captures of piñon mice over 60 trap-nights of effort (20% success). Trapping was worst in the Sagebrush Steppe and Revegetated Tailings habitats with 0 captures, and was intermediate in the Disturbed Bottomland and Grassland habitats with 1 deer mouse capture in each (1.67% success). Overall trapping success was only 4.67% (14 captures over 300 trap-nights of effort). By comparison, similar habitats in the Southwestern U.S. typically yield between 30% and 60% trap success. Therefore, as with the avian observations, the relatively low trap success within the project area suggests area habitats can be classified as being of reduced quality (poor to fair).

Of significant note regarding the results of the trapping effort was the distinct absence of small mammals that can be classified as burrowers. Taxa such as ground squirrels and kangaroo rats were anticipated, but were notably absent.

As indicated on Table 14 and Map 4, several species of wildlife, or their sign, that either excavate into or otherwise utilize subterranean habitats were observed within the project area or vicinity. These taxa are important given the potential for "bio-intrusions" of the eventual protective repository cover. Most notable among these taxa are: 1) cottontail rabbits, 2) pocket gophers, 3) Gunnison's prairie dogs, 4) coyotes, and 5) badgers. Other ground dwelling wildlife, or evidence of their existence in the area, were not noted during surveys or were noted as conspicuously absent given the results of small mammal trapping. As indicated above, these absent groups of wildlife largely include kangaroo rats and ground squirrels as well as certain smaller predators that prey upon them such as weasels.

Table 14 - NECR - Wildlife Surveys - Fall 2013	
Miscellaneous Wildlife Observations at FRCPs and Qualitative Observation Transects (Scat, Tracks, Direct Obs. etc.)	
Surveys Occurred from 10/21/13 to 10/23/13	
Sample Area (Plot No.)	**Wildlife Observations**
West Borrow Area (A)	Coyote Scat & Tracks (UC) / Cottontail Scat (VC) / Cottontail (2) / Mule Deer Tracks (UC)
East Borrow Area (B)	Coyote Scat (UC) / Cottontail Scat (VC) / Mule Deer Tracks & Pellets (UC)
Revegetated Tailings (C)	Cottontail Scat (VC) / Mule Deer Tracks & Pellets (C)
South Drainage Borrow Area (D)	Gunnison's Prairie Dogs in bottomland north of Tailings Facililty / Coyote (1) / Rock Squirrel (1) / Cottontails (2) / Cottontail Scat (VC) / Mule Deer Tracks & Pellets (C) / Badger (R)
Shrubland Analog Area (E)	Cottontail Scat (VC) / Mule Deer Tracks & Pellets (C)
Grassland Analog Area (F)	Cottontail Scat (VC) / Pocket Gophers (Burrows)-(R)
North Drainage Borrow Area (G)	Gunnison's Prarie Dogs (C) / Cottontail Scat (VC) / Mexican Woodrat (UC) / Cliff Chipmunk (UC)
Millsite Area (H)	Cottontail (1) & Cottontail Scat (VC)
Dilco Hill Area (I)	Cottontail Scat (VC)
U = Ubiquitous / VC = Very Common / C = Common / UC = Uncommon / R = Rare	

With regard to the short list of observed wildlife that exhibit subterranean habits, the only ones presenting concern for the integrity of the eventual protective repository cap are pocket gophers, Gunnison's prairie dogs, and badgers. Contrary to lay opinion, western cottontail rabbit species that could occur in the project area do not actively burrow. However, they will occupy the burrows created by other species such as prairie dogs. Unlike cottontails, coyotes are known to burrow (or to enlarge other animals' burrows) for denning purposes, but typically will not expend the energy necessary to excavate their prey except on rare occasion. Coyotes typically follow the strategy of capturing their prey above ground. Furthermore, coyotes occupy and defend large home ranges. Where the prey base is normal, coyote home ranges can average 10 square miles. Where the prey base is reduced such as the vicinity of the project area, home ranges can be significantly larger. As a result of these behaviors, it is very unlikely that burrowing by coyotes would ever be problematic for the repository cap.

However, pocket gophers, prairie dogs, and badgers could create issues for the repository cap. Pocket gopher sign (tunnel excavations) were only noted in one location, the Grassland Analog area. Though this is somewhat remote from the eventual cap location, pocket gophers could easily extend their activity perimeter. Pocket gophers (most likely *Thomomys bottae*) typically excavate burrow systems 4 to 6 inches below and parallel to the surface, but occasionally up to 18 inches deep. These burrow systems can extend for tens of yards. Burrow extensions that serve as food caches and/or nests can be significantly deeper, as much as 5 to 6 feet. Burrow diameter is typically only in the 3-inch range excepting where it is enlarged for nesting or food storage. As such, the volume of material they typically move is much less than that indicated for prairie dogs. By necessity, burrowing is restricted to finer-textured soils given that gophers primarily utilize their teeth to loosen soil. Soils with a high coarse fragment content (rock) are not suitable as gopher habitat.

As noted above, the more significant potential for bio-intrusion could come from prairie dogs. As indicated on Map 4, there is an active population of Gunnison's prairie dogs that occupies much of the valley bottom (Disturbed Bottomland community) on both the south and especially the north flanks of the tailings facility. The population to the south is more scattered and intermittent; however, the population to the north is more dense and active.

Typically, Gunnison's prairie dog populations range from 2 to 30 animals per acre, but based on site-specific observations, it is anticipated the project area population is closer to the lower end of this range. Gunnison's Prairie dogs typically excavate burrow systems that are 5.5 – 6 inches in diameter, 15 – 35 feet in length, 6 – 10 feet below the surface, and exhibit 15 – 20 entrances per acre with only a few of these exhibiting a large mound of excavated dirt. Some studies indicate an average of approximately 25 feet of tunnel per entrance. Furthermore, excavated material can average 0.2 to 0.4 tons per burrow system or between 7 and 10 tons of excavated material per acre. As with pocket gophers, burrowing is restricted to finer-textured soils given that elevated rock content precludes suitability as prairie dog habitat.

Finally, during site-specific surveys two prairie dog burrows were observed that had been enlarged by badger(s). Burrows re-excavated by badgers in pursuit of prey exhibit a characteristic oval-shape that is approximately 10-12 inches in width and 6-8 inches in height. This observation verified this predator's existence within the vicinity of the project area and is significant from the standpoint that badgers, when excavating their prey, double or triple the amount of excavated material brought to the surface. However, the primary effect of burrowing resides with prey animals; pursuit by badgers only exacerbates this effect. On the positive side, badgers reduce the populations of burrowing rodentia.

3.6 Soil Pedogenesis Considerations

In order to discuss the pedogenesis of the repository cover, the extent and degree of calcification for borrow materials must be quantified and observed in the field. Once these materials are relocated, the chemical and physical properties of the borrow soils will dictate water and gas transport, structural stability, and revegetation success. Over time, pedogenic processes such as leaching, illuviation, eluviation, salinization, calcification, and biogeochemical weathering drive soil development, potentially towards its original undisturbed state. These processes may occur much more rapidly than in natural systems due to the extent of calcification already present in the subsurface horizons of the borrow soils. Rates, timeframes, and unforeseen chemical constraints (such as salts) need to be addressed in the borrow sources by laboratory and field testing conducted by a soil scientist. Each soil horizon encountered up to the potential harvest depth should be individually characterized and tested in order to understand the pedogenic implications of using borrow soils as cover material, its nature once freshly disturbed, and how it will evolve over the lifespan of the repository.

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Appendix A

Sampling Methodologies

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SAMPLING METHODS

Cedar Creek's vegetation sampling protocols involve an emphasis upon ground cover* to facilitate repeatable future statistical comparisons among evaluation areas as well as a multitude of additional reasons. In brief, concentration on a single variable of plant ecology facilitates improved comprehension and comparability over time and among treatment scenarios. Second, ground cover data, especially when determined using a very precise method such as the point-intercept procedure, provides some of the most important information regarding community variability that ecologists can evaluate. Such data facilitate the determination of true species composition, relative health (condition), and successional status of the sampled area. Furthermore, the same data can be utilized to develop the "sister" variables of frequency and species composition if desired. Third, strong inferences can be developed with other reasonably correlated variables such as production when species composition is factored into the analysis. Fourth, ground cover is a preferred variable for revegetation monitoring because cover data can be readily obtained in a statistically adequate and cost-effective manner (using the proper procedures), has broad application for evaluation (including erosion control modeling), precisely reflects species' dominance of a given area, and when collected using bias-free techniques such as the point-intercept procedure is one of the most repeatable variables among independent observers.

In addition to ground cover evaluations, Cedar Creek recommends evaluation of woody plant density and current annual vegetative production to facilitate a broader analysis. In this regard, it was determined most appropriate to document woody plant populations (for wildlife habitat considerations) by utilizing long quadrats or belts as detailed below. The most appropriate method for measuring current annual herbaceous production is use of long rectangular quadrats. Since sampling adequacy is not required (nor recommended) for woody plant density or vegetative production samples, one density belt and one production quadrat will be co-located with each ground cover transect evaluated. Resulting data are then considered reasonable for the evaluation purposes intended.

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* To avoid confusion, the term "ground cover" is utilized to indicate the variable of <u>non-overlapping foliar cover</u> (the percent of the ground occupied by all above ground plant material) in addition to the ground surface covered by litter or rock. Non-overlapping means that only that cover which would be wetted by a light mist would be counted as opposed to that plant material which would not get wet due to overshadowing plant material. In this manner, <u>total ground cover</u> cannot exceed 100%. Other forms of "cover" would include: basal cover (the percent of the ground surface occupied by the living base of plants), crown or canopy cover (the percent of the ground occupied by the canopies of plants), or overlapping foliar cover (the percent of the ground occupied by <u>all</u> plant material allowing for overlapping vegetation - i.e., such cover can exceed 100%). Non-overlapping foliar cover is preferred because of its inherent repeatability among observers, resulting data are directly applicable to erosion control modeling efforts, and significant precedent has already been set in the mining industry. In contrast, the determination of the live portion of the base of a plant (as necessary for basal cover) becomes increasingly difficult and subjective given life forms such as certain bunch grasses and sod-formers.

1.0 Sample Site Selection / Location

The primary field effort for vegetation calls for sampling of 5 potential borrow sources, the revegetated tailings facility, and suitable analog areas for reclaimed, grassland, and shrubland vegetation communities. The analog areas were selected and established during floral evaluations in fall. The systematic procedure for determination of sample locations will occur in the following stepwise manner. First, a fixed point of reference will be selected for the entire area to facilitate location of the systematic grid in the field. Second, a systematic grid of appropriate dimensions (i.e., 150′ X 150′) will be selected by Cedar Creek to provide a minimum number of coordinate intersections within the vegetative unit that could then be used for the initial set of sample sites. Third, a scaled representation of the grid will be overlain on field maps extending parallel to major compass points to facilitate field location. Fourth, unbiased placement of this grid will be controlled by selection of two random numbers between 0 and 150 (used as coordinates). Fifth, utilizing a GPS, all of the initial sample points will be located in the field. If the initial systematic samples are not sufficient to provide an adequate ground cover sample, an "intergrid" would be selected to provide additional systematically determined sample points.

2.0 Determination of Ground Cover

Ground cover at each sampling site will be determined utilizing the point-intercept methodology (Bonham 1989) as illustrated on Figure 1. This methodology has been utilized for range studies for over eighty (80) years, however, Cedar Creek utilizes state-of-the-art instrumentation that it has pioneered to facilitate much more rapid and accurate collection of data. Implementation of the technique for the sampling effort occurs as follows: First, a transect of 10 meters length will be extended from the starting point of each sample site toward the direction of the next site to be sampled. Then, at each one-meter interval along the transect, a "laser point bar" will be situated vertically above the ground surface, and a set of 10 readings recorded as to hits on vegetation (by species), litter, rock (>2mm), or bare soil. Hits are determined at each meter interval by activating a battery of 10 specialized lasers situated along the bar at 10 centimeter intervals and recording the variable intercepted by each of the narrow (0.02″) focused beams (see Figure 1). In this manner, a total of 100 intercepts per transect are recorded resulting in 1 percent cover per intercept. This methodology and instrumentation facilitates the collection of the most unbiased, repeatable, precise, and cost-effective ground cover data possible. Furthermore, the point-intercept procedure has been widely accepted in the scientific community as the protocol of choice for vegetation monitoring and is used within the mining industry in connection with bond release determinations.

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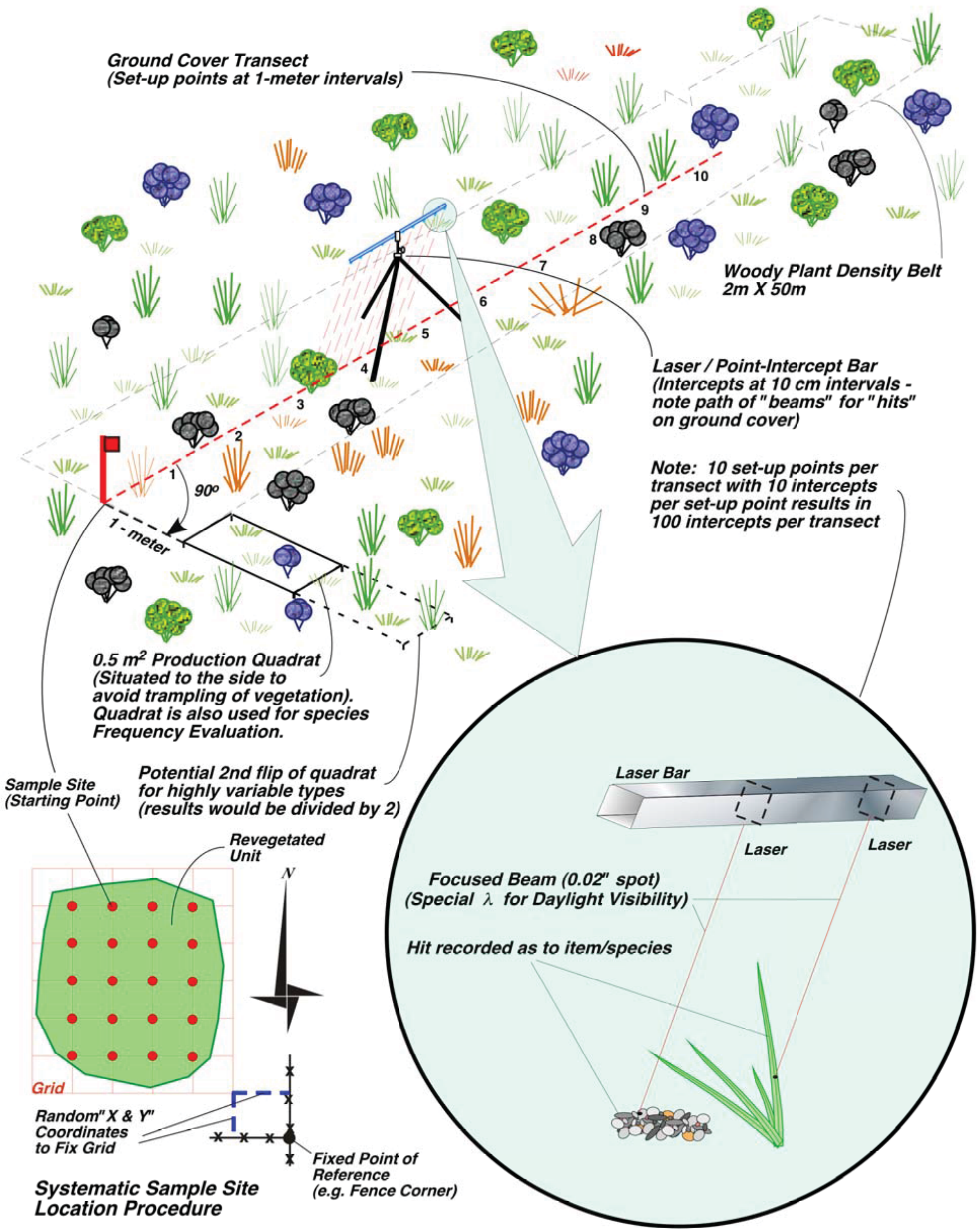

Figure - 1

Sampling Procedure at a Systematic Sample Site Location

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3.0 Determination of Leaf Area Index

Leaf area index was quantified by collecting multiple hits on the ground cover transect. In effect, overlapping foliar cover (the percent of the ground occupied by all plant material allowing for overlapping vegetation - i.e., such cover can exceed 100%) were recorded to provide a total estimation of one-sided photosynthetic potential or leaf area index. This sampling method would be considered an indirect approach to quantifying leaf area index.

4.0 Determination of Woody Plant Density

Woody plant density at each sampling site is determined using fixed length / width belt transects oriented parallel to, and co-located with, each ground cover transect. Each belt is 2 meters in width and extended from the beginning of the sample point for a distance of 50 meters (see Figure 1). All shrubs, succulents, and trees rooted within the boundaries of these belts are counted and classified according to species (sub-shrubs are not counted). Entire plants rather than stems are counted to provide a more accurate representation of actual woody plant density.

5.0 Determination of Vegetative Production

At each sample site, current annual production is collected from a $^{1}/_{2}$ m^2 quadrat frame flipped once (end to end – see Figure 1) to facilitate less variable data, therefore sampling a total of 1 m^2 at each sampling location. The quadrat is initially placed one meter and 90º to the right (clockwise) of the ground cover transect to avoid vegetation trampled by investigators during sample site location (see Figure 1). From within each quadrat, all above ground current annual vegetation within the vertical boundaries of the frame is clipped and bagged separately by life form as follows:

Native Perennial Grass
Introduced Perennial Grass
Annual Grass
Sub-Shrub
Shrub
Native Perennial Forb
Annual / Biennial Forb
Introduced Perennial Forb
Noxious Weed

All production samples are returned to the lab for drying and weighing. Drying will occur at 105º C until a stable weight is achieved (24 hours). Samples are then re-weighed to the nearest 0.1 gram.

6.0 Sample Adequacy Determination

Ground cover sampling is conducted to a minimum of 15 initial ground cover transects for the baseline area and a minimum of 15 initial ground cover transects for the reference area. Production and woody plant density samples are co-located with each ground cover transect but are not subject to a determination of sampling adequacy. From these preliminary efforts for ground cover, a sample mean and standard deviation for total non-overlapping vegetation ground cover is calculated. These parameters are calculated in the field to insure collection of an adequate sample and once again by computer during final data analyses for each area. Sampling continues until an adequate ground cover sample, $\mathbf{n_{min}}$, has been collected in accordance with the Cochran formula (below) for determining sample adequacy, whereby the population would be estimated to within 10% of the true mean (μ) with 90% confidence. Sampling to these limits facilitates a very strong estimate of target populations.

When the inequality ($\mathbf{n_{min}} \leq \mathbf{n}$) is true, sampling is adequate and $\mathbf{n_{min}}$ is determined as follows:

$$\mathbf{n_{min}} = (t^2 s^2) / (0.1\ \bar{x})^2$$

where: n = the number of actual samples collected (initial size = at least 15)

t = the value from the one-tailed t distribution for 90% confidence with n-1 degrees of freedom;

s^2 = the variance of the estimate as calculated from the initial samples;

$\bar{x}$ = the mean of the estimate as calculated from the initial samples.

If the initial at least 15 ground cover samples from each area does not provide a suitable estimate of the mean (i.e., the inequality is false), additional samples would be collected until the inequality ($\mathbf{n_{min}} \leq \mathbf{n}$) becomes true.

7.0 Threatened, Endangered, and Rare Plant Species

A list of threatened, endangered, and rare plant species that are known to occur within McKinley County and the ecotypes occurring within the project area, will be developed from several sources including New Mexico Natural Heritage Program and New Mexico Rare Plant Website before baseline evaluation.

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Prior to implementation of fieldwork, taxonomic descriptions and botanical drawings of these target species are to be compiled into a field guide. Fieldwork will involve search patterns in all portions of appropriate habitat within the project area. Search procedures involve slow implementation of qualitative pedestrian transects and careful visual scanning of the ground surface for any of the target plant species. The compiled field guide will be used to determine whether encountered plants are species of concern.

8.0 Weed Survey

A noxious weed list from McKinley County will be obtained prior to baseline evaluations. Fieldwork will involve search patterns in all portions the project area including potential sources of weed seed in the general vicinity. Search procedures involve slow implementation of qualitative pedestrian transects and careful visual scanning of the ground surface for any of the target plant species.

9.0 Root Density and Depth Survey

Root density and depth will be determined using the profile wall method, whereby the roots are counted on a freshly excavated soil profile. At least two trenches are to excavated in each suitable analog site which represent a potential ecological scenario for the ET cover. The vertical pit wall will be gently cleaned with a soft brush to expose the roots to a depth of approximately 1 to 1.5 m. A 1-m2 wire frame divided into a 10 cm2 grid will be attached to the pit face and the roots within each grid cell counted and mapped on field sheets. Roots will also described and classified by size (Soil Survey Staff, 1983). General field conditions will be logged and photographs will be taken, in accordance with MWH SOP-14.

10.0 Wildlife Survey Methodologies

Site-specific wildlife investigations were designed to address two overall needs or goals. First among these is the need to document baseline conditions of wildlife populations and their respective habitats extant within the NECR project area prior to any construction. Second, and more importantly, is the need to document the existence of “burrowing” faunal populations, or the lack thereof, with regard to “bio-intrusions” of the eventual protective repository cap.

Owing to the small size of disturbance footprints at the NECR project area, it was deemed most appropriate for the majority of site-specific wildlife evaluations to focus on qualitative techniques of direct observation, observation of sign, and/or evaluation of habitat. However, certain wildlife groups lend themselves to, or require, quantitative and semi-quantitative metrics. It was proposed that while Cedar Creek biologists were on site for vegetation and soils investigations, all observations of wildlife, either directly or by sign, would be recorded in a manner to facilitate an indication of abundance and/or use of project area habitats. In addition to site-specific "incidental" observations during vegetation evaluations, several pedestrian observation transects were extended within and external to the central disturbance area, some as far as practically allowable given land ownership, to provide a better indication of: 1) wildlife use of the overall vicinity and habitats, 2) any remaining mine-related impacts, and 3) any continuing hazards to wildlife. These transects were implemented during the early morning or late evening hours to maximize opportunity for observing indigenous wildlife. A GPS was utilized for spatial orientation, documentation (mapping) of transect alignment, and to facilitate documentation of pertinent observations. Furthermore, project area habitats were evaluated with regard to their capability to provide life requisites for anticipated indigenous wildlife, including sensitive or special status species.

In addition to the aforementioned qualitative techniques, a Cedar Creek wildlife biologist implemented two quantitative protocols designed to document population levels of two important groups of wildlife, 1) avifauna and 2) small members of the Rodentia Order. Avifauna were inventoried using fixed-radius circular plots (FRCP), and small mammals were inventoried using traplines of Sherman live-traps. The 3" x 3" x 10" Sherman live-traps were baited with a mixture of rolled oats and peanut oil and were placed in line-sets of 20 traps at 50-foot intervals (forming 1,000-foot long traplines) in each of five habitat types. Habitat types were: 1) Piñon-juniper woodland, 2) Sagebrush (Shrubland) steppe, 3) Grassland, 4) Disturbed bottomland, and 5) Revegetated tailings. Traps were checked each morning for captures (identified to species), reset as necessary, and run for three consecutive nights (October 21-23, 2013) for a total of 300 trap-nights of effort.

The FRCPs are a sampling metric whereby a biologist identifies all avian wildlife to species, either through direct visual or auditory observation within a circular plot of fixed dimensions (300-foot diameter - 150-foot radius for this effort) over a 10-minute period during the early morning hours when birds are most active. The sampling points were visited on two consecutive mornings and all birds detected through binocular observation or auditory identification were recorded. Multiple observations of the same bird were only recorded once. Occasionally, birds revealed themselves for only a moment or two (e.g., fly-overs), but repeated observations (typically following the 10-minute window) facilitated eventual identification. Data were then compiled to provide an indication of relative density and diversity for a given habitat or location. FRCPs were established at nine specific locations around the project area as follows: A] West Borrow (Ruderal/Revegetated Shrubland), B] East Borrow (Revegetated Shrubland), C] Tailings (Revegetated Shrubland), D] South Drainage Borrow (Sagebrush/Rabbitbrush Shrubland), E] Shrubland Analog (Sagebrush/Grassland), F] Grass Analog (Grassland), G] North Drainage Borrow

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(Rabbitbrush/Grassland), H] Millsite (Rabbitbrush Ruderal Shrubland), and I] Dilco Hill (Sagebrush/Grassland).

In addition to remaining vigilant for direct or indirect observations of wildlife, Cedar Creek biologists performed a literature review to determine if the NECR site offers habitat to sensitive, rare, threatened, or endangered fauna. Sources of such information included the Natural Diversity Data Base, New Mexico Department of Game and Fish, and the U. S. Fish & Wildlife Service, among others.

Because of the potential for compromise of protective caps or other designed barriers by members of the Order Rodentia (or those fauna that potentially prey upon them by means of excavation, e.g., badgers, foxes, coyotes), Cedar Creek biologists effected a determination of which species, and an estimate of their densities, that exist within reasonable proximity to the proposed repository location. Given these determinations analyses can be undertaken with regard to the risk for compromise of the designed cap. For example, it is known that pocket gophers, kangaroo rats, ground squirrels, and prairie dogs among other taxa, can directly impact isolated materials in either of two ways. The first is by burrowing whereby they excavate deep enough to penetrate into stored repository materials and then bring those materials to the surface where they can be transported off-site through erosional means. The second manner of compromise involves development of preferential pathways for water transport into the repository thereby facilitating dissolution and hydraulic transport of any contaminants.

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11.0 Literature Cited

Bonham, Charles D. 1989. Measurements for Terrestrial Vegetation. John Wiley & Sons. 338 pp.

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Appendix B

Raw Data

Table B1 Church Rock Mill - Vegetation Cover - 2013

Reclaimed Analog Area

Raw Data

Percent Ground Cover Based on Point-Intercept Sampling

		Transect No.——>	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Average Cover**	**Frequency**
Grasses																			
P	*Achnatherum hymenoides*	Indian Ricegrass			2	8		11	2					18	10	12	22	**5.67**	**53**
P	*Agropyron smithii*	Western Wheatgrass	1						1	11	9							**1.47**	**27**
P	*Elymus elymoides*	Squirreltail			5									2				**0.47**	**13**
P	*Sporobolus cryptandrus*	Sand Dropseed	25	3	3	13	5	11	1	3	3	6	4		12	7		**6.40**	**87**
A		Unidentified Annual Grass	4	11	8	2			1	4	2	5	9	1	9	1		**3.80**	**80**
Forbs																			
P	*Asclepias subverticillata*	Horsetail Milkweed										3						**0.20**	**7**
P	*Aster sp.*	Aster sp.	2	2	9													**0.87**	**20**
A	*Bassia scoparia*	Burningbush	2															**0.13**	**7**
A	*Chamaesyce serpyllifolia*	Thymeleaf Sandmat	2		6	5	6					1	3				1	**1.60**	**47**
A	*Helianthus sp.*	Helianthus sp.			2						2							**0.27**	**13**
A	*Portulaca oleracea*	Little Hogweed										2	2					**0.27**	**13**
A	*Salsola tragus*	Russian Thistle		5	3	4	5	4	4		4	5		8	5	1		**3.20**	**73**
P	*Symphyotrichum falcatum*	White Prairie Aster				13			6		2	10	8	2	8	7	7	**4.20**	**60**
Shrubs, Sub-shrubs, Cacti & Trees																			
P	*Atriplex canescens*	Fourwing Saltbush	33	46	1	5	15	11	31	31	26	1	33	9	4	7		**16.87**	**93**
P	*Chrysothamnus nauseosus*	Rubber Rabbitbrush														7		**0.47**	**7**
																		Mean	
		Total Plant Cover	**69**	**67**	**39**	**50**	**31**	**37**	**46**	**49**	**48**	**33**	**59**	**40**	**48**	**42**	**30**	**45.87**	
		Rock	0	0	0	0	0	0	4	0	2	0	0	2	0	0	10	**1.20**	
		Litter	21	9	30	22	25	24	26	34	44	40	29	12	30	22	8	**25.07**	
		Bare ground	10	24	31	28	44	39	24	17	6	27	12	46	22	36	52	**27.87**	
		Total Non-Noxious Vegetative Cover	**69**	**67**	**39**	**50**	**31**	**37**	**46**	**49**	**48**	**33**	**59**	**40**	**48**	**42**	**30**	**45.87**	
		Total Perennial Cover (noxious weeds excluded)	**61**	**51**	**20**	**39**	**20**	**33**	**41**	**45**	**40**	**20**	**45**	**31**	**34**	**40**	**29**	**36.60**	

		Multiple Hits																**Average Cover**	**Frequency**
Grasses																			
P	*Achnatherum hymenoides*	Indian Ricegrass				16	4	28	2					32	12	10	24	**8.53**	**53**
P	*Agropyron smithii*	Western Wheatgrass							2	10	20							**2.13**	**20**
P	*Elymus elymoides*	Squirreltail												2				**0.13**	**7**
P	*Sporobolus cryptandrus*	Sand Dropseed				14	10	19		5	15	10			11	2		**5.73**	**53**
A		Unknown Annual Grass				16	4		7	21	23	21	31		15	2		**9.33**	**60**
Forbs																			
A	*Amaranthus hybridus*	Slim Amaranth														2		**0.13**	**7**
P	*Asclepias subverticillata*	Horsetail Milkweed										2						**0.13**	**7**
P	*Aster sp.*	Aster spp.													3	2		**0.33**	**13**
A	*Salsola tragus*	Russian Thistle				2	6	3	3		3	1		4	11			**2.20**	**53**
P	*Symphyotrichum falcatum*	White Prairie Aster				10			1		2	2						**1.00**	**27**
Shrubs, Sub-shrubs, Cacti & Trees																			
P	*Atriplex canescens*	Fourwing Saltbush				14	18	32		44	25	4	57	12	2	9		**14.47**	**67**
P	*Chrysothamnus nauseosus*	Rubber Rabbitbrush														15		**1.00**	**7**
																		Mean	
		Overall Total Hits (LAI)	**69**	**67**	**39**	**122**	**73**	**119**	**61**	**129**	**136**	**73**	**147**	**90**	**102**	**84**	**54**	**91.00**	

Sample Adequacy Calculations	**Plant Cover Mean = 45.87** **t= 1.35** **n = 15** **Variance = 143.12** **n_{min} = 12.31**
Diversity	**Number of Species with ≥1% Average Cover = 8**

P=Perennial A=Annual B=Biennial Nw=Noxious Weed

Table B2 Church Rock Mill - Vegetation Cover - 2013

Grassland Analog Area

Raw Data

Percent Ground Cover Based on Point-Intercept Sampling

		Transect No.——>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average Cover	Frequency
Grasses																			
P	*Achnatherum hymenoides*	Indian Ricegrass				1												**0.07**	**7**
P	*Bouteloua curtipendula*	Sideoats Grama													2	8		**0.67**	**13**
P	*Bouteloua gracilis*	Blue Grama	44	34	22	23	31	29	31	30	37	20	7	19	18	1	21	**24.47**	**100**
P	*Elymus elymoides*	Squirreltail										1						**0.07**	**7**
P	*Hilaria jamesii*	Galleta												4			2	**0.40**	**13**
Forbs																			
A	*Chamaesyce serpyllifolia*	Thymeleaf Sandmat												1		1		**0.13**	**13**
A	*Chenopodium album*	Lambsquarters	1							2	1							**0.27**	**20**
A	*Portulaca oleracea*	Little Hogweed	2															**0.13**	**7**
A	*Salsola tragus*	Russian Thistle	1				2	4	2	3	7	6	7	4	1	5	1	**2.87**	**80**
Shrubs, Sub-shrubs, Cacti & Trees																			
P	*Atriplex canescens*	Fourwing Saltbush											3					**0.20**	**7**
P	*Ceratoides lanata*	Winterfat			2													**0.13**	**7**
P	*Chrysothamnus nauseosus*	Rubber Rabbitbrush						3								4	12	**1.27**	**20**
P	*Gutierrezia microcephala*	Threadleaf Snakeweed												1				**0.07**	**7**
P	*Gutierrezia sarothrae*	Broom Snakeweed	1	4	5	12	3	11		7	3	6	3	4		4	3	**4.40**	**87**
																		Mean	
		Total Plant Cover	**49**	**38**	**29**	**36**	**36**	**47**	**33**	**42**	**48**	**33**	**20**	**33**	**21**	**23**	**39**	**35.13**	
		Rock	1	1	1	1	6	0	0	4	1	21	5	7	12	35	6	**6.73**	
		Litter	27	33	27	26	22	31	27	29	26	25	21	16	34	24	11	**25.27**	
		Bare ground	23	28	43	37	36	22	40	25	25	21	54	44	33	18	44	**32.87**	
		Total Non-Noxious Vegetative Cover	**49**	**38**	**29**	**36**	**36**	**47**	**33**	**42**	**48**	**33**	**20**	**33**	**21**	**23**	**39**	**35.13**	
		Total Perennial Cover (noxious weeds excluded)	**45**	**38**	**29**	**36**	**34**	**43**	**31**	**37**	**40**	**27**	**13**	**28**	**20**	**17**	**38**	**31.73**	

	Multiple Hits		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average Cover	Frequency
Grasses																			
P	*Bouteloua curtipendula*	Sideoats Grama													2	17		**1.27**	**13**
P	*Bouteloua gracilis*	Blue Grama	20	30	11	28	26	28	19	19	29	12	9	14	6		6	**17.13**	**93**
P	*Elymus elymoides*	Squirreltail										1						**0.07**	**7**
P	*Hilaria jamesii*	Galleta												4				**0.27**	**7**
Forbs																			
A	*Chenopodium album*	Lambsquarters		1														**0.07**	**7**
A	*Salsola tragus*	Russian Thistle					2	2		7	23	5	8	3	2	1		**3.53**	**60**
Shrubs, Sub-shrubs, Cacti & Trees																			
P	*Atriplex canescens*	Fourwing Saltbush											2					**0.13**	**7**
P	*Chrysothamnus nauseosus*	Rubber Rabbitbrush						3								2	9	**0.93**	**20**
P	*Gutierrezia sarothrae*	Broom Snakeweed	7	1	10	14	5	11		8	8	7	2	6		5	3	**5.80**	**87**
																		Mean	
		Overall Total Hits (LAI)	**76**	**70**	**50**	**78**	**69**	**91**	**52**	**76**	**108**	**58**	**41**	**60**	**31**	**48**	**57**	**64.33**	

Sample Adequacy Calculations	**Plant Cover Mean = 35.13** **t= 1.35** **n = 15** **Variance = 85.55** **n_{min} = 12.54**
Diversity	**Number of Species with ≥1% Average Cover = 4**

P=Perennial A=Annual B=Biennial Nw=Noxious Weed

Table B3 Church Rock Mill - Vegetation Cover - 2013

Shrubland Analog Area

Raw Data

Percent Ground Cover Based on Point-Intercept Sampling

		Transect No.——>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average Cover	Frequency
Grasses																			
P	*Agropyron smithii*	Western Wheatgrass	1															**0.07**	**7**
P	*Bouteloua gracilis*	Blue Grama	14	14	6	10	15	3	6	7	4	13	1	10	6	10	13	**8.80**	**100**
Forbs																			
A	*Chenopodium album*	Lambsquarters	3							1	3	2		5		2	2	**1.20**	**47**
A	*Salsola tragus*	Russian Thistle										3	3			2	1	**0.60**	**27**
Shrubs, Sub-shrubs, Cacti & Trees																			
P	*Artemisia tridentata*	Big Sagebrush	7	7	2	14	16	8	3	8	10	3	4	2	8	6	5	**6.87**	**100**
P	*Atriplex canescens*	Fourwing Saltbush	1															**0.07**	**7**
P	*Ceratoides lanata*	Winterfat									1					1		**0.13**	**13**
P	*Gutierrezia microcephala*	Threadleaf Snakeweed												4			2	**0.40**	**13**
P	*Gutierrezia sarothrae*	Broom Snakeweed	3	5	7	7	6	4	12	9	7	5	2	5	16	5	7	**6.67**	**100**
																		Mean	
		Total Plant Cover	**29**	**26**	**15**	**31**	**37**	**15**	**21**	**25**	**25**	**26**	**10**	**26**	**30**	**26**	**30**	**24.80**	
		Rock	0	6	1	2	0	3	4	0	1	0	1	0	0	0	2	**1.33**	
		Litter	25	34	25	28	27	35	28	27	14	42	30	23	14	26	19	**26.47**	
		Bare ground	46	34	59	39	36	47	47	48	60	32	59	51	56	48	49	**47.40**	
		Total Non-Noxious Vegetative Cover	**29**	**26**	**15**	**31**	**37**	**15**	**21**	**25**	**25**	**26**	**10**	**26**	**30**	**26**	**30**	**24.80**	
		Total Perennial Cover (noxious weeds excluded)	**26**	**26**	**15**	**31**	**37**	**15**	**21**	**24**	**22**	**21**	**7**	**21**	**30**	**22**	**27**	**23.00**	

		Multiple Hits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average Cover	Frequency
Grasses																			
P	*Bouteloua gracilis*	Blue Grama	12	23	5	8	10	3	2	6	4	10		6		4	7	**6.67**	**87**
Forbs																			
A	*Chenopodium album*	Lambsquarters	4								2					3		**0.60**	**20**
A	*Salsola tragus*	Russian Thistle										6	3		1	10		**1.33**	**27**
Shrubs, Sub-shrubs, Cacti & Trees																			
P	*Artemisia tridentata*	Big Sagebrush	13	11	1	26	7	9	5	15	18	3	7	5	4	8	7	**9.27**	**100**
P	*Atriplex canescens*	Fourwing Saltbush	3															**0.20**	**7**
P	*Ceratoides lanata*	Winterfat									1					2		**0.20**	**13**
P	*Gutierrezia microcephala*	Threadleaf Snakeweed												1			8	**0.60**	**13**
P	*Gutierrezia sarothrae*	Broom Snakeweed	4	4	7	11	2	10	21	9	10	9	4	4	14	12	8	**8.60**	**100**
																		Mean	
		Overall Total Hits (LAI)	**65**	**64**	**28**	**76**	**56**	**37**	**49**	**55**	**60**	**54**	**24**	**42**	**49**	**65**	**60**	**52.27**	

Sample Adequacy Calculations	**Plant Cover Mean = 24.80** **t= 1.35** **n = 15** **Variance = 49.31** **n_{min} = 14.51**
Diversity	**Number of Species with ≥1% Average Cover = 4**

P=Perennial A=Annual B=Biennial Nw=Noxious Weed

Table B4 Church Rock Mill Site - Root Density and Depth - 2013

Reclaimed Analog - Pit 1 (Raw Data)

	Number of Roots per Decimeter										Row Total	Avgerage Density	Percent of Total	Cumulative Percent of Total
cm	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**				
10	10	19	18	20	23	14	15	15	13	21	168	16.8	14.58	14.58
20	8	24	30	17	13	8	13	19	13	21	166	16.6	14.41	28.99
30	21	20	24	12	4	10	14	13	8	6	132	13.2	11.46	40.45
40	21	20	18	13	18	7	22	11	12	6	148	14.8	12.85	53.30
50	14	15	24	15	21	11	39	24	14	7	184	18.4	15.97	69.27
60	10	19	19	13	17	8	26	14	3	3	132	13.2	11.46	80.73
70	15	8	12	10	7	8	13	6	4	4	87	8.7	7.55	88.28
80	6	7	4	6	7	5	5	12	9	1	62	6.2	5.38	93.66
90	3	2	3	5	6	8	7	4	6	2	46	4.6	3.99	97.66
100	1	3	3	3	3	4	4	1	4	1	27	2.7	2.34	100.00

Table B5 Church Rock Mill Site - Root Density and Depth - 2013

Reclaimed Analog - Pit 2 (Raw Data)

	Number of Roots per Decimeter										Row Total	Avgerage Density	Percent of Total	Cumulative Percent of Total
cm	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**				
10	17	23	9	10	7	7	10	13	14	8	118	11.8	23.23	23.23
20	2	1	2	9	4	2	12	7	8	4	51	5.1	10.04	33.27
30	10	3	4	0	0	0	2	2	0	2	23	2.3	4.53	37.80
40	4	11	12	1	3	9	9	9	2	3	63	6.3	12.40	50.20
50	8	14	21	4	7	6	8	7	1	6	82	8.2	16.14	66.34
60	5	8	3	10	8	4	8	7	2	3	58	5.8	11.42	77.76
70	7	6	5	4	6	4	6	3	4	3	48	4.8	9.45	87.20
80	3	1	3	2	8	7	1	4	4	3	36	3.6	7.09	94.29
90	1	0	2	1	1	3	4	2	2	1	17	1.7	3.35	97.64
100	1	1	3	0	0	2	0	2	2	1	12	1.2	2.36	100.00

Table B6 Church Rock Mill Site - Root Density and Depth - 2013

Grassland Analog - Pit 1 (Raw Data)

	Number of Roots per Decimeter										Row Total	Avgerage Density	Percent of Total	Cumulative Percent of Total
cm	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**				
10	12	30	40	51	62	65	27	96	63	43	489	48.9	24.99	24.99
20	49	38	44	22	35	35	26	21	27	34	331	33.1	16.91	41.90
30	20	19	19	13	13	13	19	22	25	39	202	20.2	10.32	52.22
40	9	27	16	18	14	14	16	11	11	16	152	15.2	7.77	59.99
50	13	18	17	14	8	8	26	14	14	13	145	14.5	7.41	67.40
60	14	8	12	11	15	15	16	16	23	22	152	15.2	7.77	75.17
70	18	16	21	35	23	23	33	39	37	28	273	27.3	13.95	89.12
80	7	7	4	9	7	7	24	22	12	14	113	11.3	5.77	94.89
90	2	2	6	7	12	12	10	2	15	5	73	7.3	3.73	98.62
100	1	2	0	4	2	2	2	5	4	5	27	2.7	1.38	100.00

Table B7 Church Rock Mill Site - Root Density and Depth - 2013

Grassland Analog - Pit 2 (Raw Data)

	Number of Roots per Decimeter										Row Total	Avgerage Density	Percent of Total	Cumulative Percent of Total
cm	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**				
10	38	27	28	18	25	23	21	20	12	24	236	23.6	15.06	15.06
20	8	10	10	15	20	27	19	13	24	29	175	17.5	11.17	26.23
30	4	8	2	19	17	26	8	12	21	22	139	13.9	8.87	35.10
40	11	8	9	19	12	12	11	7	9	19	117	11.7	7.47	42.57
50	7	6	14	11	25	25	15	18	26	9	156	15.6	9.96	52.52
60	6	2	5	8	20	5	15	25	10	22	118	11.8	7.53	60.05
70	17	23	18	24	33	20	22	65	38	25	285	28.5	18.19	78.24
80	15	24	8	19	12	8	11	53	14	13	177	17.7	11.30	89.53
90	15	27	22	7	4	5	7	9	8	6	110	11	7.02	96.55
100	6	2	8	13	3	7	3	9	3	0	54	5.4	3.45	100.00

Table B8 Church Rock Mill Site - Root Density and Depth - 2013

Shrubland Analog - Pit 1 (Raw Data)

	Number of Roots per Decimeter										Row Total	Avgerage Density	Percent of Total	Cumulative Percent of Total
cm	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**				
10	20	26	27	23	33	28	15	15	56	47	290	29	22.45	22.45
20	14	19	11	24	18	33	23	20	29	23	214	21.4	16.56	39.01
30	12	16	19	11	27	21	19	27	20	13	185	18.5	14.32	53.33
40	7	5	12	13	12	12	10	14	13	11	109	10.9	8.44	61.76
50	7	1	5	7	18	15	17	13	4	10	97	9.7	7.51	69.27
60	12	8	8	19	19	11	14	4	6	8	109	10.9	8.44	77.71
70	12	6	9	20	9	2	5	8	11	3	85	8.5	6.58	84.29
80	4	4	8	10	14	5	1	2	9	14	71	7.1	5.50	89.78
90	7	10	5	18	14	9	8	8	3	2	84	8.4	6.50	96.28
100	7	5	3	8	5	8	2	1	5	4	48	4.8	3.72	100.00

Table B9 Church Rock Mill Site - Root Density and Depth - 2013

Shrubland Analog - Pit 2 (Raw Data)

	Number of Roots per Decimeter										Row Total	Avgerage Density	Percent of Total	Cumulative Percent of Total
cm	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**				
10	19	24	14	20	24	12	8	16	27	38	202	20.2	18.45	18.45
20	9	19	18	8	27	15	19	14	37	31	197	19.7	17.99	36.44
30	8	15	11	12	10	21	18	14	22	19	150	15	13.70	50.14
40	12	11	7	4	4	6	5	6	12	18	85	8.5	7.76	57.90
50	1	8	5	3	4	4	2	11	8	21	67	6.7	6.12	64.02
60	13	9	4	11	12	10	10	8	17	19	113	11.3	10.32	74.34
70	7	11	8	7	16	8	10	6	9	14	96	9.6	8.77	83.11
80	9	12	10	5	6	3	5	7	13	9	79	7.9	7.21	90.32
90	2	5	8	4	15	13	6	5	10	1	69	6.9	6.30	96.62
100	2	3	1	3	6	7	2	3	4	6	37	3.7	3.38	100.00

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Appendix C

Photos

Plate 1 – Reclaimed Analog Area – 2013

Plate 2 – Grassland Analog Area – 2013

Plate 3 – Shrubland Analog Area – 2013

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Appendix D

Soil Survey

1.0 Soil Survey Methods

Standard soil survey methods were used throughout the study. Soils mapping, description, sampling, and classification were conducted in accordance with the standards and procedures of the National Cooperative Soil Survey (Soil Survey Staff, 1993, 1994, 1999; and Schoeneberger et.al., 2002) and the New Mexico Mining and Minerals Division Closeout Plan Guidelines for Existing Mines Attachment 1 - Soil and Topsoil suitability ratings (NM MMD, 1996), as well as the New Mexico Overburden and Soils Inventory and Handling Guidelines (EMNRD 2009).

Soil Sampling was conducted at the order 3 level by a Cedar Creek soil scientist. Soils were exposed with a backhoe, and examined on the pit wall. Soil samples from each major horizon and sub horizon were collected from each of the 6 pits.

2.0 RESULTS

2.1 Study Area Soil Characterization

The Natural Resource Conservation Service (NRCS) McKinley County Soil Survey (USDA SCS 2001) lists the soils located within proposed borrow sources, vegetation analog sites, and root density study areas as Buckle Silt Loams. The NRCS series designation was fairly accurate at describing the observed NECR sites, with few slight deviations from the general description in isolated instances. The Buckle taxonomic classification is listed as fine-loamy, mixed, superactive, mesic Ustic Haplargids. The Buckle series consists of very deep, well drained soils that formed in moderately fine textured alluvium, fan alluvium, and slope alluvium derived from shale and sandstone. Buckle soils are on dipslopes of cuestas, fan terraces and fan remnants on valley sides, drainage ways, hills and ridges and have slopes of 0-8 percent. The mean annual precipitation is about 11 inches, and the mean annual temperature is about 49 degrees F. The following is a general description of the Buckle series soil profile, followed by site specific observations made in the field.

A--0 to 2 inches; brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; weak thin platy structure; soft, friable, slightly sticky and plastic; few fine roots; few fine pores; slightly alkaline (pH 7.6); abrupt smooth boundary. (2 to 4 inches thick)

BA--2 to 5 inches; brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak medium and fine subangular blocky structure; slightly hard, friable, slightly sticky and plastic; few fine and medium roots; few fine pores; slightly alkaline (pH 7.6); clear smooth boundary. (0 to 5 inches thick)

Bt1--5 to 13 inches; brown (10YR 5/3) clay loam, dark brown (10YR 3/3) moist; weak medium and coarse prismatic structure parting to weak medium and fine subangular blocky; hard, firm, sticky and plastic; few fine roots; few fine pores; many moderately thick clay films on faces of peds; moderately alkaline (pH 8.1); clear smooth boundary. (6 to 10 inches thick)

Bt2--13 to 29 inches; brown (10YR 5/3) silty clay loam, dark brown (10YR 3/3) moist; weak medium prismatic structure parting to weak medium and fine subangular blocky; very hard, firm, sticky and plastic; few very fine roots; few very fine pores; common moderately thick clay films on faces of peds; moderately alkaline (pH 8.2); clear smooth boundary. (12 to 20 inches thick)

Btk--29 to 44 inches; brown (10YR 5/3) clay loam, brown (10YR 4/3) moist; weak fine and medium subangular blocky structure; very hard, firm, sticky and plastic; few very fine roots; few very fine pores; strongly effervescent; few fine calcium carbonate accumulations; few thin clay films on faces of peds; moderately alkaline (pH 8.4); abrupt smooth boundary. (10 to 21 inches thick)

Bk1--44 to 50 inches; pale brown (10YR 6/3) silty clay loam, brown (10YR 4/3) moist; massive; very hard, firm, sticky and plastic; strongly effervescent; few fine calcium carbonate accumulations; moderately alkaline (pH 8.4); clear smooth boundary.

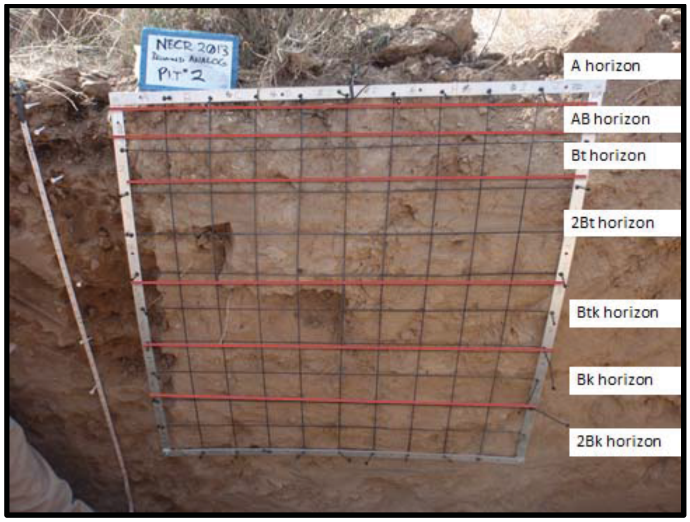
Bk2--50 to 60 inches; light brownish gray (10YR 6/2) silty clay loam, grayish brown (10YR 5/2) moist; massive; very hard, firm, sticky and plastic; strongly effervescent; few fine calcium carbonate accumulations; strongly alkaline (pH 8.6). (The combined thickness of the Bk horizons are 0 to 16 inches thick)

2.2 Reclaimed Analog

The Reclaimed Analog was located in a previous borrow source, that was last disturbed approximately ten to twenty years ago, and deviates significantly from the Buckle series due to the anthropogenic disturbance. The exact amount of material removed from this area and the type of disturbance in relative proximity to our specific sample locations is unknown. In the Reclaimed Analog, species adjacent to the excavation pit walls were predominantly alkali sacaton *(Sporobolus airoides)*, with one small rubber rabbitbrush (*Chrysothamnus nauseosus)* and a few distant fourwing saltbush *(Atriplex canescens)*. A photo of Pit 2 in the Reclaimed Analog site is presented below.

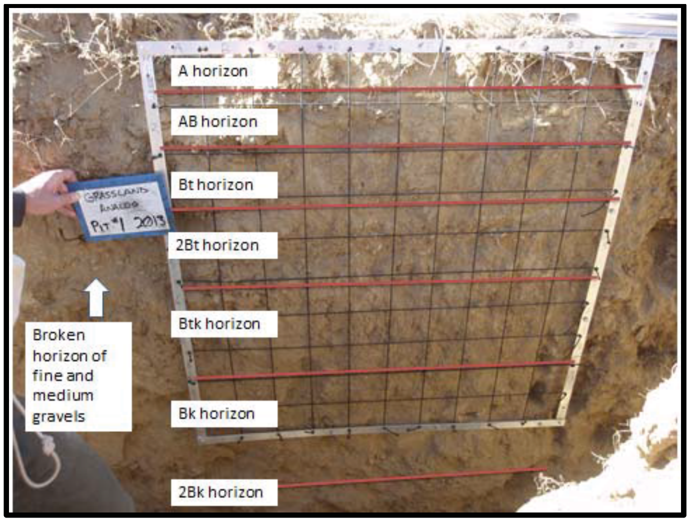
Pit 2 of the Reclaimed Analog had a very similar soil profile relative to the native areas in terms of horizon designation and order. Although, the thickness of the A, AB, and B_t horizons was much thinner than in the native, with wavy boundaries rather than smooth boundaries. Also, the reclaimed area was lacking a B_{tk} horizon, showing an abrupt change from clay dominated to calcium carbonate dominated horizonation at 27 inches depth, considerably shallower than the average native B_k horizon boundary of 35.5 inches. The thin horizonation, wavy horizon boundary, and lack of transition between the silica and carbonate dominated B horizons suggests that this reclaimed area may represent very well what the pedogenesis and root profile may look like several decades/centuries after vegetation establishment on the repository.

Pit 1 of the Reclaimed Analog did not have a similar soil profile to the native Analog sites, although Pit 1 did show a similar A horizon underlain by a B_t horizon, with the B_k horizon beginning at 15 in depth, again with no transitional layer between the dominant horizons.



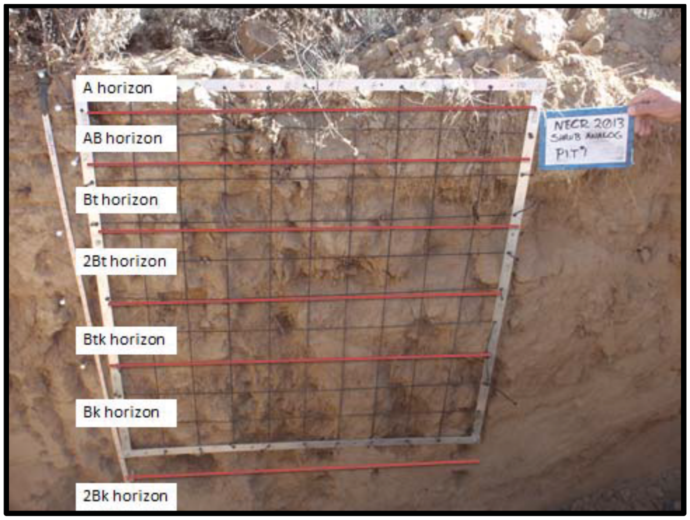
2.3 Grass Analog

The NRCS soil survey was fairly accurate at describing the soils located in the Grass Analog site. The overall order, nature, and physical and chemical properties of the horizons listed for the Buckle Series was accurate. The depth at which these horizons begin and end do vary, but the variability is mostly within the bounds of the NRCS descriptions. During field observations, the B_k horizons were found to be thicker, ranging from 19-31 inches thick. Also, thin and short broken horizons of poorly sorted fine and medium gravels were found at approximately twelve inches depth in both Grass Analog sites. Other than these two deviations, soils within the aforementioned study areas fit the general description of the Buckle series. In the Grass Analog, species adjacent to the pit wall were predominantly blue grama *(Bouteloua gracilis)* with a few scattered Russian thistle *(Salsola tragus)* and a lone fourwing saltbush. A photo of Pit 1 in the Grass Analog site is presented below.



2.4 Shrub Analog

The soil survey was fairly accurate at describing the soils located in the Shrub Analog site. The overall order, nature, and physical and chemical properties of the horizons listed for the Buckle Series was accurate. The depth at which these horizons begin and end do vary, but the variability is mostly within the bounds of the NRCS descriptions. During field observations, the B_k horizons were noted to be thicker, from 19-31 inches thick. Other than this one deviation, soils within the aforementioned study areas fit the general description of the Buckle series. In the Shrub Analog, species adjacent to the pit wall were predominantly big sagebrush *(Artemisia tridentata)* with some Russian thistle and sparse but patchy blue grama. A photo of Pit 1 in the Shrub Analog site is presented below.



3.0 LITERATURE CITED

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