CITY OF KELOWNA

MEMORANDUM

Date: February 8, 2008

File No.: 6300-00

To: City Manager

From: Urban Forestry Supervisor

Subject: Kelowna Vegetation Studies and Policy Implications

RECOMMENDATION

THAT Council receive for information the February 8, 2008 report from the Urban Forestry Supervisor on Kelowna Vegetation Studies and Policy Implications;

AND THAT Council direct staff to formulate tree canopy goals for the City, through input from the community and stakeholders;

AND THAT Council direct staff to identify potential policy changes through the Official Community Plan update and related updates to the 20 Year Servicing and Financial Plan, Development Subdivision and Servicing Bylaws and other related bylaws or policies, to implement directions reflected in this report;

AND FURTHER THAT any additional City financial requirements be submitted through the normal budgeting process.

BACKGROUND

A growing body of research demonstrates that trees and other vegetation provide important "ecosystem services", providing benefits such as clean water and air, climate regulation, cultural and recreational benefits, and supporting wildlife and biodiversity. As vegetation or "green infrastructure" is lost due to development, pine beetle or other disturbances, some of these ecosystem services may need to be replaced through increased investment in "grey infrastructure", i.e. storm sewer and drainage improvements, water treatment facilities, or upgraded power plants.

The U.S. Forest Service has developed two computer models that help to quantify the structure and benefits provided by urban vegetation:

- The Urban Forest Effects (**UFORE**) model is used to help quantify urban ecosystems, in terms of structure, environmental effects and values. UFORE analyses have been performed in many cities and areas throughout the world. In 2007, Kelowna became the fourth city in Canada to complete a UFORE analysis, along with Toronto, Oakville and Calgary. Last summer, a Master's student from the University of Toronto collected data from 150 randomly located public and private plots throughout the City of Kelowna, and data were subsequently analyzed with the assistance of the US Forest Service in Syracuse, NY. A portion of this work was funded through a grant from Tree Canada.

- The Street Tree Resource Analysis Tool for Urban-Forest Managers (**STRATUM**) is a similar model which deals only with street trees. Using the results from the Parks Division's 2006 street tree inventory, information about Kelowna's 9,500 street trees were entered into the STRATUM model, as well as information on management activities and costs. Outputs from the model included information on species composition and benefits, as well as a benefit to cost ratio for Kelowna's street trees.

These models were recently used to help determine the current state of Kelowna's urban vegetation and to help guide the development of future policy and goals for management of the urban forest.

BENEFITS OF TREES AND URBAN VEGETATION

Some of the benefits produced by urban vegetation, supported by peer-reviewed research, include:

- **Air Quality:** Air pollution can be a serious threat to human health. Although some tree species produce their own low levels of "pollutants" (Volatile Organic Compounds or VOC's), trees produce many net benefits overall for air quality improvement.
- **Mitigating Climate Change:** Increasing canopy cover of the urban forest is an effective way to mitigate the "urban heat island effect" where urban temperatures are 1 to 6°C warmer than nearby rural areas. Every 1% increase in canopy cover results in maximum mid-day air temperature reductions of 0.04° to 0.2°C.
- **Energy Conservation:** Properly placed trees near buildings can significantly lower summer temperatures and act as a winter windbreak, reducing the need for cooling or heating. By reducing energy usage, additional carbon emissions from power plants are also avoided.
- **Water Conservation:** Trees intercept significant amounts of precipitation, reducing the costs associated with storm water management as well as reducing runoff which carries salts, fertilizers, and other pollutants into creeks and lakes.
- **Social Benefits:** Studies have found that a view of trees was associated with benefits such as a faster recovery time after surgery, improved mental health and well-being, and well-maintained urban trees have even been found to be associated with significantly reduced crime levels and violence.
- **Economic Benefits:** Numerous studies have documented a significant increase in property values and rental income, as well as increased willingness to pay more for goods and services, associated with attractive tree cover and landscaping.

UFORE – RESULTS AND DISCUSSION

Attached to this report is the draft UFORE report. Key findings are summarized in Table 1 found at the back of this report.

The top three species in Kelowna, Douglas-fir, ponderosa pine and apple, comprise 76% of the total tree canopy, indicating a low level of diversity overall. Most of these species are located on natural, undeveloped lands, or on agricultural lands, demonstrating the high importance of these areas for providing ecosystem services.

Mountain pine beetle is a major and immediate threat to Kelowna's urban forest. The model estimates that Kelowna has over 600,000 ponderosa pine trees, with a replacement value of $181 million. According to the provincial government, we are likely to lose about 80% of these trees (primarily mature trees) due to pine beetle. Urban development is another threat to the urban forest, since development can significantly reduce the growing space for vegetation unless mitigation strategies are put in place to help retain or replace vegetation.

Kelowna's current tree canopy is about 13%, on average, although another 27% of Kelowna's land area could be planted. Areas with the highest tree cover include vacant / wildland (23%), and agriculture and rural lands (15%), while the lowest cover (3%) occurs on land zoned as commercial / industrial and transportation. American Forests, a North American research and education group, recommends a goal of 25% tree cover for cities in arid regions of western North America, such as Kelowna.

STRATUM – RESULTS AND DISCUSSION

Kelowna's tree and urbanized park tree inventory contains almost 20,000 trees, with about half (9,500) of those trees located on streets. Attached to this report is the draft STRATUM report summarizing the benefits of Kelowna's street trees. Some key findings are summarized in Table 2.

Kelowna's street trees also produce significant environmental and social benefits, although canopy cover is again quite low (Table 2). The overall Benefit to Cost ratio is 3.3, indicating that for every $1 spent maintaining or managing Kelowna's street trees, another $3.32 is gained in community benefits.

CONCLUSIONS

Both UFORE and STRATUM demonstrate that Kelowna's urban trees produce significant benefits for the citizens of Kelowna. An appropriate tree canopy goal for Kelowna needs to be determined, however, the existing tree cover of 13% is fairly low compared to the recommended goal of 25% (American Forests).

Kelowna has experienced very rapid growth over the last several years and is expecting to see up to 20% growth over the next decade, with single family housing development occurring primarily in forested and undeveloped natural areas of the city (Kelowna Planning Department). As the City continues to grow, increasing pressure will be placed on the existing forest cover to provide essential environmental, economic, and social services. Yet at the current pace of expansion a reduction in canopy cover will likely be seen as forested areas are cleared for residential developments. Agricultural lands are also a very significant contributor to the urban forest, and the loss of orchards or land-use changes in these areas could have broader impacts on air quality and other ecosystem services.

Other threats to the urban forest include natural disturbances such as pine beetle and wildfire, or management activities, e.g. thinning to prevent wildfire.

City policies, bylaws and education programs could have a significant role to play in preserving, enhancing and increasing Kelowna's urban forest cover in the future.

RECOMMENDATIONS:

Strategies to enhance the ecological services of urban trees in Kelowna include:

- Aiming for species, size and age diversity (reduces the impact of pests);
- Increasing the number of healthy trees;
- Maximizing the use of low VOC (pollutant) emitting trees to improve air quality;
- Sustaining and increasing existing tree cover;
- Sustaining large, healthy trees (greater benefits per tree);

- Using long-lived species (reduces carbon emissions from planting and removal activities);
- Using low-maintenance trees (reduces fossil fuel requirements and costs for maintaining vegetation);
- Planting trees in energy-conserving locations;
- Planting trees as part of transportation corridors (extends the life of streets, reduces carbon dioxide emissions, and reduces stormwater runoff from impervious surfaces) and parking lots (cooling effect and reduction of VOC emissions from parked vehicles);
- Planting trees in polluted areas;
- Avoiding pollution sensitive tree species;
- Utilizing evergreen trees for particulate matter reduction (year-round removal of pollutants).

The first step in this process should be to arrive at a reasonable tree cover goal, in consultation with the community. We propose to solicit comments from the public and other stakeholders. A plan would then be developed to attain this goal, through the use of a variety of tools, including:

- **Policies, Bylaws, Plans:** Kelowna's bylaws and policies (e.g. Subdivision bylaw, Zoning, Hillside Development Guidelines, OCP, etc.) should aim to preserve existing vegetation and increase levels of appropriate vegetation where possible. FireSmart and CPTED (Crime Prevention Through Environmental Design) guidelines will also be important to consider, to avoid creating other hazards. Comprehensive Urban Forest and Street Tree Management plans should be developed to help guide this process.

- **Public Education and Incentives:** While some opportunities exist to increase tree cover on public lands, private landowners are the most critical partners in this process. Public education and incentives could be used to help encourage property owners to retain and plant more trees, to plant the appropriate types of trees, and to properly maintain trees so that they produce maximal public benefits for many years to come.

- **Monitoring:** Periodic monitoring and progress review will be required to determine if goals are being achieved and to make adjustments as necessary.

These recommendations will help to preserve and improve the quality of Kelowna's urban forest and improve the liveability of Kelowna, and are also compatible with Kelowna's Sustainability Objectives.

INTERNAL CIRCULATION TO:

- Planning Department (Current and Long-Range Planning)
- Environment Division
- Fire Department
- Works and Utilities
- Transportation
- Engineering
- Finance
- Sustainability Working Group

FINANCIAL/BUDGETARY CONSIDERATIONS:

Future budgetary requests related to this initiative are unknown at this time, but will be handled through the normal budgeting process.

Table 1. Summary of results, 2007 UFORE analysis for City of Kelowna.

Feature	Measure
Major tree species, by % canopy cover	▪ Douglas-fir (33%) ▪ Ponderosa pine (24%) ▪ Apple (19%) ▪ Other (24%)
Estimated number of trees in Kelowna	3.3 million
Total estimated replacement value of Kelowna's trees	$ 1.1 billion
Total carbon stored in Kelowna's trees	126,900 metric tonnes
Carbon sequestered annually by Kelowna's urban forest	7,500 metric tonnes
Susceptibility to exotic and native pests (% susceptible host by leaf area)	▪ Asian longhorned beetle (34%) ▪ Pine beetle (24%) ▪ Gypsy moth (23%) ▪ Dutch elm disease (4%) ▪ Emerald ash borer (2%)
Pollution removed annually by urban forest and value of the removal	195 tonnes* ($1.1 million)
Volatile Organic Compounds (VOC's) produced annually by trees	43 tonnes
Ozone index score**	94 (out of 100)
Annual energy savings due to trees and annual carbon emission reductions due to power savings	$ 19.4 million / 1,800 tonnes carbon
Average vegetation cover, plantable space and impervious surfaces	▪ Trees - 12.8% ▪ Shrubs - 9.1% ▪ Grass - 42.3% ▪ Plantable space - 27.3% ▪ Buildings & impervious - 12%

* An emissions inventory (Environment Canada 2000) estimates that about 26,932 metric tonnes of pollutants are produced annually in the Central Okanagan, suggesting that Kelowna's trees remove about 1% of the total produced.
** A perfect score of 100 represents forest composition where all species have the maximum effect on reducing ozone (lowest possible VOC emissions).

Table 2. Summary of key findings, STRATUM analysis of Kelowna's street trees.

Feature	Measure
Total canopy cover	3.3% of total street and sidewalk area
Number of municipal street trees (1996 data)	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_2 reduction	$ 12,792 or 1,705,545 lbs
Air quality improvement benefits	$ 6,067
Stormwater runoff reduction benefits	$ 67,609 or 6,259,698 gallons
Aesthetic, social, and other benefits	$ 773,901
Total benefits	$ 942,451
Total annual costs	$ 283,698
Benefit-cost ratio	3.32

CONSIDERATIONS THAT WERE NOT APPLICABLE TO THIS REPORT:

LEGAL/STATUTORY AUTHORITY:
LEGAL/STATUTORY PROCEDURAL REQUIREMENTS:
EXISTING POLICY:
PERSONNEL IMPLICATIONS:
TECHNICAL REQUIREMENTS:
EXTERNAL AGENCY/PUBLIC COMMENTS:
ALTERNATE RECOMMENDATION:

Submitted by:

I. Wilson, Urban Forestry Supervisor

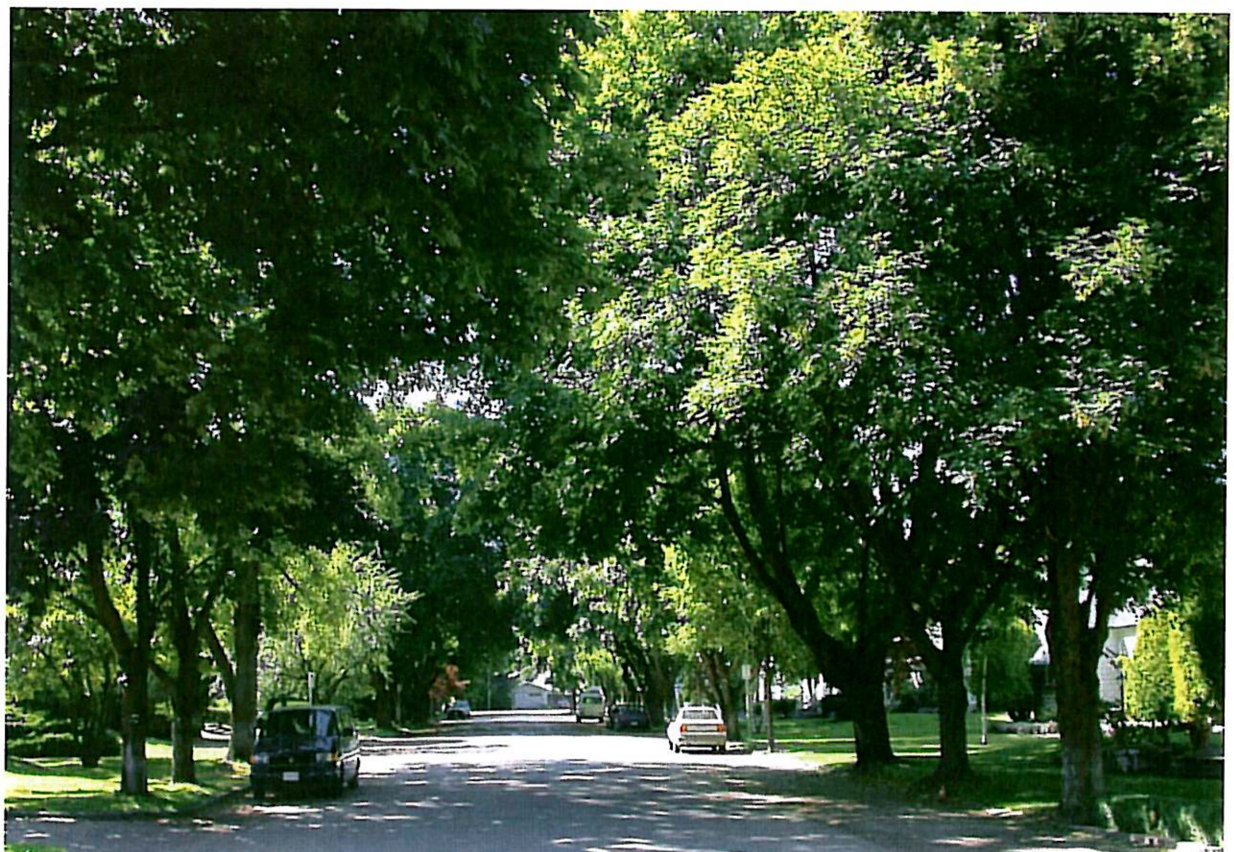
Approved for Inclusion:

Cc: David Graham, Director of Recreation Parks and Cultural Services
John Vos, Director of Works and Utilities
Joe Creron, Parks Manager
Ron Westlake, Transportation Manager
Mark Watt, Environment and Solid Waste Manager
Signe Bagh, Manager, Policy Research and Strategic Planning
Shelley Gambacourt, Current Planning Supervisor
Rene Blanleil, Fire Chief
Steve Muenz, Development Engineering Manager
Paul Macklem, Director of Finance
Sustainability Working Group (c/o Signe Bagh)

Attachments: City of Kelowna Draft UFORE Report; City of Kelowna Draft STRATUM Report

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_2, 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_2 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.

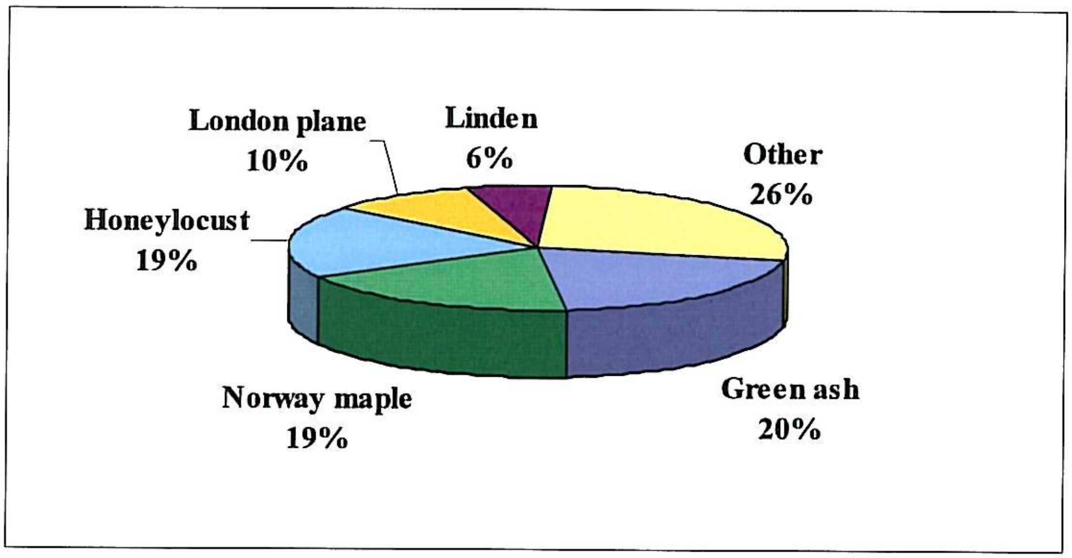


Figure 1. Species composition of street tree population

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).

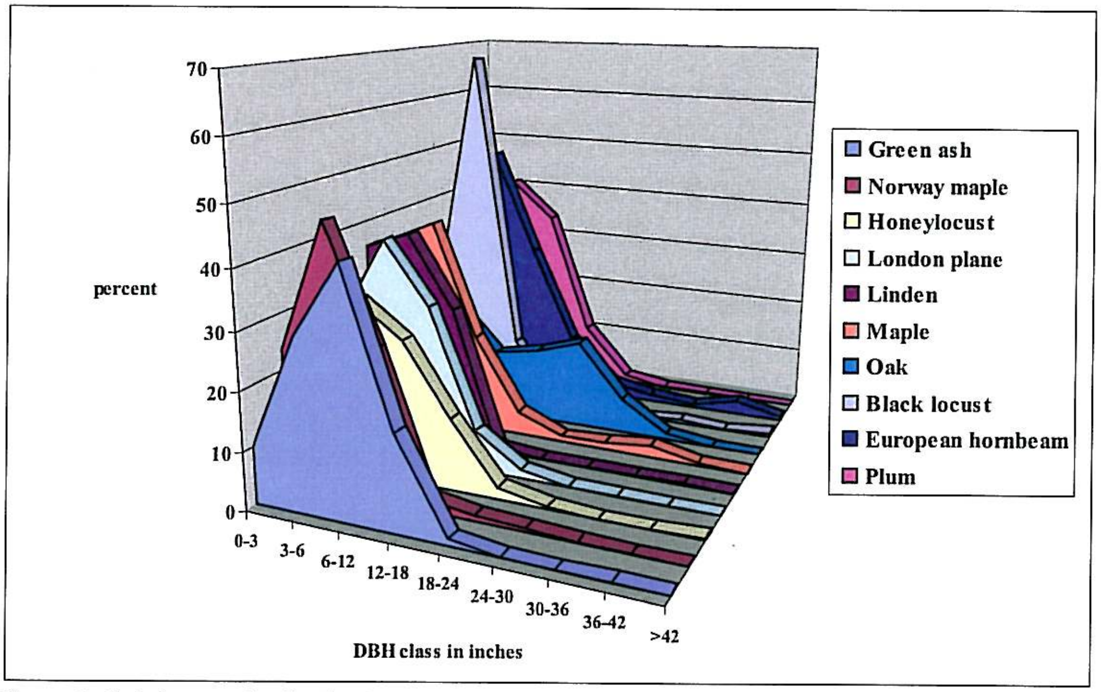


Figure 2. Relative age distribution by DBH class for ten dominant street tree species

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 that 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.

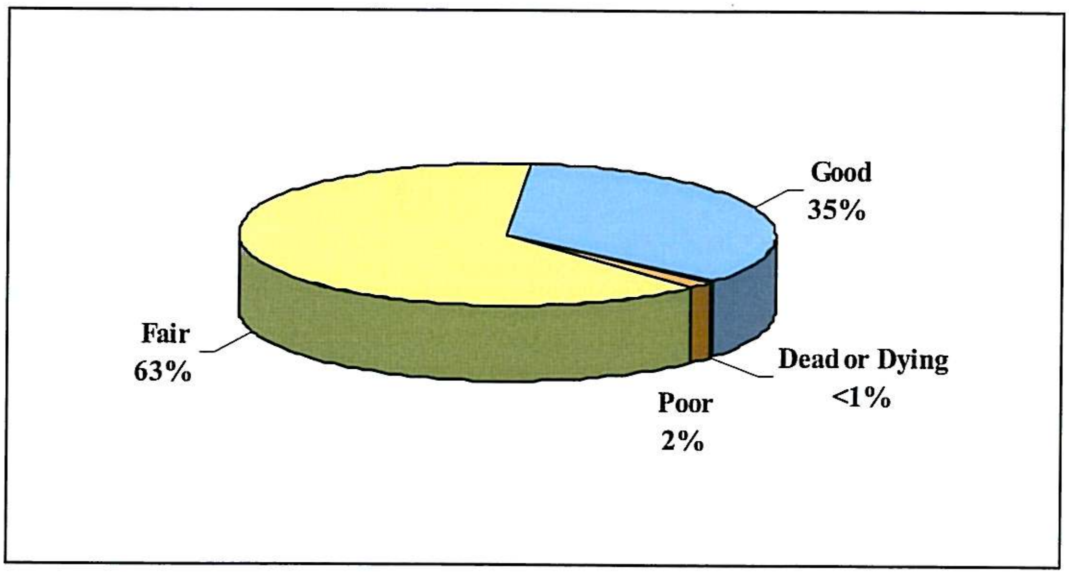


Figure 3. Structural condition of street tree population

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).

Benefits	Total ($)	$/tree	$/capita
Energy	82,082	8.68	0.76
CO_2	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
Total Benefits	**942,465**	**99.64**	**8.73**

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 CO2 due to sequestration by trees and reduced emissions from power plants as a result reduced energy use. Trees reduce atmospheric CO_2 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_2 annually. Avoided CO_2 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_2 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_3, NO_2, SO_2, PM_{10}) deposited on tree surfaces in combination with reduced emissions (NO_2, PM_{10}, VOCs, SO_2) 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 $773,901or $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.

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

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
Broadleaf Deciduous Large (BDL)										
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
Total	**2,024**	**2,857**	**2,310**	**737**	**142**	**54**	**24**	**16**	**17**	**8,181**

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Broadleaf Deciduous Medium (BDM)										
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
Total	**133**	**116**	**72**	**27**	**10**	**6**	**3**	**8**	**3**	**378**

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Broadleaf Deciduous Small (BDS)										
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
Total	**119**	**136**	**124**	**37**	**13**	**4**	**1**	**0**	**0**	**434**
Broadleaf Evergreen Large (BEL)										
Ginkgo biloba	0	0	1	0	0	0	0	0	0	1
Total	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Broadleaf Evergreen Medium (BEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Broadleaf Evergreen Small (BES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Conifer Evergreen Large (CEL)										
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
Total	**39**	**66**	**50**	**30**	**5**	**3**	**2**	**0**	**0**	**195**
Conifer Evergreen Medium (CEM)										
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
Total	**33**	**30**	**94**	**35**	**2**	**4**	**0**	**2**	**1**	**201**
Conifer Evergreen Small (CES)										
Pinus mugo	2	34	5	1	0	0	0	0	0	42
Juniperus species	1	26	0	0	0	0	0	0	0	27
Total	**3**	**60**	**5**	**1**	**0**	**0**	**0**	**0**	**0**	**69**
Zone 0 Total	**2,351**	**3,265**	**2,656**	**867**	**172**	**71**	**30**	**26**	**21**	**9,459**

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
Citywide total	**571,803.05**	**1,580,354.71**	**3,399,681.57**	**2,646,374.91**	**994,047.93**	**673,979.63**	**396,949.22**	**460,177.15**	**361,429.42**	**11,084,797.50**	**100.00**

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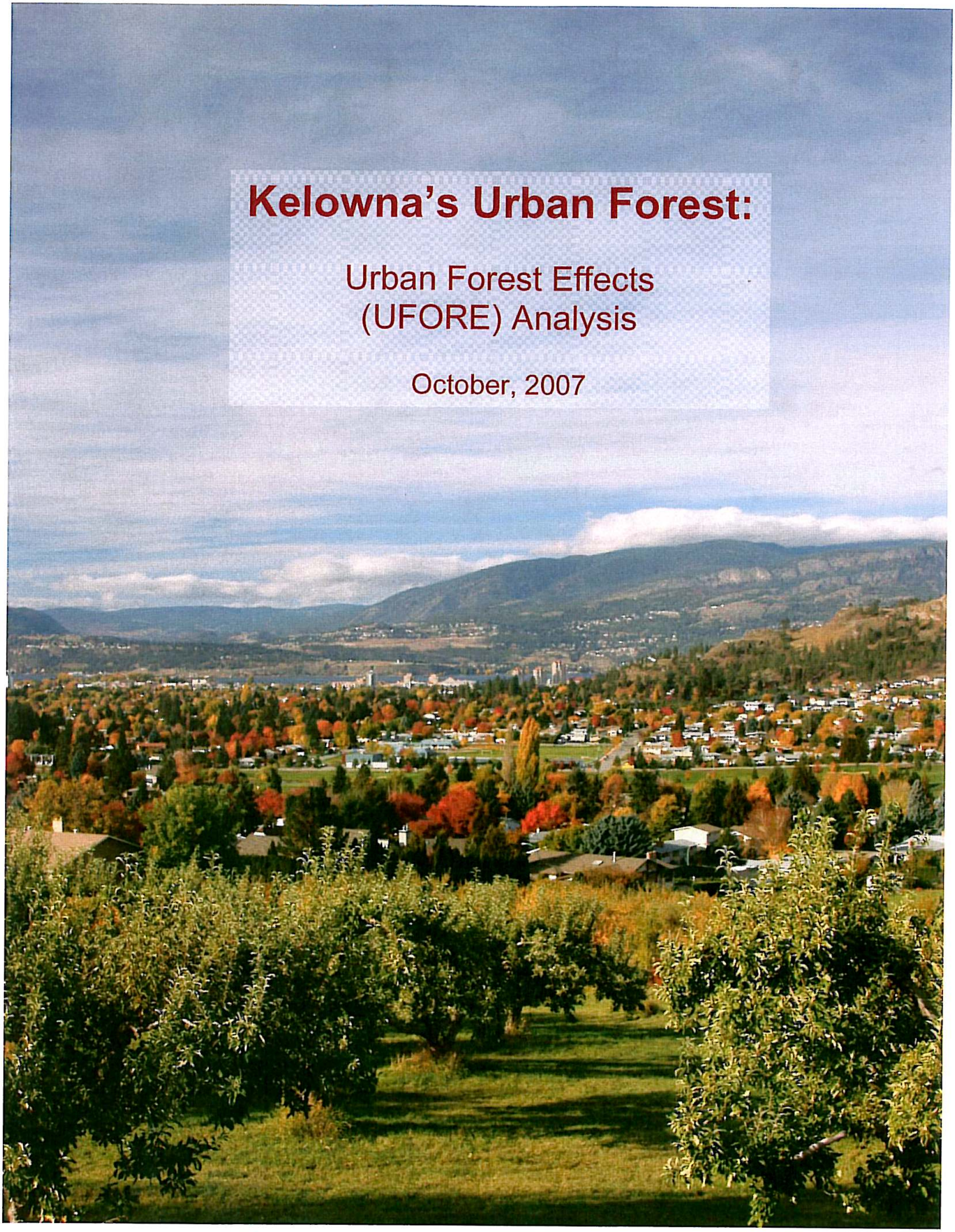
Kelowna's Urban Forest:

Urban Forest Effects (UFORE) Analysis

October, 2007



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Executive Summary

A growing body of research demonstrates that trees and other vegetation provide important "ecosystem services", providing benefits such as clean water and air, climate regulation, cultural and recreational benefits, and supporting wildlife and biodiversity. The Urban Forest Effects (UFORE) model was developed by the US Forest Service to help quantify some of the key benefits provided by urban vegetation.

During the summer of 2007, 150 randomly located plots were assessed by a ground crew to characterize the structure of Kelowna's urban vegetation. These data were analyzed in the UFORE model, to produce the following key findings:

Feature	Measure
Major tree species, by % canopy cover	▪ Douglas-fir (33%) ▪ Ponderosa pine (24%) ▪ Apple (19%) ▪ Other (24%)
Estimated number of trees in Kelowna	3.3 million
Total replacement value of Kelowna's trees	$ 1.1 billion
Total carbon stored in Kelowna's trees	126,900 metric tonnes
Carbon sequestered annually by Kelowna's urban forest	7,500 metric tonnes
Susceptibility to exotic and native pests (% susceptible host by leaf area)	▪ Asian longhorned beetle (34%) ▪ Pine beetle (24%) ▪ Gypsy moth (23%) ▪ Dutch elm disease (4%) ▪ Emerald ash borer (1.6%)
Pollution removed annually by urban forest and value of the removal	195 tonnes ($1.1 million)
Volatile Organic Compounds (VOC's) produced annually by trees	43 tonnes
Ozone index score*	94 (out of 100)
Annual energy savings due to trees and annual carbon emission reductions due to power savings	$ 19.4 million / 1,800 tonnes carbon
Average vegetation cover, plantable space and impervious surfaces	▪ Trees - 12.8% ▪ Shrubs - 9.1% ▪ Grass - 42.3% ▪ Plantable space - 27.3% ▪ Buildings, impervious – 12%

* A perfect score of 100 represents forest composition where all species have the maximum effect on reducing ozone (lowest possible VOC emissions).

The top three species in Kelowna, Douglas-fir, ponderosa pine and apple, comprise 76% of the total tree canopy, indicating a low level of diversity overall. Most of these species are located on natural, undeveloped lands, or on agricultural lands, indicating the high importance of these areas for providing ecosystem services. As some of these areas are developed in the future, some ecosystem services will be lost and may have to be replaced through investments in stormwater, water purification or other "grey infrastructure" improvements.

The major threats to Kelowna's urban forest in the next decade are mountain pine beetle, development, and wildfire. The model estimates that Kelowna has about 606,000 ponderosa pine trees, with a replacement value of $181 million. According to the provincial government, we are likely to lose about 80% of these trees (primarily mature trees) due to pine beetle.

Kelowna's current tree canopy is only about 13%, on average, although there is another 27% plantable space. Areas with the highest tree cover include vacant / wildland (23%), and agriculture and rural lands (15%), while the lowest cover (3%) occurs on land zoned as commercial / industrial and transportation.

Strategies to enhance the ecological services of urban trees in Kelowna include:

1) Aiming for species, size and age diversity (reduces the impact of pests);
2) Increasing the number of healthy trees;
3) Maximizing the use of low VOC emitting trees to improve air quality;
4) Sustaining and increasing existing tree cover;
5) Sustaining large, healthy trees (greater benefits per tree);
6) Using long-lived species (reduces carbon emissions from planting and removal activities);
7) Using low-maintenance trees (reduces fossil fuel requirements for maintaining vegetation);
8) Planting trees in energy-conserving locations;
9) Planting trees as part of transportation corridors (extends the life of streets, reduces carbon dioxide emissions) and parking lots (cooling effect and reduction of VOC emissions from parked vehicles);
10) Planting trees in polluted areas;
11) Avoiding pollution sensitive tree species;
12) Utilizing evergreen trees for particulate matter reduction (year-round removal of pollutants).

1.0 Introduction

The Urban Forest Effects (UFORE) computer model was developed by the USDA Forest Service as part of the i-Tree Software Suite. UFORE is designed to use standardized field data from randomly located plots throughout a community, along with hourly air pollution and meteorological data, to quantify the structure and function of the urban forest. The model calculates the following information:

- Urban forest structure (e.g. species composition, tree density, tree health, leaf area, leaf and tree biomass, species diversity, etc.);
- Hourly pollution removal by the urban forest and associated percent improvement in air quality (pollution removal is calculated for ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter (PM_{10}));
- Total carbon stored and net carbon sequestered annually by the urban forest;
- Effect of trees on building energy use for heating and cooling as well as the subsequent associated carbon dioxide emissions reductions; and
- Compensatory value of the urban forest, **as well as** the value for air pollution removal and carbon storage and sequestration

To date, UFORE analyses have been completed by three other Canadian cities: Toronto, Calgary, and Oakville. Kelowna is therefore the first community in British Columbia to successfully complete a UFORE analysis.

1.1 Rationale

Over the next decade and beyond, Kelowna's urban forest is likely to face three major threats: pine beetle, development, and wildfire.

The mountain pine beetle epidemic continues to spread throughout British Columbia's interior, affecting over 8 million hectares of pine forest in the central and southern regions of the province. According to projections by the Ministry of Forests and Range the infestation will likely continue to until 2018 and will kill approximately 80% of provincial pine volume in the central and southern Interior (MoFR 2007). Consequently, Kelowna is likely to see a dramatic change in forest structure and composition as both the western pine beetle (*Dendroctonus brevicomis)* and mountain pine beetle (*Dendroctonus ponderosae)* continue to attack native ponderosa pine (*Pinus pondersa*) as well as exotic pines planted in landscapes. Significant mortality in Kelowna's mature pine forests has been observed in recent months and as a result local canopy cover is quickly declining, a trend which is likely to continue in the future. The UFORE analysis will not only aid in the estimation of the potential impact of the pine beetle epidemic, it will also identify and prioritize areas for future tree planting initiatives. In addition, the study will provide a baseline for future research.

The 2006 Census revealed that Kelowna's population grew by 10.6% from 2001 to 2006, thus making it one of the fastest growing municipalities in the province. The growth rate between 2007-2017 is projected the City Planning Department to be 25%, *with most of the growth occurring in areas that are currently forested or natural areas.* As the city continues to grow, increasing pressure will be placed on the existing forest cover to provide essential environmental, economic, and social services. In particular, demand for air pollution abatement and local climate change mitigation will surely increase. Yet at the current pace of expansion a reduction in canopy cover will be seen as forested areas are cleared for residential developments.

Significant areas of forest have already been lost due to 2003 wildfires in the southwest corner of the city and in the adjacent Crown forests. Catastrophic wildfire continues to be a major threat to Kelowna's forests although management activities over the last several years have helped to lower the risk to forests, people and property. However, the desire to retain trees and vegetation will also have to be balanced with the need to thin and remove vegetation in order to mitigate the risk of wildfire.

By quantifying the current structure of Kelowna's urban forest, the UFORE project will help guide future canopy cover targets which will optimize the potential benefits of urban trees. Ultimately the results of the UFORE analysis will assist in the future management and planning of the community's green infrastructure.

1.2 The Role of the Urban Forest

Trees greatly impact the quality of urban life by providing a number of valuable environmental, economic, and recreational services. The urban forest directly benefits the community by improving local air quality, reducing energy consumption, increasing land values and local tax bases, enhancing public safety, conserving water resources, and reducing soil erosion. In addition, city trees beautify the landscape and provide invaluable psychological benefits to urban dwellers.

1.2.1 Air Quality

Urban air pollution can have direct impacts on human health. By significantly reducing the amount of airborne pollutants trees can mitigate the potential health problems associated with poor air quality. Ground level ozone (O_3) and airborne particulate matter (PM_{10}) are two pollutants which pose a significant threat to human health. Ozone is not emitted directly but rather is created by chemical reactions between oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) such as gasoline fumes, in sunlight. Trees also produce their own VOC's, with some species producing higher levels than others. However, in the absence of nitrogen oxides (which come almost entirely from human sources), these VOC's can actually reduce ozone concentrations. Because VOC emissions are temperature dependent and trees generally lower air temperatures, increased tree cover can lower overall VOC emissions and, consequently, ozone levels in urban areas. Thus, urban trees, particularly species which emit low levels of VOCs, are a viable strategy to reduce urban O_3 levels (Cardelino and Chameides 1990; Nowak et al. 2000a).

Air borne particulates consist of microscopic solids or liquid droplets, often originating from smoke and diesel soot, which form in the air from oxides of nitrogen and sulphur. These harmful pollutants are problematic as they can irritate and damage lung tissue. Trees reduce the amount of particulate matter by intercepting and storing large airborne particulate on outer leaf surfaces, rough branches and bark surfaces (Nowak et al. 2006). In addition, trees improve air quality by binding or dissolving water soluble pollutants onto moist leaf surfaces. Other gaseous air pollutants, such as carbon monoxide and sulphur dioxide, are removed primarily by leaf stomatal uptake (Smith 1990).

Urban forests also play an integral role in the mitigation of high levels of atmospheric carbon dioxide (CO_2), an important greenhouse gas which contributes to global warming. Anthropogenic production of CO_2 is most notably a result of fossil fuel combustion and large-scale deforestation. Trees reduce atmospheric CO_2 levels through photosynthetic uptake and subsequent carbon sequestration in woody biomass. Furthermore, trees which are adjacent to buildings can reduce the demand for heating and air conditioning through their moderating influence on solar insolation, wind speed, and air temperature. This in turn reduces the emissions associated with fossil fuel combustion which are a direct result of heating and the provision of electric power for cooling (Simpson and McPherson, 2000).

1.2.2 Regional Climate Change

The "urban heat island" phenomenon describes urban and suburban temperatures that are 1 to 6°C warmer than nearby rural areas. Urban heat islands form as cities replace natural land cover with pavement, buildings, and other infrastructure. Increasing the canopy cover of the urban forest is an effective way to mitigate the heat island effect. The shade generated by tree canopies reduces the amount of solar radiation transmitted to underlying surfaces. Consequently, cooler surfaces lessen the heat island effect by reducing heat transfer to the surrounding air. Furthermore, evapotranspiration can result in peak summer temperature reductions of 1° to 5°C in urban areas

(EPA 2007). Every 1% increase in canopy cover results in maximum mid-day air temperature reductions of 0.04° to 0.2°C (Simpson 1998).

1.2.3 Energy Conservation

Trees can reduce summer temperatures substantially 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. Thus, the effective placement of a tree or shrub can efficiently lower building temperatures and decrease the demand for cooling. Simpson and McPherson (1999) report that shade from two large trees planted on the west side of a house and one on the east side can save up to 30% of a typical residence's annual air conditioning costs. During winter months trees which are properly placed to create windbreaks can also decrease heating requirements and produce savings of up to 25% on winter heating costs (Heisler 1986).

1.2.4 Water Conservation

When stormwater hits impervious surfaces common in urban areas the water is heated and various pollutants, including lawn fertilizers and oils on roadways, are picked up by the runoff. Water quality problems then arise when large volumes of heated and polluted stormwater flow into receiving waters, posing threats to temperature sensitive species as well as providing conditions for algal blooms and nutrient imbalances. Tree cover helps intercept rainwater, thus reducing the amount, and speed, of stormwater in addition to filtering pollutants that eventually flow to receiving waters (Kollin 2006). A portion of the intercepted water evaporates back into the atmosphere while the remaining water soaks into the ground thereby reducing the total amount of runoff that must be managed in urban areas. Thus, the costs associated with stormwater management are much lower when significant urban canopy cover is maintained.

1.2.5 Social Benefits

Although more difficult to quantify the urban forest provides a variety of important social benefits. Urban trees have been found to significantly reduce crime levels. For example apartment buildings with high levels of greenery had 52% fewer crimes than those without trees (Kuo and Sullivan 2001). Furthermore, hospital patients were found to recover from major surgery more quickly and with fewer complications when provided with a view of trees (Ulrich 1984). Trees and urban parks also improve mental health and over all well-being by conveying a sense of calm and beauty as well as facilitating relaxation and outdoor activity. In addition, trees can offer screening, or reduce noise pollution by absorbing unwanted sound.

Trees and attractive landscaping are an important part of the "liveability" of a city and improving quality of life.

1.2.6 Economic Benefits

Trees and attractive landscaping are known to raise property values; there is also a link between proximity to green space and higher property values (Table 1). Furthermore, research shows that shoppers in well-landscaped business districts are willing to pay more for both parking and goods and services (Wolf 1999) and commercial properties can be receive higher rent with attractive landscaping (Table 1).

Table 1. Summary of research on price increase due to trees and landscaping (from Wolf 2007).

Price Increase	Condition
2%	Single mature yard tree (>9" diameter)
3-5%	Trees in front yard landscaping
4.9%	Multi-family unit with view of forested open spaces
7%	Rental rates for properties with quality landscaping
8%	House with a park view
6-9%	Good tree cover in a neighbourhood
9-12%	Increased consumer spending in forested business districts
10%	Inner-city home within ¼ mile (400 m) of a park
10-15%	Mature trees in high-income neighbourhoods
18%	Building lots with substantial mature tree cover
19%	Home adjacent to a passive park area
22%	Tree-covered undeveloped acreage
32%	Residential development adjacent to greenbelt
19-35%	Lots bordering suburban wooded preserves
37%	Open land that is 2/3 wooded

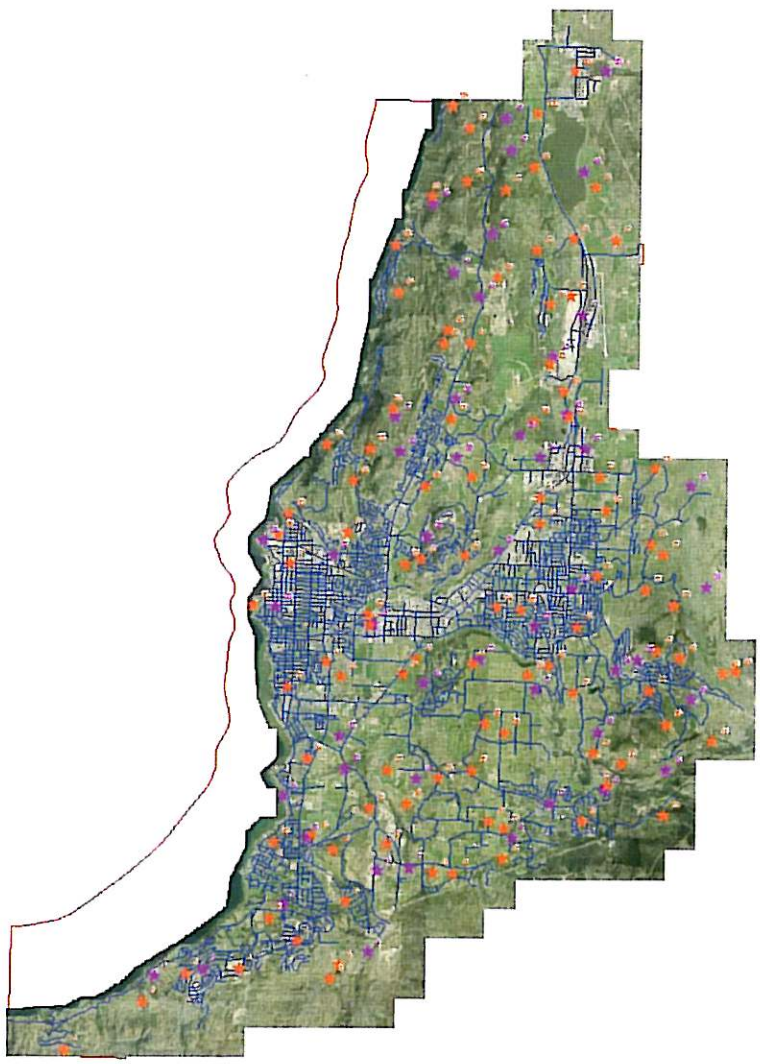
2.0 Methodology

2.1 Plot Selection

Kelowna's UFORE analysis was based on a randomized sampling scheme in which 150 circular plots (10 meters in radius) were positioned at randomly selected locations, on a grid, throughout the 48,640 ha study area (Figure 1). In order to provide a more confident estimate of the population the number of plots was increased from the original 100 to 150. Although a higher sample size would yield more accurate results, the number of plots surveyed provided an acceptable level of standard error when weighed against the time and financial constraints associated with additional field data collection.

Each individual plot was identified in the City's mapping system and a high resolution orthophoto image was produced with the plot centre and site identification markings clearly indicated. GPS coordinates were also generated in order to facilitate accurate navigation to plot centre (see Appendix 1). Prior to entry, private property owners were contacted by telephone or through written communication in order to obtain permission to access their property. In the instance that a phone number could not obtained the field crew requested permission to access the property in person. If permission was not granted or access was restricted due to physical / topographic barriers, the field crew recorded measurements from the nearest representative location (Appendix 1).

Fig. 1. Plot locations in the City of Kelowna (red and purple stars).



2.2 *Data Collection*

Field data collection was conducted by a two member field crew during the summer leaf-on season of 2007. At each plot the present land-use was determined (e.g. residential) and detailed vegetation information was recorded in accordance with the UFORE manual specifications. Variables measured included ground cover types, shrub characteristics, foliage parameters and individual attributes of tree species. Specific tree measurements included diameter at breast height (DBH), height, crown width, percent canopy missing, crown dieback, and distance and direction to residential buildings. For a complete description of variables visit the UFORE manual at http://www.fs.fed.us/ne/syracuse/Tools/UFORE.htm.

2.3 *Data Analysis*

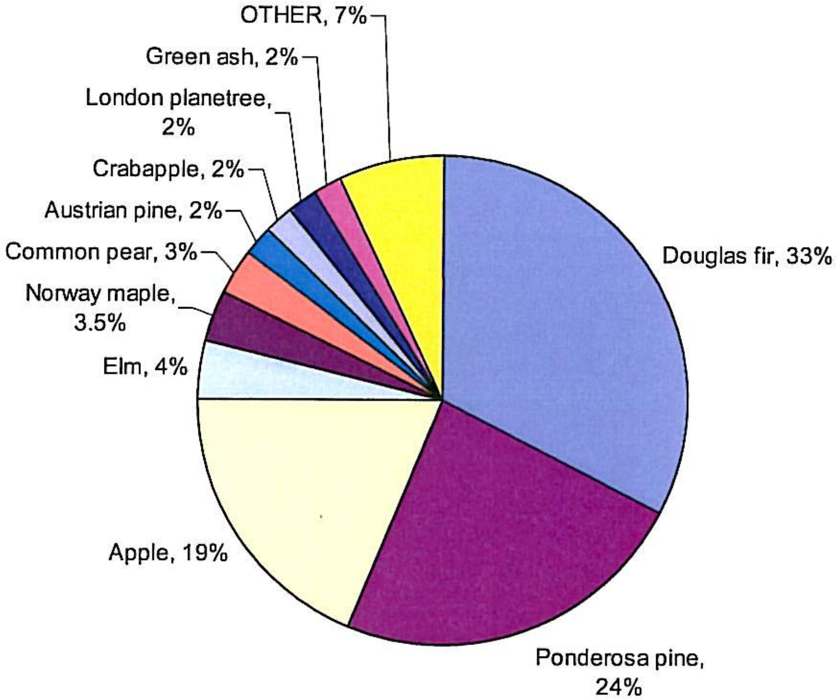
Data were input into excel spreadsheets in accordance with UFORE manual specifications, which were then submitted to the USDA Forest Service in Syracuse for analysis. Data processing was completed by the Forest Service and relevant output files were then forwarded to the Kelowna Parks Department for full interpretation.

3.0 Results and Discussion

3.1 *Urban Forest Structure*

Figure 2 illustrates the top ten tree species in Kelowna, by percentage canopy cover. Kelowna's urban forest has low diversity overall, as 75% of the total tree canopy is comprised of only three species, Douglas-fir, ponderosa pine and apple. An urban forest with higher diversity is more resilient to pest outbreaks, drought, disease, climate change or other disturbances. However, the ability to increase diversity in Kelowna's natural areas will be very limited due to the hot, dry climate. There are opportunities, however, to increase diversity in the urbanized areas where non-native species can be grown. These species will have to be chosen carefully, however, to avoid invasive species as well as species with high water (irrigation) requirements.

Fig. 2. The top ten tree species in Kelowna, by canopy cover.



Orchard trees (apple, pear and cherry) comprise almost 22% of the total tree canopy. Although these trees tend to be small and require irrigation, they are producing significant benefits for Kelowna residents. As agricultural lands are converted to other crop types (grapes or field crops), or lost to development, some of these benefits will be lost.

The total number of trees in Kelowna is approximately 3.3 million, with a replacement value of $1.1 billion (Table 2). Replacement value is based upon accepted formulae for estimating individual tree values; it is not the ecological or societal value of the tree.

Trees act as "carbon sinks", and can help mitigate global warming by removing (sequestering) carbon dioxide from the atmosphere. However, as trees eventually decay, die or burn in wildfires, this carbon is released back into the atmosphere. Kelowna's trees sequester about 7,400 metric tonnes of carbon per year (Table 2) and currently store about 127,000 tonnes of carbon. Net carbon sequestration rates, per tree, generally increase as Kelowna's trees get larger (Fig. 3).

Most trees in Kelowna are small. Approximately 94% of the tree population is less than 30cm in diameter at breast height (DBH) (Fig. 4).

Table 2. Summary of Kelowna's tree species.

Species	No. Trees %	No. Trees #	Net Carbon Sequestered (metric tonnes/yr)	Leaf Area %	Replacement Tree Value $
Apple	39.2	1,296,000	3,180	18.7	438,763,000
Douglas fir	23.1	762,00	750	32.6	159,669,000
Ponderosa pine	18.4	607,000	1,400	23.8	181,019,000
Common pear	5.5	180,000	600	2.7	84,288,000
Hedge cedar	2	68,000	110	1	10,135,000
Austrian pine	1.7	57,000	80	2.2	15,929,000
Elm	1.4	47,000	180	4	29,460,000
Crabapple	1.1	36,000	130	1.9	15,181,000
Juniper	0.8	27,000	20	0.3	556,000
Quaking aspen	0.6	19,000	6	0.1	446,000
London planetree	0.6	18,000	70	1.7	13,428,000
Black cottonwood	0.5	18,000	160	1.4	18,194,000
Red maple	0.4	14,000	40	0.7	6,158,000
Norway maple	0.4	13,500	150	3.5	37,394,000
Sweet cherry	0.4	13,500	95	0.2	11,504,000
Red cedar	0.4	13,500	25	0.1	7,275,000
Black locust	0.3	11,000	45	0.8	6,881,000
Poplar	0.3	10,500	10	0.3	856,000
Japanese maple	0.3	9,000	50	0.5	6,521,000
Hawthorn	0.3	9,000	45	0.4	5,244,000
Lodgepole pine	0.3	9,000	5	0.1	296,000
Paper birch	0.3	8,700	70	0.4	9,896,000
Freeman maple	0.3	8,500	7	0.1	1,712,000
Common chokecherry	0.3	8,500	40	0.4	5,028,000
Honeylocust	0.2	7,000	10	0	2,019,000
Aspen	0.2	7,000	2	0	151,000
Green ash	0.1	4,500	40	1.6	14,350,000
White spruce	0.1	4,500	15	0.2	601,000
Mugo pine	0.1	4,500	2	0	183,000
Prunus spp.	0.1	4,500	7	0	599,000
Mountain ash	0.1	4,500	20	0.2	2,881,000
Douglas maple	0.1	1,800	1	0.1	23,000
TOTALS	**100**	**3,300,000**	**7,400**	**100**	**$1,086,640,579**

Fig. 3. Per-Tree Net Carbon Sequestration (kg per year) for Kelowna's trees, by diameter class (DBH, in centimetres).

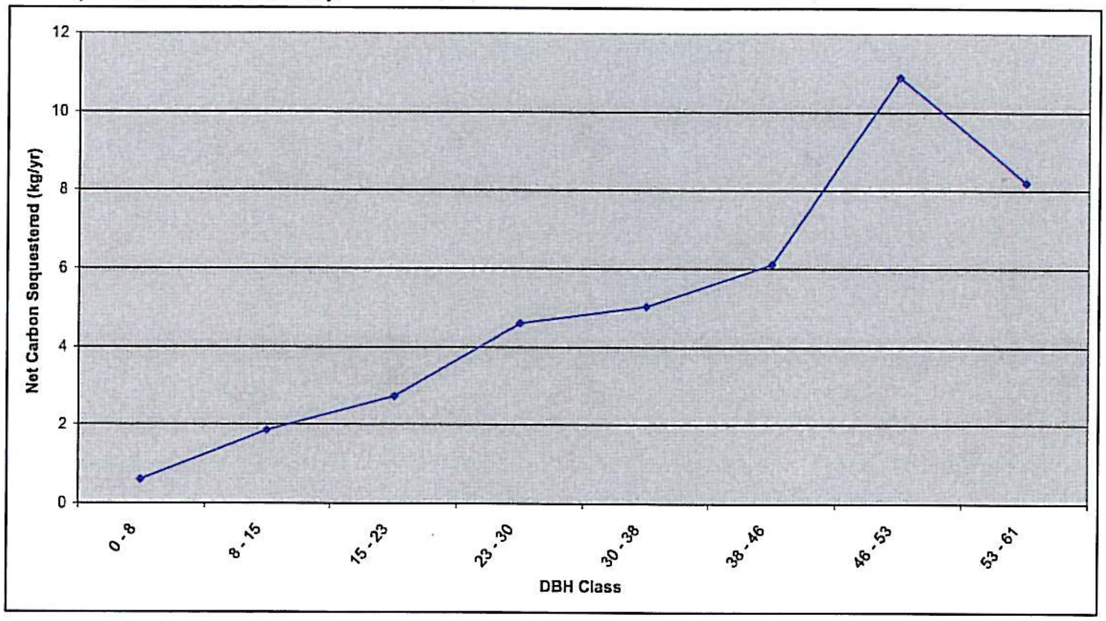
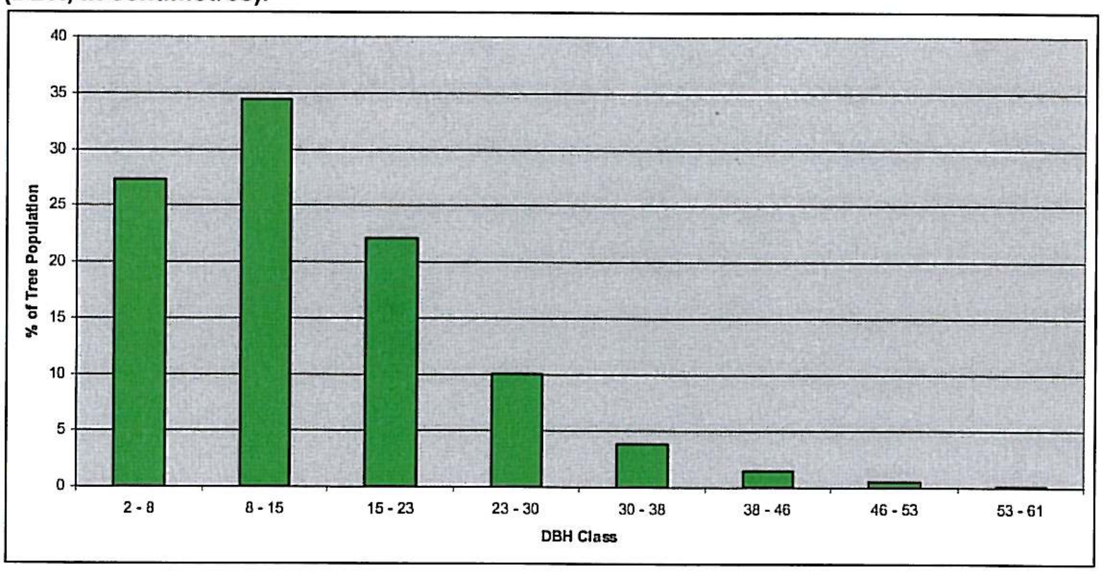
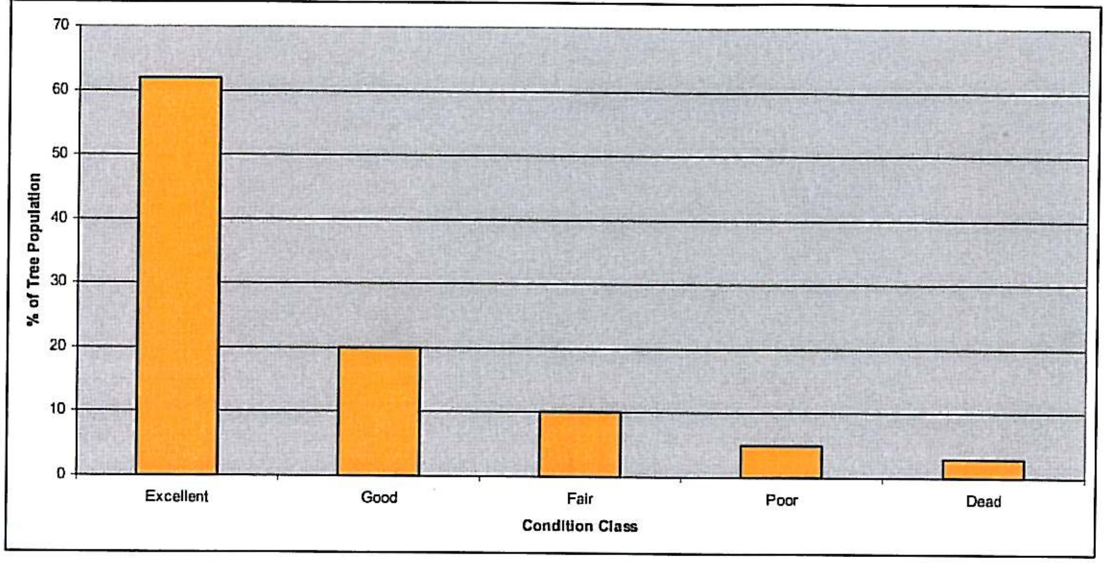


Fig. 4. The size of Kelowna's trees, shown as a percentage of trees by diameter class (DBH, in centimetres).



The health of Kelowna's trees is currently very good, with 92% of the tree population rated as "Fair" or better (Fig. 5).

Fig. 5. Tree health (condition class).



3.2 Vegetation Cover and Plantable Space

Because of the limited number of samples, several of the landuse types from the Kelowna Official Community Plan (OCP) were combined for the comparisons shown in Table 3.

Table 3. Percentage cover comparisons by landuse type.

	Percentage covered by:							
Landuse Type	**Plantable Space**	**Impervious (concrete, asphalt buildings)**	**Herbs**	**Grass**	**Water**	**Shrubs**	**Other**	**Trees**
Agriculture / Rural	17.6%	0.1%	33.8%	42.7%	0%	7.6%	0.8%	15%
Commercial / Industrial / Transportation	12.3%	47.7%	5%	6.5%	0%	5%	2.7%	3.1%
Park / Wetland / Private Recreation / Golf	27.4%	5.9%	7.4%	66.5%	2.6%	6.5%	1.2%	8.2%
Residential	35%	28.9%	5.2%	36%	0.8%	10.4%	1.5%	10.5%
Vacant / Wildland	55%	1.3%	17.3%	43.7%	0%	18.1%	0.8%	23.4%
CITY TOTAL	**27.3%**	**12%**	**18.3%**	**42.3%**	**0.6%**	**9.1%**	**1.2%**	**13%**

Average tree cover throughout the city is 13%. American Forests, a tree research and education group, recommends 25% tree cover for cities in dry areas of western North America (Table 4). The national average tree canopy for cities in the U.S. is 27% (Anonymous 2007). Average tree canopy in some of the other cities in North America is compared to Kelowna's tree canopy in Table 5. Vacant / wildland areas and agriculture lands have the highest tree canopy (23 and 15%, respectively), while the commercial / industrial / transportation zoning types have the least (3%).

The City has 27% plantable space where trees could be planted, on average. Most plantable space is in vacant / wildland areas (55%), followed by residential (35%).

Grasses (native, or planted) are the highest overall cover in the city (42%). Shrubs cover another 9% of the city. These cover types are not evaluated in detail by UFORE but do contribute ecological benefits to the city in terms of stormwater management, cooling and interception of dust or pollutants.

Impervious surfaces (concrete / tar and buildings) comprise a total of about 12% of the city area, on average. Impervious surfaces are highest in commercial / industrial / transportation areas (48%), followed by residential (29%).

Table 4. Recommended tree canopy goals for metropolitan areas of the Southwest and Dry West (American Forests 2007):

Landuse Type	Percent Cover
Average tree cover for all zones	25%
Suburban residential zones	35%
Urban residential zones	18%
Central business districts	9%

Table 5. Average tree canopy in selected North American cities*:

City	Average Canopy
San Diego, CA	7%
Calgary, AB	7.1%
Jersey City, NJ	11.5%
Kelowna, BC	**13%**
Philadelphia, PA	15.7%
Los Angeles, CA	18%
Seattle, WA	18%
Toronto, ON	20.5%
New York City, NY	21%
Boston, MA	22.3%
Syracuse, NY	24.4%
Baltimore, MD	25.2%
Oakville, ON	29.1%
Atlanta, GA	36.7%

Sources: Anonymous, 2007; USDA Forest Service, 2007.

3.3 Pest Susceptibility

UFORE assesses susceptibility of the urban forest to various exotic pests (which are not currently present in Kelowna) such as Asian longhorned beetle (ALB), gypsy moth, or Dutch Elm Disease (Table 6). If these pests became established here, this shows the proportion of the urban forest that is "at risk". Most of these exotic pests have only been detected in Eastern Canada to date, although Dutch elm disease is present in Washington State.

The most imminent threat to Kelowna's urban forest at this time is mountain and western pine beetle. UFORE estimates that Kelowna has about 606,000 ponderosa pine trees, with a replacement value of $181 million, representing about 24% of the total canopy cover (Table 2). According to the B.C. Provincial government, Kelowna is likely to lose about 80% of these trees, primarily the larger mature pines. These mature trees also contribute the most ecological benefits to the city.

Table 6. Proportion of Kelowna's urban forest that is at risk due to exotic and native pests.

Pest	% Susceptible Host, by Tree Cover
Asian Longhorned Beetle	39%
Mountain & western pine beetle	24%
Gypsy moth	23%
Dutch elm disease	4%
Emerald ash borer	2%

3.3 Pollution Removal by the Urban Forest

Kelowna's urban forest removes more than 195 tonnes of pollutants annually, and the value of this removal is estimated at $1.1 million per year (Table 7). These values are based upon an estimate of the societal cost of pollutant emissions / formation (Nowak et. al 2000b).

Trees also produce Volatile Organic Compounds (VOCs) which can be converted into ozone and affect air quality when they react with nitrogen oxides from human-sources of pollution. Kelowna's trees produce about **43** metric tons of VOCs per year. However, the **Ozone Index Score** of Kelowna's urban forest is quite high, at **94** (out of 100). A score of 100 represents forest composition where all species have the maximum effect on reducing ozone (lowest possible VOC emissions).

Certain species of trees are better at reducing ozone levels than others. The best trees and shrubs in Kelowna for reducing ozone (index values >99) include:

> Pear (*Pyrus*), apple (*Malus*), hawthorn (*Crataegus*), mountain ash (*Sorbus*), Saskatoon (*Amelanchier*), Mock orange (*Philadelphus*), snowberry (*Symphoricarpos*), rose (*Rosa*), sumac (*Rhus*), grape (*Vitis*), cotoneaster (*Cotoneaster*), weigela (*Weigela*), honeysuckle (*Lonicera*), raspberry (*Rubus*), Japanese rose (*Kerria*), and spiraea (*Spiraea*).

Overall, Kelowna's urban forest produces significant net benefits for residents in terms of air quality improvement. Mature trees produce more benefits than small trees; a large tree removes about 2.0 kg of pollution per year, about 65 times more pollution than a small tree (Nowak et al. 2000b).

Table 7. Pollution removal by Kelowna's urban forest.

Pollutant	Metric tonnes removed annually	$ Value of removal
CO	2	$ 1,800
NO_2	17	$ 115,000
O_3	83	$ 558,500
PM10	89	$ 400,200
SO_2	5	$ 8,100
	195	**$1,084,000**

3.4 Energy Savings

Only **residential** trees were found to have a significant contribution to energy savings in Kelowna. Trees save energy in the summer by shading buildings and avoiding power plant emissions due to electricity savings. Trees help save energy in the winter, through acting as a windbreak and by avoiding power plant emissions due to gas and electricity savings. However, shading of buildings during the winter months can lead to increased power usage.

Net energy savings are **$19 million** per year in Kelowna, due to residential trees. Tree cover also helps to avoid the release of **1,800 metric tonnes** of carbon into the atmosphere each year.

4.0 Conclusion and Recommendations

Kelowna faces an increasing threat of tree loss due to factors such as mountain pine beetle attack, development, and wildfire. Although mountain pine beetle appears to be the most imminent threat, trees that are lost can be replanted or regenerated over time as long as natural areas are preserved. Urbanization is the greatest long-term threat to Kelowna's urban forest, since it reduces the overall plantable space and the ability to replace areas of lost forest.

As areas of urban forest or green infrastructure are lost, the ecosystem services they provide may need to be replaced with investments in grey infrastructure such as drainage improvements, water filtration, and larger power plants for providing electricity or fossil fuels. These practices are not sustainable in the long run and can be very costly.

Strategies and tactics to enhance the ecological services of urban trees include (Nowak et al. 2000b):

1) Aiming for species, size and age diversity (reduces the impact of pests);
- Increase species diversity in urbanized parks where appropriate
- Provide the public with information on additional tree species choices, that are pest and drought tolerant, non-invasive and will help improve diversity
- Encourage local nurseries to provide a greater variety of species

2) Increasing the number of healthy trees;
- Educate the public about the benefits of proper tree care and least-toxic pest management solutions
- Educate the public about proper tree selection, to avoid problem-prone species

3) **Maximizing the use of low VOC emitting trees to improve air quality;**
   - Provide information on preferred tree species to minimize VOC emissions

4) **Sustaining and increasing existing tree cover;**
   - Set a city-wide tree canopy goal in the OCP, through input from citizens, City Council, staff
   - Increase planting on city-owned properties where appropriate
   - Promptly replant city owned areas affected by pine beetle, fire or other disturbance and encourage the same on private properties
   - Utilize techniques such as "under planting" to ensure adequate recruitment of young trees as mature trees decay or die
   - Explore incentives, partnerships, and education to encourage additional planting on private properties. This might include partnerships or subsidies to provide low cost trees to private properties
   - Change city policies and bylaws, such as the subdivision bylaw, zoning bylaws, hillside development guidelines, road design standards, landscaping and parking lot standards, etc. to maximize the amount of tree retention and new planting associated with development
   - Explore the use of "carbon credits", e.g. the sale or trading of carbon savings generated by Kelowna's urban forest, to help fund increased tree planting
   - Monitor the long-term success of these efforts, by periodically performing new UFORE analyses, or by using aerial photography or GIS analyses to determine changes in forest canopy over time

5) **Sustaining large, healthy trees (greater benefits per tree);**
   - Educate the public about proper tree selection and care, to increase the number of large specimens in the future
   - Change city policies and bylaws, such as subdivision, or road design standards to increase the amount of space available for mature trees to develop

6) **Using long-lived species (reduces carbon emissions from planting and removal activities);**
   - Educate the public on preferred species types
   - Gradually replace short-lived species on city properties with longer-lived varieties

7) **Using low-maintenance trees (reduces fossil fuel requirements for maintaining vegetation);**
   - Educate the public on preferred species types
   - Gradually replace high maintenance and problem-prone species with lower maintenance species

8) Planting trees in energy-conserving locations;

- Incorporate appropriate tree planting into the design of city-owned buildings
- Educate the public about the best locations for tree planting to reduce energy use

9) Planting trees as part of transportation corridors (extends the life of streets, reduces carbon dioxide emissions) and parking lots (cooling effect and reduction of VOC emissions from parked vehicles);

- Incorporate tree planting into all new collector / arterial road designs
- Increase standards for planting in parking lots and implement monitoring to ensure trees survive over time
- Ensure that adequate space is provided in transportation corridors and parking lot design, particularly adequate soil volume for the development of large trees which will help to reduce storm water runoff from impervious surfaces and maximize shading

10) Planting trees in polluted areas;

- Increase plantings along major transportation routes and in industrial areas to improve interception of pollutants

11) Avoiding pollution sensitive tree species;

- Public education on appropriate tree species

12) Utilizing evergreen trees for particulate matter reduction (year-round removal of pollutants).

- Encourage the use of evergreens, particularly in high-pollution areas or as windbreaks in winter.

These recommendations will help to preserve and improve the quality of Kelowna's urban forest and improve the liveability of Kelowna, and are also compatible with Kelowna's Sustainability Objectives.

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Appendix 1. Plot Locations (GPS Coordinates)

GPS Coordinates for original 100 plots (plots #1-101):

ID	X-Coordinates	Y-Coordinates
1	315206.976828	5516776.214540
2	317294.833259	5518054.341910
3	318438.964887	5518806.123160
4	319882.896053	5518935.139410
5	322311.421366	5518675.175140
6	322543.874170	5519046.166840
7	320656.647448	5520280.160620
8	321398.086621	5519695.848120
9	322727.401081	5520737.424370
10	320762.600880	5522321.428960
11	322377.598877	5522118.604310
12	323773.902244	5522271.492330
13	325034.910969	5521522.846740
14	325569.898260	5521497.738340
15	326905.362539	5521897.801050
16	321792.083368	5522501.866260
17	323321.458449	5523237.240250
18	324305.221601	5523362.756550
19	326530.961057	5522892.527590
20	326921.913248	5522714.758730
21	329001.469608	5522911.500340
22	329673.862071	5523875.208970
23	331200.192770	5523071.513030
24	321625.789342	5524551.507170
25	323791.688779	5524256.212520
26	325141.706151	5524046.849750
27	326051.502183	5524267.760180
28	326923.823446	5525273.106430
29	329314.563169	5524737.466650
30	330062.325611	5524452.512770
31	332474.437067	5525065.693900
32	321095.858100	5526463.848830
33	322526.594628	5526741.151310
34	324196.964589	5526809.488570
35	326401.371165	5525507.484330
36	327538.119402	5526799.293160
37	328764.984974	5526341.988410
38	330794.381175	5526407.402940
39	331239.833920	5525505.823750
40	332744.222585	5526860.755630
41	322134.853763	5527119.728410
42	323301.377006	5528116.192440
43	324551.823361	5527220.931750
44	326048.896627	5527087.276940
45	328097.479099	5527075.550300
46	328826.438245	5528094.861160
47	330969.857261	5527462.888190
48	331603.186160	5527265.310660
49	333073.491337	5526920.477460
50	320163.452948	5528638.946730
51	321147.429789	5529770.087160
52	323244.369935	5528414.595300
53	324209.622574	5529755.544260
54	326689.352905	5528610.243880
55	327331.498580	5528550.178190
56	329364.259698	5529448.718140
57	330672.642293	5529082.078510
58	331432.227041	5528680.406960
59	320814.917014	5530516.212840
60	321097.188629	5531080.120100
61	322678.882967	5530585.094410
62	324647.884111	5529881.407600
63	325820.063190	5530001.430400
64	327837.544115	5530848.448110
65	329588.130923	5531206.031300
66	330815.096402	5530298.626370
67	331140.315459	5530026.840260
68	322830.584007	5531969.561190
69	324734.741465	5531839.518960
70	326008.199690	5532085.203600
71	327826.051536	5531540.283170
72	329419.691676	5532094.462080
73	330896.586540	5532324.974150
74	322117.698236	5532933.517430
75	323267.753506	5532832.550430
76	323881.199561	5533881.974130
77	325431.162384	5533639.232270
78	327648.837140	5533579.914160
79	328592.401675	5533721.105630
80	325199.078160	5535636.657400
81	325928.091422	5535674.037100
82	328057.788515	5535105.456080

ID	X-Coordinates	Y-Coordinates
83	328439.739379	5534391.398930
84	323978.248278	5537012.305310
85	325324.892407	5536007.325460
86	328060.020634	5536705.565590
87	328596.589783	5536935.140030
88	323905.460092	5538285.726710
89	326633.833509	5537430.241040
90	327689.335304	5538150.490340
91	328662.404264	5538477.231420
92	329794.426354	5538425.387660
93	324870.916014	5539571.994890
94	325797.599073	5539986.585360
95	326827.587166	5539765.244460
96	329233.482198	5539843.752140
97	325856.342372	5541400.268160
98	327578.292002	5540371.647430
99	325385.136910	5542006.485290
100	327688.584442	5541810.072060
101	328670.921147	5542949.088080

GPS Coordinates for additional 50 plots (plots #1-50):

ID	X-Coordinates	Y-Coordinates
1	317591.701290	5518740.644370
2	318897.044205	5518924.502620
3	320989.070184	5520647.594550
4	323318.519928	5519396.359360
5	321635.428210	5522432.827910
6	323563.971180	5521570.849070
7	324397.444958	5521654.362480
8	327152.005445	5522458.381730
9	321000.605451	5523550.753260
10	322643.449003	5524290.886390
11	324571.226329	5524010.021070
12	328131.614987	5523391.038710
13	329592.714322	5523757.206200
14	331259.906151	5524274.590780

ID	X-Coordinates	Y-Coordinates
15	322521.122610	5525163.056930
16	324757.660867	5526570.293400
17	327735.055796	5526424.717010
18	329420.927734	5525306.657650
19	331916.572311	5526171.473280
20	320780.034369	5528608.281210
21	323376.721892	5528150.268530
22	326213.094036	5527218.479500
23	327713.431618	5528126.888490
24	329885.645766	5526949.173110
25	330473.901042	5527217.200480
26	320417.610469	5530374.621450
27	322309.442617	5529979.060170
28	324799.248659	5530507.595040
29	326714.735596	5530158.790910
30	328703.197215	5529104.019210
31	332288.433223	5529173.066470
32	324068.954665	5532776.143670
33	325597.386568	5532614.492930
34	327813.104122	5532637.276220
35	329010.445148	5532854.801730
36	331866.790175	5531858.748410
37	323947.566286	5533685.500050
38	325545.974432	5534184.003200
39	327262.654517	5533221.578150
40	328520.896302	5533774.417550
41	326166.631277	5536924.522360
42	328151.120367	5535310.446490
43	328917.540175	5536421.995500
44	325478.672430	5537560.717990
45	326477.350914	5538585.450670
46	324896.222118	5539392.156850
47	326988.707082	5540836.446600
48	328932.330430	5540257.833370
49	326844.930634	5541679.380760
50	329492.178715	5542946.221000

Plots that had to be moved to alternate locations, due to lack of access or permission was not granted by the landowner:

Plot #	Original Coordinates	Modified Coordinates	Description
30	330062.325 x 5524452.512	331544.554 x 5524779.828	~ 1500m west of original
31	332474.437 x 5525065.693		~ 1km south of original
90	327689.335 x 5538150.490	327433.933 x 5537739.096	~ 300m SW of original
94	325797.599 x 5539986.585	326109.914 x 5539735.296	~ 400m SE of original
95	326827.587 x 5539765.244	326401.000 x 5539825.167	~ 350m west of original
133	324068.954 x 5532766.143	324264.293 x 5532952.321	~ 300m SW of original
145	326477.350 x 5538585.450	326168.761 x 5537772.159	~ 850m south of original
147	326988.707 x 5540836.446	327492.468 x 5541137.415	~ 675m NE of original
149	326844.930 x 5541679.380	326239.558 x 5538042.373	~ 4km south original