

# **Street Tree Resource Analysis (STRATUM) for the City of Kelowna**

**October 12, 2007**



## Executive Summary

Trees are an essential part of Kelowna's community infrastructure and are vital to community health. Municipal street trees conserve energy, filter airborne pollutants, remove atmospheric CO<sub>2</sub>, reduce stormwater runoff and increase the value of our homes. The Street Tree Resource Analysis Tool for Urban-Forest Managers (STRATUM), developed by the USDA Forest Service, is a street tree management and analysis tool that uses tree inventory data to quantify the monetary value of annual environmental and aesthetic benefits. The benefit-cost analysis provided by STRATUM contrasts the net expenditures associated with tree planting and stewardship with the many benefits provided by trees. This analysis indicates that for every \$1 spent managing Kelowna's street trees, the city gains \$3.32 in benefits.

Kelowna's STRATUM analysis is based on an existing inventory of the City's street trees which was compiled in 2005 and 2006. This report evaluates municipally owned trees located on the street public right-of-way only. The analysis provides information on the following aspects of the street tree resource: structure, function, value, and management needs. Ultimately, the results of the STRATUM analysis will enable managers to more effectively maintain and improve the health of the urban forest.

### Major Findings

| Feature                               | Measure                                |
|---------------------------------------|--|
| Total canopy cover                    | 3.3% of total street and sidewalk area |
| Number of municipal street trees      | 9,459                                  |
| Dominant tree species                 | green ash, Norway maple, honeylocust   |
| Structural condition                  | 35% good or better; 63% fair; 2% poor  |
| Total replacement value               | \$ 11,085,107                          |
| Energy savings                        | \$ 82,082                              |
| CO <sub>2</sub> reduction             | \$ 12,792 or 1,705,545 lbs             |
| Air quality improvement               | \$ 6,067                               |
| Stormwater runoff reduction           | \$ 67,609 or 6,259,698 gal             |
| Aesthetic, social, and other benefits | \$ 773,901                             |
| Total annual costs                    | \$ 283,698                             |
| Total net benefits                    | \$ 658,753                             |
| Benefit-cost ratio                    | 3.32                                   |

## **1.0 Introduction**

The Street Tree Resource Analysis Tool for Urban-Forest Managers (STRATUM) was developed by the USDA Forest Service as part of the i-Tree Software Suite. STRATUM utilizes a complete street tree inventory to calculate the following aspects of the street tree resource:

- Structure (species composition, diversity, age distribution, condition, etc.);
- Function (environmental and aesthetic benefits);
- Value (annual monetary value of benefits minus management costs); and
- Management Needs (recommended maintenance, stocking levels, sustainability)

In order to fully realize the many benefits of the urban forest Kelowna must first have a clear description of the present municipal street tree resource. STRATUM provides a detailed structural analysis of this component of the urban forest and systematically quantifies the benefits provided by the City's street trees. These benefits include energy conservation, air quality improvement, carbon dioxide reduction, stormwater runoff reduction, and property value increase.

Kelowna's STRATUM assessment contrasts the net expenditures associated with tree planting and stewardship with the many benefits provided by trees. In doing so the analysis provides essential baseline information for evaluating program cost-efficiency and alternative management strategies and will subsequently aid in the assessment and justification of the degree of funding and the type of management program needed for Kelowna's street tree resource. Hence, this study seeks to determine whether the accrued benefits of the City's street trees outweigh their management costs. The results will also aid Kelowna's resource managers in fostering support for management programs by demonstrating the value of trees to public quality of life. Ultimately, the STRATUM analysis will enable managers to more effectively maintain and improve the health of the urban forest.

## **2.0 Methodology**

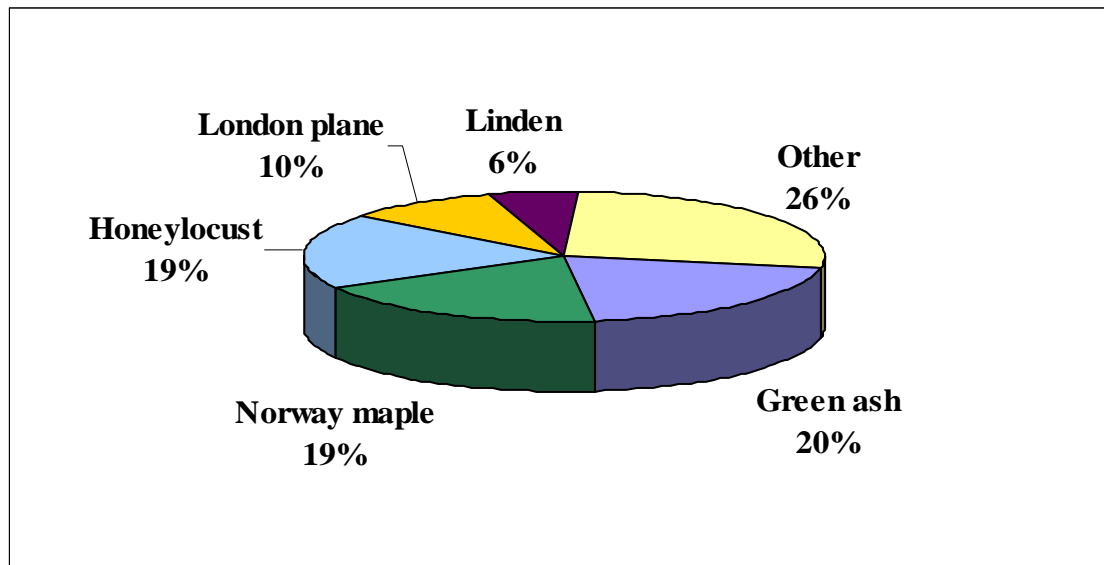
Kelowna's STRATUM analysis is based on an existing inventory of the City's street trees which was compiled in 2005 and 2006. Each tree was classified to the species level, diameter at breast height (DBH) was measured, and a rating of overall tree health was assigned. The inventory data were then manually reformatted to fit the STRATUM requirements before being imported into the computer program. Using regional growth models which account for specific topographic and climatic conditions in combination with region specific per capita values for benefits and costs, the program then produced a series of dynamic outputs which could be tailored to fit the desired report structure.

## 3.0 Results and Discussion

### 3.1 Resource Structural Analysis

#### *Species Composition and Diversity*

Determining the structural composition of the street tree population facilitates an understanding of species diversity and richness and allows for the creation of compositional targets for future planting. The dominant municipal street tree species in Kelowna are green ash (*Fraxinus pennsylvanica*, 20.3%), Norway maple (*Acer platanoides*, 18.9%), honeylocust (*Gleditsia triacanthos*, 18.7%), London plane (*Platanus acerifolia*, 9.5%), and little-leaf linden (*Tilia cordata*, 5.6%) (see Figure 1). While the large majority of street trees are of deciduous varieties, a number of conifer species are represented, including Austrian pine (*Pinus nigra*) and white spruce (*Picea glauca*). Species richness is relatively high, with over 70 species represented in the street tree resource (see Appendix A). However, given that the five dominant species account for nearly 75% of the total tree cover, species diversity is comparatively low.

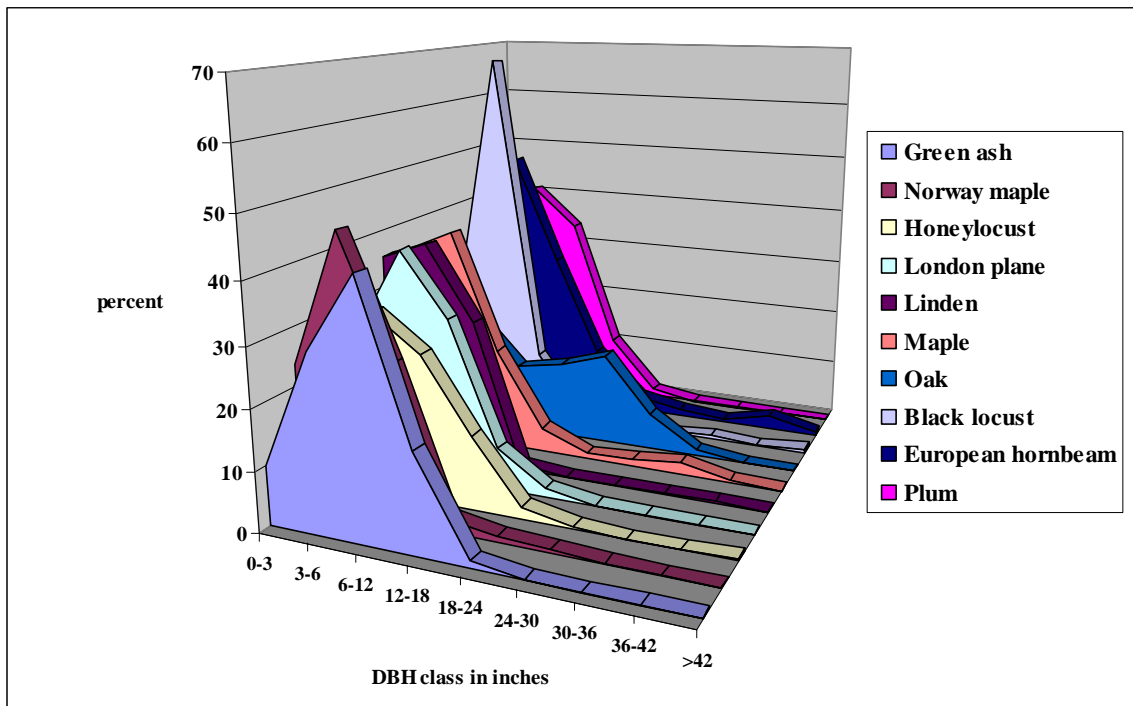


**Figure 1.** Species composition of street tree population

Drought, disease, and forest pests can have serious impacts on urban forests that are dominated by one species or genus. Insect pests and plant pathogens commonly attack only a single species or genus. Therefore, increasing species diversity will help to protect against widespread canopy loss in the event of such disturbances and will ensure that the condition of the entire community forest is not jeopardized. Yet, it is important to note that the hot, dry climate in Kelowna and the poor growing conditions typical of boulevard planting sites will restrict species selection choices. Poorly adapted trees are problematic as they result in short rotations and increased management costs. A healthy balance between a desire for diversity and the suitability of species must therefore be sought.

### Age Class Distribution

The age structure of Kelowna’s street tree population, represented by DBH class, is relatively close to an ideal distribution across all species. However, the mature tree component is underrepresented; few species maintain a healthy number of trees beyond the 12-18 inch DBH class (see Figure 2). The 3- 6 inch DBH class represents the highest proportion of the population (34.5%) followed by the 6-12 inch class (28.1%) and the 0-3 inch class (24.9%). Active tree planting initiatives in Kelowna have only become common in recent years, a trend which accounts for the existing age class distribution. An ideal age class distribution maintains a slightly higher proportion of new transplants to offset establishment–related mortality, while the percentage of older trees declines gradually with age (Richards 1982/1983).



**Figure 2.** Relative age distribution by DBH class for ten dominant street tree species

Mature trees are an essential component of the population as they provide the highest benefit-cost ratio. Large healthy trees greater than 30 inches in diameter can remove approximately 70 times more air pollution annually than small healthy trees less than 3 inches in diameter (Nowak, 1994). According to the Centre for Urban Forest Research (2003) immature, small stature trees deliver up to eight times fewer benefits than large mature trees.

### Canopy Cover

Street tree canopy cover represents only 0.17% or 81 acres of the total land area in Kelowna (48,640 acres). Of the 2, 453 acres of street and sidewalk area, municipal street trees cover 3.3%. While canopy coverage will increase in some areas as young, newly

planted trees mature, total canopy coverage may remain stagnant or even decline if space is not created in new and existing development plans. An increase in canopy cover will bring an increase in the benefits afforded by street trees such as decreased heat island effects. McPherson and Muchnick (2005) found a direct correlation between tree shade and better pavement performance. Thus, an increase in canopy cover will translate to direct economic savings as tree shade increases pavement durability and reduces maintenance costs.

### Structural Condition

Tree condition indicates both how well trees are managed as well as their relative performance given site-specific conditions. At the time of measurement approximately 35% of all street trees were in good or better condition, while 63% were in fair condition and less than 2% were in poor condition (see Figure 3). Of the citywide total, less than 1% of street trees were dead or dying. Species with the highest percentage of trees in good condition were London plane (*Platanus acerifolia*, 49.9%) honeylocust (*Gleditsia triacanthos*, 43.3%), and green ash (*Fraxinus pennsylvanica*, 40.7%). Given that all of these species exhibit a wide age class distribution and account for a large percent of the mature tree population, the results suggest that these species are relatively well suited to local climatic conditions. The only species exhibiting a significant proportion of trees in poor or worse condition was plum (*Prunus spp.*, 30.9%). However, as this species represents only 1.6% of the street tree population, the overall canopy cover is not significantly affected by the poor condition of these trees.

When analyzing tree condition it is important to consider relative age of each species in order to determine whether declining tree health is due to natural age progression or other unrelated factors. Furthermore, conclusions about the suitability of tree species should be suspended until trees have matured.

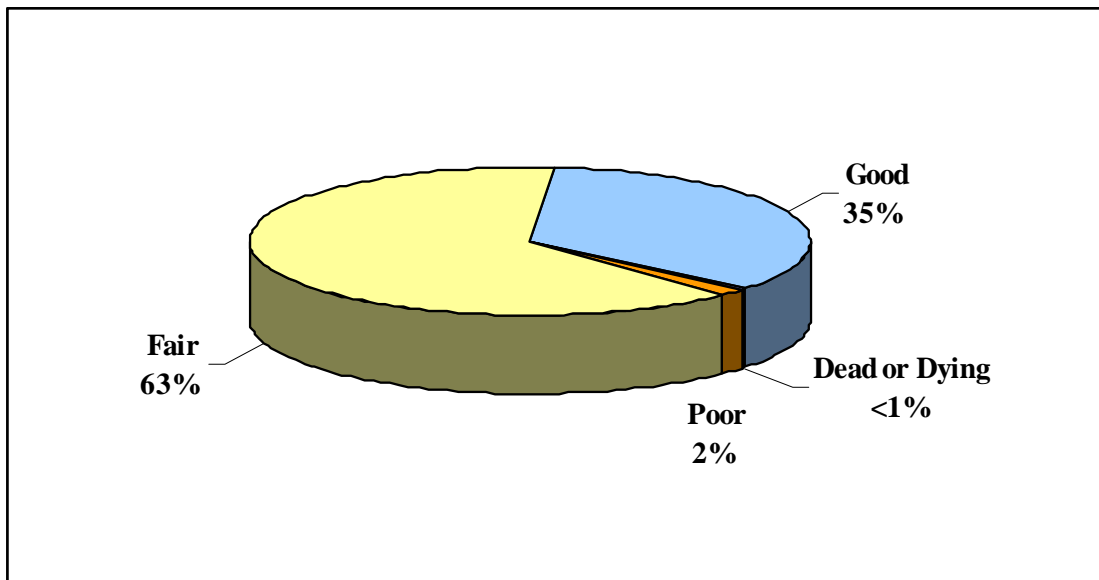


Figure 3. Structural condition of street tree population

## Replacement Value

Replacement values are estimates of the full cost of replacing trees in their current condition, should they be removed for any reason. These estimates are based on costs and species ratings provided in regional appraisal guides. The cost to replace all of Kelowna's street trees with trees of similar size, species, and condition is estimated at \$11,085,107. Although costs vary based on species and age class, the average replacement cost per tree is approximately \$1,172. The replacement value of the City's dominant tree species, green ash (*Fraxinus pennsylvanica*), is nearly \$3,000,000 (for a complete list of replacement values for all species see Appendix B). Thus, when viewed as a public asset Kelowna's street trees should be considered an extremely valuable resource.

Replacement value cannot be considered a complete measure of a trees value as it does not take into account the value of the annual benefits produced by street trees, such as pollution mitigation and energy conservation. *Annual value* is generally substantially lower than *replacement value* as the former describes only the benefits accrued over one year while the latter accounts for the historical investment in trees over their entire lifetime.

### 3.2 Annual Benefits

Reported benefits and costs are initial approximations as some benefits and costs are intangible or difficult to quantify. Also, limited knowledge about the physical processes at work and their interactions make estimates imprecise. Tree growth and mortality rates are highly variable and benefits and costs depend on the specific conditions at the site. Therefore, STRATUM provides a general accounting of the benefits street trees produce given limited knowledge of site-specific conditions. For a detailed description of the methods used to quantify and price these benefits visit: <http://www.fs.fed.us/psw/programs/cufr/>.

Five major annual benefits are assessed in STRATUM. Each benefit is quantified in terms of resource units which have an assigned dollar value. The total value of the annual benefits derived from the five variables described below is \$942,451 (see Table 1).

| <b>Benefits</b>       | <b>Total (\$)</b> | <b>\$/tree</b> | <b>\$/capita</b> |
|-----------------------|-------------------|----------------|------------------|
| Energy                | 82,082            | 8.68           | 0.76             |
| CO <sub>2</sub>       | 12,792            | 1.35           | 0.12             |
| Air Quality           | 6,081             | 0.64           | 0.06             |
| Stormwater            | 67,609            | 7.15           | 0.63             |
| Aesthetic/Other       | 773,901           | 81.82          | 7.17             |
| <b>Total Benefits</b> | <b>942,465</b>    | <b>99.64</b>   | <b>8.73</b>      |

**Table 1.** Total annual benefits of street tree population

### *Energy Savings*

The value assigned to the energy saving benefits of street trees describes the sum of energy savings due to reduced natural gas use in winter and reduced electricity use for air conditioning in summer. Urban trees can reduce summer temperatures by providing localized shade and wind speed reductions. Trees also ameliorate climate by transpiring water from their leaves, which has a cooling effect on the atmosphere. During the winter trees provide a windbreak and reduce air movement into buildings as well as conductive heat loss from buildings. Annually the shading and climate effects provided by Kelowna's municipal street trees produce an electrical and natural gas savings of 430.43 MWh (\$28,658) and 46,254.93 therms (\$53,424) respectively, for a total retail savings of \$82,082. This equates to a citywide average of \$8.68 per tree.

### *Carbon Dioxide Reduction*

Carbon dioxide reduction benefits are quantified as the sum of decreased atmospheric CO<sub>2</sub> due to sequestration by trees and reduced emissions from power plants as a result of reduced energy use. Trees reduce atmospheric CO<sub>2</sub> levels through photosynthetic uptake and subsequent carbon sequestration in woody biomass. By reducing the demand for heating and cooling, trees reduce the emissions associated with energy production. Kelowna's street trees sequester 853,552.88 lbs (\$6,401) of CO<sub>2</sub> annually. Avoided CO<sub>2</sub> emissions from power plants due to the energy savings provided by the municipal street trees total 951,143.38 lbs, valued at \$7,133. Thus the City's street trees provide a total annual net CO<sub>2</sub> reduction of 1,705,545.88 lbs or a net savings of \$12,791.

### *Air Quality Improvement*

Trees reduce harmful airborne pollutants and improve air quality by intercepting airborne particulate, absorbing gaseous pollutants, and by reducing emissions associated with power generation by curbing energy use. The value associated with this service is based on the sum of air pollutants (O<sub>3</sub>, NO<sub>2</sub>, SO<sub>2</sub>, PM<sub>10</sub>) deposited on tree surfaces in combination with reduced emissions (NO<sub>2</sub>, PM<sub>10</sub>, VOCs, SO<sub>2</sub>) from power plants due to reduced electricity. The air quality improvement benefits generated by the City's urban street trees are valued at \$6,067 annually. Trees in the 12-18 and 18-24 inch DBH classes provide the largest proportion of this benefit. These age classes are currently underrepresented in the total street tree population; as this component increases over time the associated air quality improvement benefits will increase as well.

### *Stormwater Runoff Reduction*

Healthy trees intercept and store rainfall, thus reducing the amount, and speed, of stormwater runoff. In addition tree cover improves water quality by filtering pollutants that eventually flow to receiving waters. Kelowna's street trees intercept 6,259,698 gal of rainfall each year. The value of reduced annual stormwater runoff due to street trees is \$67,609, or an average of \$7.15 per tree.

## *Aesthetic, Social, Property Value and Other Benefits*

The many psychological and social benefits of urban trees can be difficult to quantify. For example, assigning a monetary value to the beauty and comfort afforded by a tree is certainly problematic. However, several benefits can be captured in the value of the property on which a tree is located. Well maintained trees increase the “curb appeal”, which correlates to an increase in property value. Trees add texture and colour to a landscape and serve to soften the appearance of the built environment. In addition, tree lined streets beautify and neighbourhoods and stimulate a sense of well-being. The value assigned by STRATUM to the measurable aesthetic and other benefits of street trees is based on a measure of the tangible and intangible benefits reflected in the increases in property value which can be attributed to tree cover. For Kelowna’s street trees this value is \$773,901 or \$81.82 per tree on average.

### **3.3 Benefit-Cost Ratio**

In order to calculate of the annual management costs, the total net expenditures were summed based on all defined costs associated with street tree management. The total annual tree-related expenditures for Kelowna’s street tree resource are estimated to be \$283,698 (see Table 2). Given that the total benefits are estimated at \$942,451 the net annual benefits (benefits minus costs) of the municipal street trees are valued at \$658,753 or \$69.64 per tree. The benefit-cost ratio is therefore 3.32. Thus, the benefits of the municipal street trees far out-weight the costs.

|                     | <b>Total (\$)</b> | <b>\$/tree</b> | <b>\$/capita</b> |
|---------------------|-------------------|----------------|------------------|
| Total Benefits      | 942,465           | 99.64          | 8.73             |
| Total Costs         | 283,698           | 29.99          | 2.63             |
| Benefit-cost ratio  | 3.32              |                |                  |
| <b>Net Benefits</b> | <b>658,767</b>    | <b>69.64</b>   | <b>6.10</b>      |

**Table 2.** Total net benefits of street tree population

## **4.0 Conclusions**

The results of the STRATUM analysis highlight the need to protect and enhance Kelowna’s street tree resource. The City’s street trees are an extremely valuable public asset, providing \$942,465 in annual gross benefits, and \$658,767 in net benefits when expenditures are taken into account. The cost- benefit ratio of 3.32 highlights the operational efficiency of the street tree resource. In other words, the City’s street trees provide valuable services at a very cost-effective rate.

As Kelowna continues to develop at a rapid pace increasing demands will be placed on the urban forest. Careful maintenance and active expansion of the urban forest will therefore be required if these demands are to be met and the benefits of the City’s street

trees are to be enjoyed by present and future generations. Based on the results of this analysis the following recommendations can be made:

- Increase citywide canopy cover targets and stocking levels. At present, canopy cover of the total street and sidewalk area is less than 4%. A street and sidewalk canopy cover target of 10% is recommended. Increased canopy cover will reduce pavement maintenance costs.
- Increase the stocking levels of larger-growing species and maintain existing large-stature trees. Large trees provide more energy savings, store more carbon, filter larger volumes of air pollutants, have a greater stormwater reduction capacity, and do more to mitigate the heat island effect than small-stature trees.
- Increase planting around high traffic areas in order to reduce VOC's and other emissions associated with vehicle exhaust. In particular, effort should be made to increase the canopy cover in parking lots or locations with large paved surface areas.
- Increase species diversity while balancing the need to select suitably adapted species. Higher levels of species diversity will protect against mass canopy loss in the event of pest damage or disease.
- Improve the structural condition of the street tree resource by utilizing proper planting techniques, improving irrigation systems, making soil modifications when necessary at new planting sites, and providing adequate protection for root zones.
- Where possible expand the root protection zones beyond the drip-line in order to facilitate unrestricted growth. Given that a major obstacle to the provision of adequate root protection zones is a lack of sufficient space and soil volume for large-stature trees, consideration should be given to options such as wider boulevards and underground silva-cells during the development phase.
- Actively monitor and evaluate new plantings in order to determine species suitability and identify species which are most adaptable to difficult growing conditions.
- Utilize tree species with high benefit-cost ratios, such as London plane (*Platanus acerifolia*), in new planting initiatives. Future research should focus on identify species that satisfy this demand.
- Develop a public education program which encourages public cooperation and involvement in tree care and maintenance initiatives. Improved public awareness of the importance of urban trees may also serve to reduce tree damage caused by vandalism.

## Appendix A. Complete Species List

| Species                                 | 0-3          | 3-6          | 6-12         | 12-18      | 18-24      | 24-30     | 30-36     | 36-42     | >42       | Total        |
|---|--------------|--------------|--------------|------------|------------|-----------|-----------|-----------|-----------|--------------|
| <b>Broadleaf Deciduous Large (BDL)</b>  |              |              |              |            |            |           |           |           |           |              |
| Fraxinus pennsylvanica                  | 193          | 568          | 813          | 322        | 23         | 2         | 1         | 1         | 1         | 1,924        |
| Acer platanoides                        | 421          | 820          | 464          | 41         | 18         | 12        | 5         | 2         | 1         | 1,784        |
| Gleditsia triacanthos                   | 519          | 546          | 439          | 219        | 35         | 5         | 0         | 1         | 7         | 1,771        |
| Platanus acerifolia                     | 215          | 352          | 254          | 64         | 14         | 1         | 1         | 0         | 0         | 901          |
| Tilia species                           | 186          | 201          | 133          | 4          | 0          | 0         | 0         | 1         | 0         | 525          |
| Acer species                            | 81           | 90           | 41           | 10         | 2          | 3         | 5         | 1         | 0         | 233          |
| Quercus species                         | 55           | 38           | 22           | 25         | 30         | 12        | 2         | 0         | 0         | 184          |
| Robinia pseudoacacia                    | 29           | 104          | 18           | 1          | 0          | 0         | 1         | 0         | 1         | 154          |
| Acer rubrum                             | 76           | 22           | 15           | 2          | 0          | 0         | 0         | 0         | 0         | 115          |
| Acer x freemanii                        | 60           | 26           | 24           | 1          | 0          | 0         | 0         | 0         | 0         | 111          |
| Juglans nigra                           | 34           | 12           | 23           | 7          | 1          | 1         | 1         | 0         | 0         | 79           |
| Quercus macrocarpa                      | 70           | 0            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 70           |
| Ginkgo biloba                           | 60           | 0            | 0            | 1          | 0          | 0         | 0         | 0         | 0         | 61           |
| Quercus robur                           | 8            | 28           | 23           | 0          | 0          | 0         | 0         | 0         | 0         | 59           |
| Fraxinus americana                      | 0            | 4            | 5            | 11         | 6          | 2         | 0         | 1         | 0         | 29           |
| Fagus species                           | 2            | 24           | 0            | 1          | 0          | 1         | 0         | 0         | 0         | 28           |
| Quercus palustris                       | 0            | 0            | 12           | 7          | 0          | 0         | 0         | 0         | 0         | 19           |
| Ulmus species                           | 0            | 1            | 0            | 5          | 6          | 2         | 3         | 2         | 0         | 19           |
| Fagus sylvatica                         | 0            | 1            | 9            | 6          | 0          | 0         | 0         | 0         | 0         | 16           |
| Salix species                           | 0            | 1            | 6            | 4          | 1          | 1         | 0         | 0         | 1         | 14           |
| Acer saccharinum                        | 0            | 0            | 0            | 0          | 3          | 6         | 0         | 3         | 1         | 13           |
| Populus species                         | 3            | 5            | 2            | 0          | 0          | 0         | 0         | 0         | 1         | 11           |
| Morus rubra                             | 5            | 1            | 0            | 0          | 0          | 0         | 1         | 1         | 2         | 10           |
| Betula papyrifera                       | 1            | 4            | 1            | 1          | 0          | 2         | 0         | 0         | 0         | 9            |
| Liriodendron tulipifera                 | 2            | 2            | 1            | 1          | 1          | 0         | 1         | 0         | 0         | 8            |
| Quercus rubra                           | 1            | 0            | 4            | 2          | 0          | 0         | 0         | 0         | 0         | 7            |
| Ulmus pumila                            | 0            | 0            | 0            | 0          | 2          | 3         | 0         | 1         | 1         | 7            |
| Cercidiphyllum japonicum                | 3            | 2            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 5            |
| Populus nigra                           | 0            | 0            | 0            | 0          | 0          | 1         | 2         | 2         | 0         | 5            |
| Acer negundo                            | 0            | 1            | 0            | 2          | 0          | 0         | 0         | 0         | 1         | 4            |
| Betula pendula                          | 0            | 3            | 1            | 0          | 0          | 0         | 0         | 0         | 0         | 4            |
| Catalpa species                         | 0            | 1            | 0            | 0          | 0          | 0         | 1         | 0         | 0         | 2            |
| <b>Total</b>                            | <b>2,024</b> | <b>2,857</b> | <b>2,310</b> | <b>737</b> | <b>142</b> | <b>54</b> | <b>24</b> | <b>16</b> | <b>17</b> | <b>8,181</b> |
| <b>Broadleaf Deciduous Medium (BDM)</b> |              |              |              |            |            |           |           |           |           |              |
| Carpinus betulus                        | 7            | 72           | 43           | 16         | 4          | 2         | 1         | 4         | 1         | 150          |
| Pyrus species                           | 75           | 1            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 76           |
| Betula species                          | 6            | 25           | 20           | 8          | 4          | 1         | 0         | 0         | 0         | 64           |
| Zelkova serrata                         | 19           | 0            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 19           |
| Scientific Name?                        | 7            | 9            | 3            | 0          | 0          | 0         | 0         | 0         | 0         | 19           |
| Aesculus hippocastanum                  | 1            | 2            | 1            | 1          | 2          | 2         | 1         | 2         | 1         | 13           |
| Magnolia soulangiana                    | 10           | 3            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 13           |
| Ailanthus altissima                     | 0            | 0            | 3            | 0          | 0          | 1         | 1         | 2         | 0         | 7            |
| Koelreuteria paniculata                 | 6            | 0            | 0            | 0          | 0          | 0         | 0         | 0         | 1         | 7            |
| Populus tremuloides                     | 2            | 3            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 5            |
| Carpinus                                | 0            | 1            | 2            | 0          | 0          | 0         | 0         | 0         | 0         | 3            |
| Corylus americana                       | 0            | 0            | 0            | 2          | 0          | 0         | 0         | 0         | 0         | 2            |
| <b>Total</b>                            | <b>133</b>   | <b>116</b>   | <b>72</b>    | <b>27</b>  | <b>10</b>  | <b>6</b>  | <b>3</b>  | <b>8</b>  | <b>3</b>  | <b>378</b>   |

| Species                                 | 0-3          | 3-6          | 6-12         | 12-18      | 18-24      | 24-30     | 30-36     | 36-42     | >42       | Total        |
|---|--------------|--------------|--------------|------------|------------|-----------|-----------|-----------|-----------|--------------|
| <b>Broadleaf Deciduous Small (BDS)</b>  |              |              |              |            |            |           |           |           |           |              |
| Prunus species                          | 20           | 61           | 50           | 16         | 2          | 0         | 0         | 0         | 0         | 149          |
| Acer ginnala                            | 51           | 14           | 8            | 1          | 0          | 0         | 0         | 0         | 0         | 74           |
| Sorbus species                          | 10           | 12           | 23           | 12         | 6          | 4         | 1         | 0         | 0         | 68           |
| Crataegus species                       | 18           | 23           | 10           | 3          | 1          | 0         | 0         | 0         | 0         | 55           |
| Acer palmatum                           | 3            | 15           | 10           | 0          | 0          | 0         | 0         | 0         | 0         | 28           |
| Syringa reticulata                      | 17           | 2            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 19           |
| Rhus species                            | 0            | 1            | 7            | 2          | 2          | 0         | 0         | 0         | 0         | 12           |
| Malus species                           | 0            | 2            | 6            | 1          | 2          | 0         | 0         | 0         | 0         | 11           |
| Prunus virginiana                       | 0            | 4            | 5            | 0          | 0          | 0         | 0         | 0         | 0         | 9            |
| Sorbus aucuparia                        | 0            | 1            | 4            | 0          | 0          | 0         | 0         | 0         | 0         | 5            |
| Elaeagnus angustifolia                  | 0            | 1            | 1            | 1          | 0          | 0         | 0         | 0         | 0         | 3            |
| Misc.                                   | 0            | 0            | 0            | 1          | 0          | 0         | 0         | 0         | 0         | 1            |
| <b>Total</b>                            | <b>119</b>   | <b>136</b>   | <b>124</b>   | <b>37</b>  | <b>13</b>  | <b>4</b>  | <b>1</b>  | <b>0</b>  | <b>0</b>  | <b>434</b>   |
| <b>Broadleaf Evergreen Large (BEL)</b>  |              |              |              |            |            |           |           |           |           |              |
| Ginkgo biloba                           | 0            | 0            | 1            | 0          | 0          | 0         | 0         | 0         | 0         | 1            |
| <b>Total</b>                            | <b>0</b>     | <b>0</b>     | <b>1</b>     | <b>0</b>   | <b>0</b>   | <b>0</b>  | <b>0</b>  | <b>0</b>  | <b>0</b>  | <b>1</b>     |
| <b>Broadleaf Evergreen Medium (BEM)</b> |              |              |              |            |            |           |           |           |           |              |
| <b>Total</b>                            | <b>0</b>     | <b>0</b>     | <b>0</b>     | <b>0</b>   | <b>0</b>   | <b>0</b>  | <b>0</b>  | <b>0</b>  | <b>0</b>  | <b>0</b>     |
| <b>Broadleaf Evergreen Small (BES)</b>  |              |              |              |            |            |           |           |           |           |              |
| <b>Total</b>                            | <b>0</b>     | <b>0</b>     | <b>0</b>     | <b>0</b>   | <b>0</b>   | <b>0</b>  | <b>0</b>  | <b>0</b>  | <b>0</b>  | <b>0</b>     |
| <b>Conifer Evergreen Large (CEL)</b>    |              |              |              |            |            |           |           |           |           |              |
| Picea species                           | 23           | 45           | 20           | 12         | 0          | 2         | 0         | 0         | 0         | 102          |
| Picea glauca                            | 10           | 9            | 6            | 2          | 0          | 0         | 0         | 0         | 0         | 27           |
| Abies concolor                          | 0            | 3            | 8            | 6          | 3          | 1         | 0         | 0         | 0         | 21           |
| Pseudotsuga menziesii                   | 1            | 7            | 5            | 4          | 2          | 0         | 2         | 0         | 0         | 21           |
| Thuja species                           | 0            | 2            | 7            | 1          | 0          | 0         | 0         | 0         | 0         | 10           |
| Picea abies                             | 0            | 0            | 3            | 4          | 0          | 0         | 0         | 0         | 0         | 7            |
| Pinus strobus                           | 5            | 0            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 5            |
| Abies balsamea                          | 0            | 0            | 0            | 1          | 0          | 0         | 0         | 0         | 0         | 1            |
| Picea pungens                           | 0            | 0            | 1            | 0          | 0          | 0         | 0         | 0         | 0         | 1            |
| <b>Total</b>                            | <b>39</b>    | <b>66</b>    | <b>50</b>    | <b>30</b>  | <b>5</b>   | <b>3</b>  | <b>2</b>  | <b>0</b>  | <b>0</b>  | <b>195</b>   |
| <b>Conifer Evergreen Medium (CEM)</b>   |              |              |              |            |            |           |           |           |           |              |
| Pinus nigra                             | 26           | 0            | 49           | 14         | 0          | 0         | 0         | 0         | 0         | 89           |
| Pinus species                           | 7            | 26           | 33           | 12         | 2          | 4         | 0         | 2         | 1         | 87           |
| Pinus sylvestris                        | 0            | 0            | 12           | 9          | 0          | 0         | 0         | 0         | 0         | 21           |
| Thuja occidentalis                      | 0            | 3            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 3            |
| Metasequoia glyptostroboides            | 0            | 1            | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 1            |
| <b>Total</b>                            | <b>33</b>    | <b>30</b>    | <b>94</b>    | <b>35</b>  | <b>2</b>   | <b>4</b>  | <b>0</b>  | <b>2</b>  | <b>1</b>  | <b>201</b>   |
| <b>Conifer Evergreen Small (CES)</b>    |              |              |              |            |            |           |           |           |           |              |
| Pinus mugo                              | 2            | 34           | 5            | 1          | 0          | 0         | 0         | 0         | 0         | 42           |
| Juniperus species                       | 1            | 26           | 0            | 0          | 0          | 0         | 0         | 0         | 0         | 27           |
| <b>Total</b>                            | <b>3</b>     | <b>60</b>    | <b>5</b>     | <b>1</b>   | <b>0</b>   | <b>0</b>  | <b>0</b>  | <b>0</b>  | <b>0</b>  | <b>69</b>    |
| <b>Zone 0 Total</b>                     | <b>2,351</b> | <b>3,265</b> | <b>2,656</b> | <b>867</b> | <b>172</b> | <b>71</b> | <b>30</b> | <b>26</b> | <b>21</b> | <b>9,459</b> |

**Appendix B. Replacement Value of Trees by DBH Class (inches)**

| Species             | 0-3        | 3-6        | 6-12       | 12-18      | 18-24      | 24-30      | 30-36     | 36-42     | >42        | Total        | % of Total |
|---------------------|------------|------------|------------|------------|------------|------------|-----------|-----------|------------|--------------|------------|
| Green ash           | 46,398.80  | 257,552.98 | 933,317.94 | 885,709.19 | 112,172.62 | 14,515.40  | 10,503.00 | 19,621.26 | 15,463.04  | 2,295,254.25 | 20.71      |
| Norway maple        | 109,160.84 | 440,631.13 | 685,346.19 | 143,907.31 | 123,589.78 | 128,379.20 | 77,599.29 | 40,985.97 | 22,889.06  | 1,772,488.75 | 15.99      |
| Honeylocust         | 125,752.48 | 268,632.09 | 569,153.88 | 687,627.44 | 209,473.98 | 44,120.54  | 0.00      | 16,896.68 | 132,100.23 | 2,053,757.25 | 18.53      |
| London plane        | 52,325.21  | 176,028.77 | 297,675.63 | 156,771.95 | 62,524.89  | 7,257.70   | 10,503.00 | 0.00      | 0.00       | 763,087.13   | 6.88       |
| Basswood            | 44,582.69  | 93,515.29  | 185,487.89 | 11,554.36  | 0.00       | 0.00       | 0.00      | 17,138.44 | 0.00       | 352,278.69   | 3.18       |
| Maple               | 19,413.67  | 39,263.35  | 47,361.19  | 24,711.84  | 10,792.99  | 21,773.10  | 57,135.50 | 13,850.30 | 0.00       | 234,301.92   | 2.11       |
| Oak                 | 14,155.30  | 19,233.89  | 29,147.24  | 82,649.39  | 182,506.42 | 123,287.20 | 29,472.39 | 0.00      | 0.00       | 480,451.81   | 4.33       |
| Black locust        | 6,811.13   | 40,865.68  | 17,577.34  | 2,372.34   | 0.00       | 0.00       | 10,503.00 | 0.00      | 15,463.04  | 93,592.53    | 0.84       |
| European hornbeam   | 2,011.76   | 43,394.30  | 59,886.31  | 55,040.25  | 26,202.78  | 21,396.54  | 15,882.73 | 81,971.94 | 22,889.06  | 328,675.66   | 2.97       |
| Plum                | 3,687.06   | 23,196.98  | 62,180.96  | 50,308.22  | 13,364.42  | 0.00       | 0.00      | 0.00      | 0.00       | 152,737.64   | 1.38       |
| Red maple           | 17,815.91  | 9,387.42   | 15,722.41  | 5,227.80   | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 48,153.54    | 0.43       |
| Freeman maple       | 14,345.26  | 11,489.39  | 26,301.48  | 2,662.63   | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 54,798.76    | 0.49       |
| Spruce              | 5,258.46   | 18,749.74  | 21,157.91  | 31,433.46  | 0.00       | 14,515.40  | 0.00      | 0.00      | 0.00       | 91,114.97    | 0.82       |
| Austrian pine       | 3,547.97   | 0.00       | 74,842.75  | 56,035.38  | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 134,426.09   | 1.21       |
| Pine                | 1,296.02   | 9,022.53   | 36,233.09  | 39,928.46  | 14,157.77  | 36,160.58  | 0.00      | 31,443.40 | 17,564.83  | 185,806.70   | 1.68       |
| Black walnut        | 9,212.93   | 6,168.75   | 34,662.37  | 20,266.67  | 5,487.47   | 8,943.78   | 13,264.17 | 0.00      | 0.00       | 98,006.15    | 0.88       |
| Pear                | 23,019.19  | 696.08     | 0.00       | 0.00       | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 23,715.26    | 0.21       |
| Amur maple          | 7,634.59   | 7,559.42   | 13,172.61  | 3,013.88   | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 31,380.51    | 0.28       |
| Bur oak             | 17,466.63  | 0.00       | 0.00       | 0.00       | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 17,466.63    | 0.16       |
| Mountain ash        | 2,203.53   | 5,798.90   | 29,769.78  | 41,705.11  | 40,080.66  | 43,812.09  | 16,294.16 | 0.00      | 0.00       | 179,664.23   | 1.62       |
| Birch               | 1,284.55   | 10,340.38  | 22,780.32  | 21,628.31  | 22,760.59  | 8,419.75   | 0.00      | 0.00      | 0.00       | 87,213.89    | 0.79       |
| Ginkgo              | 17,707.08  | 0.00       | 0.00       | 3,116.08   | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 20,823.15    | 0.19       |
| English oak         | 1,624.14   | 13,758.35  | 31,571.86  | 0.00       | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 46,954.35    | 0.42       |
| Hawthorn            | 3,603.23   | 10,824.98  | 13,163.49  | 11,640.69  | 7,469.48   | 0.00       | 0.00      | 0.00      | 0.00       | 46,701.87    | 0.42       |
| Sweet mountain pine | 123.63     | 9,264.85   | 3,315.59   | 1,848.13   | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 14,552.20    | 0.13       |
| White ash           | 0.00       | 1,621.65   | 5,557.22   | 30,635.00  | 31,772.02  | 20,885.92  | 0.00      | 16,546.84 | 0.00       | 107,018.65   | 0.97       |
| Japanese Maple      | 511.79     | 6,564.80   | 13,389.71  | 0.00       | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 20,466.29    | 0.18       |
| Beech               | 623.89     | 14,910.52  | 0.00       | 4,802.90   | 0.00       | 15,171.83  | 0.00      | 0.00      | 0.00       | 35,509.13    | 0.32       |
| Juniper             | 100.24     | 8,290.88   | 0.00       | 0.00       | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 8,391.11     | 0.08       |
| White spruce        | 2,398.29   | 4,619.59   | 7,486.65   | 6,721.62   | 0.00       | 0.00       | 0.00      | 0.00      | 0.00       | 21,226.15    | 0.19       |
| White fir           | 0.00       | 1,270.07   | 9,783.77   | 19,444.42  | 21,413.55  | 10,302.91  | 0.00      | 0.00      | 0.00       | 62,214.72    | 0.56       |

**Appendix A. Replacement Value of Trees by DBH Class (inches)**

|                       |          |          |           |           |           |           |           |           |           |            |      |
|-----------------------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|------|
| Scotch pine           | 0.00     | 0.00     | 12,982.16 | 31,269.65 | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 44,251.81  | 0.40 |
| Douglas fir           | 131.17   | 2,557.37 | 4,920.76  | 7,723.84  | 8,631.03  | 0.00      | 26,060.04 | 0.00      | 0.00      | 50,024.20  | 0.45 |
| Japanese Zelkova      | 4,410.39 | 0.00     | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 4,410.39   | 0.04 |
| unknown               | 1,624.88 | 4,422.14 | 4,098.68  | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 10,145.71  | 0.09 |
| Pin oak               | 0.00     | 0.00     | 16,913.91 | 26,394.49 | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 43,308.40  | 0.39 |
| Japanese tree lilac   | 3,353.01 | 959.45   | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 4,312.46   | 0.04 |
| Elm                   | 0.00     | 393.31   | 0.00      | 11,067.02 | 31,808.94 | 19,529.59 | 40,679.45 | 43,799.48 | 0.00      | 147,277.81 | 1.33 |
| European beech        | 0.00     | 590.52   | 20,397.13 | 40,824.61 | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 61,812.25  | 0.56 |
| Willow                | 0.00     | 284.16   | 4,150.53  | 6,631.63  | 1,916.07  | 5,039.44  | 0.00      | 0.00      | 10,718.99 | 28,740.82  | 0.26 |
| Silver maple          | 0.00     | 0.00     | 0.00      | 0.00      | 12,381.78 | 51,516.11 | 0.00      | 49,224.56 | 14,338.74 | 127,461.19 | 1.15 |
| Horsechestnut         | 328.85   | 1,392.16 | 1,366.23  | 2,121.34  | 7,642.48  | 21,396.54 | 22,500.54 | 41,669.07 | 32,426.16 | 130,843.35 | 1.18 |
| Saucer magnolia       | 2,514.70 | 1,474.05 | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 3,988.75   | 0.04 |
| Sumac                 | 0.00     | 437.65   | 8,859.52  | 6,950.85  | 18,926.98 | 0.00      | 0.00      | 0.00      | 0.00      | 35,175.01  | 0.32 |
| Crabapple             | 0.00     | 875.31   | 8,078.46  | 3,475.43  | 13,360.22 | 0.00      | 0.00      | 0.00      | 0.00      | 25,789.41  | 0.23 |
| Cottonwood            | 503.29   | 1,788.69 | 1,550.64  | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 12,305.41 | 16,148.02  | 0.15 |
| Red mulberry          | 1,510.03 | 549.18   | 0.00      | 0.00      | 0.00      | 0.00      | 6,627.47  | 8,541.02  | 19,071.08 | 36,298.78  | 0.33 |
| Red cedar             | 0.00     | 887.90   | 6,021.73  | 3,121.66  | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 10,031.29  | 0.09 |
| Paper birch           | 177.18   | 1,843.09 | 1,070.34  | 2,703.54  | 0.00      | 16,839.49 | 0.00      | 0.00      | 0.00      | 22,633.64  | 0.20 |
| Common chokecherry    | 0.00     | 1,759.01 | 6,705.35  | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 8,464.36   | 0.08 |
| Tulip tree            | 457.10   | 905.76   | 1,714.14  | 3,004.61  | 5,696.54  | 0.00      | 13,772.34 | 0.00      | 0.00      | 25,550.49  | 0.23 |
| Tree of Heaven        | 0.00     | 0.00     | 4,098.68  | 0.00      | 0.00      | 10,698.27 | 15,519.86 | 40,985.97 | 0.00      | 71,302.78  | 0.64 |
| Goldenrain            | 1,392.76 | 0.00     | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 22,889.06 | 24,281.81  | 0.22 |
| Norway spruce         | 0.00     | 0.00     | 3,453.94  | 8,426.49  | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 11,880.43  | 0.11 |
| Northern red oak      | - 309.34 | 0.00     | 33,896.95 | 69,517.64 | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 103,105.24 | 0.93 |
| Siberian elm          | 0.00     | 0.00     | 0.00      | 0.00      | 9,914.48  | 24,243.63 | 0.00      | 15,458.64 | 10,645.75 | 60,262.50  | 0.54 |
| Katsura               | 639.54   | 775.32   | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 1,414.86   | 0.01 |
| Eastern white pine    | 673.69   | 0.00     | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 673.69     | 0.01 |
| Black poplar          | 0.00     | 0.00     | 0.00      | 0.00      | 0.00      | 5,774.63  | 16,715.24 | 22,043.59 | 0.00      | 44,533.45  | 0.40 |
| Quaking aspen         | 319.54   | 917.43   | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 1,236.97   | 0.01 |
| European mountain ash | 0.00     | 437.65   | 4,842.61  | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 5,280.26   | 0.05 |
| Boxelder              | 0.00     | 358.54   | 0.00      | 3,957.37  | 0.00      | 0.00      | 0.00      | 0.00      | 12,664.97 | 16,980.89  | 0.15 |
| European white birch  | 0.00     | 1,218.79 | 1,143.34  | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 2,362.13   | 0.02 |
| Hornbeam              | 0.00     | 491.35   | 2,732.46  | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 0.00      | 3,223.81   | 0.03 |

**Appendix A. Replacement Value of Trees by DBH Class (inches)**

|                       |                   |                     |                     |                     |                   |                   |                   |                   |                   |                      |               |
|-----------------------|-------------------|---------------------|---------------------|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|----------------------|---------------|
| Russian olive         | 0.00              | 437.65              | 1,338.97            | 3,475.43            | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 5,252.05             | 0.05          |
| White cedar           | 0.00              | 1,023.27            | 0.00                | 0.00                | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 1,023.27             | 0.01          |
| Corylus               | 0.00              | 0.00                | 0.00                | 6,880.03            | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 6,880.03             | 0.06          |
| Catalpa               | 0.00              | 438.99              | 0.00                | 0.00                | 0.00              | 0.00              | 13,917.03         | 0.00              | 0.00              | 14,356.02            | 0.13          |
| Common Name?          | 0.00              | 0.00                | 0.00                | 3,475.43            | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 3,475.43             | 0.03          |
| Ginkgo                | 0.00              | 0.00                | 2,114.87            | 0.00                | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 2,114.87             | 0.02          |
| Dawn redwood          | 0.00              | 483.21              | 0.00                | 0.00                | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 483.21               | 0.00          |
| Balsam fir            | 0.00              | 0.00                | 0.00                | 4,591.04            | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 4,591.04             | 0.04          |
| Blue spruce           | 0.00              | 0.00                | 1,184.60            | 0.00                | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 1,184.60             | 0.01          |
| <b>Citywide total</b> | <b>571,803.05</b> | <b>1,580,354.71</b> | <b>3,399,681.57</b> | <b>2,646,374.91</b> | <b>994,047.93</b> | <b>673,979.63</b> | <b>396,949.22</b> | <b>460,177.15</b> | <b>361,429.42</b> | <b>11,084,797.50</b> | <b>100.00</b> |

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