BALCONES CANYONLANDS PRESERVE
LAND MANAGEMENT PLAN

TIER II A

CHAPTER III
OAK WILT MANAGEMENT

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1.0 BACKGROUND

1.1 Oak Wilt and Endangered Species

From an economic and aesthetic viewpoint, the effects of oak wilt in urban residential areas are devastating and cost millions of dollars in property devaluation. The effect of oak wilt on the region's ecological dynamics is more complex and difficult to assess. The oak wilt epidemic is likely to affect the endangered golden-cheeked warbler (GCWA), causing habitat degradation. In addition to habitat loss and fragmentation, loss of oaks due to oak wilt has been identified as a possible factor in reducing bird abundance and habitat suitability (Wahl et a1 1990). Oak wilt control treatments are aimed at stopping the spread of individual infection centers, thus protecting oaks from almost certain death due to oak wilt. Steep and rough areas, where suitable GCWA habitats exist, are often unsuited for oak wilt suppression activities. Since oak trees are sometimes removed during suppression of individual disease centers, slight, localized habitat degradation may occur. However, this is insignificant, compared to the beneficial effect of protecting adjacent oaks from disease spread and oak mortality.

All chemicals are EPA registered, applied by state licensed applicators, environmentally safe when properly applied, and used in smallest effective quantities. They are unlikely to affect the GCWA since the birds have no opportunity to contact them. Both silvicides and fungicides are applied only to lower bole sections of oak trees in either a frill girdle or a pressure injection treatment.

1.2 History of Oak Wilt

Oak wilt is a disease of the family Fagaceae, which includes all oaks (*Quercus spp.)* and related species in the family, with some species varying in resistance or vulnerability. It is caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt, which develops in the outer sapwood of trees in vessels or tissues that conduct water and nutrients from the roots to the leaves (Appel 2001a). Oak wilt is considered to be one of the most destructive tree diseases in the U.S. It occurs in 22 states, and within 65 Texas counties. Intensive survey, research, and management programs have been carried out since the original description of the pathogen from Wisconsin in 1942 (Henry et al 1944, Appel 1995). These previous efforts are useful in providing information on the comparative epidemiology of oak wilt in Texas and may assist in determining how oak wilt control might be best managed. The initial discovery of *C. fagacearum* in Texas was made in 1961 from diseased trees in Dallas (Dooling 1961) and was well beyond the accepted range of oak wilt (Hepting 1971). It had been thought that the oak wilt fungus could not survive in Texas because of high summer temperatures and the competitive presence of the oak canker fungus, *Hypoxylon atropunctatum.* These factors were formerly believed to limit the survival of *C. fagacearum* in the South (Gibbs and French

1980). *C. fagacearum* is inhibited or killed by temperatures exceeding 90°F (Houston et al 1965), but in Texas it can survive high summer temperatures in the roots and boles of infected trees (Lewis 1985, Appel 1995).

Due to various reasons such as misdiagnoses, late detection, disease biology, large stands of homogenous live oaks, virulent fungus, alternative methods of spread, etc., this lethal disease was – for decades allowed to spread uncontrolled throughout Austin and other areas of Central Texas. Many large areas of infection have grown beyond conventional suppression capabilities, and the only practical option now is to monitor the disease and wait for natural controls such as burn out (lack of remaining host trees), or natural and manmade breaks in the terrain (escarpments, creeks or major roadways).

In 1982 an oak wilt/decline demonstration project identified oak wilt in 35 counties, most of which lie within the Edwards Plateau, and the Cross Timbers and Prairies of central Texas (Appel et al 1984). In 2003, oak wilt had been confirmed in 65 counties with 6,000 oak wilt centers (Texas Forest Service 2004). Evidence of oak wilt disease on the BCP has been recorded on the Barton Creek, Emma Long, Reicher Ranch, JJ&T, Jester, and Cortaña tracts.

Currently, there is no cure for the disease, although there are several measures available to manage oak wilt. Injecting the fungicide propiconazole (Alamo™) into the xylem may sometimes slow its progression (Lewis and Brook 1985, Osterbauer and French 1992, Eggers et al 2005). According to Dr. David Appel, although propiconazole can be considered sufficient to recommend for oak wilt control in live oaks, there are several limitations to this use of injection for disease management. Propiconazole injections did not act as a barrier to inhibit transmission of the pathogen through root connections between treated and untreated trees; many treated trees clearly became infected. Furthermore, propiconazole injections in live oaks should be used in conjunction with other control techniques to ensure that all suitable means are used to manage the disease and reduce losses (Appel 1992).

1.3 Susceptibility

Of the approximately 64 North American oak species (*Quercus* spp.), 53 are native to Texas (Kartesz 2003). All are presumably susceptible to oak wilt fungus to some degree, but some species are more resistant than others. Red oaks, particularly Spanish oak (*Q. Buckleyi),* Shumard oak *(Q. shumardii),* blackjack oak *(Q. marilandica),* and water oak *(Q. nigra)* are extremely susceptible and play a unique role in establishment of new oak wilt infections. White oaks, including post oak *(Q. stellata),* bur oak *(Q. macrocarpa),* and chinkapin oak *(Q. muehlenbergii)* are resistant to the fungus and rarely die from oak wilt. Live oaks *(Q.*

virginiana and *Q. fusiformis)* are intermediate in susceptibility to oak wilt but are most seriously affected due to their tendency to grow from root sprouts and form vast interconnected root systems that allow movement (or spread) of the fungus between adjacent trees. Live oaks are native to approximately two- thirds of the state of Texas. Also susceptible is shin oak *(Q. sinuata* var. *breviloba)* .

Spanish oaks are severely affected by oak wilt in Texas and are known to support fungal mat formation, but comprise a relatively small component of the oak savannas where wilt is epidemic (Appel et al 1987). In terms of numbers of trees, more live oaks are lost to oak wilt than any of the other species. Live oaks are the primary hosts of *C. fagacearum* in Texas (Appel and Maggio 1984, Appel 2001a), the only state reported to have oak wilt in a natural live oak population.

1.4 Disease Transmission

Oak wilt can spread mainly in two ways; long distance transmission from the activities of insect vectors and local spread between adjacent trees through root grafts or common ·root systems. There is also the possibility of spreading by firewood, cut from oak wilt infected trees (Johnson 1994, Juzwick 2000, Appel et al 2003). The limitations of each of these methods of transmission may result in the failure of *C. fagacearum* to cause catastrophic losses (Gibbs and French 1980, MacDonald and Hindal 1981).

1.4.1 Above Ground (Inoculum Production and Insect Transmission)

Insects can transmit the oak wilt fungus. Sap-feeding nitidulid beetles (Order: Coleoptera, Family: Nitidulidae) have been shown to be vectors of the oak wilt fungus (Dorsey et al 1953, Norris 1953, Jewell 1956, Himelick and Fox 1958). In Texas, fungal mat formation is known to occur only on diseased Spanish oaks (*Q. buckleyi* Small) and blackjack oaks (*Q. marilandica* Muench); both are typical deciduous red oaks (Appel et al 1987). No fungal mats have been observed on infected live oaks. Mat formation on infected red oaks is influenced by season of infection, tree condition, temperature, and rainfall (Gibbs and French 1980, MacDonald and Hindal 1981). Mat production is usually greatest during the spring, when trees are most susceptible and nitidulids are most active, but they also form in the fall (Appel and Lewis 1985). Long distance transmission of *C. fagacearum* by insect vectors is extremely important because it initiates new centers of infection. In the late fall and early spring, oak wilt fungal mats and masses of oak wilt spores are produced beneath the bark of diseased red oaks. Individual fungal mats produce spores for only a few weeks. Fungal mats are most commonly formed on standing trees, but they can also be formed on logs, stumps, and fresh firewood cut from diseased red oaks (Juzwick 2000, Appel et al 2003). Moderate

temperatures and high sapwood moisture content are conducive for mat formation (Appel et al 1987).

Fungal mats bearing oak wilt spores can appear on red oaks several months after the trees die from disease. Even after their deaths, red oaks may still contain enough moisture in their trunks to support development of the reproductive parts of the fungus, called fungal or mycelial mats. These spore-producing fungal mats crack the tree bark. The mats have a fermenting, sweet odor and they are a suitable food source that attracts insects, especially the sap-feeding beetles of the family Nitidulidae. Oak wilt spores adhere to the insect's bodies as they feed. After feeding on the mats, contaminated nitidulids emerge and disperse. These beetles are also attracted to oozing plant sap that collects at the surface of a fresh cut from pruning or wound (broken limbs) on healthy trees. While feeding on these trees, the beetles deposit the spores from the fungal mats and new infection centers are formed. A wound is only susceptible to infection for the first few days after the cut or wound occurs. In this way infection can result by vector transport from infected red oaks to uninfected oak trees. Presumably, in this manner the fungus is transmitted to live oaks over long distances (Dorsey et al 1953, Juzwik and French 1983, Juzwick 2000).

Early diagnosis and proper disposal of diseased red oaks is therefore critical to limiting the number of new infection centers. Nitidulid beetles are present most of the year, but numbers are greatest and these insects are most active in the spring and early summer, which also coincide with periods of maximum fungal mat formation in Texas (Appel et al 1987, Juzwick 2000, Appel 2001a). Therefore, pruning and other kinds of wound-inducing practices in the spring should be avoided in areas where there is a potential for fungal mat formation to prevent long-distance fungus transmission.

1.4.2 Underground (Root Transmission)

Studies have indicated that fungal mats do not form on white oaks. Important to the Texas oak wilt epidemic is the fact that fungal mats also do not form on infected live oaks. Pathogen spread among live oaks is believed to be limited to transmission between diseased and healthy trees through root grafts and common root systems. Root sprouting and root grafting are characteristic for live oaks. The local transmission of *C. fagacearum* through functional root connections is probably responsible for most oak wilt losses of live oak in Texas (Appel 1986, Appel 2001b).

Root graft transmission: Connections may form when the roots of two adjacent trees grow together and produce a union of xylem tissues. Disease centers in Texas on live oak can

involve thousands of trees and encompass dozens of hectares. Stand density and soil depth has been shown to influence tree-to-tree spread of the pathogen through root grafts (MacDonald and Hindal 1981).

Common root system spread: Several live oaks are capable of sharing one common root system. When one live oak becomes infected, all live oaks sharing the same root system have the potential for contracting oak wilt. This contributes to the rapid rate of disease spread and the large size of disease centers among the live oaks. Live oaks form rhizomes for vegetative propagation through root sprouting (Muller 1951). If the sprouts maintain common root connections through maturity, they will provide an additional mechanism for transmission of oak wilt. As in other states, the pathogen in Texas is consistently transmitted through adjacent live oaks in a highly predictable manner forming discrete, well-delineated centers (Appel et al 1989). The potential size of cloned live oak stands is unknown.

Tree-to-tree spread in central Texas may progress up to 100 feet per year and can result in very large centers of disease, up to 100-200 acres. The fungus continues to spread outward from the originally infected tree, involving more and more trees. Diseased stands are often large, discrete, and comprised of hundreds of trees in various stages of disease development. Such a group of dead and dying trees is called an infection (oak wilt) center. Spread through root connection can be prevented by mechanically trenching around infected trees, thus physically separating the trees.

1.4.3 Firewood (Transmission of Oak Wilt by Logs)

Firewood cut from diseased Spanish, Shumard, blackjack and water oak can be a means of spreading the oak wilt fungus to new areas (Johnson and Appel 1994). The wood could contain fungal mats and/or insects carrying the spores of the oak wilt fungus. Fungal mats may already be formed on trees at the time of cutting or may form during winter while logs are stored in the woodpile.

Sap-feeding beetles contaminated with the oak wilt fungus may also be moved with firewood, including live oak logs as well as red oaks (Johnson and Appel 1994). The beetle would have to have fed on a mat and then migrated to a live oak or to a tree that was cut for the firewood. During the times the logs are stacked in the wood pile, the beetles may move out of the logs and enter nearby healthy trees that have been wounded or pruned (Johnson and Appel 1994). Fungal mats are not found on firewood from oak wilt diseased live oak, but nonetheless, special care should be taken with all oak firewood.

In general, as precautions, red oak firewood should be avoided as much as possible. On the firewood cut from infected red oaks that die in late summer, fall and during the current winter, fungal mats can be formed and there is a potential of spreading the fungus that way. On red oak trees that die in late spring and early summer fungus does not form fungal mats because of high summer temperatures and wood will be too dry to support mat formation. When the moisture percentage is below 14% in the wood it is no longer capable of supporting the growth of the wilt fungus (Johnson 1994). Although fungal mats are not formed on diseased live oak trees, it is suggested that the same precautions be followed to avoid any chance of spreading the fungus. Smoke from burning diseased logs does not spread the fungus to nearby trees. Heat from the fire kills all spores or beetles that might be present.

1.5 Symptoms of Oak Wilt Disease

On live oaks, foliar symptoms of the disease are distinctive when present and can be identified by distinctive yellowing or browning along the veins of the leaf (chlorosis or necrosis) or dead tissue at tip of the leaf. The most reliable, diagnostic foliar symptoms of oak wilt on live oaks are veinal necrosis, interveinal chlorosis and tipburn (Appel and Maggio 1984, Appel et al 2003). Symptom development is the most rapid during spring and fall (Billings and Cameron 1987). Oak wilt in live oaks may also be recognized by patterns of spread in groups of trees and rates of crown deterioration (Gehring 1996). The oak wilt pathogen spreads rapidly from diseased trees to adjacent, healthy trees through root connections forming distinct centers of infection. Once live oaks are infected, most gradually drop leaves and die over a period of two months to two years. Some live oaks survive for many years in various states of decline. Other fungi such as *Hypoxylon* spp. and *Cephalosporium* spp. may colonize weakened trees (Johnson and Appel 1984). In rare cases, some do recover from the disease (Appel et al 1989). It is estimated that 10% of the live oaks infected survive the oak wilt because their roots are not connected or because they have some natural resistance (Appel et al 1986).

On red oaks, symptoms are less distinct and harder to recognize. The first foliar symptoms observed on red oaks (Spanish and blackjack oaks) are flagging. Flagging or browning occurs when the leaves on a shoot or branch suddenly turn brown or bronze colored. Typical foliar oak wilt symptoms in deciduous oaks include water soaking and browning or bronzing of leaf tips and margins (MacDonald and Hindal 1981). Leaves turn pale green and then brown, while remaining on the tree for a while. Sometimes the leaves have a wilted, water-soaked appearance and may be quickly shed. For most members of the red oak group, nearly the entire crown shows symptoms soon after the disease is evident. Once infected with oak wilt, red oaks die quickly, two weeks to several months. Red oaks do not survive once infected

with oak wilt. Diagnosis of oak wilt in the field depends on the presence of the foliar symptoms and fungal mats, and the patterns of mortality caused by fungal spread. Visible symptoms of oak wilt are not always present. Laboratory tests may be performed on the sapwood of both live and red oaks to determine the presence of the fungus. *C. fagacearum* sometimes can not be isolated by laboratory testing, nor recognized by foliar symptoms. In some cases patterns of mortality are used as an indicator of disease presence.

2.0 PREVENTION AND SUPPRESSION

Currently, there is no cure for oak wilt. The only measures against this disease are prevention and suppression. Several accepted techniques are discussed below. Other methods of oak wilt suppression are currently being tested in the field, and may prove to be useful. Preserve managers should share information about techniques and stay abreast with current literature and strategies which may prove to be economical, environmentally friendly, and applicable on a large scale.

2.1 Oak Wilt Prevention Policy on BCP

2.1.1 Public Education on Oak Wilt

Continual education of the public and staff is needed. The public must have an awareness of oak wilt and understand that treatment and prevention are a long-term project. Oak wilt can not be suppressed quickly and all at once. BCP staff needs to keep updated on new information, research and work together to share their experiences with other agencies on oak wilt management and suppression. There is a special need to work closely with non-BCP staff that clears road and utility easements on BCP lands and fence lines.

2.1.2 Proper Pruning in the Right Time of Year

In the spring a combination of spore mat production, insect activity and pruning makes for a deadly combination. Oak trees are not pruned in the BCP during the fall or spring, when fungal mats are forming and nitidulid beetles are most active. The best time to trim oaks to avoid contracting oak wilt is during the hottest months of the summer (July through September) and again in the coldest months of the winter (November through January). During these periods, the insects that can transport the oak wilt spores are the least active.

2.1.3 Wound Painting

All pruning cuts or other wounds to oak trees including freshly-cut stumps and damaged surface roots, should be immediately treated during all times of the year with an approved tree wound dressing/sealer (Appel et al 2003). Beetles are attracted to plant sap that collects at the surface of a fresh cut or wound of a healthy tree. A coat of tree wound paint makes fresh

wounds unattractive to the beetles, which come to feed on the sap. The paint also acts as a barrier, which stops any fungal spores, carried by insects from entering the wound. After 48 hours (four to five days according to some researchers), painting is not effective because the wounds are no longer attractive to the insects. Therefore painting old wounds is not beneficial.

2.1.4 Tool Sterilization

When pruning or cutting live oaks or Spanish oaks, it is recommended that tools be sterilized with either Lysol aerosol disinfectant or a 10% bleach solution after/upon leaving the immediate area. Although never scientifically explored, surface sterilization of pruning tools is highly recommended when moving from one Spanish oak to another Spanish oak and from live oaks sharing one common root system to a new group of live oaks sharing another common root system.

2.1.5 Firewood

Infected oak wood, both Spanish and live oaks, should *not* be used as firewood. The wood could contain fungal mats and/or insects carrying the spores of the oak wilt fungus. The public is encouraged and warned to store any purchased firewood under clear plastic and bury the edges. Clear plastic traps the insects, and unlike the use of black plastic, the insects cannot use light holes to escape. The public is warned to use firewood from trees other than red oaks and to burn only dry, seasoned wood. Always burn firewood in the season it is purchased

2.1.6 Planting Resistant Species and Diversity of Species

Species composition of forests probably has a strong influence on oak wilt incidence (MacDonald and Hindal 1981). The disease is prevalent in Texas where species diversity is low, as in the homogenous live oak stands in central Texas (Appel 1986). White oaks such as bur oak, chinquapin oak, and post oak are more resistant to disease and can be planted in areas affected by oak wilt. Cedar elm, American elm, Texas ash, pecan, bald cypress, escarpment black cherry and Texas mulberry are suggested trees that can be planted in most areas where oak wilt is a problem. This will reduce the chance of reoccurrence of oak wilt or similar disease problem. In oak wilt centers, recent transplants of live oak, Spanish oak, Shumard oak or blackjack oak are slow to establish root grafts with the diseased residual root systems and may be planted if precautions are taken to avoid wounds during planting.

The long-term fate of live oaks and red oaks that are replanted in oak wilt infection centers is still uncertain. Further research and observation will determine if these susceptible oak species can become infected over time through root grafts with the residual diseased root systems.

2.2 Common Suppression Practices on BCP

2.2.1 Host Elimination: Red Oak Removal

Infected red oaks are treated by several methods that stop development of fungal mats on those trees and reduce possibility of disease spread by insects (long distance disease transmission). Methods of suppression treatment on infected red oaks include removal or felling infected trees and chipping or burning or burying them immediately. When felling a tree, it should be bucked/cut into ~ 12-16 inches in length. It is recommended that large logs from the trunk of larger trees (logs with a DBH of >8 inches) be stripped of their bark, or semi-girdled, in an attempt to reinforce the drying process. All stumps of felled trees are to be girdled to the soil or rock. Other methods include deep girdling and lower bark removal or applying herbicides. An approved silvicide (including but not limited to Garlon 3A™, Roundup™, Tordon 1O1™, and Tordon RTU™) can be applied according to label instructions. The preferred method of applying silvicide is to inject the chemical in the base of all diseased red oaks displaying symptoms using the axe frill method (Texas Forest Service 1991). All silvicides (herbicides) are used only if there is no other way of removing diseased red oaks. They should be used by certified pesticide applicators on staff. All chemicals applied during project activities are EPA registered, are environmentally safe when properly applied, and should be used in small quantities. Any treatment that hastens the drying of the wood tissue under certain moisture content will tend to reduce sporulation. Even though Texas red oaks die quickly from oak wilt, the trees still have enough moisture in the roots and trunk for fungal mat production. Therefore it is very important to destroy diseased red oaks as soon as the symptoms are recognized. If done during the early stages of the disease, spores will not be produced.

2.2.2 Root Separation: Trenching

Trenching continues to be the preferred primary control method to reduce root transmission of the oak wilt fungus. Trenching is not always totally effective, but the technical guidelines are continually being modified to increase the success rate. One of the major changes has been increasing the distance and depth of a trench. Other changes involve the use of existing barriers, more back-up and secondary trenches, and the elimination of silvicide barriers (Gehring 1992). Silvicide barriers were used in the early phase of the oak wilt suppression. The intended purpose of silvicide was to kill the root system, but tests show this does not stop fungal spread, and also, silvicide was causing mortality of adjacent healthy trees. Silvicides are no longer recommended for suppression, except to hasten the death and drying out of red oaks that cannot be removed and destroyed in a timely manner. Proper placement of the trench is critical for successful protection of uninfected trees. There is a delay between

colonization of the root system by the fungus and appearance of symptoms in the crown; therefore, all trees with symptoms are carefully identified. The trenches are placed a minimum of 100 feet beyond these symptomatic trees, even though there may be healthy trees at high risk of infection inside the trench (Appel 1995, Juzwick 2000, Appel 2001a, Appel et al 2003). Recommended depth is four to five feet, in order to prevent further underground spread of oak wilt. This method of control has proven to be 70% effective statewide. In addition, water-permeable inserts can be place in the trench, which have been shown to extend trench longevity (Wilson and Lester 2002). Oak wilt infection centers are more easily suppressed when treated early, before they become too large.

2.2.3 Intravascular Injection with Propiconazole in Live Oak

The fungicide propiconazole (Alamo™) is injected into the tree's water-conducting system through small holes drilled into the root flares at the base of the newly infected trees while crown loss is still minimal. Uninfected, healthy live oaks at risk to infection by root connections are the best candidates for treatment. These preventative treatments will yield better results than therapeutic injection of infected trees in the early stages of disease (Appel 1996, Appel 2001b, Eggers et al 2005). These practices are usually done on high value live oaks (oaks impacting real estate property values), usually in combination with trenching. In some instances re-treatment with the fungicide is needed 12-24 months after the first fungicide injection.

Although this is not considered as a true suppression technique because it does not suppress the spread, it does help reduce the impact of oak wilt in the long term. Fungicide can be used to save individual trees, but it does not kill the fungus in the roots, and therefore, does not keep the disease from spreading from tree to tree. This treatment, therefore, is used best in conjunction with trenching or to protect individual high-value trees. Foliar symptoms can be used in selecting trees as candidates for preventative or therapeutic treatments.

Treatment success depends on the health condition of the candidate tree, application rate, and injection technique. Injection should be done only by trained applicators. Treatment is successful if started in early stage of infection when 80% of crown canopy is still alive.

3.0 Monitoring

All suspected oak wilt should be reported to a forester with field experience in diagnosis. A knowledgeable forester should monitor BCP tracts at least once annually during times when diseased red oaks may be flaring, *i.e.* turning red or brown inappropriately. Areas treated for previously diagnosed oak wilt should be monitored each following year for signs of additional

outbreaks of the disease. The Texas Forest Service Oak Wilt Coordinator in Austin is available to advise agencies with oak wilt problems.

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APPENDIX

GUIDELINES FOR THE PROPER HANDLING OF FIREWOOD TO PREVENT THE SPREAD OF OAK WILT DISEASE

1. If possible, find out exactly where the wood is from to ensure that it has not come from an area infected with oak wilt.
2. Make every effort to collect or obtain only wood that is properly seasoned (dead/dry). Ensure this by looking for cracks developing on the cut ends and loose bark.
3. Do not harvest red oak varieties (Spanish Oak or Blackjack Oak) for firewood which may contain infectious oak wilt spores.
4. Never stack firewood from trees known or suspected of being infected with the oak wilt fungus near healthy trees. As an added precaution, cover the wood with *clear* plastic with the ends properly tucked and sealed. Do not use black plastic.
5. Firewood from unknown origins should be burned during the winter months and do not carry it over to the next season.
6. If you are planning to harvest firewood, attempt to cut it in the summer and let it dry in full sun on site before transporting it to urban areas.