Prairie Restoration Management Plan Lyndon B. Johnson National Historical Park, Johnson City, Texas

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1.0 PREAMBLE

This report serves to provide a prairie restoration and management plan for a 12-acre (4.7-ha) pasture at the Lyndon B. Johnson National Historical Park, Johnson City, Texas. The document includes site description, available techniques, and recommended restoration and management techniques for the site. It also includes an overview of regional natural history to place this restoration project into an ecological context.

2.0 PROJECT DESCRIPTION

2.1 Present Site Description

This former pecan orchard/pasture is representative of a disturbed, mesic grassland on the Edwards Plateau, with a selection of early and mid successional native grasses including sideoats grama (*Bouteloua curtipendula*), silver bluestem (*Bothriochloa laguroides*), and Texas wintergrass (*Nasella leucotricha*), as well as colonies of invasive grasses including King Ranch bluestem (*Bothriochloa ischaemum*), Kleberg bluestem (*Dichanthium annulatum*), and Johnsongrass (*Sorghum halapense*). Johnsongrass has been dramatically reduced due to mechanical removal and spot herbicide application over the last twelve months. However, both King Ranch, and to a lesser extent, Kleberg bluestems still dominate 30% of the herbaceous canopy. Late-successional, native mixed-grass prairie dominants such as Indiangrass (*Sorgastrum nutans*), wildrye, (*Elymus canadensis*) and little bluestem (*Schizachyrium scoparium*) are present in isolated patches, but in lower than expected proportions for native prairie. In areas around the pond in the southwest corner and along portions of the southern boundary, switchgrass (*Panicum virgatum*) is the dominant grass. Several large pecans (*Carya illinoiensis*) still dominate the boundaries and alongside the central road. Many of these trees have significant infestation with mustang grape (*Vitis mustangensis*) particularly around the pond area. Several young live oaks (*Quercus viginiana*) have been planted in various locations to reestablish the oak-savanna composition. A granite gravel road forms a loose loop through the pasture, but is no longer needed in its entirety. There are also two vestigial, man-made berms associated with former agricultural use approximately 12-18 in (0.30 – 0.46 m) high and 100 feet (30.5m) in length. Recent management has included spring burning in alternate years, which may have encouraged King Ranch bluestem.

The management objective is to restore this site to a late-successional, pre-European mixed-grass prairie but with isolated native trees to produce savanna architecture.

2.2. Target Site Description

The target floral composition, typical of Edwards Plateau clay-loam range site, will be predominantly native mixed-grass prairie species comprising little bluestem (30%), Indiangrass (10%), big bluestem (*Andropogon gerardii*, 5%), other grasses (50%) with annual and perennial wildflowers (5%) that are able to coexist with tall grass species such as Maximilian sunflower (*Helianthus maximiliani*), Engelmann daisy (*Englemannia peristenia*), and bundleflower *(Desmanthus* spp.). However, depending on climate it may take several years before late-successional grasses become noticeable. Native mixed-grass prairie can take years to establish, therefore, these areas will also be sown with additional early-successional spring and early wildflowers and grasses, such as Indian blanket (*Gaillardia pulchella*), black-eyed Susan (*Rudbeckia hirta*), green sprangletop (*Leptochloa dubia*), sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), to provide rapid ground cover and reduce the potential for weedy invasion.

3.0 INSTALLATION METHODS

3.1 Restoration Process

Ecological restoration is a process that is dependent on a number of key variables, controllable (seed addition, prescribed fire, grazing, mowing), partially controllable (seed bank, soil conditions), and some (climate, immigrant seed) that are beyond the control of the restoration manager. Any one of these variables can effectively trump active management events (e.g. drought), or at any rate will interact with some or all of the afore mentioned variables. To increase the chance of success it is important to adopt an integrated management plan that constantly monitors the progress toward the target state and can direct the management accordingly. Therefore, although this plan provides an outline of the expected actions, events may force further input of resources or delay the process.

3.2 Prescribed Burning

Prescribed burning can be defined as the systematically planned application of burning to meet specific management objectives (Scifres and Hamilton 1993). It is a land management tool implemented in many systems for a variety of purposes. It can be used for brush control to increase forage (Scifres and Hamilton 1993), reduction of fuel load to reduce wildfire risk (Pyne et al. 1996), removal of invasive weeds (Britton et al. 1987), or part of a disturbance regime to maintain floral diversity (Bond and van Wilgen 1996). Whatever the objective, a prescribed burn requires thorough planning including statement of objectives, description of burn technique, and follow-up assessment and monitoring. Broadly speaking, prescribed fire is used to maintain or manipulate systems that experience, or once experienced, historical wildfires. Details concerning how to implement prescribed burns relevant to Texas ecosystems can be found in a number of available publications (White and Hanselka 1989, McPherson et al. 1986, McPherson 1997, Scifres and Hamilton 1993).

In central Texas, prescribed fire has been traditionally and effectively used for promotion of forage through the reduction of woody species and encouragement of warm season grasses. For these reasons fire installed during winter when most grasses are dormant has been promoted. Indeed, the pasture in question has already been subject to spring/late winter burning (Smeins 2003). However, recent fire research conducted elsewhere on this site has demonstrated that growing-season fire (i.e.. in summer and fall) not only encourages many native grasses and forbs, but also can help selectively eliminate unwanted grasses such as King Ranch bluestem (Simmons, unpublished data).

3.3 Prescribed Grazing

Similar to fire events (described above), the varying characteristics of grazing can be utilized to manipulate ecological systems through management of grazing livestock. The timing and duration of grazing events with phenology of grazed species can affect not only overall productivity but also species composition in the long and short term. Therefore, intensity, frequency, duration, and season of grazing can all be implemented to manage the landscape.

The characteristics of grazing, such as season and intensity (stocking rate), can be similarly manipulated toward a desired management objective. There is a range of established methods of grazing management that combine grazing, deferment (delay), rest and rotation (see Holechek et al. 1998 for details), and techniques that ensure a more uniform use of the unit by livestock (such as numerous water sources and small mineral blocks). Simulation of historic grazing use by bison can be achieved using high intensity, short duration, low frequency grazing such as "short duration grazing", and "high-intensity, low-frequency grazing" (Howell 1978), and have undergone trials in Texas (see Holechek et al. 1998 for review). Grazing is a useful method for vegetation management at the landscape scale. Grazing has been frequently demonstrated to have a greater effect on productivity, and, more significantly, species composition, than either prescribed fire or climate (Biondini and Manske 1996). However, many invasive species including those on this site, are not preferentially selected for by grazers, and may thrive under intensive grazing pressure, therefore it is unlikely that this method would work unless very carefully monitored.

3.4 Prescribed Mowing

Mowing is often used as a substitute for grazing. It does, however, have obvious differences in impact. Mowing is non-selective with regard to species. Plant material is cut and evenly redispersed across the ground as litter, as opposed to digestion and concentrated defecation by herbivores. These processes suggest that mowing will have a different impact on the plant community dynamic compared to grazing and fire. Grazing and mowing been shown, however, to exhibit some equivalence in effect (Collins et al. 1998) but may in the long-term result in thatch accumulation that may have differential effect on species propagation. The advantages of ease and variety of implementation (e.g. season, cut height, etc.), especially on a small scale, may render this technique useful in certain circumstances. Collecting the cut material (haying) will reduce thatch accumulation and may be economically self-supporting if the hay is traded for the mowing services.

3.5 Herbicide

Herbicide, if correctly selected and applied, can be cost effective method for specific herbaceous and woody plant control. Success rates are rarely 100% and monitoring and reapplication is vital. Even if alternative, landscape scale management methods are adopted, it is likely that follow-up spot herbicide application will be needed to achieve desired elimination of invasive species.

Selection of an appropriate herbicide depends on the target species, site characteristic, and objective. Herbicides utilize different modes of action which interfere with the plants physiology, can be indiscriminant with regard to plant species or species or plant category (e.g. grass) specific.

Application techniques relevant to this site depend on species.

- Foliar application via broadcast spray, spot spray, or selective direct application through 'wick bar' or glove.

- Basal/bark application, spot spraying, or painting.
- Cut application through a cut stump or incision in tree cambium.

For more details on general herbicide handling and application see (Tu et al. 2001)

3.6 Seed Installation

Some of the areas of the pasture will need to have the seed of desirable species added to promote the vigorous growth of the herbaceous community. Many of the species that are common both historically and currently in the region are readily available from commercial sources (see Appendix I). As a general rule, forbs should be sown in the fall/late summer, and grasses in the spring. However, if only one seeding time is available, all of the seed can be sown in the fall.

Processed seed, as is obtained from a commercial seed company, can be very effectively planted with either a no-till drill or a Brillion seeder. Alternatively, seed can be hand broadcast and raked in by hand or with a tractor-drawn harrow to achieve good soil-seed contact. Several distributors have developed versions of these seeding machines adapted for native seed by incorporating three separate seed bins for the three main types of seed: light fluffy seed, small hard seed, and large hard seed. By using this type of range seeding equipment, all of the seed can be planted in one pass.

4.0 MANAGEMENT RECOMMENDATIONS

The recommended process involves herbicide treatments, prescribed fire, berm and road removal, and two initial seeding events (Table 1).

4.1. Herbicide

Installation beginning winter 2005/6 will take the form of a series of herbicide treatments to remove non-native cool season grasses followed by spot attack of Johnsongrass in spring. The two herbicides that are recommended are glyphosate - a broad-spectrum herbicide, and fluazifop: a grass-specific herbicide that can be used without damage to wildflowers. The actual herbicide application will depend on real-time response of both existing plants and the dormant seedbank.

Several non-native grasses dominate this community: Johnsongrass (*Sorghum halepense*), Bermuda grass (*Cynodon dactylon*), King Ranch bluestem (*Bothriochloa ischaemum*), Kleberg bluestem (*Dicanthium annulatum*) and brome and rye grasses (*Bromus* spp.; *Lolium perenne*). Recommended management of all of these species is as follows:

JOHNSONGRASS

Johnsongrass reproduces easily from seed or vegetatively from an aggressive rhizomatous root system. It was introduced from the Mediterranean region around 1800 as a potential forage crop and is now one of the ten worst weeds of the world. The species thrives in heavily disturbed environments and often takes over patches of bare dirt exposed during construction. It is commonly spread between development sites by construction equipment and mowers. Once established, Johnsongrass often grows tall and dense, inhibiting the growth of other grasses and most other herbaceous species.

Johnsongrass seed can remain dormant in the soil years before germination, enabling the plant to continue to be a problem several years after control methods have been implemented.. Many factors such as available moisture, soil type, and management influence the growth of rhizomes. Johnsongrass rhizomes typically grow to a depth of 10 to 20 inches (25 to 50 cm) if the soil is not compacted. However, if moisture and nutrients are not limiting factors, rhizomes can penetrate deeper reaching depths of 2 to 3 feet (60 cm to 100 cm). Rhizomes are produced most extensively after Johnsongrass forms seedheads. To effectively control Johnsongrass the plant should be managed from multiple angles combating the seed, rootstock, and underground rhizomes. Given that this species is presently being successfully controlled with mechanical removal and foliar herbicide application (glyphosate), as part of the ongoing invasive control program, it is suggested that this program be continued, and the pasture monitored for any reinfestation.

BERMUDA GRASS

Bermuda grass is a common non-native turfgrass widely used across Texas. It is a relatively short (4 to 18 inches; 10 to 50 cm), sod-forming grass adaptable to a broad range of conditions that is difficult to eliminate once established. Bermuda grass reproduces easily both vegetatively and from seed with the seed being highly transferable. Even if the living plant material and the seed bank can be eliminated from a given area, Bermuda grass will swiftly recolonize. This may be a significant problem for high public-accessibility areas where the reintroduction of Bermuda grass would be accelerated by high foot and vehicular traffic in addition to maintenance equipment. Bermuda grass often overtakes native shortgrasses, particularly in deeper, mesic soils. However, native grass communities can compete more effectively with Bermuda grass in areas with low nutrient inputs subject to frequently arid conditions. Native tallgrasses are typically very competitive with Bermuda grass because they are better able to compete for light resources. Unlike Johnsongrass, project goals would not be compromised if Bermuda grass were not completely eliminated. Bermuda grass does typically allow desired native species, particularly spring wildflowers and taller grasses, to grow through it. Similarly, its height and growth habit are not inconsistent with project goals. This species can tolerate both grazing and fire therefore recommended treatment is repeated foliar application of glyphosate or grass-specific herbicide such as fluazifop.

KING RANCH AND KLEBERG BLUESTEM

King Ranch and Kleberg bluestems are Asian midgrass species once widely used across Texas as a pasture grass and for general revegetation. King Ranch bluestem's typical growth form is a bunchgrass, but will form a dense sod under mowing or intense grazing. In its sod form, King Ranch bluestem tends to form a monoculture, out-competing most other herbaceous species. Kleberg bluestem is an upright bunchgrass resembling King Ranch bluestem, but easily differentiated by the prominent hairy nodes on flowering culms.

Significant earthwork or soil disturbance tends to kill living plants but causes germination of the seed bank. This will be of significance if berm soil is used for road rehabilitation. Because both of these bluestem species form dense, monocultural stands, they can be effectively controlled using targeted spray applications of a non-specific herbicide, such as glyphosate or glufosinate-ammoniuminale, on the affected area. Repeated applications are often necessary. In areas where large patches of bare earth will remain after the invasive bluestem is removed, reseeding the area with appropriate native grasses and forbs is recommended. King Ranch bluestem is not affected by imazapic herbicide. Due to the King Ranch bluestem's proven sensitivity to growing-season fire, we recommend initial prescribed fire, and subsequent spot foliar herbicide application to control this species. Kleberg bluestem has relatively low abundance on this site, therefore spot application of herbicide is the preferred control technique.

BROME GRASSES AND RYEGRASS

Brome grasses including rescue grass (*Bromus catharticus*), Japanese brome (*Bromus japonicus*), and perennial ryegrass (*Lolium perenne*) are introduced cool-season grasses. They are fast growing annuals that are highly competitive with native cool-season grasses and forbs. Frequent mowing beginning in the late winter and continuing through the early spring should keep this species from setting seed and will, over several years, eliminate most problems caused by this species. Chemical control of this species can be accomplished utilizing broad-spectrum herbicides such as glyphosate in the early spring before other species break their dormancy or, in areas where spring forb populations need to be maintained, a selective grass herbicide such as fluazifop may be used. These grasses are, however, mainly early-succesional invasives, disappearing when more robust native plant communities are in place. It will most likely be a short-term problem in more recently disturbed areas.

WOODY SPECIES

The two dominant non-native woody taxa are Chinese tallow (*Sapium sebiferum*) and privet (*Ligustrum* spp.). Both species are common invaders in central Texas and use their prolific seed production as a mechanism of dispersal by wildlife. Privet often forms dense colonies in the understory of partially or fully closed canopy woodlands, excluding desirable native species, reducing line-of-sight, and creating impassible thickets. Both of these species will continue to be a management issue for the site as long as seed sources for these species are common on the neighboring properties. For both species, the most effective treatments are triclopyr, clopyralid, or a mixture of the two used as a stump treatment immediately following cutting.

4.2 Prescribed Fire

Fire at an appropriate return cycle will help to restore the composition and health of the prairie. Ultimately a natural season (summer) and fire frequency (6-12 years) should be established. Initially, the first fire will help to remove the unwanted dominant King Ranch bluestem and open up the herbaceous canopy for reseeding. Following success of this method, summer or alternatively a winter fire regime over successive years will help promote the native dominant grasses, provided the King Ranch (or other undesirable grass) do not reinvade.

Given the demonstrated effectiveness of selectively controlling King Ranch bluestem, it is suggested that a late summer fire be installed during a period (2-3 weeks) after low rainfall, but not long before expected fall rains, to facilitate germination of sown seed.

Fire planning should take into account the need to prevent damage to existing pecan and liveoak trees. These should be cleared of herbaceous material around the base and have lower limbs and any vines removed which might otherwise act as ladder fuel. Firebreaks should be installed along boundaries paying particular attention to the dense brush and fine fuels along the southern boundary. Fence lines and the historic barn in the northwest corner are other potential safety hazards. The dense switchgrass stands along the south are not extensively invaded and need not be subjected to a summer fire (summer fire response is unknown). However, it may be advantageous for the overall health of this stand to be subject to a cool season burn, following the summer pasture prescribed fire. The service loop and footpaths can be used to install the fire as a series of independent units and sequentially burned according to wind direction. The southerly footpath, along the boundary, may need to be temporarily widened (mowing or black lining) to serve as an effective firebreak.

4.5 Berm Removal

Although manmade berms lend a somewhat unnatural feature to this landscape, they function as microtopography for the prairie plants and appear to have only minor influence on species composition. However, should they need to be removed, it is recommended that this occurs early on in the process and synchronized with the first fire, so that the subsequent bare areas are seeded at the same time as the entire pasture. Following mechanically removal of the excess soil, the remaining 'scar' may need to be harrowed or lightly ripped to make the soil surface receptive to reseeding. Care should be taken to ensure that the disturbed area be seeded at a higher rate than other areas to prevent invasion of undesirable species.

5.5 Road Removal

It has been suggested that existing road is somewhat redundant and removal of all or part of the road may be desirable. This road is composed of limestone-derived road base and will need to be mechanically removed. Depending on the depth of road base this may result in reduction of the grade. If this were the case, soil of native origin would be needed to repair the grade to match surrounding prairie. Other areas on site should be explored to supply necessary fill. One alternative would be to utilize fill from berm removal if this option is selected. Alternatively, the road area can be deep ripped, and weed-free, low nutrient, organic material (e.g. compost) added to modify the soil. This latter technique may not support an identical species composition, especially initially. However, it is expected that after several years the establishment of dominant grasses will disguise the former presence of the road. Whatever the origin of the topsoil, it is vital that it be similar clay loam and free from weed seeds. As with berm removal, special attention should be taken to heavily reseed these areas and monitor for arrival of undesirable species.

4.4 Seeding

It is recommended that seed be sown across two distinct events: one directly after the later summer burn to synchronize with fall rains, the second to coincide with spring rainfall the following year. Many grasses will not germinate in the fall and may be lost to predation or rotting over the winter. A fall sowing of forbs will help to fill the ecological niche opened by the fire and reduce the chance of invasion by undesirable grasses. It is suggested that all forb seed and half the grass seed be sown in the fall of the first year, followed by the other half of the grass seed the following spring. The seed list (Table 2) emphasizes aggressive native forb species for this purpose. The grass mix is composed to favor early-succesional species that will have a greater likelihood of success following disturbance. Late successional species are included but not expected to appear for several years unless climatic conditions are favorable. Given the likelihood of seed failure (e.g. Smeins 2003), and synchronization with the recommended fire treatment, we recommend at least two seeding events (Table 1). The calculations for seed amount (Table 2) do not include additional seed needed for the rehabilitation of the road and berm areas. Once the decision to remove these features has been made, the total disturbed area should be estimated and seed amounts calculated from recommended rates listed in column 3 Table 2. All prices are based on those from Native American Seed, Junction, Texas. For all seed suppliers (Appendix II) it is important to inquire about geographic origin of each species and select an ecotype from a central Texas source to increase the chances of long term success.

5.0 MONITORING

Some form of project monitoring is recommended in order to gauge land management success from one year to the next. Permanent quantitatively surveyed plots or transects provide useful information, although they entail a substantial time investment for data collection and analysis. Given the objective of restoring the prairie to climax condition characterized by several key dominant species, a point intercept along a transect will serve to monitor change. This method is both fast and biased toward measuring dominant species rather than a comprehensive sample of all species. Several (2-3 would be adequate) 150 feet (50m) transects orientated to represent the plant communities, should be permanently marked (e.g. rebar or t-post). At least once a year a measuring tape is stretched between these markers and every 3 feet (1m) a thin rod is lowered to the soil surface and every species touching the rod is recorded. From this data, the occurrence frequency for each species can be estimated by simply dividing the number of 'hits' for a particular species by the number of points along the transect. For more details on this method see (Jonasson 1988).

Additional regular walkthroughs during the year will help identify any problematic episodes (e.g. invasions) as they occur as well as emergence of new desirable species.

The establishment of permanent photopoints is also recommended. By taking photographs from the same point with same azimuth, changes in dominant vegetation can be tracked. These points can be marked on the ground with t-posts, rebar stakes, or even trees or fence posts. Once the first photopoint set has been taken, these images can often be used to find the same point the following year. The best results are achieved by taking the photographs at the same times of year (e.g. spring and late summer) at the same time of day (due to the often over-riding effect of shadows). Field notes listing dominant plant species are useful for later examination.

6.0 CONCLUSION

There are many controllable and uncontrollable variables involved in the process of restoration. Unexpected events, particularly the failure of successful seed germination and appearance of unwanted species, are the largest potential problems. These issues can be addressed relatively easily if caught early on. Vigilance in monitoring followed by corrective addition of seed and/or restricted herbicide application is very cost effective when implemented at the first signs of trouble. Similarly, if unfavorable growing conditions occur during the first few years of the restoration process, there should be provision for reimplementation of some or all of the techniques. Notwithstanding these caveats, it is highly probable that once the plant composition approaches its target state, with a dominance of climax species, the restored prairie is likely to require less input of resources.

Table 1. Overview of timeline for prairie restoration.

Date	Action	Materials	Function
Winter 2005/2006	Initial spot grass herbicide	Fluazifop	Initial grass removal of cool season invasives (e.g. Japanese brome, perennial ryegrass seedlings)
Mid-late Spring 2006	Spot general herbicide x 2 minimum	Glyphosate	Spot applications to remove Johnsongrass
Late Summer 2006	Grass herbicide	Fluazifop	Spot application on regenerating (resprouts, seedlings) of Johnsongrass and King Ranch Bluestem
Summer 2006	Berm and road removal and rehabilitation		Optional
Late Summer 2006	Prescribed fire		Reduce cover of King Ranch bluestem. Open-up herbaceous canopy and recycle nutrients to promote regrowth of natives
Early Fall 2006	Broadcast wildflower and 1st grass sowing	Seed	Early and late-successional grass and wildflower sowing.
Winter 2007	Third grass herbicide	Fluazifop	Seedling removal of cool season grasses
Early Spring 2006	Spot general herbicide	Glyphosate/ Fluazifop	Removal unwanted plants as necessary
Early Spring 2006	2nd Grass sowing	Seed	Grass seed only
Spring/Summer 2006	Spot general herbicide x 2	Glyphosate/ Fluazifop	Removal unwanted plants as necessary

Table 2. Recommended seed purchase. Note that grass seed amounts are total and should be split equally when ordering to facilitate two sowing events.

Common name	Species name	Typical seed rate (lbs/acre)	% in mix	Weight lbs	Cost	Cost / lb
Flowers						
Partridge pea	*Cassia fasiculata*	20.00	1.00%	3	$72.00	$24.00
American basketflower	*Centaurea americana*	10.00	9.00%	11	$319.00	$29.00
Golden-wave	*Coreopsis basalis*	3.00	7.00%	3	$72.00	$24.00
Illinois bundleflower	*Desmanthus illinoensis*	15.00	4.00%	7	$84.00	$12.00
Cutleaf daisy	*Engelmannia pinnatifida*	18.00	7.00%	15	$435.00	$29.00
Indian blanket	*Gallardia pulchella*	10.00	12.00%	14	$266.00	$19.00
Prairie verbena	*Glandularia bipinnatifida*	2.00	4.00%	1	$64.00	$84.00
Standing cypress	*Ipomopsis rubra*	6.00	9.00%	7	$343.00	$49.00
Gayfeather	*Liatris mucronata*	10.00	10.00%	12	$696.00	$58.00
Lemon mint	*Monarda citriodora*	3.00	10.00%	4	$76.00	$19.00
Missouri primrose	*Oenothera missouriensis*	5.00	2.00%	1	$55.00	$55.00
Pink evening primrose	*Oenothera speciosa*	1.00	3.00%	1	$22.00	$64.00
Black-eyed Susan	*Rudbeckia hirta*	2.00	12.00%	3	$72.00	$24.00
Pitcher sage	*Salvia azurea*	3.00	10.00%	4	$196.00	$49.00
Forb total			100.00%		**$2,772.00**	
Grasses						
Big bluestem	*Andropogon gerardii*	8.00	10.00%	20	$265.00	$13.25
Purple threeawn	*Aristida purpurea*	4.00	10.00%	10	$499.50	$49.95
Sideoats grama	*Bouteloua curtipendula*	7.00	10.00%	17	$237.15	$13.95
Canada wildrye	*Elymus canadensis*	10.00	5.00%	12	$191.40	$15.95
Sand lovegrass	*Eragrostis trichodes*	2.00	10.00%	5	$74.75	$14.95
Green sprangletop	*Leptochloa dubia*	2.00	15.00%	7	$111.65	$15.95
Little bluestem	*Schizachyrium scoparium*	8.00	20.00%	40	$638.00	$15.95
Indiangrass	*Sorghastrum nutans*	6.00	5.00%	7	$111.65	$15.95
Sand dropseed	*Sporobolus cryptandrus*	1.00	15.00%	4	$59.80	$14.95
Grass total			100.00%		**$2,188.90**	
Grand total					**$4,960.90**	

APPENDIX I. Historical Overview

Overview

For most parts of the world, there are a number of different stable ecological systems that can be supported by the regional climate. The variation within the current system depends on events such as glaciations, catastrophic fire, normal periodic disturbance (e.g. migrating bison), or past faunal use (including humans). These historical events interact with soil and climatic extremes to result in the current ecological system, but this system is very rarely the only one that has or could exist on the site (Egan and Howell 2001). Those ecological systems that are self-sustaining within limits and require few inputs are referred to as stable ecological states. These states are the result of climatic conditions and historical events or recent management. They are resistant to change and require a shift in current management or a catastrophic event in order to move from one stable state to another. The energy required for this shift varies between systems (Laycock 1991).

There are a wide variety of tools and methodologies available to the land manager to help move between these various stable ecological states. These ecological states (grassland, savanna, or woodland) once achieved, are considered stable in that they do not require significant inputs in order to be maintained, but most will require some form of routine management. Intensive management methodologies can be used to move between differing stable or intermediary states but may be impractical to use on this property based on the amount of resources needed to undertake them, resulting soil disturbance, or conflicting neighboring land use.

Central Texas is a good example of the same climactic area having a number of stable ecological states. At any given site there has probably been, within the last several thousand years, open grassland, savanna, and woodland. All three of these conditions are stable states and, once present, are often resistant to change under normal climatic regime (Smeins 1982).

The North American prairie once stretched from San Antonio, Texas into Canada, and from the Smokey Mountains to the Rockies, covering more than 580,000 square miles (1.5 million km^2). Because of its fertility, however, this region quickly became the major agricultural center in America after colonization (Madson 1982) and the prairie was replaced with farms. Present estimates of the remaining prairie acreage range from 21% to less than 4% of its former range, making the prairie one of the most endangered ecosystems in the world (Farney 1980). Several states (Illinois, Indiana, Iowa, Minnesota, North Dakota, and Wisconsin) have lost over 99% of their former prairie (Samson and Knopf 1996).

The Hill Country vegetation has not been as well documented, but what is available describes the region as a savanna system with widely separated motts (clumps) of oaks with juniper primarily being restricted to steep slopes (Smeins et al. 1976) with the woody species probably being kept in check by a combination of periodic fire and high intensity/short duration grazing by bison (Fuhlendorf 1996). Historical accounts describe the landscape in Central Texas as becoming progressively woodier over the last 150 years (Smeins 1982). While the exact mechanisms for this transition are still under debate, it is generally accepted to be a combination of the interacting effects of fire (or its lack), grazing practice and drought. Although the historic Hill Country vegetation was probably less woody than today, there were extensive juniper breaks, savannas, and thickets of oak, particularly on shallow soils, rocky slopes, and in canyons (Smeins 1980). Moreover, early accounts during 18th and 19th centuries describe a preponderance of woody species (chiefly oak and juniper) dominating many upland areas in Central Texas (Weniger 1988). Data collated from early land surveys (Weniger 1988) includes descriptions of increasing grass density in the east (Burnet County), south (Kerr County), and west (Menard County) of the region. Indeed, early eyewitness accounts of low tree density in Kerr County (205 trees/ha) compare dramatically with densities of 815-1983 trees/ha on the Balcones Escarpment (Weniger 1988). In the Hill Country there are a variety of mechanisms that maintained this mosaic of ecosystems historically.

Models of the formation of plant species assemblages at the community- and landscape-scale invoke the association of environment, climate, and time (Begon et al. 1986). These, in turn, interact with the changes in population and distribution of floral and faunal species. In North America, however, with the spread of human activity over the last 10,000 years, the growing influence of agriculture, industry, and society has had an even more dramatic impact on vegetation change.

Fire in many ecosystems represents part of the dynamic equilibrium, which maintains the balance between productivity and decomposition (Pyne 1982). Both wild and anthropogenic fire have drastically shaped the North American landscape. Several times during the Pleistocene era, the Siberian land bridge between North America and Asia opened up as fluctuating global temperatures caused repeated drops in sea level. This allowed passage of fauna and flora between the two continents (Kreech 1999). Evidence from both North and South America suggests that humans successfully started colonizing the continent as early as 13,000 or 14,000 years ago (Kreech 1999). There is evidence of occupation and active land management practices on the Edwards Plateau for the last 11,000 years (Taylor and Smeins 1994). Although the early Paleo-Indians may have indirectly influenced landscape through hunting large herbivores, perhaps the greatest impact was the technology of fire.

Humans and Fire

Most plant communities around the world are to a greater or lesser extent fire-prone. Plants will burn under the right conditions, and many have evolved to survive under pressure of frequently occurring wild (lightning induced) fire. Many plants are fire-adapted, either dependent (e.g. smoke or heat-triggered germination), or tolerant (e.g. fire resistant bark, post-fire resprouting, etc.). Because of this, in most ecosystems, higher fire frequency enhances plant diversity by repeatedly disturbing succession, resulting in a more heterogeneous environment supporting a greater diversity of plant species (Wright 1982).

The degree to which fire plays a role in a natural system can be assessed from a number of indicators (Pyne et al. 1996):

1. Historic factors: traditional aboriginal use of fire.
2. Climatic indicators: season and amount of rainfall, and lightning frequency.
3. Floral factors: post-fire regeneration strategies (seeders/resprouters), post-fire floristic changes, fire toleration (bark thickness), presence of fire sensitive taxa.

In Texas, although lightning strikes undoubtedly significantly contribute to wildfires, it is likely that the arrival of Paleo-Indians exacerbated fire frequency in some areas, and possibly introduced it into landscapes that may have escaped fire for long periods of time.

There is some direct observational evidence from South Texas that Native Americans were using prescribed burning in Texas. Cabaza de Vaca, in 1528, records two such events:

"The Indians go about with a firebrand, setting fire to the plains and timber so as to drive off the mosquitoes, and also to get the lizards and similar things they eat, to come out of soil." (Smeins and Fuhlendorf 1997)

"They [Coahuiltecans] are accustomed also to killing deer by encircling them with fires. The pasturage is taken from the cattle [bison] by burning, that necessity may drive them to seek it in places where it is desired they should go." (Newcomb 1999)

Similarly in East Texas the Caddoes practiced crop production of beans, maize, and squash, and reportedly used prescribed burning for land preparation (Newcomb 1999).

Examination of fire-scarred trees has demonstrated that changes in season of fire and fire frequency in some areas could be attributed to frequent visits from the Mescalero Apache who inhabited West Texas and southeastern New Mexico (Kaye and Swetnam 1999). These practices would have resulted in the elevation of local fire frequencies.

Such evidence that Native Americans made a significant contribution to fire frequency in Texas is additionally supported from extensive reports of the practices of other Native American tribes throughout North America, who used prescribed burning regularly for different objectives. It has been suggested that Native Americans had at least 70 different reasons for firing vegetation (Williams 2000). These may be broadly summarized into the following categories (adapted from (Williams 2000)).

ACTIVE DRIVING OF WILD GAME. Fires were used to drive wild game into other areas where they would be easier to hunt, for example: open grasslands, canyons, cliffs, and other areas. Smoke and fire could also be used to drive alligators out of swamps, and raccoons and bears from trees.

INDIRECT DRIVING OF GAME THOUGH RANGE MANAGEMENT. Open areas of prairie, savannas, and riparian areas could be maintained by burning. This promotes regrowth of herbaceous species and reduces the encroachment of woody species, thereby encouraging wild game into these areas, or for maintaining pasture for domesticated horses. Conversely, forage areas burned would, for a short time, force animals to forage in other areas. For example, fire was used in thickets to reduce mistletoe populations, favored by some browsers, which would be forced to go in search of the browse in more open areas or areas nearer settlement.

CROP MANAGEMENT. Fire could be used to increase productivity of several wild crops for example: blackberries, strawberries, and huckleberries. The removal of leaf litter and standing herbaceous biomass could aid forage of fallen acorns.

*SMALL ANIMAL HARVEST***.** Grass fires would produce a harvest of edible lizards, moths, crickets, and grasshoppers.

PEST MANAGEMENT. Setting fires could control several pest species such as mosquitoes, blackflies, snakes, and rodents.

FIREPROOFING. Prescribed fire around areas of settlements would act as an effective firebreak against potentially lethal wildfire.

WARFARE AND SIGNALING. Not only could fire remove potential enemy hiding places, or flush them out, but also provide an effective screen during attack. Indirectly, enemy-managed pastures could be sabotaged with fire.

VISIBILITY/ACCESSIBILITY. Fire was used to clear areas around habitation for defense, trails for frequent travel, and popular hunting sites.

Lightning and Fire

Prior to the arrival of humans, lightning was the primary source of wildland fires in North America. Most lightning is cloud to cloud, but a significant proportion is cloud to ground. The area around Austin has an average of 8-13 lightning strikes per square mile per year, peaking during April through September (Reap 1994). This coincides with seasonal peak of biomass production. In spite of this these strikes often do not cause wildfires. For fuel ignition to occur, a continuing electric current must take place. Of all cloud to ground strikes, about 25% are of this category (Pyne et al. 1996). Additionally, the fuel itself must be of significant fuel moisture content to burn. Fine dead fuels (grasses) only need an hour or two of dry conditions to carry a fire. For larger sized fuels, including living trees, longer periods of dry conditions are needed to increase flammability. Dry lightning (strikes outside precipitation areas) is the most common cause of wildland fires (Rorig and Ferguson 1999). However, many wildland fires also result from "holdover" fires, those that smolder for days or weeks before weather conditions allow a spread to a more extensive fire (Pyne et al. 1996). In Texas these fires would vary from extensive (occurring over large areas of continuous fuel under prime burning conditions), to patchy (occurring in more heterogeneous environments were fuels were patchy due to changes in topography or vegetation as found in savannas) (Wells 1970). For a single square mile, the chance of a fire starting in any one year is slim. However, spreading this chance over an entire landscape, where there were few obstacles to prevent fire spread, it can readily be seen that the chance of a single wildland fire per year, in any one place, was a distinct possibility.

While it is difficult to specifically assess the extent and frequency of fires for this region, the little local narrative evidence we do have (Smeins and Fuhlendorf 1997), combined with that from other areas in North America, suggest that fires did indeed occur and would have long-term effects on vegetation, such that non-woody plants dominated (Smeins and Fuhlendorf 1997). Burn cycles in the southern plains have been estimated to be three to five years (Flores 1990). On the western Edwards Plateau over the last 100 years, the increase in population of redberry juniper (*Juniperus pinchotii*), a resprouting species that can become reproductive from 7 to 12 years (Ueckert 1997) suggests that if fire is responsible for repression of this species, they must have occurred at this return interval, at least.

Overall the historic vegetation pattern was probably one of a "moving mosaic" of different plant communities, ranging from regions that burnt frequently to areas that rarely experienced fire if ever.

Cattle versus Bison

With the increase of settlement of the area from 1700 onward, there was a transition from grazing and browsing native herbivores to free ranging and eventually confined livestock (Smeins 1980). Prior to European settlement, bison was the dominant large grazer. There are reports of extensive herds of bison throughout the region up to 1900 (e.g. (Lincecum and Phillips 1994); and (Smeins 1980) for review). This would have had significant impact on the system. Following settlement, the removal of grazing pressure by declining populations of these native herbivores, followed by (initial) low stocking rates of domestic cattle by settlers during several years of abundant rains (1874 to 1884), created more forage than could be utilized (Smith 1899). However, following this period, increased settlement and higher stocking rates decreased herbaceous productivity, and resulted in increase in brush species such as mesquite, prickly pear (Smith 1899), and juniper (Smeins 1984). It can be seen that the impact of managed cattle had a significantly different effect to that of bison. Migrating bison produced short duration but very intense grazing events, similar in some ways to a fire. Domestic cattle, on the other hand, caused continual disturbance, of varying intensity, of rangeland throughout the entire year. When herbaceous productivity is low, grazing does two things. It can cause the collapse of populations of palatable species at a local scale, which in turn aids the spread of woody species by opening-up more sites for regeneration and reducing competition between woody and herbaceous species (Walker 1993). This phenomenon is exacerbated by simultaneous drought. Cattle have marginally different diets from bison, which although slight can result in a dramatic difference in its effect on vegetation. The spread of mesquite (*Prosopis glandulosa*) throughout Central Texas has been largely attributed to the ingestion of mesquite pods and consequent defecation of seeds by cattle (Brown and Archer 1989).

The widespread distribution of cattle as a vector of dispersal, combined with reduction of fire frequency, which in top killing mesquite individuals retards pod production, has caused increased establishment of mesquite.

APPENDIX II. Seed Suppliers

DOUGLASS KING SEEDS
P.O. Box 200320
San Antonio, TX 78220-0320
1-888-357-3337
http://www.dkseeds.com

NATIVE AMERICAN SEEDS
127 N 16th Street
Junction, TX 76849
1-800-728-4043
http://www.seedsource.com

TURNER SEED
211 County Road 151
Breckenridge, TX 76424-8165
1-800-722-8616
http://www.turnerseed.com

WILDSEED FARMS
425 Wildflower Hills
P.O. Box 3000
Fredericksburg, TX 78624-3000
1-800-848-0078
http://www.wildseedfarms.com

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