HOMESTEAD NATIONAL MONUMENT OF AMERICA

BUR OAK FOREST RESTORATION PLAN:

REFERENCE CONDITION AND MANAGEMENT CONSIDERATIONS

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INTRODUCTION

The Vegetation Management Action Plan for Homestead National Monument of America includes a statement of the desired future condition that states: "The monument's natural resources are managed in such a way as to maintain a heterogeneous landscape composed of a mosaic of high quality remnant and restored tallgrass prairie, lowland bur oak forest and associated ecotones, as well as prairie streams and their hydrologic processes; that reflects the value of the site as a homestead, represents as accurately as possible the environment encountered by early settlers, and preserves native biodiversity" (Bolli 2006). The lowland bur oak forest along Cub Creek represents a remnant of a bur oak wooded community that was recorded occurring on the site prior to

the establishment of the Daniel Freeman's homestead in 1863, in the Public Land Office survey of 1857. Although the historic description is quite brief and incomplete, it is undoubtedly not the same as the current forest due to a series of changes to the environment that accompanied a shift from a landscape utilized by transient hunters to one populated by sedentary farmers. In order to more accurately represent the environment faced by the first European settlers, management actions should be undertaken that restore, to the extent possible, the historic conditions that shaped the vegetation they encountered. Before these actions can be carried out, a reference condition needs to be established as a goal toward which restoration efforts can be directed. Ideally, this reference condition should be determined by collecting data from existing sites that have similar edaphic characteristics and vegetation that has been minimally impacted by disturbance. Since we desire a reference condition that existed in an environment that has changed dramatically in the last 140 years since settlement, the likelihood of encountering a reference site that has not been similarly impacted appears very unlikely. In the absence of reference sites that reflect the 1860's vegetative condition, professional judgment must be employed to establish what the reference condition should be, guided by historical accounts and by examination of the environmental factors that were altered as a result of European settlement, and they might have shaped the composition and structure of the existing oak forest. By considering reference sites, historical accounts, and the effects of changes to the environment, we can describe and propose an historic condition that approximates the oak wooded community that existed in the 1860's and begin to chart a course to restore the forest to a condition

that closely approximates what might have been encountered by early settlers, while minimizing damage to the natural biodiversity of the existing community.

REFERENCE CONDITION

The first goal of this study is to describe the 1860's-era reference condition for the Cub Creek woods by compiling a quantitative description of its diversity and community structure. Although no sites are known that are representative of 1860's conditions, examining existing communities similar to the Cub Creek woods can provide some insights into the extent and nature of this poorly-known community and perhaps provide clues as to the possible 1860's vegetative condition of this community throughout its range.

REFERENCE SITES

Information on the historic condition of the Cub Creek woods and similar sites can be gleaned from observations of high-quality remnants of the existing forest, which in all likelihood gives us the most complete picture of the species composition of the historic community. Despite the many changes to the environment within the last 140 years, it is safe to say that the current extent and density of the forest on Cub Creek exceeds that of the original forest prior to European settlement, due primarily to fire suppression (Abrams 2000). As forests increase in extent, individual species begin to change in response to an increasingly dense tree canopy in the absence of fires that suppress woody plant regeneration. In these shaded forests, the amount of available

habitat for shade tolerant forest indicator species exceeds the amount present in pre-settlement conditions. This has led to an increase in abundance of forest plants, and perhaps an increase in diversity as well, though given the difficulty of establishing many herbaceous native forest species from seed; it appears any gains in diversity are limited to the appearance of alien species and some bird-dispersed woody species. Nonetheless, the current native species composition probably represents a subset of the total diversity of the historic community, since certain shade intolerant species have decreased or disappeared as a result of canopy closure, and likely some forest species have been selectively eliminated by disturbance. Still, the current vegetation of the highest-quality remnants of the current forested community gives us the most complete picture of the historic species composition.

Though the current vegetation of forest remnants can provide clues as to which species were present in the 1860's, it cannot necessarily provide an accurate picture of the abundance of each species or the vertical structure and extent of the historic community. Since succession tends to increase both the extent and the vertical complexity of forests, we can safely assume that the forest occupies a larger areas and that the canopy, subcanopy, shrub and herbaceous layers more clearly defined than they likely were historically.

Another rather obvious limitation of examining the current vegetation is that it cannot indicate which species existed historically that are no longer present. Since many shade intolerant species that may have formerly been abundant in the community would have failed to reproduce successfully as the forest canopy became denser, they may become very limited in extent and cryptic. Often such species will persist in closed

canopy forest either in narrow bands or favorable habitat at the forest margin, in a non-reproductive condition beneath the forest canopy, or in the seed bank. Of course, some such species may have been entirely extirpated from the community, but unless there are historic data that strongly suggest their former presence, one should resist the temptation to re-introduce them, lest one piece together a community that may never have existed on the site. In the absence of reasonable historic evidence, one should assume the current vegetation provides the best clue as to the species composition of the historic community, but in itself is not sufficient to shape a reference condition. Considering the limitations of plot sampling in the forest to provide additional insights into the historic condition, the bulk of this study will concern itself with historical accounts of similar communities and examination of the effects of environmental changes on shaping the lowland bur oak forest at the monument. Data on the composition of the current forest from previously completed vegetation monitoring studies (Mlekush & DeBacker 2003) will suffice for the purposes of the study.

Current vegetation of the Cub Creek woods

The 60 acres of wooded vegetation at Homestead National Monument primarily represents a closed-canopy forest that has been subject to varying degrees of logging, grazing, fire, and other disturbances since settlement. Some areas within the northern half of the site are relatively undisturbed. In the highest-quality portions of the site, the canopy is dominated by large spreading-crowned bur oaks (*Quercus macrocarpa*) about 60 ft. tall, with scattered large cottonwoods (*Populus deltoides*) and honey-locust (*Gleditsia triacanthos*) among them. A well-defined subcanopy is presently consisting

mostly of hackberry (*Celtis occidentalis*) and slippery elm (*Ulmus rubra*) with silver maple (*Acer saccharinum*) conspicuous in lower places, especially along the stream banks. A short shrub layer of coralberry (*Symphoricarpos orbiculatus*) is frequently present, with an herbaceous layer dominated by wood nettle (*Laportea candensis*), sedges (*Carex* spp.,) wingstem (*Verbesina alternifolia*) and early wildrye (*Elymus macgregorii*).

Though they are prominent, bur oaks are not dominant throughout the canopy of the north portion. Immediately along the stream, oaks are absent and the dominant trees include a few large cottonwoods and some tall hackberry and black walnut (*Juglans nigra*). These areas also contain a ground layer with conspicuous patches of stinging nettle (*Urtica dioica*) and Jerusalem artichoke (*Helianthus tuberosus*).

The outer margins of the forest along the prairie margin also lack the characteristic bur oak canopy and are dominated by small to medium trees of hackberry, green ash (*Fraxinus pennsylvanica*), honey-locust, American elm (*Ulmus americana*), and white mulberry (*Morus alba*). The herbaceous understory along the perimeter includes much Virginia wildrye (*Elymus virginicus*) and a lesser amounts of wood nettle and wingstem than are present under the oak canopy.

The south portion of the forest was extensively logged prior to the establishment of the monument. At present, it has a 40-50 ft. high woody canopy dominated by hackberry and honey-locust, with a few large cottonwoods. The subcanopy and shrub layers are more poorly developed in this area, and the herbaceous understory is evidently less diverse (Mlekush & DeBacker 2003).

Quantitative sampling in the forest in 2002 revealed hackberry to be the most abundant tree in terms of basal area, followed by bur oak, green ash, white mulberry,

slippery elm and black walnut. Hackberry was also by far the most abundant tree seedling and sapling encountered, followed by elms, bur oak, eastern red cedar (*Juniperus virginiana*) and honey-locust. Broadleaf herbs constitute the bulk of the herbaceous cover in the understory, with fall-flowering species such as wood nettle, stinging nettle (misreported as *Boehmeria cylindrica* by Mlekush & DeBacker [2003]), and wingstem most abundant. Among the ten most abundant non-tree species listed in the 2002 survey, three were vines, namely Virginia creeper (*Parthenocissus quinquefolia*), greenbrier (*Smilax hispida*), and poison ivy (*Toxicodendron radicans*). The herbaceous understory species with the largest mean cover values include wood nettle, stinging nettle, catchweed bedstraw (*Galium aparine*), wingstem, sedges, nodding fescue (*Festuca subverticillata*), Pennsylvania pellitory (*Parietaria pensylvanica*), Virginia wildrye, and violets (*Viola* spp.). A list of 116 species observed in the Cub Creek woods is included in Mlekush & DeBacker (2003).

Community classification of the Cub Creek woods

Reference sites that are potentially useful for defining a reference condition for the Cub Creek woods should be similar communities that occur under similar conditions, namely oak-hackberry dominated forest stands that occur in the floodplain of a stream. Until recently, such forests were not distinguished from upland bur oak forest in the Nebraska state community classification, but analysis of plot data from lowland sites suggests they are distinct from upland forest, primarily because of the abundance of hackberry (*Celtis occidentalis*) in the canopy and subcanopy. The Cub Creek woods are considered an exemplary lowland bur oak forest in the Nebraska Natural Heritage

Programs community classification (Steinauer & Rolfsmeier 2003), and very few examples of this community are currently known in the state.

The United States National Vegetation Classification considers the lowland bur oak forest community of the Nebraska community classification and the mixed oak floodplain woodland of Kansas (Lauver *et al.* 1999) equivalent to the *Quercus macrocarpa* / *Andropogon gerardii - Panicum virgatum* Woodland community, which is evidently restricted to eastern Nebraska, eastern Kansas, and possibly Oklahoma (NatureServe 2006). It is considered historically dominated by bur oak (*Quercus macrocarpa*), with a short shrub layer of coralberry (*Symphoricarpos orbiculatus*), and an understory of mixed woodland and grassland species, including big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and prairie cordgrass (*Spartina pectinata*). This community is considered critically imperiled, with probably fewer than 20 occurrences rangewide. It is suggested that many historical occurrences have been destroyed by conversion to agriculture, or degraded by overgrazing and fire suppression (NatureServe 2006).

Examples of similar woodlands

Since occurrences of this community are rare, few other sites are available for comparison. In Nebraska, two additional sites have been documented; one on private land in the Nemaha River drainage in Pawnee County, and another in Wilderness Park in the Salt Creek drainage south of Lincoln. Both sites have a slightly different species composition from the Cub Creek woods, but have been subject to similar environmental conditions so that neither approximates pre-settlement conditions any better than the Cub

Creek woods. They are similar in that they have been subject to minimal management activity. No examples of this community are currently known in the Big or Little Blue River drainages in Nebraska. Although bur oak is associated with the Big Blue River in Seward County (Rolfsmeier 1988), it apparently is restricted to upland bluffs adjacent to the river valley. No oak-dominated floodplain forest has been recorded from the Blue River drainages in Kansas, but apparently these areas have yet to be surveyed (Delisle personal communication 2006). Oak-dominated forest occurs in floodplains at Konza Prairie in the Flint Hills of northeastern Kansas, and these communities appear related to the *Quercus macrocarpa* / *Andropogon gerardii* - *Panicum virgatum* Woodland community of the national classification (NatureServe 2006). Fortunately, the forested areas at Konza Prairie have been extensively studied, and the effects of restoring historic environmental conditions such as fire and bison grazing have been included as part of these studies, making these forests useful as potential reference sites and valuable sources of information for establishing a reference condition, despite some noteworthy differences in species composition.

Descriptions of possible reference sites

The following sites represent additional examples of fairly high-quality lowland bur oak forest that may be useful for research into a reference condition for this community and for comparison with the Cub Creek woods.

Stateline Forest

This site occurs along a branch of the South Fork of the Big Nemaha River in Pawnee County, Nebraska just north of the Kansas border, *ca*. 2 miles south of Du Bois. This small (*ca*. 40 acre) site is located on private property on the west side of State Highway 50. Data from a 20 × 20 m relevé plot collected by the Natural Heritage Program in 1998 indicates the site is dominated by very large bur oaks and hackberry trees ca. 70 ft tall with a 15 -20 ft. subcanopy composed mainly of hackberry (*Celtis occidentalis*) and slippery elm (*Ulmus rubra*). Other trees recorded include basswood (*Tilia americana*), red mulberry (*Morus rubra*), buckeye (*Aesculus glabra*), bitternut hickory (*Carya cordiformis*), and American elm (*Ulmus americana*). A short shrub layer of gooseberry (*Ribes missouriense*) and coralberry (*Symphoricarpos orbiculatus*) is conspicuous, and the herbaceous understory is relatively dense and is dominated by graminoids and some broad-leaved herbs. The herbaceous plants and vines with the highest cover values include nodding fescue (*Festuca subverticillata*), Virginia creeper (*Parthenocissus quinquefolia*), waterpod (*Ellisia nyctelea*), wood nettle (*Laportea canadensis*), catchweed bedstraw (*Galium aparine*), wood sedge (*Carex blanda*), lopseed (*Phryma leptostachya*), motherwort (*Leonurus cardiaca*), stickseed (*Hackelia virginiana*), white snakeroot (*Ageratina altissima*), spreading chervil (*Chaerophyllum procumbens*) and wingstem (*Verbesina alternifolia*).

Wilderness Park

Wilderness Park is a city park that extends *ca*. 5 miles along Salt Creek south of Lincoln. Much of the area is forested, including a number of patches of lowland bur oak forest in varying condition; the highest quality areas being found near the south end of

the park. This area has long been studied by botanists and is possibly the most intensely botanized wooded area in the state. Nonetheless, efforts to enumerate and describe the vegetation have been rather incomplete and haphazard. The park has received attention lately due to concerns about the effects of rapid urban development on the south side of Lincoln, which has already begun encroaching on the perimeter of the park. Although some studies of the vegetation have been carried out, no definitive data on the composition of the oak-forested portions of the park are available. A study commissioned by the city of Lincoln indicated the presence of several wooded communities including a "bur oak - hackberry woodland" and a "hackberry - elm - honey locust woodland," both of which are considered degraded bur oak dominated "savanna" (EA Engineering 1998). Unfortunately, the author provides very little relevant data that indicate how this conclusion was reached or what the reference condition of this savanna community might be. An extensive floristic survey based on field and literature work was compiled concurrently by a student at the University of Nebraska (Klein 1998) but includes many species based on unsubstantiated reports. A list of vascular plant species documented as occurring in the park is in preparation (Klein personal communication 2006). The lowland bur oak forest at Wilderness Park is more extensive and has a higher diversity of species than the Cub Creek site, with the presence of some large bitternut hickory (*Carya cordiformis*) and Kentucky coffeetree (*Gymnocladus dioica*) among the most conspicuous differences.

Konza Prairie

Konza Prairie is an 8600+ acre preserve of tall-grass prairie and woodland located in the Flint Hills of northeast Kansas. The site contains bur oak forested draws that have been subject to fire and bison grazing in recent years. Descriptions of the forest communities are scant, and though a complete plant species list has been published for the site (Towne 2002), it lists only the habitats in which each species occurs, without descriptions of the habitats themselves. Some studies have provided information on the dominant trees of these communities, with one study listing chinkapin oak (*Quercus muehlenbergii*), bur oak (*Q. macrocarpa*), hackberry (*Celtis occidentalis*), and elms (*Ulmus* spp.), as the species with highest importance values in most stands, with redbud (*Cercis canadensis*), red mulberry (*Morus rubra*), honey-locust (*Gleditsia triacanthos*), black walnut (*Juglans nigra*) and green ash (*Fraxinus pennsylvanica*), also occurring in about half of the stands studied (Abrams 1986). Another study lists honey-locust, American elm (*Ulmus americana*), cottonwood (*Populus deltoides*), hackberry, eastern red cedar (*Juniperus virginiana*) and chinkapin oak as accounting for more than 98% of all tree species mapped (Briggs *et al.* 2002) and mentions the most abundant shrub species are rough-leaf dogwood (*Cornus drummondii*), smooth sumac (*Rhus glabra*), wild plum (*Prunus americana*), skunkbrush sumac (*Rhus aromatica*) and prickly-ash (*Zanthoxylum americanum*). In addition to lowland forest, upland forest is associated with slopes of the drainages, and it is these areas which appear to contain the majority of the chinkapin oak and redbud (Abrams 1986). Herbaecous species in these woods are not recorded, save for what can be gleaned from the species list of Towne (2002).

HISTORICAL ACCOUNTS

Due to the paucity of occurrences of lowland bur oak forest and the presumed degree of divergence between the modern community and its historic progenitor, some amount of speculation is necessary to arrive at a reference condition for this historic community. To this end, historical accounts can provide information that cannot be inferred from the current vegetation. Ideally, direct observations made at or near the vicinity of the Cub Creek woods close to the time of establishment of the Freeman homestead are most valuable for our purposes, but such information is usually lacking or, at best, woefully incomplete. Historical accounts of similar communities in the region can help flesh out some of the missing information, though these accounts often vary considerably in degree of reliability.

Pre-settlement observations of the Cub Creek woods

Fortunately, direct observations of the Cub Creek site were made before the Homestead Act took effect, as part of the field notes of the original Public Land Office Survey in 1857. At the time, every section line was surveyed for construction material, vegetation type, and quality of land. The notes from the survey mention the occurrence of bur oak, elm and walnut, with an undergrowth of "plumb" and vines along the creek at the west boundary of the monument (the N-S line separating sections 26 & 27). Along the north boundary (the E-W line separating sections 23 & 26) timber is recorded including bur oak, elm and box elder with "same plumb and vines". The general description of the township in which the monument is situated indicates that there was a "considerable quantity" of timber on both banks of the Big Blue River and also on the smaller streams, consisting of bur oak, elm, walnut and cottonwood.

Though it provides only a sketchy account, these pre-settlement observations confirm the presence of an oak-wooded community on the Cub Creek site prior to settlement. But other than the occurrence of five tree species, we know little about the nature of the dominant species of this community. Such factors as how far the timber extended into the adjacent grassland, the abundance of each tree, and whether a subcanopy layer was developed are not known. Less satisfactory is the brief description of the understory as containing only wild plum (*Prunus americana*) and "vines". Wild plum is an "edge" species, but the identity of the vines (some of which are also edge species) is unknown, and no mention is made of species that would indicate the existence of a shaded forest understory, or a more open situation with forest and grassland elements. These data are critical for assessing a reference condition for the forest, and must be extrapolated from other sources of data, preferably reliable historic observations of similar communities.

Other accounts of pre-settlement forest in the region

Although the University of Nebraska was at the forefront of studies of prairie ecology, studies of Nebraska's indigenous woodlands are comparatively rare. Studies of pre-settlement vegetation to the east of our region have suggested that tall-grass prairie and oak savannas dominated vast areas of the Central Lowlands to the east of Nebraska prior to European settlement (Nuzzo 1994). Homestead National Monument is near the western extent of pre-settlement oak forest, and the number of trees and types of woodlands found here are more limited than those of more heavily forested states such as Missouri or Illinois. Studies undertaken at Konza Prairie, also near the western limit of

pre-settlement oak forest suggest that these communities were apparently often restricted to stream margins and ravines and existed as relatively narrow bands of "gallery forest" (Abrams 1986). Such a scenario seems reasonable for the Cub Creek woods as well, particularly since the 1857 accounts suggest that much of the existing woodlands in the areas occurred in association with stream courses.

Post-settlement accounts of oak gallery forest

Though studies of the history of oak gallery forest are lacking for Nebraska, there are some historical observations of oak forest that provide some of the clues necessary to address those questions left unanswered by the Public Land Office Survey field notes.

Pound & Clements (1898)

The first detailed descriptions of vegetative communities in Nebraska were published in 1898 in the pioneering "Phytogeography of Nebraska". Its authors, Roscoe Pound and Frederick Clements, were students of C.E. Bessey at the University of Nebraska, and were involved in botanical surveys of southern and northeast Nebraska, respectively, in the early 1890's. Their observations (as well as some apparent guesswork about communities that they didn't visit) are summarized in a volume that includes our earliest detailed descriptions of oak forested communities in the state, based on field work completed about thirty years after the Homestead Act was initiated.

Pound & Clements include fairly detailed descriptions of the oak-forested communities of their day, which they divide into two categories: the red oak - hickory formation, which appears mostly restricted to the bluffs of the Missouri River valley, and

a bur oak - elm - walnut formation that is widespread west to the Big and Little Blue Rivers. They imply that much of the oak forest occurring in the state was gallery forest, as they assert that the presence of deciduous forest in Nebraska is "conditioned chiefly upon the presence of water courses, and they occur only in the immediate vicinity of such, being, in fact, practically confined to the valleys of streams."

Unfortunately, Pound & Clements provide much less discussion of the bur oak - elm - walnut formation than the red oak - hickory formation. They state that the two are very similar, with the major differences being that the two dominant species of the latter are replaced by bur oak and "elm", often with abundant walnut, and that the former is less diverse, containing a subset of the species found in the red oak - hickory formation. One significant difference relevant to the Cub Creek woods is the inclusion of elms as dominant species in the bur oak - elm - walnut formation, which presumably includes most of the oak gallery forest in the State. Another distinguishing character of the bur oak - elm - walnut formation is the presence of dense thickets along its margins, forming a barrier-like border between woodland and prairie. In the region of the Blue Rivers, these thickets are dominated almost wholly by wild plum (*Prunus americana*) and choke cherry (*Prunus virginiana*). Pound & Clements give a few other clues that are relevant for determining the historic species composition of the bur oak-elm-walnut formation. Slippery elm (*Ulmus rubra*) is said to be much more abundant in this formation than it is along the Missouri River, and silver maple (*Acer saccharinum*) is often abundant along the Big Blue. The oak woods along the Blues are also said to resemble those of the Missouri River, only less extensive and more interrupted or patchy.

Although they give little detail as to the canopy cover and vertical structure of the gallery forests of the bur oak - elm - walnut formation, they do mention some details of the red oak - hickory formation that are likely applicable, given their assertion of the similarity of the two types. Along the lower Missouri, red oak and shagbark hickory form patches of forest with contiguous canopies, which may contain lesser amounts of other tree species within these patches. They do not appear to recognize the presence of a subcanopy layer, but mention that the taller trees "become merged with" the canopy and the smaller ones "are masked by it". This suggests that layers of shorter trees are a feature of these forests, but the authors appear to regard them either as indistinguishable from the canopy (in the case of taller trees) or of little consequence (in the case of young subcanopy). The forest patches of the red oak - hickory formation are also described as being surrounded by a zone of more open oak - hickory woodland with scattered elm, ash, and walnut among the oaks. This zone eventually becomes so widespread that the forest gains a heterogenous appearance, presumably due to succession, as patches of oak forest become surrounded by woods of elm, ash and walnut. Within the zones between these expanding forest patches, numerous other species such as hackberry (*Celtis occidentalis*), silver maple (*Acer saccharinum*), and Kentucky coffee-tree (*Gymnocladus dioica*) are said to invade. Toward the edge of the community, the forest begins to lose somewhat of its closed character and is populated with "a host of small trees and large shrubs, which constitute immense thickets". They regard this tall shrub layer as representing a part of the secondary (short woody) layer of the neighboring woodlands, suggesting that in the more open woodlands surrounding the forest, this tall shrub layer is found in place of a tree subcanopy, which is probably poorly developed or absent. In

addition to a well-developed canopy and tall shrub layer, they mention the presence of a short-shrub layer that is continuous and dense except in the more heavily shaded portions of the red oak - hickory forest. Vines or climbers are said to play an important role, and with the exception of greenbrier (*Smilax hispida*) are usually found only at the forest edge or in thickets "where they climb over shrubs and trees alike, forming a dense wall of foliage." They go on to describe the herbaceous layer in great detail, dividing these into upper, middle, and lower layers, but give little information here that is directly relevant to the species composition of the Cub Creek site, though they do mention some species found in the woods of Wilderness Park.

Aikman (1929)

The next (and last) comprehensive survey of oak-dominated forest in Nebraska is that of John Aikman (1929), a student of pioneering ecologist John Weaver. His dissertation focuses on describing various types of oak-dominated communities, of which he recognizes three types: bur oak - bitternut hickory, black oak - shagbark hickory, and red oak - basswood communities. Unlike Pound & Clements, his descriptions include only woody species, are based almost exclusively on observations of forest in the Missouri River valley, and focus more on upland oak forest rather than oak gallery forest. Nonetheless he includes information of relevance to the historic condition of the Cub Creek woods, including some not presented by Pound & Clements (1898). Aikman briefly mentions a "bur oak consocies", equivalent to his bur oak - bitternut hickory community minus the hickory, which is found on the floodplains of smaller streams throughout eastern Nebraska. Also he puzzlingly mentions that in the western part of the

range of oak-forested communities, that bur oak is "able to compete with the flood-plain species along the larger streams [including] the Blue Rivers". Aikman is somewhat vague on the relationship between oak gallery forest and riparian forest, but provides a fairly detailed description of riparian forest, and the successional stages of its development.

The first stage in development of riparian forest (which he calls the *Fraxinus pennsylvanica - Ulmus americana* associes) occurs in broad prairie valleys that contain intermittent steams which carry enough moisture to support trees. The initial vegetation consists of isolated individuals of willows (*Salix* spp.) and cottonwoods (*Populus deltoides*), followed by occasional mesophytic shrubs such as false-indigobush (*Amorpha fruticosa*) and elderberry (*Sambucus canadensis*). He then indicates, interestingly, that "when the stream begins to cut a channel [suggesting that stream channel downcutting is part of the process of succession], protected banks or low areas in its meandering course afford sufficient moisture for growth of *Symphoricarpos orbiculatus* [coralberry], *S. occidentalis* [wolfberry], and *Prunus americana* [wild plum]". He later states that although the increasingly steep banks increase the amount of runoff, the presence of forest cover along the stream and especially shrubs on the banks are effective in reducing erosion.

The next stage of development involves the presence of box-elder (*Acer negundo*) with the willows and cottonwoods, at which point the stream is no longer intermittent, but usually ranges from 1 to 10 feet wide, with a width of 15-50 feet wide between the sloping banks, and the beginning of a floodplain. At this point, the trees spread from the banks out onto the floodplain for a distance of a few yards, with shrubs and vines

extending beyond the trees. Among the dominant shrubs of the banks are the tall shrubs false-indigobush and elderberry, which are restricted to low places on the stream banks. Smooth sumac (*Rhus glabra*), wild plum, wolfberry and coralberry fringe the floodplain forest and extend into the prairie, with other shrubs and vines such as black raspberry (*Rubus occidentalis*), rough-leaved dogwood (*Cornus drummondii*), riverbank grape (*Vitis riparia*), American bittersweet (*Celastrus scandens*), greenbrier (*Smilax hispida*) and poison-ivy (*Toxicodendron radicans*). The boundary between woodland and prairie at this stage is not stationary, but constantly shifting in response to fires, cuttings, intentional plantings, and cycles of climatic variation. This developmental stage was evidently found along considerable distances in the western part of the area in Aikman's time, especially the small tributaries of the Big and Little Blue Rivers.

Finally in the third stage, elms (*Ulmus americana* and *U. rubra*) and green ash (*Fraxinus pennsylvanica*) become dominant and the willows disappear, followed by the cottonwoods and box-elder. Gooseberry (*Ribes missouriense*) becomes the most typical floodplain shrub at this stage. In better-developed floodplain forests, black walnut (*Juglans nigra*) may share dominance with these species, and increased shade results in the decrease of shade-intolerant species. Aikman speculates that since red oak (*Quercus rubra*) and basswood (*Tilia americana*) sometimes advance into forests at the stage, the red oak - basswood stage represents the climax stage toward which riparian succession eventually leads. It appears that Aikman's red oak - basswood community is roughly equivalent with the red oak - hickory formation of Pound & Clements (1898) (Aikman indicated that a fungal disease had killed off many hickories at some sites prior to his study), which Pound & Clements regard as unrelated to riparian forest. Pound &

Clements did recognize a riparian forest community which they called the "wooded island formation". Their description is clearly synonymous with Aikmans' 1st and 2nd stage riparian forest. The trees associated with the third stage of riparian forest, however, appear to be regarded by Pound & Clements as a natural part in the succession of oak-dominated forest. They even go so far as to suggest that when a third-stage forest dominated by ash and elms appears on an island in a river that it is an illusion created because a stream channel has shifted, cutting it off from the rest of the oak forested formation. Despite these differences in interpretation, it is apparent that the remnant gallery forest on Cub Creek contains elements of oak forest, riparian forest, and a shrub-dominated zone both on the banks of the stream, and between the forest and prairie.

Post-settlement accounts of the Cub Creek woods

The Homestead National Monument of America was established in 1936, a little over 73 years from the establishment of a homestead on the site. A fire protection report (Shelvin 1939) gives us the first account of the composition of the forested areas after settlement. The report states that 22% of the site is covered with hardwood forest dominated by oak, with a "liberal sprinkling of elm, black walnut, hackberry, red maple [presumably silver maple, *Acer saccharinum*], cottonwood, box-elder, Osage orange, and honey-locust". While indicating a "limited number" of large trees were present, the majority of trees were relatively young (6-12 inches in diameter). The presence of stumps of large trees indicated that many more were present prior to establishment of the monument. A later report (Dickison 1960) depicts the forest as "uneven aged" and composed of mixed species including oak, maples, elm, hackberry and cottonwoods.

Stands of willow were also noted, the result of plantings made to stablilize the streambanks in 1952. The presence of additional tree species not included in the 1857 account suggests that these species were either overlooked, or had come in at a later time. We know that some trees (such as Osage orange [*Maclura pomifera*] and the willows [*Salix* sp.]) were intentionally introduced, but we cannot say for certain which of these trees were present other than the five mentioned in the Public Land Survey notes. Looking at the changes made to the environment as a result of settlement may yield clues as to which species may have arrived following the establishment of the first homestead.

CHANGES TO THE ENVIRONMENT AS A RESULT OF HOMESTEADING

Pre-settlement human environment

The objective of this and many environmental restoration projects in North America is to restore biological communities to a state that approximates conditions that existed prior to the settlement of Europeans. Shortly after arrival of European immigrants, the grassland environment of the Central Plains was subject to a series of environmental changes that greatly altered the landscape. The greatest impact was the destruction of much of the existing biological communities, and these changes had profound effects on the portions of the native ecosystem that remained.

Prior to the increased settlement that resulted from enactment of the Homestead Act, the environmental factors that shaped the vegetation of the Plains were primarily the results of natural phenomena and the efforts of the indigenous inhabitants to shape their environment. When Daniel Freeman first homesteaded the Cub Creek tract, the influence

of native peoples over this area had already waned, yet the changes that would be wrought by Europeans had not yet taken effect, resulting in an environment transitional between the one managed by nomadic hunters and the one shaped by stationary settlers. The landscape the first settlers encountered had until recently been largely utilized by transient populations of people who used the land primarily for hunting bison and gathering native foods, and the degree to which the environment was managed to favor these activities is intimately tied to the history of native peoples in the region.

The land upon which the monument is situated was part of the territory utilized by the Oto-Missouri Tribe, who appear to have traveled into this area possibly as early as the late 17th century (Access Genealogy 2007). In the early 19th century, the Oto-Missouri people, who had re-united with the Missouri tribe following a smallpox outbreak, had settled in several villages on the south side of the Platte River near its mouth. After reaching these villages in July of 1804, while much of the tribe were away hunting bison, the Corps of Discovery were met by a small group of Oto-Missouri, at Council Bluff, resulting in the first formal meeting between representatives of the United States and indigenous people of the west (National Geographic 2007). Several decades later, in 1830, the first of several treaties were signed which ceded claims to portions of Oto-Missouri lands. By 1854, they had given up all their lands except a strip 10 miles wide and 25 miles long on the Big Blue River, which was exchanged later in the year for another tract taken from the Kansas Indians (Access Genealogy 2007). By the time of the Public Land Office survey in 1857, the Oto-Missouri were three years removed from the lands that included the Cub Creek site. The following year, work was begun on a freight road connecting Brownville to Fort Kearny that apparently intersected the Cub Creek

woods (Lass 1972). While this trail brought Europeans through the area, there is no evidence of settlement until a squatter built a simple log cabin on the northernmost end of the current Monument site in 1862. Freeman bought the squatter's interest in the land a few months later, and by the time he homesteaded the tract, nine years had passed since the native people had managed these lands. Only 708 Oto-Missouri people were recorded in an 1862 census (Access Geneology 2007).

Pre-settlement fire

The single most important tool utilized by native people to alter their environment was fire. Fire was primarily used to surround or drive grazing animals for the purposes of hunting, and special hunting sites were often maintained by annual burning, usually in the autumn, to promote more palatable spring grasses. While lightning fire would have naturally played a role in the environment, native peoples were probably responsible for increasing the incidence of forest and prairie fires above that caused by lightning (Pyne 1983). Frequent burning during the period of habitation by Native Americans would have maintained the majority of the landscape as tall-grass prairie by retarding the growth of woody vegetation. Oaks were undoubtedly present during this period, but would have likely been relegated to protected areas, or would have occurred in rather open woodland or savanna. The frequency of fire in the landscape likely varied tremendously, with estimates of pre-settlement fire intervals of 1-10 years (Abrams 2000). Given the frequency of fire and the rather level topography of the broad valley of the Cub Creek site, it would be rather easy to assert that the area was maintained as an open oak savanna, with the presence of the stream channel providing some protection for some of

the less fire-resistant trees. However, the presence of fire in and by itself is not sufficient to assure that we can predict the nature of the community present. Recent studies of the effects of different fire intervals in oak gallery forest suggest the picture is much more complicated.

Recruitment and cover of small trees and shrubs is noticeably reduced by annual burning. A study of oak gallery forest at Konza Prairie indicated that shrub cover dramatically decreased from near 60% to less than 10% following fire in two successive years (Abrams 1988). In the same study, tree saplings were reduced from 1,200 per hectare to zero following the fires, and seedling stems also declined considerably except for elms (*Ulmus* spp.) and hackberries (*Celtis occidentalis*), in which basal sprouting resulted in a greater number of stems.

On the other hand, studies of the responses of woody species to a longer interval between burns provide much different results. A fifteen year survey of oak gallery forest at Konza Prairie indicated that fire return intervals of greater than one year increased cover and recruitment of woody species (Briggs *et al*. 2002). In fact, the density of the selected shrub rough dogwood (*Cornus drummondii*) increased more dramatically with an intermediate fire interval of 3-5 years than with a very low fire frequency of 15 years. Tree density similarly increased 2 to 10 fold in areas burned less frequently than yearly. In areas with an intermediate or low fire frequency, the most abundant trees were American elm (*Ulmus americana*) and honey-locust (*Gleditsia triacanthos*), both of which resprout vigorously following fire or cutting (Briggs *et al.* 2002). Hackberry and eastern red cedar (*Juniperus virginiana*), on the other hand, proved intolerant to fire and were found only in areas with low fire frequency. Hackberries, despite their ability to

resprout, apparently do not tolerate fire long, due to their thin bark, while eastern red cedar is unable to resprout following fire or cutting.

The presence of elm and shrubs in the notes of the Public Land Office survey suggests that a fire interval at the Cub Creek site was greater than one year by 1857, which is not surprising, given the fact the indigenous population would have been removed from this area no later than 1854. The prevalence of spring-flowering wild plum (*Prunus americana*), however, suggests that the fires that did occur at the site primarily happened in the summer or fall, since spring burns would have likely promoted the spread of smooth sumac (*Rhus glabra*) at the expense of wild plum.

Post-settlement fire

As indigenous hunters were replaced by European farmers, the frequency and practice of burn management changed considerably. Although the fires set by native peoples would have been eliminated before settlement, wildfires started by natural causes such as lightning were certainly an occasional occurrence in the lives of early settlers, and remained a risk until about the 1880's (Pyne 1983). Whereas data on pre-settlement fire interval for the Central Plains are apparently lacking, studies at Konza Prairie indicate a fire interval of 11.2 - 19.7 years between 1862 and 1983, based on fire scars on 19 trees (Abrams 1985). During this same time period, the estimated fire interval for Flint Hills tall-grass prairie was 2-3 years, suggesting the fire interval was actually shorter than is indicated by fire scars, since fires might not have scarred every trunk due to limited fuel accumulation under the trees and lower combustibility of hardwood foliage. Although most fires that affected oak gallery forest certainly started in adjacent

prairie, many of these fires may have had little impact in wooded areas due to the protection afforded these sites by their proximity to stream channels, faster litter decomposition, higher relative humidity, and the slow movement of fire downhill (Abrams 1985).

Following increased settlement of the region due to railroads, and subsequent fragmentation of the prairie landscape by its conversion to cropland, the risk of wildfire eventually diminished in frequency and extent. For instance, the oldest tree in the Konza study, which apparently began growth in 1858, showed fire scars in 1862 and 1865, then not again until 1980, and other trees show a less frequent fire interval in later years (Abrams 1985). Measures were also undertaken to limit the spread of fires that did start, and controlled burns were used only as an agricultural tool, rather than a means of hunting. Controlled burning of stubble was often utilized as a means of clearing crop fields and controlling weeds, until mechanical and chemical methods replaced fire (Pyne 1983). Such fires were apparently utilized at the Cub Creek site, as evidenced by fire scars seen on some trees in 1939 (Shevlin 1939). The Forester's report for that year implicates fire as one of the factors in decreasing the extent of the forest at the monument from 64 acres to 35 acres, though other factors certainly had a greater impact, such as timber cutting. The degree to which fire impacted the Cub Creek woods following settlement is unknown, though studies of fire intervals based on fire scars might help shed some light on its importance. Photos of the woods, taken in 1939, show that much of the area at that time was an open woodland, though it is unlikely that fire was the primary factor responsible, due to the influence of other settler-related disturbances.

Additionally, it is difficult to estimate the extent to which the woods in 1939 resembled those found at the time of settlement. The forester's report indicates that of the 35 acres of hardwoods remaining at the monument (primarily the north portion of the current tract), 29 acres were oak-wooded, with only 6 acres dominated by other hardwoods. What is certain is that fire suppression has been a factor in the subsequent increase of fire-sensitive hackberry (*Celtis occidentalis*), which is currently the most abundant tree in the woods in terms of basal area, seedlings and saplings (Mlekush & DeBacker 2003).

Timber cutting

Undoubtedly one of the major reasons Daniel Freeman selected the Cub Creek site for his homestead was the presence of trees. Since timber was infrequent on the plains prior to European settlement, woodlands served as a particularly valuable source of building material and fuel. Although we do not know how much timber was removed from the Cub Creek woods in the early years following settlement, it is safe to say that removal of standing timber had an effect on the composition of the forest, particularly in an environment in which fire was becoming less a factor.

Although bur oaks (*Quercus macrocarpa*) resprout after they are cut, in the absence of fire they would have to compete with faster growing fire-sensitive trees such as hackberry (*Celtis occidentalis*). As long as occasional wildfire was still possible, the oaks would continue to have an advantage over less fire tolerant competitors. Without fire, the secondary successional species would begin to fill in the gaps in the woody canopy, with the additional shade hindering oak regeneration. Studies in Pennsylvania

show that secondary successional species tend to replace early successional species following selective cutting (Orwig & Abrams 1999), and it is likely that timber cutting and fire suppression are responsible for the present-day rarity of remnant oak gallery forest in our area. This distinction is dramatically evident by comparing the current condition of the north and south portions of the Cub Creek woods in light of their recent histories.

In 1936, prior to the establishment of the monument, the south portion of the Cub Creek woods were almost entirely clear-cut. Once the land was acquired by the monument, oaks and hackberry were replanted, but in the absence of fire, the faster growing hackberries demonstrated their competitive advantage by dominating the canopy of the subsequent forest to the near exclusion of bur oak. Even if hackberries had not been replanted, it is likely that the resulting forest would have resembled the current condition due to the absence of fire as a selective pressure in favor of the oaks. That bur oak remains in the northern half of the forest suggests that this site was either selectively thinned during its early history, or that fire remained a factor in that allowed the oaks to resprout without competition from more fire-sensitive species. Even without timber cutting posing a threat to the oaks, it appears that succession may eventually eliminate their presence from the north portion of the woods, given that without fire, they will likely be replaced by hackberry and other secondary successional species after they die.

Dead and down material

Given the frequency of fire before settlement and the use of dead and down timber as fuel by the settlers, it is likely that little fallen timber was present in the Cub

Creek woods during the early years of settlement. Shevlin (1939) noted similar conditions, with intensive grazing, and (presumably) its suppressive effects on timber growth an additional contributing factor.

Impacts of bison and cattle grazing

Another factor that has greatly impacted the Cub Creek woods continuously over the years is ungulate grazing. Prior to European settlement, the primary grazers of the tall-grass prairies would have naturally been bison. Given the fact that native people used fire to attract bison to given sites, bison and fire were probably to two leading factors in shaping pre-settlement oak gallery forest in the Plains. Whereas yearly fire has been shown to reduce the growth and spread of woody vegetation, studies at Konza Prairie indicate that the introduction of bison into a woodland ecosystem that experiences frequent fire actually encourages the growth of woody plants (Briggs *et al.* 2002). As bison primarily feed on grasses and sedges, these fine fuels, which are primarily responsible for carrying fire into the woods, are reduced and the intensity and spread of fire is limited. In watersheds in which bison were introduced at Konza Prairie, woody plant abundance increased 4 to 40-fold as compared with ungrazed watersheds (Briggs *et al*. 2002). Bison grazing is likely a factor that helped oak gallery forest survive in the Plains prior to settlement.

By the time of the first homestead at the Cub Creek site, bison would have been reduced or eliminated from the area, and the frequency of fire would have been reduced. Whereas fire suppression undoubtedly increased the spread of woody vegetation, the pressures of farming and timber harvest would continue to exert pressure on the

expansion of forest. In particular, intensive grazing of cattle would have suppressed woody plant growth. Although cattle, like bison, primarily consume fine fuels, they also tend to lounge in riparian areas and their continued presence negatively impacts woody species as well. Under high-density grazing conditions, cattle tend to compact soil, browse and break tree seedlings and consume seeds, contributing to an overall decrease of woody vegetation in the lower forest strata and a decreased recruitment of woody species. Shevlin (1939) attests to the decrease of the forest understory and woody plant reproduction as a result of grazing, and photos show sparse forest cover in portions of the woods. Once grain and cattle farming ceased at the monument in the late 1930's, the woody vegetation would have undoubtedly spread to its current extent, though in the years following the establishment of Homestead National Monument of America, wildlife grazing would become an increasingly significant factor negatively impacting the Cub Creek woods.

Impacts of deer

At the time that the monument was established, the number of white-tail deer in the area would have been much lower than at present. Deer numbers and range declined considerably during the second half of the nineteenth century due to overexploitation, and it is thought that deer were likely eliminated from Nebraska by 1900 (Holoweb 2007). Protection of deer via restricted hunting seasons and game laws has led to rapid population increases, especially during the 1960's and 1970s. Current deer populations are at unprecedented levels, and deer overabundance is one of the primary threats to the Cub Creek woods at present.

Since grazing, along with fire, was a natural process affecting oak gallery forest prior to European settlement, some grazing is necessary for forest health, particularly in the absence of fire. In the total absence of grazing, or at very low deer densities (< 6 deer per square mile) species diversity in woodlands may decrease due to a lack of selective grazing and seed dispersal (George 2007). However, at densities greater than 25 deer per square mile, quality and diversity of woodlands begin to be compromised. Historical population densities of white-tail deer in Missouri have been estimated at between 10 and 30 per square mile (George 2007), while pre-settlement density estimates of 10 per square mile have been made for Wisconsin (Rooney & Waller 2003). Current estimates for Nebraska range from 5 deer per 100 square miles in some counties to 100 per square mile near Fontenelle Forest near Bellevue (Holoweb 2007). An ideal deer density to promote forest health is an intermediate density of 6-25 deer per square mile (George 2007). For a 60 acre site, such as the Cub Creek woods, this would calculate to 1-2 deer for the entire forest. A deer census carried out at the monument in 2004 determined a density of 76 deer per square mile, with seasonal variation of 36 per square mile in late summer to 140 in late fall (Bolli 2004).

Deer overpopulation has been shown to have negative consequences for the health and diversity of forests. Though white-tail deer favor agricultural crops as a food source, among their primary native foods in Nebraska are native woody plants, in particular shrubs including buckbrush (*Symphoricarpos* spp.), dogwoods (*Cornus* spp.), chokecherry (*Prunus virginiana*) and wild plum (*P. americana*) (Holoweb 2007). Deer also browse tree seedlings and saplings, limiting regeneration of preferred food species. They also browse herbaceous understory, exhibiting preference for broad-leaf herbs over

grasses and sedges. Studies in Wisconsin indicate that in wooded areas in which hunting is prohibited, the overall species diversity has declined, and the proportions of graminoids and ferns increased from 22% to 91% at one site and from 23% to 61% at another (Rooney & Waller 2003). Sustained deer overpopulation has also been implicated in steep declines in overall species diversity as well. Ground layer surveys conducted in a Pennsylvania woodland in 1929 and 1995 indicated no new species present in the later survey, and the disappearance of 81% of species from one stand and 59% from another. A similar survey in a Wisconsin forest in 1949 and 1999 demonstrated a 48% net species loss (Rooney 2001). Loss of herbaceous biodiversity has indirect impacts on other organisms such as monophagous insects, including butterflies (Rooney 2001). By preferentially browsing the lower woody layers, the vertical structure of the forest is simplified, with a more open savanna-like structure present in the understory, which can negatively effect shrub-nesting birds, and making small mammals more visible to predators (Rooney 2001). The spread of ticks carrying disease-carrying organisms such as Lyme disease could have an impact on human visitors as well.

While baseline studies against which the impact of deer upon the vegetation of Cub Creek woods can be compared have not been undertaken, evidence such as the near absence of saplings and very low cover values for forest shrubs such as coralberry and gooseberry in the 2002 survey (Mlekush & DeBacker) suggest deer have already had measurable impacts of the vegetation of the forest.

Hydrology

Prior to European settlement, it is likely the channel of Cub Creek was not nearly as deep as it currently is. The 1857 Public Land Office survey indicates that cottonwoods and box-elder were present, and it was likely they were part of the riparian/riverbank ecosystem, given their sensitivity to fire. This survey also mentioned that most trees in the region were confined to the banks along the Big Blue River. With the introduction of farming and roads as a result of European settlement, an increase in runoff from fields would have altered the stream channel through siltation and subsequent downcutting. This process has left steep, eroded, sparsely-vegetated stream banks in place of the wooded banks presumably once present. This disturbed habitat serves as a pathway for colonization by alien (non-indigenous) species, both intentionally and accidentally. In 1952, willows were planted as an effort to stabilize the eroding stream banks (Mlekush & DeBacker 2002), and the results of recent botanical collections suggest the species planted there was the Eurasian hybrid *Salix* ×*rubens*. These trees are sterile, and most have since died, but other presumably alien species such as reed canarygrass (*Phalaris arundinacea*) appear to be colonizing portions of the banks. Reed canarygrass is a particularly aggressive perennial grass that competes with native vegetation. While restoring the channel to its 1860's condition may not be possible, it is certain that the vegetation currently on the banks differs greatly from that found there presently due to these disturbances. Unfortunately, no descriptive account of the current vegetation of the stream banks is available.

Alien (non-indigenous) organisms

Although indigenous people were undoubtedly involved in the spreading of important food and medicinal plants, with the arrival of European settlers came numbers of immigrant plants and animals that transformed the landscape in often unforeseen ways. Although some alien plants preceded the arrival of white settlers in early North America, it is likely that very few non-native plants were present at the time of the first homestead, with the possible exception of early arrivals such as Kentucky bluegrass (*Poa pratensis*). Homesteaders often intentionally introduced trees alien to the region, such as the Osage orange (*Maclura pomifera*) which was planted as a hedgerow at the Cub Creek site by the Freemans. More significantly, farming allowed the tall-grass prairie region to gradually be altered from grassland dominated by perennial warm-season grasses to a landscape primarily of annual cereal grains. Some unwanted species arrived as contaminants in grain seed, and while many of them likely never became a permanent part of the flora, other species with invasive tendencies were subsequently introduced by various means.

At present, alien species are not an overwhelming component of the current vegetation in the Cub Creek woods. Seventeen alien species were observed by Mlekush and DeBacker (2002) in the forest (two additional species, *Euphorbia davidii* and *Echinochloa muricata* are native, but were erroneously reported as non-native). Of these, five appear to be potentially invasive, namely Japanese barberry (*Berberis thunbergii*), field bindweed (*Convolvulus arvensis*), yellow sweet-clover (*Melilotus officinalis*), white mulberry (*Morus alba*), and smooth brome (*Bromus inermis*). Additionally, reed canarygrass (*Phalaris arundinacea*), which was listed as native by Mlekush and DeBacker, is highly invasive and likely not indigenous to this site. Of these species, white mulberry and Japanese barberry are the most likely to alter the composition of the

community, and it appears already that white mulberry has begun to do so, having been listed as the fifth most abundant tree at the site (in terms of basal area) during vegetation monitoring in 2002.

In addition to the introduction of alien plants that compete with native vegetation, the plants in the woods are at risk from introduced pathogens and insects. Perhaps the best known is Dutch elm disease, which was first recorded in North America in 1930 (Karnosky 1982), and in Nebraska 30 years later. Though both the native American elm (*Ulmus americana*) and slippery elm (*U. rubra*) are affected, American elms in particular seem susceptible, and their rarity in the Cub Creek woods at present is probably in part because of the effects of this pathogen. Given the apparent importance of American elm in the settlement era woods, Dutch elm disease has had a significant impact on the condition of the forest. Other introduced organisms potentially threaten the woods, such as the emerald ash borer, which has not yet been recorded in Nebraska.

PROPOSED REFERENCE CONDITION FOR THE CUB CREEK WOODS

Data from the current vegetation, historical accounts and examination of the changes to environment that shaped the current forest suggest that the historical woodland on Cub Creek apparently existed as three definable yet somewhat intergradient zones which can be recognized to some extent in the current forest: a riparian zone confined to the banks and perhaps the margins of the floodplain closest the stream channel; an oak woodland zone, containing patches of bur oak with some associated fire-resistant trees scattered in the canopy or sub-canopy; and a shrubby transition zone which

represents a broad ecotone between woodland and tall-grass prairie. Given what little is known about the historic makeup of this oak gallery forest in our region and its current scarcity, a certain amount of conjecture will be necessary to develop a quantitative description of the distribution, composition and abundance of the species that composed the historic woodland, and it is likely that reintroducing historic conditions to the site will give us further insights as to how this forest may have responded to factors such as fire. It should be kept in mind that the reference condition proposed here is not "set in stone" but is merely the best guess based on the available evidence, and that future changes may be in order as more information comes to light.

Summary of reference conditions

Riparian zone

The portion of the current forest that constitutes the stream channel and the margin of the floodplain immediately adjacent to the upper banks currently lacks bur oaks (*Quercus macrocarpa*), and is populated by a few large cottonwoods (*Populus deltoides*), some tall hackberries (*Celtis occidentalis*), and black walnut (*Juglans nigra*), with silver maple (*Acer saccharinum*) conspicuous in places along the stream banks. Since it is likely that Cub Creek would have been subject to occasional flooding, the riparian woodland occurring along the stream would have remained in an early stage of succession. The presence of cottonwoods and box-elder (*Acer negundo*) suggests the historic community most closely matches Aikman's (1929) stage 2 riparian forest, dominated by cottonwoods, willows (*Salix* spp.) and box-elder, and probably accompanied by numerous short shrubs, especially on the stream banks. Given that this

represents an early successional stage, it is likely that hackberries were not present, and although black walnut is sometimes associated with riparian forest, it may have been confined to the floodplain, likely along the margins of the bur oaks rather than with the cottonwoods and box-elder. Although we cannot closely estimate the density of the woods, the likelihood of shrubs occurring on the stream banks and among the trees suggest an open canopy, unlike the shaded conditions that currently exist.

Canopy - Cottonwoods would probably constitute the largest trees in the riparian zone, and it is likely the canopies were not contiguous, as this condition is rare even in modern cottonwood-dominated communities. On the stream banks, cottonwoods probably existed with scattered willows, most likely peach-leaf willow (*Salix amygdaloides*).

Subcanopy - Mature cottonwood dominated communities in Nebraska often show very little subcanopy development. The Eastern Cottonwood - Dogwood riparian woodland community in northeast Nebraska appears in fact to lack a subcanopy and has a dense tall shrub layer in its place (Steinauer & Rolfsmeier 2003). Given the rather rich soils present at the Cub Creek site, along with the presence of box-elder, it appears likely that subcanopy trees were present. Black walnut may also have occurred here, near the perimeter of the adjacent oak-forested woods, and although it was not recorded in the 1857 survey, it is likely silver maple was either overlooked or appeared at the site soon afterward, given its historic prevalence in the Big Blue River drainage (Pound & Clements 1898). Like the cottonwoods, it seems unlikely that the subcanopy trees would

have contiguous canopies, and it is likely that the overall canopy cover of the riparian zone would have been typical of a woodland (canopy cover between 40 and 67% in best developed areas near oak, probably less than 40% elsewhere).

Shrub layer - a short shrub layer of shade-tolerant coralberry (*Symphoricarpos orbiculatus*) seems likely to have been present on the banks, perhaps growing under a tall shrub layer of wild plum (*Prunus americana*), given its historic presence. This shrub layer probably was also found in openings among the canopy of the riparian trees, and perhaps even in openings of the adjacent oak woodlands (with coralberry likely present in more densely wooded areas as well). Open areas on the banks that might have supported wild plum also likely contained wild grape (*Vitis riparia*), which is appropriately known as "riverbank grape", and perhaps elderberry (*Sambucus canadensis*).

Herbaceous layer - it is not possible to know what the herbaceous vegetation of this zone is, based on these accounts, but it is likely that it included numerous species associated with the adjacent oak woods in shaded areas, and possibly some mesophytic grassland species in open areas.

Overall description: The riparian areas were probably quite variable in terms of cover and extent. In the lowest areas of the floodplain, or in areas protected by the presence of an adjacent oak wooded community, a canopy of tall cottonwoods with shorter scattered box-elder and some black walnut and possibly silver maple occurred as a woodland with an intermediate canopy cover (40-67%). In areas away from the patches

of oaks, the riparian community would have likely been more exposed to frequent fire and may have been an open savanna-like condition (10-40% canopy cover), or may have been replaced by shrubland. Wild plum and coralberry were probably the most common shrubs, and would have likely occurred on the streambanks with scattered cottonwoods and probably peach-leaf willow. Shrubs would have extended into the riparian wooded areas of the floodplain, and beyond into the adjacent oak woods or prairie. The herbaceous layer of this community is difficult to describe, but probably contained some woodland and "edge" species in shaded areas, and mesic prairie plants in open areas along the stream.

Oak woodland

Bur oaks (*Quercus macrocarpa*) were clearly present in the Cub Creek woods at the time of settlement, along with elms (*Ulmus* spp.) and black walnut (*Juglans nigra*). It appears the oak woods should have been very similar to the description of the oak-elm-walnut formation of Pound & Clements (1898), with the major difference being the canopy would have likely been more open. The Public Land Survey notes did not distinguish which elms were present, but Pound & Clements (1898) make clear in their book that American elm (*Ulmus americana*) was one of the principal constituents of forest and woodland throughout the oak wooded region.

Canopy: The oak wooded areas were almost certainly dominated by bur oak, though it is unclear if it was the only tree in the canopy. Pound & Clements (1898) suggest that in the best-developed oak forest subcanopy trees are either difficult to

distinguish from the canopy, or are rather short. It seems that a few American elms and black walnuts may have constituted a tall subcanopy or may have occurred in gaps within the canopy. Aerial photos from the 1930's show a mostly closed canopy forest in the north portion of the Cub Creek woods with a few conspicuous openings visible in places. It seems reasonable, based on the presence of a diverse shade-tolerant herbaceous understory, that the oak canopy varied from somewhat open near its margin to nearly closed in parts of the interior.

Other fire-resistant trees may have been part of the canopy or subcanopy as well. Of the species listed by Shevlin (1939), honey-locust (*Gleditsia triacanthos*), which readily resprouts following fire, seems a likely candidate to have survived and even thrived in gallery forest subject to fire. Its absence from the 1857 description may be accurate though, since it appears that honey-locust has apparently expanded its range considerably since settlement. Historic herbarium collections and literature sources (e.g. Pool 1951) suggest that in the late 19th and early 20th century, honey-locust may have been nearly restricted to the bluffs of the Missouri and quite rare westward. The fire-susceptible cottonwoods (*Populus deltoides*), silver maple (*Acer saccharinum*), box-elder (*Acer negundo*) and hackberry (*Celtis occidentalis*) were likely rare in, or absent from, this community.

Subcanopy - If present, this layer would have probably be nearly as tall as the canopy and possibly not very distinguishable from it. A short subcanopy of young trees may also have been present in the 1860's as fire became less frequent. This shorter layer probably contained elms, walnut, and possibly hackberry sometime after settlement.

Shrub layer: Scattered tall shrubs such as wild plum (*Prunus americana*) and possibly chokecherry (*Prunus virginiana*) may have been present in openings and along the perimeter of the woods. A short shrub layer of coralberry (*Symphoricarpos orbiculatus*) and gooseberry (*Ribes missouriense*) was probably also conspicuous. Also, some vines such as greenbrier (*Smilax hispida*), Virginia creeper (*Parthenocissus quinquefolia*) and poison ivy (*Toxicodendron radicans*) may have been scattered, particularly along the edges and in openings.

Herbaceous layer - the herbaceous layer may have resembled that currently present in the oak-wooded areas of the forest, which sedges and tall, coarse fall-flowering perennials dominating, with a spring-flowering component present in more shaded areas. Some "edge" forbs may have occurred with shrubs in the openings.

Overall description: The oak-wooded areas were probably patchy and varied in canopy cover. Overall they probably constituted open woodland with a canopy coverage of 40-67%, with some areas in the interior more shaded and approaching forest, with a canopy cover of >67%. Bur oaks were the dominant tree, though American elm and black walnut may have formed a tall subcanopy and possibly also a short subcanopy after settlement. Hackberry may have become part of a short subcanopy after a time, but was probably not conspicuous in the 1860's. Slippery elm (*Ulmus rubra*) may also have been present, but honey-locust was probably absent at that time.

Along the margins and in openings tall shrubs and perhaps some short trees would have been found. Wild plum was almost certainly present, with chokecherry also possible. Vines such as riverbank grape (*Vitis riparia*), Virginia creeper, greenbrier, and poison-ivy probably occurred with the shrubs. In the more shaded areas, a short shrub layer of coralberry and gooseberry was likely present, though were probably not especially dense due to occasional fire (probably <25% cover). Herbaceous species in the shaded areas were probably similar to those found in less disturbed portions of the forest at present. In the openings, some forb species tolerant of shade (such as goldenrods [*Solidago* spp.]) may have been present as well.

Shrubby Transition Zone

Both the Public Land Office notes and historical accounts suggest a well-developed woody transition zone existed between the woods and the prairie, and it is likely this zone included small trees and thickets of wild plum and vines, and possibly other shrubs and trees. This zone would have been strongly affected by fire, and its extent and density would likely been quite variable.

Canopy - It is difficult to guess whether trees were part of the transition zone, though with the reduced frequency of fire after 1854, it is likely that some young trees were present. It is even possible that a few scattered larger trees occurred, though there is not enough evidence to suggest this zone constituted a savanna (10-40% woody cover). If trees were present though, it is likely they constituted a relatively small amount of cover (certainly <40%).

Subcanopy - This layer was likely not present, though some short trees were likely present.

Shrub layer - Tall shrubs including wild plum would probably have been the primary constituents of this zone, with chokecherry (*Prunus virginiana*), rough-leaf dogwood (*Cornus drummondii*), smooth sumac (*Rhus glabra*) and elderberry (*Sambucus canadensis*) likely also scattered. Short shrubs such as coralberry (*Symphoricarpos orbiculatus*) likely occurred among the taller shrubs, along with copious vines including riverbank grape (*Vitis riparia*), Virginia creeper (*Parthenocissus quinquefolia*) and poison ivy (*Toxicodendron radicans*) scrambling over the shrubs. An overall shrub cover of greater than 25% might have been present under an intermediate fire interval, though this would vary frequently in response to fire.

Herbaceous layer - the composition of the herbaceous layer would be dependent on the density of shrubs. Prairie grasses might have been present in openings, though shrub and vine growth would likely inhibit their persistence in the absence of frequent fire. Shade-tolerant forbs and grasses may have been among the major constituents. Possibilities among the species found at the monument include white panicled aster (*Symphyotrichum lanceolatum*), Canada lettuce (*Lactuca canadensis*), giant goldenrod (*Solidago gigantea*), white avens (*Geum canadense*) and white verbena (*Verbena urticifolia*).

Overall description: The shrubby transition zone likely occurred adjacent to the oak woodland and riparian zones and extended into the adjacent prairie in response to fire. Some small trees fire-resistant trees and perhaps even some large ones may have been present, but the dominant vegetation would have included tall shrubs, primarily wild plum with numerous vines. The shrub cover would likely have been sufficient to classify the community as shrubland (>25%). Prairie grasses and shade tolerant forbs were likely interspersed among the shrubs.

Extent of communities

The historical reference condition proposed for the Cub Creek woods consists of a heterogeneous assemblage of early successional riparian woodland, bur oak dominated woodland varying in cover from fairly open to possibly closed canopy, and a dynamic ecotonal shrub zone forming a boundary between the wooded communities and the adjacent tall-grass prairie. How far these communities extended onto the prairie is difficult to estimate. The riparian community probably never extended very far beyond the stream banks, except perhaps in particularly low, mesic portions of the floodplain. The oak-forest probably occurred in patches near the stream, particularly in areas associated with stream bends where the zone of contact between the woods and the adjacent shrub zone would have been minimal. The shrub zone might have extended outward as far as the current boundaries of the forest following reduction in fire frequency after settlement. Studies have shown a correlation between soil quality variables (such as nitrogen and organic matter) and vegetation in oak savanna

communities (Meisel et al. 2002), and it is possible the soils in the woods may provide information on the distribution of historic woodland.

ACTIONS FOR ACHIEVING THE REFERENCE CONDITION

Although the goal of this project is to restore the Cub Creek woods to the historic reference condition, this is not entirely achievable. Although we can reintroduce some important historical conditions (such as fire) we cannot hope to replace all that was present in the 1860's environment that has since been lost, meaning that some compromises will be necessary. Restoration goals should include preserving what remains in the highest quality portions of the ecosystem, while adjusting the abundance and distribution of species in the site to levels as closely as we can to those proposed by the reference condition. Given the likelihood that the forest occupies a larger extent of the site than it did historically, and that the density of tree cover has increased, it will be necessary to remove some of what is standing at present-- particularly species that became more abundant as a result of changes in environmental conditions such as hackberry (*Celtis occidentalis*). Other species, such as shrubs, were likely more abundant historically than they are presently, and re-introduction of species such as wild plum (*Prunus americana*) into the woods may be necessary as well. Since some destructive management practices may be necessary to achieve an approximation of the historic oak

gallery forest on Cub Creek, it must be remembered that these actions must be balanced against the needs of protecting the diversity and resources of the current community, while striving to increase biological diversity through a gradual process of modifying the community to a more heterogeneous condition than currently exists.

RESTORING HISTORIC CONDITIONS

Deer control

Perhaps the most immediate action that should be considered is to bring the whitetail deer density at the monument to a level more conducive to forest health. At present, deer browsing represents the greatest threat to protecting the biodiversity of the site, and any restoration efforts that increase the amount of food plants favored by deer will only serve to make the site more attractive and tend to increase the population further. The deer census for the monument did not suggest control of the white-tail deer population, and recommended studies to determine if the deer are having a negative impact on the monument's vegetation (Bolli 2004). Observations of the forest strongly suggest deer are impacting the vegetation structure of the forest, and studies to detect loss of biodiversity would help substantiate this impact. Nonetheless, the census indicates the current deer density is well in excess of the level at which forest biodiversity begins to be compromised (George 2007), and developing a strategy for creating a healthy level of browsing should be considered a priority. Increasing the density of shrubs and saplings of desired tree species through canopy thinning can allow a greater amount of the woody underlayer to escape browsing (Côté et al. 2004). Nonetheless, unless efforts are

undertaken to reduce or deter deer populations, an increase in preferred food plants is likely to be followed by an increase in deer population

Decreasing deer population at the site by removing deer is a cost-effective means of control in small areas. Redirecting sport hunting specifically to reduce deer number (e.g. extending hunting season, liberalizing bag limits and increasing hunter participation) is perhaps the most effective strategy, however if firearms cannot be used at the site, trapping and relocating deer may be a preferable option (Côté et al. 2004). However, a recent study in Missouri has shown that this practice has a mortality rate of about 70% within the first year after relocation due to capture shock and hunting (George 2007). Trapping and euthanizing deer may be a more humane alternative, particularly if the deer is subsequently processed and donated to a food pantry (provided it is killed by a method other than lethal injection) (George 2007). Deer immunocontraception has been heralded as an effective, non-lethal means of reducing populations, but is expensive, requires use of firearms and projectiles to administer; and while it may be effective in reducing fawning rates in a percentage of an existing population, no study has shown it effective in reducing a deer population (George 2007).

Deer deterrents may be used along with or in place of deer removal, but are generally more expensive and often less effective. Perhaps the most effective deterrent is the use of individual plastic tubing and wire fences around stands of seedling or sapling trees (Côté et al. 2004). The most effective fencing is an 8 foot high, woven wire, though it is considerably more expensive than electrical fencing. Recent advances in electric fencing (high tensile strength and high impedance chargers) have made them more resistant to damage from falling branches and voltage losses from vegetation coming in

contact with wire (Tilghman & Marquis 2007), although they are still not completely deer-proof. Chemical repellants may be effective for moderate deer densities, but their effectiveness is limited by time elapsed since application, attractiveness of the food plant, deer hunger, and rainfall (Côté et al. 2004). Reflectors and sound devices are generally ineffective over long periods unless they are triggered by motion sensors (Côté et al. 2004).

Although it may be possible to protect certain trees with the use of barriers such as plastic tubing, deer overpopulation will continue to impact the makeup of the shrub and herbaceous layers. Monitoring changes in shrub and sapling density and in the extent of the herbaceous graminoid understory can be useful for detecting the overall success of control efforts.

Alien species control

After deer, the most immediate threat to the current biodiversity of the forest community is the spread of non-indigenous species. Species with invasive tendencies have the greatest impact for displacing desirable native plants, and efforts to eradicate the most aggressive species should be an early priority of restoration efforts.

Among the species already present in the woods, white mulberry (*Morus alba*) and Japanese barberry (*Berberis thunbergii*) appear to have the greatest potential to spread into openings where native species are desired. Smooth brome (*Bromus inermis*) and reed canarygrass (*Phalaris arundinacea*) may also hinder efforts to re-establish native herbaceous vegetation along the woodland margins on the stream banks, respectively. Chemical control of smooth brome and reseeding with native grasses and

forbs may be an effective strategy for re-establishing native understory in the prairie-forest transition area, particularly if fall burns are to be carried out at some point. Removal of reed canarygrass should not be dismissed as unfeasible, and should be considered as part of stream bank stabilization efforts. Osage orange (*Maclura pomifera*), which was introduced on the site, should also be removed, with the exception of those in the historic hedgerow.

Another essential consideration of alien species control is monitoring not only the persistence and spread of non-indigenous species currently known to be present, but also early detection and control of invasive species not yet recorded on the site. Siberian elm (*Ulmus pumila*), European buckthorn (*Rhamnus cathartica*), multiflora rose (*Rosa multiflora*), dame's rocket (*Hesperis matronalis*), and garlic mustard (*Alliaria petiolata*) are all established nearby and surveys to detect the presence of these species should be carried out annually. Dame's rocket is already present on the monument and may be controlled by hand-pulling. Garlic mustard, which has been established in Beatrice since the early 1990's, represents a serious potential threat, and it should be pulled and monitored yearly if encountered in the woods.

Forest thinning

Thinning of existing trees (along with deer control) is a necessary step for increasing shrub and sapling density. Restoring the forest to the more open condition suggested by the 1860's reference condition will require thinning of canopy trees through much of the existing forest.

In addition to removing alien trees such as white mulberry (*Morus alba*), native trees that have increased in density due to fire suppression will also need to be thinned in order to create a canopy dominated by fire-resistant species. Hackberry (*Celtis occidentalis*) is the dominant tree in much of the forest, and should be considered the highest priority for removal among natives in order to achieve the suggested canopy cover values proposed for the reference condition. Removal of hackberry from the subcanopy could be considered a priority throughout the forest, and in some areas removal of most or all of the hackberries in the canopy will also be necessary, especially in the south portion of the woods. Another native species that ought to be considered a priority for removal is honey-locust (*Gleditsia triacanthos*). Historical data suggest it may have not been present at the site at the time of settlement, and its tendency to aggressively colonize open areas and its ability to resprout and spread by sucker shoots following fire suggests it could increase significantly following thinning and burning. Species known to have been present in the historic community, such as bur oak (*Quercus macrocarpa*), elms (*Ulmus americana* and *U. rubra*), black walnut (*Juglans nigra*), cottonwood (*Populus deltoides*) and box-elder (*Acer negundo*) should not be removed if possible. Other species that are not documented to have been present but which likely were during early settlement, such as silver maple (*Acer saccharinum*) and green ash (*Fraxinus pennsylvanica*), should be considered low priority for thinning.

Reintroducing fire

Following thinning, regeneration of the shrubs and saplings is likely to increase dramatically (unless deer densities experience similar increase). Reintroducing fire

following thinning will promote increased regeneration of desirable fire-tolerant species such as bur oak (*Quercus macrocarpa*), American elm (*Ulmus americana*), and black walnut (*Juglans nigra*). An early spring burn within the woods may be the most effective means of promoting regeneration of the desired species. Hopefully, after this initial burn, the amount of fine fuels will become abundant enough that fire will carry in the woods more easily than is currently possible. Following the initial spring burn, a fire interval of 3 to 5 years is recommended to encourage regeneration of these species and to control the spread of hackberry (*Celtis occidentalis*). Fall burns, following a hard freeze, are probably most effective for removing undesirable woody vegetation, and the most effective strategy for recreating historic conditions may be to allow fire to spread into the woods from a fall burn of the adjacent prairie. Both the north and south section of the woods should be burned in the spring at a two-year interval until the regeneration of the desired trees exceeds that of hackberries, and the fine fuels make a comeback. Following this, the 3-5 year fall burn interval should be initiated.

Reintroducing desirable species

Though fire will help encourage the growth of species desirable for achieving the reference condition, certain species may presently occur at such a low density that additional efforts may be necessary to increase their abundance to the levels suggested by the reference condition. Wild plum (*Prunus americana*), which is not currently recorded as occurring in the forest (Mlekush & DeBacker 2003), is one such species that should be transplanted along the forest margins from material taken from the adjacent tall-grass prairie. Transplanting wild plum and other shrubs is also suggested for restoring

vegetation on the stream banks, given such plantings are feasible as part of bank stabilization.

Other than wild plum, the major species of the historic woods are still present on the site, though many in very low densities. American elm (*Ulmus americana*) is currently uncommon, and it is possible that Dutch elm disease may hamper efforts to re-establish its presence as an abundant tree in the woods. In the south portion of the forest, efforts may need to be undertaken to increase the density of bur oak (*Quercus macrocarpa*), preferably from seedling stock taken from the monument. The suggested methodology for restoring the bur oak canopy to the south part of the site is included in the next section.

Finally some herbaceous species may need to be re-introduced into portions of the woods. Native grasses and forbs were probably a part of the shrubby transition zone, and can be allowed to spread from the adjacent prairie. Some seeding may be necessary to replace the existing band of smooth brome that occurs along the margin of the forest. Certain species that are demonstrably threatened by deer browsing may also warrant efforts to increase their abundance. At presence, those species are not known, though broad-leaved forest understory plants, and especially petaloid monocots, are known to be favored by white-tail deer (Rooney & Waller 2003).

ACHIEVABLE GOALS

Riparian zone

Since it seems highly unlikely that the hydrologic conditions that existed in the 1860's can ever be restored, it is unlikely an early successional woodland community can

be permanently sustained at the site. Without periodic flooding that creates bare spaces in the floodplain, cottonwoods (*Populus deltoides*) and willows (*Salix* spp.) are unlikely to regenerate naturally. The chances for native riparian vegetation to persist here might be increased if the woody canopy is opened sufficiently to allow light penetration along the banks and at the margin of the floodplain. Removing the hackberries (*Celtis occidentalis*) nearest the stream channel might help achieve this. Also, plantings of native woody vegetation should be considered for bank stabilization wherever possible. Cottonwoods and peach-leaf willow (*Salix amygdaloides*) would have been the most likely trees present on the banks, with coralberry (*Symphoricarpos orbiculatus*), gooseberry (*Ribes missouriense*), wild plum (*Prunus americana*) and perhaps elderberry (*Sambucus canadensis*) scattered among them. Increasing native vegetation on the banks would likely be the most beneficial outcome of restoration efforts in the riparian zone.

Oak woodland

Since oak dominated areas are present only in the north portion of the monument at present, different strategies are necessary for restoring the oak-gallery forest in the different sections of the woods. In the north portion, most of the efforts will focus on removing hackberries (*Celtis occidentalis*) and perhaps honey-locust (*Gleditsia triacanthos*) from the subcanopy throughout the existing oak patches, and removing some canopy trees along the margins to create more open conditions where this community borders the riparian and transition zones. Given that American elm (*Ulmus americana*) was likely part of the canopy and/or subcanopy, it appears that there may be some benefit to keeping some large hackberries and honey-locust in parts of the oak woods, since

restoring large American elms to this community might not be possible. Oak, elm and black walnut (*Juglans nigra*) regeneration should be encouraged, while hackberry regeneration should be controlled by fire. Openings along the margin of the oak woodland should ideally be occupied by shrubs and herbaceous species occurring in the shrubby transition zone. Thinning activities should be done in such a way as to minimally damage the existing understory, and recently cleared areas should be monitored for the spread of alien species.

The south portion of the Cub Creek woods will require more aggressive management to restore an oak-dominated woodland community, as bur oak is rare or absent from the canopy of the forest. Since large-scale canopy replacement has the potential to be destructive to native biodiversity, a gradual approach needs to be employed that alters the canopy composition over time, rather than an all-at-once solution such as a clear-cut. The shelterwood-burn method has recently been developed in the southeastern United States for use in mixed hardwood stands of oak and yellow poplar (Van Lear *et al*. 2000) and may be modified for use in the Cub Creek woods.

The shelterwood - burn technique starts by removing roughly half (40-60%) of the basal area of the overstory trees, which at this site would primarily be hackberries. These are selectively cut to leave the most vigorous understory oaks, preferably those with straight stems over 1.3 m tall and with no major competitors within 3 m. Directional felling of overstory trees should be employed to ensure that logging slash is kept away from the base of the oaks.

After the initial shelterwood cut, the area should be left to rest for 3-5 years, allowing the slash to settle and the remaining overstory trees to recover from the initial

shock of the first cutting. During this time, the regenerating seedling/sapling layer will be dominated by faster growing hackberries. If it is necessary to transplant bur oak into this area, this would best be done at the beginning of this period. At the end of this time, a relatively high-intensity controlled burn should be carried out in the spring to top-kill hackberry seedlings and saplings. Overstory damage is limited to trees with slash at their bases.

Following the burn, oak should begin to dominate the regeneration pool, with additional spring burns at two year intervals suggested if oak regeneration does not exceed that of hackberries following the initial burn. Once oak dominates the regeneration pool, the remaining hackberry shelterwood trees can be removed, and a fall burn cycle similar to that suggested for the north portion of the woods can be employed.

Shrubby transition zone

The areas of young mixed hardwoods at the margins of the forest will similarly require overstory cutting to achieve a canopy density of no more than 40%. Following thinning, it may be desirable to remove the smooth brome (*Bromus inermis*) and reseed the margins of the community with native grasses and forbs from the adjacent prairie. Wild plum (*Prunus americana*) might also need to be planted into the newly opened areas. Eventually, these areas should be fall-burned at a 3-5 year interval to control reproduction of hackberry and to encourage resprouting of wild plum and other shrubs. Deer control will be of particular concern as these ecotonal areas become more open.

SPECIFIC ACTIONS FOR ACHIEVING GOALS

Management objectives for achieving the goals of restoring the lowland bur oak forest on Cub Creek to a realistic approximation of the proposed reference condition include controlling deer population, eradication of alien species, thinning of undesirable woody vegetation, reintroduction of fire to control regeneration of these species, and introducing species back into the ecosystem where necessary. Goals and specific actions are listed below.

Deer control

- Develop and implement a plan to reduce white-tail deer population density at the monument to a level between 6 and 25 deer per square mile

- Monitor effectiveness of plan through deer census and/or monitoring of ground layer woody vegetation and understory graminoid cover.

Alien species eradication

- Cut and stump kill all individuals of white mulberry (*Morus alba*), Japanese barberry (*Berberis thunbergii*), and Osage orange (*Maclura pomifera*) that have escaped from the historic hedgerow.

- Eradicate smooth brome (*Bromus inermis*) and reed canarygrass (*Phalaris arundinacea*) in association with tree thinning and stream bank stabilization efforts, using chemical control if necessary.

- Reseed areas from which alien grasses are eliminated to native grasses and forbs.

- Monitor spread of these species and survey for presence of invasive species not currently recorded from the woods, especially Siberian elm (*Ulmus pumila*), European buckthorn (*Rhamnus cathartica*), multiflora rose (*Rosa multiflora*), dame's rocket (*Hesperis matronalis*) and garlic mustard (*Alliaria petiolata*).

Thinning undesirable trees

- Remove all hackberry (*Celtis occidentalis*) and honey-locust (*Gleditsia triacanthos*) from the subcanopy of the forest and the riparian zone

- Selectively remove hackberry and honey locust from the canopy of the oak woodland and transition zone as suggested by the following guidelines:

    - Thin canopy at margins of oak wooded areas to a cover of 40-67% if possible.
    - Thin canopy of non-oak dominated areas along periphery of woods to a canopy cover of <40%
    - Thin overstory layer of south portion of woods by a reduction in basal area of 40--60%, felling trees in such a way as to avoid the presence of slash near understory bur oaks (*Quercus macrocarpa*) and other desirable trees such as elms (*Ulmus* spp.) and walnuts (*Juglans nigra*).

Reintroducing fire

- Re-introduce fire into the ecosystem 3-5 years after initial thinning, utilizing a high-intensity spring burn to top kill seedlings and saplings of hackberry. If oak regeneration does not exceed hackberry regeneration in the south part of the woods, repeat spring burns there at two year intervals. Remove remaining hackberry/honey-locust canopy thereafter and initiate a fire regimen similar to that used for the north portion of the woods thereafter.

- Use fall burns (after first hard frost) every 3-5 years to regenerate shrubs and control the spread of undesirable woody vegetation. Allowing fire to spread into the woods from the adjacent prairie is preferable.

Reintroducing desirable species

- Transplant bur oak into the south portion of the woods if necessary following the initial thinning.

- Transplant wild plum into the openings in the forest margin following initial thinning.

- Transplant herbaceous understory plants impacted by deer browsing, if evidence from vegetation monitoring suggests certain species are in decline.

SUMMARY

Evidence from the current vegetation, historical accounts, and considerations of the changes to environmental conditions at Homestead National Monument of America suggests that at the time of European settlement in the 1860's, the lowland bur oak forest currently along Cub Creek was an oak gallery forest consisting of three contiguous and somewhat intergrading vegetative zones:

- An open riparian woodland with abundant shrubs that covered the banks of the stream and extended a short distance onto the floodplain of the stream.

- Patches of bur oak - American elm - black walnut dominated woodland that were relatively open along the outer edges and more densely shaded within, with an understory of tall-shrubs, grasses and forbs in the openings, and short shrubs and shade-tolerant plants in the interior.

- A shrubby transition zone dominated by wild plum and vines, fringing the wooded communities and varying in extent and composition in response to fire.

Restoring the woods to a reference condition resembling the historic communities will require reducing deer populations to healthy levels, removing alien species, thinning undesirable native trees (primarily hackberry), reintroducing fire into the ecosystem at a 3-5 year interval, and replanting bur oak and wild plum where necessary. Management

decisions should balance the desire to restore the biodiversity of the historic community against the needs of conserving the resources and species diversity of the existing forest.

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