

**Effectiveness of Glyphosate Herbicide on Buffelgrass (*Pennisetum ciliare* L.)
at Saguaro National Park, Tucson, Arizona.**

**Technical Report to Saguaro National Park
April 2007**



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What will happen to the Sonoran Desert's charismatic species?



Desert tortoise surrounded by alive and senescent buffelgrass.



Young and mature saguaros in a sea of buffelgrass.

Acknowledgements:

We would like thank the many folks who helped gather the data, mow the plots, and apply herbicides. All photos were taken by Saguaro National Park staff. Thank you to Park staff who helped collect the data and apply the treatments, and statistical guidance from Thereesa M. Crimmins. We appreciate the importance Saguaro National Park places on protecting natural resources from the buffelgrass invasion.

Introduction

Invasive non-native species pose a serious threat to native organisms, ecological processes and overall biological diversity. In the Sonoran Desert biome, several perennial and annual non-native grasses have invaded and quickly expanded over the past couple of decades. Of particular concern is *Pennisetum ciliare* L. (buffelgrass), a perennial apomitic grass native to Africa and parts of Asia. It was first introduced into the United States in the 1930s as part of an effort to stabilize degraded rangelands and provide livestock forage (Cox et al. 1988, Tellman 1997). Since then, purposeful introductions have occurred for forage and mine stabilization. More alarming is the vigorous spread along roadsides and the explosive expansion of the population into urban landscapes and natural areas (Felger 1990, Rutman and Dickson 2002, Ward 2003).

Buffelgrass poses a serious threat to common and signature plants of the Arizona Uplands of the Sonoran Desert. Buffelgrass competes with native vegetation for soil resources and nutrients, can limit or reduce native plant diversity, and interfere with natural ecosystem processes (Fairfax and Fensham 2000, Burquez et al. 2002, McIvor 2003, Jackson 2005). The greatest risk buffelgrass poses is the alteration of fire regimes, increasing fire size, frequency and intensity (Martin 1999, Butler and Fairfax 2003, Esque et al. 2004). Plants characteristic of the Arizona Upland subdivision of the Sonoran Desert, such as the saguaro, palo verdes, and other co-occurring species are particularly at risk because they are fire-intolerant plants and suffer high mortality from fire (McLaughlin and Bowers 1982, Esque et al. 2004). Buffelgrass provides abundant and continuous combustible fine fuel not typically present in this environment. Recurrent fires threaten many Sonoran Desert plant species, especially the saguaro, to the point of localized extinction and could result in vegetative type conversion into a grassland (McLaughlin and Bowers 1982, D'Antonio and Vitousek 1992, Esque and Schwalbe 2002).

Buffelgrass severely threatens the integrity for which Saguaro National Park (SNP) was established and expanded: to preserve the 'exceptional growth thereon of various species of cacti, including the so-called giant [saguaro] cactus' and the 'prime Sonoran desert habitat' that the saguaro lives in. Park staff report known populations of buffelgrass within the Rincon Mountain District as early as 1994 when volunteers began pulling it (Kline, personal communication 2007). Subsequently, it was listed as common in the Tucson Mountain flora (Bowers and McLaughlin 1996) and has precipitously increased over the years to form dense patches greater than 10 acres in size. An extensive survey of buffelgrass at both districts of SNP in 2002 estimated approximately 350 acres of buffelgrass or <1% of the Arizona Upland within SNP was infested with buffelgrass. A spatial logistic regression model predicted buffelgrass could occupy up to 32% of the Arizona Upland (Ward 2003). Recent observations and mapping at the Park suggest buffelgrass has more than quadrupled since 2002 most likely due to favorable climatic conditions and prevalence of seed sources.

Background

In the late 1990s, SNP began mechanical control (hand-pulling) of buffelgrass, averaging approximately 50 acres per year. Due to seed viability of approximately 2-4 years (Winkworth 1971) and possible longer depending on the cultivar, most of these acres treated had to be re-

visited, making progress slow. Plus, seeds will continue to migrate to a treated site because of the propagules in the surrounding area. With rapid expansion within the park other means of control were considered, with special regard to protecting the natural and cultural resources. Overall, the consensus among park managers was that the detrimental impact of buffelgrass on the native plant community and wildlife it supports was far greater if not treated than the potential minor impacts of control efforts.

Based on the best available information at the time, herbicides with active ingredient glyphosate were known to be effective at killing buffelgrass (personal communications with various local herbicide applicators). A feasibility and control study conducted at the park by USGS between 2002-2004, indicated glyphosate was effective at controlling buffelgrass and more cost effective than mechanical control (Esque, personal communications 2003). AZ Department of Transportation successfully used glyphosate with pre-emergent Oust (sulfometuron) to control roadside populations of buffelgrass (Horsley, personal communications 2004). Other buffelgrass control studies using glyphosate at concentrations between 4-6% and in combination with other chemicals had variable results. Efficacy information available for grass-specific herbicides indicated that they were not consistently effective at controlling buffelgrass (AZ Department of Transportation, personal communication 2004).

After completing the Exotic Plant Management Plan and Environmental Assessment (2004) and awarded NRPP funds (2005), SNP expanded its exotic plant management program to include herbicide application with a focus on controlling buffelgrass and fountain grass. During the first phase of herbicide application in winter 2005, SNP used a solution comprised of 4.8% concentration of glyphosate (RoundUp Pro), 0.5% concentration of surfactant (LI-700) and 0.2% concentration of water conditioner (Choice) for terrestrial applications and 4.4% concentration of aquatic approved glyphosate (AquaMaster) and 0.6% concentration of surfactant (LI-700) solution for aquatic and riparian environments. Another additive to both mixtures was an indicator dye (0.6%). The south facing slope of the Tanque Verde Ridge (Figure 1) was the focal area because of the size and density of the infestation and the critical habitat for desert tortoise, cactus ferruginous pygmy-owl, lesser long-nosed bats, and lowland leopard frog. Although this area is designated wilderness it is fairly accessible and requires minimal logistics for staging supplies and materials.

When the park began herbicide treatment, it selected the concentration that was known to effectively kill buffelgrass. Staff was limited at the time therefore it was not feasible to test the effectiveness of lower concentrations. As staff became available, this study was designed to determine if a lower concentration would effectively control buffelgrass. Lower herbicide concentrations would benefit the park both economically and ecologically. Thus, the short-term objective of this study was to investigate the effectiveness of a lower concentration of glyphosate herbicide in combination with surfactant and a mechanical pre-treatment on buffelgrass mortality and to compare effectiveness of aquatic approved glyphosate with terrestrial glyphosate.

Two means of reducing the amount of herbicide include reducing the glyphosate concentration or reducing the amount of biomass to which the herbicide is applied. The latter was accomplished by mowing the senescent buffelgrass using a string-fed weed trimmer (i.e. pre-treatment). Thus, at the time of green up, the live biomass would be concentrated at the base of

the plant and herbicide would be applied directly to the base and not to the senescent foliage. In addition, the study investigated the effectiveness of LI-700 (phospholipids and propionic acid) a leaf penetration and pH adjuster surfactant. Other components of the study included quantifying the duration of time to exhaust the seedbank after repeated seasonal herbicide applications, native plant recruitment following one treatment application, and quantifying non-target plant mortality due to human error or drift. From a long-term perspective, the study is intended to assess the vegetation community response to the removal of buffelgrass competition and stress. Due to the potential impact on non-target plants, pre-emergent herbicides were not considered in this study.

Methods

The most dense and continuous buffelgrass patches of adequate size ($> 500\text{m}^2$) and within close proximity to a trail or road were selected as the focal area. The macroplots were on the south facing slopes of the Tanque Verde Ridge (Figure 1). There were four replications of each treatment and four non-buffelgrass control plots. Two replicates were located in lower Box Canyon at approximately 3020 ft elevation and the other two replicates were up canyon (Upper Box Canyon) at approximately 3500 ft (Table 2). Slope (10-25%), aspect (south – southwest), vegetation community (Arizona Upland subdivision of the Sonoran Desert, Brown 1994), and soil type (Cellar Rock Outcrop Complex, Department of Agriculture 2002) were all similar.

The variables under consideration included: 1) terrestrial glyphosate at 3% and 4.8%, and aquatic-approved glyphosate at 4.4%; 2) addition of surfactant at 0.5% or no surfactant; and 3) mowing as a pre-treatment or no pre-treatment. All treatments included 0.6% concentration of indicator dye and except for the aquatic-approved glyphosate, a 0.2% concentration of water conditioner (see Table 1 for formulations). The factorial design resulted in 12 combinations, which were randomly assigned to a treatment block within each macroplot (Figure 2).

Between June 20 and July 6, 2005, prior to application of any treatments, the number, age class, and percent cover of all living species was recorded within a 2m by 2m quadrat centrally located if possible, within each 5m by 5m (see Appendix A for specific measurements and layout of each macroplot). The location of the quadrat was permanently marked and photographed (Figure 3). Treatment combinations were applied to the entire 5m by 5m plot which allowed for a buffer between treatments and any potential drift. Following the summer monsoon rains and buffelgrass green-up, chemical applications were applied on August 24 and 25, 2005. The plan was to conduct the post-treatment monitoring following the next rainy season or when there was evidence of active growth. Due to the lack of precipitation in the winter and spring of 2006, the treatment effectiveness could not be determined because there was no above ground growth of buffelgrass. Thus, post-treatment data collection did not occur until after the summer monsoon rains began in 2006. Post-treatment data was gathered on August 28 and 29, 2006 and followed the same methodology as the pre-treatment with the addition of recording mortality and partial mortality of any species, and notation if there was any indication of drift on non-target species.

Data were inspected for outliers and transformed using a log base 10 to account for skewness. Statistical software JMP 5.0 was used for analyses. The following analyses and results were

performed with the exclusion of the control plots unless otherwise noted because they received no treatment and contained no buffelgrass.

Results and Discussion

Due to climate variability and the buffelgrass response, the time lag between pre-treatment data collection, treatment, and post-treatment data collection was less than ideal. The buffelgrass and native annual forbs and grasses present during the pre-treatment monitoring were in response to winter 2005 weather conditions and buffelgrass was senescent at that time. The buffelgrass plants chemically treated late August 2005 were mature plants with a majority of live photosynthetic biomass (green foliage) and at various flowering stages. The period from September 2005 through June 2006 was an extremely dry period. The Tucson Airport reported 1.28 inches precipitation during this time period (WRCC 2007). The plants present at the time of post-treatment data collection in August 2006 were responding to summer monsoon precipitation and conditions. Precipitation recorded at the Tucson Airport was 5.4 inches, 3.11 inches above average (Figure 4, WRCC 2007). In comparison to winter precipitation, summer rains are more predictable, concentrated within a shorter time frame (July through September), and account for at least half of the annual rainfall (Sheppard et al. 1999). The patterns of summer rainfall coupled with higher ambient and soil temperatures tend to favor buffelgrass growth and germination (Cox et al. 1988).

Prior to chemical treatment, the number of buffelgrass individuals ranged from 7 to 26 mature plants with no difference between plots. Also, percent cover of buffelgrass ranged from 25% to 95% with most plots having between 35% and 55% cover and no difference between treatment blocks. Excluding control plots, the number of native plants across all life forms, prior to treatment, ranged from 0 to 4, with no significant differences between plots.

Across all treatments, there was 98% mortality of buffelgrass. Each combined treatment was equally effective at killing buffelgrass ($p = 0.832$, ANOVA). A Tukey-Kramer pairwise comparison showed no differences between the aquatic-approved and terrestrial glyphosate treatments nor any pre-treatment mowing effect. The small number of buffelgrass plants that survived (total of 14) had been partially killed and regrowth occurred in portions of the plant that appeared difficult to reach with the herbicide, usually under rocks. Due to a surge in germination of buffelgrass seedlings observed in the post-treatment monitoring, seedlings ranging from 36 to 848 individuals (mean = 241.9, standard deviation = 175.8), additional analyses were conducted. Although glyphosate is not known to have any residue or pre-emergent properties, a statistical analyses showed that treatment had no effect on number of buffelgrass seedlings present at the time of post-treatment monitoring ($p = 0.929$, ANOVA). There was no observed mortality to non-target plants. This was not directly measured because each individual was not specifically tracked during pre- and post-treatment monitoring time period but rather the total number of non-target individuals by species was recorded. Additional analyses investigating treatment effect on the number and cover of native plants, number of natives by life form, and cover of buffelgrass showed no significant differences due to treatment.

Due to stress and competition of buffelgrass on native plants, pre- and post-treatment buffelgrass conditions were assessed relative to number of native plants present following herbicide

application. It was suspected that the percent cover of either the live or dead buffelgrass might influence germination of any plant. There was only a slight increase in the number of cacti and woody plants during the study period; differences were most likely a result of recruitment or sampling error (overlooking individuals during pre-treatment conditions due to buffelgrass density). An increase in native grasses (total of 10 individuals) was minor. There was a dramatic increase in herbaceous plants across all plots; a total of 17 individuals during the pre-treatment monitoring and 259 during post-treatment monitoring. *Abutilon* sp., a common herbaceous plant in the Malvaceae family, accounted for 58% of the new plants, compared to 12% during pre-treatment monitoring. Based on the ANOVA results, there was no influence of pre-treatment buffelgrass cover on the total number of native plants, herbaceous plants, or germinated buffelgrass seedlings that were present during the post-treatment monitoring. However, post-treatment buffelgrass cover had an inverse effect on total number of native plants and herbaceous plants present ($p < 0.01$ and $p < 0.05$ respectively, ANOVA). An increase of herbaceous vegetation was also observed in the non-buffelgrass control plots thus the above results may be more of an influence of season and climate and not buffelgrass cover. The herbaceous increase on control plots was not a result of *Abutilon* sp. but a diversity of species.

The amount of mixed herbicide applied to the mowed (pre-treatment) and the un-mowed (no pre-treatment) treatment blocks was difficult to measure in the field and was confounded by the density of buffelgrass plants in each of the subplots. Observations suggest no substantial difference in the quantity of mixture applied across the different treatments.

The results from this study confirm that glyphosate is an effective herbicide for controlling buffelgrass. A 3% glyphosate concentration (the lesser of the concentrations) without additional surfactants or without having a pre-treatment mowing is sufficient to kill mature green buffelgrass plants. The application of aquatic-approved glyphosate at 4.4% concentration, with or without the surfactant, is as effective as terrestrial glyphosate at 3% concentration. It is unknown if aquatic-approved glyphosate may be as effective at lower concentrations. Similarly, it is uncertain what the necessary minimum percent concentration of glyphosate is to have high buffelgrass mortality. The percent concentration of glyphosate may depend on other factors such as environmental conditions and buffelgrass physiology, neither of which were components of this study. Unfortunately, glyphosate-based products do not list buffelgrass on the label nor effective concentrations for similar species.

Due to the high density of seeds in the soil and seed viability, repeated applications of glyphosate are necessary. For a single application, this study showed that higher concentrations of herbicide is not more effective at controlling buffelgrass. It also demonstrates that focused herbicide applicators can have good results both in terms of high buffelgrass mortality and negligible non-target impacts. As new herbicides become available and are used to control buffelgrass, it will be important to understand the short-term and long-term impacts on native plant communities. It is also important to properly test any new herbicides prior to relying on them for control.

Properly timed application and properly executed applications (the amount sprayed on each plant) are also very important in the control of buffelgrass. Timing can be very difficult in the controlling buffelgrass because it is dependent on rainfall for green up and in this region, rainfall

is inconsistent and unpredictable. An additional challenge is ensuring field crews are available and trained whenever the plants do green-up.

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Figure 1: Buffelgrass – herbicide study at Saguaro National Park (2005-2006).

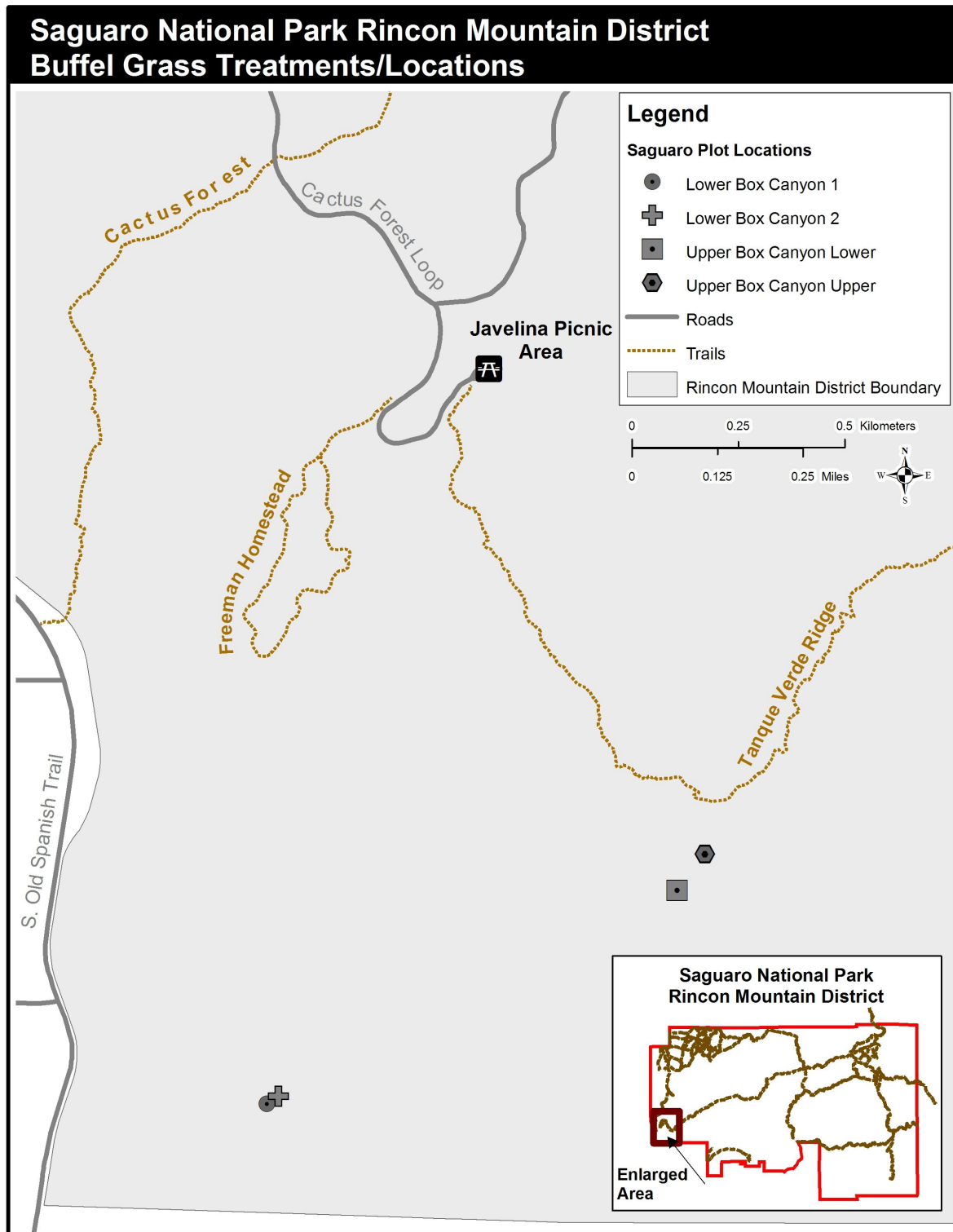
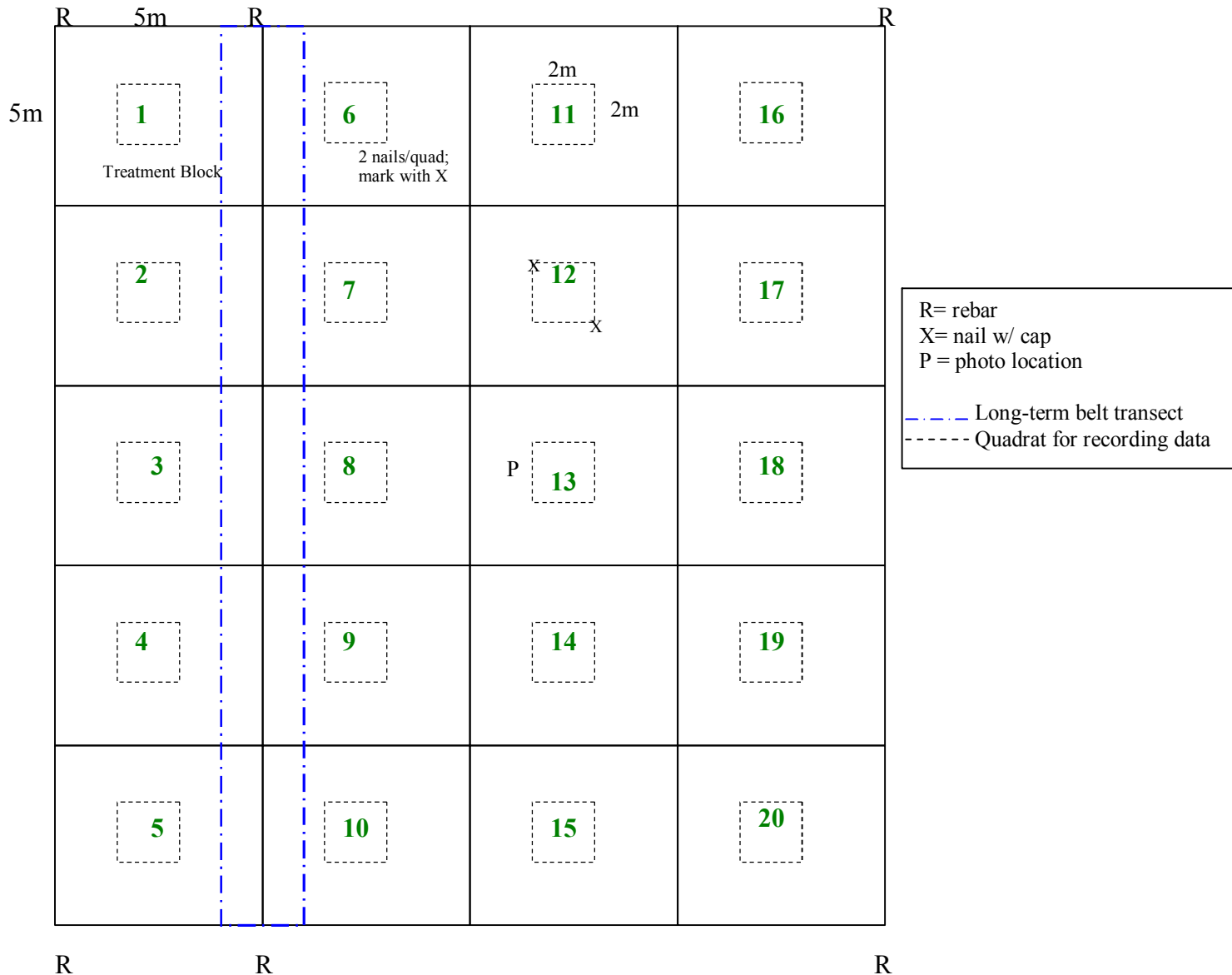


Figure 2: Macroplot for buffelgrass treatment (4 replications); not to scale.



Variables in combination (letters) were assigned randomly; if treatment block does not work (too much rock, not enough plants, etc.) select the next available block.

a-3% glyphosate (roundup); surfactant; cut
b-3% glyphosate ; no surfactant; cut
c-3% glyphosate ; surfactant; uncut
d-3% glyphosate ; no surfactant; uncut
e-4.8% glyphosate ; surfactant; cut
f-4.8% glyphosate ; no surfactant; cut
g-4.8% glyphosate ; surfactant; uncut
h-4.8% glyphosate ; no surfactant; uncut

i-4.4% aquatic glyphosate; surfactant; cut
j-4.4% aquatic glyphosate ; no surfactant; cut
k-4.4% aquatic glyphosate ; surfactant; uncut
l-4.4% aquatic glyphosate ; no surfactant; uncut

Figure 3: Photographs of 2m x 2m quadrat within treatment block.

Lower Box Canyon 1 (5% Aquatic glyphosate, with surfactant, cut)



Pre-treatment



Post-treatment

Upper Box Canyon 1 (5% glyphosate, without surfactant, cut)



Pre-treatment



Post-treatment

Figure 4: Monthly precipitation during herbicide treatment study (WRCC 2007).

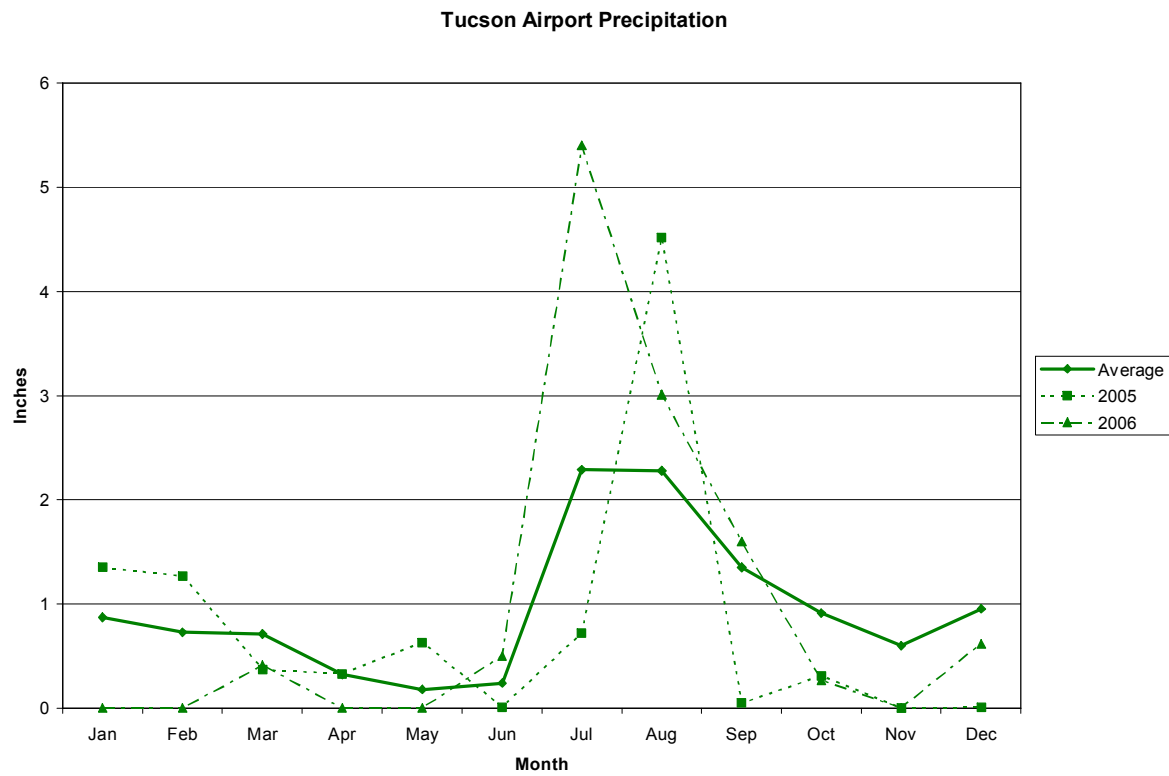


Table 1: Glyphosate solution formulations for one gallon water.

	3% w surfactant	% conc.	3% w/o surfactant	% conc.	4.8% w surfactant	% conc.	4.8% w/o surfactant	% conc.	AQUATIC 4.43% w surfactant	% conc.	AQUATIC 4.45% w/o surfactant	% conc.
Choice	0.3 oz	0.2%	0.3 oz	0.2%	0.3 oz	0.2%	0.3 oz	0.2%	N/A	N/A	N/A	N/A
Glyphosate	4.0 oz	3.0%	4.0 oz	3.0%	6.5 oz	4.8%	6.5 oz	4.8%	6.0 oz	4.43%	6.0 oz	4.45%
LI-700	0.65 oz	0.5%	N/A	N/A	0.65 oz	0.5%	N/A	N/A	0.65 oz	0.5%	N/A	N/A
indicator dye	0.75 oz	0.6%	0.75 oz	0.6%	0.75 oz	0.6%	0.75 oz	0.6%	0.75 oz	0.6%	0.75 oz	0.6%

Table 2: Global Position System coordinates for macroplots.

UTM (NAD 83)		
Plot Name	X	Y
Lower Box Canyon 1	525518	3557130
Lower Box Canyon 1 Belt	525540	3557125
Lower Box Canyon 1	525541	3557121
Lower Box Canyon 1Belt	525518	3557124
Lower Box Canyon 1	525523	3557118
Lower Box Canyon 2	525567	3557143
Lower Box Canyon 2 Belt	525563	3557139
Lower Box Canyon 2	525569	3557133
Lower Box Canyon 2	525547	3557123
Lower Box Canyon 2 Belt	525543	3557137
Lower Box Canyon 2	525543	3557140
Upper Box Canyon Whole	526569	3557711
Upper Box Canyon Whole Belt	526560	3557715
Upper Box Canyon Whole	526552	3557724
Upper Box Canyon Whole	526563	3557733
Upper Box Canyon Whole	526568	3557736
Upper Box Canyon Whole Belt	526576	3557729
Upper Box Canyon Whole	526578	3557724
Upper Box Canyon Lower Split	526490	3557615
Upper Box Canyon Lower Split	526490	3557671
Upper Box Canyon Lower Split	526503	3557626
Upper Box Canyon Lower Split	526506	3557623
Upper Box Canyon Upper Split	526472	3557634
Upper Box Canyon Upper Split Belt	526468	3557636
Upper Box Canyon Upper Split	526467	3557641
Upper Box Canyon Upper Split	526479	3557650
Upper Box Canyon Upper Split Belt	526483	3557648
Upper Box Canyon Upper Split	526487	3557641
Upper Box Canyon Undisturbed	526436	3557650
Upper Box Canyon Undisturbed	526446	3557655
Lower Box Canyon Undisturbed	525461	3557101
Lower Box Canyon Undisturbed	525469	3557104
Fountain Grass Hope Camp Belt	531795	3556889
Fountain Grass Hope Camp Belt	531807	3556874

Appendix A

BUFFELGRASS AND FOUNTAIN GRASS STUDY

The short-term objective of this study is to investigate if less herbicide (lower concentration, no surfactant and pre-cutting the grass) can be applied and have an equal chance of success. Also wanted to compare the effectiveness of aquatic approved glyphosate with Roundup Pro (terrestrial) in the upland situations.

The motivation behind this study was to try and reduce the amount of herbicide that was being used from both an ecological and economic perspective. Also, we wanted to investigate whether the surfactant LI-700, which is the most toxic of the chemicals we use, could be eliminated and still have the same effectiveness. Weed wacking the senescent grass (i.e. pre-treatment) removed a significant amount of the biomass so when the plant did green up, there was a lot less biomass to spray, in fact, there was only green blades to spray. If weed-wacking is to continue, one should consider that this requires an additional field visit and cutting acres and acres of buffelgrass may not be efficient use of time. The plan was to determine which combination of variables were most effective and continue spraying with that formulation into the future. Follow-up control measures will be necessary due to new seed germinations, and the most appropriate method should be used. Pre-, post- and follow-up monitoring associated with this study should be conducted in the quadrats and belt transects.

Additional short-term objectives include quantifying how long seeds remain viable in the seed bank, native recruitment post-buffelgrass infestation, and how much non-target kill occurs either due to human error or drift.

The long-term objectives are to evaluate how the community recovers with passive restoration, what species (native/non-native) respond when they are released from the stress of buffelgrass, and how do respond (ie growth, density). The monitoring associated with this is conducted in the belt transect and is tied only to the cut/uncut variable, not any of the herbicide variables. Post treatment monitoring should occur in the summer (post monsoon) 2008 and then on a five year frequency.

All data and plot location is stored in the N:\GPS\GIS_Work\Exotic_Plants\Treatment\Treatment Study\buffel_study. Hard copies of datasheets and plot orientation are in the exotic plant filing drawer. See below for treatment assignment within macroplot.

What to Monitor

Buffelgrass plots – 2 in Upper Box Canyon and 2 in Lower Box Canyon (see Table 2)

Quadrat (2m x 2m): Two nails with rebar caps mark two corners of where the quadrat (PVC poles) should be placed. The nails were most often placed in the NW and SE corner but see the individual plot diagram for nail location. Due to vegetation and terrain, the quadrats are not always in the center of the treatment block.

Record all species that are at least 50% rooted in the plot. Record number of individuals* by age class (seedling, mature) and degree of mortality (live, dead, partial mortality), and for mortality or partial mortality of non-target species indicated if you think it was due to drift. Record percent

cover by species into the one of the following categories: 1-5%, 6-10%, 11-20%, 21-30%, 31-40%, 41-50%, 51-60%, 61-70%, 71-80%, 81-90%, 91-100%. List all other species that occur in the treatment block that are not present in the quadrat. Record overlapping canopies of different species.

Belt transect (1-20m x 2m): String tape between rebar and using a 2m belt with 1m in cut pre-treatment and 1m in uncut treatment. For cacti, perennial, and biennial species that are rooted in the transect record height and two horizontal axes at right angles to each other. For height record to the tallest leaf blade (green or senescent) where it rests (do not pull it up to straighten it out). For the axis, measure from biomass to biomass using the leaves, not the inflorescence. Look to see what is attached and on the ground. An individual buffelgrass* is defined below. Count overlapping canopies. If plant crosses the line between cut and uncut, measure the full length of the axis and record in the treatment column in which it is rooted. If plant crosses outside of the belt but is rooted inside, measure to the edge of the transect line.

Time constrained additional species list. Spend twenty minutes total (2 ppl 10 minutes) recording species that were not observed in the belt transect but are present in the adjacent treatment blocks.

*Individual for buffelgrass means that plants must be 10 cm apart at the base otherwise they are considered the same plant (even when they dog-ear a rock).

Fountain Grass plots – 2 located in drainage east of Deer Camp and before Hope Camp also referred to as site 6C.

Because the fountain grass distribution in the drainage is irregular, the subplots are not continuous and each has a different orientation. The subplots are 4m x 4m. Some of the subplots share corners. Pin flags were used to denote corners and they may no longer be present. Rebar is used to mark the inner 2x2m quadrat. The quadrats may not be aligned with the subplot. There is only one belt transect and it has portions of each replicate but that has no significance. There is also no distinction on the transect for cut and uncut.

Controls (native, undisturbed plots)

There are 2 5m x 5m subplots in both the Upper Box Canyon and Lower Box Canyon and 1 in the drainage east of Deer Camp (downstream from the fountain grass plots). There are only 5m x 5m subplots with the 2m x 2m quadrat inside, and no transects.

Photopoints:

Take photos at either end of the belt transect. For the treatment plots, take photos of the quadrat from the specified location (see the plot diagram; the P indicates where the picture was taken from. Most photos were taken from approximately 3-6 ft outside the quadrat and the camera was zoomed so that the quadrat filled the field of view. Taking the previous photos in the field might help for repeat photography.

GPS at all rebars

Aspect, elevation, and slope for plot (all treatment blocks collectively)

How often monitor

Quadrats

Pre-treatment; 2) approx 1 month following treatment; and 3) next season (before treat again).

Note: post-treatment monitoring occurred in August 2006, 12 months after the initial treatment. Hand pulling of the quadrats occurred at the time of post-monitoring in order to accurately count the number of individuals. The remainder of the macroplots were hand pulled by Southwest Conservation Corps in the fall of 2006. Quadrat marker nails were removed in the winter of 2007. New growth of buffelgrass was sprayed by the Lake Mead Exotic Plant Management Team in March 2007.

Photopoints should be re-taken annually to document. Because the nails are no longer in place, it will be necessary to take out the plot diagrams and previous photos in order to retake the photos from the same location.

Belt transect

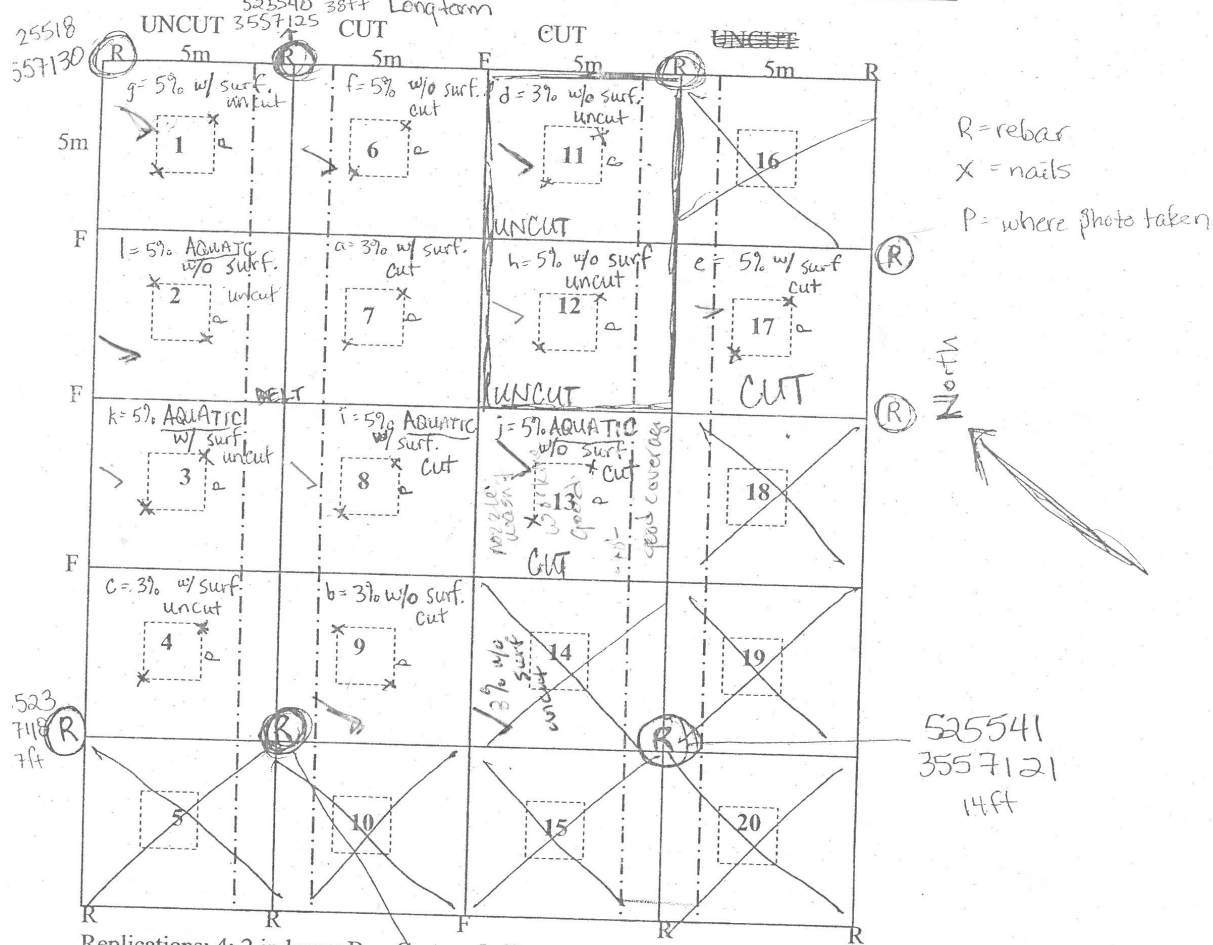
1) Pre-treatment; 2) 3 years post treatment; and 3) on a 5 year frequency

Pre-treatment readings occurred in June-July before monsoons. First round of spraying took place in August-September. As of May 2006, there have not been substantial rains to conduct post-treatment monitoring. The rebar for the belt transects remains in place and post-treatment monitoring should take place in September 2008.

Individual Macroplot Layouts (see Table 2 for coordinates)

- 1-Lower Box Canyon –macroplot 1 (closest to road)
- 2-Lower Box Canyon – macroplot 2 (approx 15 meters east of macroplot 1)
- 3-Lower Box Canyon – undisturbed plot (no buffelgrass in spring 2005)
- 4-Upper Box Canyon – whole plot
- 5-Upper Box Canyon – split plot lower portion
- 6-Upper Box Canyon – split plot upper portion
- 7-Upper Box Canyon – undisturbed plot (no buffelgrass in spring 2005)

Buffelgrass Treatment Study
 Draw N Arrow
 Date: 6/21/05
 Aspect: 140° Slope: 77° Elevation: 3020ft Accuracy:
 Recorders: D. Becker, D. Foster
 Plot Name: Lower Box Canyon - 1
 GPS (nad83/UTM)
 525540 38ft Long-term
 525540 3557125
 525541 3557121 14ft
 Mike
 9/24/05 AM
 Chris
 Dana
 Post 1
 8/28/06
 DB
 DS
 M10310



Replications: 4; 2 in lower Box Canyon [off road] and 2 in upper Box Canyon [off TV trail]

Variables (16 treatments)

- a-3% glyphosate (roundup); surfactant; cut
- b-3% glyphosate; no surfactant; cut
- c-3% glyphosate; surfactant; uncut
- d-3% glyphosate; no surfactant; uncut
- e-5% glyphosate; surfactant; cut
- f-5% glyphosate; no surfactant; cut
- g-5% glyphosate; surfactant; uncut
- h-5% glyphosate; no surfactant; uncut

LT Belt Transect
 525518
 3557124
 19ft

- i-5% aquatic glyphosate (Rodeo, AquaM); surfactant; cut
- j-5% aquatic glyphosate; no surfactant; cut
- k-5% aquatic glyphosate; surfactant; uncut
- l-5% aquatic glyphosate; no surfactant; uncut

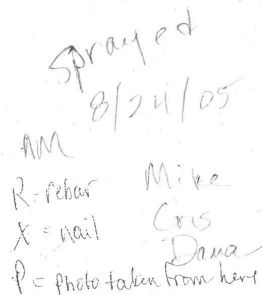
Rule-if trmt block doesn't work select next available block within appropriate pretreatment

Draw N Arrow

GPS (nad83/UTM)

Aspect: 160° Slope: 10% Elevation: 3062 ft Accuracy:

Recorders: D. Foster D. Backer



8/28/04

DB
DS
Meg

525547 38ft
3557123

Variables (16 treatments)

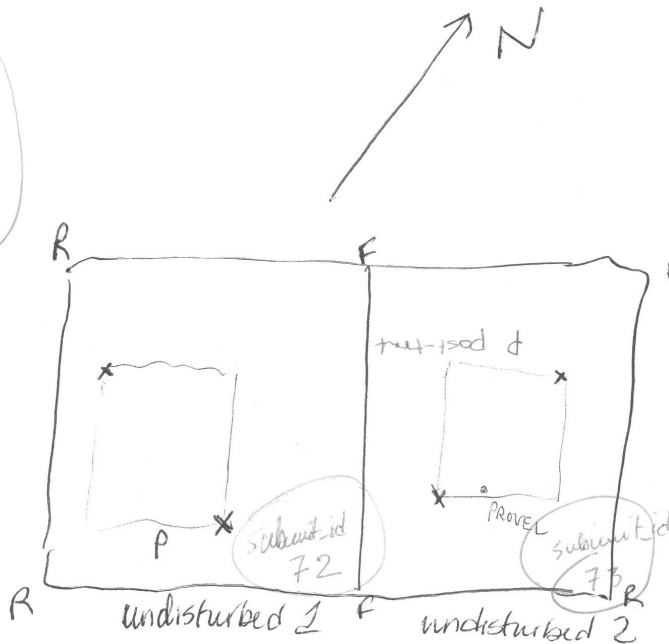
- a-3% glyphosate (roundup); surfactant; cut
b-3% glyphosate ; no surfactant; cut
c-3% glyphosate ; surfactant; uncut
d-3% glyphosate ; no surfactant; uncut
e-5% glyphosate ; surfactant; cut
f-5% glyphosate ; no surfactant; cut
g-5% glyphosate ; surfactant; uncut
h-5% glyphosate ; no surfactant; uncut

- i-5% aquatic glyphosate (Rodeo, AquaM); surfactant; cut
j-5% aquatic glyphosate ; no surfactant; cut
k-5% aquatic glyphosate ; surfactant; uncut
l-5% aquatic glyphosate ; no surfactant; uncut

Rule-if trmt block doesn't work select next available block within appropriate pretreatment

Undisturbed
Lower Box Canyon

Macro B



Aspect 150°
Slope 4%
Elev. 2985

R 525469 | 3557104
24 ft

no photo on 2

525461
3557101

Macro plot id = 1
for Access -
DB

Buffelgrass Treatment Study

Draw N Arrow

Plot Name: Upper Box Canyon - whole

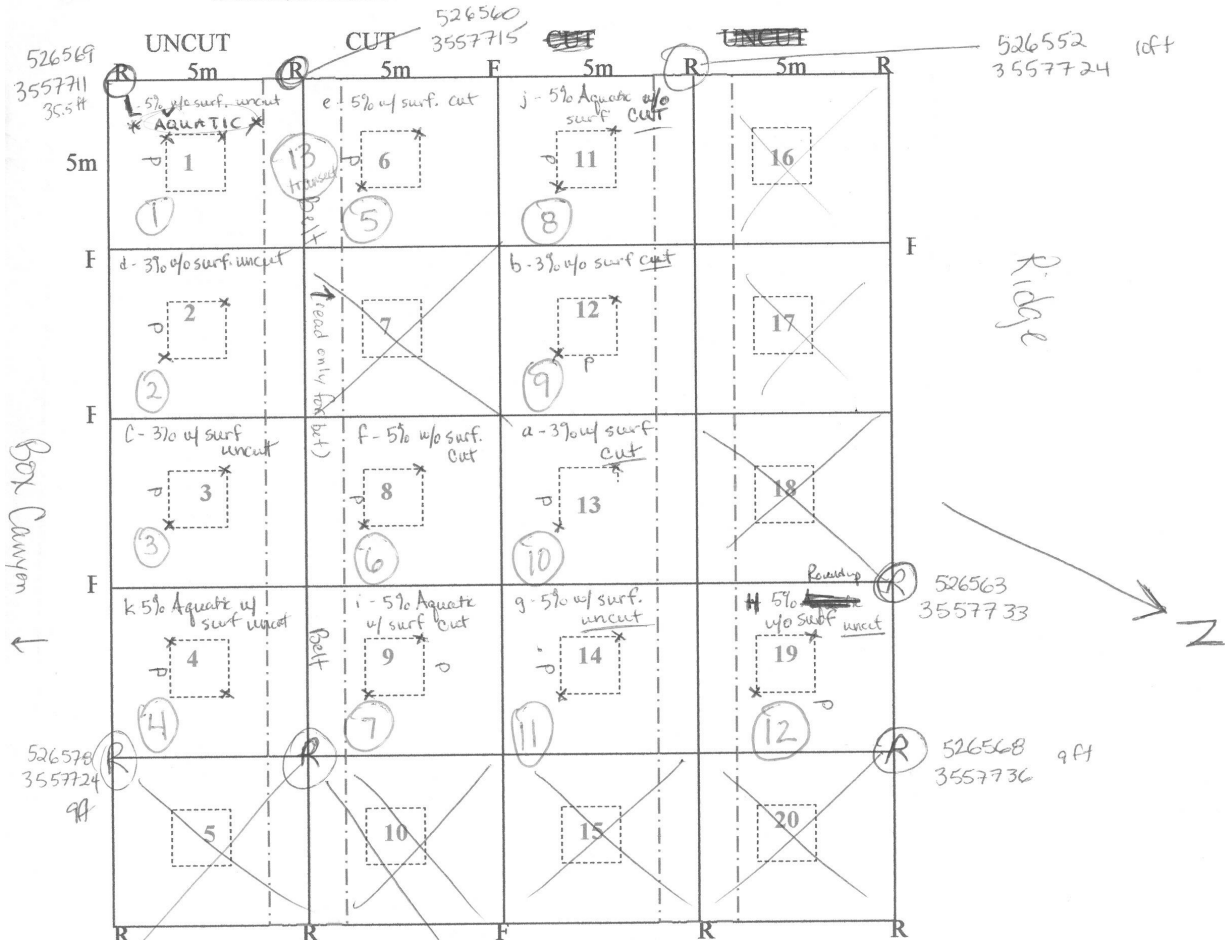
GPS (nad83/UTM)

submit ID

Date: 6/30/05

Aspect: 120° Slope: 10-15% Elevation: 3522 Accuracy: _____

Recorders: DB, MKW



Replications: 4; 2 in lower Box Canyon [off road] and 2 in upper Box Canyon [off TV trail]

Variables (16 treatments)

- a-3% glyphosate (roundup); surfactant; cut
- b-3% glyphosate ; no surfactant; cut
- c-3% glyphosate ; surfactant; uncut
- d-3% glyphosate ; no surfactant; uncut
- e-5% glyphosate ; surfactant; cut
- f-5% glyphosate ; no surfactant; cut
- g-5% glyphosate ; surfactant; uncut
- h-5% glyphosate ; no surfactant; uncut

- i-5% aquatic glyphosate (Rodeo, AquaM); surfactant; cut
- j-5% aquatic glyphosate ; no surfactant; cut
- k-5% aquatic glyphosate ; surfactant; uncut
- l-5% aquatic glyphosate ; no surfactant; uncut

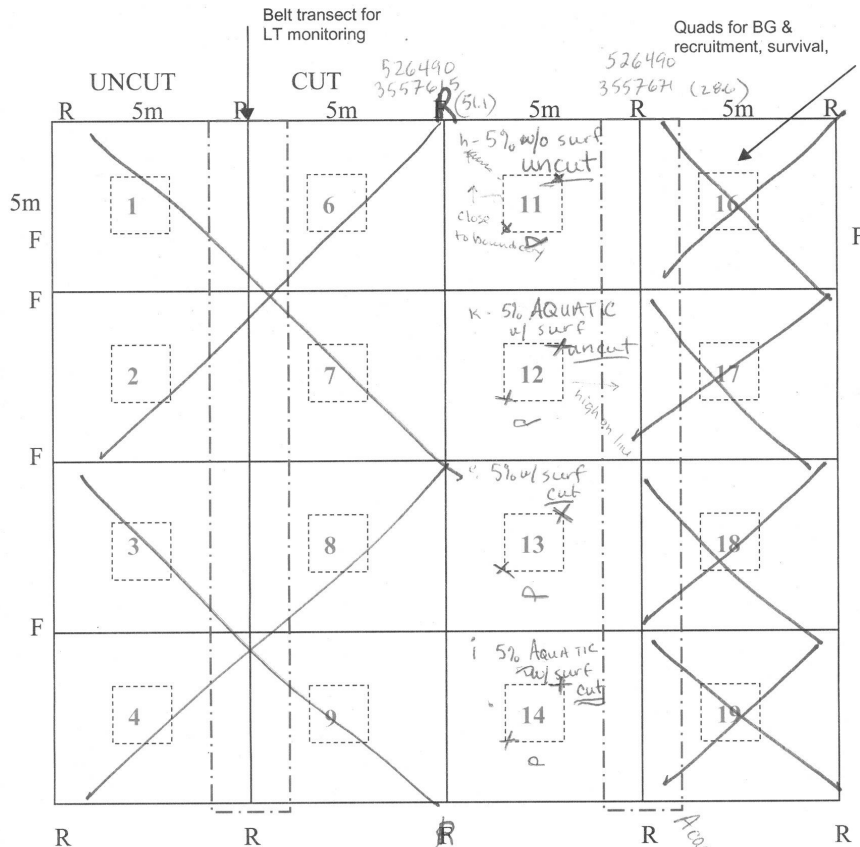
Rule-if trmt block doesn't work select next available block within appropriate pretreatment

16/05

Aspect 180° Slope 15-20% Elev 3441

Upper Box Canyon - split
(Lower portion)

Buffelgrass Treatment Study (initiated June 2005)



Buffelgrass replications

2 in lower Box Canyon [off road] and 2 in upper Box Canyon [off TV trail]

Variables (16 trmt & 4 replicates)

3% glyphosate (roundup); surfactant; cut
3% glyphosate ; no surfactant; cut
3% glyphosate ; surfactant; uncut
3% glyphosate ; no surfactant; uncut
5% glyphosate ; surfactant; cut
5% glyphosate ; no surfactant; cut
5% glyphosate ; surfactant; uncut
5% glyphosate ; no surfactant; uncut

5% aquatic glyphosate (Rodeo, AquaM); surfactant;
cut
5% aquatic glyphosate ; no surfactant; cut
5% aquatic glyphosate ; surfactant; uncut
5% aquatic glyphosate ; no surfactant; uncut

(Although the numbers are not sequential, these numbers are used on the original plot diagrams)
Rule-if trmt block doesn't work select next available block within appropriate pretreatment

24

elev 3452
 aspect 152°
 slope 5°

7/21/05
 55-70

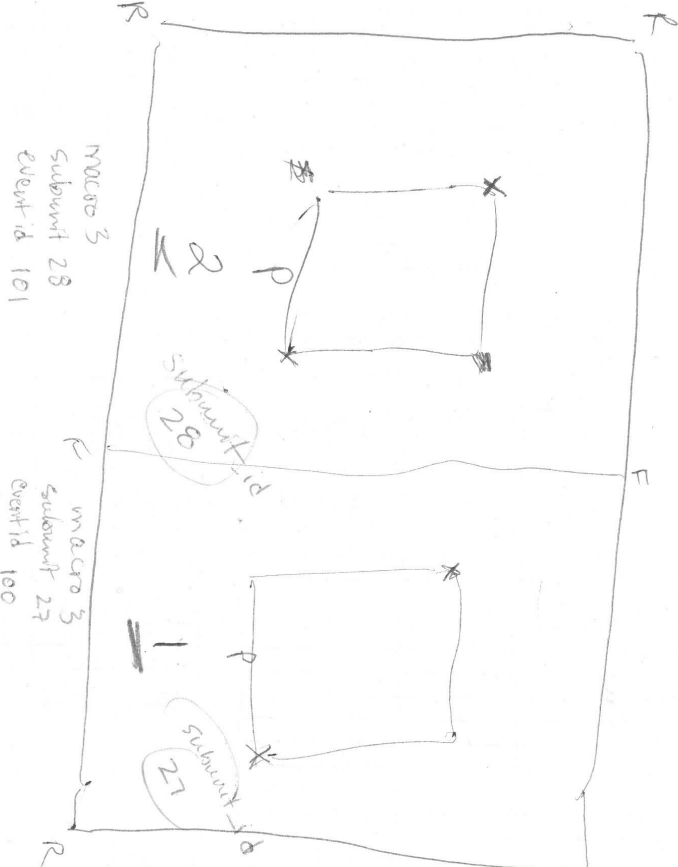
1-4
 89

Undisturbed Plot

Upper Box Canyon

Macro plot 3

526436
 3557650



need caps
 rebar

60m
 to
 the east
 is upper
 box canyon
 plot

526446
 3557655