Revegetation Experiment in an Active Prairie Dog Town

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ABSTRACT

This project examined the response of vegetation and a prairie dog population to interseeding (overseeding) native shortgrass and mid-grass species in an active colony that occurs at a highly disturbed site (Figure 1) dominated by introduced weeds. Native grasses were seeded on April 6, 2000 using a low-till seed drill. Vegetation was sampled immediately before treatment and on June 3, June 30, August 4, and September 6, 2000. Prairie dog population characteristics were also assessed before and after treatment by means of above-ground prairie dog counts, active burrow counts (relative density), spatial dispersion, and burrow utilization.

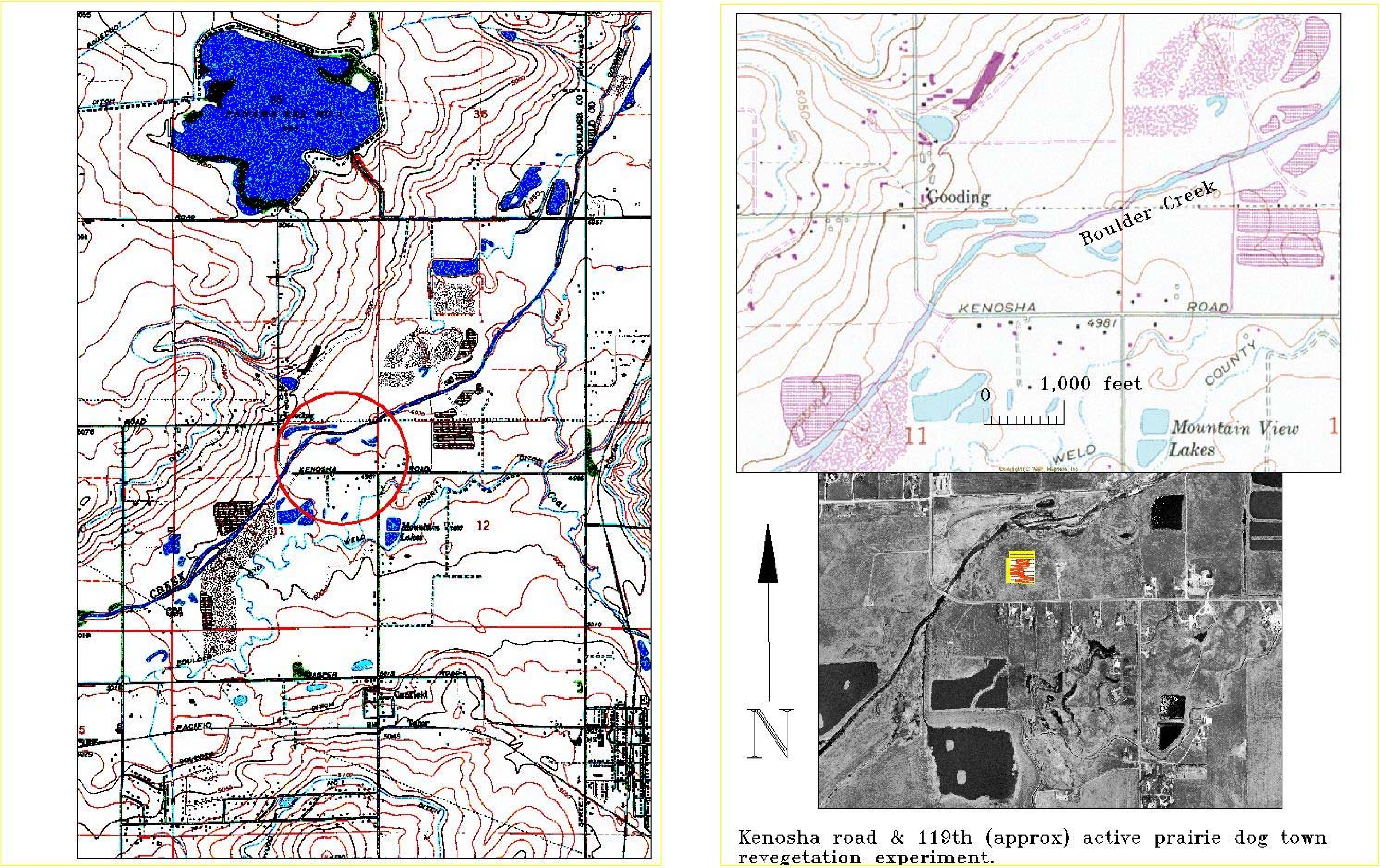
This experiment was conducted to address the issue of prairie dog survival in the highly disturbed urban and rural environments of Boulder County. Prairie dog populations in these urban/agricultural "islands" are artificially isolated from both resources and predators that would naturally keep the populations in balance. This experiment tests the possibility of using direct seeding in order to revegetate an active prairie dog town in an area that is heavily disturbed and dominated by introduced weeds. This experiment addresses only the resource aspects of the food pyramid in which the prairie dog plays such an important role.

Prairie dogs are difficult subjects for a population monitoring program because of their below ground activities. One methodology, mark-resighting is both costly and labor-intensive, and creates significant risks to the animals and humans that capture them. However, relative estimates of density, and thus, colony (population) size can be obtained by observational data on above ground animals at similar times of the day and under similar weather conditions. Because the most obvious and measurable activity of prairie dogs is the creation of burrows; the number, density, utilization, and spatial distribution were also used as an indication of the effect of seeding on prairie dogs.

The extremely dry period of April-May-June (the 5th driest in 105 years of record) greatly reduced the germination and establishment of the native grasses. Baseline conditions for both the prairie dog population and vegetation conditions have been documented and the potential for additional germination by remaining seed exists for spring 2001. The relationship between vegetation and prairie dog population is represented in this report using graphic, statistical, and multivariate methods. A new method for detecting change in prairie dog populations based on burrow utilization is also presented.

Acknowledgements

We would like to thank those that supported and assisted with this research project. Boulder County Parks and Open Space provided the funding to initiate this study through their Small Grants Program. All experimentation has a risk of failure and we appreciate Boulder County for allowing this effort to try new ways of sustaining prairie dogs in the rapidly developing Colorado Front Range. Boulder City Open Space provided the use of the Trimble Pro XRS for the prairie dog utilization GPS survey data. Their ongoing vegetation monitoring in prairie dog towns helped us design our project, and provided data that can be used to understand and manage prairie dog populations. Field assistance was provided by Mike Campo, and Claire Boyce; and data entry was provided by Judith Broeker. Special thanks to the volunteers who helped, including Steven LeBlanc and Scott Harvey (King of Volunteers).



Kenosha road & 119th (approx) active prairie dog town revegetation experiment.

Figure 1. Project Location - Revegetation in an active prairie dog town experiment.

INTRODUCTION

The purpose of this experiment was to address the issue of prairie dog survival in the highly disturbed urban and rural environments of Boulder County. Prairie dogs are grazers that do not quickly migrating to better areas once an area's resources are depleted. The artificial barriers created by urban and agricultural boundaries prevent the more natural slow migration process of the prairie dog. Survival of the prairie dogs in these island refugia in the urban/agricultural matrix would be valuable for the following reasons:

1. Maintenance of the food base for the more adaptable predators such as raptors, badgers, fox and coyote,
2. Human observation and understanding of the food pyramid and web of life can be directly interpreted from the presence of prairie dog towns. This sometimes emotional focal point includes the lessons of both human and prairie dog overpopulation as demonstrated by depletion of resources, population stress, erosion, and propagation of non-native weedy plant species.

For prairie dog populations to survive in this highly modified environment, both the resources necessary for the prairie dog's survival and the prairie dog population densities must be managed. The alternative is the suffering and demise of prairie dogs due to starvation and plague, or the social decision to remove them due to the human and economic risks associated with plague and the establishment of aggressive non-native weeds. Methods for maintaining healthy populations of prairie dogs in the urban/agricultural environment have not yet been developed.

This experiment approaches two aspects of this issue:

1. providing resources to sustain the prairie dogs,
2. reducing the risk associated with aggressive introduced weeds.

It does not address the critical issue of prairie dog health and population control in the inevitable situation where the managed vegetation resources are eventually depleted.

It is reasonable to assume, and probable, that the prairie dogs will respond to the new vegetation growth and consume it, resulting in population growth and an expansion of the population. The response of the prairie dogs and amount and timing of the vegetation recovery can not be quantified until this simple experimental effort is made. This approach is sometimes called "Ockhams razor" and is the principle that sometimes the simplest solution is the correct one. It is our objective to test the simplest solution first.

The health of prairie dogs is fundamentally associated with their diet. The quantification of the amount and type of vegetation cover may be an easy way to estimate the health of a population, and may provide an advanced warning when population management is needed. Prairie dogs are difficult subjects for a population monitoring program because of their below ground activities. One methodology, mark-resighting is both costly and labor-intensive, and creates significant risks to the animals and humans that capture them. However, relative estimates of density, and thus, colony (population) size can be obtained by obtaining observational data on burrows; the number, density, and area covered by them.

Regardless of the ultimate outcome of the experiment, the relationship between vegetation establishment and prairie dogs will be documented. Because this is not a greenhouse or laboratory experiment, climate and soils rather than prairie dogs may have a controlling effect on vegetation establishment. That is why climatic and soil factors are also incorporated into this experiment.

Specific Objectives

Prairie Dog Population Change Questions

1. What is the immediate response of the prairie dog population to the seeding treatment?
2. What is the response of the prairie dog population after one growing season (May to October)?

Revegetation Questions.

1. What is the vegetation response to seeding considering climate, soil, and prairie dog population factors?

LITERATURE SURVEY

This experiment will test the possibility of using direct seeding in order to revegetate an active prairie dog town in an area that is heavily disturbed and dominated by introduced weeds. No other studies of this type have been documented. Some undocumented (Dangoule Bockus FWS at Rocky Mtn. Arsenal) and anecdotal information (Mark Buckley with Custom Services of Colorado - Reclamation) is available, but real studies that incorporate climate, soils, and prairie dog population characteristics have not been discovered. A recently completed prairie dog management plan was prepared for Highlands Ranch and included the following information regarding Prairie dog carrying capacity.

> 1) Prairie dog population exceeds carrying capacity and/or results in destruction of natural resources. When there is 20% bare ground within a colony's boundary, this indicates the carrying capacity within that specific geographic area may have been met or exceeded. This is regardless of the ratio between the amount of original bare ground and the total town area before prairie dog inhabitation (Seery 1997). If the population exceeds 50 prairie dogs per hectare (20 per acre), this is also a good indicator that the carrying capacity has been exceeded in an area (Seery 1997). Site specific analysis will determine if natural resources are being destroyed.
>
> When prairie dog populations exceed carrying capacities, the prairie dogs are subjected to increased stress and higher incidence of disease. The lack of predators, high levels of outdoor recreation use of open space, and conflicts with adjacent residential and commercial properties, dictate that prairie dog populations (*located in suitable sites as defined in Section 4*), be best managed at 80% or less of the carrying capacity for that specific site.

The Seery reference was not fully documented and we could not find the original source.

The ecological consequences of Prairie Dog disturbance have been discussed by Whicker & Detling (1988). These studies were conducted in South Dakota grasslands that may have been dominated by native species, but no list of species was provided. Prairie dog colonies were compared based on subjectively determined periods of occupation vs. net primary production (NPP), and total above and below ground biomass. Net primary production was found to respond to precipitation but was not found to vary based on grazing intensity. Total biomass, however, was found to decrease with increased age of the colony.

Weltzin et al. studied the species composition and community diversity aspect of prairie dog grazing at a site that was estimated to have been established for 20 to 50 years near the southeastern corner of the Texas panhandle. Comparisons with off-site control areas indicated lower species diversity on the prairie dog site and lower biomass for all species other than the short grass species. Both of the on-site dominant species were short grasses. These dominant species were buffalo grass (*Buchlöe dactyloides*) a native warm-season grass, and tumble grass (*Schedonnardus paniculatus*) a native cool-season grass.

The Weltzin study did not include species associated with the heavily impacted prairie dog mounds thus obscuring the diversity estimate. The study discussed the conflicting diversity results in the prairie dog literature. Diversity itself is a term that is filled with uncertainty and is ecologically confusing in the sense that it is sometimes confused with community stability, and must be represented as a pair of values rather than just one (Magurran 1988).

The literature also has conflicting reports regarding the development of the plant communities after the removal of prairie dogs. Klatt & Hein (1978) compared vegetation differences among one active and 3 abandoned prairie dog towns. They confirmed findings by Koford (1958) that total vegetation cover was actual greater in the active prairie dog towns than it was in recovering areas outside of the towns. Both studies discuss the fact that cattle also grazed these areas but did not consider the potential for cattle selectively grazing the areas outside of the prairie dog towns. The dominant species at all sites was buffalo grass (25% - 37.2%) typically followed blue grama (9.8-22.8%). Western wheatgrass (*Pascopyrum smithii*) was observed to increase with recovery duration. The fact that western wheatgrass produces most of its growth in a vertical direction (which is more available to cattle) was not discussed.

A much more comprehensive study by Cid et al. (1991) studied vegetation response after the exclusion of prairie dogs and/or bison in South Dakota. This study was very revealing because it was not obscured by the cattle grazing uncertainties. The four treatments were; 1) exclusion of prairie dogs, 2) exclusion of bison, 3) exclusion of prairie dogs and bison, 4) grazed by both species. What makes this study especially interesting is that it was a two-year study that included a dry year (11% below average) and a wet year (27% above average), and incorporated the climate into the analysis. They found that in the dry year the differences between the treatments were not significant (i.e, climate rather than grazing was controlling biomass). In the wet year the prairie dog exclusion areas averaged 38% greater biomass, the bison exclusion areas averaged 40% greater biomass and in the areas where both grazers were excluded the results were additive with approximately 78% greater biomass compared to areas that were grazed by both species. Although biomass data were collected by growth form rather than species, the authors indicated that buffalo grass was the dominant species followed by blue grama, western wheatgrass, and tumblegrass.

Archer et al. studied the reverse of the process that we hope to observe with the current revegetation study. The Archer study quantified the vegetation changes after a population of prairie dogs colonized and expanded. The colonization and expansion had been documented and mapped by previous studies. The trend was from a mixed grass community composed primarily of buffalo/blue grama, needle-and-thread (*Hesperostipa comata* cool season mid-grass), and bluegrass *(Poa pratensis* cool season mid-grass); to buffalo/blue grama and western wheatgrass after two years; to buffalo/blue grama, fetid marigold (*Dyssodia papposa* native annual forb), and spiderwort (*Tradescantia bracteata* native perennial forb) after 3 years; to a community dominated by fetid marigold and spiderwort after 4 years. This study also noted that the burrow density correlated with vegetation better than prairie dog density.

All of these studies demonstrated the dominance of buffalo grass in the typical prairie dog towns. The grass species used in this study included buffalo grass, blue grama, side oats grama, and western wheatgrass. These are common species recommended for reclamation in our area (McGinnies et al. 1963; CNAP 1998), but buffalo grass is surprisingly missing in some documents that provide seed mixes for highway reclamation See (1986) or cattle grazing Hart et al. (1996).

Germination, growth and establishment of the reclamation species used in the current study are discussed in Jones (1985) and Cheplick (1998). Large seed size with a hard coat, combined with cool dry conditions can extend seed longevity in the soil Baskin and Baskin (1998). Moisture stress (drought) can reduce the germination rates of seeds. The moisture stress that can reduce the germination rate to 50% or less is:

Blue grama = >1.6 -MPa
Side oats grama = >1.6 -MPa
Western wheatgrass = 0.7 -MPa
Buffalo grass = 0.1 -MPa

The greater the number, the greater the capacity to germinate in spite of moisture stress. Although this may be advantageous in some circumstances, if seeds germinate quickly, but hot dry weather follows germination, the seedlings may be killed. Additional discussion is found in the Results section. The inherently high longevity potential for buffalo grass has been reported in Justice & Bass (1978) and discussed in Desai et al. (1997).

The seeding rates used in the current study were much higher than is typically recommended. Hoffmann et al. (1995) studied the seed predation by rodents on buffalo and blue grama grass and found that although there was a preference for large seeded species such as buffalo grass, the increase of seeding rates was not significantly correlated with foraging rate. The rodents in the Hoffmann study did not include prairie dogs.

METHODS

Plant species nomenclature follows Weber & Wittmann 1992 (with 1999 addenda).

Site Surveying and Seeding

The sample plots were initially surveyed and marked with pin-flags as indicated on Figure 2. The 4.6 m (15 ft.) wide by 88.4 (290 ft.) long, seeded plots have an East-West orientation and alternate with unseeded "no treatment" control plots with the same dimensions. There are a total of 10 seeded and 10 unseeded plots. The endpoints of the perimeter of each plot are marked with wooden stakes and subsurface rebar. The rebar is placed below the surface to allow recovery of the location with a metal detector if the wooden stakes are lost or removed. The total area of the seeded plots is approximately one acre. An additional area to the north and east of the strips was also seeded to take advantage of the low cost of each additional acre of seeding in relation to the relatively high cost of the first acre. The mobilization expense of the seeding equipment makes the first acre almost three times more expensive than the second acre.

The seed mix, seed certification, and seed bag tags are presented in Appendix A. Only four native grass species were used. Three of the species are warm season grasses (buffalo grass *Buchloe dactyloides*, blue grama grass *Chondrosum gracile*, side-oats grama *Bouteloua curtipendula*) and the fourth was a cool season grass (western wheatgrass *Pascopyrum smithii*). These species were selected for their grazing tolerance or aggressive germination. Previous observations on Rocky Flats indicate that only buffalo grass and blue grama tolerated the heavy grazing of prairie dogs.

The initial seeding was done with a 2.13m (7 ft.) wide low-till seed drill, which left a 0.3m (1 ft.) wide unseeded strip in the center of the plot (Photograph 1). Rather than leave this strip unseeded, a third pass by the seed drill was centered on the unseeded strip (Photograph 2). This complicated the seeding rate within the plot by creating two different seeding rates. The outer four feet and the central one-foot wide strip are seeded at the original rate of 972 pure live seeds (PLS) per square meter (90 PLS/sq.ft.), but there are also two 0.91 m (3 ft.) wide strips on either side of the central strip that are seeded at 1,944 PLS/sq.m. (180 PLS/sq.ft.). This results in an average seeding rate of 1,360 PLS/sq.m. (126 PLS/sq.ft.). The vegetation cover sampling methodology averages this factor, but there may be visual evidence of the two seeding rates over time.

The presence of control plots closely associated with the treatment plots will allow continued assessment over time since there will be both treatment and control rows for comparison if the prairie dog population expands.

Vegetation transect location selection

Vegetation sample transects were located within the control and treatment plots. Prior to seeding, transect locations were subjectively selected within each seeded and unseeded plot to best represent the areas most affected by prairie dogs. The 50 meter (164 ft.) transects were oriented at a diagonal to the seed furrows, and the endpoints were marked with wooden stakes and subsurface rebar.

Vegetation Monitoring

Vegetation cover was sampled at the 20 transects (Figure 2) in April prior to seeding and after seeding on June 3, June 30, August 4 and September 6, 2000. Each 50 meter transect was sampled with 100 points using a point-intercept optical device (see Photograph 9). Two points were sampled at each meter on either side of the transect at 0.5 meter from the transect centerline (Figure 2). Each sample point recorded first-hit (top canopy) and additional hits for vegetation by species, litter, bare soil, rock, and standing-dead vegetation. Because the dominant cover at the site in April was provided by the standing-dead of the two dominant weed species (i.e., bindweed *Convolvulus arvensis*, and burning-bush *Bassia sieversiana* [a.k.a. *Kochia scoparia*]), the cover points were also distinguished for these species. Species within one meter (3.28 ft.) of the transect centerline were also recorded as "present". This will allow species with low cover to be represented in the data and provides a species density per 100 square meters (i.e., 50 meters long by 2 meters wide plot). This methodology is identical to the vegetation monitoring used by Boulder City Open Space in their prairie dog studies. Each transect was documented with a photograph immediately prior to each sample.

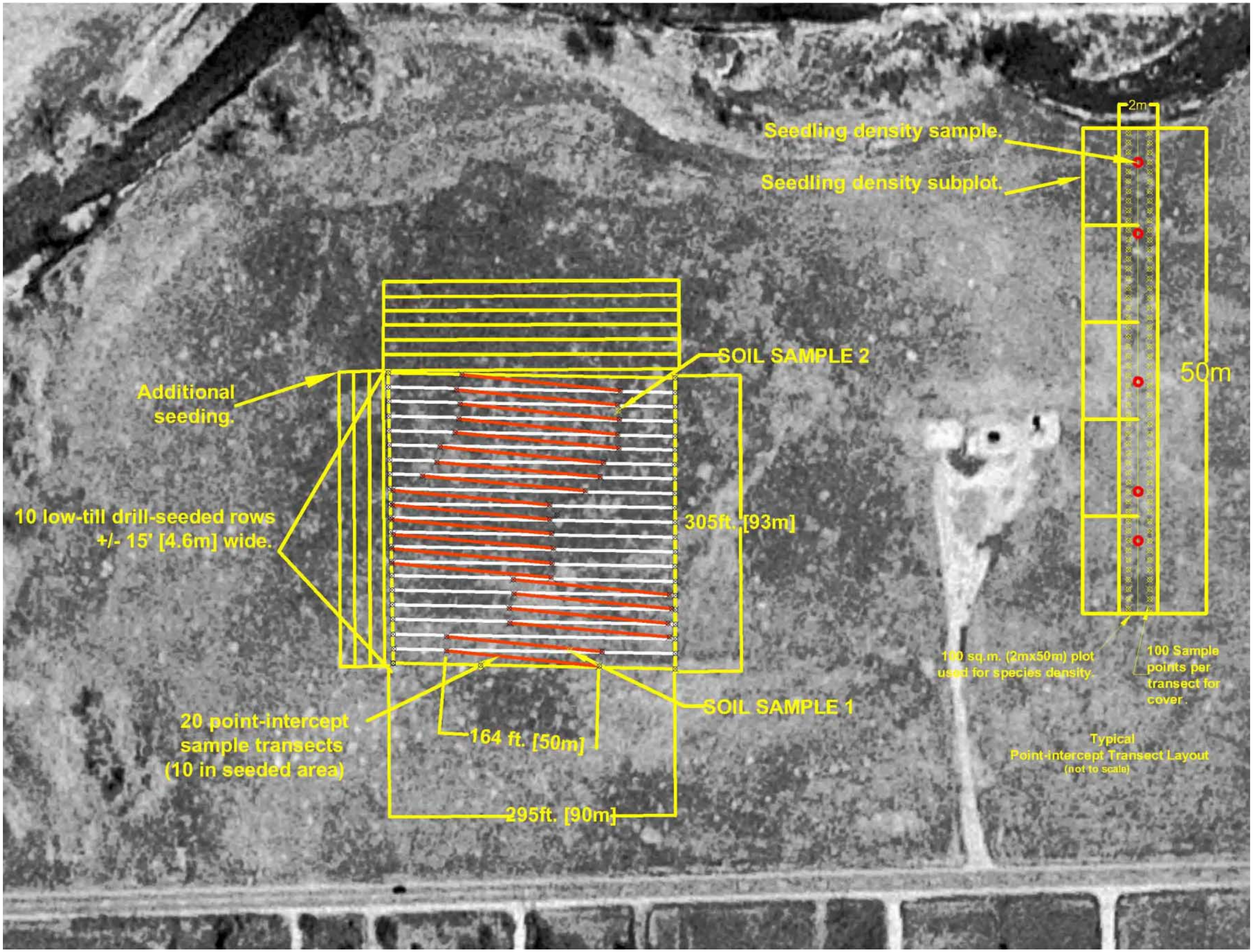
Soil sampling and description

Because soil characteristics vary even in this small sample area, two shallow soil pits were excavated and two soil samples were collected. One horizon description and soil sample was collected from both the northern area (with lower total vegetation cover) and the southern area (with higher vegetation cover). The soil pits were used to describe the upper soil horizons to a depth of about 31cm (12+ inches). Horizon depth, color (based on Munsell soil color charts), and texture were recorded and photographed. The soil samples for analysis were collected from the top 15cm (6 inches). The soil samples were analyzed for the routine suite of agricultural characteristics (NO_3, P, K, Zn, Fe, Cu, Mn, lime estimate, texture estimate) by Colorado State University Soil Testing Lab.

Climate

Climate data from Boulder was used to assess the monthly precipitation, temperature and potential evapotranspiration. On-site data-logging temperature and precipitation gauges were installed at the site, but wildlife and humans disturbed the precipitation gauges. The precipitation data are unusable but most of the temperature data were recovered. The temperature and precipitation data were collected near the center of the study area at 1 meter (3.3 ft.) above the soil surface and additional temperature data were collected at the same site 2.5 cm (1 inch) below the soil surface.

Figure 2. Sample Transects.



Intra-Colony Burrow Density & Burrow Area Utilization

Prairie dog response to seeding was estimated by measurement of burrow density and burrow utilization. Burrow density was estimated by recording the locations of burrows using a GPS (Global Positioning System) and simple counts of burrows within each plot. UTM coordinates, recorded to an accuracy of ≤ 1.0 meters, of each burrow were used to calculate plot burrow density and dispersion characteristics.

Burrow utilization was estimated based on measurements of the height of the mound, length of the longest axis of the mound, ground cover by live vegetation, and relative abundance of prairie dog scat. Mound height and length were measured to the nearest decimeter, ground cover was visually estimated to the nearest percent, and scat was recorded in three classes [None, Few (+/- 12/mound), Many (>>12/mound)]. After the data were collected, the distribution of values for each factor was examined and the range of values for each factor was divided into classes that reflected the frequency distribution of the values. Each class was then assigned a rank based on utilization, with high values indicating high utilization. The ranks for each factor were summed for each mound and the resulting sum was the utilization value. Although subjective weighting of the four factors could easily be achieved, the factors were weighted equally. The utilization scores were then used to construct a study area utilization "topography" with the "elevation" at each mound equal to the utilization. A contour plot was then constructed to reveal zones of high and low utilization. The distribution of the utilization scores was also examined to see if this might be a useful value for statistical testing of changes in utilization.

Burrow Spatial Dispersion

There is ample evidence that herbivore populations adjust to changes in resource abundance or distribution by altering dispersion patterns (random, clumped, uniform). Previous observations and empirical evidence suggest that the coterie social structure of prairie dogs produce burrows in a clumped distribution pattern. Each cluster of burrows or coterie is comprised of related females, their (typically unrelated) mates and young of the year (Dobson et al. 1998). While it is unlikely that the clumped dispersion pattern would change due to this experiment, there is the possibility that the degree of clustering might change as increased resources allow less inter-coterie competition. ANTELOPE, a software program developed by Jay Bradbury and Sandra Vehrencamp was used to calculate and compare point-burrow and burrow-nearest burrow distances before and after seeding. Owing to the relatively small number of burrows per plot, these measures were recorded at the scale of the entire study area. Thus, comparisons are made between the spatial dispersion pattern of the entire area sampled prior to (May), and 4 months (October) after seeding. This is the period and duration during which new burrow establishment is greatest (Powell et al., 1994).

Above Ground Animal Sightings, The Disturbance Effect of Seeding on Plot Use

The effect of seeding on prairie dog use of treated plots was examined by observing above ground sightings of animals. Observations were made from an elevated [3-meter (10 ft.) ladder] position at a distance of 300 meters (984 ft.), along the long axis of each plot (Figure 2). Counts of prairie dogs above ground and entirely within each plot were made in each plot twice each visit and averaged for the visit. Counts were then repeated before (n = 3), immediately after treatment (n = 3), and several months after treatment (n =3), the last being on October 3rd, 2000.

A repeated measures ANOVA was employed to test the following null hypotheses:

1. Prairie dog use of treated plots would not be affected by seeding. Comparing counts before and immediately after seeding examine whether the seeding mechanism itself was a disturbance or deterrent to plot use.
2. Prairie dog use of treated plots at the end of the summer/early fall would not be different than their use of untreated plots.

RESULTS & DISCUSSION

Site Surveying and Seeding

An overview of the site prior to any on-site activities is shown in Photograph 3. The treatment and control plot boundaries are shown on Figure 2. The seed mixture, seed quality verification, and seed bag tags are presented in Appendix A. The low-till seeding equipment is shown in Photograph 4. Seeding was conducted on April 5, 2000.

Vegetation transect locations

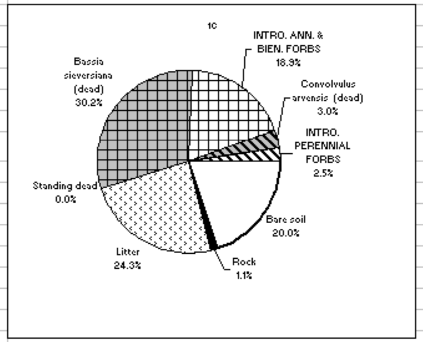
Vegetation transect locations are presented in Figure 2. The transects were numbered from 1 to 20, starting with the southern transect. The start point for each transect was the eastern end.

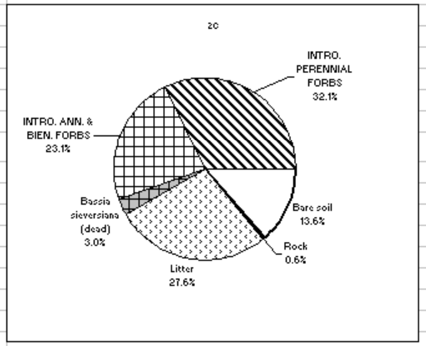
Vegetation Monitoring

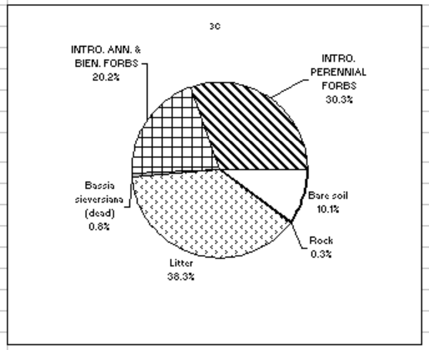
Vegetation summary tables are presented in Appendix B. Three tables are presented for each of the 5 sampling events (April 4, June 3, June 30, August 4, and September 6). Each set of three tables has one table with the combined summary statistics and original data for each transect, one table has the summary statistics for the combined control plots, and one table has the summary statistics for the combined treatment plots. Figure 3 summarizes the changes over the five sample events. These pie diagrams present the proportions of each growth form as well as litter, bare ground, rock and standing dead vegetation along with a summary table at the bottom of the figure that highlights the statistically significant differences between the control and treatment areas plots. These graphics and statistics are based on averages that do not reveal the large variation between plots. Future comparisons that test changes over time should be based on comparisons of at least two subsets of the data. The average of the June 3, June 30, and August 4 data for each transects were compared against all other transects in a t-test comparison matrix. The means for the transects were sorted in ascending order (Table 1), and the highest and lowest means were tested for significant difference with a one-tailed t-test with $\alpha = 0.05$. The second highest and second lowest were then tested, then the third highest and the third lowest etc. Once the paired comparison were not significantly different (i.e., 13 & 2), the two inner comparisons were also made (i.e., 11&2 and 5&13). These were found not to be significantly different. This resulted in three groups, two groups that were significantly different, and one group that was not significantly different from either of the two groups. When the samples were resorted based on transect number the "-" group and the "+" group could easily be divided between samples 10 and 11. The "-" group (low cover values group) has ten members, three of which are not significantly different from the "+" (higher cover values group). Using these two groups in future comparisons rather than a combined group can reduce within-group variation and may allow easier statistical testing with fewer samples.

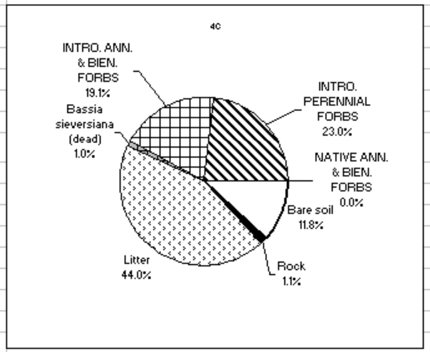
April 5, 2000 **June 3, 2000** **June 30, 2000** **August 4, 200** **September 6, 2000**

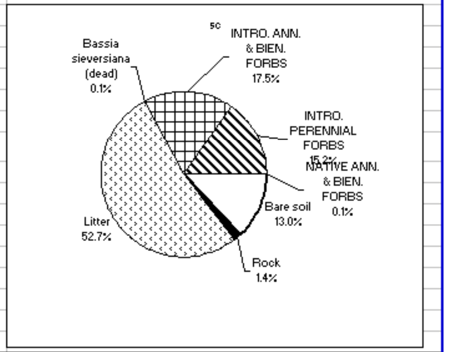
Control





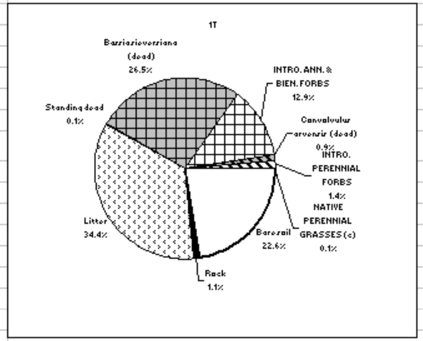


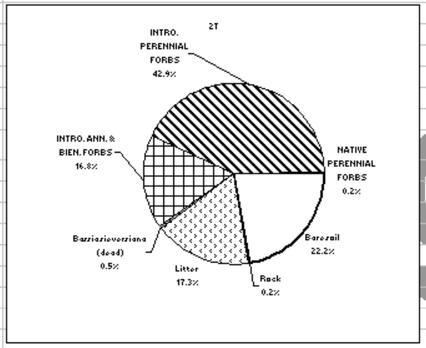


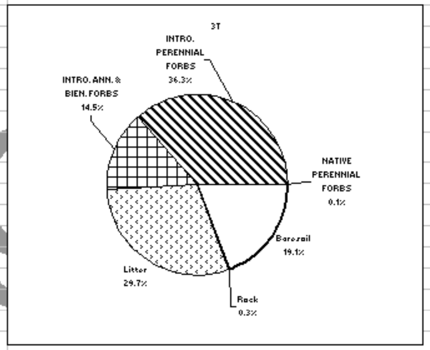


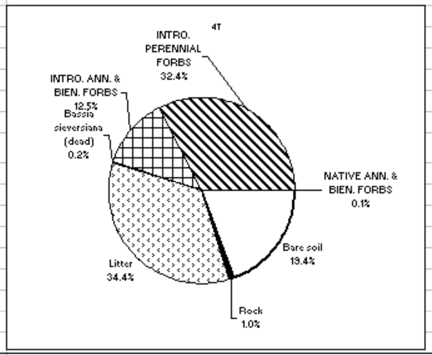
	1C	2C	3C	4C	5C
Bare soil	20	13.6	10.1	11.9	13
Rock	1.1	0.6	0.3	1.1	1.4
Litter	24.3	27.7	38.3	44.3	52.7
Standing dead					
Bassia sieversiana (dead)	30.2	3	0.8	1	0.1
INTRO. ANN. & BIEN. FORBS	18.9	23.2	20.2	19.2	17.5
Convolvulus arvensis (dead)	3	0			
INTRO. PERENNIAL FORBS	2.5	32.2	30.3	23.1	15.2
NATIVE ANN. & BIEN. FORBS					0.1
NATIVE PERENNIAL FORBS					
NATIVE PERENNIAL GRASSES (c)					
NATIVE PERENNIAL GRASSES (w)					
Total Vegetation Cover	21.40	55.40	50.50	42.30	32.80

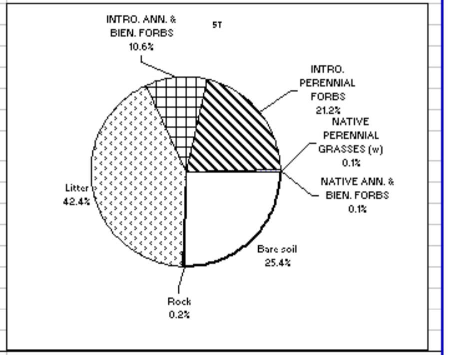
Treatment











	1T	2T	3T	4T	5T
Bare soil	22.6	22.2	19.1	19.4	25.4
Rock	1.1	0.2	0.3	1	0.2
Litter	34.4	17.3	29.7	34.4	42.4
Standing dead	0.1				
Bassia sieversiana (dead)	26.5	0.5		0.2	
INTRO. ANN. & BIEN. FORBS	12.9	16.8	14.5	12.5	10.6
Convolvulus arvensis (dead)	0.9	0			
INTRO. PERENNIAL FORBS	1.4	42.9	36.3	32.4	21.2
NATIVE ANN. & BIEN. FORBS				0.1	0.1
NATIVE PERENNIAL FORBS		0.2	0.1		
NATIVE PERENNIAL GRASSES (c)	0.1				
NATIVE PERENNIAL GRASSES (w)					0.1
Total Vegetation Cover	14.40	59.90	50.90	45.00	32.00

Significant Difference Testing - boxed values indicate significant difference.
two-tailed test, α = 0.05, n = 10

		April 5, 2000	June 3, 2000	June 30, 2000	August 4, 200	September 6, 2000
INTRO. ANN. & BIEN. FORBS	control	18.9	$\boxed{23.2}$	20.2	$\boxed{19.2}$	$\boxed{17.5}$
INTRO. ANN. & BIEN. FORBS		12.9	$\boxed{16.8}$	14.5	$\boxed{12.5}$	$\boxed{10.6}$
INTRO. PERENNIAL FORBS	control	2.5	$\boxed{32.2}$	30.3	$\boxed{23.1}$	15.2
INTRO. PERENNIAL FORBS		1.4	$\boxed{42.9}$	36.3	$\boxed{32.4}$	21.2
Vegetation Cover	control	$\boxed{21.40}$	55.40	50.50	42.30	32.80
Vegetation Cover		$\boxed{14.4}$	59.9	50.9	45	32

Summary of site characteristics for year 2000:
NOTE: These graphics and statistics are based on averages that do not reveal the large variation between plots. Future comparisons will need to be based on comparisons of at least two subsets of the data. The northern paired transects (15-20) have significantly less cover than the southern transects (1-14).
Vegetation at this site is dominated by introduced weeds with perennial weeds more abundant than the annual weeds.
Total vegetation cover peaked in June and slowly declined through the summer.
The pretreatment baseline was dominated by litter and standing dead, with vegetation cover less than 50% of the summer maximum in June.
Although the vegetation cover values in the control and treatment areas were significantly different in April, these differences were not evident through the growing season.
The cover of introduced annual/biennial forbs (Bassia sieversiana = dominant) was consistently higher in the control and the difference was commonly statistically significant.
The cover of introduced perennial forbs (Convolnulus arvensis = dominant) was consistently higher in the treatment and the difference was commonly statistically significant.
Because these previous two differences have no 1999 comparison, they can not be attributed to the treatment effect, but rather establish a baseline for additional future change. It may, however, be possible that the low-till seeding discourages annuals weeds and promotes perennial weeds.

Figure 3. Vegetation Summary by Growth Form.

		A					B		
Average	STDev	ID		Group	Average	STDev	ID		Group
27.67	12.50	20	C	-	62.67	4.51	1	T	+
29.00	6.08	18	C	-	58.00	5.57	2	C	#
30.00	9.64	16	C	-	72.33	5.51	3	T	+
30.33	13.65	19	T	-	79.33	8.14	4	C	+
30.67	8.08	17	T	-	60.00	12.49	5	T	+
39.33	10.26	14	C	-	48.67	2.08	6	C	#
45.67	11.02	11	T	-	62.00	3.61	7	T	+
45.67	12.86	13	T	#	69.67	4.04	8	C	+
46.67	0.58	15	T	#	63.33	9.07	9	T	+
48.67	2.08	6	C	#	57.33	10.79	10	C	#
55.00	7.81	12	C	#	45.67	11.02	11	T	-
57.33	10.79	10	C	#	55.00	7.81	12	C	#
58.00	5.57	2	C	#	45.67	12.86	13	T	#
60.00	12.49	5	T	+	39.33	10.26	14	C	-
62.00	3.61	7	T	+	46.67	0.58	15	T	#
62.67	4.51	1	T	+	30.00	9.64	16	C	-
63.33	9.07	9	T	+	30.67	8.08	17	T	-
69.67	4.04	8	C	+	29.00	6.08	18	C	-
72.33	5.51	3	T	+	30.33	13.65	19	T	-
79.33	8.14	4	C	+	27.67	12.50	20	C	-
		A					B		

Table 1. Comparison of Sample Means.

Photographs 5-10 show the changes over time at transect 1. Photograph 5 shows transect 1 prior to treatment. Photograph 6 shows plot 1 after treatment. Photographs 7-10 were taken June 3, June 30, August 4, and September 6 respectively at transect 1. Photograph 9 also shows the Cover-Point point-intercept optical device used for sampling.

The following points summarize the vegetation results:

1. Vegetation at this site was dominated by introduced weeds with perennial weeds (dominated by bind-weed) more abundant than the annual weeds (dominated by burning-bush).
2. Total vegetation cover (dominated by weeds) peaked in June and slowly declined through the summer.
3. The April pretreament baseline was dominated by litter and standing dead, with vegetation cover less than 50% of the summer maximum in June.
4. Although the total vegetation cover values in the control and treatment areas were significantly different in April, these differences were not evident through the remainder of the growing season.
5. The cover of introduced annual/biennial forbs (burning-bush = dominant) was consistently higher in the control and the difference was commonly statistically significant.
6. The cover of introduced perennial forbs (bindweed = dominant) was consistently higher in the treatment and the difference was commonly statistically significant.
7. Because the differences described in item 5 & 6 have no 1999 comparison, they can not be attributed to the treatment effect, but rather establish a baseline for future change. It is impossible to know if the treatment plots would have been this different from the controls, even if they had never been treated, without data for all plots from a previous year. It may, however, be possible that the low-till seeding discourages annual weeds and stimulates perennial weeds.
8. The native grasses never achieved a level of cover that was measurable using point-intercept sampling. This is probably a result of the 5th driest April-May-June period in the last 105 years of record (see Climate section). Observations documented with photographs show that there are patches of seedlings scattered throughout the study area in all treatment plots. Recommendations for next year include randomly located plots within the treatment plots to estimate seedling density. Photograph 11 shows a seedling established in the understory of the bindweed and burning-bush. Photograph 12 shows a 1-meter section of furrow with 10 seedlings. Some areas of treatment plots showed no seedling establishment. It is hoped that the very hot and dry summer allowed the ungerminated seeds to survive until the 2001 growing season (see soil temperature information in the Climate section). Recommendations for next year include no modifications to the site other than additional monitoring. All it may take to establish the native grasses is a little rain. Whether the seeds have survived the extremely dry 2000 spring season and can establish in spring 2001 is a compelling question.

Photographs 13 & 14 show an overview of the site on October 10, 2000.

Soil samples and description

The Boulder County soil survey (USDA 1975) maps this area as Loveland Series, 0 to 1 percent slopes. These soils are described as follows, "The Loveland series is made up of deep, somewhat poorly drained soils. These soils formed on terraces and bottomlands in loamy alluvium that over lies gravelly and sandy materials. In a representative profile the surface layer is calcareous, dark grayish-brown light clay loam about 20 inches thick. It is mottled in the lower part. The underlaying material, about 10 inches thick, is strongly calcareous, grayish-brown light clay loam that is mottled. Loveland soils have moderate permeability. Available water capacity for the profile is moderate to high, depending upon the depth to very gravelly sand. Roots can penetrate to a depth of 60 inches or more and the seasonal high water table is at a depth of 2 to 4 feet. "

Two soil samples were collected on October 10, 2000 to represent the best and worst sites for existing vegetation at the site (see Figure 2 for locations). Because there was a significant difference between the northern (low productivity) and southern (higher productivity) transects, the samples were taken from the northern and southern areas respectively. The soil analysis results are presented in Table 2. The discussion of the results follows the following horizon descriptions.

Soil Sample 1:
This sample was taken in an area with relatively high vegetation cover in control plot 2 adjacent to treatment plot 1, about 32 m (105 ft.) from the east end of the plot. The upper horizons appear to have been mixed in the past (early 1900's?) with no clear A1 or O horizons (Photographs 13 & 14). Clay films were visible at about 23 cm (9 in.) indicating that some soil development has had time to occur.

0-9 inches mixed AB currently functioning as A. Moist color 10YR 3/2 (very dark grayish brown), silty loam. Lots of fine roots and open wormholes.
10-12 inches lower mixed AB currently functioning as B. Moist color 10YR 4/2 (dark grayish brown) with clay films and streaked with dry color 10YR 3/4 (dark yellowish brown) mottles. The matrix is a clay loam with sandy clay loam mottles. Mostly larger roots with few fine roots, most wormholes filled with castings.

Soil Sample 2:
This sample was taken in an area with relatively low vegetation cover (dominated by burning-bush) in control plot 18 adjacent to the start of the plot 19 transect. Lots of coarse gravel around the prairie dog mounds in this area, with an abundance of anthills.

0-11 inches mixed AB currently functioning as A. Moist color 10 YR 3/2 (very dark grayish brown) with dry color 10 YR 3/4 (dark yellowish brown) mottles which appear to be coarser materials filling worm holes. Matrix is loam/silt loam with coarse sand mottles.

Soil Analysis Results
These soil analyses are intended only to identify gross deficiencies or toxicities in the routine soil test parameters. Nitrate (N) and Phosphorus (P) were slightly deficient at both sites with approximately half as much P and slightly less N at the more productive Site 1. The other factors were similar with the exception of pH and Zinc (Zn), but both of these were within normal limits. Although soil texture in the analysis indicates similar results, these estimates are made by hand in the lab, and I have more confidence in the field textures that indicated a sandier soil at Site 2.

Based on the similarity of the soil analysis results and field observations of soil textures, I feel that the shallow sandy gravels of the northern transects may cause the soils to be better drained and drier, thus reducing vegetation growth. Patterns of alluvial deposition that deposit either fine or coarse textured sediments may be the primary source for the current pattern of high and low productivity at the site.

ID	pH	Salts mmhos/cm	Lime %	Texture	Organic %	N ppm	P ppm	K ppm	Zn ppm	Fe ppm	Mn ppm	Cu ppm
1-south	7.4	0.3	Low	Clay loam	2.3	4	1.9	242	2.2	10.0	2.4	2.5
2-north	6.5	0.2	Low	Clay loam	3.3	5	4.4	211	0.8	16.7	2.4	2.9

Table 2. Soil Analysis Results

Climate

On-site temperature and precipitation data-logging equipment was installed but was not maintained often enough to counteract the effects of wildlife and human disturbance. Human disturbances included placing large stones in the barrel of the precipitation gauge and triggering the reset buttons of the gauges. Wildlife disturbances included the gnawing of the cable that measured soil temperatures, removal of the cotton wick that was part of the precipitation gauge and bird excrement in the precipitation gauge. The temperature cable was later protected by plastic pipe. Additional protective measures will be needed to protect the equipment in the future.

Figure 5 shows a selected set of annual climate diagrams for Boulder. The study site is approximately 10 miles ENE of Boulder and is probably in a drier site than the Boulder NOAA Weather Station near 30th and Arapaho. The climate diagrams display the monthly precipitation and temperature along with the Thornthwaite potential evapotranspiration (Dunn & Leopold 1954). The graphs can be interpreted by observing the area under the curve of the potential evapotranspiration that exceeds precipitation. This area of the graph where potential evapotranspiration exceeds precipitation is a good indicator of drought stress experienced by plants. The first graph provides the long-term average (104 years, 1897-2000), and the five years with the combined warmest and driest April-May-June periods over the 104 years. The April-May-June period for year 2000 was the 5th warmest and driest in the last 104 years of record.

A review of a complete set of climate diagrams for Boulder indicates that climate, especially precipitation is highly variable with respect both to total annual precipitation and the monthly average precipitation. Climate must be a component of every vegetation monitoring plan especially with this level of variability. Although the precipitation at the study site is likely to have been different from that collected at the NOAA weather station, the temperature is more likely to have been similar. There were 51 days this summer with temperatures in the 90s with 31 days as the normal. The heat combined with the low precipitation naturally suppressed seedling establishment and growth.

Although these were extremely poor conditions for seed germination and establishment, some seedlings were observed in the more mesic sites. Mesic sites were typically slight depressions with slightly more growth of either bind-weed or burning bush. The hope is that the dry weather and the survivability of the native seed will allow remaining seed to germinate next spring. The soil conditions during this hot dry summer are demonstrated by Figure 6 that shows air temperature at 1 m (3.3 ft.) versus soil temperature at 2.5 cm (1 inch) below the surface. These data were collected on-site August 13th & 14th when the temperature maximum in Boulder was 34°C (93°F) for both days, and the temperature maximums on-site were 36°C and 38°C (97°F and 100°F) respectively. Even when the air temperature reached these maximums, the soil temperature was relatively stable around 12.8-14.5°C (55-58°F), perhaps supporting seed survival.

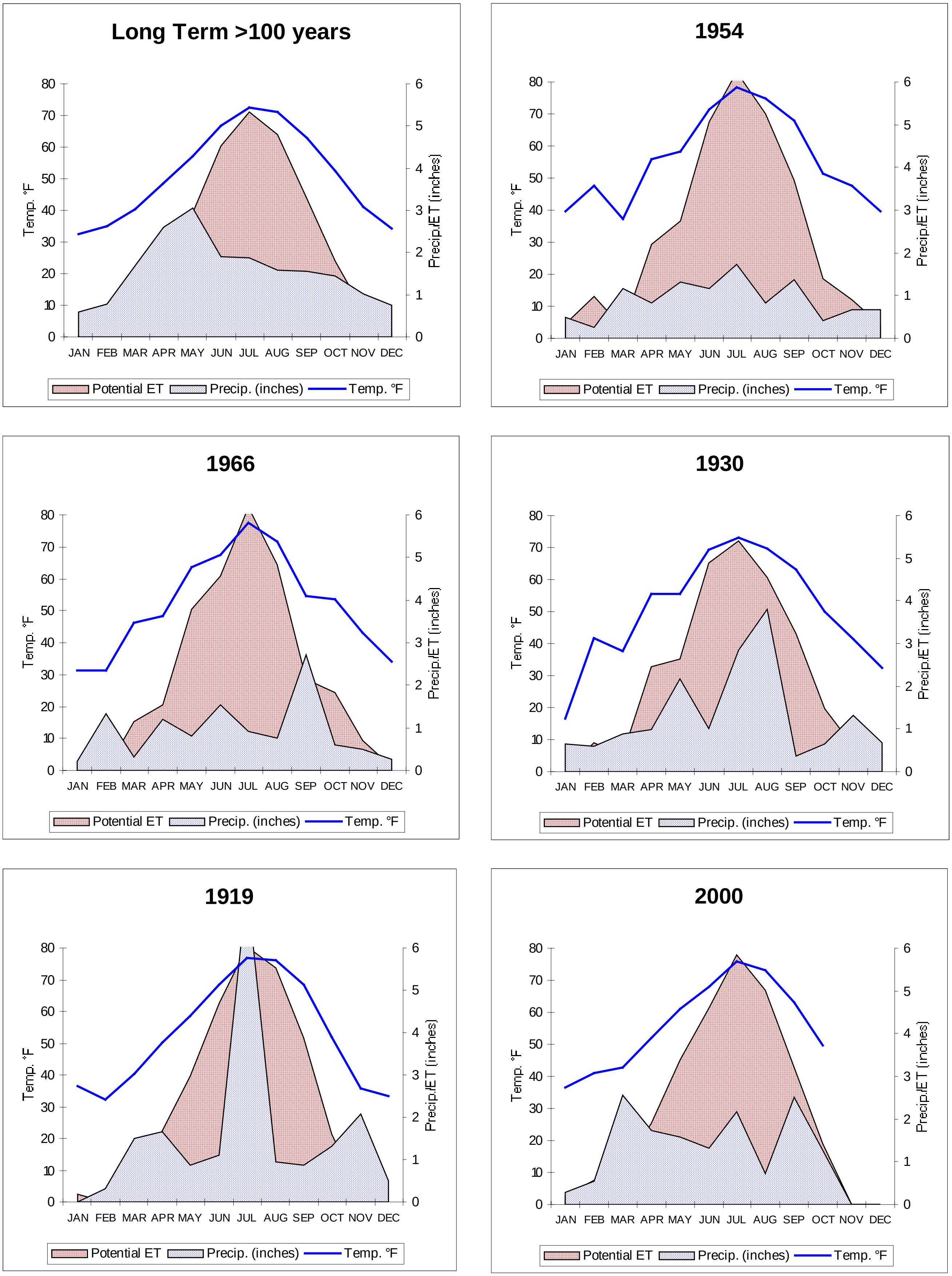


Figure 5. Boulder Climate Diagrams.

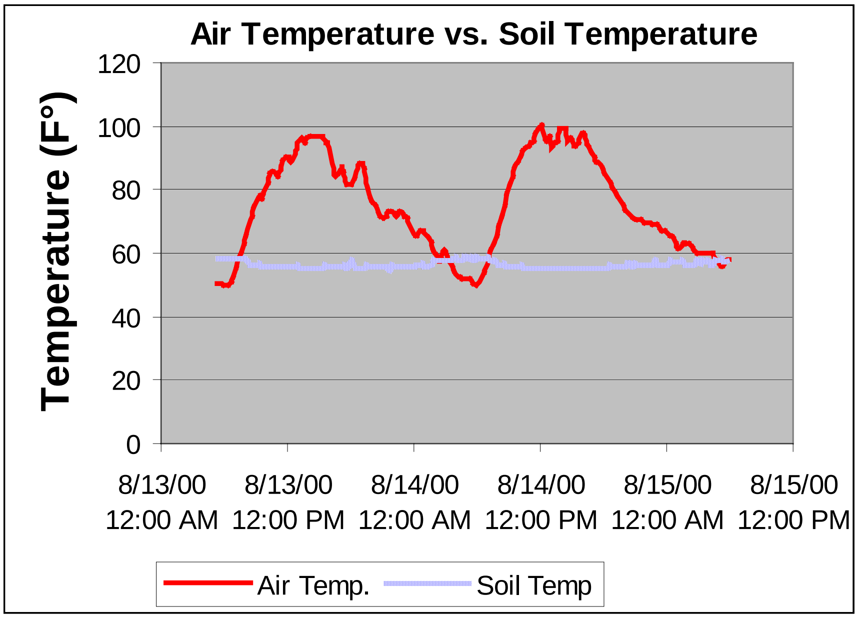


_Figure 6. Air Temperature vs. Soil Temperature

Intra-Colony Burrow Density & Burrow Area Utilization

As expected, burrow density increased during the course of the experiment in all but two plots, both of which were seeded (Table 3). For these two plots, the reduction in burrows (-1 in one plot and -2 in the other) can be explained as having happened as a result of the seeding mechanism.

Table 3. Summary Statistics for Sample Plots

Plot No.	*Count*	*Mean Utilization*	*Std. Dev. Utilization*	*Std. Err. Utilization*	*Count*	*Mean Utilization*	*Std. Dev. Utilization*	*Std. Err. Utilization*	*Count Change*
	Before Seeding				After Seeding				
1	15	12.27	3.08	0.80	19	9.74	2.23	0.51	4
2	14	12.86	2.74	0.73	17	11.53	3.30	0.80	3
3	15	12.93	2.87	0.74	16	12.31	2.55	0.64	1
4	10	11.60	2.50	0.79	10	12.80	1.62	0.51	0
5	8	12.38	2.50	0.89	10	13.70	1.89	0.60	2
6	11	12.46	3.36	1.01	11	12.55	3.05	0.92	0
7	8	10.88	3.44	1.22	6	10.00	3.10	1.27	-2
8	7	12.57	3.36	1.27	9	9.56	2.79	0.93	2
9	9	12.22	4.15	1.38	12	10.75	1.49	0.43	3
10	4	9.00	1.41	0.71	14	11.36	3.05	0.82	10
11	8	11.50	3.16	1.12	7	11.00	3.46	1.31	-1
12	7	11.00	4.93	1.86	10	11.20	2.82	0.89	3
13	13	10.08	2.93	0.81	14	11.50	3.55	0.95	1
14	7	10.71	3.35	1.27	10	10.60	2.63	0.83	3
15	10	10.30	2.41	0.76	13	11.23	3.94	1.09	3
16	5	9.40	2.30	1.03	8	10.63	2.88	1.02	3
17	3	8.33	1.16	0.67	10	11.20	1.40	0.44	7
18	4	8.50	1.92	0.96	11	9.73	2.24	0.68	7
19	4	8.75	2.22	1.11	10	11.70	3.53	1.12	6
20	7	9.43	2.99	1.13	8	9.88	2.36	0.83	1
Outside	351	12.13	3.06	0.16	334	13.07	2.79	0.15	-17

Figure 7 demonstrates the construction of the utilization value using the following histograms of length, height, vegetation cover, and scat class measurements. These histogram classes were adjusted to allow selection of 5 categories (some of which included more than one histogram class) that could be used to estimate utilization. The 5 categories were assigned scores of 1 to 5 with high scores indicating higher utilization. The sum of the four scores was the final utilization score. These histograms included mounds that were adjacent to, as well as within, the study plots.

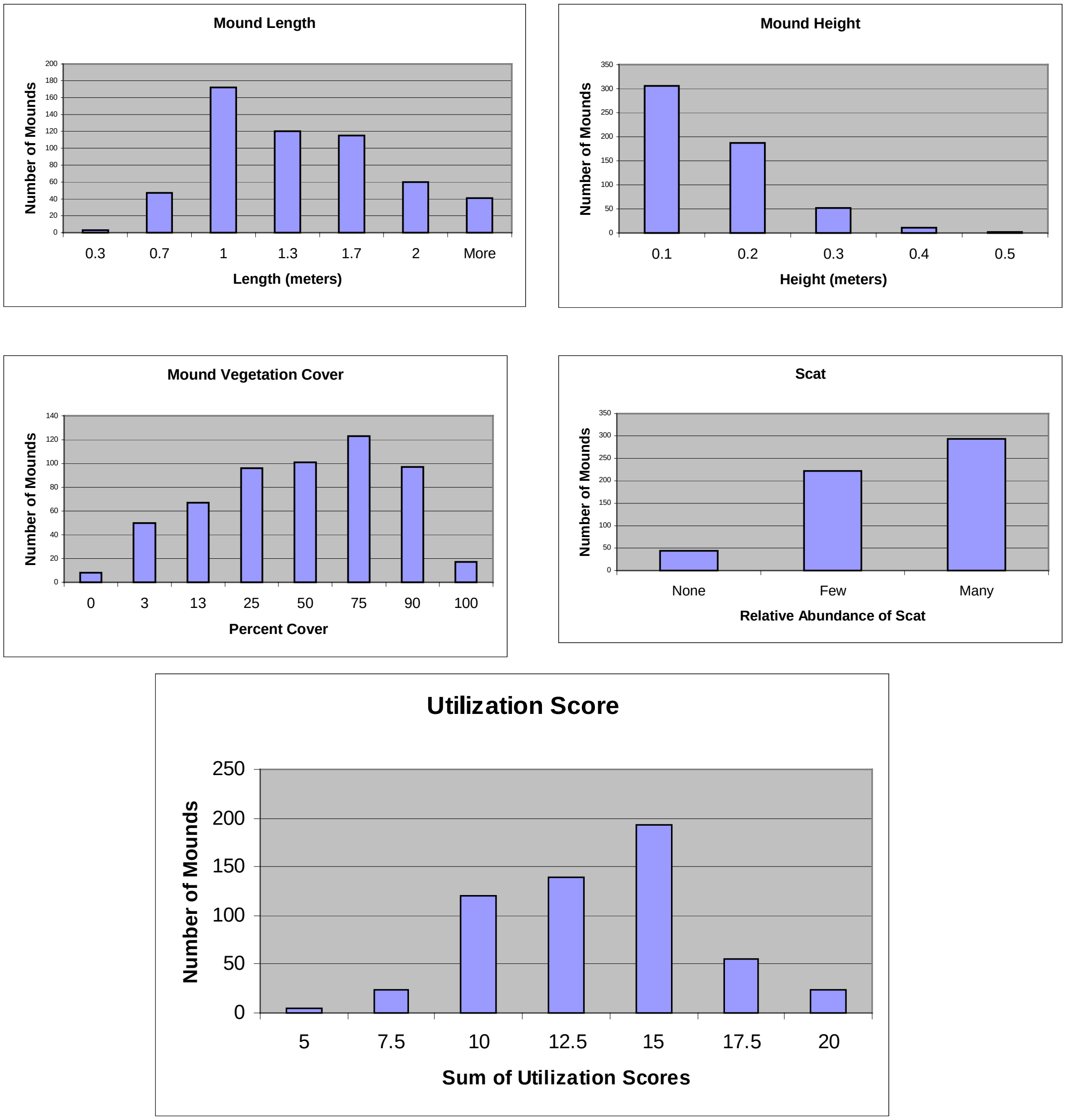


Figure 7. Mound Characteristics Histograms.

The utilization scores were used to construct a utilization topography that allows visual evaluation of changes in the distribution of activity within the prairie dog colony. Figure 8 indicates that the utilization was more centrally focused in April and more dispersed by September. Red contours indicate areas of relatively high utilization and dark blue contours indicate areas of relatively low utilization.

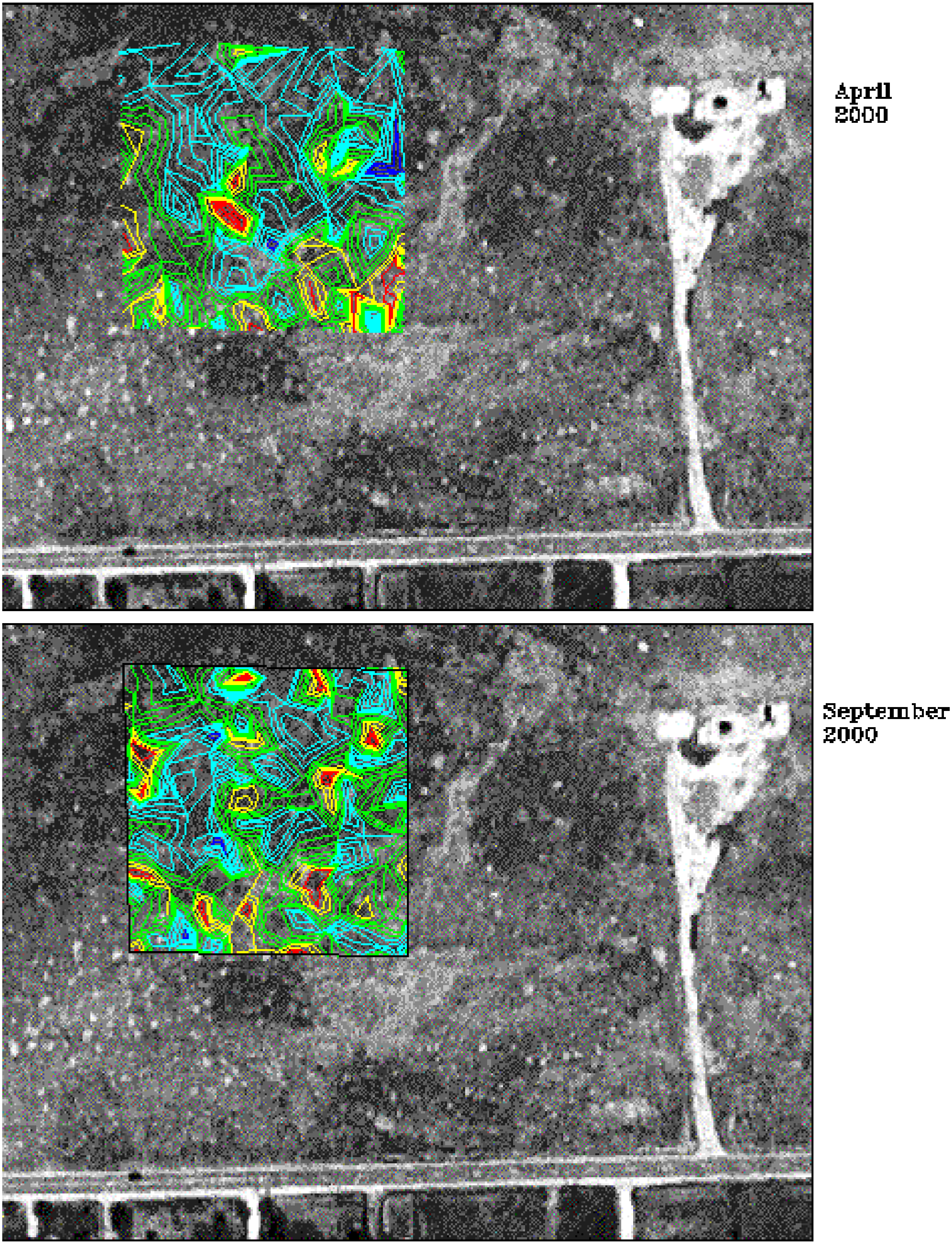


Figure 8. Utilization Contours.

The repeated measures ANOVA results in the following tables were used to detect change over the coarse of the season for the factors of interest. Since the control and treatment may have differences (significant or not) prior to treatment, this allows changes over time to be evaluated regardless of the initial differences.

Overall, the largest increases in burrow densities occurred in control plots however these changes were not significantly different than those in seeded plots (Table 4, Figure 9).

Table 4. Repeated Measures ANOVA Table for Number of Burrows

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Treatment	1	16.9	16.9	0.809	0.3804	0.809	0.131
Plots	18	376.2	20.9				
Number of Burrows per Plot	1	78.4	78.4	17.64	0.0005	17.64	0.986
Number of Burrows * Treatment	1	1.6	1.6	0.36	0.556	0.36	0.086
Number of Burrows * Plots	18	80	4.444				

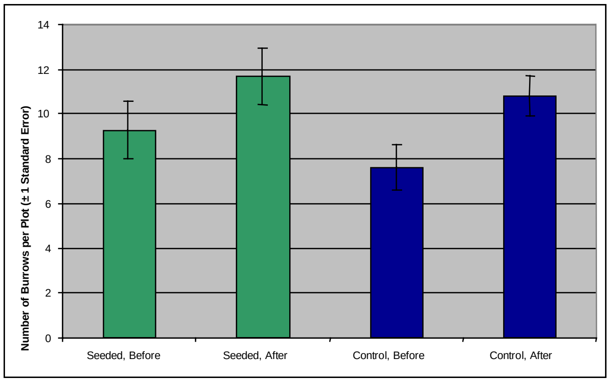


Figure 9. Comparison of burrow counts in seeded and control plots before and after treatment.

Mean utilization was not significantly affected by seeding (Table 5, Figure 10).

Table 5. Repeated Measures ANOVA Table for Utilization

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Treatment	1	0.735	0.735	0.307	0.5862	0.307	0.081
Plots	18	43.048	2.392				
Number of Burrows per Plot	1	0.837	0.837	0.592	0.4517	0.592	0.109
Number of Burrows * Treatment	1	0.037	0.037	0.026	0.874	0.026	0.053
Number of Burrows * Plots	18	25.453	1.414				

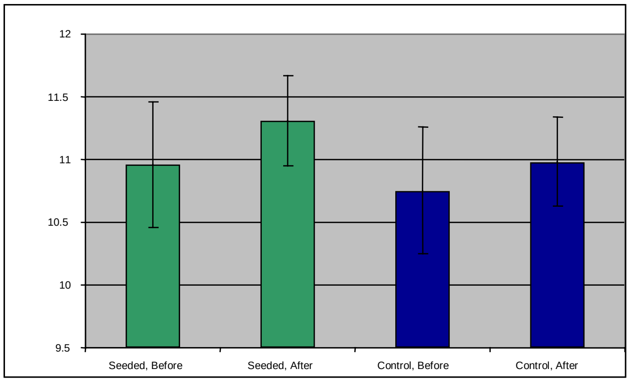


Figure 10. Comparison of burrow area utilization in seeded and control plots before and after treatment.

Burrow Spatial Dispersion

In all instances Point-Burrow distances were more than Burrow-Nearest Burrow distances indicating a clumped spatial arrangement of burrows as expected. This pattern did not change measurably following seeding except that both measures decreased equally with the addition of new burrows (Table 6, Figure 11).

Table 6 . Spatial Dispersion characteristics of burrows in all plots before seeding (April) and after seeding (October)

	Before		**After**	
	Mean	**SE**	**Mean**	**SE**
Point-Burrow	12.5	18.1	11.5	14.8
Burrow-Nearest Burrow	12.3	12.8	10.3	11.4

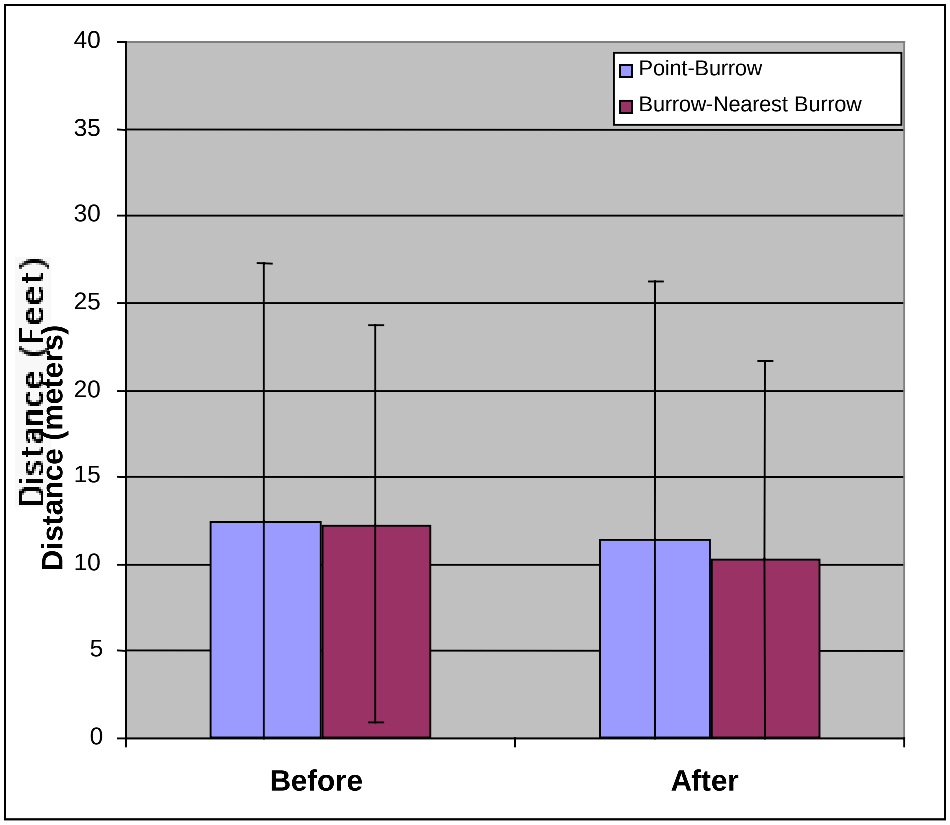


Figure 11 . Comparison of spatial dispersion characteristics of burrows in all plots before seeding (April) and after seeding (October).

Above Ground Animal Sightings, The Effect of Seeding on Disturbance and Plot Use

Although prairie dogs were initially observed more in plots that would be seeded, seeding did not have a significant effect on aboveground prairie dog counts (F = 0.872, P = 0.503; Table 7, Figure 12). These same results indicate that there was no significant difference between prairie dog use of seeded or control plots.

Table 7. Repeated Measures ANOVA Table for Aboveground Prairie Dog Counts

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Treatment	1	2.408	2.408	3.797	0.0671	3.797	0.442
Plots	18	11.417	0.634				
Sample Period	5	2.542	0.508	2.801	0.0213	14.005	0.816
Sample Period * Treatment	5	0.792	0.158	0.872	0.5029	4.362	0.294
Plots * Sample Period	90	16.333	0.181				

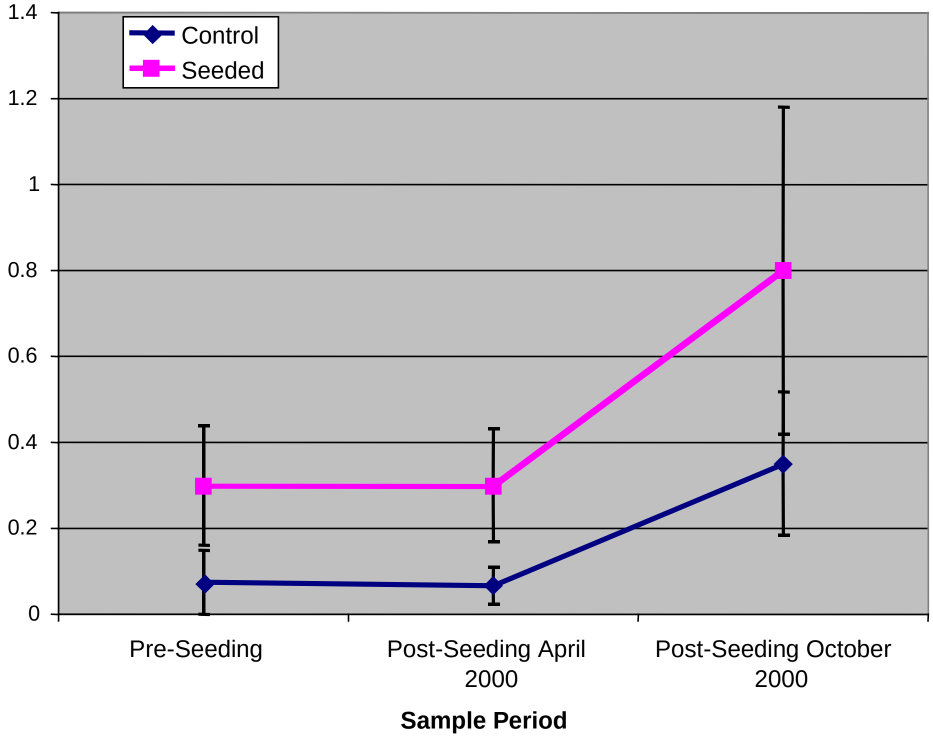


Figure 12. Comparison of aboveground prairie dog counts in seeded and control plots before, immediately after, and several months after treatment.

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APPENDIX A

Seeding Mix
Certified Seed Analysis
Seed Bag Tags

Seed Mixture for Doniphan Property, Revegetation Experiment - Summer 2000

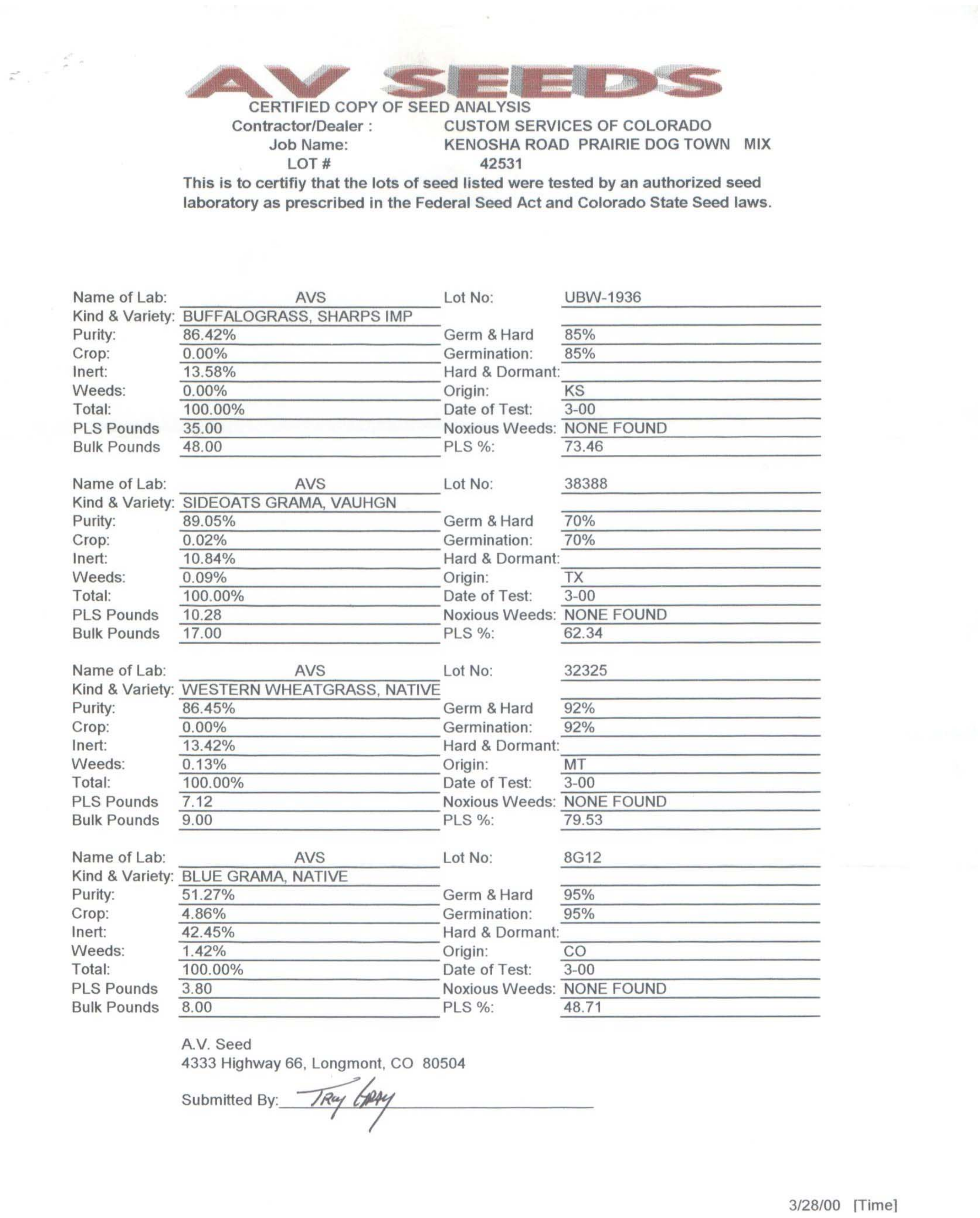
Doniphan Property - Kenosha Road

SEED MIXTURE EVALUATION:

PLS = Pure Live Seed

SPECIES	**Composition %**	**Seeds/lb**	**Germination %**	**Purity %**	**PLS %**	**Recommended Drill Seeding Rate**		**Bulk Seed lbs./Acre**
						PLS lbs./Acre	**PLS/ Sq./ft.**	
TOTALS	**100**					**28.10**	**90**	**40.45**
asses								
Buffalo grass (*Buchloe dactyloides*) -Topgun	25	56,000	85	86.42	73.46	17.50	22.5	23.83
Blue grama (*Chondrosum* [*Bouteloua*] *gracilis*) -	40	825,000	95	51.27	48.71	1.90	36.0	3.90
Sideoats grama (*Bouteloua curtipendula*) - Unknown	25	191,000	70	89	62.30	5.13	22.5	8.24
Western wheatgrass (*Pascopyrum* [*Agropyron*] *smithii*) -	10	110,000	92	86.45	79.53	3.56	9.0	4.48

Certified Seed Analysis for Doniphan Property - Revegetation Experiment - Summer 2000



AV SEEDS

CERTIFIED COPY OF SEED ANALYSIS

Contractor/Dealer : CUSTOM SERVICES OF COLORADO
Job Name: KENOSHA ROAD PRAIRIE DOG TOWN MIX
LOT # 42531

This is to certifiy that the lots of seed listed were tested by an authorized seed laboratory as prescribed in the Federal Seed Act and Colorado State Seed laws.

Name of Lab:	AVS	Lot No:	UBW-1936
Kind & Variety:	BUFFALOGRASS, SHARPS IMP		
Purity:	86.42%	Germ & Hard	85%
Crop:	0.00%	Germination:	85%
Inert:	13.58%	Hard & Dormant:	
Weeds:	0.00%	Origin:	KS
Total:	100.00%	Date of Test:	3-00
PLS Pounds	35.00	Noxious Weeds:	NONE FOUND
Bulk Pounds	48.00	PLS %:	73.46

Name of Lab:	AVS	Lot No:	38388
Kind & Variety:	SIDEOATS GRAMA, VAUHGN		
Purity:	89.05%	Germ & Hard	70%
Crop:	0.02%	Germination:	70%
Inert:	10.84%	Hard & Dormant:	
Weeds:	0.09%	Origin:	TX
Total:	100.00%	Date of Test:	3-00
PLS Pounds	10.28	Noxious Weeds:	NONE FOUND
Bulk Pounds	17.00	PLS %:	62.34

Name of Lab:	AVS	Lot No:	32325
Kind & Variety:	WESTERN WHEATGRASS, NATIVE		
Purity:	86.45%	Germ & Hard	92%
Crop:	0.00%	Germination:	92%
Inert:	13.42%	Hard & Dormant:	
Weeds:	0.13%	Origin:	MT
Total:	100.00%	Date of Test:	3-00
PLS Pounds	7.12	Noxious Weeds:	NONE FOUND
Bulk Pounds	9.00	PLS %:	79.53

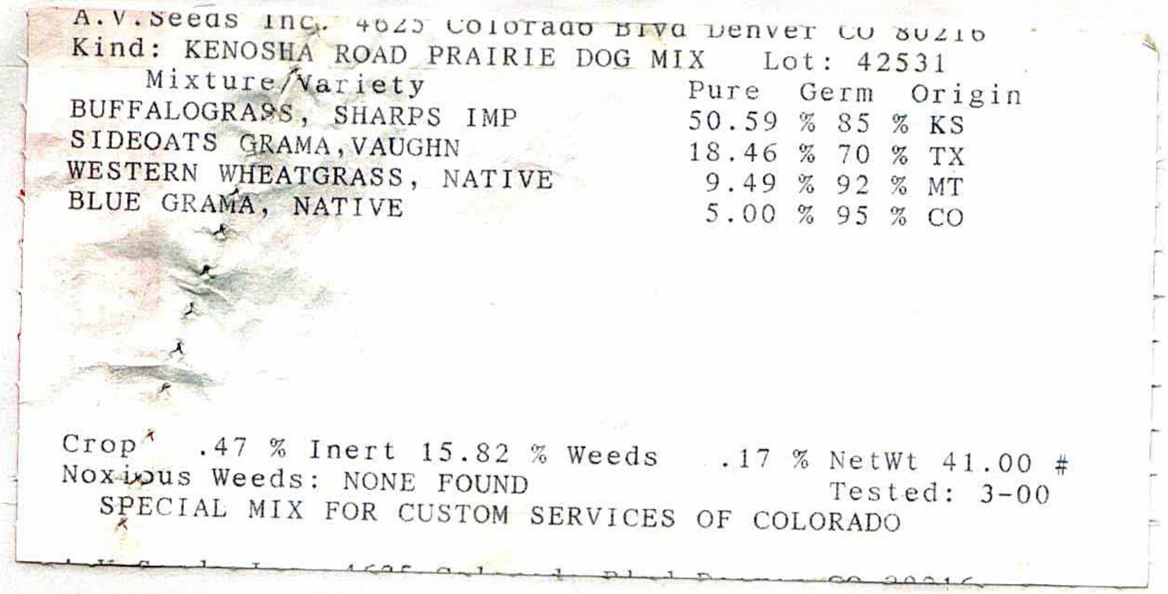
Name of Lab:	AVS	Lot No:	8G12
Kind & Variety:	BLUE GRAMA, NATIVE		
Purity:	51.27%	Germ & Hard	95%
Crop:	4.86%	Germination:	95%
Inert:	42.45%	Hard & Dormant:	
Weeds:	1.42%	Origin:	CO
Total:	100.00%	Date of Test:	3-00
PLS Pounds	3.80	Noxious Weeds:	NONE FOUND
Bulk Pounds	8.00	PLS %:	48.71

A.V. Seed
4333 Highway 66, Longmont, CO 80504

Submitted By: Troy Gray

3/28/00 [Time]

Doniphan Property Seed Tags - Revegetation Experiment - Summer 2000



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A.V.Seeds Inc. 4625 Colorado Blvd Denver CO 80216
Kind: KENOSHA ROAD PRAIRIE DOG MIX    Lot: 42531
     Mixture/Variety                   Pure   Germ   Origin
BUFFALOGRASS, SHARPS IMP               50.59 % 85 % KS
SIDEOATS GRAMA,VAUGHN                  18.46 % 70 % TX
WESTERN WHEATGRASS, NATIVE              9.49 % 92 % MT
BLUE GRAMA, NATIVE                      5.00 % 95 % CO

Crop   .47 % Inert 15.82 % Weeds    .17 % NetWt 41.00 #
Noxious Weeds: NONE FOUND                 Tested: 3-00
  SPECIAL MIX FOR CUSTOM SERVICES OF COLORADO
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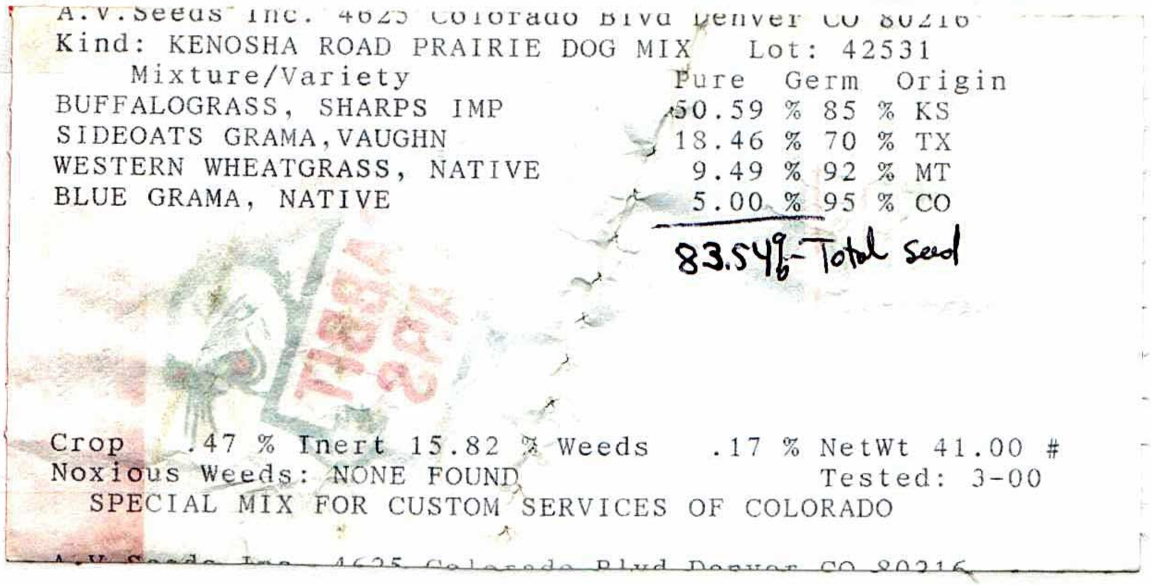

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A.V.Seeds Inc. 4625 Colorado Blvd Denver CO 80216
Kind: KENOSHA ROAD PRAIRIE DOG MIX    Lot: 42531
     Mixture/Variety                   Pure   Germ   Origin
BUFFALOGRASS, SHARPS IMP               50.59 % 85 % KS
SIDEOATS GRAMA,VAUGHN                  18.46 % 70 % TX
WESTERN WHEATGRASS, NATIVE              9.49 % 92 % MT
BLUE GRAMA, NATIVE                      5.00 % 95 % CO

Crop   .47 % Inert 15.82 % Weeds    .17 % NetWt 41.00 #
Noxious Weeds: NONE FOUND                 Tested: 3-00
  SPECIAL MIX FOR CUSTOM SERVICES OF COLORADO
```

83.54% - Total seed

APPENDIX B

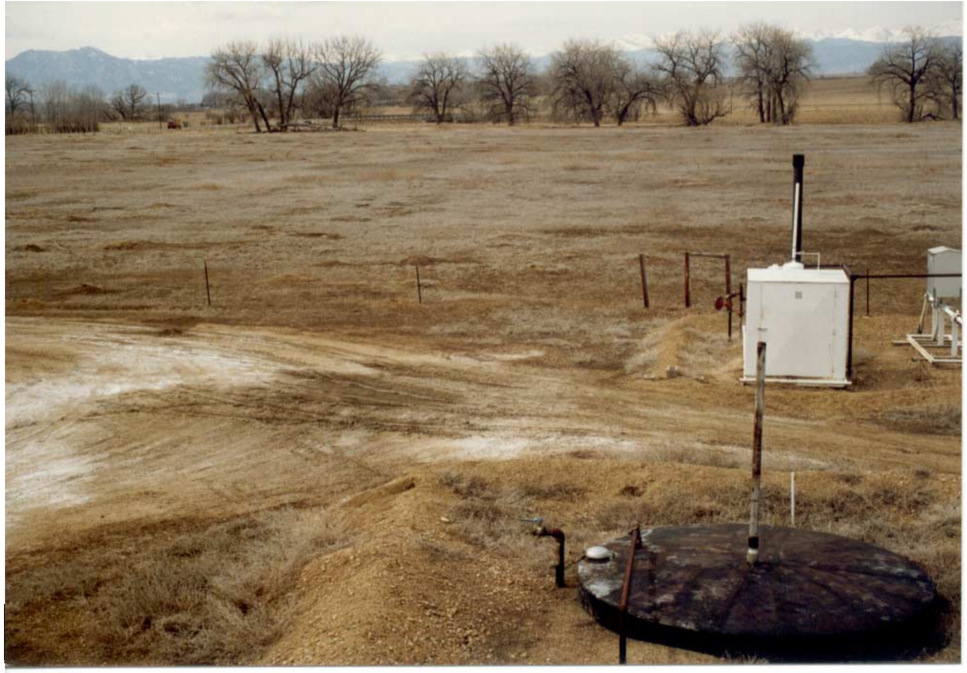
Data Summary Tables

1X - Combined Transects April 5, 2000
1C - Control Transects April 5, 2000
1T - Treatment Transects April 5, 2000
2X - Combined Transects June 3, 2000
2C - Control Transects June 3, 2000
2T - Treatment Transects June 3, 2000
3X - Combined Transects June 30, 2000
3C - Control Transects June 30, 2000
3T - Treatment Transects June 30, 2000
4X - Combined Transects August 4, 2000
4C - Control Transects August 4, 2000
4T - Treatment Transects August 4, 2000
5X - Combined Transects September 6, 2000
5C - Control Transects September 6, 2000
5T - Treatment Transects September 6, 2000

Photographs

Photograph 1. Plot 3, second pass with low-till seed drill. Note unseeded center strip - April 5, 2000.

Photograph 2. Plot 3 after third pass with low-till seed drill.



Photograph 3. Study area prior to survey and treatment.

Photograph 4. Seed drill operation.

Photograph 5. Transect 1 prior to treatment - April 4, 2000.
2000.

Photograph 6. Plot 1 after treatment. Transect 1 starts in middle of photo. April 5,

Photograph 7. Transect 1, June 3, 2000.

Photograph 8. Transect 1, June 30, 2000.

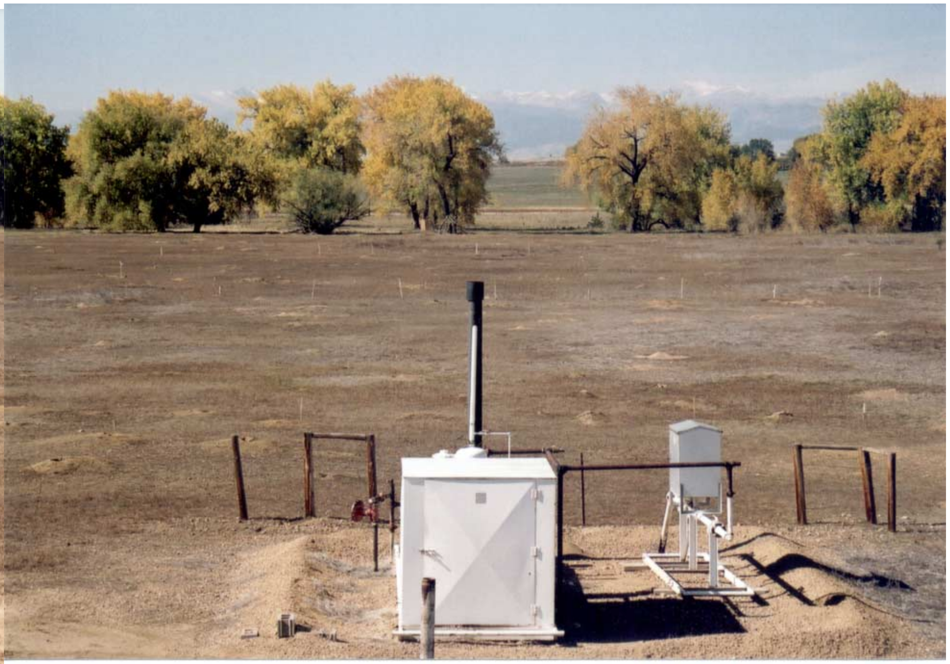
Photograph 9. Transect 1, August 4, 2000.

Photograph 10. Transect 1, September 6, 2000

Photograph 11. Grass seedling in understory of weed species.

Photograph 12. Ten grass seedlings per meter.

Photograph 13. Study area, October 10, 2000.



Photograph 14.

Photograph 15. Soil Sample 1 profile.

Photograph 16. Soil Sample 1 location.

Photograph 17. Soil Sample 2 profile.

Photograph 18. Soil Sample 2 location.