SWCA ENVIRONMENTAL CONSULTANTS
Sound Science. Creative Solutions.®

Field Sampling of Biotic Turbation of Soils at the Clive Site, Tooele County, Utah

Prepared for

EnergySolutions

Prepared by

SWCA Environmental Consultants

January 2011

FIELD SAMPLING OF BIOTIC TURBATION OF SOILS AT THE CLIVE SITE, TOOELE COUNTY, UTAH

Prepared for

EnergySolutions
423 West 300 South
Suite 200
Salt Lake City, Utah 84101

Prepared by

Hope Hornbeck, Bridget Crokus, Eleanor Gladding, Amanda Childs

SWCA Environmental Consultants
257 East 200 South
Suite 200
Salt Lake City, Utah 84111

January 12, 2010

CONTENTS

APPENDICES

FIGURES

TABLES

MAPS

1 INTRODUCTION

EnergySolutions operates a mixed-waste nuclear disposal facility at their Clive Site in Clive, Utah on privately-owned lands. Nuclear waste emits radiation for thousands of years. Over the course of time entire landscapes may change due to biologic, climatic, and geologic shifts. Because site conditions may radically change before nuclear waste is entirely depleted, careful consideration must be given to projections of future site conditions.

Waste products at the Clive Site are buried in an impermeable clay layer and covered with concrete. Small amounts of radiation may be absorbed by surrounding soils. Soil turbation (mixing) by plants and animals is a potentially important pathway through which buried waste can be transported to the soil surface or to different layers of the subsurface soil profile. Studies indicate that ants, burrowing mammals, and deeply rooted plants are the primary biota of interest for movement and mixing of soils in arid ecosystems. Ants and burrowing mammals provide constant mixing of the soil column, whereas plants can move buried wastes through root uptake and translocation of contaminants to various parts of the plant.

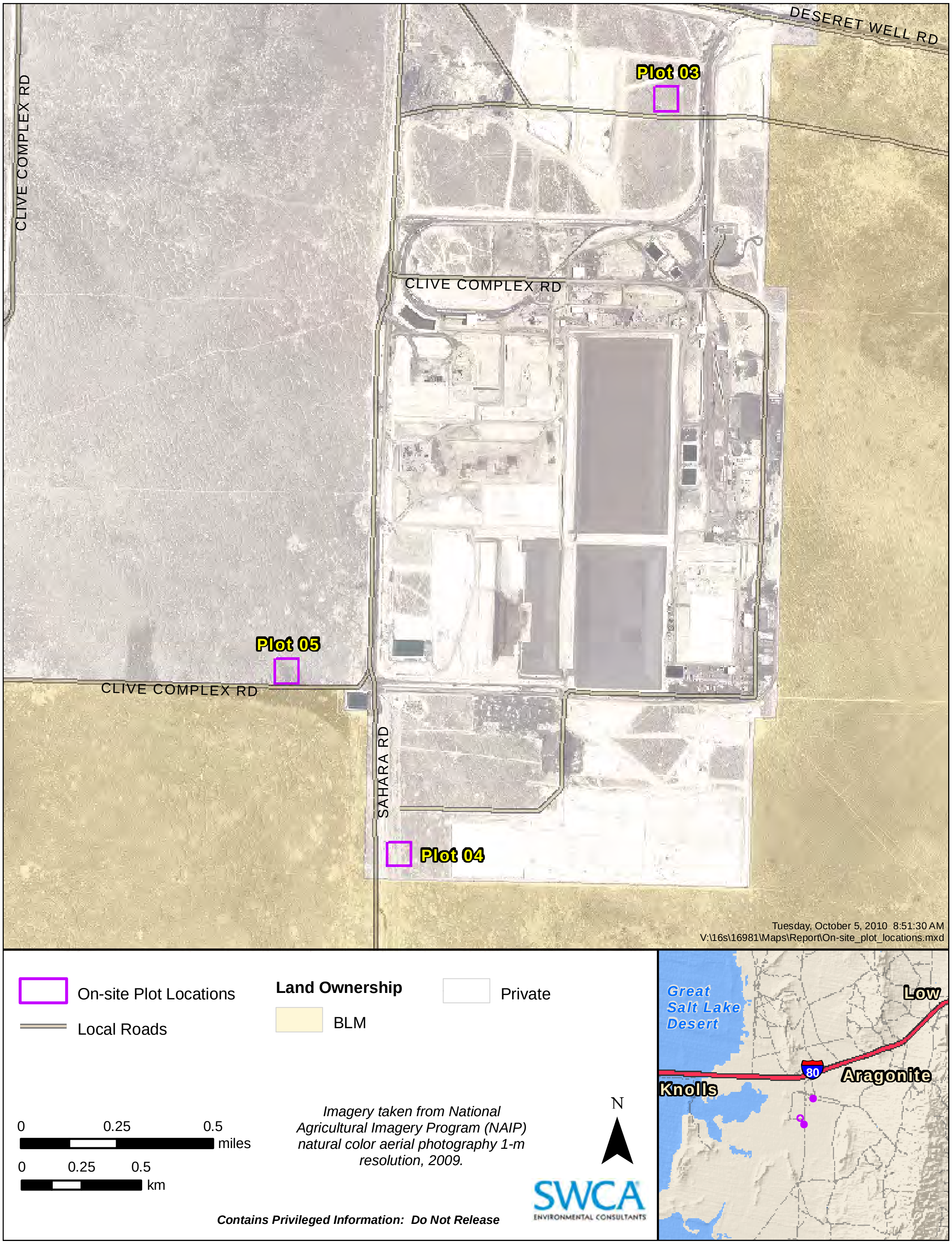
SWCA Environmental Consultants (SWCA) was contracted by Energy*Solutions* to gather soil turbation data at five sites in and around the Clive Site. Sites were established in three locations at the Clive Site, and two locations off the Clive site on lands administered by the Bureau of Land Management (BLM).

SWCA's field sampling objectives were to 1) identify ant species present and nest density of each species, and quantify surface features of each nest; 2) identify plant species present and estimate the percent cover and stem densities of grasses, forbs, shrubs, and trees in each vegetative association; and 3) identify burrowing mammal species present and density of mammal burrows in each vegetative association, and quantify volume of soil excavated at each mammal burrow. In addition to the field sampling objectives, site excavations were conducted at six locations in two field plots (Plot 3 and Plot 4) located on the Clive Site. The objective of the site excavations was to measure the aboveground and belowground biomass of dominant plant species, and to determine the maximum rooting depth and width of root masses for dominant plant species.

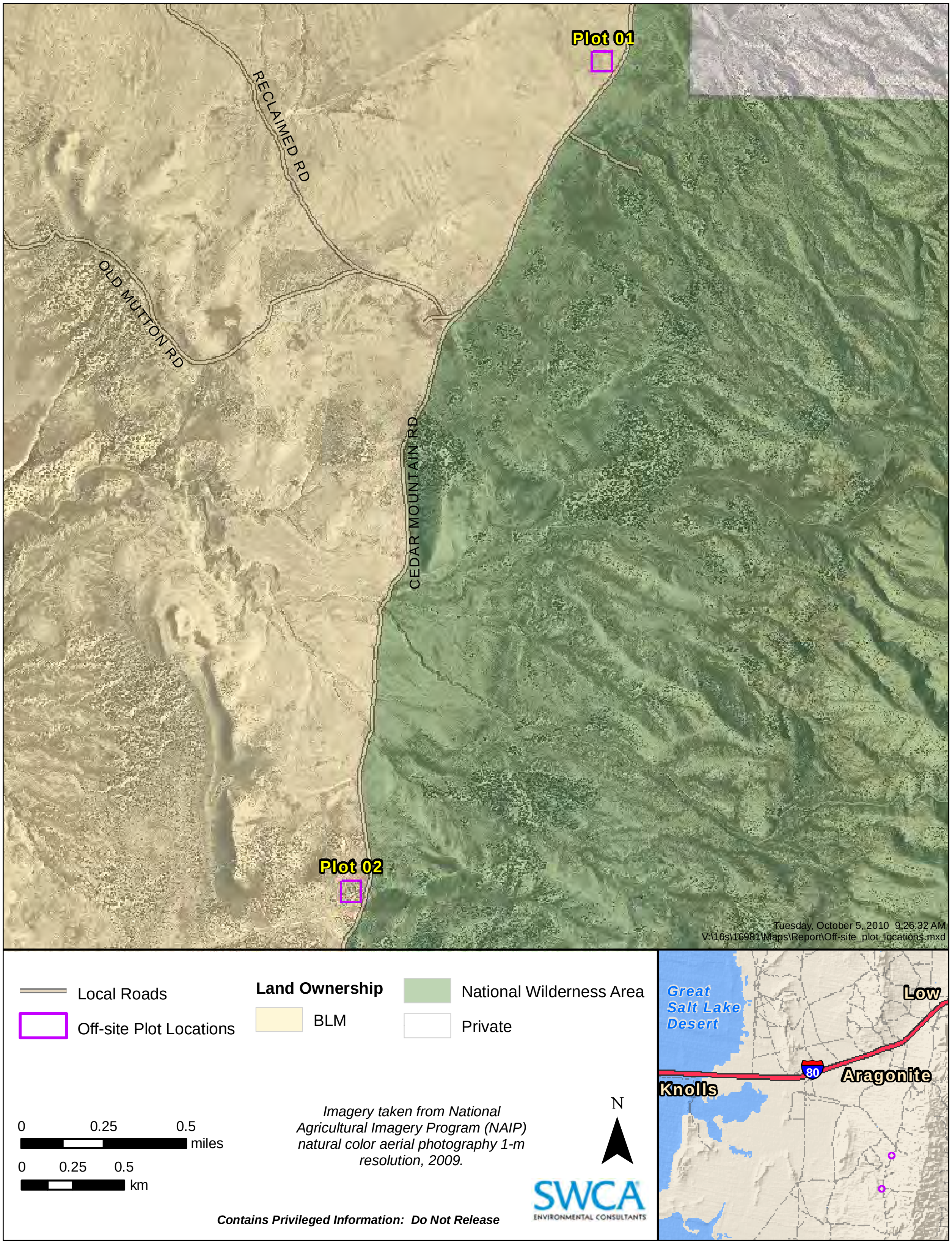
The following report presents the field sampling data. These results, along with other variables, will be placed into a predictive landscape model currently being developed by Neptune and Company, Inc. Once complete, the model will contribute understanding of future conditions at the Clive Site.

1.1 Field Sampling Locations

Field sampling was conducted in September and October 2010 in five 1-ha plots (100 × 100 m; 10,000 m^2) that were each subdivided into four 50 × 50–m subplots. Field plots were oriented from north to south. Three plots were established in each of the three primary vegetation associations present at the Clive Site: 1) shadscale–gray molly, 2) black greasewood, and 3) halogeton-disturbed (Map 1). Two plots were established off of the Clive Site in vegetation associations that represent 1) potential vegetation on elevated soil mounds with lower soil salinities, and/or 2) potential future climatic conditions that would be cooler than present-day conditions at the Clive Site (Map 2). The two off-site field plots were on lands administered by the BLM: one in a mixed grassland association and one in a juniper-sagebrush association. Additional field sampling of plant stem densities was conducted on December 13, 2010.



Map 1. On-site field plots.



Map 2. Off-site field plots.

2 RESULTS

Five field plots were established: three in the primary vegetation associations present at the Clive Site (shadscale–gray molly, black greasewood, and halogeton-disturbed), and two in nearby upland areas (mixed grassland and juniper-sagebrush).

2.1 Vegetation

Vegetation sampling was performed from September 30 through October 12, 2010. In each field plot, two of the four subplots were randomly selected for sampling. Five 50-m-long transects were oriented south to north every 10 m from the southeastern corner of the subplot. Ten 1-m^2 sampling quadrats were sampled at 0, 5, 10, 15, 20, 25, 30 35, 40 and 45 m along each 50-m transect for a total of 50 sample quadrats per subplot, or 100 quadrats per plot (100 m^2 or 1% of each 10,000 m^2 plot area).

Plot 1 (mixed grassland) and Plot 2 (juniper-sagebrush) were located to the southeast of the Clive Site on BLM-administered lands. Plots 3 and 4 (black greasewood and halogeton-disturbed) were located in the Clive Site. Plot 5 (shadscale–gray molly) was located immediately west of the Clive Site on adjacent private property.

Additional field sampling of plant stem densities was performed on December 13, 2010. In each plot, one transect comprised of 10 quadrats was randomly selected in each of the previously sampled plot quadrants. A total of 100 quadrats, or 20 quadrats per plot, were sampled and vegetation cover and stem densities were recorded for each species in each quadrat. Stem counts were made as follows: individual shrubs were counted as 1 stem; perennial bunchgrasses were counted as 1 stem; annual grass culms (grass stems) were each counted as 1 stem; and annual forb species were counted where plant condition allowed counting. Plants were counted only if rooted in the plot. Bunch grasses were counted if 50% or more of the plant base was rooted in the plot. From these data we modeled species-specific relationships between percent cover and plant density and used the model parameters to calculate stem densities from percent cover for the entire data set.

Forty-one plant species were identified in the five field plots. Because many desert forbs are spring ephemerals and field sampling was conducted at the end of the growing season, the plant species diversity and cover, particularly for herbaceous forbs, is underrepresented. Of the few forb species that were detected during vegetation cover sampling, all were dead or senesced, with the exception of *Halogeton* (*Halogeton glomeratus*), a late-season invasive annual weed.

Biological soil crusts are a dominant feature of vegetation communities throughout the Great Salt Lake basin. Soil crusts were present in all five vegetation associations sampled, but were more prevalent in the low desert vegetation associations (e.g., black greasewood, haltogeton-disturbed, and shadscale-gray molly) present on and adjacent to the Clive Site.

2.1.1 Plot 1: Mixed Grassland

Plot 1 comprised a mix of native and non-native grass species with a few scattered shrubs and forbs (Figure 1, Table 1). The ground cover was dominated by biological soil crust (52%). Twenty plant species were recorded. Eleven species of grass, dominated by needle-and-thread grass (*Hesperostipa comata*), comprised approximately 25% of total cover. The mixture of primarily desirable non-native grass species present in Plot 1 and surrounding grasslands is the result of recent fire disturbance and subsequent seeding with a mixture of needle-and-thread, intermediate wheatgrass (*Thinopyrum intermedium*), bluegrass (*Poa* spp.), crested wheatgrass (*Agropyron cristatum*), tall wheatgrass (*Thinopyrum ponticum*), slender wheatgrass (*Elymus trachycaulus*), western wheatgrass (*Pascopyrum smithii*), and other species. The reseeded area covers a large portion of uplands surrounding the Clive Site, and these desirable non-native grass species have become established in the area and are likely to persist.

Table 1. Plot 1 Average Vegetation Percent Cover, Ground Cover, and Stem Densities (plants per $100m^2$; nd = no data)

Cover Type	Name	Percent Cover	Plants / $100m^2$
Shrubs	Broom snakeweed	2.0%	48.6
Forbs	Bur buttercup	2.2%	nd
Grasses	Needle-and-thread grass	12.3%	495.6
	Cheatgrass	3.7%	20,783.5
	Intermediate wheatgrass	2.6%	47.9
	Sandberg bluegrass	2.3%	360.4
	Crested wheatgrass	1.6%	37.3
	Slender wheatgrass	1.1%	111.5
	Tall wheatgrass	1.1%	13.5
	Western wheatgrass	1.0%	nd
	Indian ricegrass	0.7%	39.2
Ground Cover	Biological soil crust	51.6%	
	Plant litter	16.1%	
	Bare ground	1.7%	
Total		**100.0%**	

Figure 1. Mixed grassland vegetation association (Plot 1).

2.1.2 Plot 2: Juniper-sagebrush

Plot 2 comprised an overstory of Utah juniper (*Juniperus osteosperma*; 6.2%) with a multilayered mid-level canopy of big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*; 17.1%), and a subcanopy of broom snakeweed (*Gutierrezia sarothrae*; 1.0%), grasses (9.8%), and forbs (1.4%) (Figure 2, Table 2). This plot was the most diverse of the five field plots with 25 plant species recorded. The ground cover was dominated by biological soil crust (44.9%) and plant litter (23.5%), with some bare ground (9.9%) where game and livestock trails pass through the plot.

Table 2. Plot 2 Average Vegetation Percent Cover, Ground Cover, and Stem Densities (plants / 100 m^2; nd = no data)

Cover Type	Name	Percent Cover	Plants / 100 m^2
Trees	Utah juniper	6.2%	7.0
Shrubs	Big sagebrush	17.1%	36.9
	Broom snakeweed	1.0%	24.7
	Varying buckwheat	0.3%	11
	Prickly phlox	0.3%	9
	Spiny hopsage	0.2%	1
Forbs	Curveseed buttercup	1.2%	nd
	Globemallow	0.1%	nd
	Milkvetch	0.1%	nd
Grasses	Cheatgrass	3.7%	20,417.6
	Needle-and-thread grass	2.9%	128.3
	Muttongrass	1.4%	207.7
	Bluebunch wheatgrass	0.6%	23.1
	Sangberg bluegrass	0.6%	170.7
	Fringed fescue	0.4%	16,045.9
	Indian ricegrass	0.2%	17.0
Ground Cover	Biological soil crust	44.9%	
	Plant litter	23.5%	
	Bare ground	9.9%	
Total		**100.0%**	

Figure 2. Juniper-sagebrush vegetation association (Plot 2).

2.1.3 Plot 3: Black Greasewood

Plot 3 comprised primarily black greasewood (*Sarcobatus vermiculatus*; 4.5%) and halogeton (0.7%) (Figure 3, Table 3). The ground cover was dominated by biological soil crust (84.8%). Six plant species were recorded within the sample quadrats. Total cover was greater than 100% in some areas due to the presence of a shrub overstory. Total cover is slightly less than 100% due to rounding error.

Table 3. Plot 3 Average Vegetation Percent Cover, Ground Cover, and Stem Densities (plants / 100 m^2; nd = no data)

Cover Type	Name	Percent Cover	Plants / 100m^2
Shrubs	Black greasewood	4.5%	11.5
	Mojave seablite	0.3%	6.6
	Gray molly	0.2%	34.4
	Shadscale saltbush	0.1%	16.4
Forbs	Halogeton	0.7%	720.5
	Fivehook smotherweed	<0.1%	1.5
Ground Cover	Biological soil crust	84.8%	
	Plant litter	6.1%	
	Bare ground	2.3%	
Total		**99.1%**	

Figure 3. Black greasewood vegetation association (Plot 3).

2.1.4 Plot 4: Halogeton-disturbed

Plot 4 comprised scattered native shrubs (5.2%) and halogeton (3.3%) (Figure 4, Table 4). The ground cover is dominated by biological soil crust (85.6%). Nine plant species were recorded. Crested wheatgrass and squirreltail (*Elymus elymoides*) are not included in Table 4 because they were detected at trace levels (less than 0.005%). Total cover was slightly less than 100% due to rounding error.

Table 4. Plot 4 Average Vegetation Percent Cover, Ground Cover, and Stem Densities (plants / 100 m^2; nd = no data)*

Cover Type	Name	Percent Cover	Plants / 100m^2
Shrubs	Shadscale saltbush	2.3%	107.2
	Mojave seablite	1.5%	19.3
	Gray molly	1.2%	68.9
	Black greasewood	0.2%	0.4
Forbs	Halogeton	3.3%	3534.0
	Fivehook smotherweed	0.5%	28.9
	Bur buttercup	<0.1%	nd
Ground Cover	Biological soil crust	85.6%	
	Plant litter	4.3%	
	Bare ground	0.2%	
Total		**99.2%**	

*Two plant species were detected at trace levels (<0.01%): squirreltail and crested wheatgrass.

Figure 4. Halogeton-disturbed vegetation association (Plot 4).

2.1.5 Plot 5: Shadscale–Gray Molly

Plot 5 comprised native shrubs (13.3%) and scattered weeds (1.1%) (Figure 5, Table 5). The ground cover is dominated by biological soil crust (70.7%) and plant litter (11.7%). Fifteen plant species were recorded. Nine of these plant species are listed in the footnote in Table 5 because they were detected at trace levels (less than 0.01%). Total cover was slightly greater than 100% due to the presence of a shrub overstory.

Table 5. Plot 5 Average Vegetation Percent Cover, Ground Cover, and Stem Densities (plants / 100 m^2; nd = no data)*

Cover Type	Name	Percent Cover	Plants / 100m^2
Shrubs	Shadscale saltbush	12.5%	430.1
	Gray molly	0.6%	34.7
	Black greasewood	0.2%	0.6
Forbs	Halogeton	0.9%	959.1
	Bur buttercup	0.1%	nd
Grasses	Cheatgrass	0.1%	126.1
Ground Cover	Biological soil crust	70.7%	
	Plant litter	11.7%	
	Bare ground	3.8%	
Total		**100.6%**	

Nine plant species were detected at trace levels (<0.01%): squirreltail, fivehook smotherweed, rockcress sp., burningbush, alkali birdsbeak (*Cordylanthus maritimus*), broom snakeweed, Sandberg bluegrass, Mojave seablite, and an unknown forb species.

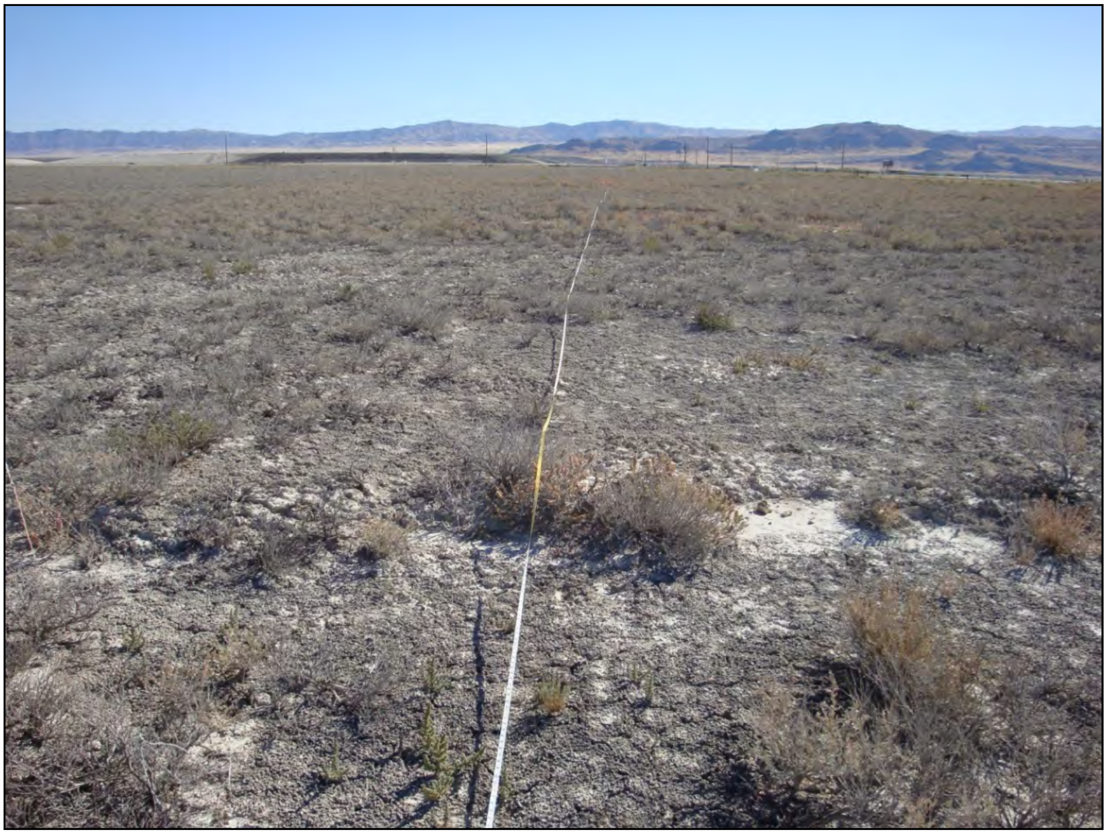


Figure 5. Shadscale–gray molly vegetation association (Plot 5).

2.1.6 Plant Root Densities and Rooting Depths

Excavations were conducted to examine the root density and maximum rooting depth of dominant plant species on the Clive Site. Excavations were performed in the two plots on the Clive Site: Plot 3 (black greasewood) and 4 (halogeton-disturbed). Three excavation locations were selected in each plot and excavated using a backhoe. Six locations were excavated.

Figure 6. Mojave seablite biomass measurements in Plot 4.

The focus of the excavations was to obtain cross-sections of the rooting mass of dominant plant species in each field plot. The roots were carefully exposed by gradual removal of vertical layers of soil with the backhoe and hand tools. Root density measurements were collected by measuring the width of the rooting mass and by counting visible roots across a set of sample widths or for the entire width of the root mass. Root density measurements were taken at the soil surface and at 10 cm increments until no roots could be detected. Roots were continuous at just below the soil surface in all excavated soil profiles. A summary of the average root densities and maximum rooting depth of dominant plant species in Plots 3 and 4 is given in Table 6.

Root densities were higher near the surface of the soil, where roots were mostly fibrous with few woody structures. A few large, woody roots were encountered in deeper soils. Rooting depths were shallower than expected, with the maximum rooting depth of dominant woody plant species ranging from 40 to 70 cm. Woody plant species maximum rooting depths were proportional to aboveground plant mass with an aboveground height:root depth ratio of 1:1 and an aboveground width:root depth ratio of approximately 1.4:1. The herbaceous dominant in Plot 4, halogeton, had higher ratios of plant height and width to maximum rooting depth (1.4:1 and 1.7:1, respectively). The low proportion of roots to aboveground biomass is expected for annual plants, which invest the bulk of their energy in reproduction and little energy in root systems.

Table 6. Average root density (roots per cm) and maximum rooting depth (cm) of dominant plant species in Plots 3 and 4

	Plot 3			Plot 4		
	Excavation Number			Excavation Number		
	1	2	3	1	2	3
Rooting Depth (cm)	**Black greasewood roots/cm**					
0	2.7	0.9	1.8	–	–	–
10	2.7	2.0	0.9	–	–	–
20	0.7	0.4	0.4	–	–	–
30	0.3	0.2	0.2	–	–	–
40	0.1	0.2	0.2	–	–	–
50	0.2	0.1	0.0	–	–	–
60	0.1	0.2	0.0	–	–	–
70	2.0	0.0	–	–	–	–
80	0.0	–	–	–	–	–
Rooting Depth (cm)				**Halogeton roots/cm**		
0	–	–	–	–	–	2.0
10	–	–	–	–	–	2.0
20	–	–	–	–	–	0.2
30	–	–	–	–	–	0.0
Rooting Depth (cm)				**Mojave seablite roots/cm**		
0	–	–	–	–	2.4	–
10	–	–	–	–	0.5	–
20	–	–	–	–	0.5	–
30	–	–	–	–	0.2	–
40	–	–	–	–	0.1	–
50	–	–	–	–	0.0	–
Rooting Depth (cm)				**Shadscale saltbush roots/cm**		
0	–	–	–	2.0	2.0	1.6
10	–	–	–	2.0	0.5	0.9
20	–	–	–	0.7	0.3	0.5
30	–	–	–	0.5	0.2	0.2
40	–	–	–	0.1	0.1	0.3
50	–	–	–	0.3	0.0	0.0
60	–	–	–	2.0	–	–
70	–	–	–	0.3	–	–
80	–	–	–	0.0	–	–

In Plot 3, a compacted layer of clay was encountered at approximately 60 cm depth in all three excavation sites. Plant roots spread out laterally across the top of this dense clay layer that appears as a smooth line of soil across the bottom of the soil cross section in Figure 7.

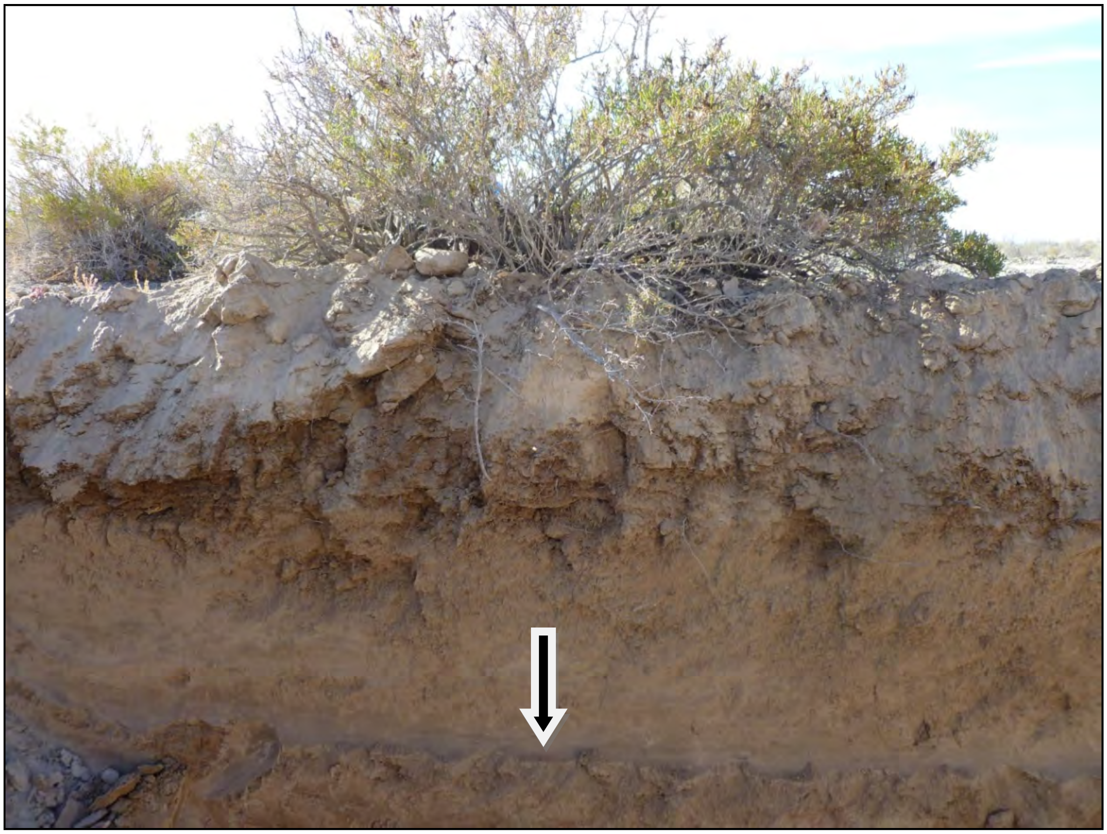


Figure 7. Plot 3 soil cross section with compacted clay layer at approximately 60 cm depth.

2.2 Mammals

2.2.1 Mammal Trapping

Each 1.0-ha plot was subdivided into 25 20 × 20–m subplots. At the center of the each subplot, two Sherman® live traps were placed, for a total of 50 traps per plot. Of the 50 traps, 37 were large traps (approximately 8 × 8 × 23 cm) and 13 were extra-large traps (approximately 10 × 10 × 40 cm). One large trap was placed at each trapping station and one extra-large trap was placed at every other station. The remaining stations had one additional large trap placed in them. Figure 8 illustrates the trapping station design.

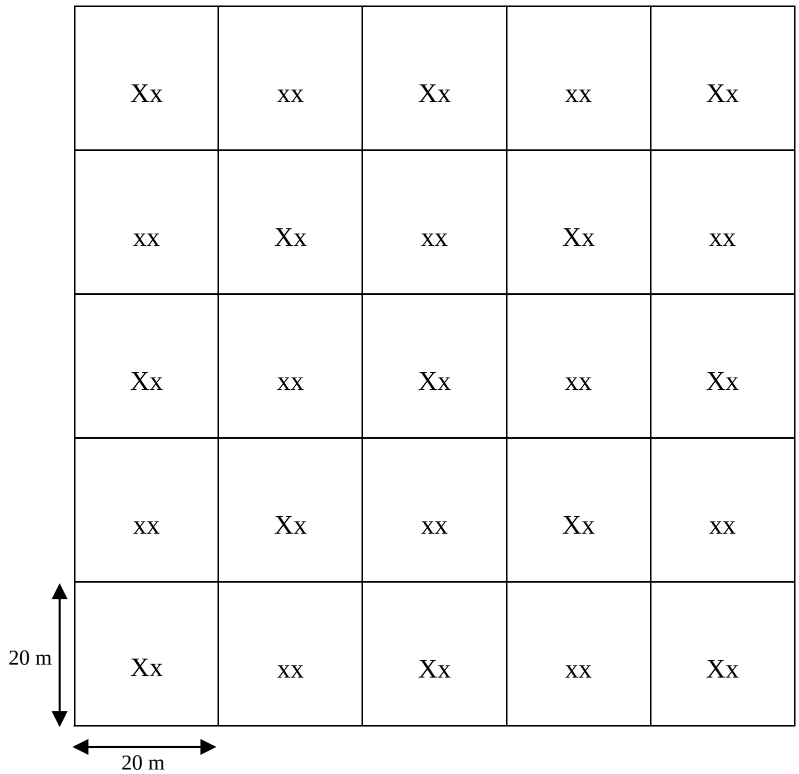


Figure 8. Trapping station layout, where X represents extra-large traps and x represents large traps.

The traps were placed at trapping stations for a minimum of three days prior to the beginning of trapping efforts in order to acclimate the animals to the presence of the traps. The traps were set during the week of the new moon (October 4–7, 2010) before dusk, and checked the following mornings. The traps were baited with a four-grain horse feed rolled in molasses. Cotton balls were also placed in the traps to be used as bedding by any captured small mammal.

Captured mammals were identified to species and released. Mouse species were marked with nail polish before release; however, kangaroo rats did not tolerate the marking process. Additionally, during the course of trapping, it became apparent that at least some mice were chewing off the mark or pulling out marked fur, making recapture information difficult to obtain. For these reasons, no attempts to analyze recapture data were made.

2.2.1.1 PLOT 1

The mixed grassland plot yielded three species of small mammal: deer mouse (*Peromyscus maniculatus*), northern grasshopper mouse (*Onchomys leucogaster*), and Great Basin kangaroo rat (*Dipodomys microps*). Deer mice accounted for 22 of the 24 captured mammals (92%). One northern grasshopper mouse and one Great Basin kangaroo rat were captured. Northern grasshopper mice were only trapped at Plot 1. Plot 1 experienced the only mortalities during trapping (13% of captures). No cause of death was apparent in any of the three mortalities. Table 7 summarizes the mammal captures at Plot 1.

Table 7. Summary of Species Captured, Number of Individuals Recaptured, and Number Found Deceased in Trap in Plot 1

Species	Captured	Recaptured	Deceased
10/5/2010			
P. maniculatus	4	0	0
Subtotal	*4*	*0*	*0*
10/6/2010			
P. maniculatus	4	0	1
Subtotal	*4*	*0*	*1*
10/7/2010			
D. microps	1	0	0
O. leucogaster	1	n/a	0
P. maniculatus	6	3	1
Subtotal	*8*	*3*	*1*
10/8/2010			
P. maniculatus	8	4	1
Subtotal	*8*	*4*	*1*
Total	**24**	**7**	**3**

2.2.1.2 PLOT 2

The most individuals (43) were captured at the juniper-sagebrush plot. Deer mice comprised 84% of the captures, Great Basin kangaroo rats 14%, and Ord's kangaroo rat (*D. ordii*) 2%. Ord's kangaroo rats were captured only at this site. One deer mouse gave birth to four live young in a trap. Table 8 summarizes the mammal captures at Plot 2.

Table 8. Summary of Species Captured, Number of Individuals Recaptured, and Number Found Deceased in Trap in Plot 2

Species	Captured	Recaptured	Deceased
10/5/2010			
P. maniculatus	7	0	0
Subtotal	*7*	*0*	*0*
10/6/2010			
P. maniculatus	8	2	0
Subtotal	*8*	*2*	*0*
10/7/2010			
D. microps	3	n/a	0

Table 8. Summary of Species Captured, Number of Individuals Recaptured, and Number Found Deceased in Trap in Plot 2

Species	Captured	Recaptured	Deceased
D. ordii	1	n/a	0
P. maniculatus	10	0	0
Subtotal	*14*	*0*	*0*
10/8/2010			
D. microps	3	n/a	0
P. maniculatus	11	3	0
Subtotal	*14*	*3*	*0*
Total	**43**	**5**	**0**

2.2.1.3 PLOT 3

Two deer mice were captured in the black greasewood plot. Table 8 summarizes the mammal captures at Plot 3. Table 9 summarizes the mammal captures at Plot 3.

Table 9. Summary of Species Captured, Number of Individuals Recaptured, and Number Found Deceased in Trap in Plot 3

Species	Captured	Recaptured	Deceased
10/5/2010			
Subtotal	*0*	*0*	*0*
10/6/2010			
P. maniculatus	1	0	0
Subtotal	*1*	*0*	*0*
10/7/2010			
P. maniculatus	1	1	0
Subtotal	*1*	*1*	*0*
10/8/2010			
Subtotal	*0*	*0*	*0*
Total	**2**	**1**	**0**

2.2.1.4 PLOT 4

One deer mouse was captured during the last night of trapping in the halogeton-disturbed plot. Table 10 summarizes the mammal captures at Plot 4.

Table 10. Summary of Species Captured, Number of Individuals Recaptured, and Number Found Deceased in Trap in Plot 4

Species	Captured	Recaptured	Deceased
10/5/2010			
Subtotal	*0*	*0*	*0*
10/6/2010			
Subtotal	*0*	*0*	*0*
10/7/2010			
Subtotal	*0*	*0*	*0*
10/8/2010			
P. maniculatus	1	0	0
Subtotal	*1*	*0*	*0*
Total	**1**	**0**	**0**

2.2.1.5 PLOT 5

Four deer mice were captured in the shadscale–gray molly plot. Table 11 summarizes the mammal captures at Plot 5.

Table 11. Summary of Species Captured, Number of Individuals Recaptured, and Number Found Deceased in Trap in Plot 5

Species	Captured	Recaptured	Deceased
10/5/2010			
Subtotal	*0*	*0*	*0*
10/6/2010			
P. maniculatus	1	0	0
Subtotal	*1*	*0*	*0*
10/7/2010			
P. maniculatus	1	0	0
Subtotal	*1*	*0*	*0*
10/8/2010			
P. maniculatus	2	1	0

Table 11. Summary of Species Captured, Number of Individuals Recaptured, and Number Found Deceased in Trap in Plot 5

Species	Captured	Recaptured	Deceased
Subtotal	*2*	*1*	*0*
Total	**4**	**1**	**0**

2.2.2 Mammal Burrow Surveys

Each 1.0-ha plot was surveyed for mammal burrows by walking transects approximately 3 m (10 feet) apart, depending on topography and vegetation. These surveys were conducted September 28 and 30, October 21, and November 4, 2010. The universal transverse mercator (UTM) location was recorded using a handheld global positioning system (GPS) unit for individual burrows or a group of similar burrows. If a group of burrows was recorded, an approximate area was recorded. Burrows were identified to species level when possible; however, in many cases burrows were assigned a likely “group” of burrowers (i.e., mouse/vole/rat). Considering the large number of deer mice captured during trapping efforts, it is possible burrows in this particular category are deer mice burrows.

The plots on the Clive Site (Plots 3–5) were found to have far fewer burrows than the reference plots (Plots 1 and 2) on BLM land. Though the Clive Site field plots had fewer burrows, those burrows had larger amounts of displaced soil at their entrances than the BLM field plots.

After burrow surveys were completed, soil volumes were collected in a randomly selected ¼-plot (0.25 ha) in each plot. The obviously mounded or disturbed soil around a burrow entrance was collected and measured (in L).

2.2.2.1 PLOT 1

A total of 235 burrow locations were located during the burrow survey (see Table 12). The majority (56%) of burrows were identified as mouse/vole/rat burrows.

Table 12. Number of Burrows, by Type, in Plot 1

Burrow Type	Number of Burrows
Ground squirrel	2
Kangaroo rat	102
Mouse/vole/rat	131
Total	**235**

The southwest quadrant of Plot 1 was randomly selected for burrow soil volumes. Because of heavy disturbance in the area from cattle grazing, human foot traffic, and winds, it was somewhat difficult to determine exact amounts of disturbed soils at burrow entrances. Only small amounts of soil were found around burrow entrances. This may indicate burrowing activity is only taking place in a shallow sub-surface layer. Table 13 summarizes soil mound volumes in Plot 1.

Table 13. Summary of Soil Mound Volume (in L) by Burrow Type in the Southwestern Quadrant of Plot 1

Burrow ID	Kangaroo Rat (L)	Mouse/Vole/Rat (L)	Total (L)
1SW104	3.500	–	3.500
1SW105	–	0.010	0.010
1SW106	–	0.200	0.200
1SW107	–	0.010	0.010
1SW108	0.050	–	0.050
1SW110	1.250	–	1.250
1SW111	0.300	–	0.300
1SW112	0.560	–	0.560
1SW113	–	0.030	0.030
1SW114	–	0.010	0.010
1SW115	0.250	–	0.250
1SW116	0.050	–	0.050
1SW117	2.500	–	2.500
1SW118	–	0.080	0.080
1SW119	0.030	–	0.030
1SW120	0.030	–	0.030
1SW121	0.090	–	0.090
1SW122	0.030	–	0.030
1SW123	0.030	–	0.030
1SW124	0.200	–	0.200
1SW125	0.150	–	0.150
1SW126	0.100	–	0.100
1SW127	–	0.010	0.010
1SW128	2.860	–	2.860
1SW129	0.050	–	0.050
1SW130	–	0.040	0.040
1SW131	–	0.050	0.050
1SW132	–	0.030	0.030
1SW133	–	0.100	0.100
1SW134	–	0.020	0.020
Total	**12.030**	**0.590**	**12.620**

2.2.2.2 PLOT 2

A total of 239 burrows were located during the burrow survey (see Table 14). The majority (93%) of burrows were identified as kangaroo rat burrows.

Table 14. Number of Burrows, by Type, in Plot 2

Burrow Type	Number of Burrows
Badger	1
Kangaroo rat	222
Mouse/vole/rat	16
Total	**239**

The northeast quadrant of Plot 2 was randomly selected for burrow soil volumes. Because of the extreme sandiness of the soil in the northeastern quadrant and windiness at the site, it was difficult to determine the amount of disturbed soil outside of burrows. Burrows with no recent digging (prior few days) had very small amounts of soil disturbed at their entrances. The eastern portion of Plot 2 is very sandy and dune-like. This sandy area is most likely experiencing constant soil mixing at the surface and shallow subsurface. Most burrows in Plot 2 appeared to be shallow, sub-surface burrows and only one deep badger burrow was identified. Table 15 summarizes soil mound volumes in Plot 2.

Table 15. Summary of Soil Mound Volume (in L) by Burrow Type in the Northeastern Quadrant of Plot 2

Burrow ID	Badger (L)	Kangaroo Rat (L)	Mouse/Vole/Rat (L)	Total (L)
2NE002	–	0.050	–	0.050
2NE006	–	–	0.010	0.010
2NE007	–	0.010	–	0.010
2NE009	–	0.150	–	0.150
2NE010	–	–	0.060	0.060
2NE012	–	0.225	–	0.225
2NE015	6.000	–	–	6.000
2NE019	–	1.350	–	1.350
2NE020	–	6.830	–	6.830
2NE021	–	2.975	–	2.975
2NE025	–	0.060	–	0.060
2NE026	–	0.185	–	0.185
2NE027	–	–	0.100	0.100
2NE028	–	0.050	–	0.050
2NE029	–	0.200	–	0.200
2NE037	–	–	0.010	0.010
2NE040	–	0.010	–	0.010

Table 15. Summary of Soil Mound Volume (in L) by Burrow Type in the Northeastern Quadrant of Plot 2

Burrow ID	Badger (L)	Kangaroo Rat (L)	Mouse/Vole/Rat (L)	Total (L)
2NE041	–	0.040	–	0.040
2NE044	–	–	0.010	0.010
2NE046	–	0.300	–	0.300
2NE048	–	0.100	–	0.100
2NE051	–	15.010	–	15.010
2NE052	–	9.500	–	9.500
2NE104	–	0.800	–	0.800
Total	**6.000**	**37.845**	**0.190**	**44.035**

2.2.2.3 PLOT 3

Three burrows were located during the burrow survey (see Table 14).

Table 16. Number of Burrows, by Type, in Plot 3

Burrow Type	Number of Burrows
Ground squirrel	1
Kangaroo rat	1
Mouse/vole/rat	1
Total	**3**

The northeastern quadrant of Plot 3 was randomly selected for burrow soil volumes. One burrow was found in this quadrant (see Table 17).

Table 17. Summary of Soil Mound Volume (in L) by Burrow Type in the Northeastern Quadrant of Plot 3

Burrow ID	Mouse/Vole/Rat (L)	Total (L)
3NE003	1.000	1.000
Total	**1.000**	**1.000**

2.2.2.4 PLOT 4

No burrows were found in Plot 4.

2.2.2.5 PLOT 5

One burrow was located during the burrow survey (see Table 18).

Table 18. Number of Burrows, by Type, in Plot 5

Burrow Type	Number of Burrows
Mouse/vole/rat	1
Total	**1**

The southwestern quadrant of Plot 5 was randomly selected for burrow soil volume. One burrow was present in the quadrant (see Table 19).

Table 19. Summary of Soil Mound Volume (in L) by Burrow Type in Plot 5

Burrow ID	Mouse/Vole/Rat (L)	Total (L)
5SW001	13.750	13.750
Total	**13.750**	**13.750**

2.3 Ants

2.3.1 Methods

2.3.1.1 FIELD METHODS

Each field plot was surveyed via pedestrian transects to ensure 100% coverage of the whole plot. Ant mounds were located, the UTM location of each mound was recorded using a handheld GPS unit, details regarding the mound were recorded, and sample specimens were taken from the mound. Each plot was surveyed three times. The first time was the most intensive and required mapping and data recording of each mound, whereas the other two visits were only to collect additional specimens. Multiple specimen collection was done to determine if more than one species was utilizing the same mound, because data on desert ant species suggest that this is possible. At minimum, 10 individuals from each mound were collected on the first survey, and then 5–10 each survey thereafter. At each mound, sample specimens were collected with either forceps or aspirator and placed into a vial filled with a 95% ethyl alcohol solution and labeled with the sample number and date.

The following information was collected at each mound:

- Height and width/diameter (in order to calculate the surface area of the mound)
- A photograph of the mound
- A brief description of the mound and its location, i.e., soil and vegetation features
- The orientation of the mound entrance, i.e., N, S, NNE, etc.
- Date, observer, plot number, subplot number, and UTM coordinates

2.3.1.2 ANT IDENTIFICATION METHODS

Identification of ant species was performed by Kenneth J. Kingsley, a Ph.D. entomologist with extensive experience in insect identification. He examined all of the 188 vials containing the collected species under a binocular dissecting microscope, and identified each of the 1,628 collected ants to genus and all *Pogonomyrmex* individuals to species, using the keys in Allred (1982)[1].

2.3.2 Ant Identification Results

A total of 1,624 ants in the genus *Pogonomyrmex* was collected in all plots and determined to be the western harvester ant, (*P. occidentalis* [Cresson]). Four other ants collected in Plot 1 were determined to be in the genus *Lasius*, with species not positively determined but most likely *niger* (Linnaeus). The western harvester ant is a widely distributed ant occurring throughout most of Utah and many other western states. It frequently occurs in areas that are relatively flat and have been recently disturbed by human activities[2]. A table for each field plot listing the number of ants collected by mound, date, and species can be found in Appendix A.

2.3.3 Mound Dimension Results

Because the mounds were roughly conical in shape, the formula for surface area of a cone was used to estimate area of the mounds. The maximum (basal) diameter of each mound, as measured by the field crew, was then entered into a Microsoft Excel© spreadsheet, which was used to calculate the surface area of the mound. It is possible that the basal area of the mound may have some mathematical relationship to the depth and subterranean area of the nest and the quantity of soil excavated, but that relationship has not been clearly established for *P. occidentalis* mounds in the particular soil types present on the sampling sites. Table 20 summarizes the results of the mound dimension survey.

Table 20. Mound Surface Area and Density By Plot

Plot	Average surface area (dm^2)	Average mound density (mounds/hectare)
Plot 1	95	33
Plot 2	39	2
Plot 3	120	7
Plot 4	84	16
Plot 5	138	6
Average across plots	**97**	**13**

Density of the mounds was determined by tallying the number of mounds observed per plot and calculating the density per hectare.

[1] Allred, D.M. 1982. Ants of Utah. *Great Basin Naturalist* 42(4):415–511.
[2] Allred, D.M. 1982. Ants of Utah. *Great Basin Naturalist* 42(4):415–511.

This page intentionally left blank.

Appendix A

Ant Collection Results

PLOT 1

Four *Lasius* individuals and 804 *Pogonomyrmex occidentalis* individuals were collected in Plot 1.

Table A-1. Ant Species by Mound in Plot 1

Mound No.	Collection Date	Number of Ants Collected	Species
P1-NE-20	10/5/2010	13	*P. occidentalis*
P1-NE-20	10/6/2010	6	*P. occidentalis*
P1-NE-20	10/7/2010	6	*P. occidentalis*
P1-NE-21	10/5/2010	12	*P. occidentalis*
P1-NE-21	10/6/2010	6	*P. occidentalis*
P1-NE-21	10/7/2010	8	*P. occidentalis*
P1-NE-22	10/5/2010	11	*P. occidentalis*
P1-NE-22	10/6/2010	8	*P. occidentalis*
P1-NE-22	10/7/2010	7	*P. occidentalis*
P1-NE-23	10/5/2010	11	*P. occidentalis*
P1-NE-23	10/6/2010	8	*P. occidentalis*
P1-NE-23	10/6/2010	2	*Lasius* sp.
P1-NE-23	10/7/2010	7	*P. occidentalis*
P1-NE-24	10/5/2010	16	*P. occidentalis*
P1-NE-24	10/6/2010	8	*P. occidentalis*
P1-NE-24	10/7/2010	8	*P. occidentalis*
P1-NE-25	10/5/2010	20	*P. occidentalis*
P1-NE-25	10/6/2010	7	*P. occidentalis*
P1-NE-25	10/7/2010	7	*P. occidentalis*
P1-NE-31	10/5/2010	14	*P. occidentalis*
P1-NE-31	10/6/2010	11	*P. occidentalis*
P1-NE-31	10/7/2010	8	*P. occidentalis*
P1-NW-17	10/5/2010	17	*P. occidentalis*
P1-NW-17	10/6/2010	5	*P. occidentalis*
P1-NW-17	10/7/2010	5	*P. occidentalis*
P1-NW-18	10/5/2010	14	*P. occidentalis*
P1-NW-18	10/6/2010	6	*P. occidentalis*
P1-NW-18	10/7/2010	5	*P. occidentalis*
P1-NW-19	10/5/2010	15	*P. occidentalis*
P1-NW-19	10/6/2010	9	*P. occidentalis*
P1-NW-19	10/7/2010	5	*P. occidentalis*
P1-NW-26	10/5/2010	14	*P. occidentalis*
P1-NW-26	10/6/2010	6	*P. occidentalis*
P1-NW-26	10/7/2010	5	*P. occidentalis*

Table A-1. Ant Species by Mound in Plot 1

Mound No.	Collection Date	Number of Ants Collected	Species
P1-NW-27	10/5/2010	12	*P. occidentalis*
P1-NW-27	10/6/2010	7	*P. occidentalis*
P1-NW-27	10/7/2010	5	*P. occidentalis*
P1-NW-28	10/5/2010	12	*P. occidentalis*
P1-NW-28	10/6/2010	5	*P. occidentalis*
P1-NW-28	10/7/2010	5	*P. occidentalis*
P1-NW-29	10/5/2010	15	*P. occidentalis*
P1-NW-29	10/6/2010	5	*P. occidentalis*
P1-NW-29	10/7/2010	6	*P. occidentalis*
P1-NW-30	10/5/2010	12	*P. occidentalis*
P1-NW-30	10/6/2010	5	*P. occidentalis*
P1-NW-30	10/7/2010	6	*P. occidentalis*
P1-SE-1	10/5/2010	11	*P. occidentalis*
P1-SE-1	10/6/2010	12	*P. occidentalis*
P1-SE-1	10/7/2010	6	*P. occidentalis*
P1-SE-10	10/5/2010	14	*P. occidentalis*
P1-SE-10	10/6/2010	8	*P. occidentalis*
P1-SE-10	10/7/2010	5	*P. occidentalis*
P1-SE-11	10/5/2010	14	*P. occidentalis*
P1-SE-11	10/6/2010	6	*P. occidentalis*
P1-SE-11	10/7/2010	7	*P. occidentalis*
P1-SE-12	10/5/2010	14	*P. occidentalis*
P1-SE-12	10/5/2010	2	*Lasius* sp.
P1-SE-12	10/6/2010	6	*P. occidentalis*
P1-SE-12	10/7/2010	6	*P. occidentalis*
P1-SE-13	10/5/2010	11	*P. occidentalis*
P1-SE-13	10/6/2010	8	*P. occidentalis*
P1-SE-13	10/7/2010	6	*P. occidentalis*
P1-SE-14	10/5/2010	14	*P. occidentalis*
P1-SE-14	10/6/2010	9	*P. occidentalis*
P1-SE-14	10/7/2010	4	*P. occidentalis*
P1-SE-15	10/5/2010	13	*P. occidentalis*
P1-SE-15	10/6/2010	5	*P. occidentalis*
P1-SE-15	10/7/2010	5	*P. occidentalis*
P1-SE-2	10/5/2010	11	*P. occidentalis*
P1-SE-2	10/6/2010	6	*P. occidentalis*
P1-SE-2	10/7/2010	7	*P. occidentalis*

Table A-1. Ant Species by Mound in Plot 1

Mound No.	Collection Date	Number of Ants Collected	Species
P1-SW-16	10/5/2010	17	*P. occidentalis*
P1-SW-16	10/6/2010	5	*P. occidentalis*
P1-SW-16	10/7/2010	8	*P. occidentalis*
P1-SW-3	10/5/2010	13	*P. occidentalis*
P1-SW-3	10/6/2010	5	*P. occidentalis*
P1-SW-3	10/7/2010	5	*P. occidentalis*
P1-SW-4	10/5/2010	11	*P. occidentalis*
P1-SW-4	10/6/2010	5	*P. occidentalis*
P1-SW-4	10/7/2010	5	*P. occidentalis*
P1-SW-5	10/5/2010	11	*P. occidentalis*
P1-SW-5	10/6/2010	5	*P. occidentalis*
P1-SW-5	10/7/2010	5	*P. occidentalis*
P1-SW-6	10/5/2010	11	*P. occidentalis*
P1-SW-6	10/6/2010	5	*P. occidentalis*
P1-SW-6	10/7/2010	5	*P. occidentalis*
P1-SW-7	10/5/2010	10	*P. occidentalis*
P1-SW-7	10/6/2010	5	*P. occidentalis*
P1-SW-7	10/7/2010	5	*P. occidentalis*
P1-SW-7	10/7/2010	6	*P. occidentalis*
P1-SW-8	10/5/2010	12	*P. occidentalis*
P1-SW-8	10/6/2010	5	*P. occidentalis*
P1-SW-8	10/7/2010	5	*P. occidentalis*
P1-SW-9	10/4/2010	9	*P. occidentalis*
P1-SW-9	10/5/2010	13	*P. occidentalis*
P1-SW-9	10/7/2010	5	*P. occidentalis*
Total		**806**	

Plot 2

A total of 20 *Pogonomyrmex occidentalis* individuals were collected in Plot 2.

Table A-2. Ant Species by Mound in Plot 2

Mound No.	Collection Date	Number of Ants Collected	Species
P2-SE-2	10/4/2010	8	*P. occidentalis*
P2-SE-2	10/5/2010	5	*P. occidentalis*
P2-SE-2	10/6/2010	7	*P. occidentalis*
Total		**20**	

Plot 3

A total of 148 *Pogonomyrmex occidentalis* individuals were collected in Plot 3.

Table A-3. Ant Species by Mound in Plot 3

Mound No.	Collection Date	Number of Ants Collected	Species
P3-NW-4	10/4/2010	14	*P. occidentalis*
P3-NW-4	10/6/2010	5	*P. occidentalis*
P3-NW-4	10/9/2010	6	*P. occidentalis*
P3-SE-3	10/4/2010	8	*P. occidentalis*
P3-SE-3	10/6/2010	5	*P. occidentalis*
P3-SE-3	10/7/2010	5	*P. occidentalis*
P3-SE-5	10/5/2010	9	*P. occidentalis*
P3-SE-5	10/6/2010	5	*P. occidentalis*
P3-SE-5	10/7/2010	5	*P. occidentalis*
P3-SW-1	10/4/2010	10	*P. occidentalis*
P3-SW-1	10/6/2010	6	*P. occidentalis*
P3-SW-1	10/7/2010	8	*P. occidentalis*
P3-SW-2	10/4/2010	6	*P. occidentalis*
P3-SW-2	10/6/2010	7	*P. occidentalis*
P3-SW-2	10/7/2010	9	*P. occidentalis*
P3-SW-6	10/5/2010	11	*P. occidentalis*
P3-SW-6	10/6/2010	2	*P. occidentalis*
P3-SW-6	10/7/2010	10	*P. occidentalis*
P3-SW-7	10/5/2010	10	*P. occidentalis*
P3-SW-7	10/7/2010	7	*P. occidentalis*
Total		**148**	

Plot 4

A total of 477 *Pogonomyrmex occidentalis* individuals were collected in Plot 4.

Table A-4. Ant Species by Mound in Plot 4

Mound No.	Collection Date	Number of Ants Collected	Species
P4-NE-13	10/4/2010	16	*P. occidentalis*
P4-NE-13	10/6/2010	6	*P. occidentalis*
P4-NE-13	10/7/2010	10	*P. occidentalis*
P4-NE-14	10/4/2010	16	*P. occidentalis*
P4-NE-14	10/6/2010	5	*P. occidentalis*
P4-NE-14	10/7/2010	11	*P. occidentalis*
P4-NE-15	10/4/2010	18	*P. occidentalis*
P4-NE-15	10/6/2010	5	*P. occidentalis*
P4-NE-15	10/7/2010	6	*P. occidentalis*
P4-NE-16	10/4/2010	12	*P. occidentalis*
P4-NE-16	10/6/2010	5	*P. occidentalis*
P4-NE-16	10/7/2010	5	*P. occidentalis*
P4-NW-1	10/4/2010	19	*P. occidentalis*
P4-NW-1	10/6/2010	5	*P. occidentalis*
P4-NW-1	10/7/2010	6	*P. occidentalis*
P4-NW-2	10/4/2010	17	*P. occidentalis*
P4-NW-2	10/6/2010	5	*P. occidentalis*
P4-NW-2	10/7/2010	5	*P. occidentalis*
P4-NW-3	10/4/2010	16	*P. occidentalis*
P4-NW-3	10/6/2010	5	*P. occidentalis*
P4-NW-3	10/7/2010	6	*P. occidentalis*
P4-NW-4	10/4/2010	14	*P. occidentalis*
P4-NW-4	10/6/2010	5	*P. occidentalis*
P4-NW-4	10/7/2010	5	*P. occidentalis*
P4-SE-10	10/4/2010	12	*P. occidentalis*
P4-SE-10	10/6/2010	8	*P. occidentalis*
P4-SE-10	10/7/2010	10	*P. occidentalis*
P4-SE-11	10/4/2010	15	*P. occidentalis*
P4-SE-11	10/6/2010	6	*P. occidentalis*
P4-SE-11	10/7/2010	8	*P. occidentalis*
P4-SE-12	10/4/2010	7	*P. occidentalis*
P4-SE-12	10/4/2010	16	*P. occidentalis*
P4-SE-12	10/7/2010	16	*P. occidentalis*
P4-SE-9	10/4/2010	16	*P. occidentalis*
P4-SE-9	10/6/2010	6	*P. occidentalis*

Table A-4. Ant Species by Mound in Plot 4

Mound No.	Collection Date	Number of Ants Collected	Species
P4-SE-9	10/7/2010	15	*P. occidentalis*
P4-SW-5	10/4/2010	22	*P. occidentalis*
P4-SW-5	10/6/2010	5	*P. occidentalis*
P4-SW-5	10/7/2010	6	*P. occidentalis*
P4-SW-6	10/4/2010	20	*P. occidentalis*
P4-SW-6	10/6/2010	5	*P. occidentalis*
P4-SW-6	10/7/2010	7	*P. occidentalis*
P4-SW-7	10/4/2010	17	*P. occidentalis*
P4-SW-7	10/6/2010	5	*P. occidentalis*
P4-SW-7	10/7/2010	5	*P. occidentalis*
P4-SW-8	10/4/2010	16	*P. occidentalis*
P4-SW-8	10/6/2010	6	*P. occidentalis*
P4-SW-8	10/7/2010	5	*P. occidentalis*
Total		**477**	

Plot 5

A total of 177 *Pogonomyrmex occidentalis* individuals were collected in Plot 5.

Table A-5. Ant Species by Mound in Plot 5

Mound No.	Collection Date	Number of Ants Collected	Species
P5-NW-5	10/4/2010	11	*P. occidentalis*
P5-NW-5	10/5/2010	6	*P. occidentalis*
P5-NW-5	10/6/2010	5	*P. occidentalis*
P5-NW-6	10/4/2010	16	*P. occidentalis*
P5-NW-6	10/5/2010	5	*P. occidentalis*
P5-NW-6	10/6/2010	5	*P. occidentalis*
P5-SE-1	10/4/2010	20	*P. occidentalis*
P5-SE-1	10/5/2010	5	*P. occidentalis*
P5-SE-1	10/6/2010	5	*P. occidentalis*
P5-SE-3	10/4/2010	12	*P. occidentalis*
P5-SE-3	10/5/2010	5	*P. occidentalis*
P5-SE-3	10/6/2010	5	*P. occidentalis*
P5-SE-4	10/4/2010	15	*P. occidentalis*
P5-SE-4	10/5/2010	7	*P. occidentalis*
P5-SE-4	10/6/2010	5	*P. occidentalis*
P5-SW-1	10/4/2010	12	*P. occidentalis*
P5-SW-1	10/5/2010	5	*P. occidentalis*
P5-SW-1	10/6/2010	6	*P. occidentalis*
P5-SW-2	10/4/2010	16	*P. occidentalis*
P5-SW-2	10/5/2010	6	*P. occidentalis*
P5-SW-2	10/6/2010	5	*P. occidentalis*
Total		**177**	