A COST BENEFIT ANALYSIS OF MANITOBA'S INTEGRATED DUTCH ELM DISEASE MANAGEMENT PROGRAM 1975 - 1990

WESTWOOD, A.R., Forestry Branch, Manitoba Natural Resources, 300-530 Kenaston Blvd., Winnipeg, MB. R3N 1Z4

ABSTRACT

Since the discovery of Dutch elm disease in Manitoba in 1975, the average annual elm loss rate in rural communities has been 2.4%. The value of the urban elm forests within these communities and the City of Winnipeg exceeds $1.1 billion. In 1990 the Province of Manitoba spent $2,063,000 to manage Dutch elm disease within an area of 100,000 km^2. This expenditure represents approximately 0.2% of the value of the urban elm trees currently in the provincial inventory. An average annual rate of expenditure of approximately $1.5 million by the Province of Manitoba since 1981 has kept annual elm losses in Manitoba communities to less than 2.5%. An increase of the annual loss rate by a few percentage points would translate directly into costs of $22,300,000 for elm removal, $21,000,000 for replacement trees, a decline in real estate values and a near complete loss of the urban forests in many towns and cities. These costs would be condensed into a 5 to 10 year period. The Province of Manitoba has realized a minimum savings of $5,010,000 since 1981 by managing Dutch elm disease. An expenditure of approximately $10 million since 1981 has conserved $276,204,000 worth of elm trees in 35 rural communities. Implementation of buffer zones around selected communities has significantly reduced urban elm losses. The present program has been successful in spreading the costs of DED management over many years and more importantly, provided protection for the elm resource until a "cure" is found or more effective management techniques are developed. In terms of the economic cost-benefit, the integrated Dutch elm disease management program conducted by the Province of Manitoba and Cities of Brandon and Winnipeg has been a worthwhile investment.

INTRODUCTION

Dutch elm disease was first discovered in American elm trees (*Ulmus americana* L.) in Manitoba in 1975. In anticipation of its introduction, forestry personnel of the Province of Manitoba and Cities of Winnipeg and Brandon followed the progress of Dutch elm disease through eastern North America and in the early 1960's initiated measures to lessen the impact of the disease in Manitoba. These early measures were primarily aimed at maintaining a healthy elm population and encouraging planting of alternate tree species. Following the introduction of the disease into Manitoba in 1975, an aggressive province-wide Dutch elm disease management program was implemented. This program has undergone constant evolution and continues to embrace the goals and objectives that were set over a decade ago. The Manitoba program has

developed into a truly integrated pest management program utilizing insect vector, pathogen and host biology in a multifaceted approach to manage the elm resource. The purpose of this analysis is to assess the benefits provided by the provincial Dutch elm disease program, 15 years after its inception. In simplest terms, an economic benefit assessment of this type attempts to determine if it makes financial sense to implement control programs (Stemeroff 1991). This synopsis will briefly describe the biology and history of Dutch elm disease in Manitoba, components of the Dutch elm disease management program and will present a cost-benefit analysis for the program.

BIOLOGY OF DUTCH ELM DISEASE

Detailed information on the biology and bionomics of Dutch elm disease in North America has been published by Sinclair and Campana (1978), Strobel and Lanier (1981) and Hiratsuka (1987). The following is a brief summary of this published information. The causal agent of Dutch elm disease is *Ceratocytis ulmi* (Buis.) C. Moreau (=*Ophiostoma ulmi* (Buis.) Nannf.). Once introduced into the tree, the fungus quickly spreads through the xylem vessels and surrounding cells, inhibiting the transportation of nutrients and water through the tree (Hiratsuka 1987).

The first external symptom of Dutch elm disease is leaf wilting. Usually wilting starts at the site of infection, and spreads rapidly throughout the canopy. Leaves turn brown, but may not fall for some months after the tree has died. The rate of spread of the fungus through an elm tree is dependent on a number of factors, including overall health of the tree, virulence of the fungal pathogen, and time of the year when the tree is initially infected (Hubbes and Jeng 1981; Hubbes 1988). Elm trees generally succumb to Dutch elm disease much faster when under environmental stress (e.g. drought, heat stress, frost damage, etc.). Stress leads to losses of carbohydrate reserves that further increases susceptibility to Dutch elm disease. Healthy, vigorous trees located in favourable sites can withstand infections for some years (Hildahl and Jeffrey 1980; Stipes and Campana 1981).

Dutch elm disease is transmitted between elm trees by bark beetles. Beginning in the spring, adult bark beetles feed and mate in the crotches of twigs in the tree canopy. After mating, female beetles construct brood galleries within the cambium and lay eggs. Brood galleries may be constructed in the canopy or lower down on main branches or the trunk of the tree. Larvae feed and develop within these galleries and eventually pupate within specially constructed pupal chambers (Hiratsuka 1987). During summer, newly emerged adults move to healthy uninfected trees to feed. In late summer and fall, the beetles move to the bases of infected or healthy trees to overwinter (Kondo *et al.* 1981). The following spring, the overwintered beetles move from the bases of trees to the canopy to feed and mate. If the fungus was present in the brood galleries bark beetles will carry the sticky spores of *C. ulmi* from tree to tree.

In North America the vectors of Dutch elm disease include the Native elm bark beetle, *Hylurgopinus rufipes* (Eichh.), and the introduced European Elm Bark beetle, *Scolytus multistriatus* (Marsh.). While the Native elm bark beetle currently comprises approximately 99% of the Manitoba vector population, occasional European elm bark beetles are found every year at various locations (Westwood 1991). The biology of these species is similar, but the European

elm bark beetle is considered to be a more effective vector of Dutch elm disease because the adults often feed at more sites in the tree canopy than do adult Native elm bark beetles.

The condition of the host tree affects the attractiveness to bark beetles; stressed or overmature trees attract more beetles than young vigorously growing trees (Hiratsuka 1987).

The primary host of *C. ulmi* in Manitoba is the American elm. The Siberian elm (*Ulmus pumila* L.) is fairly widespread in the province and has shown minor levels of susceptibility to Dutch elm disease.

HISTORY OF DUTCH ELM DISEASE IN MANITOBA

Prior to the occurrence of Dutch elm disease the natural elm population in south and central portions of Manitoba was approximately 20 million trees of 10 cm dbh (diameter at breast height) or greater (Jeffrey 1981). In addition, several million elms have been planted in urban areas and shelterbelts. In 1975, Dutch elm disease was first detected in Manitoba in Selkirk, Brandon and Winnipeg. These mutual outbreaks were most likely linked to campers carrying infected elm firewood from infected areas outside of the province. From 1975 to 1980, Dutch elm disease spread steadily throughout the southern portion of the province south of the Trans-Canada highway. During the 1980's the disease moved northward to the Whiteshell Provincial Park, the Interlake area and to Dauphin. In 1990 the disease was found in southeastern Saskatchewan and along the Saskatchewan River in eastern Saskatchewan near the Manitoba border. Currently at the time of writing, the disease extends from the eastern Manitoba-Ontario border across the province north to Fisher Branch in the Interlake, to slightly north of Dauphin in western Manitoba and westward across the Manitoba-Saskatchewan border and southward into North Dakota.

MANITOBA'S DUTCH ELM DISEASE MANAGEMENT PROGRAM

When Dutch elm disease was first discovered, the Manitoba Department of Agriculture was responsible for surveillance and removal and disposal of diseased and hazard trees in Selkirk and assisting the cities of Brandon and Winnipeg. In 1980 the responsibility was transferred to Manitoba Natural Resources. The program was then expanded to provide focus for the entire province. It was necessary to enact a legal framework for the administration of a province-wide program and in 1981 the Dutch Elm Disease Act was passed. This act regulates all aspects of disease management in the province and enabled implementation of an effective Dutch elm disease program. During the 1980's the program was refined and additional resources were added to provide a fully integrated pest management effort that by 1990 encompassed 50 rural communities and the City of Winnipeg across an area of approximately 100,000 km^2.

The primary components of the current Dutch elm disease management program include site-specific inventory of trees within control areas, elm tree sanitation by pruning and removal, basal spraying with an insecticide to kill overwintering elm bark beetles, preventative and curative tree injections with fungicides, replacement of elms with alternate species, establishment of elm disposal sites, surveillance, research, education and public information and the community Elm Guard Program.

An integral part of the management program was the development of the Cost Sharing Agreement component, which was designed to share costs of activities such as basal spraying,

tree replacement and pruning, between Manitoba Natural Resources and communities. The result has been the development of close relationships between provincial forestry research, surveillance, enforcement and sanitation personnel and workers in the towns and cities throughout the province. The Cost Shared Agreement program has fostered significant investment by these towns, cities and municipalities in their rural and urban forests. The result has been a commitment by all government levels to manage Dutch elm disease.

ELM LOSSES AND PROGRAM COSTS

To measure the cost-effectiveness of Manitoba's Dutch elm disease program, requires measurement of elm loss rate due to Dutch elm disease, measurement of the value of the elm resource being protected, measurement of the cost of the program itself and a comparison of elm losses in the absence of Dutch elm disease management. Manitoba's Dutch elm disease program can be further divided into two program components, that of the Provincial forestry branch in 50 rural towns, cities and municipalities and that of the City of Winnipeg's forestry branch.

A) Dutch elm disease loss rate in rural Manitoba

For the purpose of this analysis, all areas outside of the City of Winnipeg are considered as part of the provincial Dutch elm disease rural program. Numbers of elm trees and numbers lost from all causes, including Dutch elm disease and hazard elm removals are accurately known for 28 of the 50 communities during the period 1975 to 1990 (Table 1). Hazard elms are those trees with more than 40% deadwood, and are highly attractive to elm bark beetles. These inventory data represent both public and privately owned elm trees greater than 10 cm dbh within town or city limits. The mean cumulative loss rate of elms in the 28 communities since the inventories were taken was 16.4% and the average annual loss rate was 2.4% (Table 1). This loss of 2.4% per annum is the best available measurement of overall elm loss in communities participating in the rural Dutch elm disease management program. Miner (1990) stated that in Winnipeg, mortality of elms to causes other than Dutch elm disease may be as high as 0.75%. Recent data on mortality of elms in an area without Dutch elm disease were obtained from Saskatchewan (D.A. Domke, personal commun. 1990). Both Regina and Saskatoon have significant elm populations. For example, in 1990, Saskatoon's elm inventory was approximately 50,000 boulevard trees. Based on current inventories and past losses the average annual mortality rate of elm in Regina and Saskatoon ranged from 0.25 to 0.35%. Using Saskatchewan data, a yearly mortality rate for elm of at least 0.25% from causes other than Dutch elm disease could be expected in the 28 Cost Shared Agreement communities, and so the average annual loss rate to Dutch elm disease in these communities is estimated to be 2.15%.

B) Buffer Zones

As part of the Cost Shared Agreement program, buffer zones have been established around certain towns or cities along rivers or creeks where there are large numbers of elm trees. Elsewhere in North America river or creek corridors with high densities of elm have been routes into communities for migrating Dutch elm disease carrying bark beetles (Strobel and Lanier

1981). Dutch elm disease tends to move along these corridors and, once within a town, the disease spreads outward from the watercourse into adjacent street and private property trees. Buffer zones were established outside of community boundaries within a number of Cost Shared Agreement areas in Manitoba to help regulate beetle movement. Various management components of the Dutch elm disease program such as basal spraying, sanitation and surveillance were practised within the buffer zone.

Table 2 shows the comparison of yearly elm loss rates between Cost Shared Agreement communities not located on a river or creek, those that have extensively elm lined rivers or creeks running through the community, but have no buffer zone, and finally those communities with buffer zones on rivers or creeks adjacent to town boundaries. Communities not located on a river or creek have experienced an average annual elm loss rate of 1.02% (sample size = 13 communities). Those on a river or creek with no buffer zone have experienced an annual average loss rate of 4.76% (10 communities). Towns or cities on a river or creek with a buffer zone have experienced an average annual elm loss rate of 1.46% (5 communities).

Towns not located on water courses were either infected through the introduction of disease carrying beetles on elm wood or from beetles moving into communities from adjacent farmland. The rate of infection is generally slower for communities without rivers or creeks in comparison to those areas where continuous elm cover leading into a community facilitates beetle movement.

The implementation of buffer zones around communities has reduced the expected average annual loss of elms by 3.3% versus non-buffered communities on rivers or creeks. The impact of this reduction in loss translates into significant savings in terms of Dutch elm disease management and conservation of the elm resource. For example, an additional 3.3% annual loss of elms in the City of Brandon over the last decade would have equalled 14,535 trees. The actual cost saving attributable to the buffer zone program (using Brandon and Winnipeg as examples) will be described in detail under Dutch elm disease program costs in the next section.

Statistical analysis (ANOVA and Duncan's Multiple Range Test) indicated there existed no significant difference ($p > 0.05$) between the average annual elm loss in communities without rivers or creeks or those with buffer zones on their rivers or creeks. Communities with rivers or creeks and no buffer zones lost significantly more ($p < 0.05$) elm trees than either of the other location types (Table 2).

C) Dutch elm disease loss rate in Winnipeg

Since the introduction of Dutch elm disease into Winnipeg, 34.4% of the cities elms have been removed (1975 - spring 1991) (Table 3). Strobel and Lanier (1981) noted that in many towns and cities in eastern North America where there was no significant effort made to manage Dutch elm disease, elm losses often reached 20% per annum. The removals in Winnipeg included 27% hazard trees and 7.4% infected with Dutch elm disease. The average annual loss rate of both hazard and Dutch elm disease infected trees was 2.59% over this period. The 1975 inventory for Winnipeg showed 275,000 elms (not including elms in some wild river bank areas), with the number of elms remaining in 1990 at 180,651. For comparative purposes, the City of Minneapolis, which also maintains a Dutch elm disease management program, lost 52.6% of its elms (4.91% per annum) during the period 1975 to 1989. In comparing the

Winnipeg and Minneapolis programs it is necessary to take into account differences in both geographical location (weather), tree growth and the biology of vectors and pathogen.

The 2.59% elm loss rate per annum for Winnipeg is misleading in comparison to rural loss rates for most Cost Shared Agreement communities. Data from the rural Cost Shared Agreement communities represent losses primarily from high value public, private and park trees as determined from the inventories. The loss rates reported from Winnipeg include a considerable number of elms from semi-wild and wild river bank areas throughout the city (some of which were never inventoried). The actual loss rate of higher value street, park and private elms is lower than 2.59% per year.

The provincial Dutch elm disease management program maintains a buffer zone around the City of Winnipeg. The average annual elm loss rate of 2.59% for Winnipeg is higher than the provincial average of 1.46% for towns and cities with buffer zones. This is probably because of the number of entry routes into Winnipeg for migrating bark beetles. There are only two entry routes into each of the five rural Cost Shared Agreement communities with buffer zones, because each community is located on only one river or creek. Winnipeg, on the other hand, has five potential invasion routes for bark beetles (the entry and exit points for the Red River and the entry points of the La Salle, Seine and Assiniboine Rivers which empty into the Red).

Winnipeg annual elm loss rates would have been considerably higher without the buffer zone, as illustrated by the annual loss rate of 4.76% in Cost Shared Agreement communities located on one or more rivers or creeks, but having no buffer zones (Table 2). The Winnipeg buffer zone appears to have potentially reduced Winnipeg's losses by at least 2.17% annually, about 95,480 elms during the period 1975-1990. This estimate of potential loss is conservative because the higher overall disease pressure from the surrounding areas would have reduced the effectiveness of the Winnipeg program.

D) Costs of the provincial program

The Dutch elm disease management program has cost Manitoba Natural Resources $14,497,000 or $1,449,000 per annum from 1981-1990 (Table 4). The sanitation and survey components also include expenditures for operational research into Dutch elm disease management techniques and basic research into curative and preventative measures. The actual costs of tree removals by provincial crews are shown in Table 4. The average cost for all types of removal combined is $85.35 per tree. These removals range from very large trees overhanging buildings or other property (which require expensive and sophisticated mechanical removal equipment and advanced training for staff) to smaller buffer zone or river bank trees growing in wild or semi-wild areas. Manitoba Natural Resources mechanical crews consist of at least three staff with an aerial bucket truck and a removal vehicle (picker truck) for movement of felled trees to disposal sites. Community Services and Provincial Corrections crews (ranging in size from 4 to 10 people) are supervised by Manitoba Natural Resources Dutch elm disease operational staff and require picker truck support if on site burning of cut elms is not practical.

The cost range for tree removal by Manitoba Natural Resource crews ($124.09 for large trees over buildings to $46.12 for riverbank trees) compares very favourably to removal by private contracting. Recent quotes by private contractors in the City of Winnipeg for removal

of "big bucket type trees" ranged from $150.00 to $300.00 per tree in 1990 (M. Allen personal commun. 1991).

VALUE OF THE ELM RESOURCE VERSUS EXPENDITURES

A) Value of an individual elm in Manitoba.

The most recent assessment of the value of Manitoba's elm resource was provided by Miner (1990). The value of individual trees was calculated using a formula developed by the International Society of Arboriculture (Chadwick and Neely 1988). This formula is based on a cumulative point system and the inputs are updated on a continuous basis by the society. The formula is used widely in North America and provides for a variety of appraisal needs (e.g. property appraisers etc.). The formula used to appraise the City of Winnipeg's elm trees is:

APPRAISED VALUE = (BASIC) X (SPECIES) X (CONDITION) X (LOCATION)
where:

BASIC = the value of the tree based on replacement value given its current dbh and height. This BASIC calculation takes into account the initial investment of purchase of the tree and the annual accrued value, plus costs of maintenance over time. The BASIC calculation used for tree appraisal is similar to that used by the insurance industry in North America (e.g. Manitoba Public Insurance Corporation). The BASIC value of the average tree in Winnipeg (45 cm dbh) was calculated to be $8582.00 in 1990 (Miner 1990).

SPECIES = rating based on the durability, resistance to disease, life expectancy and aesthetic value. The species value for elms in North America ranges from 80 to 100% (Chadwick and Neely 1988). Although Winnipeg's elms are long living, have a desired growth shape and are well adapted to the local climate they were given the lowest rating of 80% due to susceptibility to Dutch elm disease.

CONDITION = state of decay of tree at time of appraisal. The condition factor ranges from 20 to 100%. Most of Manitoba's elms in towns and cities were judged to be in above average condition (excluding Dutch elm disease infected trees), showing little decay and were assigned a condition factor of 75% based on the formula criteria. (M. Allen personal commun. 1991).

LOCATION = the location factor was calculated based on real estate values for boulevard trees (valued for noise reduction and aesthetics) and park and private trees (valued for shade, wind brake, architectural effects, erosion reducing and air purifying qualities). The results for the different site types were then averaged to provide a location value of 70%.

The value of the average Winnipeg elm (45 cm dbh) was then calculated to be:

BASIC ($8582.00) X SPECIES (0.8) X CONDITION (0.75) X LOCATION (0.7) = $3604.44

The value of approximately $3600 for the average Winnipeg elm also applies to elms in most rural Cost Shared Agreement communities where the condition of the trees and general real estate values are similar. Considering that some of the rural Cost Shared Agreement communities do not have significant tree cover outside the town boundaries, the elms in these towns are probably of even greater value in enhancing the local environment than those in Winnipeg.

B) Value of the Provincial Elm Resource

Based upon the average value of $3600 per tree, the 1990 value of the elm inventory is $350,710,000 in the 28 Cost Shared Agreement towns and cities in Table 1 and $651,060,000 in the City of Winnipeg. The combined value for the inventoried elms within the 28 Cost Shared Agreement areas and Winnipeg is 1.0 billion dollars. Although original elm inventories do not exist for the remaining 22 Cost Shared Agreement communities, inventories were assessed in Gretna, Emerson, Riverton, Winnipeg Beach, Pinawa, Letellier and St. Jean during 1990 (total = 3246 trees). The value of the elms in 35 Cost Shared Agreement communities and Winnipeg exceeds $1.1 billion. To date accurate inventories have not been obtained for the remaining 15 Cost Shared Agreement communities in the Manitoba.

C) Value of elm losses

Winnipeg has lost an average of $25,639,200 worth of elm trees per year since the initial introduction of Dutch elm disease in 1975 and a cumulative loss of approximately $410,040,000.

Since 1975 the 28 Cost Shared Agreement communities have lost $10,062,000 worth of elms per year and a cumulative loss of $100,642,000. The incremental savings to the Province of Manitoba by keeping the elm loss rate to an average of 2.4% per annum is evident. A doubling of this loss rate in the provincial program to 4.8% per year would have equalled a loss of elms worth in excess of $200 million.

D) Cost of tree removal

There are several scenarios concerning tree removal that require discussion in a cost-benefit analysis of the Dutch elm disease program. Assuming an average cost to the province of $85.35 to remove a tree, the costs of discontinuing the provincial Dutch elm disease program can be estimated. If Dutch elm disease were allowed to run its' course in Manitoba, approximately 80% of all elms would be dead within 5-10 years, based on experience in many cities through eastern North America (Strobel and Lanier 1981). The cost to remove these elms in the 35 inventoried Cost Shared Agreement communities would be approximately $6.9 million (this does include trees in the remaining 15 Cost Shared Agreement communities without elm inventories). This cost projection is conservative, as many of the trees within communities fall into the "Big bucket", high risk category (see Table 5). The removal cost for all 50 rural Cost Shared Agreement communities would probably approach $10,000,000.

The costs of removal of dead elms in the City of Winnipeg if the Dutch elm disease program were discontinued in 1990 would be conservatively estimated to exceed $12,300,000 if removal costs averaged $83.35, and 80% of the trees were removed. The cost of removal to

the City of Winnipeg in 1989 for large boulevard elms was estimated to range from $150.00 to $200.00 per tree (M. Allen personal commun. 1991). Most Winnipeg removals are "big" bucket types and therefore removal costs are greater than the provincial average.

E) Cost of buffer zones

Buffer zones dramatically reduce elm losses and the costs of tree removal in urban areas. Using Brandon as an example (see Elm Losses and Program Costs, Buffer zones), the implementation of the buffer zone prevented the loss of an additional 14,535 trees. The value of these trees is $52,326,000 and the cost to remove them would be $1,211,492. Winnipeg provides a more dramatic example of cost savings provided by buffer zones, where it is projected that an additional 95,480 trees would have been lost without implementation of buffer zones (based on a provincial rate of 4.76% for communities on rivers or creeks without buffer zones). The value of this loss based on provincial costs, would be $343,728,000 and the cost of removal $7,958,258.

F) Benefit of Dutch elm disease Management

The Province of Manitoba has spent $10,297,000 million on Dutch elm disease management since 1981 to manage Dutch elm disease in 50 rural communities (Table 4). In the absence of a Dutch elm disease program the costs of removal of 80% of the elms in the 28 Cost Shared Agreement communities in Table 1 during the period 1981-1990 is $7,765,000. The cost to replace an elm (purchase, transportation, labour and materials) with a three meter tree is approximately $75.00 (Slivitsky 1990). The cost to replace trees lost in the 28 Cost Shared Agreement communities if there had been no program since 1981 is $7,542,000. The Province of Manitoba has realized a saving of $5,010,000 since 1981 by managing Dutch elm disease. The actual saving is considerably greater if original inventory data for the remaining 22 communities existed and could be included in the estimate.

The Province of Manitoba has expended $10,297,000 on Dutch elm disease management since 1981 and lost 16.4% of the provincial inventory in the 28 Cost Shared Communities. In 1990 the remaining elm tree inventory in 35 Cost Shared communities is valued at $362,395,000. Without the Dutch elm disease program (assuming an cumulative 80% loss rate since 1981-1990) the elm inventory remaining in the 35 communities would be worth $86,191,000. An expenditure of approximately $10 million has conserved $276,204,000 worth of elm trees during the last decade.

CONCLUSION

Since the discovery of Dutch elm disease in Manitoba in 1975, the average annual elm loss rate in rural communities has been 2.4%. The value of the urban elm forests within the rural communities and the City of Winnipeg exceeds $1.1 billion. In 1990 the Province of Manitoba spent $2,063,000 to combat Dutch elm disease in 50 rural communities and the City of Winnipeg (Table 4). This represents is 0.2% of the value of the elm trees currently in the provincial inventory. The annual rate of provincial expenditure of approximately $1.5 million since 1981 has kept average annual elm losses to less than 2.5%. A partial reduction in Dutch

elm disease management that would allow even a doubling in the annual elm loss rate would mean a significant increase in expenditures. An increase of the annual loss rate by only a few percentage points would translate directly into costs of $22,300,000 for elm removal, $21,000,000 for replacement trees ($75.00 per 3.0 m tree), a decline in real estate values and a near complete loss of the urban forests in many towns and cities. These costs would be condensed into a 5 to 10 year period. The Province of Manitoba has realized a saving of over $5.0 million since 1981 by managing Dutch elm disease. An expenditure of approximately $10 million on Dutch elm disease management since 1981 has conserved $276,204,000 worth of elms in rural communities during the last decade.

The implementation of buffer zones around selected communities has significantly decreased the loss rate of elm in the urban forests.

The present program has been successful in spreading the costs of Dutch elm disease management over many years and more importantly, provided protection for the elm resource until a "cure" is found or more effective management techniques are developed. In terms of economic cost-benefit, the Provincial and Cities of Brandon and Winnipeg Dutch elm disease programs have been worthwhile.

The significance of Manitoba's urban forests is clearly evident when it is considered that 80% of the population of the province lives and works beneath this resource. The integrated Dutch elm disease management program is an example of how a multifaceted, integrated pest control effort can be developed to minimize an impact on a natural resource. The key component to the program is a commitment to all aspects of integrated management by several levels of government.

ACKNOWLEDGEMENTS

The author would like to acknowledge the helpful advice and comments provided by Mr. L. Matwee, Mr. K. Knowles and Mr. T. Boyce, Manitoba Department of Natural Resources, Forestry Branch, Winnipeg, Manitoba; Mr. K. Fosty, Manitoba Forestry Association, Winnipeg, Manitoba; Mr. M. Allen and Mr. P. Pines, City of Winnipeg, Forestry Branch, Winnipeg, Manitoba; Dr. E. Kondo, Forestry Canada, Forest Pest Management Institute, Sault Ste. Marie, Ont.; Dr. M. Hubbes, Faculty of Forestry, University of Toronto, Toronto, Ont.; Mr. G. Munro, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario; Dr. F. Baker, Department of Forest Resources, Utah State University, Logan, Utah; Dr. D. French, Department of Plant Pathology, University of Minnesota, St. Paul, Minnesota; and two anonymous reviewers from the Manitoba Entomological Society.

REFERENCES

Chadwick, L.C. and D. Neely. ed. 1988. Guide for establishing the values of trees and plants. Urbana, Illinois, International Society of Arboriculture.

Hildahl, V. and C.A. Jeffrey. 1980. The elm's enemy - Dutch elm Disease and its control in Manitoba. Dep. Nat. Resour., Winnipeg, Man.

Hiratsuka, Y. 1987. Forest tree diseases of the prairie provinces. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-286.

Hubbes, M. 1988. Pathogen virulence and host reaction in Dutch elm disease. Naturaliste can. 115:157-161.

Hubbes, M. and R. Jeng. 1981. Aggressiveness of *Ceratocytis ulmi* strains and induction of resistance in *Ulmus americana*. J. of Forest Path. 11:257-264.

Jeffrey, C.A. 1981. Manitoba Dutch elm disease program development. Proceedings of the Dutch elm disease workshop and symposium. Manit. Dep. Nat. Resour. Winnipeg, Manitoba.

Kondo, E.S.; Hiratsuka, Y. and W.B.G. Denyer, editors. 1981. Proceedings of the Dutch elm disease workshop and symposium. Manit. Dep. Nat. Resour., Winnipeg, Manitoba.

Miner, R. 1990. Program evaluation of the City of Winnipeg Dutch elm disease program. Prepared for the Natural Resource Institute. U. of Manitoba. 1990. 20 pp.

Sinclair, W.A. and R.J. Campana, editors. 1978. Dutch elm disease - perspectives after 60 years. Search Agric. (Geneva, N.Y.) 8(5):1-52.

Slivitsky, M. 1990. Dutch elm disease tree replacement program - Winnipeg, Manitoba. Manitoba Natural Resources. Rpt. pp. 1-67.

Stemeroff, M. 1991. Economic Benefit Assessment of Spruce Budworm Control in Eastern Canada. Deloitte and Touche, Guelph, Ont. pp. 1-99.

Stipes, R.J. and R.J. Campana, 1981. Compendium of elm diseases. Am. Phytopathol. Soc., St. Paul, Minnesota.

Strobel, G.A. and G.N. Lanier. 1981. Dutch elm disease. Scientific American. 245:40-50.

Westwood, A.R. 1991. Report of the Eighteenth Annual Forest Pest Control Forum - November 1990. Forestry Canada, Ottawa, Ontario pp. 245-256.

Table 1: Elm losses for 28 Cost Shared Agreement communities in Manitoba 1975-1990.

Location	No.Elms (Year)	No. Elms 1990	% Loss Cumulative	% Loss Per Year	Site[1] Type
Altona	1186 (1982)	1029	1.5	1.6	No River
Boissevain	3140 (1982)	3045	3.0	0.4	No River
Brandon	43649 (1981)	39004	10.6	1.2	River/B
Carman	2346 (1980)	1561	33.4	3.7	River
Crystal City	724 (1982)	556	23.2	2.9	River
Dauphin	9673 (1981)	9309	3.8	0.4	River/B
Deloraine	2137 (1982)	1989	6.9	0.8	No River
Gimli	822 (1978)	708	13.8	1.2	No River
Gladstone	1448 (1981)	1244	14.0	1.6	River/B
Killarney	1321 (1981)	1287	2.6	0.3	No River
Lac du Bonnet	549 (1977)	174	68.3	7.9	River
Manitou	1548 (1981)	1514	2.2	0.3	No River
Minnedosa	1740 (1981)	1707	1.9	0.3	River
Morden	5673 (1982)	4696	17.2	2.1	River/B
Morris	2840 (1981)	2162	23.6	2.7	River
Neepawa	2635 (1981)	2557	3.0	0.3	No River
Pilot Mound	1194 (1982)	1138	4.7	0.6	No River
Pine Falls	755 (1976)	205	72.8	8.3	River
Portage	5777 (1981)	3453	40.2	5.1	River
Rivers	901 (1981)	837	7.1	0.7	River
Selkirk	3656 (1975)	1039	71.5	7.6	River
Souris	4713 (1982)	3896	17.3	2.0	River/B
Steinbach	2317 (1981)	2015	13.0	1.4	No River
Ste. Anne	2907 (1979)	1013	65.1	8.4	River
Stonewall	2017 (1977)	1843	11.0	0.7	No River
Teulon	894 (1976)	519	41.9	3.6	No River
Virden	3803 (1981)	3732	1.9	0.2	No River
Winkler	6051 (1982)	5082	16.0	1.9	No River
	116,460	97,314	16.4	2.42	

1. River = River/creek running through or adjacent to community - no buffer zone.
   River/B = River/creek and adjacent buffer zone.
   No River = No river/creek with significant elm population

2. $$\% \text{ Loss per year} = 100 \left(1 - \left[\left(\frac{\text{Final Inventory}}{\text{Initial Inventory}} \right) \text{(Years Elapsed)} \right] \right)$$

Table 2: Comparison of elm loss per year in Cost Shared Agreement communities with and without watercourses and buffer Zones.

No River/Creek in community	1.02A	13
River/Creek - No Buffer Zone	4.76B	10
River/Creek - With Buffer Zones	1.46A	5

[1] Means followed by different letters are significantly different at the 5% level (Duncan's Multiple Range Test).

Table 3: American elm tree losses in the City of Winnipeg due to Dutch Elm Disease and hazard removals.

Year	No. Removals	% of Elms	Hazard Removals	Total Removals	% of Elms	No. of Elms[1] Remaining
1975	7	.003	---	7	.003	274,993
1976	74	.030	---	74	.030	274,919
1977	73	.030	--	73	.030	274,846
1978	53	.020	4,060	4,113	1.50	270,733
1979	93	.034	3,727	3,820	1.41	266,913
1980	315	.120	5,393	5,708	2.14	261,205
1981	757	.280	6,070	6,827	2.61	254,378
1982	1,100	.364	5,265	6,365	2.50	248,013
1983	1,569	.571	6,392	7,961	3.21	240,052
1984	1,866	.679	7,858	9,724	4.05	230,328
1985	2,219	.810	3,245	5,464	2.37	224,864
1986	1,290	.450	7,191	8,481	3.77	216,383
1987	1,644	.760	4,606	6,250	2.89	210,133
1988	1,426	.679	6,203	7,629	3.63	202,504
1989	3,859	1.906	6,875	10,734	5.30	191,770
1990	3,786	1.974	7,333	11,119	5.80[2]	180,651
Total	20,131		74,218	94,349	2.59[3]	

(M. Allen personal commun. 1991)

[1] Original number of elms was set at 275,000 based on survey.

[2] Since 1975, the American elm tree population has been reduced by 7.3% due to Dutch elm disease and by 27.0% due to hazard removal for a total of 34.4%.

[3] Mean.

Table 4: Summary of expenditures on Dutch elm disease by Manitoba Natural Resources 1981 - 1990 (thousands of dollars).

Year	Winnipeg CSA[1] $ (000's)	Rural CSA $ (000's)	Sanitation Program $ (000's)	Survey Program $ (000's)	CSA Program[2] $ (000's)
1981	350	100	500	70	50
1982	350	100	500	70	50
1983	350	100	500	80	50
1984	350	100	760	90	45
1985	350	100	825	90	45
1986	350	100	825	106	40
1987	350	100	791	106	40
1988	350	100	945	106	40
1989	700	100	1,145	125	40
1990	700	100	1,063	160	40
	4,200	1,000	7,854[3]y	1,003	440

EXPENDITURES (RURAL AND WPG.) 1981 - 1990 = $14,497,000 or $1,449,000 per year.

EXPENDITURES (RURAL ONLY) 1981 - 1990 = $10,297,000 or $1,029,700 per year.

[1] Cost Shared Agreement Program

[2] Costs in managing the province-wide Cost Shared Agreement program include all public advertising, Dutch elm disease literature, service calls, etc.

[3] Both sanitation and survey program costs from the period 1981 to 1983 are estimated as the Dutch elm disease budgets were included with other forest protection activities during this period.

Table 5. Costs to remove Dutch elm disease infected or hazard Elm trees in 1990 by Manitoba Natural Resources (MNR) sanitation crews.

Crew Type	Cost Per Tree $	+ Administration/ Capital Costs (Approximate)	Total $
Big Bucket[1]	104.09	20.00	124.09
Small Bucket[2]	94.00	20.00	114.60
DNR Labour Crews[3]	65.23	20.00	85.23
Community Services Crews[4]	36.71	20.00	56.71
Corrections Crews[5]	26.12	20.00	46.12

AVERAGE COST FOR ALL REMOVAL TYPES = $85.35

[1] Largest piece of removal equipment owned by MNR. Used on large trees around buildings, etc. High risk removal.

[2] Used for moderately sized trees around buildings, etc. High risk removal.

[3] DNR employed sanitation crews. Used on both private properties (around buildings, etc.) and within buffer zones. Moderate risk removals.

[4] Labour supplied by community services. Supervised by MNR staff. Low risk removals on public lands, buffer zones, riverbanks, etc.

[5] Labour supplied by Department of Corrections. Supervised and paid for by MNR. Low risk removal same as #4 above.