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Elms of the Monumental Core

History and Management Plan

Natural Resource Report NPS/NCR/NRR--2009/001

ON THE COVER
American elms, *Ulmus americana*, on the National Mall.

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EXECUTIVE SUMMARY

Like many communities throughout the United States, Washington, D.C., relied on the majestic American elm to grace its residential streets and public spaces. The introduction of Dutch elm disease in the 1930s radically changed the character of these communities and this beautiful urban-resilient species became an anathema to the urban forest. Despite the devastation elsewhere, the American elm is still the unifying backbone of the federal parklands of our nation's capital Monumental Core. The species' graceful, monumental presence is ideally suited to the monuments, boulevards, and parks of our Capital. While Dutch elm disease has been present in the population for over 60 years, the National Park Service continues to successfully manage the disease and sustain the health of its elm population. Success has been founded on a clear appreciation of the singular importance of the American elm in this monumental landscape and the National Park Service's dedication to sustain its future. This *History and Management Plan* outlines the history of the American elm in the Monumental Core, reviews previous management efforts, and describes a management strategy that will ensure its future success.

HISTORY

Introduction

The American elm has played a long and distinguished role in the American urban forest. Prior to 1930 it was estimated that there were 77 million elms in just the incorporated jurisdictions of the United States (USDA Forest Service 1977). The species success was propelled by its unsurpassed form and beauty, its abundance in the wild, its ease of transplant, its rapid growth, and its compatibility with man's contrived and often harsh urban landscapes. America's obsession with this arboreal icon is wonderfully related in "Republic of Shade *New England and the American Elm*" by Thomas J. Campanella which describes the role the elm played for over a century in defining the cultural landscape of New England (Campanella 2003).

Washington, D.C., was among many municipalities favoring the American elm as a street tree. In the early 1870s Alexander Robey "Boss" Shepherd, the second and last Governor of the District of Columbia who dominated the city's Board of Public Works, initiated a three-year public works program to build a new infrastructure for the city (Evers 2007). In addition to roads, sidewalks and sewers the initiative included the planting of over 60,000 trees many of which were elm. As Washington's urban forest continued to expand and grow it earned the title "The City of Trees" or the "City Within a Park." In 1889, Harpers Magazine stated

> *"The city of Washington, the capital of the nation, exceeds in beauty any city in the world. The grand conception of the plan of its broad streets and avenues paved with asphalt, smooth as marble, and its hundreds of palatial residences erected in the highest style of art, but above all, its magnificent trees, make it without peer."* (Henderson 1889).

With its maturing elms Washington developed the classic appearance of a New England village with interlacing branches arching over many of the city's streets (Figure 1).

Figure 1. Early scene of American elms lining East Capitol Street, Washington, D.C.

Elms of the Monumental Core

L'Enfant and McMillan Plans

The federal government has wisely used the elm to help fulfill and sustain the vision of L'Enfant and later the McMillan Commission's plan for the National Mall and the entire Monumental Core. The elm has been the unifying element linking the parks, avenues, and memorials of the Federal City's parkland. The National Mall, the "Grand Avenue" envisioned by Pierre L'Enfant in 1791, was the centerpiece of this landscape, and was designed to link the Capitol with a memorial to George Washington.[1] This grand avenue now extends from the Capitol to the Lincoln Memorial and intersects at the Washington Monument with a north-south axis connecting the White House and the Jefferson Memorial (Figure 2).

[1] George J. Olszewski, *History of the Mall, Washington, D.C.* (U.S. DOI, NPS, Eastern Service Center, Office of History and Historic Architecture, Washington, D.C., 1970) p.3.

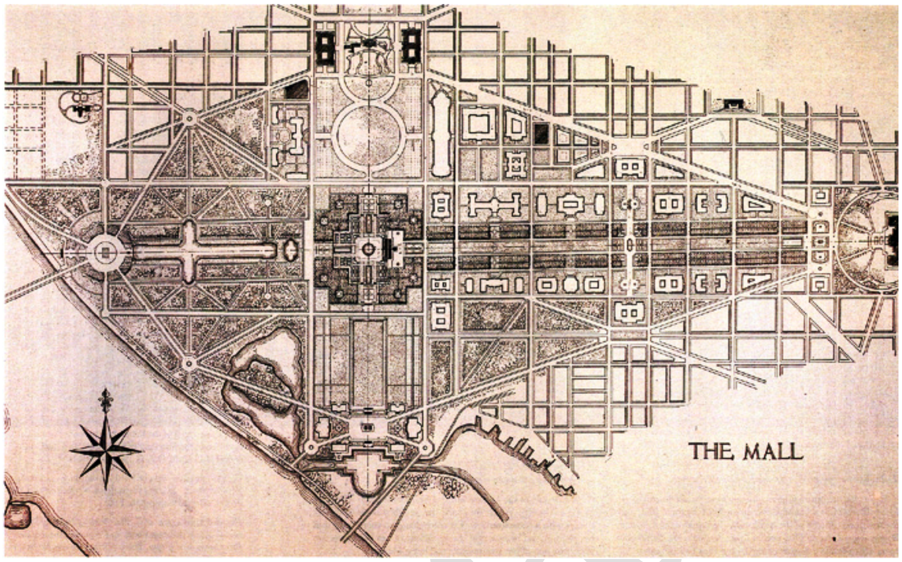

Figure 2. The McMillan Plan.

L'Enfant's plan experienced a long evolution before finally being molded into the grand avenue he and Washington envisioned. Construction of the Smithsonian began in 1848, as did that of the Washington Monument. In the 1850s the Botanic Garden at the foot of the Capitol was planted and an informal naturalistic landscape designed by Andrew Jackson Downing was installed around the Smithsonian and intruded on L'Enfant's grand avenue vista.[2] During the Civil War the Mall was used to billet troops and served as a stockyard for horses and cattle. In the 1870s a railroad line was built through the Mall at 6th street. And, during the First World War, a heating plant was built in the center of the Mall to service temporary buildings built on the Mall for the war effort. These and other features obscured L'Enfant's grand avenue and it was not until 1902, 110 years later, that his vision was resurrected and began to be fulfilled.

In 1900, the American Institute of Architects acknowledged Washington's Centennial Celebration as Capital of the United States by sponsoring a series of papers that inspired the Senate Committee on the District of Columbia to form a sub-committee to develop a plan to develop the city's park system. The sub-committee became the McMillan Commission named for Senator James B. McMillan, who chaired the committee until his death in 1902. The Commission, with the advice of the American Institute of Architects, invited Daniel H. Burnham, a prominent Chicago architect and Frederick Law Olmsted, Jr., the famous Massachusetts landscape architect, to lead the effort. They agreed to invite the New York architect Charles F. McKim and the famous New York sculptor Augustus Saint-Gaudens to join them. The group became known as the Senate Park Commission or Burnham Commission. Their report was completed and presented by McMillan to Congress as the McMillan Plan of 1902 for the "improvement of the Park System of the District of Columbia." While the Plan dealt with Washington's entire park system, fulfilling L'Enfant's plan for a grand avenue, the Mall, was a principal focus. The

[2] Olszewski, *History of the Mall, Washington, D.C.*, pp. 20-22.

Commission examined many landscapes, including the old estates of Virginia which had inspired Washington and Jefferson. The Commission considered these estates to be "the very source of the original inspiration." [3] They also toured landscapes in the great cities of Europe to gather inspiration for their plan.[4] After their tours and careful consideration of L'Enfant's plan for the grand avenue, they conceived an open vista created by a greensward connecting the Capitol to the Washington Monument. The Commission had several significant issues to resolve before the plan could be implemented. The length of the Mall from the Capitol to the Washington Monument is approximately one mile. Given this predetermined length what would be the appropriate proportional width of the greensward and how should it be framed? By placing flagpoles at selected widths along the length of the Mall they determined that 300 feet was the essential width for the open vista. Based on their experience in Europe, they decided that nothing less than four rows of trees on either side would be effective (Figure. 3).

Figure 3. American elms in four rows flank the National Mall, 1949.

In order to ensure the proper spacing of the trees they measured hundreds of elms and determined that they should be planted fifty feet apart.[5]
Their selection of the American elm was based on its success and prominence in Washington.

> *The American elm was chosen not only because of the architectural character of its columnar trunk and the delicate traceries formed by its widespreading branches, but also because in the District of Columbia this tree is at its best, notable examples being found in the city parks and in the grounds of the Capitol.*[6]

[3] Charles Moore, *Daniel H. Burnham* 2 vols. (Boston: Houghton Mifflin Co, 1921), p. 222.
[4] Moore, *Daniel H. Burnham, pp.* 222-223.
[5] More, *Daniel H. Burnham*, p. 224.
[6] Charles Moore ed., *The Improvement of the Park System of the District of Columbia* (Washington: Government Printing Office, 1902), p. 45.

The Senate Park Commission's passion for the elm is reflected in their coat-of-arms which depicts the Washington Monument on a shield surrounded by elms.[7]

Although McMillan presented the plan in 1902, it was another 30 years before significant development began. In the intervening years gradual clearing of the area occurred. The Andrew Jackson Downing landscapes were removed to clear the vista, temporary buildings and the heating plant were removed, and the length of the Mall was expanded to the Lincoln Memorial, which was built in 1922.

In 1933 the Works Progress Administration grant "Public Works Mall Development Project" provided funding for the NPS to begin rehabilitation of the site. Thirty-seven and one half acres of grass were planted and the initial 333 American elms were planted (Figure 4). The elms were supplied by Leissler Nurseries in Connecticut and planted between June and August of 1935.[8]

Figure 4. American elms newly planted between 12th ands 14th Streets on the National Mall, summer 1935. Possible Civilian Conservation Corps encampment in the center. (from MRCE; CLP file "Gov buildings and Mall 1935")

[7] More, *Daniel H. Burnham*, p. 167.
[8] Cultural Landscape Inventory: *The Mall National Mall & Memorial Parks.* National Capital Region, National Park Service, U.S. Department of the Interior. 2006, p. 63.

At the time of planting, park horticulturists predicted that the elm grove would be unsurpassed in the entire world for beauty and excellence (Figure 5).[9] The remainder of the current 600 elms was planted later as temporary buildings were removed.

Figure 5. The National Mall looking west towards the Washington Monument.

In addition to the Mall's formal planting between 3rd and 14th streets, there are over 2000 additional elms planted throughout the 1100 acres of the Monumental Core. Other major elm plantings include the Ellipse, where 214 American elms are planted in two concentric circles, the grounds of the Lincoln and Jefferson Memorials, West Potomac Park, Independence Avenue, and other streets within the Monumental Core.

In 1915 and 1916 the two walks flanking the Reflecting Pool between the Lincoln Memorial and the site of the new World War II Memorial were planted with 396 "English elms," *Ulmus campestris* on 25-foot centers.[10] Frederick Law Olmsted, Jr. believed this tree to be ideally suited to flank the Reflecting Pool stating that "its habits being exactly right for the purpose, and its foliage harmonizing with that of the American elm which is designed for use around the Washington Monument and to the eastward." [11] Five hundred trees were purchased from Dicksons Nursery in Chester, England. These trees were believed to be grafted on root stock of Scotch elm, or *Ulmus montana*

[9] Department of the Interior, *Memorandum for the Press*, Oct. 4, 1936, p. 3.
[10] Cultural Landscape Report: *West Potomac Park Lincoln Memorial Grounds*. National Capital Parks Central. Prepared by the Denver Service Center for National Capital Region, National Park Service, U.S. Department of the Interior, 1999, p. 21.
[11] Frederick Law Olmsted, Jr. to Commission of Fine Arts members, May 26, 1915, Section E-4, Part I, Series B, Olmsted Associates; and Commission of Fine Arts Minutes, May 20 1915 and July 19, 1915.

latifolia.[12,13] The exact identity, however, is still unknown. In the 1980s Horace Wester tentatively identified the tree as *U.* x *hollandica* 'Dauvessei.' (H.V. Wester, personal communication). Of the original 396 elms flanking the Reflecting Pool, approximately 35 remain. [14] An additional 104 European trees were planted south of the walkway trees.[15] None of these remain today.

Since the original species has not been commercially available, theses trees have been replaced with at least five other commercially available *Ulmus* hybrids (Table1). The number and locations of these replacements have not been recorded. An effort is being made to vegetatively propagate the original selection at the NPS nursery at Daingerfield. With the exception of the Reflecting Pool elms, the majority of the elms throughout the Monumental Core are *Ulmus americana*. There are, however, representative plantings of other elm species and a collection of cultivars. These were planted over many years to assess their form and performance. Unfortunately, the quantity, specific location and condition of these trees have not been recorded. (Table 1)

[12] Cultural Landscape Report: West Potomac Park Lincoln Memorial Grounds. National Capital Parks Central. Prepared by the Denver Service Center for National Capital Region, National Park Service, U.S. Department of the Interior, 1999, p. 22.
[13] Frederick Law Olmsted, Jr. to Hans J. Koehler, July 27, 1915; and Col. William H. Hart, to Olmsted Brothers, September 11, 1915, both in section C-6, Part I, #2843, Series B, Olmsted Associates. See also Hans J. Koehler to H.S. Wagner, October 26, 1939, Section C-6, part I, #2843, Series B, Olmsted Associates stating that Dicksons nursery probably sent a form of, or root stock, Scotch elm, or *Ulmus montana latifolia*.
[14] James L. Sherald. Field Notes. March 21, 2008.
[15] Cultural Landscape Report: West Potomac Park Lincoln Memorial Grounds. National Capital Parks Central. Prepared by the Denver Service Center for National Capital Region, National Park Service, U.S. Department of the Interior, 1999, p. 22.

Table 1. Elm species and cultivars planted in the Monumental Core[a]

Elm Species	Cultivars	Locations
American elm *Ulmus americana L.*		Mall, West Potomac Park, White House, Independence Avenue
	Augustine Ascending	Mall, White House, Lincoln Memorial
	Dedfree	West Potomac Park, Mall
	Delaware II	West Potomac Park, Mall, Independence Av.
	Jefferson (NPS 3-487)	Mall, West Potomac Park - FDR Memorial, Hains Point
	Liberty Elm Series	Jefferson Memorial, West Potomac Park
	Princeton	Mall, Pennsylvania Av. - in front of White House
	Washington (NPS 3-178)	Jefferson Memorial, Arlington House, Mall, West Potomac Park
Chinese elm *U. parvifolia* Jacq.		NPS National Capital Region, Hqts.
Dutch elm *U.* x *hollandica* Mill. (*U. carpinifolia* x *U. glabra*)	Belgica	Location Unknown
	Blandford	Location Unknown
	Buisman	East Potomac Park Golf Course
	Commelin	Lincoln Reflecting Pool
	Dauvessei	Lincoln Reflecting Pool – Putative original tree (Wester pers. communication)
	Groeneveld	Lincoln Reflecting Pool
	Vegeta	Lincoln Reflecting Pool, Constitution Gardens
	NPS – 443 (Wester selection)	East Potomac Park, Ohio Dr. by Metro Bridge
	NPS – 1409 (Wester selection)	Location Unknown

English elm *U. procera* Salisb.		Lafayette Park (removed)
Japanese elm *U. japonica* (Rehd.) *U. davidiana* var. *japonica* (Rehd.) Nakai		NW Corner 21st St. & C St. NW (State Dept.)
Scotch or Wych elm *U. glabra* Huds.		Locations Unknown
	Camperdown	White House, Thomas Circle
September elm *U. serotina*		Capitol Reflecting Pool (removed)
Siberian elm *U. pumila* L.	'arborea' Litv.	Locations Unknown
Smooth-leaved elm *U. carpinifolia* Gleditsch		West Potomac Park
	Bea Schwarz	Location Unknown
	Superosa	Location Unknown
Hybrid elm *U. japonica* x *U. wilsoniana*		Jefferson Memorial, Ellipse, White House
Hybrid elm *U. pumila x U. japonica*	Sapporo Autumn Gold	14th St. between Madison and Constitution Av. West side.
Hybrid elm (*U. x hollandica "Vegeta"* x *U. carpinifolia)* x *U. pumila*	Urban elm	West Potomac Park, Lincoln Reflecting Pool
Hybrid elm *U. pumila × ('Commelin' × [U. pumila × U. minor 'Hoersholmiensis'])*	Homestead	Lincoln Reflecting Pool

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[a] Species and cultivars are derived from various records which do not always give quantities and locations. Some trees may no longer be standing.

Memorial Elms

Over the years certain elms have attained individual prominence. The Adams Elm was planted by John Quincy Adams on the Jefferson Mound on the southeast grounds of the White House in March 1826 (Sidey 1982) (Figure 6).

Figure 6. The John Quincy Adams Elm, White House Grounds, 1965.

The tree was 165 years old when it was removed in 1991 because of structural concerns. The Adams Elm was replaced by First Lady Barbara Bush in December 1991 with a sapling derived from a rooted cutting of the original tree. In 1975 First Lady Betty Ford planted an elm on the northwest grounds along the North Portico Drive and President Bill Clinton and First Lady Hillary Clinton planted an elm in 1993 on the South Grounds near the tennis court. In 2006 President George W. Bush and First Lady Barbara Bush planted three elms on the northwest grounds of the White House. Two were the DED resistant American elm cultivar 'Jefferson' and one was a native American elm. These trees replaced three missing elms, two lost to storms and one to DED, lining the circular drive to the North Portico. Elms flanking the north side of the White House are depicted on the back of the twenty dollar bill.

Numerous commemorative elms have been planted throughout the parks, primarily at the Lincoln Memorial and in West Potomac Park.[16] In 1921, in honor of the signing of the World War I Armistice, two American elms, the "Armistice Elms," were planted by American Forests at the Lincoln Memorial at the head of International Avenue, Constitution Avenue and 23rd Street. Other elms were planted in honor of Clara Barton, Abraham Lincoln, and Generals - Grant, Sherman, Sheridan, and McClellan. In 1923 the Massachusetts Society of the District of Columbia planted 40 elms on the grounds of the Lincoln Memorial in honor of the mayors of prominent Massachusetts cities. The exact locations of many of the memorial elms have been lost and it is not know if any survive. In commemoration of the bicentennial of George Washington's birth in 1932, elms derived from the Washington Elm in Cambridge, Massachusetts, were planted throughout the United States. The Washington Elm is the tree under which it was long held that George Washington accepted command of the Continental Army on July 3, 1775 (Campanella 2003). Several of these were planted on the George Washington Memorial Parkway by Riverside Park and a few in Washington, D.C. One still stands on the grounds of the Daughters of the American Revolution Museum and Constitution Hall on D street, Northwest. Interestingly, however, it was suspected that these trees were actually English elms (Wissman 1945).

Ecological and Monetary Value

In 2004 the USDA Forest Service's Urban Forest Effects (UFORE) model was used to determine the ecological monetary values of Washington's urban forest (Nowak et al. 2006). To gather data for the model, 201 plots were sampled throughout the city. The analysis showed that Washington's urban forest played a major role in the removal of pollutants and in carbon storage and was a valuable structural component of the city's infrastructure (Table 2).

Table 2. Washington, D.C., urban forest ecological roles and monetary values.[a]

Feature	Measure
Number of trees	1,928,000
Tree cover	28.6%
Most common species	American beech, red maple, boxelder
Percentage of trees <6-inches diameter	56.3%
Pollution removal	540 tons/year ($2.5 million/year)
Carbon storage	526,000 tons ($9.7 million)
Carbon sequestration	16,200 tons/year ($299,000/year)

[16] Memorial Trees in the Monumental Core. NPS, Center for Urban Ecology, Elm Files.

Building energy reduction	\$2.653 million/year
Avoided carbon emissions	\$96,000/year
Structural values	\$3.6 billion

[a] Nowak et al. 2006.

A similar analysis was made for the entire tree population of the Monumental Core and the ecological and monetary value of the elm population was determined. The structural value of this elm population (i.e., the cost of having to replace approximately 2700 elms with trees of similar value) was estimated to be 13.8 million dollars. The elms annually removed 0.8 metric tons of pollution, sequester 36 metric tons of carbon, and store 1.7 thousand metric tons of carbon.[17] The trees also have significant value in the shade they provide the visitor as well as the habitat they provide for wildlife (Figure 7).

Figure 7. American elms on the National Mall (Photo by Alice McLarty).

[17] USDA Forest Service's Northern Research Station, Syracuse New York. (pers. commun. December, 2007).

Dutch Elm Disease

Washington, D.C.

Dutch elm disease (DED) first appeared in Europe in 1919 in the Netherlands and Northern France. The first occurrences in the United States were reported in Cleveland, Ohio, in 1930 and then in New York in 1933 where it likely entered through the port of New York on elm veneer logs. DED remained predominantly in the Northeast until World War II when control efforts diminished as the national focus turned toward the War. The disease was first reported in Washington, D.C., in 1947 by Horace V. Wester.[18] The first infected tree was found on the grounds of the Lincoln Memorial (Figure 8).

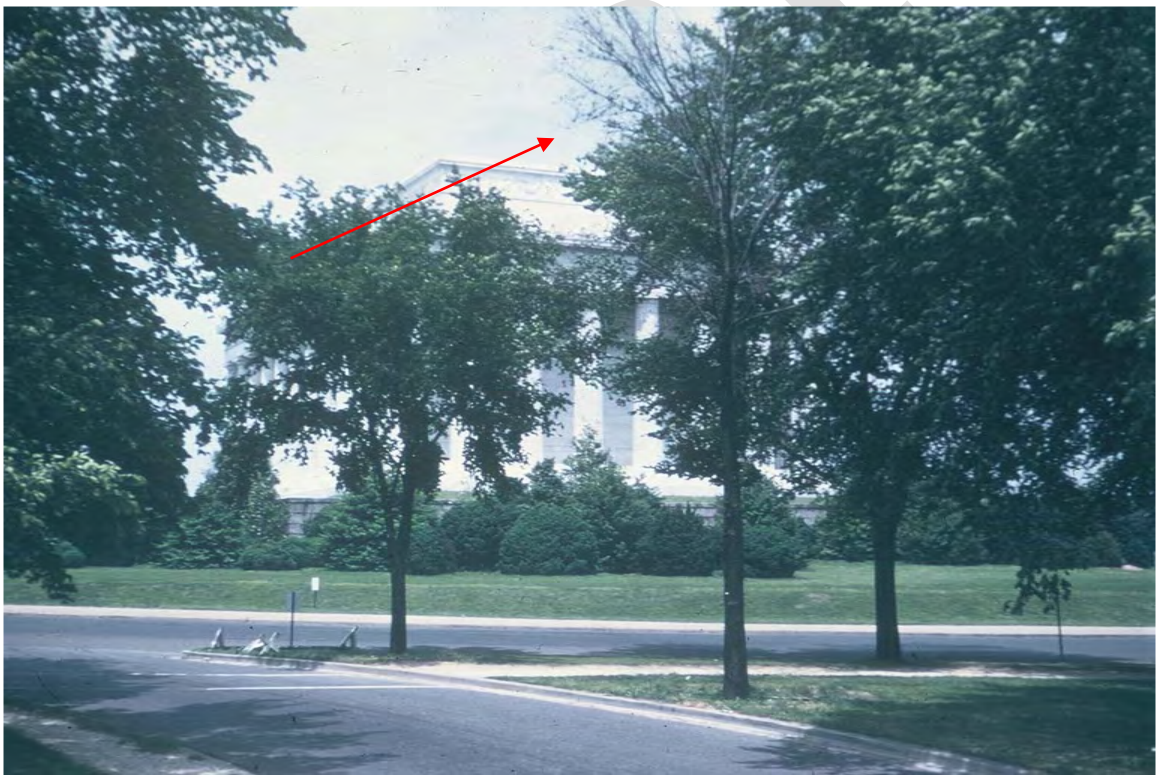

Figure 8. First elm found to be infected with Dutch elm disease in Washington, D.C.; Lincoln Memorial, 1947.

Wester, a NPS Plant Pathologist, had previously worked for the USDA Bureau of Plant Industry's Dutch Elm Disease Laboratory in Morristown, New Jersey. He was very familiar with the disease and anticipated its arrival and the potential impact

[18] Horace V. Wester, *Disease Tolerant Elms, Zelcovas, Hackberries, and Sycamore Recommended for the Washington Area*. Paper presented at the Metropolitan Shade Tree Conference, November 20, 1969, p. 2. NPS, Center for Urban Ecology, Elm Files.

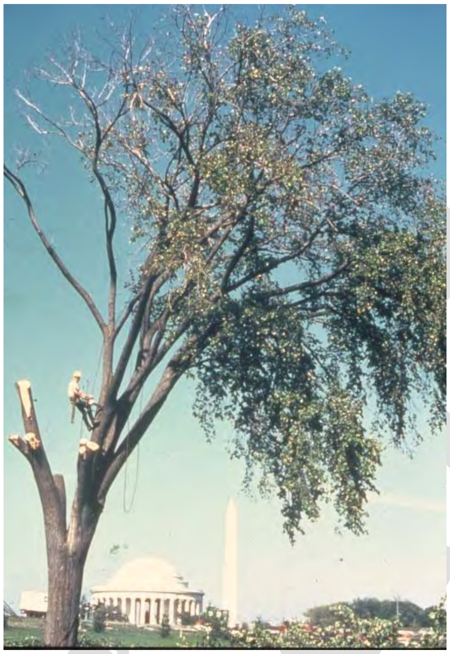

Figure 9. Removal of an American elm infected with Dutch elm disease near the Jefferson Memorial.

it could have on the city's elms (Figure 9). In the first few years after the initial case little was done.[19] However, by 1951 470 DED cases had been detected and the disease was recognized as a major city-wide problem.[20] A meeting was held on July 9, 1951, in the office of Mr. J. N. Robertson, the City's Director of Highways to discuss the problem. It was decided that, because of his experience, disease scouting would be managed by Mr. Wester assisted by Mr. Bailer of the Division of Trees and Parking. The Division of Trees and Parking would remove diseased trees from city streets and the NPS would remove infected trees from NPS land. The program also called for treating critical areas with DDT.[21] Removing infected trees on private property was the responsibility of the owner. However, since cooperation by private property owners was lacking,[22] authority to remove diseased trees on private property under Section 15 of the Plant Quarantine Act was issued to the city through a Cooperative Agreement signed in 1952 and amended in 1961.[23,24] Laboratory diagnostic services for the city-wide program were provided by

[19]Ibid

[20] Horace V. Wester, Annual Report on control of Dutch Elm Disease in Washington, 1952. NPS, Center for Urban Ecology, Elm Files.

[21] Memorandum to Colonel C.H. Whitesell, Assistant Engineer Commissioner from J.N. Robertson, Director of Highways, D.C. July 10, 1951.NPS, Center for Urban Ecology Elm Files.

[22] Horace V. Wester, Annual report on control of Dutch elm disease in Washington in 1952. NPS, Center for Urban Ecology, Elm Files.

[23] Cooperative Agreement between Trees and Parking Division, Highway Department, District of Columbia, Office of National Capital Parks, Department of the Interior, and the Bureau of Entomology and Plant Quarantine, Agricultural Research and Administration, United States Department of Agriculture, November 28, 1952. NPS, Center for Urban Ecology, Elm Files.

[24] Amendment No. 1 to the Memorandum of Understanding between the Tree Division, Department of Highways, District of Columbia National Capital Region, Department of the Interior and United States

the National Park Service's National Capital Region Ecological Services Laboratory (ESL), which later became the Center for Urban Ecology (CUE). Wester and the ESL staff provided city-wide coordination and tracking of the disease incidence and management until 1979. In 1980 the District's Tree Division decided to no longer submit samples to the ESL. This ended the program's ability to sustain a long-term record of city-wide DED incidence.

Over the first 35 years the disease incidence was about 1% or less. However, in the 1970s it began to rise and was estimated to have increased to as high as 5-7% in 1980-82.[25] The increase was suspected to be the consequence of a declining sanitation program in the city. Expansion of the aggressive strain, *O. novo-ulmi*, in the same period may have also played a role.[26]

The rise in the disease incidence prompted the NPS to attempt to reinvigorate city-wide disease management efforts by engaging the Commission of Fine Arts in 1980 to sponsor the Save-the-Elms Task Force. The Task Force included the City's six land management entities responsible for managing elms: National Park Service's National Capital Region, District of Columbia, General Services Administration, Department of Defense, Architect of the Capitol, and Smithsonian Institution. The Task Force developed the *Management Program for the Perpetuation of the American Elm Tree in the Nation's Capital***.**[27] The program specified management tactics such as sanitation, root graft control, prophylactic insecticide sprays, therapeutic treatments, mass trapping of the elm bark beetle vectors, biological controls, fertilization, reduction of the population of susceptible elms, and the integration of all tactics into a city-wide program. The city was divided into two management zones. An Intensive Management Zone was designated for the Monumental Core which included the Mall between 3rd and 14th streets, major avenues, monument grounds, and a one kilometer perimeter band or buffer surrounding the Intensive Management Zone. The intent of the Intensive Management Zone was to perpetuate the elm population where its form was intrinsic to the cultural and aesthetic character of the landscape**.** The rest of the city was designated as the Conventional Management Zone where the existing elm population was to be sustained, but not necessarily perpetuated. The level of management intensity was prescribed according to the Management Zones. The Management Program was reviewed and endorsed by 12 experts and in 1985 the six land management agencies signed a Memorandum of Understanding (MOU) supporting the program. The first five years of the program was considered a success. It was

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Department of Agriculture Agricultural Research Service Plant Quarantine Division. Relative to: Eradication of Dutch Elm Disease and Removal of Infected Elms on Private Property in the District of Columbia, April 20, 1961. NPS, Center for Urban Ecology, Elm Files.

[25] Dutch elm disease losses – Monumental Core and National Mall, 1947-2007. NPS, Center for Urban Ecology, Elm Files.

[26] Letter from Dr. Clive M. Brasier, UK Forestry Commission, to Dr. James L. Sherald, USDI NBS, October 26, 1994, regarding the race of Dutch elm disease isolates in Washington, D.C. NPS, Center for Urban Ecology, Elm Files.

[27] Management Program for the Perpetuation of the American Elm Tree in the Nation's Capital and Memorandum of Agreement to Support the Management Program, 1983. Renewed 1994. NPS, Center for Urban Ecology, Elm Files.

estimated that the city-wide disease incidence was reduced from 6.2% in 1986 to 1.9% in 1992-1993.[28] The MOU was last renewed in 1993 to continue through 1998.

Dr. Jerry Lanier, Professor of Forest Entomology, College of Environmental Science and Forestry, State University of New York, an expert in elm bark beetle biology and municipal DED management, was an advisor to the City and the NPS. In 1976 he was asked to assist the elm management program in Chevy Chase Village, Montgomery County, MD, adjacent to the District of Columbia. Lanier installed bark beetle traps at 12 "isolated" elm groves along the East Coast and in the Midwest. Within two years Chevy Chase Village was the only one of the groves where the disease incidence was not reduced (Lanier 1979). The continued high incidence was attributed to the abundance of dead and dying elms on the adjacent streets managed by the District of Columbia Department of Transportation's Tree Division. In 1981 Dr. Lanier began providing technical direction to the Department and to the National Park Service. Lanier worked closely with the Save-the-Elms Task Force and encouraged the City to improve its DED scouting and removal program emphasizing the economic advantages of sustaining a comprehensive sanitation program. His work was supported by the Morris and Gwendolyn Cafritz Foundation, USDA Cooperative State Research, Education, and Extension Service, and the National Park Service.[29]

Although the District was a participant in the Save-the-Elms Task Force and agreed to follow the Elm Management Plan, financial and administrative constraints prohibited the city from conducting adequate sanitation. In 1981 Lanier and his students inspected 1300 elms on 21 elm streets in the District and found that 75% of the first year infections were missed by the Department of Transportation inspectors. Most of the trees they detected were infected for 2-3 years and easily detected by "windshield surveys". Lanier and his team of students found that they were able to detect 94% of DED infections during the first year by intensive crown surveys conducted on foot.[30] Lanier persistently criticized the City for its inability to detect trees with early infections and its failure to quickly remove hopelessly infected trees.

From 1994 through 1997, a backlog of almost 800 dead and dying elms accumulated on the streets of Washington. In another attempt to regain control, the US Forest Service Northeastern Area joined with the District of Columbia Department of Transportation and the National Park Service's National Capital Region in an intensive effort to locate and remove the backlog of dead and dying elms. Between 1998 and 1999, the USFS contributed $450,000 to this intensive catch-up effort.

[28] Continuing Memorandum of Agreement to Support the Management Program for the Perpetuation of the American Elm Tree in the Nation's Capital. June, 1993, p. M-1. NPS, Center for Urban Ecology, Elm Files.
[29] A Liberty American Elm dedicated to Dr. Lanier in recognition of his service to the National Park Service, National Capital Region was planted on the southwest side of the Jefferson Memorial, February 1, 1990.
[30] Gerald N. Lanier, Detection of Dutch Elm Disease Infection by Intensive Examination - Report 1984, p. 3. NPS, Center for Urban Ecology, Elm Files.

There were approximately 38,250 street elms present in Washington, D.C. in the late 1950s.[31] When the Save-the-Elms Task Force was organized in 1983, the City estimated that there were18,000 street elms.[27] A comprehensive street tree survey of 105,914 trees conducted by Casey Trees in 2002 recorded 10,699 street elms (Casey Trees 2003). In the 43 years from 1959 to 2002 the City lost 70% of its street elms (Figure 10).

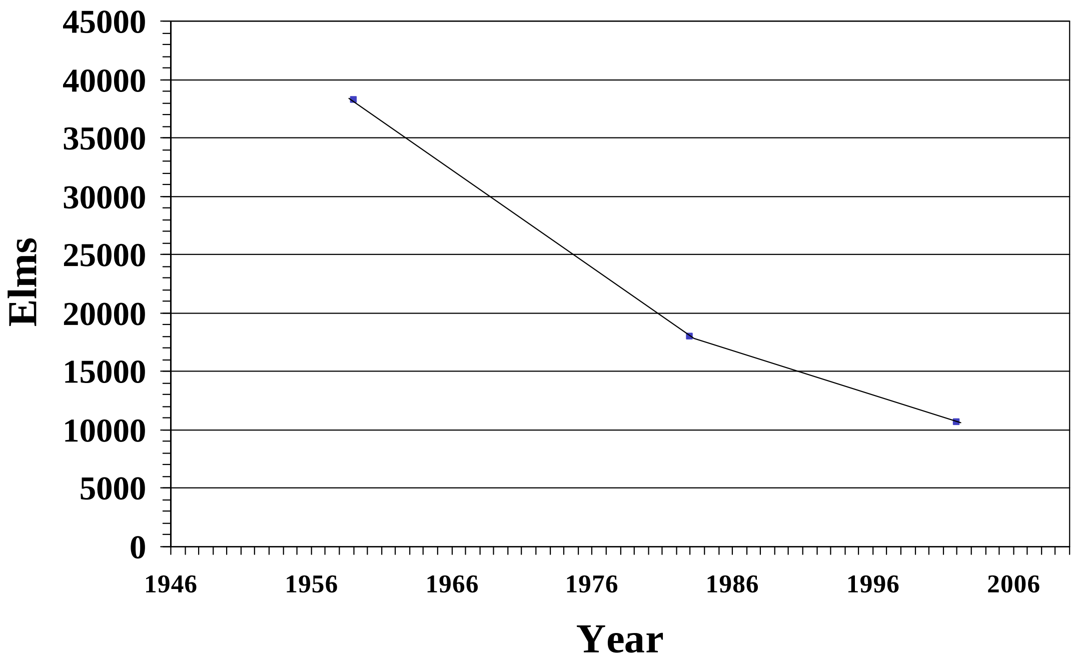

Figure 10. Street elm population in Washington, D.C.

In 1983 Lanier conducted a survey of 43 plots each 40 ha (100 A) in size representing 11.1% of the City. Extrapolating from this survey, he estimated that there were actually 32,459 elms - 9,432 private and 23,027 municipal - within the City exclusive of federal elms.[32] His municipal elm estimate probably also included elms on other city managed lands besides street elms. Many other elms on private property, school grounds, city parks, and other spaces undoubtedly experienced a rate of loss similar to the street elm population. While it is not possible to know exactly how many elms existed in the City at any time, the rate of loss of street elms is indicative of the city-wide elm loss. American Forest estimates a tree canopy loss of 16% between 1973 and 1997 (American Forests). Although development is responsible for much of this decline, the loss of thousands of large canopy elms is also a major contributing factor.

[31] Records of the Columbia Historical Society of Washington, D.C., 1957-1959, p. 271.
[32] Gerald N. Lanier. Integrated Management of Dutch Elm Disease in Washington D.C. 1983 Report, p. 12. NPS, Center for Urban Ecology, Elm Files.

Monumental Core

DED has been present within the parks of the Monumental Core for over 60 years. However, through diligent disease management, coupled with persistent replanting, the parks have been able to sustain a constant population of approximately 2700 elms. Since 1947 when the first case appeared on the grounds of the Lincoln Memorial the annual disease incidence has remained predominantly below 2% (Figure 11).

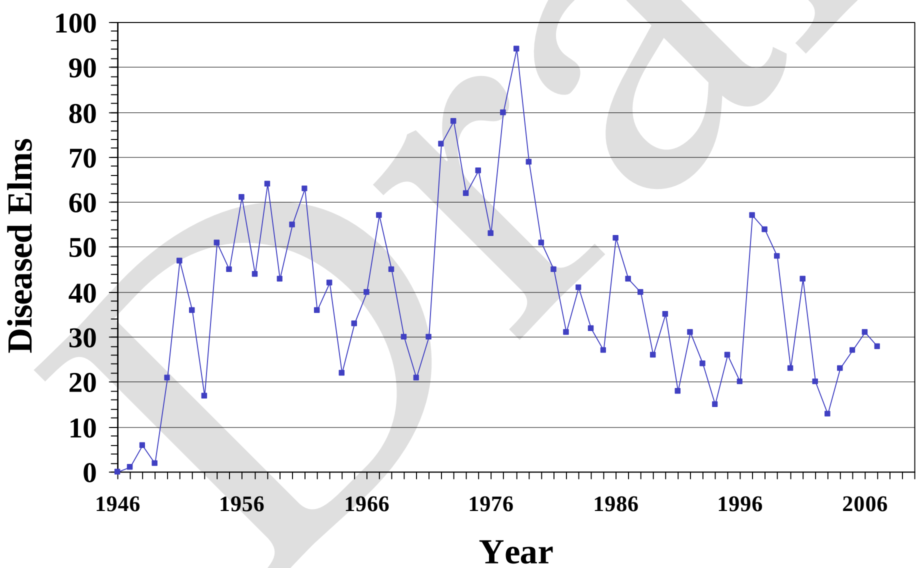

Figure 11. Dutch elm disease incidence in the Monumental Core, 1947 - 2007.

Sustained periods of losses greater than 2% occurred in the late 1950s and in the 1970s. The highest disease incidence occurred in 1978 when 94 trees became infected. While the disease incidence has been relatively low compared with many other municipal elm populations, there have been only 11 years when the incidence was 1% or less. The 1% goal was established by the Save-the-Elms Task Force and while ambitious, it was felt that it was appropriate for this significant elm population. Throughout the past 60 years approximately 2400 trees were infected with DED in the Monumental Core and most were removed (Figure 11).[25] While many planting sites have had multiple infections and replacements, there are still many large elms within the Monumental Core that have survived 60 years of exposure to DED.

It is interesting to note that the initial planting of the National Mall between 3rd and 14th streets began in the 1930s as DED began to appear in the United States. Concern was expressed about the potential consequences DED could have on these elms. On October 23rd, 1933, Mr. Gilmore D. Clark, Chairman of the Commission of Fine Arts, wrote to Frederick Law Olmsted, Jr. expressing this concern and seeking his opinion. While the disease had not yet appeared in Washington, he suggested that no further elms be planted until it was known if the disease could be brought under control. Olmstead replied on October 24, 1933:

> *I entirely agree with you that we do not now know and that probably we shall not be able to determine with reasonable confidence for many months whether Dutch Elm Disease is likely to make the further planting and maintenance of American Elms in this country impracticable as the Chestnut Blight did in the case of American chestnuts; or whether it will prove simply another one of the many hazards to which practically all species of trees are subject and in spite of which they may be expected in most cases with proper care to survive. There have been many panics in regard to many species of trees which have later proved to be unfounded.*[33]

It was not until 1952 that the first case of DED appeared on the Mall. Between 1952 and 2007 440 elms were infected and most were removed.[25] As throughout the Monumental Core, many individual tree locations on the Mall experienced multiple losses and replacements and it is not possible with the disease records alone to determine how many of the original 600 trees have escaped DED. The disease incidence on the Mall has remained low, below 2% for 45 of the last 56 years. For 29 years the incidence has been 1% or less as prescribed by the Save-the-Elms Task Force (Figure 12).

[33] Commission of Fine Arts, Minutes, Oct. 6-7, 1933, pp 21-22, Exhibit P. From microfilm NARA RG 66. Copy, NPS, Center for Urban Ecology, Elm Files.

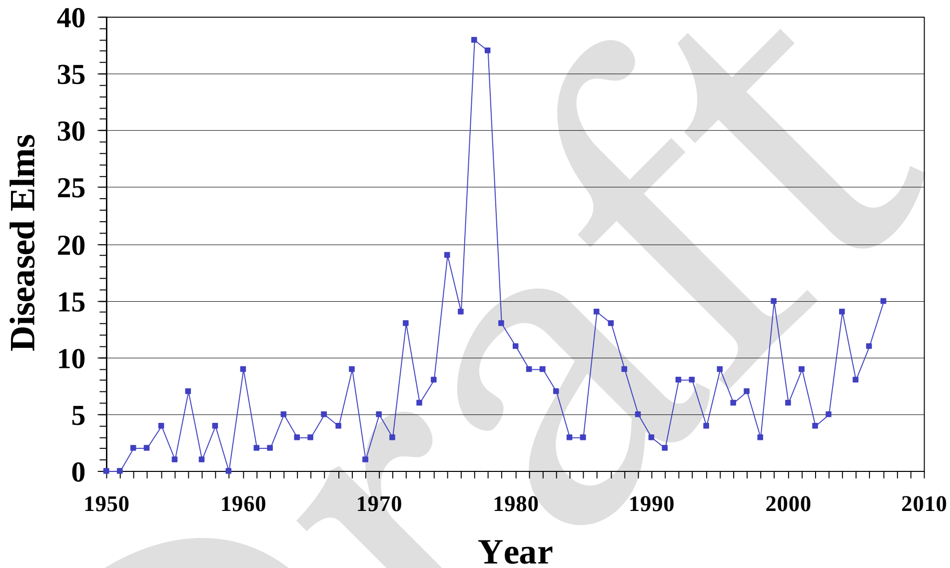

Figure 12. Dutch elm disease incidence on the National Mall, 1952 - 2007.

The highest disease incidence was reached in 1977 and 1978 when losses were 38 and 37 trees respectively. In spite of DED Olmstead was wise to insist on the American elm. Thanks to good disease management and immediate tree replacement, the population has remained intact for the past 70 years. However, while the disease incidence has generally remained low, the cumulative losses caused by DED and other factors have begun to disrupt the planting’s uniformity (Figures 13-15).

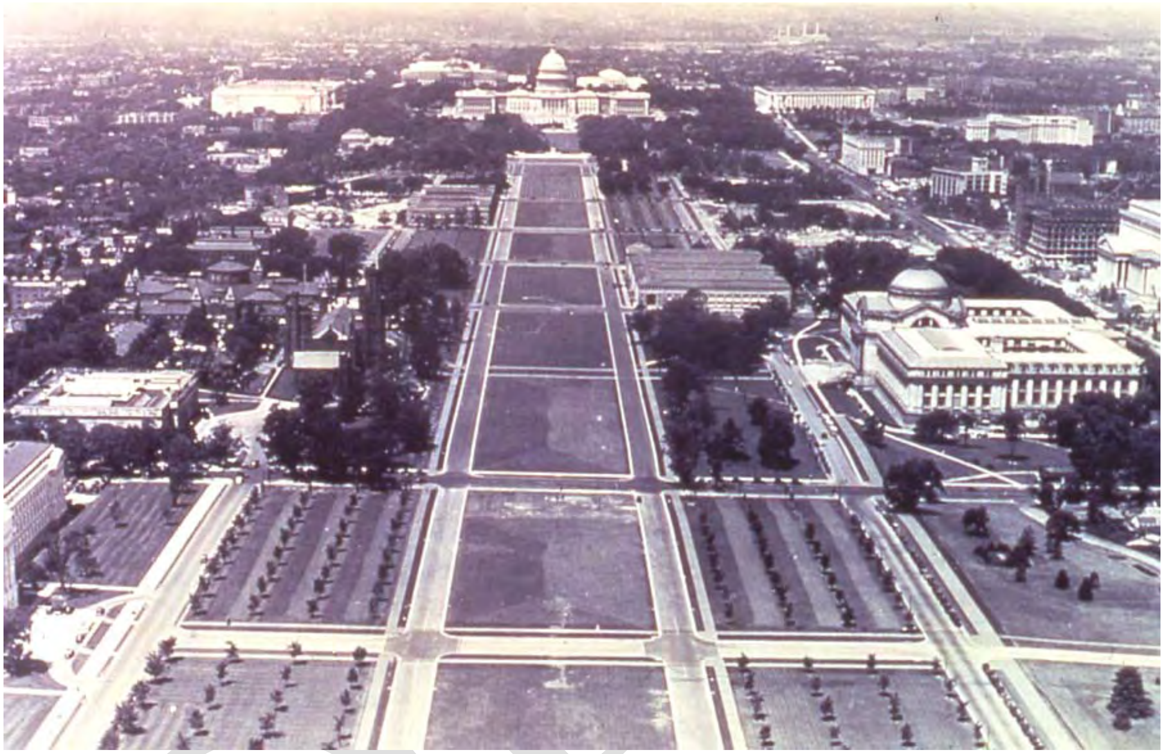

Figure 13. National Mall, 1936.

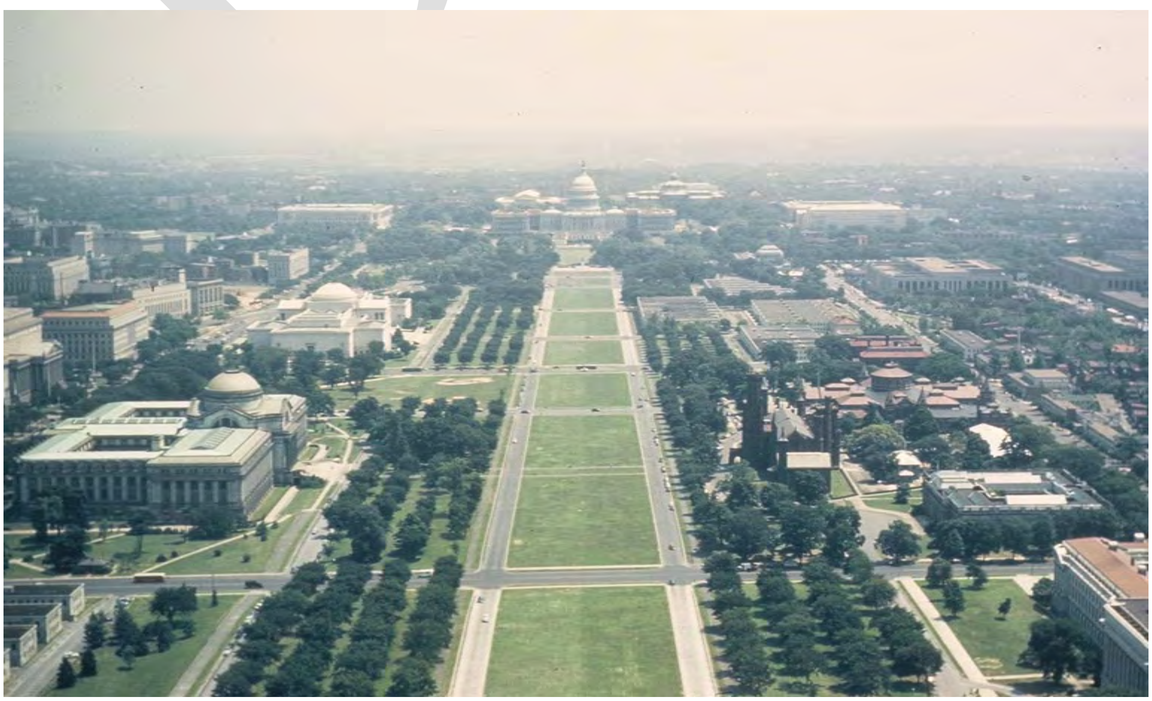

Figure 14. National Mall, 1949.

Figure 15. National Mall, 1991.

Biology and Management History

Pathogen

Two species of the fungal pathogen *Ophiostoma* cause Dutch elm disease, *O. ulmi* the non-aggressive species and *O. novo-ulmi*, the aggressive species. The species are readily distinguished by several features, such as growth rate and colony morphology, but most significantly by their degree of pathogenicity. American elms are highly susceptible to both species of *Ophiostoma*, European elm species are less susceptible to the non-aggressive species. In the 1970s Wester had local isolates typed by Dr. Clive M. Brasier, a leading expert on the genius *Ophiostoma* at the Forest Authority Research Division of Britain's Forestry Commission. The samples were all classified as *O. ulmi,* the non-aggressive species. In 1994 branch segments from 20 infected Washington elms were again sent to Dr. Brasier. Isolates from all 20 samples were confirmed as *O. novo-ulmi* NAN (North American Race), the aggressive species.[26] Brasier estimated that the aggressive species had probably arrived in Washington 10-15 years earlier, 1979-1984. The aggressive species is now the predominant species throughout the United States.

Vector

The smaller European elm bark beetle, *Scolytus multistriatus*, is the principal insect vector of the DED pathogen in Washington, D.C. (Figure 16). The beetle was first detected in the United States in 1904 and because of its breeding dominance it has largely displaced the native elm bark beetle *Hylurgopinus rufipes.* The European elm beetle breeds beneath the bark of stressed, dying, or recently dead elms, many of which are infected with DED (Figure 17). Elms or portions of elms in decline emit a host attractant which stimulates breeding attacks. While boring into the bark of trunks and limbs, virgin females release two other attractants, or aggregating pheromones, which lure thousands of additional male and female beetles to the brood tree. The mated female can lay as many as 100 eggs in two rows along a vertical gallery between the bark and the wood of the tree. Eggs hatch in about a week, producing white, legless larvae, or grubs, which bore tunnels perpendicular to the egg gallery. Larvae tunnel for 4-5 weeks before developing into pupae (Figures 18 & 19). Adults develop from the pupae in 1 to 2 weeks and emerge from the bark through pin size holes (Figure 20). Adults are shiny red-brown and approximately 1/8 inch long (Figure 16). Beetles emerging from trees infected with DED are covered with sticky fungal spores produced on fruiting structures called coremia formed within the beetle galleries and pupal chambers (Figure 21). The beetles fly to nearby healthy elms where they feed in twig crotches and infect the tree (Figure 22).

Figure 16. Smaller European elm bark beetle, *Scolytus multistriatus*. (J.R. Baker & S.B. Bambara, North Carolina State University, Bugwood.org).

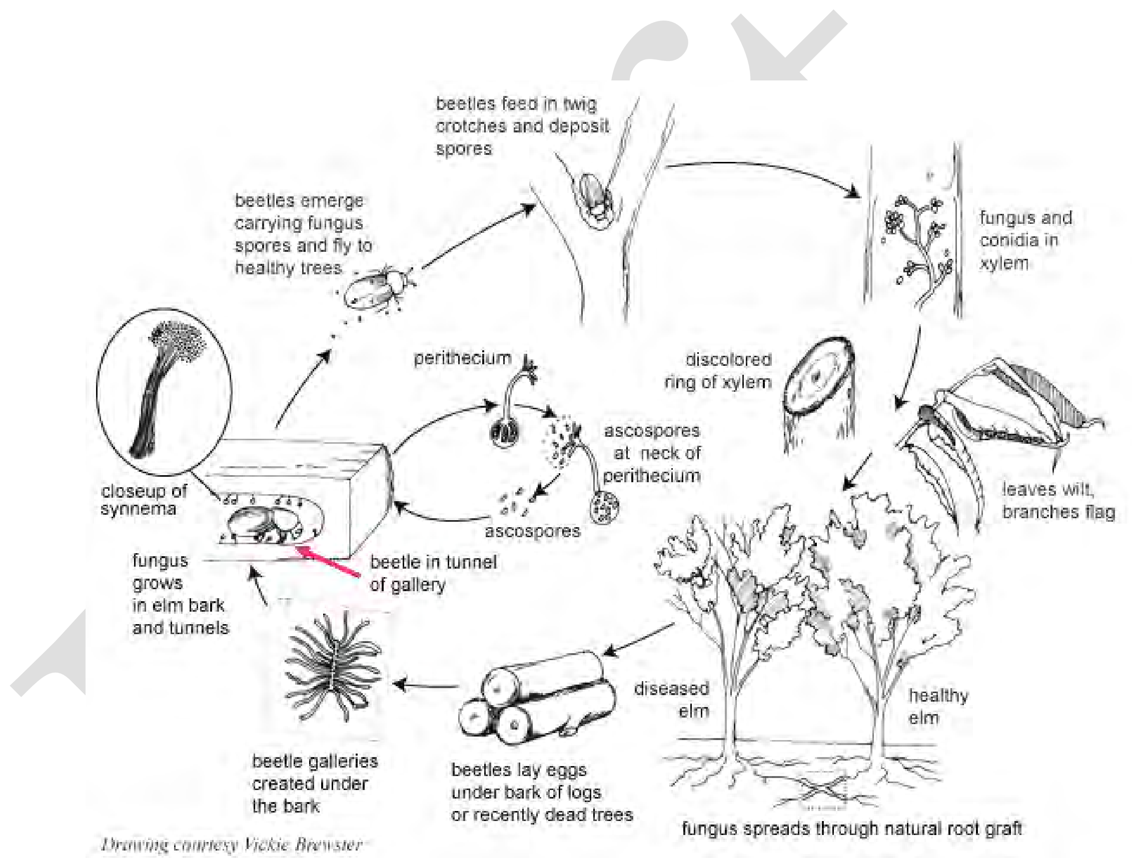

Figure 17. Dutch elm disease cycle (Vickie Brewster).

Figure 18. Maternal galleries of the smaller European elm bark beetle, *Scolytus multistriatus,* and sapwood streaking caused by Dutch elm disease.

Figure 19.   Maternal and larval galleries of the smaller European elm bark beetle, *Scolytus multistriatus* (W. M. Ciesla, Forest Health Management International, Bugwood.org).

Figure 20. Emergence holes of the smaller European elm bark beetle, *Scolytus multistriatus.*

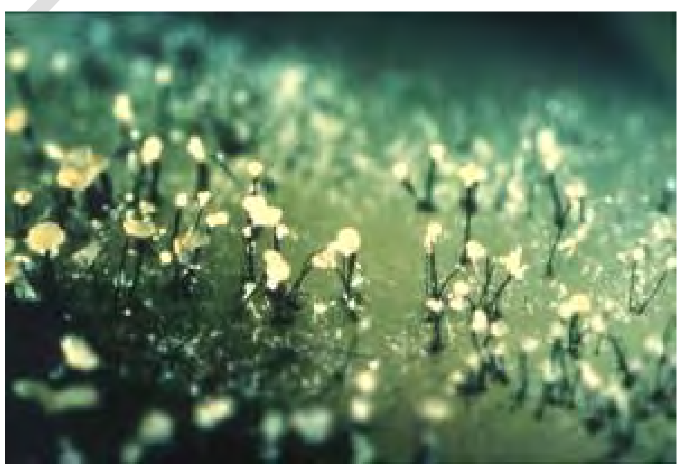

Figure 21. Coremia, fruiting structures of the Dutch elm disease pathogen *Ophiostoma novo-ulmi* on elm wood.

Figure 22. Smaller European elm bark beetle, *Scolytus multistriatus,* feeding in elm twig crotch.

In the Washington area the beetle goes through two breeding cycles between May and September (Figure 23).

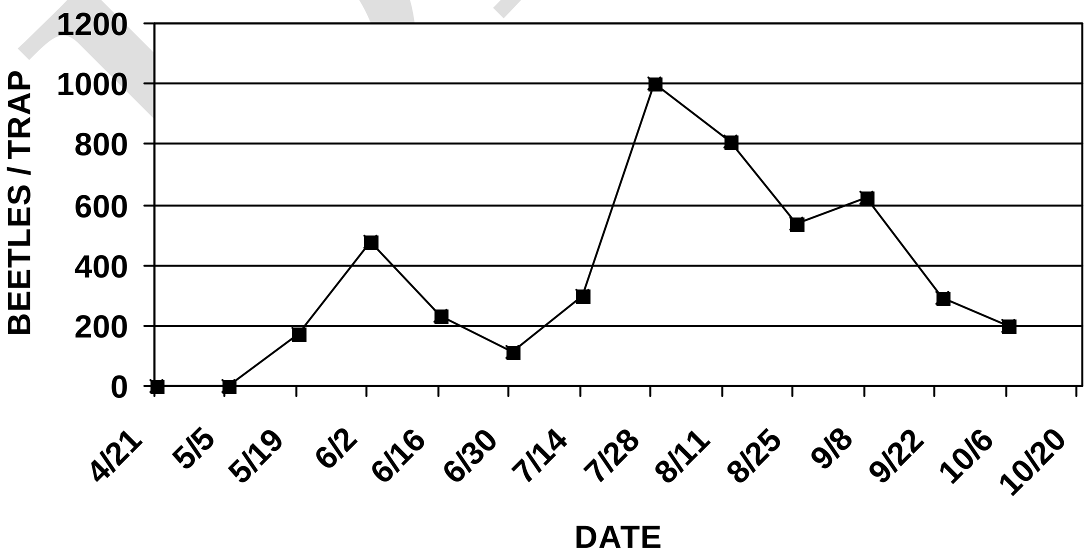

Figure 23. Biweekly trap catch of the smaller European elm bark beetle, *Scolytus multistriatus,* collected in 1975 from 50 "Multilure" pheromone traps showing the spring and summer emergence periods in Washington, D.C.

The first cycle, or spring emergence, consists of adults that develop from overwintering larva. The spring emergence can begin as early as mid-April and is usually completed by the end of June. The second, or summer emergence, develops from the progeny of the spring adults with emergence occurring from early July through early October. There are usually three to five times as many beetles emerging in the summer emergence as in the spring. However, since elms are most susceptible to infection in the spring and early summer, it is the spring or overwintering brood that can cause the most serious infections.

The banded elm beetle, *Scolytus schevyrewi*, native to Asia, was detected in Maryland in 2004 (Figure 24). What effect this new introduction may have on the spread of DED is unknown. (Pest Alert http://www.na.fs.fed.us/pubs/palerts/banded_elm_beetle/beb.pdf)

Figure 24. Banded elm beetle *Scolytus schevyrewi* Pest and Disease Image Library, Bugwood.org).

Since DED was first detected in Washington, D.C., early disease management has focused on controlling the beetle vector primarily through sanitation, i.e., the detection, removal, and destruction of brood wood. Managers were encouraged to remove diseased trees as soon as possible, and certainly before the next year, to minimize the emergence of fungus infested beetles in the spring. Since elms are typically infected through twig crotch feeding, city-street and NPS park elms were also sprayed annually with insecticide in the early spring, before the leaves developed, to protect the twig crotches from beetle feeding. Trees were usually sprayed by mist blower which could reach the crowns of tall elms and could be easily maneuvered along streets and through parks (Figure 25).

Figure 25. Early spring application of insecticide to American elms.

Elms within the Monumental Core were sprayed annually with DDT from around 1952 until 1964 when DDT was replaced with methoxychlor. Elms in the Core were often given a second cover spray in mid-summer to protect against the elm bark beetle and other insect pests (Figure 26).

Figure 26. Mid-summer application of insecticide to American elms on the National Mall.

As an outgrowth of its Integrated Pest Management program initiated in 1979, the National Capital Region (NCR) reviewed the efficacy of methoxychlor treatments and concluded that cover sprays added little value to a management program where sanitation was practiced rigorously. The NPS stopped spraying around 1984.

Beetle Trapping: While it was determined that spraying was not likely to provide a significant advantage over a good sanitation program, there was still concern that beetles could fly in from areas where sanitation was not rigorously enforced. The smaller European elm bark beetle has a minimum flight range of 12,000 feet (3,657 m) and can fly as far as 5 miles (8 km) (Birch et al. 1981 and Lanier 1981). The pheromone attractant "Multilure" was developed in 1975 for the smaller European elm bark beetle. (Pearce et al. 1975). It was anticipated that pheromone traps could be used as a biological control. In 1985 the Ecological Services Laboratory (ESL, currently Center for Urban Ecology, CUE) established a perimeter of elm bark beetle traps around the Monumental Core to intercept beetles. Traps consisted of sticky boards baited with "Multilure"

Figure 27. Elm bark beetle pheromone trap on back of street sign

which were placed on the backs of street signs, light posts, and other structures (Figure 27). The traps were collected throughout the summer and the beetles counted.

It was later determined that protecting elm populations with beetle traps would not be effective if there was a large beetle population. In Washington the beetle population was far too great for the traps to reduce the disease incidence. Beetle trapping, however, showed the emergence periods (Sherald 1976) (Figure 23).

Wild Elm Management: There are many places such as riparian areas, rights-of-way, and waste areas within and near the Monumental Core where wild elms, DED, and the bark beetle naturally proliferate. Since a good sanitation program should include a 0.5 mile (800 m) buffer around the elms of concern (Lanier 1989), an effort was made to manage DED in the most immediate wild areas in and around the Monumental Core. Lanier developed a procedure for injecting hopelessly diseased elms with the herbicide cacodylic acid (sodium dimethylarsenate) (Lanier 1989). Cacodylic acid, unlike other herbicides, killed elms quickly causing the rapid desiccation of bark beetles before they could emerge. Treated elms could also be baited with “Multilure,” to attract additional beetles and turn cacodylic acid-treated trees into “trap trees.” Cacodylic acid injections were ideally suited for managing DED in wild populations where it was expensive, difficult, and environmentally damaging to remove trees from natural settings. The treatment could also be used on cultivated trees not likely to be removed in a timely manner. The NPS began injecting wild infected elms along the C&O Canal in the Georgetown area in 1981. Treatments were later extended to Rock Creek Park, Anacostia Park, and the George Washington Memorial Parkway, including Teddy Roosevelt Island. Treatment ceased after 1988 because of a lack of funding.[34] Wild elms continue to occur in abundance in the natural and derelict areas adjacent to the cultivate population and will continue to contract DED, harbor beetles, and serve as a source of infection for the cultivated population.

[34] Cacodylic acid–treated diseased elm trees in the National Capital Region, 1981-1988. NPS, Center for Urban Ecology, Elm Files.

Root Graft Treatments

Elms growing in close proximity, i.e., crowns overlapping, naturally develop root grafts which enable the transmission of the DED pathogen from an infected tree to adjacent trees (Figure 28).

Figure 28. Natural root graft between two adjacent elms.

Severance of root grafts chemically or mechanically is a recommended management tool. This tool has been used rarely in the Monumental Core. There is only a photographic record of the injection of the fumigant Metham (Vapam) to sever root grafts of the European elms at the Lincoln Reflecting Pool. These trees were planted on 25-foot centers which have led to several occurrences of serial infections (Figure 29).

Figure 29. Loss of adjacent European elms at the Lincoln Memorial Reflecting Pool caused by root graft transmission of Dutch elm disease.

Therapy

Therapeutic treatment of infected elms began as a pilot project in the Monumental Core in 1975. The Ecological Services Laboratory (currently Center for Urban Ecology) joined with the USDA Forest Service, Forest Insect and Disease Laboratory, Delaware, Ohio, in evaluating high pressure injection of fungicides MBC.HCL (methyl 2-benzimidazole carbamate hydrochloride) and Lignasan BLP (methyl 2-benzimidazole carbamate phosphate) in conjunction with surgical pruning to save infected trees (Figures 30).

Figure 30. High pressure fungicide injection of American elm limb infected with Dutch elm disease.

The three year program saved 55% of the trees treated in the early stages of infection, 30% wilt or less (Sherald and Gregory 1980). Guidelines were developed for DED therapy and the practice has continued as a standard tree maintenance tactic. Injections are now made using low pressure and the fungicide Arbotect (Figure 31). On occasion pruning therapy without injection is attempted.

Figure 31. Low pressure fungicide injection of American elm infected with Dutch elm disease.

Replacements

Since the elm is considered integral to the overall landscape character and cultural history of the Monumental Core, when trees are lost they are quickly replaced in order to sustain a constant population of approximately 2700 elms. While the American elm provides the most reliable form, occasionally, other elm species and cultivars have been planted (Table 1). In the 1960s the American elm cultivar ‘Augustine Ascending’ was planted in several locations including the Mall (Figure 32).

Figure 32. Two ‘Augustine Ascending’ American elms on the National Mall.

This was an unfortunate choice because the cultivar’s pronounced upright form is out of character with the broad umbrella form of the American elm. The cultivar was probably selected because it was the only American elm commercially available and the nature of the form was not fully appreciated. ‘Augustine Ascending’ is highly susceptible to DED. Although many have succumbed, some still stand in the Monumental Core, including 32 on the Mall (J.L. Sherald, Unpublished Survey, 12-12-07).

During the 1961 construction of the 12th street underpass, four rows of elms were removed on both sides of the Mall and replaced with a selection of *U. hollandica*. It is likely that *U. hollandica* was recommended by Horace Wester to diversify the Mall elm population by incorporating a species that had greater DED tolerance. The trees are shorter than the American elm with rounded crowns that are quite different from the American elm. As these trees have died, they have been replaced with American elms. Seventeen of the 32 remain (J.L. Sherald, Unpublished Survey, 12/12/07).

The lack of commercially available elm replacements became a concern in the late1970s. In an attempt to ensure availability, in 1980 the NCR developed a long term elm production contract with C.R. Burr & Co., a subsidiary of United Nurseries in Middlefield, CT, to produce approximately 20 elm species and cultivars. The project failed when the nursery went out of business. Princeton Nurseries informally agreed to produce several NCR tree selections without a contract. The American elm selection NPS 3-178 was one of the trees produced under this arrangement. Selection 3-178 was an original Mall American elm which demonstrated DED resistance in nursery trials (H. V. Wester, pers. commun.). Princeton Nurseries named the selection 'Washington' and advertised it in their catalog without NPS consultation or formal agreement. This cultivar name was unfortunate since it has been confused with the historic Washington Elm under which George Washington was thought to have taken command of the Continental Army in Cambridge, MA, July 3, 1775.

Recognizing that there was no reliable commercial source of American elm, the Superintendent of Central (National Mall and Memorial Parks) requested that the ESL continue elm production at its research nursery at Daingerfield Island.[35] It was understood that while other species of elm may offer more DED tolerance, the American elm form was paramount and any replacement species or cultivar would have to strongly resemble the American elm regardless of disease tolerance. Over the years numerous species and cultivars were planted throughout the Monumental Core on a trial basis (Table 1). In 1983 the National Capital Region's Tree Advisory Committee ranked several species and cultivars for their acceptability in the Monumental Core.[36] While some selections were found to be acceptable, the committee recommended that the Monumental Core's elm population should retain no less than 50% *U. americana*. Other species and cultivars that closely resemble the American elm could be planted in back rows and in open spaces where the American elm form was not as critical.

'Jefferson' is one of the original American elms planted on the Mall and was recognized by Wester in the 1960s to have the unique distinction of coming into leaf and retaining leaves longer than its neighboring elms (Figure 33). Subsequent studies by the NPS, USDA, and Michigan State University found that 'Jefferson' is an American triploid elm with considerable resistance to DED (Sherald et al. 1994; Pooler and Townsend 2005; Townsend et al. 2005). Many 'Jefferson' elms propagated at NCR's Daingerfield Island nursery were planted throughout the Monumental Core (Figure 34). The NPS, in Cooperation with the USDA Agricultural Research Service, released the 'Jefferson' elm (Formerly NPS 3-487) to the nursery trade in 2005 under a Non-funded Cooperative Agreement (58-1230-4-402) (Sherald 2005).[37]

[35] Memorandum to Regional Director from Superintendent, National Capital Parks - Central. American Elm Propagation, Jan.5, 1987. NPS, Center or Urban Ecology, Elm Files.
[36] Memorandum to Chairman, Tree Advisory Committee from Chief, Ecological Services Laboratory. Elms with American elm form for NCR. Oct. 7, 1983. NPS, Center for Urban Ecology, Elm Files.
[37] Non-funded Cooperative Agreement between the United States Department of the Interior National Park Service and the United States Department of Agriculture Agricultural Research Service U.S. National Arboretum, April 2004 AND Notice to Nurserymen Relative to Release of Jefferson, American Elm Cultivar, February 2005. NPS, Center for Urban Ecology, Elm Files.

Figure 33. American elm ‘Jefferson’. Parent tree on the National Mall in front of the Freer Gallery of Art on Jefferson Drive, flanked on either side by trees vegetatively propagated from it.

Figure 34. Young ‘Jefferson’ elms on the National Mall come into full leaf before native American elms.

In 2005, 88 ‘Princeton’ elms were planted on Pennsylvania Avenue in front of the White House (Figure 35).

Figure 35. Recently planted ‘Princeton’ American elms on Pennsylvania Avenue in front of the White House, 2005.

‘Princeton’, an old cultivar originally selected for its form, was found to have high tolerance to DED (Townsend et al. 2005). The cultivar was planted in the Monumental Core for many years before it was recognized as DED tolerant. Princeton elms are distinguished by their prolific branching habit.

Other Factors Affecting Elms

Physical Environment

Construction: The American elm, while well recognized for its beauty, has also been appreciated for its vigor and resilience to the urban environment. However, like all trees, it is not immune to physical and environmental stresses. Elms weakened by stress attract the elm bark beetle in their search for breeding sites and are subsequently infected with DED. There have been many construction activities throughout the Monumental Core that have had unavoidable impacts on the trees. In most instances, because of the elms' vigor, they have withstood the impacts far better than any other species would have responded. The construction of the sidewalks along Jefferson and Madison drives for the 1976 Bicentennial renovation of the Mall adversely impacted the root systems of the two outside rows of elms (Figure 36).

Figure 36. Walkway elms on the National Mall showing the effects of construction.

During construction tubes for supplemental feeding and watering were installed in a circle around the root zones of these trees in an attempt to mitigate some of the adverse effects. In spite of this effort, the outside rows of trees were adversely affected. Many declined and have been replaced. Elms within the walkways will always have less root space and access to moisture than the interior trees growing in turf.

Soil Compaction: The Monumental Core and particularly the Mall between 3rd and 14th streets receives tremendous use. The Mall hosts over eight million visitors a year and issues 3000 permits for activities (Figures 37 & 38). All of this activity has a major impact on soil compaction.

Figure 37. Promise Keepers Rally, National Mall, October 4, 1997.

Figure 38. National Mall following Festival of American Folklife.

In 1978, in response to concerns over the intense activity on the Mall, a soil analysis was conducted (Short et al. 1986a; Short et al. 1986b). The analysis involved the collection of soil samples from 100 soil profiles located along 5 transects from 3rd to 14th streets. Comprehensive physical and chemical analyses of the soils at the surface and at 30 cm depths were performed. It was noted that much of the area was physically constructed between 1872 and 1920, with fill that was characterized as predominantly loam which makes it particularly prone to compaction. The mean bulk density was 1.61 $Mg\ m^{-3}$ on the surface and 1.74 $Mg\ m^{-3}$ at 30 cm, a depth spanning much of the tree root zone. These are high bulk densities. The bulk density of brick is 1.75 $Mg\ m^{-3}$ (Patterson 1976). A function of high bulk density is reduced pore space. The mean surface pore space on the Mall spanned from 37% at the surface to 33% at 30 cm. Ideal pore space for plant growth is 50%. High bulk densities restrict moisture penetration and gas exchange. The reduced pore space limits the amount of moisture and oxygen available for root respiration. Root growth can also be physically impeded by bulk densities of 1.55 $Mg\ m^{-3}$ (Veihmeyer and Hendrickson 1948). Clearly, the physical nature of the Mall’s soil as characterized by bulk density and pore space is not ideal for tree growth. While there have been limited attempts to reduce some activities within the tree panels by the use of post and chain barriers to direct visitors, compaction will likely continue to adversely affect the elms’ environment.

Diseases and Insects

Elm Yellows

It is important to remember that there are other biological threats to the elm population besides DED. Elm yellows is a serious and largely unmanageable lethal disease. Yellows causes the foliage to turn bright yellow in mid- to late summer and then defoliate (Sinclair and Lyon 2005) (Figure 39).

Figure 39. Elm yellows.

By the time the leaf symptoms are observed, the fine feeder roots have already been destroyed and the tree usually dies by the next year. Yellows was earlier known as elm phloem necrosis because of the dark brown discoloration of the phloem tissue. The disease is caused by a unicellular obligate parasite called a phytoplasma which is transmitted by leaf hoppers. The white-banded elm leaf hopper, *Scaphoideus luteolus*, is the principal vector. The disease can occur sporadically affecting only a few trees, or it can devastate a large number of trees over a short period. There is little that can be done other than to remove affected trees. An outbreak in eastern West Virginia in 1995 was dangerously close, approximately 50 miles, from Washington, D.C (Figure 40).

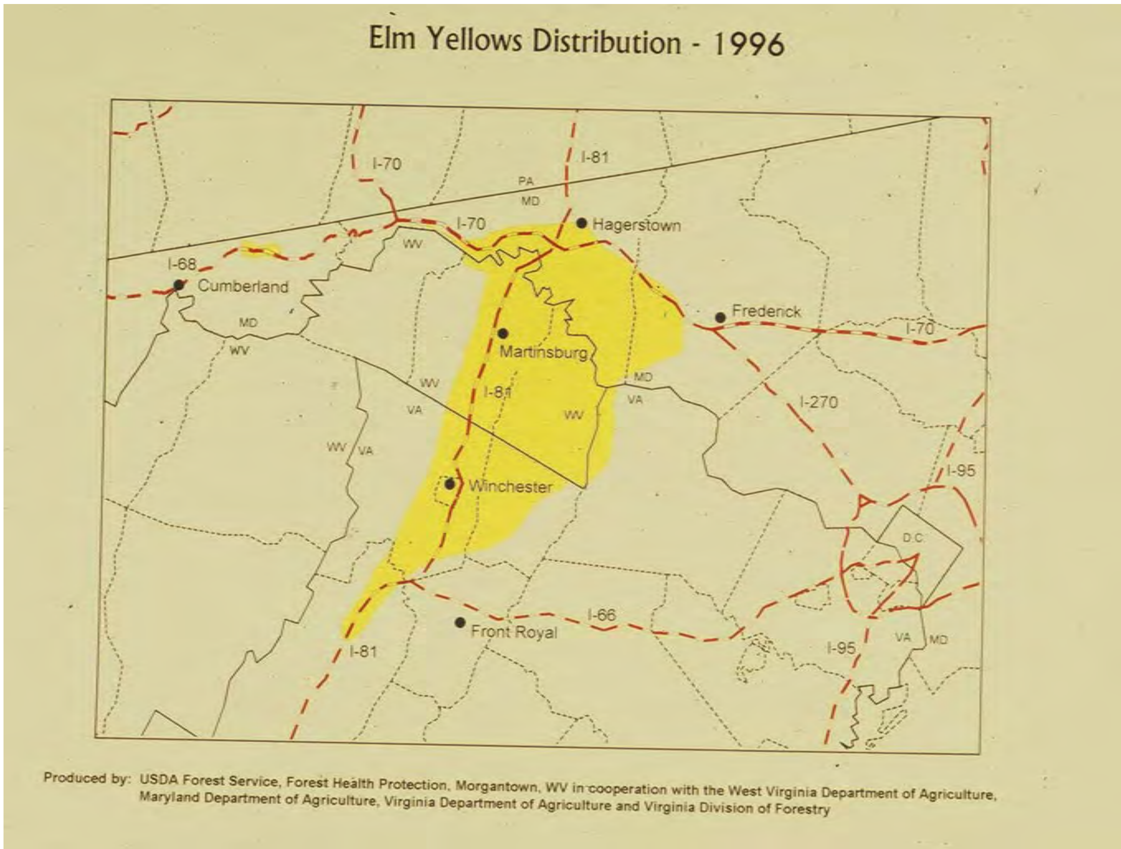

Figure 40. Distribution of elm yellows between Hagerstown, MD, and Winchester, VA, 1996.

The epidemic extended along a 75-mile front from Chambersburg, Pennsylvania, to Winchester, Virginia. Some cases were reported as far east as Frederick County, Maryland (Sherald 1999). No cases have ever been reported in Washington, D.C., however, elm yellows will always remain a serious threat and is another reason why the elm population in the Monumental Core should probably not be significantly increased.

Bacterial Leaf Scorch

Bacterial leaf scorch, BLS, is a chronic disease that affects many elms in the Monumental Core (Sherald et al .1994, Sherald 2007)[38] (Figures 41, 42, & 43).

Figure 41. American elm infected with bacterial leaf scorch.

Figure 42. Leaf symptoms of American elm infected with bacterial leaf scorch showing chlorotic halo preceding irregular marginal necrosis.

[38] Sherald, *Bacterial Leaf Scorch of Landscape Trees.* NPS Center for Urban Ecology Information Bulletin. Maryland Cooperative Extension Service, Home and Garden Information Center. (http://www.hgic.umd.edu/_media/documents/publications/bacterial_leaf_scorch.pdf) Accessed 4/30/2008.

Figure 43. Leaf symptoms of American elm infected with bacterial leaf scorch showing progression of symptom severity from older to younger leaves.

The disease is caused by the fastidious xylem-limited bacterium *Xylella fastidiosa*. BLS was first observed in Washington, D.C., by Fowler in 1931 and reported by Wester and Jylkka (1959). While DED causes leaf wilt in late spring and early summer, leaf scorch symptoms appear in mid-summer and become increasingly severe as the summer progresses. Symptoms first appear in a branch or sector of the crown and progress throughout the crown in subsequent years. In addition to leaf scorch symptoms, the disease also causes a reduction in growth and an increase in dieback. BLS affected trees are under moisture stress and prone to breeding attacks by the smaller European elm bark beetle. Consequently, it is not surprising that elms affected with BLS are more likely to contract DED (Wester and Jylkka 1963). A survey of the 600 elms on the Mall found an annual mean disease incidence of 30% (Sherald et al. 1994). *X. fastidiosa* is responsible for many other diseases including leaf scorches of oak and sycamore, which are also common in the Monumental Core. *X. fastidiosa* is transmitted by leaf hoppers and possibly tree hoppers, however, the specific vector(s) has not been determined (Bentz and Sherald 2001). The pathogen is prevalent in many hosts including those that are asymptomatic. Therefore, it is not likely that sanitation, the removal of BLS affected elms, will significantly reduce the disease incidence since the vector(s) may be transmitting the pathogen from many other hosts, including asymptomatic herbaceous species. Elms affected with BLS can remain aesthetically acceptable in the landscape for many years before they must be removed. Currently there are no proven therapeutic treatments available; however, the removal of symptomatic limbs and irrigation may be helpful (Sherald 2001, Sherald 2007)

Wet-wood

One of the most ubiquitous diseases affecting elm is wet-wood or slime flux. The slime is a fermentation product produced by a bacterial infection in the heart wood. It is an odorous, rancid complex of fatty acids that is under pressure and oozes from pruning cuts or other wounds. As it drains down the trunk it leaves a light gray streak (Figure 44).

Figure 44. American elm with wetwood or slime flux streaking.

Because the slime has a high pH it will kill the callus tissue it contacts at the wound and will also kill the vegetation below a dripping wound. Wet-wood infections are not harmful. The occurrence of slime flux on the trunks and limbs of elms is very common throughout the Monumental Core. In the past, drain pipes were inserted to relieve the fermentation pressure and drain the flux. While very old elms may still retain these pipes, the procedure is not necessary and no longer performed.

Black Spot

Elm black spot, or elm anthracnose, is a common foliar disease caused by the fungus *Stegophora ulmea*. The disease is particularly prevalent in wet springs and summers. Symptoms consist of small whitish spots on the upper leaf surface which become raised and shiny black with a white halo (Figure 45).

Figure 45. Black spot of elm or elm anthacnose (*Stegophora ulmea*). (Oklahoma State University, Entomology and Plant Pathology Digital Diagnostics).

The spots are numerous and eventually coalesce promoting early defoliation. While the symptoms may be aesthetically displeasing, the disease is not particularly harmful and does not warrant treatment. Most elms are susceptible, but some more so than others.

Scale Insects

Two scale insects commonly occur on the elms of the Monumental Core. The elm scurfy scale (*Chionaspis americana*), an armored scale, and the European elm scale (*Gossyparia spuria*) a soft bodied scale. While at times both of these pests can be abundant, they do not cause significant harm and do not warrant treatment. There are beneficial insects that help keep scale populations under control. Insecticide treatments, damaging to parasites and predators, should be avoided. The European elm scale, as well as aphids, produce honeydew, a substance rich in sugars, proteins, minerals and vitamins. Honeydew supports sooty mold fungi whose colonies form a black coating on leaves and other surfaces. The fungus does not infect the leaf.

Elm Leaf Beetle

Over-wintering adults of the elm leaf beetle (*Xanthogaleruca* (= *Pyrrhalta*) *lyteola*) lay eggs in the spring (Figure 46). The emerging larvae skeletonize the underside of the leaf. Larvae fall to the base of the tree where they pupate. The emerging adults then feed on the upper surfaces of the leaves causing shot holes. The dual feeding by both the larvae and the adults causes leaf desiccation and defoliation. While considered a serious elm pest, it has not been a serious problem affecting the elms of the Monumental Core. Since 1975 there has been only one major elm leaf beetle infestation. In 1988 a major infestation occurred on the European elms (*U.* x *hollanadica*) on the south side of the Reflecting Pool.

While there are many other elm insect pests and diseases, most are not serious concerns in the Monumental Core (Sinclair and Lyon 2005, Johnson and Lyon 1991).[39]

Figure 46. Adult, eggs, and first instar larva of elm leaf beetle (*Xanthogaleruca* (= *Pyrrhalta*) *lyteola*). Photo by Jack Kelly Clark.

[39] *Insect Pests of Deciduous Trees*. CUES: Center for Urban Ecology and Sustainability, University of Minnesota. (http://www.entomology.umn.edu/cues/dx/dec_pest.htm) Accessed 4/30/2008.

MANAGEMENT PLAN

(See Appendix C)

Dutch Elm Disease Management

Dutch Elm Disease Surveys

The entire elm population of the Monumental Core, including the National Mall and Memorial Parks and the President's Park, should be examined year-around for bark beetle brood wood including dead limbs and young transplants that have not survived. In early March, as elms begin to flower and leaf buds begin to swell, dead limbs are readily apparent and should be removed before the first beetle emergence (Figure 47).

Figure 47. Dead branches of American elm contrast with adjacent branches developing buds in early March.

Scouting for DED symptoms should begin the third week in May after leaves have fully expanded and symptoms are apparent. If scouting begins too early, infected trees may be missed on the first inspection. The entire elm population should be scouted rapidly, but thoroughly, before mid-July while symptoms are most distinct (Figures 48 & 49).

Figure 48. First year Dutch elm disease infection.

Figure 49. Leaf chlorosis and necrosis are characteristic symptoms of Dutch elm disease.

It may be necessary to work overtime to get the entire population examined during this period of optimal symptom expression. A second survey should be conducted in August to detect any trees missed in the first survey, including late DED summer infections and other disorders such as drought stress and bacterial leaf scorch.

In mature elms (20-30” DBH), trees exhibiting 1-10% crown wilt are usually first year infections. These trees will have complete bud set and little or no dead wood. Trees with 10-80% crown wilt have likely been infected for two years, while third year infections can show 30-100% crown symptoms.[40] In addition to leaf symptoms, trees infected for two or more years will also have dead wood. Generally elms do not live beyond the third year following infection. Older trees, however, can survive for a long time with chronic infections because spread is limited by the trees' older and less conductive vascular systems. Young trees, 8-inches or less in DBH, usually die the first year.

Scouting should be conducted by NPS employees, contractors, or volunteers who are well-trained in symptom detection, elm locations, and in the reporting and recording procedures. Most first year infections can be detected if scouting is thorough, while cursory windshield inspections will likely miss first year infections. Scouting should be conducted on foot by paired observers who thoroughly examine the full crown and discuss the quality and extent of symptom expression. Each tree should be examined with the aid of binoculars from all aspects and at a distance that provides full view of the entire crown, as well as from the base of the tree looking up through the interior of the crown. The percent wilt, chlorosis, and dieback, as well as the location of the symptoms in the crown should be recorded. Branches should be removed with a pole pruner or the aid of a bucket truck and the sap wood examined for the brown streaking characteristic of DED infection (Figure 50).

Figure 50. Sapwood streaking characteristic of Dutch elm disease infection (Top), and healthy twig (Bottom).

A bucket truck may be required to examine suspected trees where branches are beyond the reach of a pole pruner. All data should be entered in hand-held digital recorders that contain the current elm inventory and tree location map. The recorder keeps track of the trees as they are examined and is useful for directing scouts to suspicious symptoms detected in earlier inspections. **All infected trees that are candidates for therapy should be reported immediately for treatment.** If leaf and branch samples are

[40] Gerald N. Lanier and Alan H. Jones. Integrated Management of Dutch Elm Disease in Washington DC 1984 Report, p. 7. NPS, Center for Urban Ecology, Elm Files.

inconclusive or if a laboratory diagnosis is desired, branch samples (6.0 – 8.0” x 0.50 – 0.75”) should be submitted for laboratory culture to confirm infection (Figure 51).

Figure 51. Elm wood chips incubated on potato dextrose agar showing growth of the Dutch elm disease fungus, *Ophiostoma novo-ulmi*.

From mid-summer through fall, drought and hot weather make it difficult to distinguish DED symptoms from other disorders and laboratory diagnosis becomes increasingly useful to confirm infections. **At a minimum, confirmation of infection should be based on irrefutable leaf symptoms and vascular streaking, both of which should be recorded.**

Surveys for Other Diseases

While scouting for DED, scouts should report other disorders. Scouts should be especially trained to detect elm yellows and bacterial leaf scorch (BLS). Elm yellows is a particularly devastating disease which is not currently in the elm population, but occurred 50 miles west of Washington in 1995 (Sherald 1999). Any elm suspected of having elm yellows should be examined by an expert immediately. BLS is a chronic disorder that appears in mid- to late summer. A large percentage of the Washington elm population is affected and the incidence in the Monumental Core should be monitored (Sherald et al. 1994). BLS can predispose elms to DED and severely affected trees may warrant removal. Other disorders, especially hazardous trees and limbs, should be immediately reported.

Reporting Symptomatic Trees

Observations for every tree should be recorded on a hand-held digital recorder that retains the current tree inventory and corresponding maps of the entire elm population (Figure 52).

Figure 52. Recording Dutch elm disease scouting observations on hand-held digital recorder.

This will ensure that the scouting team locates and examines every tree.
Recorded information should include:

1.) Location of DED symptoms, i.e., crown quadrant and height.
2.) Percent wilt.
3.) Percent dieback.
4.) Sapwood streaking (yes/ no).
5.) Laboratory confirmation of DED infection (yes / no).
6.) Comments on suspicious symptoms that need further examination.
7.) BLS (yes / no) % crown affected.
8.) Recommendation: Reexamine, test, therapy, remove.
9.) Comments, e.g., poor specimen.

Data should be downloaded daily by the parks' grounds maintenance divisions (GMDs) and used to direct further examination, therapy, or removal. Actions taken by the GMD or contractors will be retained in the elm tree data base. The data base will provide a continuous record for each tree and tree space informing managers of previous observations and activities. The data base should be used to generate current and historical disease incidence reports, determine the number and location for tree replacements, and map disease foci based on current and previous detections.

Sanitation

Sanitation is the detection, removal, and destruction of the breeding habitat of the European elm bark beetle, *Scolytus multitstriatus.* This is the only insect vector of DED in the Washington area and its management is the only effective way to control the disease.

Cultivated Elm Sanitation

All infected trees not receiving therapy should be removed and destroyed within 20 days after detection. Similarly, dead and dying limbs, weak transplants, and trees dying from drought, or other conditions should be removed when detected. Regardless of the cause of decline, trunks or branches greater than 6-15 inches in diameter are potential breeding sites for the elm bark beetle (Johnson and Lyon, 1991) and their removal will help reduce the endemic beetle population. No brood wood should be allowed to remain into the spring for the spring beetle emergence. **Brood wood must be either chipped or buried and should not be stockpiled for later disposal**. Pruning cuts attract beetles and lead to new infections. Therefore, routine pruning, line clearing, and structural support must be confined to the dormant period, mid-October to mid-April, when the beetle vector is not in flight.

Wild Elm Sanitation

The American elm produces seed prolifically, producing an abundance of elms in wild and waste areas near the cultivated elms of the Monumental Core (Figure 53).

Figure 53. Seedling American elm growing out of the seawall in East Potomac Park..

Wild elms are abundant along the Rock Creek Park and Potomac Parkway, along the C&O Canal in Georgetown, on Theodore Roosevelt Island, and along the banks of the Anacostia and Potomac Rivers. Other naturalized areas throughout the District such as abandoned lots, alleys, and railroad right-of -ways support large populations of wild American elms. Since these trees are a constant source of beetles and DED, an effective city-wide sanitation program should include the detection and removal of all elms growing in close proximity to cultivated trees. The herbicide cacodylic acid had been used in a chemical sanitation program. The herbicide was injected into infected elms to rapidly kill the tree and desiccate the bark beetle vectors (Lanier 1989). By killing the tree in place it was not necessary to remove and destroy the tree. Cacodylic acid products are no longer available and currently no products are registered for this purpose. The detection and physical removal of wild elms could be performed by contractors and volunteers and should be done in coordination with other city land managers so that all sources of infection on all properties can be included. Maps of the potential wild areas where elms are likely to occur should be maintained and updated to direct the wild elm sanitation program.

Preventative Fungicide Injections for Dutch Elm Disease

A register and map of significant elms based on size, form, and location should be maintained and continually updated. Significant elms should be routinely injected with the fungicide Arbotect 20S on a two year cycle according to the NPS Specifications for Technical Arboricultural Services.[41] These treatments should be recorded in the elm tree data base and the efficacy of the treatments evaluated annually. Repeated wounding for injection may have long term adverse effects and should be monitored.

Dutch Elm Disease Therapy

Infections spread quickly, particularly in the spring and early summer, so **it is imperative that infected trees be treated immediately** when detected. Trees in the first year of infection with 1-10% of their crown exhibiting symptoms are the best candidates for therapy. However, in trees where symptomatic branches involve more than 10% of the crown the infection may still be confined to a single major limb and not systemic throughout the tree. These trees are also candidates for therapy providing removal of the infected limb will not destroy the tree's structure and appearance. Many elms can have large segments of their crowns removed and still retain or regain their aesthetic appeal. **Each infected tree must be evaluated individually.** The decision to provide therapy should be based on the tree's size, location, aesthetic quality, and the likelihood that its infection is not systemic. The extent of spread can sometimes be determined through "windows" made by removing small pieces of bark on the trunk and limbs to observe for sapwood discoloration.

Since removal of an infected limb can cause a back flow of xylem fluid carrying the fungus further into the tree, **it is never advisable to attempt therapy by pruning alone.**

[41] National Park Service Specifications - Technical Arboricultural Services - 3.08 Therapeutic and Preventative Systemic Fungicide Injection, January 2008

Infected trees should be treated with a macro-injection of the fungicide Arbotect 20S (Figures 31). One to two days following injection, the symptomatic limb should be radically pruned to remove as much discolored wood as possible. Allowing the infected limb to remain one to two days following injection enables the fungicide to be pulled by transpiration into areas of the limb and trunk that may still retain the pathogen following pruning.

It has been found that there is an 87 % likelihood of curing an infected tree if there is 10 feet of clear wood between the last visible discoloration and the final pruning cut (Campana 1975). Since this is not always possible, **trees should always be injected to restrain the residual pathogen,** allowing the tree to physically wall-off the infection.

In some trees where the infection is confined to a single large limb, it is advisable to inject the limb as well as the trunk, calibrating the volume to be injected as if the limb were a trunk. Always inject first and then radically prune the infected limb. In a three year study in NCR 55% of the elms treated for DED survived, including several with 20-30% wilt (Sherald and Gregory 1980). Lanier found that therapeutic treatments were 90% effective for current year infections and 54% effective for trees infected the previous year.[42]

Arrangements for therapy should be planned in advance so that park staff or contractors can respond as soon as the daily scouting report locates an infected tree. **All logistical impediments such as awarding the contract, purchasing the fungicide and equipment, etc., should be completed preseason so that the response can be IMMEDIATE.** While the cost for complete therapy, i.e., injection and pruning, may be high, the value of a tree worthy of treatment is far greater that the cost of treatment. **The investment is worth it!** An elm in good health with a 30" DBH within the Monumental Core is worth approximately $15,000. Therapy for the same tree would cost approximately $1,000 (Appendix B).

Root Graft Treatment

While Dutch elm disease is primarily transmitted by the smaller European elm bark beetle, it is also transmitted through root grafts between adjacent trees. This has been commonly seen in street tree plantings where trees are growing in close proximity and have become sequentially joined by root grafts (Figure 28). Grafts connect the vascular systems and allow the pathogen to move with xylem fluid from an infected tree to adjacent trees. As elms mature and their root systems expand, root grafts become more likely. Generally, when crowns of adjacent trees touch there is potential for root grafts. Root graft transmission is an increasing concern with adjacent older trees on the Mall where pockets of older adjacent elms have become infected, suggesting root graft

[42] Gerald N. Lanier and Alan H. Jones. Integrated Management of Dutch Elm Disease in Washington DC 1984 Report, p. 4. NPS, Center for Urban Ecology, Elm Files.

transmission. Root graft transmission has also occurred along the Lincoln Reflecting Pool where the European elms were closely planted on 25-foot centers and where multiple adjacent trees have been lost at one time (Figure 29). The standard practice for treating root grafts is to sever roots between the infected and adjacent trees, as well as the next tree in case adjacent trees have already become infected (Figure 54).

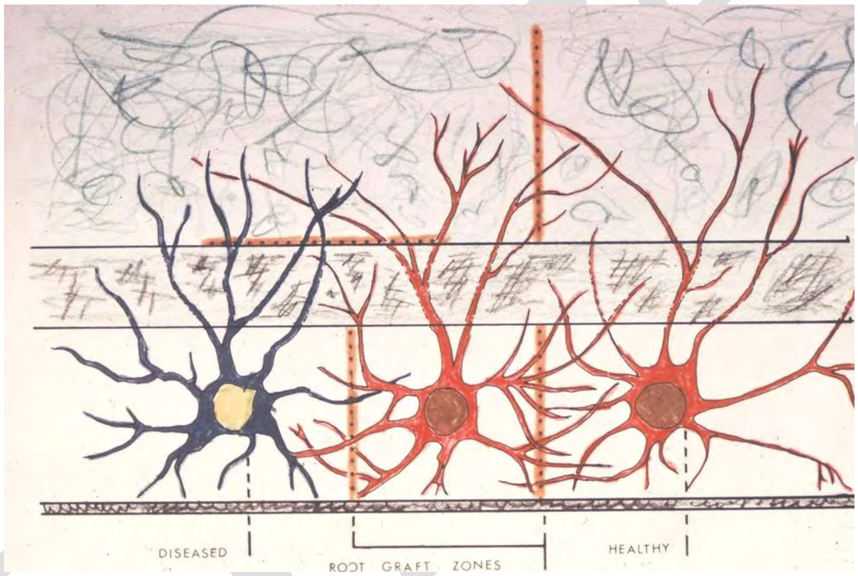

Figure 54. Recommended root pruning between infected (Black) and adjacent healthy elms (Red).

Roots are severed with a trenching device that cuts 36-40 inches deep. **Roots should be severed before the infected tree is removed** to avoid a back flush of xylem fluid and fungal inoculum into the adjacent tree. Infections that occur through the roots immediately become systemic and cannot be saved through therapy. When considering root graft treatment, consideration should be given to the damage root severance could inflict. If large trees are growing closer together than 50 feet, root severance itself may cause significant damage and be detrimental to the tree.

Elm Population Management

Sustaining the Elm Population

Within the 1000 acres of the Monumental Core there are approximately 16,238 trees maintained by the National Mall and Memorial Parks (NAMA) and the President's Park (WHHO) (Noojibail and Conway 2004). The 2,767 elms represent approximately 17% of the tree population. The elms are the one unifying element linking the Monumental Core's diverse park and memorial landscapes. The Streetscape Manual for the National Mall Road Improvement Program emphasizes this role by calling for the planting of disease resistant American elms along the major streets and park roads.[43] Many of the landscapes within the Monumental Core are historic and tree replacements must be consistent with the historic landscape plans. When elms are removed they are replaced with elms. While sustaining the current population is imperative, the population should not be expanded. In order to limit the risk of a catastrophic loss to disease as well as to minimize the effort required to manage the risk, future developments within the Monumental Core should not rely heavily on the American elm. In 1978 the Region's Plant Pathologist recommended that DED susceptible elms should be only used if "--- the presence of an elm is of historic importance or absolutely necessary to sustain an existing significant landscape design."[44]

Native American Elms

As the elm population decreases throughout the city, DED will be less of a threat to the Monumental Core. The risk could be reduced further if the disease were better managed in the Core's surrounding naturalized elm populations. As long as the DED incidence within the Monumental Core can be maintained between 1- 3%, the native American elm should continue to be planted. While continued planting of native American elms perpetuates the disease risk, the native must be retained in sufficient numbers to sustain the true American elm form intended for the Monumental Core. As the parks develop better accounting procedures for the removal and replacement of trees, it will be possible to track and control the proportion of native and other elms within the population and set "not-to-exceed quotas." Maintaining at least 50% native American elms may be a reasonable quota with which to start.

Disease Resistant Species and Cultivars

European and Asiatic elms are more resistant to DED than the American elm. Their forms, however, are quite different from the American elm and they should not be substituted for the American elm. Likewise, the zelcova, *Zelcova serrata*, a distant relative of the elm in the family *Ulmaceae*, and once promoted as a replacement for the American elm, is vastly different in form and should not be a substitute.
Over the last few years several American elm cultivars have been selected for resistance to DED and some of these have been planted within the National Mall (Table 1). The renewed national interest in the American elm will likely encourage the search for new and better cultivars.[45] While DED resistance is important, the parks should be equally concerned about form and not substitute a selection unless there is assurance that it has a form truly evocative of the American elm. Once a tree is planted it is unlikely that it will

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[43] Streetscape Manual: Interagency Initiative for National Mall Road Improvement Program, Streetscape Elements. December 22, 2004, 8. (http://www.nps.gov/streetscape/). Accessed 4/30/2008.
[44] Memorandum to Regional Chief Scientist, Professional Services from Plant Pathologist / Pesticide Coordinator, Ecological Services Laboratory. Elm Replacements. Oct. 17, 1978. NPS, Center for Urban Ecology, Elm Files.
[45] Forest and shade tree health Research: National Elm Trial Colorado State University (http://treehealth.agsci.colostate.edu/research/nationalelmtrial/NationalElmTrial.htm). Accessed 4/30/2008.

be removed because its form is incompatible. The presence of the upright American elm 'Augustine Ascending' on the National Mall demonstrates the consequences of a bad choice (Figure 32).

Maintaining Diversity

While selected cultivars may be resistant to DED and have acceptable forms, it must be understood that they could become susceptible to a new strain of the DED pathogen, or to some other disease or insect problem, or they may be plagued by structural faults that do not appear until mature. **Consequently, no one cultivar should be used as the preferred replacement tree** and multiple cultivars should be planted whenever they are found and determined to be acceptable. In urban tree populations the rule-of-thumb is for no genus to exceed 20% of the population and no species to exceed 10% (Santamour 1990). A suggested extension of this rule would be to restrict the use of any cultivar to 5% of the elm population. This recommendation is intended as a guide and should be periodically reevaluated. The 2003-2004 tree inventory is accurate to the genus level and should be updated and refined to include species and cultivar identifications.[46] The inventory can then be used to monitor and direct overall and area-specific diversity.

Replacement Elm Availability

There is little national interest in planting native American elms so there are no commercial sources. Native American elms have only been available through the National Capital Region's Daingerfield Island Nursery on the George Washington Memorial Parkway. The Region must ensure that this facility remains in operation to provide a continuous supply of native elms, as well as disease resistant and historically significant elm cultivars that are not commercially available. Other elm selections propagated include: (Sherald 2008 personal communication)

a.) *U. americana* 'Washington', a DED resistant selection propagated from its parent tree on the National Mall. 'Washington' was named and previously sold by Princeton Nurseries, but it is no longer commercially available (Figure 55).
b.) *U. americana* 'Jefferson', a DED resistant selection propagated from its parent on the National Mall (Figures 33 & 34). 'Jefferson' is also being produced commercially.
c.) *U. x hollandica* putative 'Dauvessei', the original Reflecting Pool elm.
d.) *U. carpinifolia sarniensis* 'Jersey Elm', a grove of which was planted with great effect near Belle Haven on the George Washington Memorial Parkway (Figure. 56).

[46] NAMA Tree Survey 2003-2004

Figure. 55. American elm ‘Washington’ east of the Jefferson Memorial.

Figure 56. Jersey elm, *Ulmus carpinifolia sarniensis*, Belle Haven, George Washington Memorial Parkway.

Maintaining High Quality Elms

Numerous elms of poor or minimal quality have been planted or have developed on the Mall and in other parks of the Monumental Core. Some of these are inappropriate cultivars such as the 'Augustine Ascending' elms, some are replacements that have poor form, and some are simply old and in decline. These trees should be identified, mapped, scheduled for systematic removal, and replaced with high quality specimens. In the future, only native American elms and cultivars of the finest form and quality should be selected and planted. This can be achieved through rigorous training and pruning of the elms produced at the Daingerfield Island Nursery; and by the selection of high quality commercial nursery stock by qualified professionals. **Selection of a tree simply because it is available is unacceptable.**

Planting and Soil Management

Since the early 1970s concerns have been repeatedly expressed about soil compaction and its effect on the turf and elm trees on the National Mall (Patterson 1976; Craul 1990; National Park Service 1993) (See - Other factors Affecting Elms – Physical Environment p. 40).[47] Although all the soils throughout the Monumental Core have not been studied as extensively as the Mall, it is likely that most areas where elms are planted are compacted. The recommendations proposed over the last 30 years to alleviate and manage compaction are as relevant today as when first proposed. In fact, they are even more relevant as public use of the entire Monumental Core has continued to increase.

While elms are tolerant of adverse conditions, like any tree, they would thrive under better soil conditions. Compaction is not naturally alleviated even over the long term. Once soil is compacted only deliberate management tactics can alleviate the problem. In areas where turf is the only vegetation, soil can be renovated. When trees are present, however, options for soil renovation are limited. Tree roots in compacted soils are close to the surface and extend widely. Expansive deep soil renovation by tilling can destroy much of the trees' root systems. Soils around trees can be surface drilled to improve aeration and top dressed with organic matter and inorganic, light-weight aggregates that resist compaction. Routine top dressing helps renovate the surface soils and alleviate hydrophobic surface crusting and compaction, thereby promoting moisture penetration and gas exchange. While these measures are helpful, they will do little to alleviate extensive deep compaction.

The best opportunity to remediate soil compaction is when trees are planted. Soils can be renovated over an expanded area, 20-25 feet, beyond the planting pit. Existing soil should be tilled to a depth of 18 inches and mixed with organic matter and Solite® or other inorganic material that will enhance and retain pore space while resisting compaction.

[47] Memorandum to Acting Superintendent, National Mall and Memorial Parks from Chief, Natural Resources and Science, National Capital Region. Soils of the National Mall. March 5, 2007. NPS, Center for Urban Ecology, Elm Files.

When multiple adjacent trees are being replaced an even greater area can be renovated. Expansive and extensive soil renovation will enable tree replacements to quickly fill canopy voids and sustain long term growth.

Recognizing the limited opportunities available to improve soil conditions in treed landscapes, every effort should be made after renovation to protect the soil. Activities within elm plantings should be restricted through the permitting process to passive recreation and visitor use managed by physical barriers and interpretive signs. All activities should be avoided when the soil is wet.

Wherever possible, confined root spaces, such as those in walkways, should be expanded or linked to a greater rooting area by removing or bridging root obstructions. Particular attention should be given to newly planted elms that have been in the ground for less than three years. New elms are prone to drought stress and can become susceptible to breeding attacks by the elm bark beetle. Transplants should be watered frequently, particularly during drought.

Pruning and Other Maintenance

Pruning cuts and other wounds attract beetles by eliciting attractants similar to trees under stress. Routine pruning, line clearing, and structural support other than the removal of hazardous limbs, should be conducted in the dormant season when the beetle vectors are not active. Pruning, fertilization, cabling, bracing, lightning protection, and other tree maintenance practices should be conducted according to the standard procedures prescribed by the International Society of Arboriculture and specified in the National Park Service Specifications – Technical Arboricultural Services.

Program Management Review

National Park Service

The status of the elm population, including the disease incidence, should be reviewed and reported annually. Hot spots, areas of high disease incidence, should be closely examined to determine contributing factors and how they can be corrected. The elm data base will provide a continual record of each tree, its annual disease and condition report, and its treatment record. Trees with condition concerns can be monitored to assess change and trees receiving preventative or therapeutic treatments can be evaluated to determine the long-term effectiveness of the treatments. The species composition of the elm population should be reviewed annually and replacement plans developed to ensure that cultivars and native elms are well distributed and that the population remains balanced according to the plan’s goals. Whenever possible, the NPS should participate in city-wide disease assessments and planning.

City-wide

Since the first occurrence in 1947, the city-wide response to DED has been erratic. Over the first 35 years, city and federal land managers engaged in a comprehensive disease management program and successfully maintained the disease incidence at 1% or less.[27] When the program began to falter and the disease incidence began to rise in the 1970s, reaching 5-7% in 1980-82, managers tried to rekindle disease management efforts by establishing the Save-the-Elms Task Force.[27] Unfortunately, the City's response to the plan was not sufficient and the disease continued to cause major elm losses. The urban forest is the responsibility of all managers and must be approached holistically. Successful management of DED, or any threat to Washington's municipal forest, requires full participation of all the City's public land managers as well as those in the private sector. NPS regional and park managers should actively participate with urban foresters in Washington, D.C., and surrounding jurisdictions to continually review the status of DED and other urban forestry issues and participate in and encourage all city-wide efforts to protect and restore the City's forest.

Research

Managers continually benefit from advances in research and this has been particularly true with DED. Research developments in sanitation, therapy, and disease resistance have all led to more effective disease management. The NCR Center for Urban Ecology (Ecological Services Laboratory) has conducted research on DED since 1948 when Wester conducted DDT spray tests on the smaller European elm bark beetle.[48] Studies on remote sensing of infected trees (Hammerschlag and Sopstyle 1975), biological control, pheromone beetle trapping (Sherald 1976), fungicide therapy (Sherald and Gregory 1980), rapid screening for DED resistance (Figure 57) (Sherald 1993) and the selection of DED resistant trees (Sherald et al. 1994) have been conducted by NCR staff working with federal and academic partners. In 1992 the NCR and Michigan State University sponsored the International Dutch Elm Disease Conference to explore new research pertaining to the biology and management of DED. (Sticklen and Sherald 1993). NCR must continually encourage managers to review research and advances in DED and other issues affecting elms to ensure that its management program is the best that it can be and whenever possible actively support research within the parks.

[48] Statement by Horace Wester. DDT spray test by mist blower for control of *Scolytus multistriatus*, Washington, D.C. Report of Elm bark Beetle Control Conference Dutch Elm Disease Control Policy Conference, New York City Feb 17-218, 1949, p. 9. NPS, Center for Urban Ecology, Elm Files.

Figure 57. Testing elm selections for Dutch elm disease resistance at the NPS Daingerfield Island Nursery.

Conclusion

The Monumental Core is the centerpiece of the City of Trees. While over 16,000 trees representing many species and cultivars surround the parks and monuments of the Core, it is the majestic American elm that is the soul of the landscape. This wonderful tree has withstood the onslaught of DED for over 60 years because of the dedicated arborists and park managers who understood the biology of the disease and who continuously and rigorously provided the best disease management practices available. The NCR must continue to persist in its efforts to sustain the elm and all of the parks' trees and to work in partnership with public and private sectors to restore and expand the entire urban forest of our nation's capital, "The City of Trees."

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Appendix A.

Elm Management Chronology

1791	L'Enfant proposes the "Grand Avenue," the National Mall.
1870s	Alexander "Boss" Shepherd's public works program planted 60,000 trees expanding the City's existing elm population.
1902	McMillan Plan: Report of the Senate Committee on the District of Columbia on the Improvement of the Park System of the District of Columbia.
1915-1916	European elms planted along the Lincoln Memorial Reflecting Pool.
1930	First Case of Dutch elm disease (DED) reported in the United States.
1933	Works Progress Administration Public Works Mall Development Project.
1935	First elms planted on the National Mall.
1947	First case of DED in the District of Columbia reported on the Lincoln Memorial grounds by Horace V. Wester.
1951	July 9, 1951, National Capital Parks and the District Government agreed to cooperate in a city-wide Dutch elm disease control program. Wester put in charge of the scouting program.
1952	Cooperative Agreement between Trees and Parking Division, Highway Department, District of Columbia, Office of national Capital Parks, Department of the Interior, and the Bureau of Entomology and Plant Quarantine, Agricultural Research and Administration, United States Department of Agriculture, November 28, 1952.
	First elm infected with DED on the National Mall.
	Initiated city-wide application of DDT for the smaller European elm bark beetle.
	NPS Ecological Services Laboratory began city-wide laboratory analysis of DED samples.
1964	Methoxychlor replaced DDT.

1965	First cases of DED reported on the European elms at the Lincoln Memorial Reflecting Pool.
1975	National Capital Region's Ecological Services Laboratory (Currently, Center for Urban Ecology) and the USDA Forest Service, Forest Insect and Disease Laboratory, Delaware, Ohio, began cooperative studies of bark beetle trapping with the pheromone "Multilure" and fungicide injection therapy for DED infected elms.
1979 – 1984	Aggressive strain of the DED pathogen, *Ophiostoma novo-ulmi* Race NAN entered Washington, D.C. area.
1976	Dr. Jerry Lanier, Professor Forest Entomology, College of Environmental Science and Forestry, State University of New York, began advising the NPS and the City on DED management.
1977-1978	Record high DED incidence on the National Mall.
1980	NCR initiated a contract for long-term elm production with C.R Burr & Co., a subsidiary of United Nurseries in Middlefield, CT. Contract failed when nursery went out of business.
	Washington, D.C. Tree Division ceased providing samples to NCR for DED diagnosis making it no longer possible for NPS to maintain City-wide DED incidence record.
1981 – 1988	NCR treated wild elms infected with DED in and near the Monumental Core with the herbicide cacodylic acid.
1983	The six land agencies responsible for elms in Washington, D.C., organized the Save-the-Elms Task Force.
1984	NCR stopped spraying for the smaller European elm bark beetle.
1985	*Management Program for the Perpetuation of the American Elm Tree in the Nation's Capital* - Memorandum of Agreement signed by six agencies responsible for elms in Washington, D.C.
1988	Began planting DED resistant 'Jefferson' elm (NPS 3-487) in the Monumental Core.
1993	Renewal of the "Management Program for the Perpetuation of the American Elm Tree in the Nation's Capital" and a Memorandum of Agreement among the six agencies to support the management program.

1992 U.S. National Park Service, National Capital Region and the Michigan State University Foundation, and the MSU Pesticide Research Center sponsored the International Dutch Elm Disease Conference *Dutch Elm Disease Research: Cellular and Molecular Approaches.* August 1-4.

1994-1997 Backlog of 800 dead and dying street elms accumulated on Washington, D.C streets because of lack of funding for removal.

1996 Outbreak of elm yellows in eastern West Virginia 50 miles from the Monumental Core.

1998-1999 USFS Northeastern Area contributed $450,000 to the City's elm management program. The USFS, NCR and D.C. Department of Transportation intensify efforts to control DED.

2002 Washington, D.C. street tree survey conducted by Casey Trees.

2003-2004 Tree assessments conducted in Washington, D.C. and within the Monumental Core for the USDA Forest Service Urban Forest Effects model (UFORE).

2005 DED resistant 'Jefferson' released to the nursery trade under a joint agreement between the National Park Service and the USDA Agricultural Research Service.

Appendix B.

Economic Assessment of Dutch Elm Disease Therapy.

Example:

American elm: 30" Diameter at Breast Height (DBH)
Cross sectional area: 706.9 square inches;

Base Value:
@ $48.00 / sq. in.[49] $33,931

X

Species Factor 90%: $30,538
Elm is a significant component of the National Mall landscape.

X

Condition Factor 70%: $21,377
Most trees are in Condition Class "good" 60-80%.

X

Location Factor 70%: $14,963
Elms on the National Mall have at least a 70% location value.

Estimated Value - 30" DBH elm: $14,963

Therapy for 30" DBH Elm[50]

Trunk Injection @ $15-20/in DBH: $450-600
Limb Removal: $500
Total $1,100

[49] Southeastern United States Tree Species Guide, March, 2001 International Society of Arboriculture-Southern.
[50] Based on estimates provided by NPS Regional Horticulturist, Rob DeFeo, 2-12-08.

Appendix C.

Elm Management Plan

Month	Biological Cycle	Management
January - February	Smaller European elm bark beetle overwinters as larvae under the bark of recently dead and dying elm trees.	Examine elms for brood wood and remove dead trees and limbs. **All brood wood must be destroyed** and not stockpiled. Remove wild elms in waste areas in and near the Monumental Core. Continue routine pruning. Prepare for or establish contracts to provide therapeutic and preventative fungicide injections.
March	Overwintering beetle larvae begin to pupae as temperature rises.	Examine elms for limbs that are not flowering or slow in developing leaves. This may be an early indication of DED.
April	Larvae develop into pupae. Pupae develop into adults in 1-2 weeks. Adults can emerge as early as mid-April.	Examine newly planted (1-3 yr old) elms and remove weak trees infested with beetles. Stop routine pruning by mid-April.

May	Emergence of the spring generation of bark beetles accelerates. Many emerging beetles are laden with spores of the DED pathogen. Beetles feed in 3-4 year old twig crotches initiating new infections. Elms are most susceptible to DED in the spring and early summer during the first beetle emergence when the elm's water conducting vessels are large. Newly infected elms begin to exhibit wilt.	**Begin scouting elms for DED symptoms in mid-May.** Report observations electronically with hand held recorders. Continue scouting throughout the summer. Examine for symptoms of elm yellows. Begin providing **preventative fungicide injections** to selected elms in the last week of May. **Inject and surgically prune infected trees immediately.** Sever root grafts between infected elms and healthy elms.
June	Spring beetle emergence peaks in early June and declines by the end of June. Feeding adults continue to infect elms. Adults begin to breed in diseased and declining elms. New adults develop in approximately 6 weeks.	Continue scouting for infected trees. Examine waste areas for infected wild elms. Remove and destroy all infected trees and other brood wood before the summer beetle emergence period begins. Continue therapy for infected elms. .
July	Summer beetle emergence begins in early July and peaks in late July – early August.	Continue to scouting and sanitation for infected trees and brood wood

	Water conducting vessels in summer elm wood are smaller, so summer infections develop more slowly.	Provide therapy to newly infected trees Begin scouting for bacteria leaf scorch (BLS).
August	Summer beetle emergence continues.	Scouting for DED symptoms becomes more difficult because symptoms can confused with BLS, drought, and other stress factors.
September	Summer beetle emergence declines as beetles seek diseased and stressed elms in which to overwinter.	Continue scouting and sanitation.
October	Beetle larvae begin to overwinter beneath bark of diseased and stressed elms.	Routine pruning can begin and can continue through mid-April. Determine the disease incidence for the season and see if there are “hot spots,” i.e., areas of concern where management attention should be focused. Assess the elm population and determine the percentages and distribution of elm replacements. Begin replanting.
November December	Beetles overwinter as larvae.	Continue routine tree maintenance.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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