CITY OF KIRKLAND
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MEMORANDUM

To: Houghton Community Council and Planning Commission

From: Deb Powers, Urban Forester
Adam Weinstein, AICP, Deputy Planning Director

Date: November 26, 2018

Subject: Code Amendments with Moderate/Major Policy Impacts,
Kirkland Zoning Code Chapter 95, Tree Management and Required Landscaping, File Number CAM18-00408

Staff Recommendation

Provide feedback on the most complex and controversial proposed code amendments so that staff can develop KZC 95 draft code.

Background

Balancing growth and development while maintaining a livable community is a primary reason municipalities adopt tree canopy goals and protection codes. KZC 95 (Attachment 1) establishes a permit process and standards for the protection and replacement of trees primarily on private property. With the exception of minor code amendments, KZC 95 was last updated in 2010 and was identified for an update in the 2018-20 Planning Work Program.

The purpose of the city-wide 2018 tree code revision is to support the city-wide 40 percent canopy cover and other goals established in Kirkland's Comprehensive Plan and the objectives in the Urban Forestry Strategic Management Plan, to address issues and challenges that have arisen since the last major tree code revision and to update the code so that it is effective and easier to use.

As a foundation to the code update project, the background of Kirkland's tree code and a description of how the code currently works was outlined in the June 28, 2018 memo (pages 4-11) to the Planning Commission (PC). Since a basic understanding of tree canopy cover was needed to make decisions on whether the City should change its metric for code requirements, background information on canopy cover was provided in the same memo (pages 2-3). At that time, the PC indicated that using canopy cover in place of the current tree credit metric was not a consideration.

Staff assembled code interpretation issues identified since 2014, forming an initial list of potential code amendments. Additional issues and potential amendments were identified from various sources such as the:

Holmes Point Overlay (HPO) Code Amendment Process
There were a number of proposed HPO code amendments that were identified for consideration on a city-wide basis, including the use of:

- Canopy cover (2-D outline of tree leaves, typically seen in aerial imagery) instead of tree density credits (based on trunk diameter)
- Minimum canopy cover requirements on a lot-by-lot basis that would increase tree retention/planting
- Heritage or Exceptional tree definitions with enhanced protection requirements

Field Studies on Tree Code Efficacy
The Planning and Building Department hired an intern in 2018 to conduct a field study with the objective of better understanding how the City's tree regulations play out on actual development sites. Data was collected from 159 single family residential lots created from 54 short plats developed between 2008 and 2013. These findings were presented in the August 9, 2018 Planning Commission memo. Some of the key takeaways of this research project are:

- New trees required with development are planted in abundance, however many are poorly located
- Improvements in retaining mature trees on development sites are needed
- The use of arborvitae, a slow-growing columnar conifer, is used in excess and sometimes exclusively as tree replacements on short plats

Canopy Cover Analysis
The 2018 Urban Tree Canopy Assessment report (Attachment 2) was presented to the PC by the City's project consultant at the November 8, 2018 PC meeting. The report outlines the methodology and outcomes from analyzing existing canopy cover city-wide and by various smaller geographic units (such as neighborhoods) and land use (such as residential and park areas). Changes in canopy cover since the last assessment were examined, in addition to assessing areas where there are opportunities to increase canopy cover.

Overall, urban tree canopy cover (UTC) city-wide dropped from 40 to 38 percent between 2010 and 2017. The consultant pointed out that this period spanned a historical peak in development activity and that the City is within 75-100% of its canopy goal, considered an "optimal" performance measure for canopy cover. Other findings from the analysis include:

- The Single Family Residential land classification had the greatest canopy loss by acreage
- Moss Bay and South Rose Hill neighborhoods have the lowest UTC percentages
- Tree canopy cover increased in Industrial, Parks and Institutional land classifications

All data created by the canopy study were collected and delivered in a manner that the City's GIS staff may use to conduct further analysis or develop publicly-accessible maps. The field study findings and canopy assessment data are significant tools used to inform staff recommendations for the KZC 95 code amendments.

Additional sources of potential code amendments

Other sources include recent changes to arboricultural industry standards and continued discussions with Planners, Code Enforcement and Legal staff. Input from the PC and Houghton Community Council (HCC), local developers, neighborhood groups, and the general public also contributed to additional code changes, as described in the following sections.

Public Comment

Public outreach was conducted as scoped in the Public Engagement Plan (Attachment 3) presented in the November 8, 2018 PC memo. Staff conducted two facilitated stakeholder group meetings (Kirkland developers and citizens from the Finn Hill Neighborhood) and utilized multiple events to engage the general public, including a stand at the Juanita Beach Farmers Market. Recorded comments derived from all events are listed at the end of the Public Engagement Plan. Over 900 subscribers signed up to receive project updates through a City listserv. All letters and correspondence addressed to the PC, HCC, City Council, Urban Forester or Planning Department received up to 12 p.m. on October 31, 2018 were included in the same memo.

Many of those letters and emails were sent from members of two key stakeholder groups (Master Builders and Finn Hill Neighborhood Alliance), who also attended and provided comments at the November 8, 2018 PC meeting. The issues described at the stakeholder meetings, in correspondence and through public testimony are fairly consistent:

- Requests for a more streamlined, clear and less subjective code
- Allow tree removal (no development) in relation to lot size
- Adjust the current tree credit requirements
- Use tree canopy cover instead of tree credit requirements
- Address the seemingly disparate tree credit and retention value requirements
- Clearly define and prioritize existing tree retention requirements
- Clarify the City's authority with existing tree retention requirements
- Require tree retention decisions early in the short plat/subdivision design process (Integrated Development Plan or IDP) or allow phased development review
- Improve maintenance requirements for newly-planted required trees
- Regulate hedges (comprising trees)
- Improve tree protection, code enforcement, inspections and fines

All issues identified through public engagement are addressed with potential KZC 95 code amendments, with the exception of the last bullet point. While minor changes to KZC 95 can address tree protection methods, code enforcement, inspections and fines will need to be addressed with amendments to Kirkland Municipal Code (KMC) 1.12.100. Note that the KMC is not within the jurisdiction of the Houghton Community Council.

Staff expects that continued public involvement with the tree code update project will likely involve the same issues. Representatives from the Master Builders Association and the Finn Hill Neighborhood Alliance announced at the November 8, 2018 PC meeting that the two groups will try to meet in an effort to find common areas of agreement on

KZC 95 code amendments. The PC advised that any outcomes should be shared with staff, and the groups committed to doing so.

Letters and emails received since the November 8 PC meeting memo, up to 5 p.m. on November 15, 2018, are included in Attachment 4. While some of the memo contents below may be redundant to the PC, they are provided to ensure an efficient and productive joint meeting.

Houghton Community Council Comments

The Houghton Community Council (HCC) met with staff at an August 27, 2018 meeting and communicated that code changes should address areas where the code is:

- Too ambiguous or unclear
- Not very predictable for developers
- Inconsistent in its outcomes across multiple users encountering similar situations

More specifically, the HCC expressed an interest in code or procedural changes that would address:

- A High Retention Value tree definition that is less subjective
- Retaining tree groves when designing parking lots
- Clarifying the modification process for additional tree removals occurring with short plat/subdivision development
- Planned girdling and tree removal prior to development permit submittal
- Damage to trees adjacent to development properties (which should remain a civil issue)
- Integrating tree protection inspections with building inspection procedures

Since the August 27 HCC meeting, staff presented potential code amendments to the Planning Commission in manageable segments over the course of multiple study sessions. The HCC should review the potential code amendments outlined below so that if the HCC does not agree with the approach taken, alternatives can be discussed at the joint meeting November 26. Note that with the exception of the most straightforward potential code amendments, no draft code language has been developed.

Planning Commission Comments

In review, the no/minor policy impact potential code amendments, shown listed and as revised code in Attachment 5, were the focus of the September 13, 2018 Planning Commission meeting. At the September 27, 2018 PC meeting, the moderate- and major-impact potential code amendments involving KZC 95 Definitions, Tree Removal Allowances and Landscape Requirements by Zone were discussed (Attachment 6, unshaded lines). The PC acknowledged the general approach to these potential code amendments was appropriate.

Remaining Code Amendments under Consideration

The remaining potential code amendments, which are the most complex and controversial, fall under the Tree Retention Associated with Development Activity section of KZC 95 (shown as shaded lines in Attachment 6). These were the focus of the November 8, 2018 PC meeting memo, which describes each code issue, and provides a brief background discussion, options for code updates and staff recommendations.

The PC agreed with staff recommendations for the majority of the potential code amendments discussed on November 8. Potential code amendments are referenced by number so that the HCC can review each without much difficulty:

- Prevent girdling/tree removal prior to development permit submittal (#59)
- No additional Tree Plan review by a Landscape Architect (#65), but provide some assurance that canopy cover goals will be met
- Address renewable energy system-tree conflicts, but be clear so that the code does not become a mechanism for unwarranted tree removal (#71)
- Determine tree retention early in the shortplat/subdivision design process, also referred as IDP, or Integrated Development Plan (#73)
- Clarify grove definition and preservation requirements (#63)
- Specify appropriate planting locations for required (new) trees (#44 et al.)
- Continue using 5 Year Maintenance Agreements following development rather than require developers to post bonds for protected/planted trees (#81)
- Define "hedges" for the purpose of allowing removal and replanting, but not to regulate the height of hedges (#67)

There were five potential code amendments that the PC was unsure about or requested additional information in order to continue its discussion. Most involve tree retention requirements and the consideration of using tree canopy cover instead of the current tree density credit system. The description of each issue below includes the additional information requested by the Planning Commission.

<u>Limit credits awarded for planting arborvitae on new development sites</u> (#55).
Field study findings revealed an excessive use of arborvitae, a slow-growing columnar conifer, to meet tree density credits on Single Family lots resulting from short plats and subdivisions. Very often these sites had little to no other trees and vegetation.

Arborvitae is appropriate for extremely limited yard areas, provides screening and some of the benefits of trees (more so than a fence), but its limited size results in little to no canopy contribution in 10 years' time. The recent canopy cover analysis indicates the greatest loss in canopy acreage is in Single Family land use. While tree retention can help slow the loss of existing canopy, new trees should aim to meet the intent of the code.

Per KZC 95.05.2: The intent of this chapter is to *mitigate the consequences of required tree removal in land development through on- and off-site tree replacement with the goals of halting net loss and enhancing Kirkland's tree canopy to achieve an overall healthy tree canopy cover of 40 percent City-wide over time.*

Improvements to the current tree credit system should include limiting the number of credits awarded for arborvitae or establishing a maximum percentage of arborvitae allowed to count towards tree credits on development sites.

Staff recommendation: Strike "six (6) feet tall for Thuja/Arborvitae" language in KZC 95.33.4 as it implies the City encourages arborvitae planting. Limit the number of tree credits awarded (or establish a maximum percentage) for slow-growing columnar conifers such as arborvitae planted on development sites. Or, consider eliminating tree density credits as described below and in more detail under #64/72 in the November 8, 2018 memo to the Planning Commission.

Establish a cut-off point or maximum credits awarded for retained trees (#40).
Tree credit systems associate points or units according to tree trunk size. The standard measure of trunk size is DBH (trunk diameter at breast height, 4.5 feet above grade). Other cities in the region using credit-based tree code systems include Issaquah, Medina, Kenmore, Woodinville and Vancouver, WA.

Because Kirkland's tree code awards up to 21 credits per tree (depending on the maximum size of the trees on site), the minimum required credits can be achieved by retaining the least number of large trees, resulting in greater canopy cover loss with development. Planning staff notes that with potential short plat and subdivision sites, groves of trees and individual trees of merit are often overlooked as candidates for retention due to the differing code interpretations of "grove" and "High Retention Value" trees (see potential code amendments #63, 64, 72). Combined with the perception that only the minimum tree density credit requirement need to be met, the result is often sites with as few retained trees as possible.

Below is a table showing how Kirkland's tree code associates credits with trunk size per KZC 95.33.1:

Tree Density for Existing Significant Trees (Credits per minimum diameter – DBH)					
DBH	**Tree Credits**	**DBH**	**Tree Credits**	**DBH**	**Tree Credits**
3 – 5"	0.5				
6 – 10"	1	24"	8	38"	15
12"	2	26"	9	40"	16
14"	3	28"	10	42"	17
16"	4	30"	11	44"	18
18"	5	32"	12	46"	19
20"	6	34"	13	48"	20
22"	7	36"	14	50"	21

One option to improve the current tree density credit system is to "cap" or limit tree density credits at a lower trunk diameter, as with the Kenmore (KMC 18.57), Mercer Island (MICC 19.10.070), and Woodinville (WMC 21.50.060) tree codes. Doing so meets the intent of KZC 95.30: *The City's objective is to retain as many viable trees as possible* *on a developing site while still allowing the development proposal to move forward in a timely manner.*

Staff recommendation: limit the maximum tree density credit table at 30" DBH (11 credits), or consider other changes to the current tree density credit system to preserve trees on sites that are the most worthy of retention efforts. One of the changes to the current system under consideration is to *deemphasize or eliminate credit requirements for tree retention*. The City would still require tree planting at the same rate.

This last concept, a shift in focus for tree retention criteria, marks a progression from Kirkland's earliest 25 percent retention of all trees on short plat/subdivision sites (resulting in poor quality tree retention) to the current code, which is a combination of quantitative and qualitative requirements. This concept is described below in more detail and under #64/72 in the November 8, 2018 PC memo.

Replace tree density credits with canopy-cover-based requirements (#75).
The FHNA strongly advocates using a canopy-based metric on a lot-by-lot basis to ensure adequate tree retention/planting achieves canopy cover goals. FHNA's concern is that tree credits, based on trunk diameter, do not easily translate to canopy cover, making it harder to monitor code effectiveness. Staff has maintained that canopy cover expressed in 2-D mapping is just one performance measure for resilient urban forest management (in addition to species diversity and uneven-aged inventory) and shouldn't be a principal focus of tree code requirements.

The pros/cons of using canopy cover as a tree retention/replanting metric were discussed in the linked [June 28, 2018 Planning Commission memo]() or in Attachment 7 of this memo. At the June 28 meeting, the PC expressed skepticism about transitioning to a canopy-based system due to:

- Ease of trunk diameter data collection, regardless of expertise
- Requests to clarify and streamline the code
- The general correlation of trunk diameter to overall tree size
- The number of cities with tree credit systems in place

At the November 8 PC meeting, the PC expressed a desire for better understanding how new regulations could help support the City canopy goal and requested additional information showing some general correlation between trunk diameter and canopy cover. Attachment 8, a recent USDA Forest Service publication, discusses the correlation between tree age, trunk diameter and crown diameter in the Introduction on page 1, showing the association of DBH to canopy cover is an industry and scientific standard. During the Holmes Point Overlay (HPO) code revisions in 2017, a discussion paper (Attachment 9) was written in response to the FHNA's desire to better understand how tree credits relate to canopy cover.

Note the point of the discussion paper was to provide a broad idea of how tree credits relate to canopy cover over time, not to examine different tree species or address canopy cover differences between conifers and deciduous trees. The outcome of the exercise was that a newly-planted "average tree" attains an estimated 245 square foot canopy cover in 20 years. The paper goes on to apply the calculation to a hypothetical development scenario under the Holmes Point Overlay code.

Most cities regulating trees in the region use tree credit systems, indicating confidence in its effectiveness and ease of use, while Snohomish County and Lake Forest Park are the only local jurisdictions using a canopy cover-based metric for retention/replanting requirements.

The Lake Forest Park Urban Forester reports that although aerial imagery is used by permit applicants and staff to determine canopy cover on a lot-by-lot basis, an approximate 10-15% canopy cover differential is considered an acceptable margin of error in assessing development permit requirements. She also reported that development activity in Lake Forest Park is significantly lower than Kirkland and that given permit volumes equal to Kirkland, a more efficient tree code requirement system may be desirable.

Snohomish County adopted a canopy cover-based tree code in 2014 that applies only to unincorporated urban growth areas (very large, heavily-wooded rural parcels). The code was developed in response to issues such as: due to typical property conditions, the cost to complete a tree survey was considered prohibitive and prospective property owners and developers were bypassing heavily forested sites. The code requirements are based on quantitative criteria rather than assessing and retaining existing trees.

As a quantitative approach prompted by rural site conditions, Snohomish County's tree code aims to avoid surveying and assessing individual tree health and condition (Attachment 10), essential to determine high quality trees that are worthy of retention on suburban infill development sites.

The Snohomish County tree code requirements (SCCS 30.25) do include a number of incentives such as retaining trees to reduce onsite recreation areas otherwise required in multifamily developments, and bonuses for retaining individual significant trees, tree groves and significant trees qualified to receive flow control credits for drainage.

The Snohomish County [2016 Annual Report on Tree Canopy] includes data collected from the first full year the code was in effect in 2015, with no determination on whether or not the tree canopy regulations are meeting the intended outcomes. Upon examination of data collected from 36 development permits, most projects just met the required proposed tree canopy cover (the properties exceeding proposed canopy cover consisted of critical areas), and only 5 out of 36 development projects used the incentive and bonus provisions for retaining trees. This suggests a tendency to just meet numerical quotas for tree retention, regardless if the metric is credits or canopy cover.

Finally, the Snohomish County Tree Canopy Calculation Sheet (Attachment 11) is an example of the issues that arise when developing a canopy cover-based code that is clear, objective and attempts to have a high level of accuracy. Consider how many $CA=pr^2$ calculations are needed for *each tree* in Option 1 or to obtain the average canopy for *each tree* in Option 2 (the sum of the longest branch tip and the shortest branch tip, divided by 2).

Even with the goal of avoiding survey costs from assessing individual trees on site, half as many Snohomish County permit applicants chose to use the Tree Survey Method as the Aerial Estimation in 2015, and a third of all permit applicants did not elect to retain trees, even with as many incentives in place. In deciding whether the City should adopt a canopy-cover based requirement system, factors such as meeting the policy goals and intent of the code, the ease of use (which equates to greater compliance/staff efficiency) and effectiveness should be carefully considered.

Staff recommendation: No change to existing tree credit requirements, or consider a shift to focus on trees worthy of retention and less on numerical thresholds (see #64/72). The City would still require tree planting at the same rate.

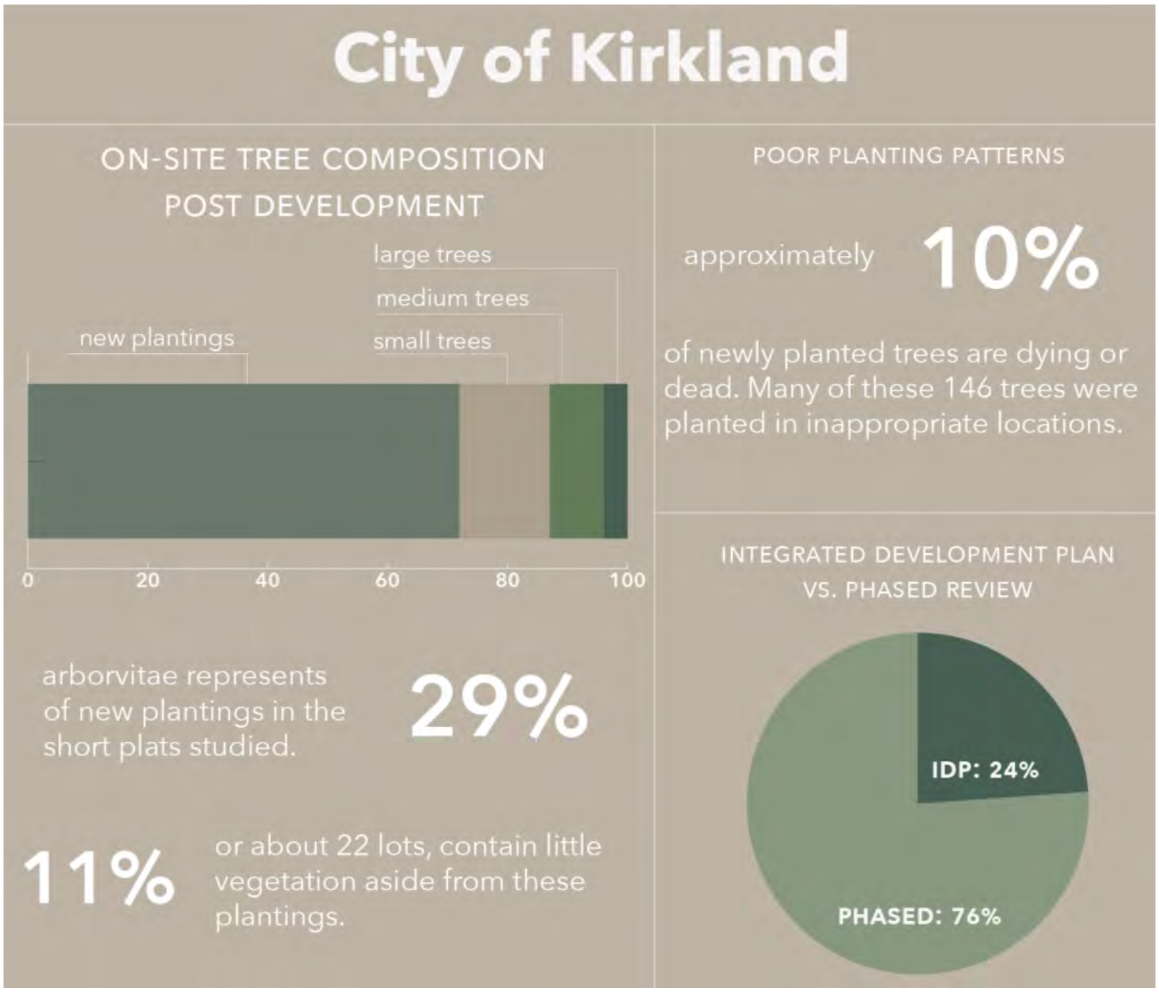
<u>Increase credit/canopy cover requirements for retention/replanting city-wide</u> (#77). The Finn Hill Neighborhood Alliance (FHNA) advocates increasing quantitative tree requirements (whether credits or canopy cover) to ensure canopy cover goals are met over time. When examining canopy cover in the HPO as part of the 2017 code revision process, staff found what is typical when looking at canopy cover at such a granular level: that although the HPO averaged to over 60 percent canopy cover overall (not including parks), canopy cover percentages varied on a lot-by-lot basis from under 25 percent to over 60 percent.

Even in a community that values its wooded community character, there are property owners that do not wish to increase canopy cover on their property. These factors raise equity issues when applying uniform increases in requirements city-wide.

The Planning Commission raised the prospect of applying different quantitative tree requirements (whether credits or canopy cover) according to land use. Staff found that Lake Forest Park (LFPMC 16.14.070), Issaquah (IMC 18.12.1370) and Renton (RMC 4-4-130-C-9) tree codes use this approach, with generally a 5-10 percent difference in canopy cover goal requirements from one land use to another. Staff commented at the November 8 PC meeting that tree code requirements for different land use categories further complicates the existing code, which can result in an avoidance of meeting requirements and less cooperation towards compliance. Further complicating this approach is recent canopy assessment findings that show a diversity in canopy loss rates across different land-use categories.

The development community desires the predictability of quantitative (credit) requirements for tree *retention* in particular. Planning staff explained at the November 8, 2018 PC meeting that the credit system is often perceived by the development community as the sole tree retention requirement, meaning that Kirkland's requirements to retain high quality trees and groves are frequently overlooked. Emails attached to the November 8 PC memo, a permit determination appeal and public testimony from the development community confirm that assertion.

In looking at the field study gauging the efficacy of the City's tree code, new trees required to be planted on development sites comprise the majority of post-development tree composition, indicating that the City's tree planting requirements are sufficient. However, when it comes to tree retention, the large tree category, a main contributor to an uneven-aged urban forest, shows an area of improvement.



Staff recommendation: Improve and simplify the existing code where tree credits or quotas are concerned; consider code changes that focus less on quantitative requirements. Work towards a more resilient, uneven-aged urban forest by strengthening the language on retention requirements for trees of merit (see #70 below). Require new tree planting at the same rate, the equivalent of 30 tree density credits per acre.

<u>Strengthen the language on retention requirements for trees of merit</u> (#70).
KZC 95.30.5 currently reads: *retain High Retention Value trees to the maximum extent possible;* and the applicant *shall pursue where feasible applicable variations in the development standards*. As Planning staff explained at the November 8 PC meeting, the existing code language often results in code interpretation disagreements between

Planning staff and permit applicants. The development community desires prescriptive requirements that are flexible for unusual development scenarios, and the FHNA has expressed the code is inadequate where tree retention is concerned.

A surprising number of local tree codes contain examples of code language that provide the authority to balance tree retention with site planning, building and development practices simultaneously. Some examples include:

- Redmond: *The Administrator may specify conditions for work, at any stage of the application or project as he/she deems necessary to ensure the proposal's compliance with the requirements of this division…*
- Shoreline: *Specify that site improvements shall be designed and constructed to protect trees with the following characteristics…*followed by definitions and retention priorities
- Medina: *Applicant must show where alternative design of the building is feasible in retaining the tree*

Some cities reinforce the authority to require tree retention by having applicants use variations to development standards for tree retention. In KZC 95.32.5, the Planning Official is *authorized to require site plan alterations to retain trees with a high retention value* and goes on to describe that such alterations may include *minor adjustments to the location of building footprints, adjustments to the location of driveways*, etc. Applicants are also encouraged to pursue provisions in Kirkland's codes that allow development standards to be modified; however these code sections are not prominent enough so that permit applicants understand the City's authority to require tree retention.

And finally, some cities avoid the back-and-forth negotiations regarding tree retention altogether with Reasonable Use Exceptions. If the applicant feels required tree retention encumbers the development potential of a property, rather than facing numerous plan revisions the applicant would apply for an exception to the code with the Hearing Examiner with the assertion that the code requirements prevent any reasonable economic use of the owner's property (Redmond, Lake Forest Park).

Staff recommendation: Clearly define and prioritize trees of merit by size (Landmark), condition (Specimen), grove status, etc. (#63, 64/72). Revise the current code so the City's authority is clear on requiring variations to development standards for tree retention with the same level of authority seen with neighboring city tree codes. The City would still require tree planting at the same rate.

It should be noted that the PC requested stakeholder feedback on eliminating the Low, Moderate, and High Retention Value tree definitions (#64, 72) and supports incentivizing tree preservation on private property if resources allow, the use of Voluntary Tree Conservation Easements, City support of a citizen-led volunteer Heritage Tree Program similar to the [City of Seattle-PlantAmnesty]() model, and conducting public education on the benefits of trees and mature tree maintenance.

City Council Comments

Staff will be providing a status update to City Council on Nov 20, 2018. Due to packet deadlines, the City Council comments could not be included in this memo but will be conveyed to the PC and HCC with the November 26 joint meeting presentation.

Next Steps

The intent of the joint meeting is to allow continued discussion on the more complex and controversial potential KZC 95 code amendments, provide the additional information requested by the PC and to obtain feedback and clear direction for draft code language. At the November 26 joint Planning Commission-Houghton Community Council meeting, staff would appreciate feedback on the following:

- *Does the PC/HCC agree with staff's recommendations for code amendments to KZC 95, focusing on those included in this memo?*
- *Can the PC/HCC confirm staff has covered all key topics for KZC 95 code amendments?*
- *Is there any other information the PC/HCC needs to review the potential KZC 95 code amendments?*

Staff will be returning with draft code at the December 13, 2018 Planning Commission meeting so that any changes to the draft code can be made prior to the Public Hearing scheduled for January 24, 2019.

Depending on the outcome of the November 26 meeting, the PC-HCC may need to direct staff to adjust the project scope/schedule, allowing more time to study new information in greater detail or to consider related issues. The Planning Commission has also expressed an interest in receiving additional feedback resulting from collaborative efforts between major stakeholders, which may also necessitate an adjustment to the project schedule.

Amendments to Kirkland Municipal Code 1.12.100 (tree code enforcement) is planned to follow KZC 95 code amendment adoption. Proposed changes to KMC 1.12.100 include increased penalties for unauthorized tree removal and revising tree protection inspection procedures. Planning staff anticipates amendments to the Holmes Point Overlay code will resume shortly after KZC 95 adoption.

Attachments:

1. Kirkland Zoning Code Chapter 95, Tree Management and Required Landscaping
2. 2018 Urban Tree Canopy Assessment report
3. Public Engagement Plan and Correspondence up to 10/31/18
4. Public Comments up to 11/15/18
5. Potential KZC 95 Code Amendments with No/Minor Policy Impact
6. Potential KZC 95 Code Amendments with Moderate/Major Policy Impact
7. Excerpts from June 28 Memo to Planning Commission re: canopy cover
8. Urban Tree Database and Allometric Equations
9. Holmes Point Overlay Code Revision – Tree Density Credits & Canopy Cover Whitepaper

10. Snohomish County Urban Tree Canopy Coverage Requirements, Assistance Bulletin #105
11. Snohomish County Tree Canopy Calculation Sheet

cc: File Number CAM18-00408

Attachment 1

Chapter 95 – TREE MANAGEMENT AND REQUIRED LANDSCAPING

Sections:

4. Storm Water

5. Additional Variations

95.33 Tree Density Requirement
1. Tree Density Calculation

2. Supplemental Trees Planted to Meet Minimum Density Requirement

3. Tree Location

4. Minimum Size and Tree Density Value for Supplemental Trees

95.34 Tree and Soil Protection during Development Activity
1. Placing Materials near Trees

2. Protective Barrier

3. Grade

4. Directional Felling

5. Additional Requirements

95.40 Required Landscaping
1. User Guide

2. Use of Significant Existing Vegetation

3. Landscape Plan Required

95.41 Supplemental Plantings
1. General

2. Standards

95.42 Minimum Land Use Buffer Requirements
95.43 Outdoor Use, Activity, and Storage
95.44 Internal Parking Lot Landscaping Requirements
95.45 Perimeter Landscape Buffering for Driving and Parking Areas

1. Perimeter Buffering – General

2. Exception

3. Design Districts

4. Overlapping Requirements

95.46 Modifications to Landscaping Standards
1. Modification to Land Use Buffer Requirements

2. Modifications to General Landscaping Requirements

95.47 Nonconforming Landscaping and Buffers
95.50 Installation Standards for Required Plantings

1. Compliance

95.05 Purpose and Intent

1. Trees and other vegetation are important elements of the physical environment. They are integral to Kirkland's community character and protect public health, safety and general welfare. Protecting, enhancing, and maintaining healthy trees and vegetation are key community values. Comprehensive Plan Policy NE-3.1 describes working towards achieving a City-wide tree canopy coverage of 40 percent. The many benefits of healthy trees and vegetation contribute to Kirkland's quality of life by:

   a. Minimizing the adverse impacts of land disturbing activities and impervious surfaces such as runoff, soil erosion, land instability, sedimentation and pollution of waterways, thus reducing the public and private costs for storm water control/treatment and utility maintenance;

   b. Improving the air quality by absorbing air pollutants, mitigating the urban heat island effect, assimilating carbon dioxide and generating oxygen, and decreasing the impacts of climate change;

   c. Reducing the effects of excessive noise pollution;

d. Providing cost-effective protection from severe weather conditions with cooling effects in the summer months and insulating effects in winter;

e. Providing visual relief and screening buffers;

f. Providing recreational benefits;

g. Providing habitat, cover, food supply and corridors for a diversity of fish and wildlife; and

h. Providing economic benefit by enhancing local property values and contributing to the region's natural beauty, aesthetic character, and livability of the community.

2. Tree and vegetation removal in urban areas has resulted in the loss to the public of these beneficial functions. The purpose of this chapter is to establish a process and standards to provide for the protection, preservation, replacement, proper maintenance, and use of significant trees, associated vegetation, and woodlands located in the City of Kirkland.

The intent of this chapter is to:

a. Maintain and enhance canopy coverage provided by trees for their functions as identified in KZC 95.05(1);

b. Preserve and enhance the City of Kirkland's environmental, economic, and community character with mature landscapes;

c. Promote site planning, building, and development practices that work to avoid removal or destruction of trees and vegetation, that avoid unnecessary disturbance to the City's natural vegetation, and that provide landscaping to buffer the effects of built and paved areas;

d. Mitigate the consequences of required tree removal in land development through on- and off-site tree replacement with the goals of halting net loss and enhancing Kirkland's tree canopy to achieve an overall healthy tree canopy cover of 40 percent City-wide over time;

e. Encourage tree retention efforts by providing flexibility with respect to certain other development requirements;

f. Implement the goals and objectives of the City's Comprehensive Plan;

g. Implement the goals and objectives of the State Environmental Policy Act (SEPA); and

h. Manage trees and other vegetation in a manner consistent with the City's Natural Resource Management Plan.

i. Preserve and protect street trees, trees in public parks and trees on other City property.

(Ord. 4238 § 2, 2010; Ord. 4010 § 2, 2005)

95.10 Definitions
The following definitions shall apply throughout this chapter unless the context clearly indicates otherwise. Definitions that apply throughout this code are also located in Chapter 5 KZC.

1. Caliper – The American Association of Nurserymen standard for trunk measurement of nursery stock. Caliper of the trunk shall be the trunk diameter measured six (6) inches above the ground for up to and including 4-inch caliper size and 12 inches above the ground for larger sizes.

2. Critical Root Zone – The area surrounding a tree at a distance from the trunk, which is equal to one (1) foot for every inch of trunk diameter measured at 4.5 feet from grade or otherwise determined by a qualified professional (example: one (1) foot radius per one (1) inch DBH).

3. Crown – The area of a tree containing leaf- or needle-bearing branches.

4. Diameter at Breast Height (DBH) – The diameter or thickness of a tree trunk measured at 4.5 feet from the ground. DBH is also known as Diameter at Standard Height (DSH).

5. Dripline – The distance from the tree trunk, that is equal to the furthest extent of the tree's crown.

6. Grove – A group of three (3) or more significant trees with overlapping or touching crowns.

7. Hazard Tree – A tree that meets all the following criteria:

   a. A tree with a combination of structural defects and/or disease which makes it subject to a high probability of failure;

   b. Is in proximity to moderate to high frequency targets (persons or property that can be damaged by tree failure); and

   c. The hazard condition of the tree cannot be lessened with reasonable and proper arboricultural practices nor can the target be removed.

8. Impact – A condition or activity that affects a part of a tree including the trunk, branches, and critical root zone.

9. Limit of Disturbance – The boundary between the protected area around a tree and the allowable site disturbance as determined by a qualified professional measured in feet from the trunk.

10. Nuisance Tree – A tree that meets either of the following criteria:

   a. Is causing obvious physical damage to private or public structures, including but not limited to: sidewalk, curb, road, driveway, parking lot, building foundation, or roof; or

   b. Has sustained damage from past maintenance practices.

   The problems associated with the tree must be such that they cannot be corrected by reasonable practices including but not limited to: pruning of the crown or roots of the tree, bracing, and/or cabling to reconstruct a healthy crown.

11. Public Works Official – Designee of the Public Works Director.

12. Qualified Professional – An individual with relevant education and training in arboriculture or urban forestry, having two (2) or more of the following credentials:

   - International Society of Arboriculture (ISA) Certified Arborist;

   - Tree Risk Assessor Certification (TRACE) as established by the Pacific Northwest Chapter of ISA (or equivalent);

   - American Society of Consulting Arborists (ASCA) registered Consulting Arborist;

   - Society of American Foresters (SAF) Certified Forester for Forest Management Plans;

   For tree retention associated with a development permit, a qualified professional must have, in addition to the above credentials, a minimum of three (3) years' experience working directly with the protection of trees during construction and have experience with the likelihood of tree survival after construction. A qualified professional must also be able to prescribe appropriate measures for the preservation of trees during land development.

13. Retention Value – The Planning Official's designation of a tree based on information provided by a qualified professional that is one (1) of the following:

a. High, a viable tree, located within required yards and/or required landscape areas. Tree retention efforts shall be directed to the following trees if they are determined to be healthy and windfirm by a qualified professional, and provided the trees can be safely retained when pursuing alternatives to development standards pursuant to KZC 95.32:

1) Specimen trees;

2) Tree groves and associated vegetation that are to be set aside as preserved groves pursuant to KZC 95.51(3);

3) Trees on slopes of at least 10 percent; or

4) Trees that are a part of a grove that extends into adjacent property, such as in a public park, open space, critical area buffer or otherwise preserved group of trees on adjacent private property. If significant trees must be removed in these situations, an adequate buffer of trees may be required to be retained or planted on the edge of the remaining grove to help stabilize;

b. Moderate, a viable tree that is to be retained if feasible; or

c. Low, a tree that is either (1) not viable or (2) is in an area where removal is unavoidable due to the anticipated development activity.

14. Significant Tree – A tree that is at least six (6) inches in diameter at breast height (DBH) as measured at 4.5 feet from the ground.

15. Significantly Wooded Site – A subject property that has a number of significant trees with crowns that cover at least 40 percent of the property.

16. Site Disturbance – Any development, construction, or related operation that could alter the subject property, including, but not limited to, soil compaction, tree or tree stump removal, road, driveway or building construction, installation of utilities, or grading.

17. Specimen Tree – A viable tree that is considered in very good to excellent health and free of major defects, as determined by the City's Urban Forester.

18. Street Tree – A tree located within the public right-of-way; provided, that if the trunk of the tree straddles the boundary line of the public right-of-way and the abutting property, it shall be considered to be on the abutting property and subject to the provisions of this chapter.

19. Tree Removal – The removal of a tree, through either direct or indirect actions, including but not limited to: (1) clearing, damaging or poisoning resulting in an unhealthy or dead tree; (2) removal of at least half of the live crown; or (3) damage to roots or trunk that is likely to destroy the tree's structural integrity.

20. Viable Tree – A significant tree that a qualified professional has determined to be in good health, with a low risk of failure due to structural defects, is windfirm if isolated or remains as part of a grove, and is a species that is suitable for its location.

21. Wildlife Snag – The remaining trunk of a tree that is intentionally reduced in height and usually stripped of its live branches.

22. Windfirm – A condition of a tree in which it withstands average peak local wind speeds and gusts.

(Ord. 4551 § 4, 2017; Ord. 4238 § 2, 2010; Ord. 4193 § 1, 2009; Ord. 4010 § 2, 2005)

95.20 Exemptions
The following activities are exempt from the provisions of this chapter:

1. Emergency Tree Removal. Any tree that poses an imminent threat to life or property may be removed. The City must be notified within seven (7) days of the emergency tree removal with evidence of the threat for removing the tree to be considered exempt from this chapter. If the Planning Official determines that the emergency tree removal was not warranted or if the removed tree was required by a development permit, the Planning Official may require that the party obtain a permit and/or require that replacement trees and vegetation be replanted as mitigation.

2. Utility Maintenance. Trees may be removed by the City or utility provider in situations involving interruption of services provided by a utility only if pruning cannot solve utility service problems. Utility maintenance shall conform to a City-approved Utility Vegetation Management Plan.

3. Commercial Nurseries or Tree Farms. A nursery or tree farm owner may remove trees that are being grown to be sold as Christmas or landscape trees.

(Ord. 4238 § 2, 2010; Ord. 4010 § 2, 2005)

95.21 Tree Pruning

1. Tree Pruning of Street Trees. It is the responsibility of the abutting property owner to maintain street trees abutting their property, which may include pruning, watering, and mulching. In order to prune, trim, modify, or alter a street tree, the abutting property owner shall apply for a permit by filing a written application with the City. Pruning shall conform to the most recent version of the American National Standards Institute (ANSI) A300 Part 1 – 2001 pruning standards or as outlined in an approved Utility Vegetation Management Plan. The City reserves the right to have City or utility crews perform routine pruning and maintenance of street trees.

2. Tree Pruning on Private Property. A permit is not required to prune trees on private property. Pruning which results in the removal of at least half of the live crown will be considered tree removal and subject to the provisions in KZC 95.23.

Tree topping is not allowed. If a tree required by this chapter is smaller than six (6) inches in diameter and is topped, it must be replaced pursuant to the standards in Chapter 1.12 KMC. If a tree six (6) inches or larger in diameter is topped, the owner must have a qualified professional develop and implement a 5-year restoration pruning program.

(Ord. 4281 § 1, 2011; Ord. 4238 § 2, 2010)

95.23 Tree Removal – Not Associated with Development Activity

1. Introduction. Tree and vegetation removal in urban areas has resulted in the loss of beneficial functions provided by trees to the public. The majority of tree canopy within the City of Kirkland is on private property. The purpose of this section is to establish a process and standards to slow the loss of tree canopy on private property, contributing towards the City's canopy goals and a more sustainable urban forest.

2. Permit Required for Removal of Trees on Private Property or City Right-of-Way. It is unlawful for any person (other than City crews) to remove, prune, trim, modify, alter or damage a tree in a public park or on any other City property.

No person, directly or indirectly, shall remove any significant tree on any property within the City, or any tree in the public right-of-way, without first obtaining a tree removal permit as provided in this chapter, unless the activity is exempted in KZC 95.20 and subsection (5) of this section.

3. Tree Removal Permit Application Form. The Planning and Building Department and Public Works Department shall establish and maintain a tree removal permit application form to allow property owners to request City review of tree removal for compliance with applicable City regulations. The tree removal application form shall include at a minimum the following:

a. A site plan showing the approximate location of significant trees, their size (DBH) and their species, along with the location of structures, driveways, access ways and easements.

b. For required replacement trees, a planting plan showing location, size and species of the new trees in accordance to standards set forth in KZC 95.33(3).

4. Tree Removal Permit Application Procedure and Appeals.

a. Applicants requesting to remove trees must submit a completed permit application on a form provided by the City. The City shall review the application within 21 calendar days and either approve, approve with conditions or modifications, deny the application or request additional information. Any decision to deny the application shall be in writing along with the reasons for the denial and the appeal process.

b. The decision of the Planning Official is appealable using the applicable appeal provisions of Chapter 145 KZC.

c. Time Limit. The removal shall be completed within one (1) year from the date of permit approval.

5. Tree Removal Allowances.

a. Except in the Holmes Point Overlay zone, any private property owner of developed property may remove up to two (2) significant trees from their property within a 12-month period without having to apply for a tree removal permit; provided, that:

1) There is no active application for development activity for the site;

2) The trees were not required to be retained or planted as a condition of previous development activity; and

3) All of the additional standards for tree removal and tree removal permits as described in subsections (5)(b) through (e) of this section are met.

The Planning and Building Department shall establish and maintain a tree removal request form. The form may be used by property owners to request Department review of tree removal for compliance with applicable City regulations.

b. Tree Retention and Replacement Requirements.

1) Tree Retention. For single-family homes, cottages, carriage units, two/three-unit homes, two (2) trees shall be required to remain on the subject property.

2) Tree Replacement.

a) For every significant tree that is removed and is not required to remain based on subsection (5)(b)(1) of this section, the City encourages the planting of a tree that is appropriate to the site.

b) If a tree removal request is for one (1) or both of the trees required to remain, a tree removal permit and one-for-one replacement is required. the replacement tree shall be six (6) feet tall for a conifer and 2-inch caliper for deciduous or broad-leaf evergreen tree.

c) For all other uses not listed in subsection (5)(b)(1) of this section, a tree removal permit is required and the required tree replacement will be based on the required landscaping standards in KZC 95.40 through 95.45.

c. Shoreline Jurisdiction. Properties located within the City's shoreline jurisdiction are subject to additional tree removal and replacement standards if the tree(s) to be removed are located within the required shoreline setback. See Chapter 83 KZC for additional standards.

d. Removal of Hazard or Nuisance Trees. Any private property owner seeking to remove any number of significant trees which are a hazard or nuisance from developed or undeveloped property or the public right-of-way shall first obtain approval of a tree removal permit and meet the requirements of this subsection.

1) Tree Risk Assessment. If the nuisance or hazard condition is not obvious, a tree risk assessment prepared by a qualified professional explaining how the tree(s) meet the definition of a nuisance or hazard tree is required. Removal of nuisance or hazard trees does not count toward the tree removal limit if the nuisance or hazard is supported by a report prepared by a qualified professional and approved by the City.

2) Trees in Critical Areas or Critical Areas Buffers. See Chapter 90 KZC.

3) The removal of any tree in the Holmes Point Overlay Zone requires the planting of a native tree of a minimum of six (6) feet in height in close proximity to where the removed tree was located. Selection of native species and timing of installation shall be approved by the Planning Official.

4) Street Trees. Street trees may only be removed if determined to be a hazard or nuisance. If the removal request is for street trees, the Public Works Official may consider whether the tree(s) are now, or may be in the future, part of the City's plans for the right-of-way. The City shall require a one-for-one tree replacement in a suitable location.

e. Forest Management Plan.

1) A Forest Management Plan must be submitted for developed, significantly wooded sites (over 40 percent canopy coverage) of at least 35,000 square feet in size in which removal of more than two (2) trees is requested and is not exempt under KZC 95.20. A Forest Management Plan must be developed by a qualified professional and shall include the following:

a) A site plan depicting the location of all significant trees (a survey identifying tree locations is not required) with a numbering system of the trees (with corresponding tags on trees in the field). The site plan shall include size (DBH), species, and condition of each tree;

b) Identification of trees to be removed, including reasons for their removal and a description of low impact removal techniques pursuant to subsection (5)(e)(2) of this section;

c) A reforestation plan that includes location, size, species, and timing of installation;

2) The following Forest Management Plan standards shall apply:

a) Trees to remain should be dominant or co-dominant in the stand, healthy and windfirm.

b) No removal of trees from critical areas and their buffers, unless otherwise permitted by this chapter.

c) No removal of specimen trees, unless otherwise permitted by this chapter.

d) No removal of healthy trees that would cause trees on adjacent properties to become hazardous.

e) The reforestation plan ensures perpetuity of the wooded areas. The size of planted trees for reforestation shall be a minimum of three (3) feet tall.

f) Logging operations shall be conducted so as to expose the smallest practical area of soil to erosion for the least possible time. To control erosion, native shrubs, ground cover and stumps shall be retained where feasible. Where not feasible, appropriate erosion control measures to be approved by the City shall be implemented.

g) Removal of tree debris shall be done pursuant to Kirkland Fire Department standards.

h) Recommended maintenance prescription for retained trees with a specific timeline for such management.

(Ord. 4551 § 4, 2017; Ord. 4491 § 3, 2015; Ord. 4437 § 1, 2014; Ord. 4408 § 1, 2013; Ord. 4372 § 1, 2012; Ord. 4238 § 2, 2010)

95.25 Sustainable Site Development

All activities regulated by this chapter shall be performed in compliance with the applicable standards contained in this chapter, unless the applicant demonstrates that alternate measures or procedures will be equal or superior to the provisions of this chapter in accomplishing the purpose and intent of this chapter as described in KZC 95.05.

Applicants requesting alternative compliance shall submit a site assessment report prepared by a qualified professional detailing how the proposed alternative measures will be equal or superior to the benefits provided by the established trees to be removed. Qualifying projects shall implement sustainable site development strategies throughout the construction process as well as contain measurable performance standards for the techniques used. Examples of sustainable site development include building placement with minimal site impact, habitat protection, water conservation, heat island reduction, storm water flow runoff control and water quality, and utilization of the site's natural services such as solar and wind. Requests to use alternative measures and procedures shall be reviewed by the Planning Official, who may approve, approve with conditions, or deny the request.

(Ord. 4238 § 2, 2010; Ord. 4010 § 2, 2005)

95.30 Tree Retention Associated with Development Activity

1. Introduction. The City's objective is to retain as many viable trees as possible on a developing site while still allowing the development proposal to move forward in a timely manner. To that end, the City requires approval of a tree retention plan in conjunction with all development permits resulting in site disturbance and for any tree removal on developed sites not exempted by KZC 95.20. This section includes provisions that allow development standards to be modified in order to retain viable significant trees.

In order to make better decisions about tree retention, particularly during all stages of development, tree retention plans will require specific information about the existing trees before removal is allowed. Specific tree retention plan review standards provided in this section establish tree retention priorities, incentives, and variations to development standards in order to facilitate preservation of viable trees.

A minimum tree density approach is being used to retain as many viable trees as possible with new development activity. The requirement to meet a minimum tree density applies to new single-family homes, cottages, carriage units, two/three-unit homes, and new residential subdivisions and short subdivisions. If such a site falls below the minimum density with existing trees, supplemental planting is required. A tree density for existing trees to be retained is calculated to see if new trees are required in order to meet the minimum density for the entire site. Supplemental tree location priority is set as well as minimum size of supplemental trees to meet the required tree density.

The importance of effective protection of retained trees during construction is emphasized with specific protection standards in the last part of this section. These standards must be adhered to and included on demolition, grading and building plans as necessary.

Properties within jurisdiction of the Shoreline Management Act are subject to additional tree retention and protection regulations as set forth in Chapter 83 KZC.

Properties within the Holmes Point Overlay zone are subject to additional tree retention and protection regulations as set forth in Chapter 70 KZC.

2. Tree Retention Plan Required. An applicant for a development permit must submit a tree retention plan that complies with this section. A qualified professional may be required to prepare certain components of a tree retention plan at the applicant's expense. If proposed development activities call for more than one (1) tree retention plan component, the more stringent tree retention plan component shall apply; provided, that the Planning Official

may require a combination of tree plan components based on the nature of the proposed development activities. If the proposed activity is not clearly identified in this chapter, the Planning Official shall determine the appropriate tree retention plan requirements.

The chart in subsection (5) of this section sets forth the tree retention plan requirements for development activities and associated tree removal. Applicants for development are encouraged to confer with City staff as early in the design process as possible so that the applicable tree planting and retention concepts can be incorporated into the design of the subject property. The Planning Official may waive a component of the tree retention plan if the Planning Official determines that the information is not necessary.

3. Tree Retention Plan Review. Any proposed development of the subject property requiring approval through a building permit, land surface modification permit, and/or demolition permit, or Design Review, Process I, IIA or IIB, described in Chapters 142, 145, 150 and 152 KZC respectively, shall include a tree retention plan to be considered as part of that process.

Based on the tree retention plan information submitted by the applicant and the Planning Official's evaluation of the trees relative to the proposed development on the subject property, the Planning Official shall designate each tree as having a high, moderate, or low retention value as defined in KZC 95.10, Definitions, for application towards the regulations in this chapter.

4. Tree Retention Plan Components. The tree retention plan shall contain the following information as specified in the chart in subsection (5) of this section, unless waived by the Planning Official:

a. A tree inventory containing the following:

1) A numbering system of all existing significant trees on the subject property (with corresponding tags on trees); the inventory must also include significant trees on adjacent property with driplines extending over the subject property line;

2) Limits of disturbance (LOD) of all existing significant trees (including approximate LOD of off-site trees with overhanging driplines);

3) Size (DBH);

4) Proposed tree status (trees to be removed or retained);

5) Brief general health or condition rating of these trees (i.e.: poor, fair, good, excellent, etc.);

6) Tree type or species.

b. A site plan depicting the following:

1) Location of all proposed improvements, including building footprint, access, utilities, applicable setbacks, buffers, and required landscaped areas clearly identified. If a short plat or subdivision is being proposed and the location of all proposed improvements cannot be established, a phased tree retention plan review is required as described in subsection (6)(a) of this section;

2) Accurate location of significant trees on the subject property (surveyed locations may be required). The site plan must also include the approximate trunk location and critical root zone of significant trees that are on adjacent property with driplines extending over the subject property line;

3) Trees labeled corresponding to the tree inventory numbering system;

4) Location of tree protection measures;

5) Indicate limits of disturbance drawn to scale around all trees potentially impacted by site disturbances resulting from grading, demolition, or construction activities (including approximate LOD of off-site trees with overhanging driplines);

6) Proposed tree status (trees to be removed or retained) noted by an 'X' or by ghosting out;

7) Proposed locations of any supplemental trees and any required trees in order to meet tree density or minimum number of trees as outlined in KZC 95.33.

c. An arborist report containing the following:

1) A complete description of each tree's health, condition, and viability;

2) A description of the method(s) used to determine the limits of disturbance (i.e., critical root zone, root plate diameter, or a case-by-case basis description for individual trees);

3) Any special instructions specifically outlining any work proposed within the limits of the disturbance protection area (i.e., hand-digging, tunneling, root pruning, any grade changes, clearing, monitoring, and aftercare);

4) For trees not viable for retention, a description of the reason(s) for removal based on poor health, high risk of failure due to structure, defects, unavoidable isolation (windfirmness), or unsuitability of species, etc., and for which no reasonable alternative action is possible must be given (pruning, cabling, etc.);

5) Describe the impact of necessary tree removal to the remaining trees, including those in a grove or on adjacent properties;

6) For development applications, a discussion of timing and installation of tree protection measures that must include fencing and be in accordance with the tree protection standards as outlined in KZC 95.34; and

7) The suggested location and species of supplemental trees to be used when required. The report shall include planting and maintenance specifications pursuant to KZC 95.50 and 95.51.

5. Tree Retention Plan. The applicant shall submit a Tree Retention Plan that includes the components identified in the following chart based on the proposed development activity.

TREE RETENTION PLAN

Development Activity **Required Components**	**Minor (1)(3) – Single-Family, or two attached, detached, or stacked dwelling units, and related demolition and land surface modification applications**	**Major (2)(3) Single-Family, or two attached, detached, or stacked dwelling units, and related demolition and land surface modification applications**	**Multifamily, Commercial, any other use other than residential, and related demolition and land surface modification applications**	**Short Plat, Subdivisions, cottages, carriage units, two/three-unit homes, and related demolition and land surface modification applications (see KZC 95.30(6)(a), Phased Review, for additional standards)**
TREE INVENTORY AS DESCRIBED IN KZC 95.30(4)(a) FOR:				
All significant trees on the subject property		**X**	**X**	**X**
Significant trees potentially impacted by proposed development activity	**X**			
SITE PLAN AS DESCRIBED IN KZC 95.30(4)(b) TO INCLUDE:				
Surveyed tree locations if required by the Planning Official		**X**	**X**	

Development Activity **Required Components**	**Minor (1)(3) – Single-Family, or two attached, detached, or stacked dwelling units, and related demolition and land surface modification applications**	**Major (2)(3) Single-Family, or two attached, detached, or stacked dwelling units, and related demolition and land surface modification applications**	**Multifamily, Commercial, any other use other than residential, and related demolition and land surface modification applications**	**Short Plat, Subdivisions, cottages, carriage units, two/three-unit homes, and related demolition and land surface modification applications (see KZC 95.30(6)(a), Phased Review, for additional standards)**
Surveyed tree locations				**X**
A final landscape plan showing retained trees			**X**	
REQUIREMENTS IN KZC 95.30(4)(c) SHALL BE PREPARED BY A QUALIFIED PROFESSIONAL AND APPLY TO:				
Significant trees within required yards or within 10 feet of any side property line		**X**		
Significant trees potentially impacted by proposed development activity as determined by the Planning Official			**X**	
Proposed removal of trees with a high retention value in required landscaping areas			**X**	
All significant trees				**X**
TREE RETENTION STANDARDS				
Applicant is encouraged to retain viable trees	**X**(4)			
Retain and protect trees with a high retention value to the maximum extent possible		**X**(4)	**X**(4)	**X**(4)
Retain and protect trees with a moderate retention value if feasible		**X**	**X**	**X**
Preservation and maintenance agreements pursuant to KZC 95.51 are required for all remaining trees on the subject property	**X**	**X**	**X**	**X**(5)
TREE DENSITY				
Tree density requirements shall apply as required in KZC 95.33		**X**		**X**
A minimum of two trees must be on the lot following the requirement set forth in KZC 95.33(4)	**X**			
LANDSCAPING				
Preserved trees in required landscaping areas shall apply toward required landscaping requirements			**X**	

(1) Applicable when new development, redevelopment, or development in which the total square footage of the proposed improvements is less than 50 percent of the total square footage of the existing improvements on the subject property.

(2) Applicable when new development, redevelopment, or development in which the total square footage of the proposed improvements is more than 50 percent of the total square footage of the existing improvements on the subject property.

(3) For lots created through a short subdivision, subdivision, or planned unit development with an approved Tree Retention Plan, the applicant must comply with the Tree Retention

Plan approved with the short subdivision, subdivision, or planned unit development unless subsection (6)(a) of this section, Phased Review, applies.

(4) To retain trees with a high retention value, the applicant shall pursue, where feasible, applicable variations in the development standards of this code as outlined in KZC 95.32.

(5) Prior to short plat or subdivision recording.

6. Additional Tree Retention Plan Standards for Short Plats and Subdivisions.

a. Phased Review.

1) If during the short plat or subdivision review process the location of all proposed improvements, including the building footprint, utilities, and access, was not able to be established, the applicant may submit a Tree Retention Plan that addresses trees only affected by the known improvements at the time of application. Tree removal shall be limited to those affected areas.

2) A new Tree Retention Plan shall be required at each subsequent phase of the project as more information about the location of the proposed improvements is known subject to all of the requirements in this section.

3) Phased review of Tree Retention Plans is not permitted in the Holmes Point Overlay zone. In the HPO zone, subdivision or short plat applications shall provide a comprehensive review of Tree Retention Plans as outlined in subsections (2) through (5) of this section.

b. Modifications to Tree Retention Plan for Short Plats and Subdivisions. A Tree Retention Plan modification request shall contain information as determined by the Planning Official based on the requirements in subsection (5) of this section, Tree Retention Plan. The fee for processing a modification request shall be established by City ordinance.

For Tree Retention Plans approved during the short plat or subdivision review process that established the location of all proposed improvements, including the building footprint, utilities, and access, a modification to the Tree Retention Plan may be approved as follows:

1) Modification – General. The Planning Official may approve minor modifications to the approved Tree Retention Plan in which the minimum tree density credits associated with trees identified for retention are not decreased.

2) Modification Prior to Tree Removal. The Planning Official may approve a modification request to decrease the minimum number of tree density credits associated with trees previously identified for retention if:

a) Trees inventoried in the original Tree Retention Plan have not yet been removed; and

b) The Planning Official shall not approve or deny a modification pursuant to this section without first providing notice of the modification request consistent with the noticing requirements for the short plat.

3) Modification after Tree Removal. A modification request is required to decrease the minimum number of tree density credits associated with trees previously identified for retention after which trees inventoried in the original Tree Retention Plan have already been removed. Such a request may be approved by the Hearing Examiner only if the following are met:

a) The need for the modification was not known and could not reasonably have been known before the tree retention plan was approved;

b) The modification is necessary because of special circumstances which are not the result of actions by the applicant regarding the size, shape, topography, or other physical limitations of the subject property relative to the location of proposed and/or existing improvements on or adjacent to the subject property;

c) There is no practicable or feasible alternative development proposal that results in fewer additional tree removals;

d) The Hearing Examiner shall not approve or deny a modification pursuant to this section without the Planning Official first providing notice of the modification request consistent with the noticing requirements for the short plat and providing opportunity for comments for consideration by the Hearing Examiner; and

e) Said comment period shall not be less than 14 calendar days.

(Ord. 4619 § 1, 2017; Ord. 4437 § 1, 2014; Ord. 4252 § 1, 2010; Ord. 4238 § 2, 2010; Ord. 4010 § 2, 2005)

95.32 Incentives and Variations to Development Standards
In order to retain trees, the applicant should pursue provisions in Kirkland's codes that allow development standards to be modified. Examples include but are not limited to number of parking stalls, right-of-way improvements, lot size reduction under Chapter 22.28 KMC, lot line placement when subdividing property under KMC Title 22, Planned Unit Developments, and required landscaping, including buffers for lands use and parking/driving areas.

Requirements of the Kirkland Zoning Code may be modified by the Planning Official as outlined below when such modifications would further the purpose and intent of this chapter as set forth in KZC 95.05 and would involve trees with a high or moderate retention value.

1. Common Recreational Open Space. Reductions or variations of the area, width, or composition of required common recreational open space may be granted.

2. Parking Areas and Access. Variations in parking lot design and/or access driveway requirements may be granted when the Public Works and Planning Officials both determine the variations to be consistent with the intent of City policies and codes.

3. Required Yards. Initially, the applicant shall pursue options for placement of required yards as permitted by other sections of this code, such as selecting one (1) front required yard in the RSX zone and adjusting side yards in any zone to meet the 15-foot total as needed for each structure on the site. The Planning Official may also reduce the front, side or rear required yards; provided, that:

   a. No required side yard shall be less than five (5) feet; and

   b. The required front yard shall not be reduced by more than five (5) feet in residential zones. There shall not be an additional five (5) feet of reduction beyond the allowance provided for covered entry porches;

   c. Rear yards that are not directly adjacent to another parcel's rear yard but that are adjacent to an access easement or tract may be reduced by five (5) feet;

   d. No required yard shall be reduced by more than five (5) feet in residential zones.

4. Storm Water. Requirements pertaining to stormwater may be varied if approved by the Public Works Official under KMC 15.52.060.

5. Additional Variations. In addition to the variations described above, the Planning Official is authorized to require site plan alterations to retain trees with a high retention value. Such alterations include minor adjustments to the location of building footprints, adjustments to the location of driveways and access ways, or adjustment to the

location of walkways, easements or utilities. The Planning Official and the applicant shall work in good faith to find reasonable solutions.

(Ord. 4547 § 1, 2016; Ord. 4350 § 1, 2012; Ord. 4238 § 2, 2010)

95.33 Tree Density Requirement
The required minimum tree density is 30 tree credits per acre for single-family homes, cottages, carriage units, two/three-unit homes, short plats, and/or subdivisions and associated demolition and land surface modification. For individual lots in a short subdivision or subdivision with an approved Tree Retention Plan, the tree density shall be calculated for each lot within the short plat or subdivision. The tree density may consist of existing trees pursuant to the tree's retention value, supplemental trees or a combination of existing and supplemental trees pursuant to subsection (2) of this section. Existing trees transplanted to an area on the same site shall not count toward the required density unless approved by the Urban Forester based on transplant specifications provided by a qualified professional that will ensure a good probability for survival.

1. Tree Density Calculation. In calculating tree density credits, tree credits may be rounded up to the next whole number from a 0.5 or greater value. For the purpose of calculating required minimum tree density, public right-of-way, areas to be dedicated as public right-of-way, and vehicular access easements not included as lot area with the approved short plat shall be excluded from the area used for calculation of tree density.

Tree density calculation for existing individual trees:

a. Diameter breast height (DBH) of the tree shall be measured in inches.

b. The tree credit value that corresponds with DBH shall be found in Table 95.33.1. Existing native conifers (or other conifer species as approved by the Urban Forester) shall count 1.5 times credits for retention.

Table 95.33.1

Tree Density for Existing Significant Trees

(Credits per minimum diameter – DBH)

DBH	Tree Credits	DBH	Tree Credits	DBH	Tree Credits
3 – 5"	0.5				
6 – 10"	1	24"	8	38"	15
12"	2	26"	9	40"	16
14"	3	28"	10	42"	17
16"	4	30"	11	44"	18
18"	5	32"	12	46"	19
20"	6	34"	13	48"	20
22"	7	36"	14	50"	21

Example: a 7,200-square-foot lot would need five (5) tree credits (7,200/43,560 = 0.165 X 30 = (4.9) or five (5)). The tree density for the lot could be met by retaining one (1) existing 16-inch deciduous tree and one (1) existing 6-inch deciduous tree on site. The same 7,200-square-foot lot would meet the required five (5) tree credits by retaining one (1) existing 14-inch conifer.

2. Supplemental Trees Planted to Meet Minimum Density Requirement. For sites and activities requiring a minimum tree density and where the existing trees to be retained do not meet the minimum tree density requirement, supplemental trees shall be planted to achieve the required minimum tree density.

3. Tree Location. In designing a development and in meeting the required minimum tree density, the trees shall be planted in the following order of priority:

a. On-Site. The preferred locations for new trees are:

1) In preserved groves, critical areas or their buffers.

2) Adjacent to storm water facilities as approved by Public Works under KMC 15.52.060.

3) Entrance landscaping, traffic islands and other common areas in residential subdivisions.

4) Site perimeter – The area of the subject property that is within 10 feet from the property line.

5) On individual residential building lots.

b. Off-Site. When room is unavailable for planting the required trees on site, then they may be planted at another approved location in the City.

c. City Forestry Account. When the Planning Official determines on-site and off-site locations are unavailable, then the applicant shall pay an amount of money approximating the current market value of the supplemental trees into the City forestry account.

4. Minimum Size and Tree Density Value for Supplemental Trees. The required minimum size of the supplemental tree worth one (1) tree credit shall be six (6) feet tall for Thuja/Arborvitae or four (4) feet tall for native or other conifers and 2-inch caliper for deciduous or broad-leaf evergreen tree. Additional credits may be awarded for larger supplemental trees. The installation and maintenance shall be pursuant to KZC 95.50 and 95.51 respectively.

(Ord. 4547 § 1, 2016; Ord. 4238 § 2, 2010)

95.34 Tree and Soil Protection during Development Activity
Prior to development activity or initiating tree removal on the site, vegetated areas, individual trees and soil to be preserved shall be protected from potentially damaging activities pursuant to the following standards:

1. Placing Materials near Trees. No person may conduct any activity within the protected area of any tree designated to remain, including, but not limited to, operating or parking equipment, placing solvents, storing building material or stockpiling any materials, or dumping concrete washout or other chemicals. During construction, no person shall attach any object to any tree designated for protection.

2. Protective Barrier. Before development, land clearing, filling or any land alteration, the applicant shall:

a. Erect and maintain readily visible temporary protective tree fencing along the limits of disturbance which completely surrounds the protected area of all retained trees, groups of trees, vegetation and native soil. Fences shall be constructed of chain link and be at least six (6) feet high, unless other type of fencing is authorized by the Planning Official.

b. Install highly visible signs spaced no further than 15 feet along the entirety of the protective tree fence. Said sign must be approved by the Planning Official and shall state at a minimum "Tree and Soil Protection Area, Entrance Prohibited" and provide the City phone number for code enforcement to report violations.

c. Prohibit excavation or compaction of soil or other potentially damaging activities within the barriers; provided, that the Planning Official may allow such activities approved by a qualified professional and under the supervision of a qualified professional retained and paid for by the applicant.

d. Maintain the protective barriers in place for the duration of the project until the Planning Official authorizes their removal.

e. Ensure that any approved landscaping done in the protected zone subsequent to the removal of the barriers shall be accomplished with machinery from outside the protected zone or by hand.

f. In addition to the above, the Planning Official may require the following:

1) If equipment is authorized to operate within the protected zone, the soil and critical root zone of a tree must be covered with mulch to a depth of at least six (6) inches or with plywood, steel plates or similar material in order to protect roots and soil from damage caused by heavy equipment.

2) Minimize root damage by hand-excavating a 2-foot-deep trench, at edge of critical root zone, to cleanly sever the roots of trees to be retained. Never rip or shred roots with heavy equipment.

3) Corrective pruning performed on protected trees in order to avoid damage from machinery or building activity.

4) Maintenance of trees throughout construction period by watering and fertilizing.

3. Grade.

a. The grade shall not be elevated or reduced within the critical root zone of trees to be preserved without the Planning Official's authorization based on recommendations from a qualified professional. The Planning Official may allow coverage of up to one-half (1/2) of the area of the tree's critical root zone with light soils (no clay) to the minimum depth necessary to carry out grading or landscaping plans, if it will not imperil the survival of the tree. Aeration devices may be required to ensure the tree's survival.

b. If the grade adjacent to a preserved tree is raised such that it could slough or erode into the tree's critical root zone, it shall be permanently stabilized to prevent soil erosion and suffocation of the roots.

c. The applicant shall not install an impervious surface within the critical root zone of any tree to be retained without the authorization of the Planning Official. The Planning Official may require specific construction methods and/or use of aeration devices to ensure the tree's survival and to minimize the potential for root-induced damage to the impervious surface.

d. To the greatest extent practical, utility trenches shall be located outside of the critical root zone of trees to be retained. The Planning Official may require that utilities be tunneled under the roots of trees to be retained if the Planning Official determines that trenching would significantly reduce the chances of the tree's survival.

e. Trees and other vegetation to be retained shall be protected from erosion and sedimentation. Clearing operations shall be conducted so as to expose the smallest practical area of soil to erosion for the least possible time. To control erosion, it is encouraged that shrubs, ground cover and stumps be maintained on the individual lots, where feasible.

4. Directional Felling. Directional felling of trees shall be used to avoid damage to trees designated for retention.

5. Additional Requirements. The Planning Official may require additional tree protection measures that are consistent with accepted urban forestry industry practices.

(Ord. 4547 § 1, 2016; Ord. 4238 § 2, 2010)

95.40 Required Landscaping

1. User Guide. Chapters 15 through 56 KZC containing the use zone or development standards tables assign a landscaping category to each use in each zone. This category is either "A," "B," "C," "D," or "E." If you do not know which landscaping category applies to the subject property, you should consult the appropriate use zone or development standards tables.

Requirements pertaining to each landscaping category are located throughout this chapter, except that Landscaping Category E is not subject to this section.

Landscape Categories A, B, C, D, and E may be subject to additional related requirements in the following other chapters:

a. Various use zone charts or development standards tables, in Chapters 15 through 56 KZC, establish additional or special buffering requirements for some uses in some zones.

b. Chapter 85 KZC, Geologically Hazardous Areas, addresses the retention of vegetation on steep slopes.

c. Chapter 90 KZC, Critical Areas, addresses vegetation within critical areas and critical area buffers.

d. Chapter 110 KZC and Chapter 19.36 KMC address vegetation within rights-of-way, except for the I-405 and SR-520 rights-of-way, and the Cross Kirkland Corridor railbanked rail corridor or the Eastside Rail Corridor.

e. KZC 115.135, Sight Distance at Intersections, which may limit the placement of landscaping in some areas.

f. Chapter 22 KMC addresses trees in subdivisions.

2. Use of Significant Existing Vegetation.

a. General. The applicant shall apply subsection KZC 95.30(3), Tree Retention Plan Procedure, and KZC 95.32, Incentives and Variations to Development Standards, to retain existing native trees, vegetation and soil in areas subject to the landscaping standards of this section. The Planning Official shall give substantial weight to the retained native trees and vegetation when determining the applicant's compliance with this section.

b. Supplement. The City may require the applicant to plant trees, shrubs, and groundcover according to the requirements of this section to supplement the existing vegetation in order to provide a buffer at least as effective as the required buffer.

c. Protection Techniques. The applicant shall use the protection techniques described in KZC 95.34 to ensure the protection of significant existing vegetation and soil.

3. Landscape Plan Required. In addition to the Tree Retention Plan required pursuant to KZC 95.30, application materials shall clearly depict the quantity, location, species, and size of plant materials proposed to comply with the requirements of this section, and shall address the plant installation and maintenance requirements set forth in KZC 95.50 and 95.51. Plant materials shall be identified with both their scientific and common names. Any required irrigation system must also be shown.

(Ord. 4551 § 4, 2017; Ord. 4547 § 1, 2016; Ord. 4476 § 3, 2015; Ord. 4408 § 1, 2013; Ord. 4238 § 2, 2010; Ord. 4121 § 1, 2008; Ord. 4097 § 1, 2007; Ord. 4037 § 1, 2006; Ord. 4030 § 1, 2006; Ord. 4010 § 2, 2005)

95.41 Supplemental Plantings

1. General. The applicant shall provide the supplemental landscaping specified in subsection (2) of this section in any area of the subject property that:

a. Is not covered with a building, vehicle circulation area or other improvement; and

b. Is not a critical area, critical area buffer, or in an area to be planted with required landscaping; and

c. Is not committed to and being used for some specific purpose.

2. Standards. The applicant shall provide the following at a minimum:

a. Living plant material which will cover 80 percent of the area to be landscaped within two (2) years. If the material to be used does not spread over time, the applicant shall re-plant the entire area involved immediately. Any area that will not be covered with living plant material must be covered with nonliving groundcover. Preference is given to using native plant species. See Kirkland Native Tree/Plant Lists.

b. One (1) tree for each 1,000 square feet of area to be landscaped. At the time of planting, deciduous trees must be at least two (2) inches in caliper and coniferous trees must be at least five (5) feet in height.

c. If a development requires approval through Process I, IIA or IIB as described in Chapters 145, 150 and 152 KZC, respectively, the City may require additional vegetation to be planted along a building facade if:

1) The building facade is more than 25 feet high or more than 50 feet long; or

2) Additional landscaping is necessary to provide a visual break in the facade.

d. In RHBD varieties of rose shrubs or ground cover along with other plant materials shall be included in the on-site landscaping.

e. If development is subject to Design Review as described in Chapter 142 KZC, the City will review plant choice and specific plant location as part of the Design Review approval. The City may also require or permit modification to the required plant size as part of Design Review approval.

(Ord. 4547 § 1, 2016; Ord. 4238 § 2, 2010)

95.42 Minimum Land Use Buffer Requirements

The applicant shall comply with the provisions specified in the following chart and with all other applicable provisions of this chapter. Land use buffer requirements may apply to the subject property, depending on what permitted use exists on the adjoining property or, if no permitted use exists, depending on the zone that the adjoining property is in.

ADJOINING PROPERTY / **LANDSCAPING CATEGORY**	***Public park or low density residential use or if no permitted use exists on the adjoining property then a low density zone.**	**Medium or high density residential use or if no permitted use exists on the adjoining property then a medium density or high density zone.**	**Institutional or office use or if no permitted use exists on the adjoining property then an institutional or office zone.**	**A commercial use or an industrial use or if no permitted use exists on the adjoining property then a commercial or industrial zone.**
A	Must comply with subsection (1) (Buffering Standard 1)	Must comply with subsection (1) (Buffering Standard 1)	Must comply with subsection (2) (Buffering Standard 2)	
B	Must comply with subsection (1) (Buffering Standard 1)	Must comply with subsection (1) (Buffering Standard 1)		
C	Must comply with subsection (1) (Buffering Standard 1)	Must comply with subsection (2) (Buffering Standard 2)		
D	Must comply with subsection (2) (Buffering Standard 2)			
E				
Footnotes:	*If the adjoining property is zoned Central Business District, Juanita Business District, North Rose Hill Business District, Rose Hill Business District, Finn Hill Neighborhood Center, Houghton/Everest Neighborhood Center, Business District Core or is located in TL 5, this section KZC 95.42 does not apply.			

This chart establishes which buffering standard applies in a particular case. The following subsections establish the specific requirement for each standard:

1. For standard 1, the applicant shall provide a 15-foot-wide landscaped strip with a 6-foot-high solid screening fence or wall. Except for public utilities, the fence or wall must be placed on the outside edge of the land use buffer or on the property line when adjacent to private property. For public utilities, the fence or wall may be placed either on the outside or inside edge of the landscaping strip. A fence or wall is not required when the land use buffer is adjacent and parallel to a public right-of-way that is improved for vehicular use. See KZC 115.40 for additional fence standards. The land use buffer must be planted as follows:

    a. Trees planted at the rate of one (1) tree per 20 linear feet of land use buffer, with deciduous trees of two and one-half (2-1/2) inch caliper, minimum, and/or coniferous trees eight (8) feet in height, minimum. At least 70 percent of trees shall be evergreen. The trees shall be distributed evenly throughout the buffer, spaced no more than 20 feet apart on center.

    b. Large shrubs or a mix of shrubs planted to attain coverage of at least 60 percent of the land use buffer area within two (2) years, planted at the following sizes and spacing, depending on type:

        1) Low shrub – (mature size under three (3) feet tall), 1- or 2-gallon pot or balled and burlapped equivalent;

        2) Medium shrub – (mature size from three (3) to six (6) feet tall), 2- or 3-gallon pot or balled and burlapped equivalent;

        3) Large shrub – (mature size over six (6) feet tall), 5-gallon pot or balled and burlapped equivalent.

    c. Living ground covers planted from either 4-inch pot with 12-inch spacing or 1-gallon pot with 18-inch spacing to cover within two (2) years 60 percent of the land use buffer not needed for viability of the shrubs or trees.

2. For standard 2, the applicant shall provide a 5-foot-wide landscaped strip with a 6-foot-high solid screening fence or wall. Except for public utilities, the fence or wall must be placed on the outside edge of the land use buffer or on the property line when adjacent to private property. For public utilities, the fence or wall may be placed either on the outside or inside edge of the landscaping strip. A fence or wall is not required when the land use buffer is adjacent and parallel to a public right-of-way that is improved for vehicular use. See KZC 115.40 for additional fence standards. The landscaped strip must be planted as follows:

    a. One (1) row of trees planted no more than 10 feet apart on center along the entire length of the buffer, with deciduous trees of 2-inch caliper, minimum, and/or coniferous trees at least six (6) feet in height, minimum. At least 50 percent of the required trees shall be evergreen.

    b. Living ground covers planted from either 4-inch pot with 12-inch spacing or 1-gallon pot with 18-inch spacing to cover within two (2) years 60 percent of the land use buffer not needed for viability of the trees.

3. Plant Standards. All plant materials used shall meet the most recent American Association of Nurserymen Standards for nursery stock: ANSI Z60.1.

4. Location of the Land Use Buffer. The applicant shall provide the required buffer along the entire common border between the subject property and the adjoining property.

5. Multiple Buffering Requirement. If the subject property borders more than one (1) adjoining property along the same property line, the applicant shall provide a gradual transition between different land use buffers. This transition must occur totally within the area which has the less stringent buffering requirement. The specific design of the transition must be approved by the City.

6. Adjoining Property Containing Several Uses. If the adjoining property contains several permitted uses, the applicant may provide the least stringent land use buffer required for any of these uses.

7. Subject Property Containing Several Uses. If the subject property contains more than one (1) use, the applicant shall comply with the land use buffering requirement that pertains to the use within the most stringent landscaping category that abuts the property to be buffered.

8. Subject Property Containing School. If the subject property is occupied by a school, land use buffers are not required along property lines adjacent to a street.

9. Encroachment into Land Use Buffer. Typical incidental extensions of structures such as chimneys, bay windows, greenhouse windows, cornices, eaves, awnings, and canopies may be permitted in land use buffers as set forth in KZC 115.115(3)(d); provided, that:

a. Buffer planting standards are met; and

b. Required plantings will be able to attain full size and form typical to their species.

(Ord. 4637 § 3, 2018; Ord. 4636 § 3, 2018; Ord. 4495 § 2, 2015; Ord. 4238 § 2, 2010)

95.43 Outdoor Use, Activity, and Storage
Outdoor use, activity, and storage (KZC 115.105(2)) must comply with required land use buffers for the primary use, except that the following outdoor uses and activities, when located in commercial or industrial zones, are exempt from KZC 115.105(2)(c)(1) and (2)(c)(2) as stated below:

1. That portion of an outdoor use, activity, or storage area which abuts another outdoor use, activity, or storage area which is located on property zoned for commercial or industrial use.

2. Outdoor use, activity, and storage areas which are located adjacent to a fence or structure which is a minimum of six (6) feet above finished grade, and do not extend outward from the fence or structure more than five (5) feet; provided, that the total horizontal dimensions of these areas shall not exceed 50 percent of the length of the facade or fence (see Plate 11).

3. If there is an improved path or sidewalk in front of the outdoor storage area, the outdoor use, activity or storage area may extend beyond five (5) feet if a clearly defined walking path at least three (3) feet in width is maintained and there is adequate pedestrian access to and from the primary use. The total horizontal dimension of these areas shall not exceed 50 percent of the length of the facade of the structure or fence (see Plate 11).

4. Outdoor dining areas.

5. That portion of an outdoor display of vehicles for sale or lease which is adjacent to a public right-of-way that is improved for vehicular use; provided, that it meets the buffering standards for driving and parking areas in KZC 95.45(1); and provided further, that the exemptions of KZC 95.45(2) do not apply unless it is fully enclosed within or under a building, or is on top of a building and is at least one (1) story above finished grade.

6. Outdoor Christmas tree lots and fireworks stands if these uses will not exceed 30 days, and outdoor amusement rides, carnivals and circuses, and parking lot sales which are ancillary to the indoor sale of the same goods and services, if these uses will not exceed seven (7) days.

(Ord. 4547 § 1, 2016; Ord. 4238 § 2, 2010)

95.44 Internal Parking Lot Landscaping Requirements
The following internal parking lot landscape standards apply to each parking lot or portion thereof containing more than eight (8) parking stalls.

1. The parking lot must contain 25 square feet of landscaped area per parking stall planted as follows:

a. The applicant shall arrange the required landscaping throughout the parking lot to provide landscape islands or peninsulas to separate groups of parking spaces (generally every eight (8) stalls) from one another and each row of spaces from any adjacent driveway that runs perpendicular to the row. This island or peninsula must be surrounded by a 6-inch-high vertical curb and be of similar dimensions as the adjacent parking stalls. Gaps in curbs are allowed for stormwater runoff to enter landscape island.

b. Landscaping shall be installed pursuant to the following standards:

1) At least one (1) deciduous tree, two (2) inches in caliper, or a coniferous tree five (5) feet in height.

2) Groundcover shall be selected and planted to achieve 60 percent coverage within two (2) years.

3) Natural drainage landscapes (such as rain gardens, bio-infiltration swales and bioretention planters) are allowed when designed in compliance with the stormwater design manual adopted in KMC 15.52.060. Internal parking lot landscaping requirements for trees still apply. Refer to Public Works Pre-Approved Plans.

c. Exception. The requirements of this subsection do not apply to any area that is fully enclosed within or under a building.

2. Rooftop Parking Landscaping. For a driving or parking area on the top level of a structure that is not within the CBD zone or within any zone that requires design regulation compliance, one (1) planter that is 30 inches deep and five (5) feet square must be provided for every eight (8) stalls on the top level of the structure. Each planter must contain a small tree or large shrub suited to the size of the container and the specific site conditions, including desiccating winds, and is clustered with other planters near driving ramps or stairways to maximize visual effect.

3. If development is subject to Design Review as described in Chapter 142 KZC, the City will review the parking area design, plant choice and specific plant location as part of the Design Review approval. The City may also require or permit modification to the required landscaping and design of the parking area as part of Design Review approval.

(Ord. 4547 § 1, 2016; Ord. 4350 § 1, 2012; Ord. 4238 § 2, 2010)

95.45 Perimeter Landscape Buffering for Driving and Parking Areas

1. Perimeter Buffering – General. Except as specified in subsection (2) of this section, the applicant shall buffer all parking areas and driveways from abutting rights-of-way and from adjacent property with a 5-foot-wide strip along the perimeter of the parking areas and driveways planted as follows (see Figure 95.45.A):

a. One (1) row of trees, two (2) inches in caliper and planted 30 feet on center along the entire length of the strip.

b. Living groundcover planted to attain coverage of at least 60 percent of the strip area within two (2) years.

c. Natural drainage landscapes (such as rain gardens, bio-infiltration swales and bioretention planters) are allowed when designed in compliance with the stormwater design manual adopted in KMC 15.52.060. Perimeter landscape buffering requirements for trees in driving and parking areas still apply. Refer to Public Works Pre-Approved Plans.

2. Exception. The requirements of this section do not apply to any parking area that:

a. Is fully enclosed within or under a building; or

b. Is on top of a building and is at least one (1) story above finished grade; or

c. Serves detached dwelling units exclusively; or

d. Is within any zone that requires design regulation compliance. See below for Design District requirements.

3. Design Districts. If subject to Design Review, each side of a parking lot that abuts a street, through-block pathway or public park must be screened from that street, through-block pathway or public park by using one (1) or a combination of the following methods (see Figures 95.45.A, B, and C):

a. By providing a landscape strip at least five (5) feet wide planted consistent with subsection (1) of this section, or in combination with the following. In the RHBD Regional Center (see KZC Figure 92.05.A) a 10-foot perimeter landscape strip along NE 85th Street is required planted consistent with subsection (1) of this section.

b. The hedge or wall must extend at least two (2) feet, six (6) inches, and not more than three (3) feet above the ground directly below it.

c. The wall may be constructed of masonry or concrete, if consistent with the provisions of KZC 92.35(1)(g), in building material, color and detail, or of wood if the design and materials match the building on the subject property.

d. In JBD zones:

1) If the street is a pedestrian-oriented street, the wall may also include a continuous trellis or grillwork, at least five (5) feet in height above the ground, placed on top of or in front of the wall and planted with climbing vines. The trellis or grillwork may be constructed of masonry, steel, cast iron and/or wood.

2) If the wall abuts a pedestrian-oriented street, the requirements of this subsection may be fulfilled by providing pedestrian weather protection along at least 80 percent of the frontage of the subject property.

e. If development is subject to Design Review as described in Chapter 142 KZC, the City will review plant choice and specific plant location as part of the Design Review approval. The City may also require or permit modification to the required plant size as part of Design Review approval.

4. Overlapping Requirements. If buffering is required in KZC 95.42, Land Use Buffering Standards, and by this subsection, the applicant shall utilize the more stringent buffering requirement.

Perimeter Parking Lot Landscaping

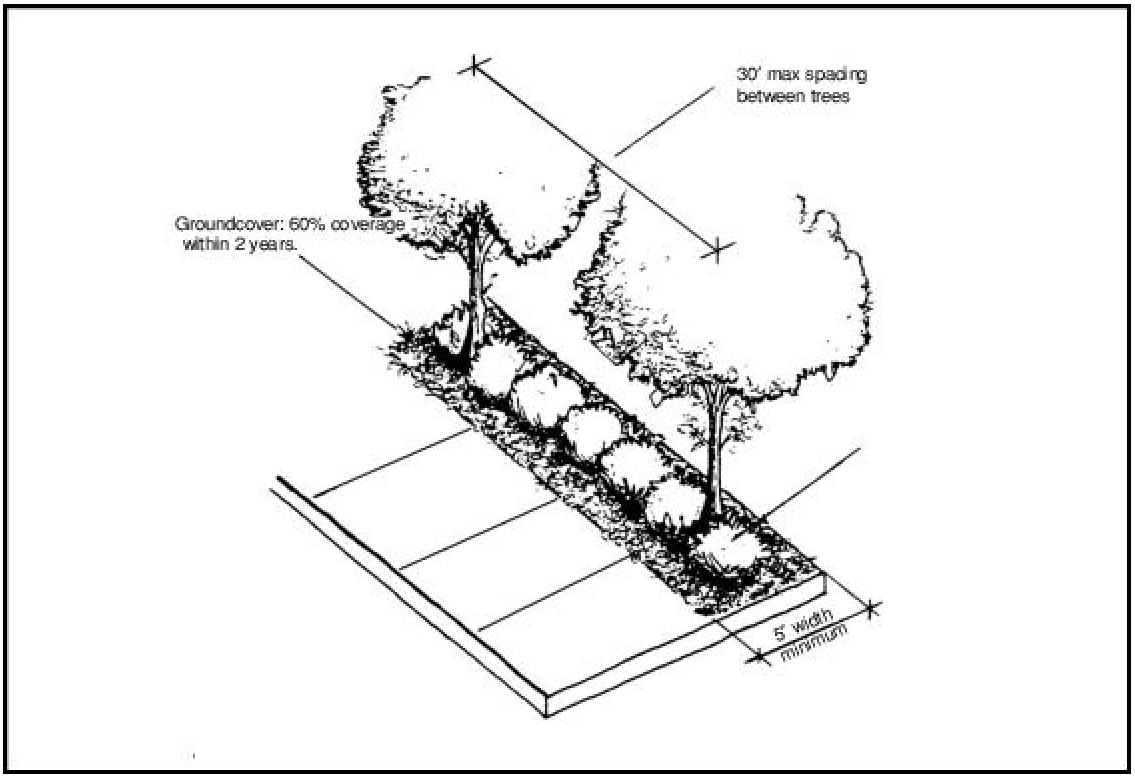


FIGURE 95.45.A

Perimeter Parking – Examples of Various Screen Wall Designs

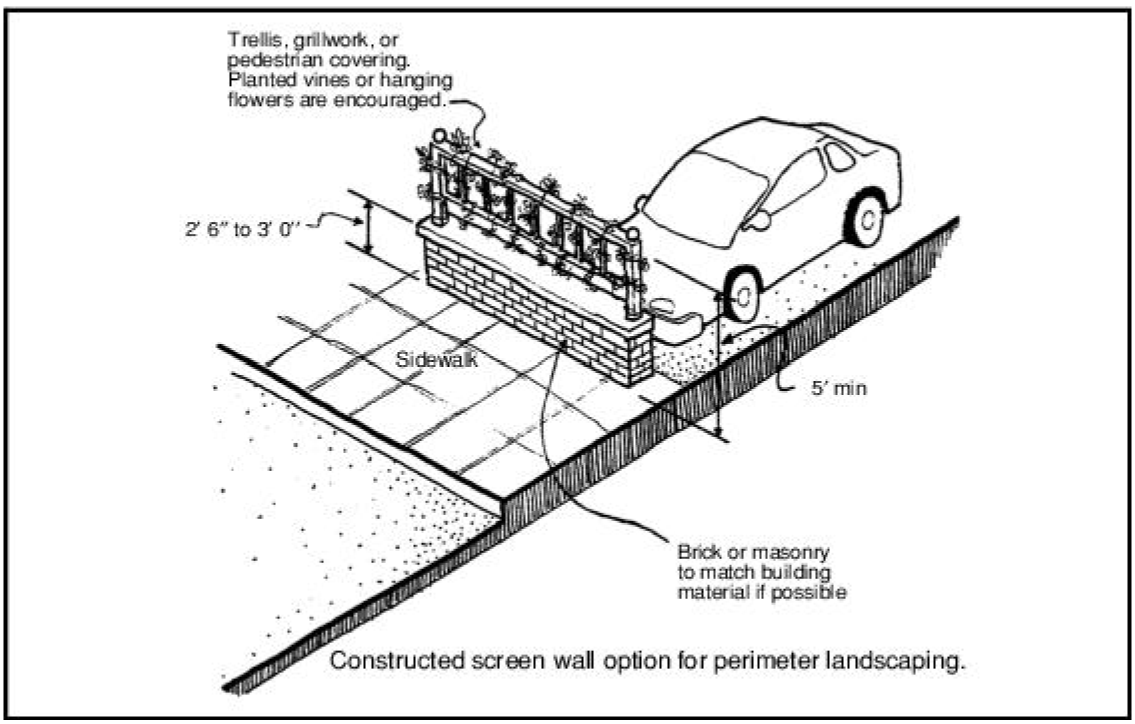


FIGURE 95.45.B

Perimeter Parking – Examples of Various Screen Wall Designs

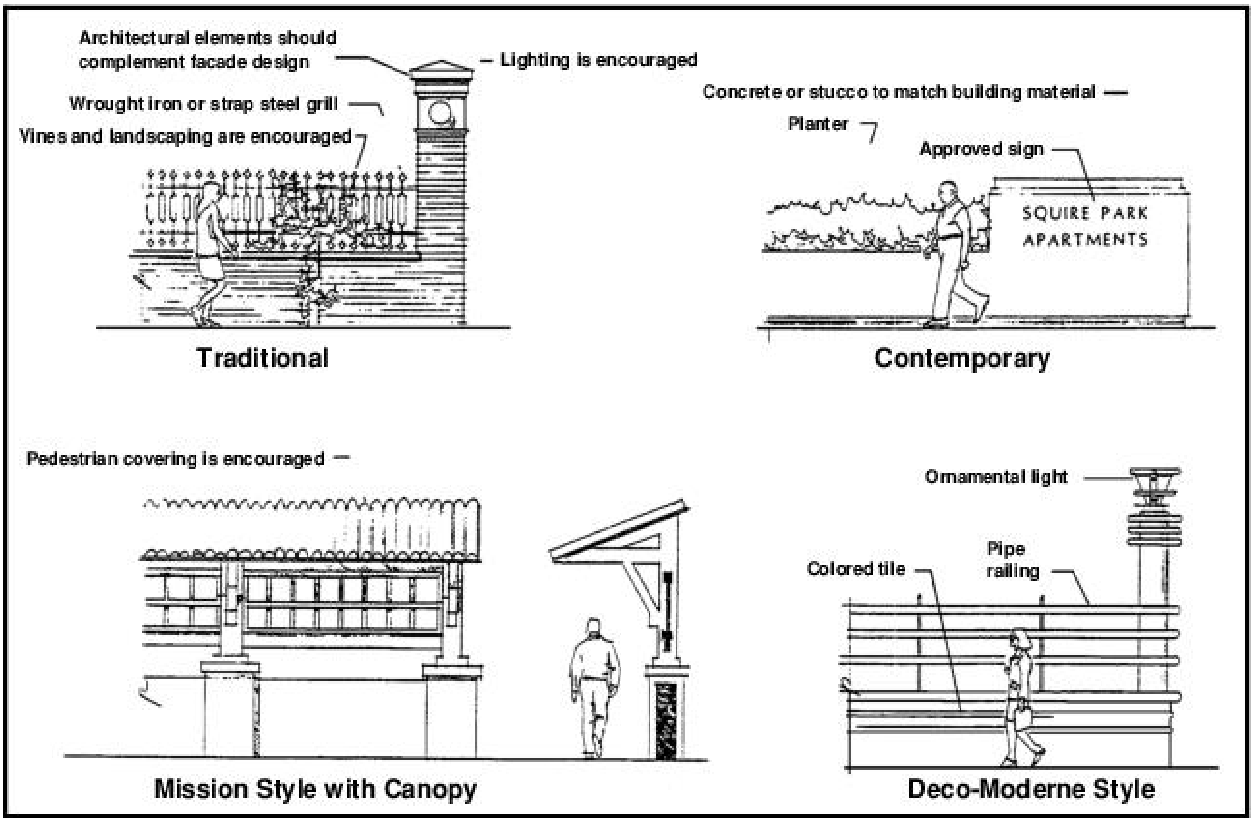


FIGURE 95.45.C

(Ord. 4547 § 1, 2016; Ord. 4238 § 2, 2010; Ord. 4010 § 2, 2005)

95.46 Modifications to Landscaping Standards

1. Modification to Land Use Buffer Requirements. The applicant may request a modification of the requirements of the buffering standards in KZC 95.42. The Planning Official may approve a modification if:

   a. The owner of the adjoining property agrees to this in writing; and

   b. The existing topography or other characteristics of the subject property or the adjoining property, or the distance of development from the neighboring property decreases or eliminates the need for buffering; or

   c. The modification will be more beneficial to the adjoining property than the required buffer by causing less impairment of view or sunlight; or

   d. The Planning Official determines that it is reasonable to anticipate that the adjoining property will be redeveloped in the foreseeable future to a use that would require no, or a less intensive, buffer; or

   e. The location of pre-existing improvements on the adjoining site eliminates the need or benefit of the required landscape buffer.

2. Modifications to General Landscaping Requirements.

a. Authority to Grant and Duration. If the proposed development of the subject property requires approval through Design Review or Process I, IIA, or IIB, described in Chapters 142, 145, 150, and 152 KZC, respectively, a request for a modification will be considered as part of that process under the provisions of this section. The City must find that the applicant meets the applicable criteria listed in subsections (2)(b) and (2)(c) of this section. If granted under Design Review or Process I, IIA, or IIB, the modification is binding on the City for all development permits issued for that development under the building code within five (5) years of the granting of the modification.

If the above does not apply, the Planning Official may grant a modification in writing under the provisions of this section.

b. Internal Parking Lot Landscaping Modifications. For a modification to the internal parking lot landscaping requirements in KZC 95.44, the landscape requirements may be modified if:

1) The modification will produce a landscaping design in the parking area comparable or superior to that which would result from adherence to the adopted standard; or

2) The modification will result in increased retention of significant existing vegetation; or

3) The purpose of the modification is to accommodate low impact development techniques as approved by the Planning Official.

c. Perimeter parking lot and driveway landscaping. For a modification to the perimeter landscaping for parking lots and driveways, the buffering requirements for parking areas and driveways may be modified if:

1) The existing topography of or adjacent to the subject property decreases or eliminates the need for visual screening; or

2) The modification will be of more benefit to the adjoining property by causing less impairment of view or sunlight; or

3) The modification will provide a visual screen that is comparable or superior to the buffer required by KZC 95.45; or

4) The modification eliminates the portion of the buffer that would divide a shared parking area serving two (2) or more adjacent uses, but provides the buffer around the perimeter of the shared parking area.

(Ord. 4547 § 1, 2016; Ord. 4238 § 2, 2010)

95.47 Nonconforming Landscaping and Buffers

1. The landscaping requirements of KZC 95.41, Supplemental Plantings, KZC 95.43 Outdoor Use, Activity and Storage, KZC 95.44, Internal Parking Lot Landscaping, and KZC 95.45, Perimeter Landscape Buffering for Driving and Parking Areas, must be brought into conformance as much as is feasible, based on available land area, in either of the following situations:

a. An increase of at least 10 percent in gross floor area of any structure; or

b. An alteration to any structure, the cost of which exceeds 50 percent of the replacement cost of the structure.

2. Land use buffers must be brought into conformance with KZC 95.42 in either of the following situations:

a. An increase in gross floor area of any structure (the requirement to provide conforming buffers applies only where new gross floor area impacts adjoining property); or

b. A change in use on the subject property and the new use requires larger buffers than the former use.

(Ord. 4547 § 1, 2016; Ord. 4238 § 2, 2010)

95.50 Installation Standards for Required Plantings
All required trees, landscaping and soil shall be installed according to sound horticultural practices in a manner designed to encourage quick establishment and healthy plant growth. All required landscaping shall be installed in the ground and not in above-ground containers, except for landscaping required on the top floor of a structure.

When an applicant proposes to locate a subterranean structure under required landscaping that appears to be at grade, the applicant will: (1) provide site-specific documentation prepared by a qualified expert to establish that the design will adequately support the long-term viability of the required landscaping; and (2) enter into an agreement with the City, in a form acceptable to the City Attorney, indemnifying the City from any damage resulting from development activity on the subject property which is related to the physical condition of the property. The applicant shall record this agreement with the King County Recorder's Office.

1. Compliance. It is the applicant's responsibility to show that the proposed landscaping complies with the regulations of this chapter.

2. Timing. All landscaping shall be installed prior to the issuance of a certificate of occupancy, except that the installation of any required tree or landscaping may be deferred during the summer months to the next planting season, but never for more than six (6) months. Deferred installation shall be secured with a performance bond pursuant to Chapter 175 KZC prior to the issuance of a certificate of occupancy.

3. Grading. Berms shall not exceed a slope of two (2) horizontal feet to one (1) vertical foot (2:1).

4. Soil Specifications. Soils in planting areas shall have soil quality equivalent to Washington State Department of Ecology BMP T5.13. The soil quality in any landscape area shall comply with the soil quality requirements of the Public Works Pre-Approved Plans. See subsection (9) of this section for mulch requirements.

5. Plant Selection.

   a. Plant selection shall be consistent with the Kirkland Plant List, which is produced by the City's Natural Resource Management Team and available in the Planning and Building Department.

   b. Plants shall be selected and sited to produce a hardy and drought-resistant landscape area. Selection shall consider soil type and depth, the amount of maintenance required, spacing, exposure to sun and wind, the slope and contours of the site, and compatibility with existing native vegetation preserved on the site. Preservation of existing vegetation is strongly encouraged.

   c. Prohibited Materials. Plants listed as prohibited in the Kirkland Plant List are prohibited in required landscape areas. Additionally, there are other plants that may not be used if identified in the Kirkland Plant List as potentially damaging to sidewalks, roads, underground utilities, drainage improvements, foundations, or when not provided with enough growing space.

   d. All plants shall conform to American Association of Nurserymen (AAN) grades and standards as published in the "American Standard for Nursery Stock" manual.

   e. Plants shall meet the minimum size standards established in other sections of the KZC.

   f. Multiple-stemmed trees may be permitted as an option to single-stemmed trees for required landscaping provided that such multiple-stemmed trees are at least 10 feet in height and that they are approved by the Planning Official prior to installation.

6. Fertilization. All fertilizer applications to turf or trees and shrubs shall follow Washington State University, National Arborist Association or other accepted agronomic or horticultural standards.

7. Irrigation. The intent of this standard is to ensure that plants will survive the critical establishment period when they are most vulnerable due to lack of watering. All required plantings must provide an irrigation system, using either Option 1, 2, or 3 or a combination of those options. For each option irrigation shall be designed to conserve water by using the best practical management techniques available. These techniques may include, but not be

limited to: drip irrigation to minimize evaporation loss, moisture sensors to prevent irrigation during rainy periods, automatic controllers to ensure proper duration of watering, sprinkler head selection and spacing designed to minimize overspray, and separate zones for turf and shrubs and for full sun exposure and shady areas to meet watering needs of different sections of the landscape.

Exceptions, as approved by the Planning Official, to the irrigation requirement may be approved xeriscape (i.e., low water usage plantings), plantings approved for low impact development techniques, established indigenous plant material, or landscapes where natural appearance is acceptable or desirable to the City. However, those exceptions will require temporary irrigation (Option 2 and/or 3) until established.

a. Option 1. A permanent built-in irrigation system with an automatic controller designed and certified by a licensed landscape architect as part of the landscape plan.

b. Option 2. An irrigation system designed and certified by a licensed landscape architect as part of the landscape plan, which provides sufficient water to ensure that the plants will become established. The system does not have to be permanent if the plants chosen can survive adequately on their own, once established.

c. Option 3. Irrigation by hand. If the applicant chooses this option, an inspection will be required one (1) year after final inspection to ensure that the landscaping has become established.

8. Drainage. All landscapes shall have adequate drainage, either through natural percolation or through an installed drainage system. A percolation rate of one-half (1/2) inch of water per hour is acceptable.

9. Mulch.

a. Required plantings, except turf or areas of established ground cover, shall be covered with two (2) inches or more of organic mulch to minimize evaporation and runoff. Mulch shall consist of materials such as yard waste, sawdust, and/or manure that are fully composted.

b. All mulches used in planter beds shall be kept at least six (6) inches away from the trunks of shrubs and trees.

10. Protection. All required landscaped areas, particularly trees and shrubs, must be protected from potential damage by adjacent uses and development, including parking and storage areas. Protective devices such as bollards, wheel stops, trunk guards, root guards, etc., may be required in some situations.

(Ord. 4551 § 4, 2017; Ord. 4547 § 1, 2016; Ord. 4491 §§ 3, 11, 2015; Ord. 4350 § 1, 2012; Ord. 4238 § 2, 2010; Ord. 4010 § 2, 2005)

95.51 Tree and Landscape Maintenance Requirements

The following maintenance requirements apply to all trees, including street trees, and other vegetation required to be planted or preserved by the City:

1. Responsibility for Regular Maintenance. Required trees and vegetation, fences, walls, and other landscape elements shall be considered as elements of the project in the same manner as parking, building materials, and other site details. The applicant, landowner, or successors in interest shall be responsible for the regular maintenance of required landscaping elements. Plants that die must be replaced in kind. It is also the responsibility of the property owner to maintain street trees abutting their property pursuant to KZC 95.21.

2. Maintenance Duration. Maintenance shall be ensured in the following manner except as set forth in subsections (3), (4) and (5) of this section:

a. All required landscaping shall be maintained throughout the life of the development. Prior to issuance of a certificate of occupancy, the proponent shall provide a final as-built landscape plan and an agreement to maintain and replace all landscaping that is required by the City.

b. Any existing tree or other existing vegetation designated for preservation in a tree retention plan shall be maintained for a period of five (5) years following issuance of the certificate of occupancy for the individual lot or development. After five (5) years, all trees on the property are subject to KZC 95.23 unless:

1) The tree and associated vegetation are in a grove that is protected pursuant to subsection (3) of this section; or

2) The tree or vegetation is considered to be a public benefit related to approval of a planned unit development; or

3) The tree or vegetation was retained to partially or fully meet requirements of KZC 95.40 through 95.45, required landscaping.

3. Maintenance of Preserved Grove. Any applicant who has a grove of trees identified for preservation on an approved Tree Retention Plan pursuant to KZC 95.30(2) shall provide prior to occupancy the legal instrument acceptable to the City to ensure preservation of the grove and associated vegetation in perpetuity, except that the agreement may be extinguished if the Planning Official determines that preservation is no longer appropriate.

4. Maintenance in Holmes Point Overlay Zone. Vegetation in designated Protected Natural Areas in the Holmes Point Overlay Zone is to be protected in perpetuity pursuant to KZC 70.15(8)(a). Significant trees in the remainder of the lot shall be protected in perpetuity pursuant to KZC 70.15(8)(b).

5. Nonnative Invasive and Noxious Plants. It is the responsibility of the property owner to remove nonnative invasive plants and noxious plants from the vicinity of any tree or other vegetation that the City has required to be planted or protected. Removal must be performed in a manner that will not harm the tree or other vegetation that the City has required to be planted or protected.

6. Landscape Plans and Utility Plans. Landscape plans and utility plans shall be coordinated. In general, the placement of trees and large shrubs should adjust to the location of required utility routes both above and below ground. Location of plants shall be based on the plant’s mature size both above and below ground. See the Kirkland Plant List for additional standards.

(Ord. 4551 § 4, 2017; Ord. 4437 § 1, 2014; Ord. 4238 § 2, 2010)

95.52 Prohibited Vegetation
Plants listed as prohibited in the Kirkland Plant List shall not be planted in the City or required to be retained.

For landscaping not required under this chapter, this prohibition shall become effective on February 14, 2008. The City may require removal of prohibited vegetation if installed after this date. Residents and property owners are encouraged to remove pre-existing prohibited vegetation whenever practicable.

(Ord. 4450 § 1, 2014; Ord. 4238 § 2, 2010; Ord. 4121 § 1, 2008)

95.55 Enforcement and Penalties
Upon determination that there has been a violation of any provision of this chapter, the City may pursue code enforcement and penalties in accordance with the provisions of Chapter 1.12 KMC, Code Enforcement.

(Ord. 4286 § 1, 2011; Ord. 4281 § 1, 2011; Ord. 4238 § 2, 2010; Ord. 4010 § 2, 2005)

95.57 City Forestry Account
1. Funding Sources. All civil penalties received under this chapter and all money received pursuant to KZC 95.33(3)(c) shall be used for the purposes set forth in this section. In addition, the following sources may be used for the purposes set forth in this section:

a. Agreed upon restoration payments imposed under KZC 95.55 or settlements in lieu of penalties;

b. Sale of trees or wood from City property where the proceeds from such sale have not been dedicated to another purpose;

c. Donations and grants for tree purposes;

d. Sale of seedlings by the City; and

e. Other monies allocated by the City Council.

2. Funding Purposes. The City shall use money received pursuant to this section for the following purposes:

a. Acquiring, maintaining, and preserving wooded areas within the City;

b. Planting and maintaining trees within the City;

c. Establishment of a holding public tree nursery;

d. Urban forestry education;

e. Implementation of a tree canopy monitoring program; or

f. Other purposes relating to trees as determined by the City Council.

(Ord. 4238 § 2, 2010)

Attachement 2

URBAN TREE CANOPY ASSESSMENT

KIRKLAND, WASHINGTON

OCTOBER | 2018

King Conservation District

plan-it GEO

City of Kirkland Washington

AN ASSESSMENT OF
URBAN TREE CANOPY

KIRKLAND, WASHINGTON

Someone is sitting in the shade today because someone planted a tree a long time ago.
-Warren Buffet

PREPARED BY
Plan-It Geo, LLC, Arvada, Colorado

PREPARED FOR
City of Kirkland, Washington

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4,361

ACRES OF TREE CANOPY

EXECUTIVE SUMMARY

PURPOSE OF THIS ANALYSIS

The City of Kirkland is located within King County, Washington, in the Seattle metropolitan area (Figure 1). It is approximately 18.2 square miles or 11,671 acres, of which 11,394 are land acres. Across the city, trees along streets, in parks, yards, and natural areas constitute a valuable urban and community forest. This resource is a critical element of the region's green infrastructure, contributing to environmental quality, public health, water supply, local economies and aesthetics. The primary goal of this assessment is to provide an updated baseline and benchmark of the City's tree canopy and interpret the results across a range of geographic boundaries. Canopy change since 2010 is also assessed to determine the extent and location of growth or decline in Kirkland's urban forest to better inform future management actions.

URBAN TREE CANOPY IN KIRKLAND

Results of this study indicate that in 2017, the city of Kirkland contains 37 percent urban tree canopy (or 4,361 of the city's 11,671 total acres); 20 percent non-canopy vegetation (2,392 acres); 2 percent soil/dry vegetation (244 acres); 38 percent impervious surfaces (4,398 acres); and 2 percent water (277 acres). In further subdividing the impervious areas, 12 percent (1,421 acres) of Kirkland's total area are buildings, 8 percent (973 acres) are roads, 5 percent (585 acres) are parking lots, 3 percent (326 acres) are driveways, 1 percent (159 acres) are sidewalks, and 8 percent (933 acres) are "other impervious" areas such as trails, medians, etc.

Existing urban tree canopy covers 38 percent of Kirkland's land area (4,361 of the city's 11,394 land acres). Of the city's 62 percent of land area not presently occupied by tree canopy, 30 percent (3,421 acres) are suitable for future tree plantings, and 32 percent (3,612 acres) are unsuitable due to its current land use or other restraint. In further dividing the city's urban tree canopy, 12 percent are overhanging impervious surfaces. A change analysis shows that the city's canopy has decreased by approximately 2 percent, down from 41 percent when it was last assessed based on 2010 imagery.

ASSESSMENT BOUNDARIES

This study assesses urban tree canopy (UTC), possible planting areas (PPA), and change at multiple geographic scales in order to provide actionable information to a diverse range of audiences. By identifying what resources and opportunities exist at these scales, the City can be more proactive in their approach to protect and expand their urban tree canopy. Metrics are available at the following geographic boundaries: the citywide boundary; the citywide boundary prior to annexation of the Finn Hill, North Juanita, and Kingsgate neighborhoods; HUC-12 watersheds (2); King County comprehensive plan land

Figure 1. | Kirkland occupies approximately 18.2 square miles in King County, Washington.

use classes (10); neighborhoods (14); drainage basins (15); U.S. census block groups (80); the Holmes Point overlay (1); rights-of-way (1); a buffer around the City's critical area buffers (1); park and open space classes (4); and shoreline jurisdiction areas (48). Canopy change since 2010 was also assessed for all geographic boundaries. Additionally, the city's urban tree canopy is delineated as overhanging impervious surfaces or not.

RECOMMENDATIONS

The results of this analysis can be used to develop a continued strategy to protect and expand Kirkland's urban forest. The UTC, PPA, and change metrics should be used as a guide to determine where the city has succeeded in protecting and expanding its urban forest resource, while also targeting the best areas to concentrate future efforts based on needs, benefits, and available planting space. Existing tree canopy in single-family residential areas and rights-of-way have decreased in the last seven years. Increased tree planting activities are recommended in these areas to expand Kirkland's urban forest.

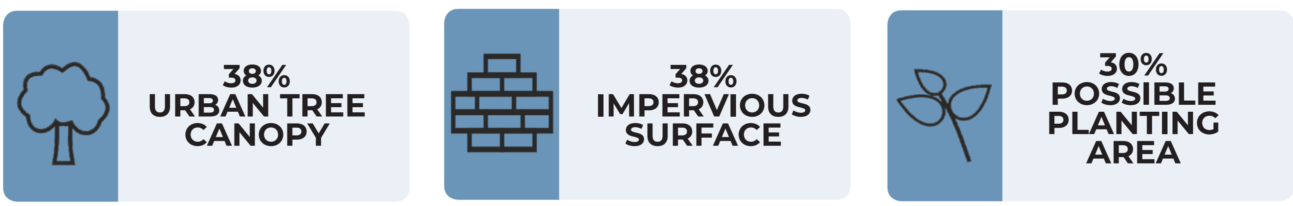


Figure 2. | Based on an analysis of 2017 high-resolution imagery, Kirkland contains 38% tree canopy, 30% areas that could support canopy in the future, and 38% total impervious areas.

PROJECT METHODOLOGY

This section describes the methods through which land cover, urban tree canopy, and possible planting areas were mapped. These datasets provide the foundation for the metrics reported at the selected target geographies, as well as the change in canopy over time.

DATA SOURCES

This assessment utilized 2017 high-resolution (1-meter) multispectral imagery from the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP) and 2016 LiDAR data from King County, Washington to derive the land cover data set. The NAIP imagery is used to classify all types of land cover, whereas the LiDAR is most useful for distinguishing tree canopy from other types of vegetation. Additional GIS layers provided by the City of Kirkland were also incorporated into the analysis, such as the impervious surfaces layers (buildings, roads, parking lots, etc.) and the 2010 urban tree canopy data which provided the basis of the change analysis.

MAPPING LAND COVER

An initial land cover dataset was to be created prior to mapping tree canopy and assessing change. The land cover data set is the most fundamental component of an urban tree canopy assessment. An object-based image analysis (OBIA) software program called Feature Analyst was used to classify features through an iterative approach. In this process, objects' spectral signatures across four bands (blue, green, red, and near-infrared), textures, pattern relationships, and object height were considered. This remote sensing process used the NAIP imagery and LiDAR to derive five initial land cover classes. These classes are shown in Figure 3.After manual classification improvement and quality control were performed on the remote sensing products, additional data layers from the city (such as buildings, roads, and other impervious surfaces) were utilized to capture finer feature detail and further categorize the land cover dataset. Using those impervious surface data provided by the city (buildings, roads, parking lots, etc.), the amount of urban tree canopy overhanging impervious surfaces was also quantified to assist with hydrologic modeling.

URBAN TREE CANOPY | OTHER VEGETATION | SOIL AND DRY VEGETATION | IMPERVIOUS | WATER

Figure 3. | Five (5) distinct land cover classes were identified in the 2017 tree canopy assessment: urban tree canopy, non-canopy vegetation, bare soil and dry vegetation, impervious (paved) surfaces, and water.

IDENTIFYING POSSIBLE PLANTING AREAS AND UNSUITABLE AREAS FOR PLANTING

In addition to quantifying Kirkland's existing tree canopy cover, another metric of interest in this assessment was the area where tree canopy could be expanded. To assess this, all land area in Kirkland that was not existing tree canopy coverage was classified as either possible planting area (PPA) or unsuitable for planting. Possible planting areas were derived from the non-canopy vegetation and impervious classes that could be modified or have trees planted adjacent to them (e.g. parking lots, driveways, and sidewalks) to provide aesthetic value as well as localized shading and cooling. Unsuitable areas, or areas where it was not feasible to plant trees due to biophysical or land use restraints (e.g. airport runways, recreation fields, etc.), were manually delineated and overlaid with the existing land cover data set (Figure 4). The final results were reported as PPA Vegetation, PPA Impervious, Total PPA (vegetation and impervious), Unsuitable Vegetation, Unsuitable Impervious, Unsuitable Soil, and Total Unsuitable.

Figure 4. | Vegetated areas where it would be biophysically feasible for tree plantings but undesirable based on their current usage (left) were delineated in the data as "Unsuitable" (right). These areas included recreational sports fields and other open space.

DEFINING ASSESSMENT LEVELS

In order to best inform the City Council and all of Kirkland's various stakeholders, urban tree canopy and other associated metrics were tabulated across a variety of geographic boundaries (Figure 5). These boundaries include the city boundary; the pre-annexation city boundary; HUC-12 watersheds; King County comprehensive plan land use classes; neighborhoods; drainage basins; U.S. census block groups; the Holmes Point overlay; rights-of-way; critical area buffers; parks and open spaces; and shoreline jurisdiction areas.

- The City of Kirkland's citywide boundary is the one (1) main area of interest over which all metrics are summarized.
- Metrics were also calculated for the City of Kirkland's area prior to its annexation of the Finn Hill, North Juanita, and Kingsgate neighborhoods (approximately 4,601 acres), which became effective in 2011.
- Two (2) HUC-12 watersheds were assessed to interpret differences in urban tree canopy across a naturally occurring geographic boundary.
- Ten (10) King County comprehensive plan land use classes were analyzed to assess differences in tree canopy across different human uses of land.
- Fourteen (14) neighborhoods were assessed to quantify tree canopy at an easily-conceptualized scale for local residents.
- Fifteen (15) drainage basins make up the city of Kirkland. Since trees play an important role in regulating stormwater runoff and preventing flooding, the basins were analyzed to explore differences in tree canopy across the City's drainage areas.
- Eighty (80) census block groups were assessed. Census block groups (CBGs) are used by the U.S. Census Bureau to assure statistical consistency when tracking populations across the United States and can be valuable indicators of environmental justice as they are directly linked with demographic and socioeconomic data.
- Metrics were assessed for Kirkland's heavily-wooded, coastal region of Holmes Point.
- Right-of-way (ROW) was also assessed. ROW refers to the areas that are publicly maintained, such as streets, sidewalks, and medians, and is helpful for quantifying the city's street trees.
- Trees also provide many environmental benefits such as preventing erosion, offering a habitat for wildlife species, and improving air and water quality. For this reason, a 100' buffer was applied to all of the City's critical areas and urban tree canopy was assessed within this area.
- Four (4) different classes of parks and open spaces were assessed to determine how tree canopy is distributed in the city's green spaces.
- Forty-eight (48) shoreline jurisdiction areas were assessed to determine how tree canopy is distributed in the City's coastal regions.

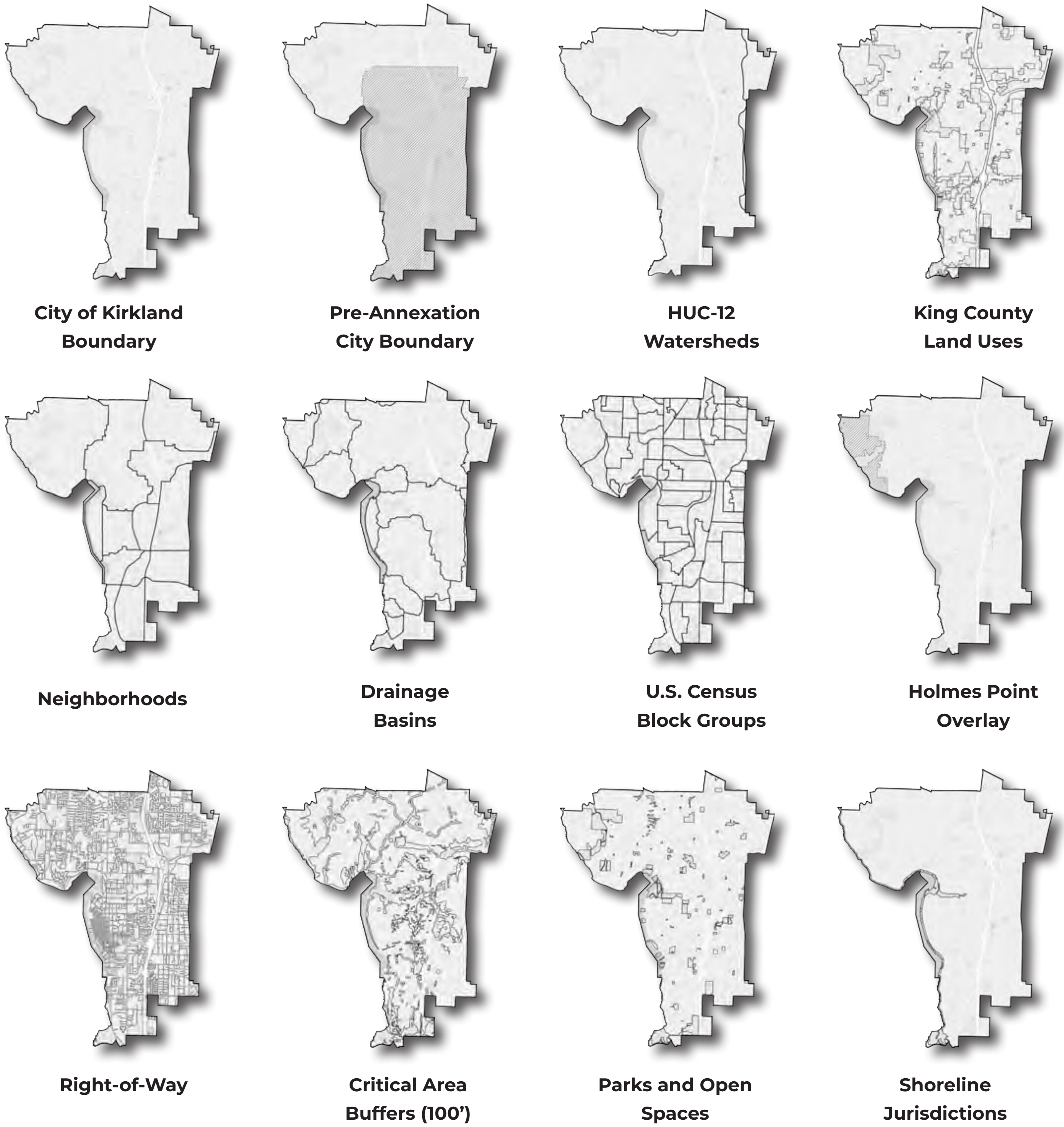


Figure 5. | Twelve (12) distinct geographic boundaries were explored in this analysis: the full city boundary, the pre-annexation city boundary, watersheds, land use classes, neighborhoods, drainage basins, U.S. Census block groups, the Holmes Point overlay, right-of-way, critical area buffers, parks and open spaces, and shoreline jurisdictions.

STATE OF THE CANOPY AND KEY FINDINGS

This section presents the key findings of this study including the land cover base map, canopy analysis, and change analysis results which were analyzed across various geographic assessment boundaries. These results, or metrics, help inform a strategic approach to identifying existing canopy to preserve and future planting areas. Land cover percentages are based on the total area of interest while urban tree canopy, possible planting area, and unsuitable percentages are based on land area. Water bodies are excluded from land area because they are typically unsuitable for planting new trees without significant modification.

CITYWIDE LAND COVER

In 2017, tree canopy constituted 37 percent of Kirkland's land cover; non-canopy vegetation was 20 percent; soil/dry vegetation was 2 percent; impervious was 38 percent; and water was 2 percent. These generalized land cover results are presented below in Table 1.

The impervious land cover class was then subdivided into more specific classifications. Approximately 12 percent was buildings, 8 percent was roads, 5 percent was parking lots, 1 percent was sidewalks, 3 percent was driveways, and 8 percent was "other impervious" (all other paved surfaces not included in the previous classes). Parking lots and sidewalks may offer opportunities for new tree plantings and additional canopy cover, but the data for these opportunistic impervious land classifications would require further analyses to determine their planting suitability. The detailed land cover results, including impervious classifications, are presented in Figure 6.

Table 1. | Generalized land cover classification results.

City Boundary	Total Area	Tree Canopy	Non-Canopy Vegetation	Impervious Surfaces	Soil & Dry Vegetation	Water
Acres	11,671	4,361	2,392	4,398	244	277
% of Total	100%	37%	20%	38%	2%	2%

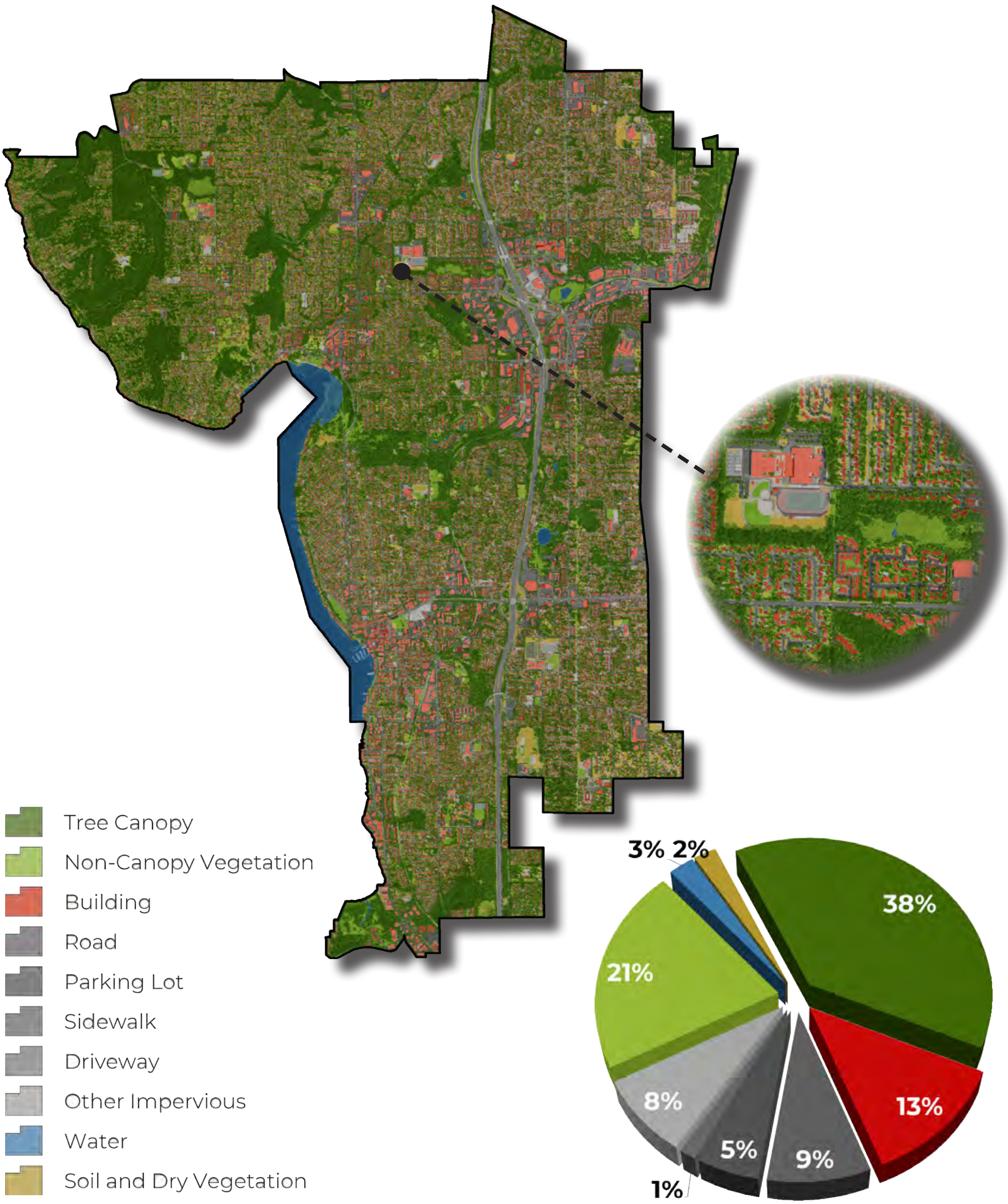


Figure 6. | Detailed land cover classes for Kirkland, Washington based on 2017 NAIP imagery and 2016 PSLC LiDAR data. (Percentages based on land acres.)

CITYWIDE URBAN TREE CANOPY

This urban tree canopy assessment utilized the land cover map as a foundation to determine Possible Planting Areas throughout the City. Additional layers and information regarding land considered unsuitable for planting were also incorporated into the analysis. Note that the results of this study are based on land area as opposed to total area (note the difference between Total Acres and Land Acres in Table 2).

Results of this study indicate that within the City of Kirkland, 4,631 acres are covered with urban tree canopy, making up 38 percent of the city's 11,394 land acres; 3,421 acres are covered with other vegetation or impervious surfaces (parking lots, driveways, and sidewalks) where it would be possible to plant trees (PPA), making up 30 percent of the city; and the other 3,612 acres were considered unsuitable for tree planting, making up 32 percent of the city. The unsuitable areas include recreational sports fields, buildings, roads, other impervious surfaces, and areas of bare soil and dry vegetation. Bare soil and dry vegetation are considered unsuitable as these areas would require modification through irrigation or other methods to support healthy trees.

Table 2. | Urban tree canopy assessment results, by acres and percent. (Percentages based on land acres.)

City of Kirkland	Acres	%
Total Area	11,671	100%
Land Area	11,394	98%
Urban Tree Canopy	4,361	38%
Possible Planting Area - Vegetation	2,351	21%
Possible Planting Area - Impervious	1,070	9%
Total Possible Planting Area	3,421	30%
Unsuitable Vegetation	40	<1%
Unsuitable Impervious	3,330	29%
Unsuitable Soil	242	2%
Total Unsuitable Areas	3,612	32%

Urban Tree Canopy and Possible Planting Area in the City of Kirkland

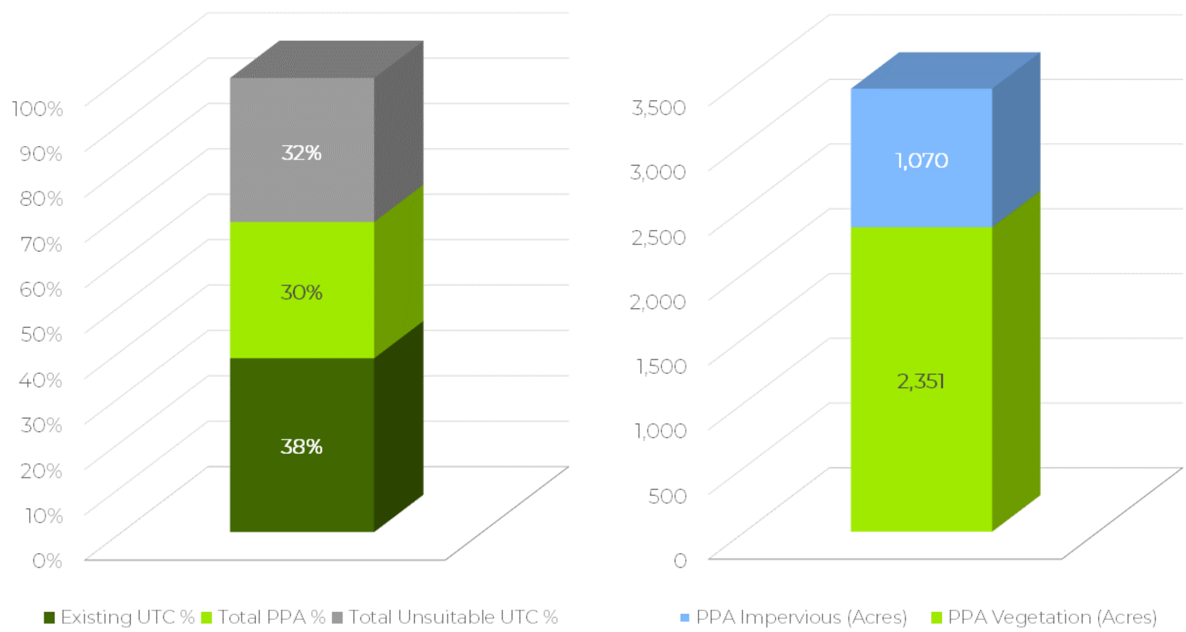


Figure 7. | Urban tree canopy, potential planting area, and area unsuitable for UTC by percentage (left) and types of possible planting area by acreage (right) in the City of Kirkland.

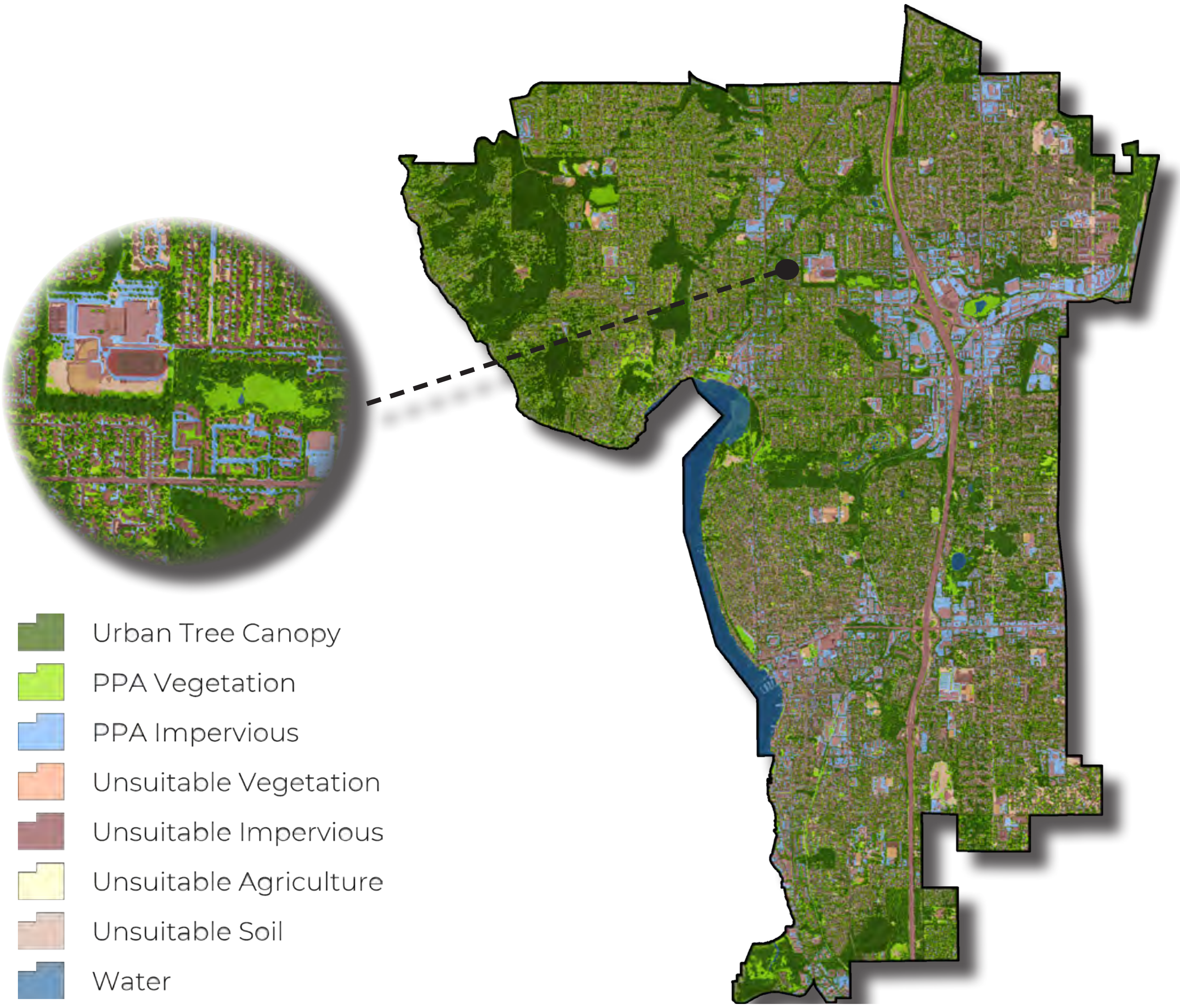


Figure 8. | Urban tree canopy, possible planting area, and area unsuitable for UTC in the city of Kirkland.

The city's 4,631 acres of urban tree canopy were further divided into subcategories based on whether the trees' canopy had an impervious understory or pervious understory. Tree canopy overhanging an impervious surface can provide many benefits through ecosystem services such as localized cooling provided by shading of impervious surfaces and increased stormwater absorption. Results indicated that in Kirkland, 540 acres or 12 percent of urban tree canopy had an impervious understory.

Table 3. | Urban tree canopy classification for the City of Kirkland by acres and percent.

City of Kirkland	Acres	%
Tree Canopy with Pervious Understory	3,821	88%
Tree Canopy with Impervious Understory	540	12%

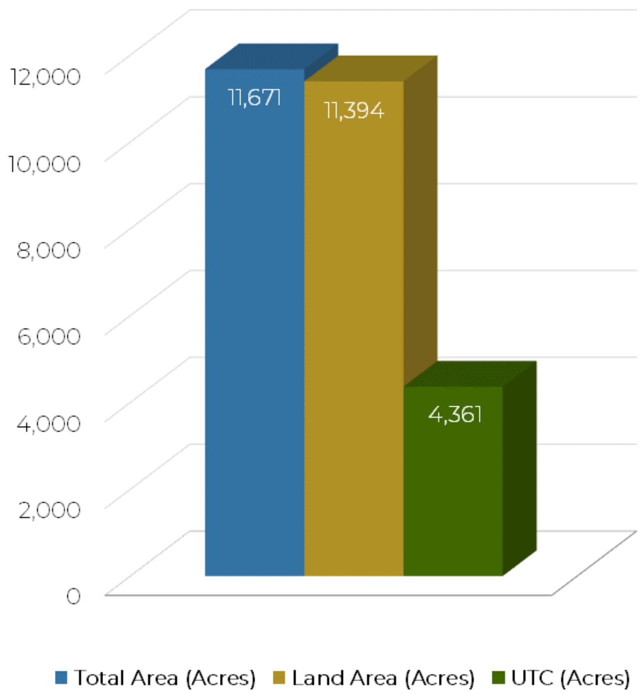
URBAN TREE CANOPY BY PRE-ANNEXATION CITY BOUNDARY

Prior to its annexation of three additional neighborhoods in 2011 (Finn Hill, North Juanita, and Kingsgate), the City of Kirkland was composed of approximately 11 square miles or 7,071 acres, of which 6,802 (96 percent) were land acres. In 2017, this pre-annexation boundary contained 35 percent UTC (2,371 acres), 30 percent total PPA (2,040 acres), and 35 percent total unsuitable acres (2,391 acres). The annexation of these three neighborhoods had a large impact on the total amount of tree canopy within the current city boundary: over 50% of all canopy is found in these neighborhoods.

Table 4. | Urban tree canopy assessment results by pre-annexation boundary. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within the boundary (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Pre-Annexation Boundary	6,802	60%	2,371	35%	54%	2,040	30%	60%

Urban Tree Canopy Compared to Total Area and Land Area, Post- and Pre-Annexation



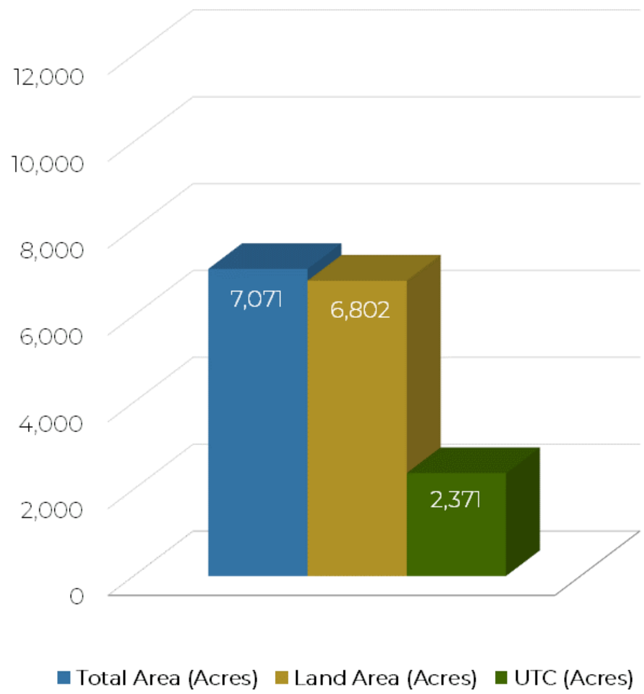


Figure 9. | Urban tree canopy, land acres, and total acres in the City of Kirkland's current boundary (left) and pre-annexation boundary (right).

URBAN TREE CANOPY BY WATERSHEDS

UTC and PPA were assessed for the two HUC-12 watersheds that intersect the City of Kirkland. The Lake Washington-Sammamish River watershed occupies the vast majority of the City's area (94 percent), while the Bear Creek-Sammamish River watershed intersects a small portion of its northern and eastern edges. The larger of the two watersheds closely reflected the citywide metrics with 38 percent UTC and 30 percent total PPA, while the smaller watershed had slightly less of each with 36 percent UTC and 27 percent total PPA. However, the smaller watershed contained a higher percentage of PPA-Impervious than its counterpart with 12 percent compared to 9 percent.

Table 5. | Urban tree canopy assessment results by HUC-12 watershed. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within each watershed (dist.).

Watersheds	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Bear Creek-Sammamish River	699	6%	252	36%	6%	189	27%	6%
Lake Washington-Sammamish River	10,695	94%	4,108	38%	94%	3,232	30%	94%
Totals	**11,394**	**100%**	**4,361**	**38%**	**100%**	**3,421**	**30%**	**100%**

URBAN TREE CANOPY BY LAND USES

UTC and PPA were assessed for the ten different land uses found within the King County comprehensive plan land use data layer. UTC ranged from 17 percent in General Commercial areas to 70 percent in Park/Golf Course/Trail/Open Space areas, with the majority of other land uses having between 25-35 percent UTC. Although General Commercial areas had the lowest existing UTC, they contained the greatest percentages of all types of plantable space with 41 percent total PPA, 41 percent PPA-Vegetation, and 35 percent PPA-Impervious. Single-family residential areas contributed the most to the City's total UTC and PPA, with 37 percent UTC making up 69 percent of the City's total canopy and 30 percent total PPA making up 72 percent of the City's total plantable space.

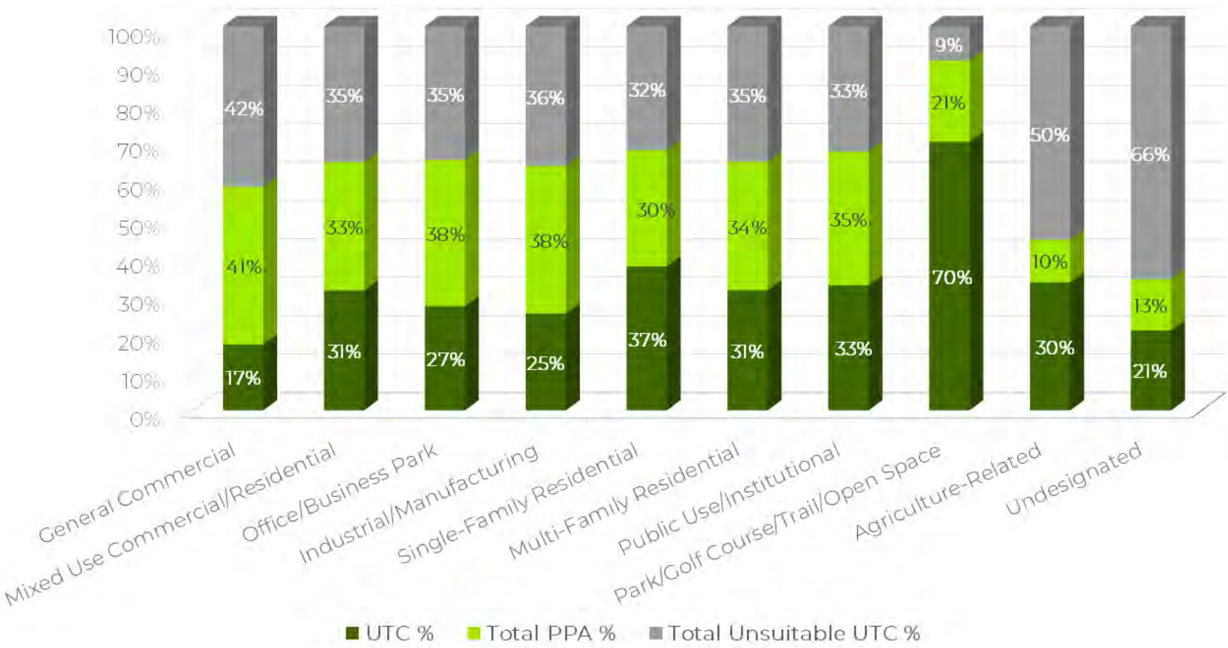


Figure 10. | Urban tree canopy, potential planting area, and area unsuitable for UTC by county land uses.

Table 6. | Urban tree canopy assessment results by King County land use. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within each land use (dist.).

Land Use	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
General Commercial	602	5%	103	17%	2%	247	41%	7%
Industrial/Manufacturing	285	2%	72	25%	2%	109	38%	3%
Mixed Use Commercial/Residential	226	2%	71	31%	2%	76	33%	2%
Multi-Family Residential	414	4%	129	31%	3%	139	34%	4%
Office/Business Park	178	2%	48	27%	1%	68	38%	2%
Park/Golf Course/Trail/Open Space	1,132	10%	791	70%	18%	240	21%	7%
Public Use/Institutional	154	1%	50	33%	1%	53	35%	2%
Single-Family Residential	8,081	71%	3,029	37%	69%	2,446	30%	72%
Undesignated	323	3%	67	21%	2%	43	13%	1%
Totals	**11,394**	**100%**	**4,360**	**38%**	**100%**	**3,421**	**30%**	**100%**

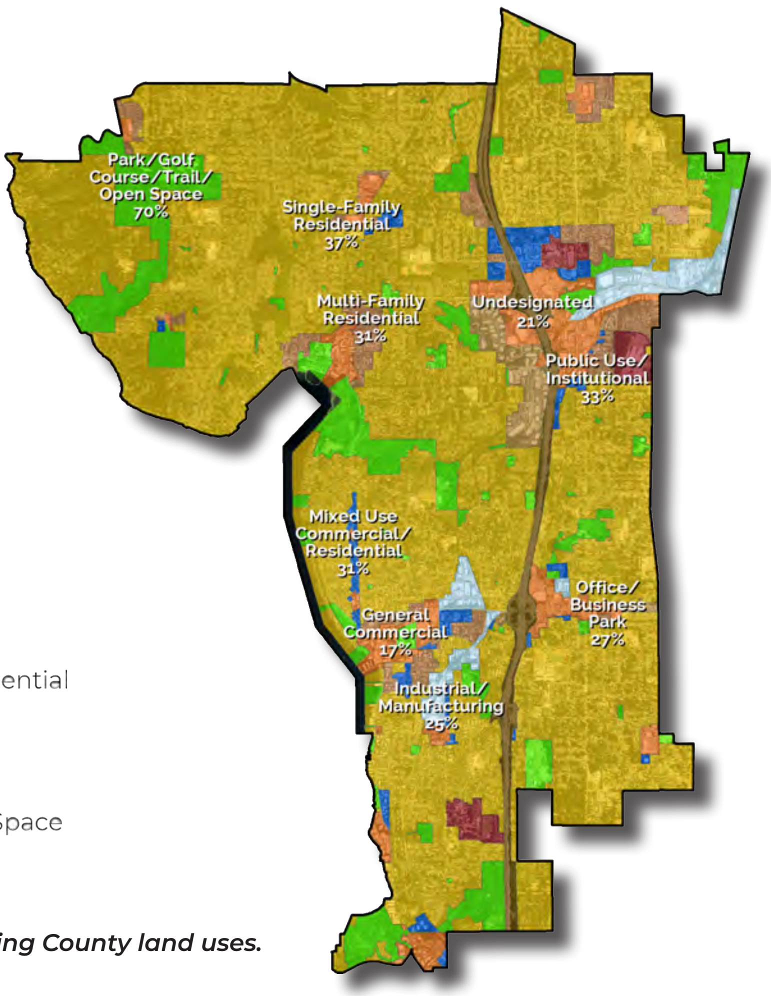


Figure 11. | Urban tree canopy by King County land uses.

URBAN TREE CANOPY BY NEIGHBORHOODS

UTC and PPA were assessed for Kirkland's 14 neighborhoods. The neighborhoods with the least existing UTC included Moss Bay with 22 percent, South Rose Hill with 27 percent, and Totem Lake with 29 percent. All other neighborhoods had a canopy cover of 30 percent or greater, and Highlands and Finn Hill contained the greatest percentage of UTC with 40 and 50 percent, respectively. Finn Hill, which was one of the three neighborhoods annexed by the City in 2011, also contained the greatest proportion of the City's total UTC, comprising 30 percent of all canopy in Kirkland. In terms of plantable space, the Highlands neighborhood offered the least PPA (25 percent) while Totem Lake offered the greatest (36 percent), indicating that PPA within Kirkland's neighborhoods tends to be inversely related to their existing UTC.

Table 7. | Urban tree canopy assessment results by neighborhood. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within each neighborhood (dist.).

Neighborhood	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Bridle Trails	610	5%	213	35%	5%	182	30%	5%
Central Houghton	610	5%	233	38%	5%	172	28%	5%
Everest	220	2%	81	37%	2%	60	27%	2%
Finn Hill	2,609	23%	1,313	50%	30%	802	31%	23%
Highlands	363	3%	147	40%	3%	92	25%	3%
Juanita	1,865	16%	712	38%	16%	609	33%	18%
Kingsgate	1,279	11%	438	34%	10%	340	27%	10%
Lakeview	363	3%	142	39%	3%	115	32%	3%
Market	291	3%	96	33%	2%	89	31%	3%
Moss Bay	314	3%	70	22%	2%	89	28%	3%
Norkirk	511	4%	162	32%	4%	139	27%	4%
North Rose Hill	978	9%	361	37%	8%	276	28%	8%
South Rose Hill	508	4%	139	27%	3%	144	28%	4%
Totem Lake	874	8%	254	29%	6%	310	36%	9%
Totals	**11,394**	**100%**	**4,360**	**38%**	**100%**	**3,421**	**30%**	**100%**

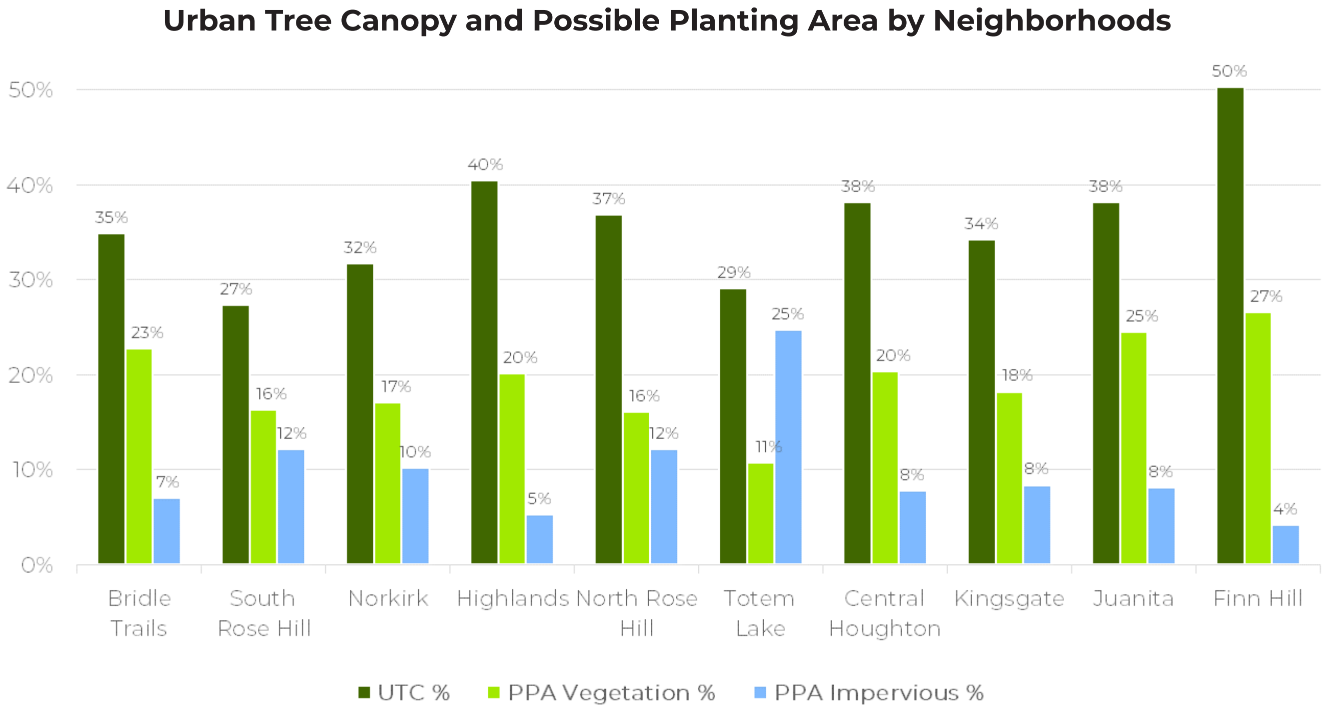


Figure 12. | Urban tree canopy and potential planting area in Kirkland neighborhoods.

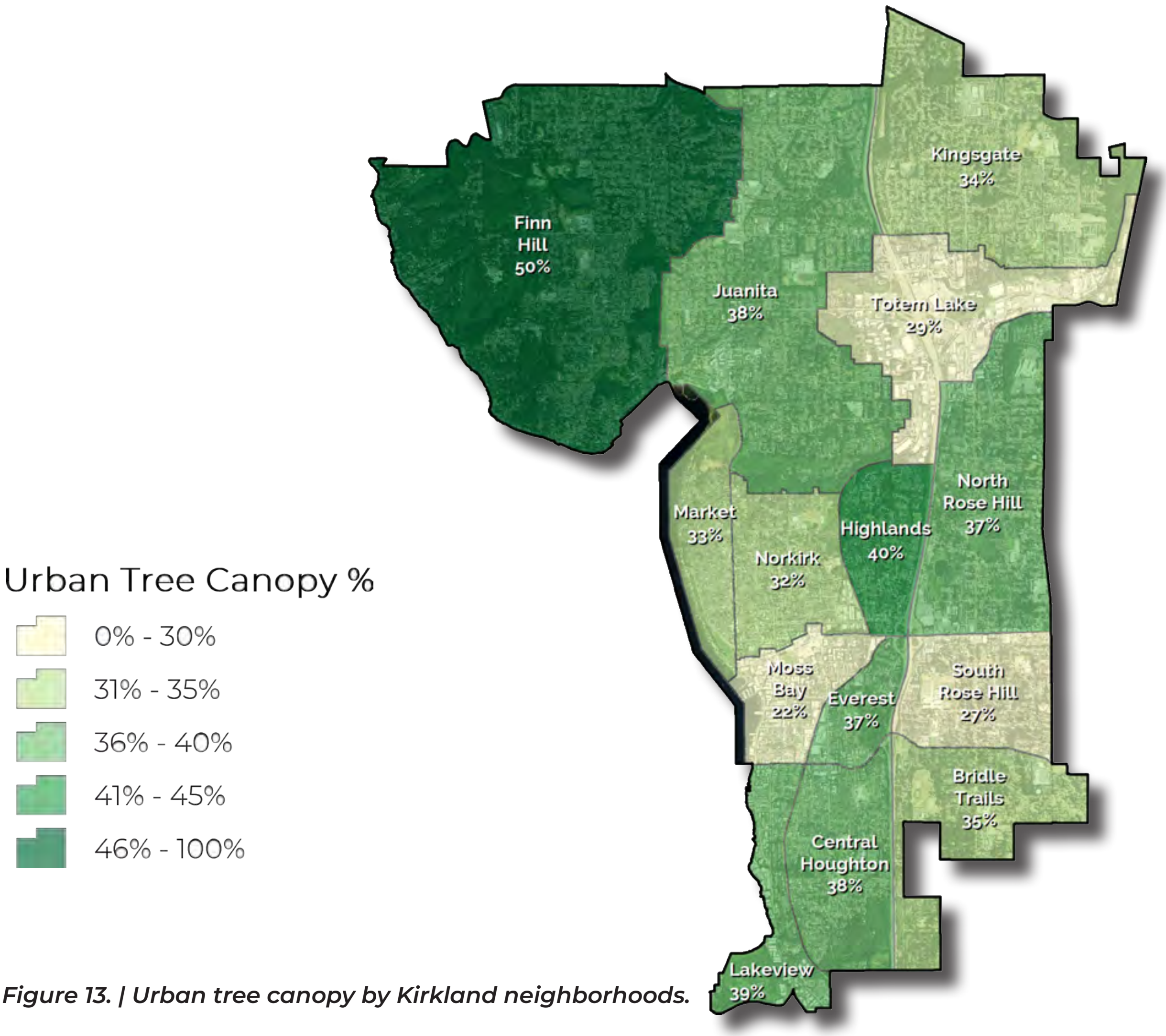


Figure 13. | Urban tree canopy by Kirkland neighborhoods.

URBAN TREE CANOPY BY DRAINAGE BASINS

Because trees play an important role in stormwater management, UTC and PPA were assessed for the 15 local drainage basins found within Kirkland. Houghton Slope A and To Redmond had the lowest percentages of existing UTC with 26 and 28 percent, while Yarrow Creek, Denny Creek, and Holmes Point had the greatest with 50, 53, and 60 percent respectively. PPA was varied less and ranged from 26 percent in Kingsgate Slope to 36 percent in South Juanita Slope. The largest drainage basin, Juanita Creek, contributed the most to the City's totals with 32 percent UTC contributing 29 percent of the City's total canopy and 32 percent total PPA contributing 35 percent of the City's total PPA.

Table 8. | Urban tree canopy assessment results by drainage basins. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within each basin (dist.).

Drainage Basin	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Carillon Creek	106	1%	36	34%	1%	35	33%	1%
Champagne Creek	621	5%	281	45%	6%	218	35%	6%
Denny Creek	803	7%	429	53%	10%	231	29%	7%
Forbes Creek	1,824	16%	715	39%	16%	515	28%	15%
Holmes Point	457	4%	276	60%	6%	130	28%	4%
Houghton Slope A	376	3%	99	26%	2%	117	31%	3%
Houghton Slope B	134	1%	44	33%	1%	45	33%	1%
Juanita Creek	3,615	32%	1,279	35%	29%	1,153	32%	34%
Kingsgate Slope	562	5%	212	38%	5%	145	26%	4%
Kirkland Slope	210	2%	66	31%	2%	62	30%	2%
Lower Sammamish River Valley	24	0%	10	43%	0%	8	33%	0%
Moss Bay	1,486	13%	444	30%	10%	405	27%	12%
South Juanita Slope	287	3%	94	33%	2%	105	36%	3%
To Redmond	303	3%	84	28%	2%	92	31%	3%
Yarrow Creek	577	5%	287	50%	7%	158	27%	5%
Totals	**11,385**	**100%**	**4,356**	**38%**	**100%**	**3,419**	**30%**	**100%**

URBAN TREE CANOPY BY CENSUS BLOCK GROUPS

UTC and PPA were assessed for the 80 U.S. census block groups (CBG) found within Kirkland. CBGs are delineated by the U.S. Census Bureau and tied to all population and demographic census data. This makes them helpful for assessing environmental equity. 6 percent of CBGs had less than 20 percent UTC; 28 percent had 20-30 percent UTC; 40 percent had 30-40 percent UTC; and the other 26 percent had 40 percent of greater. For the complete results by CBG, refer to the UTC Results spreadsheet.

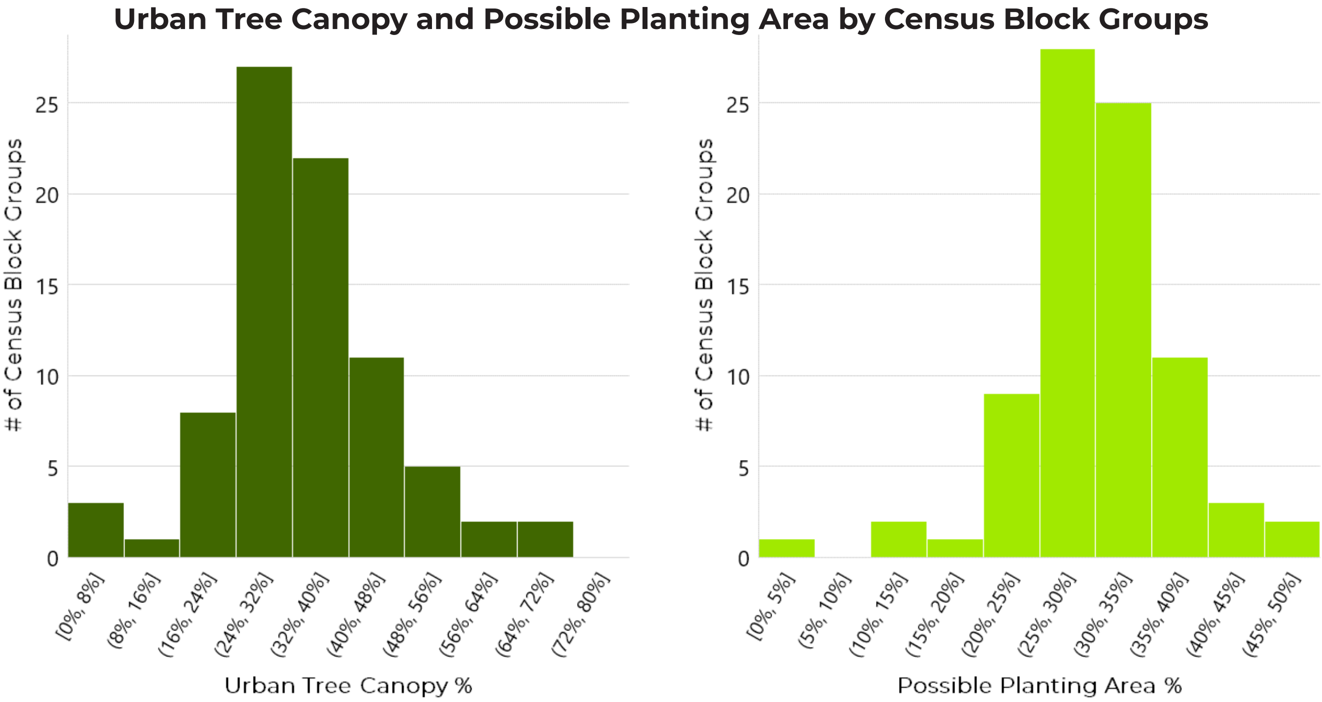


Figure 14. | Number of census block groups within urban tree canopy (left) and possible planting area (right) ranges.

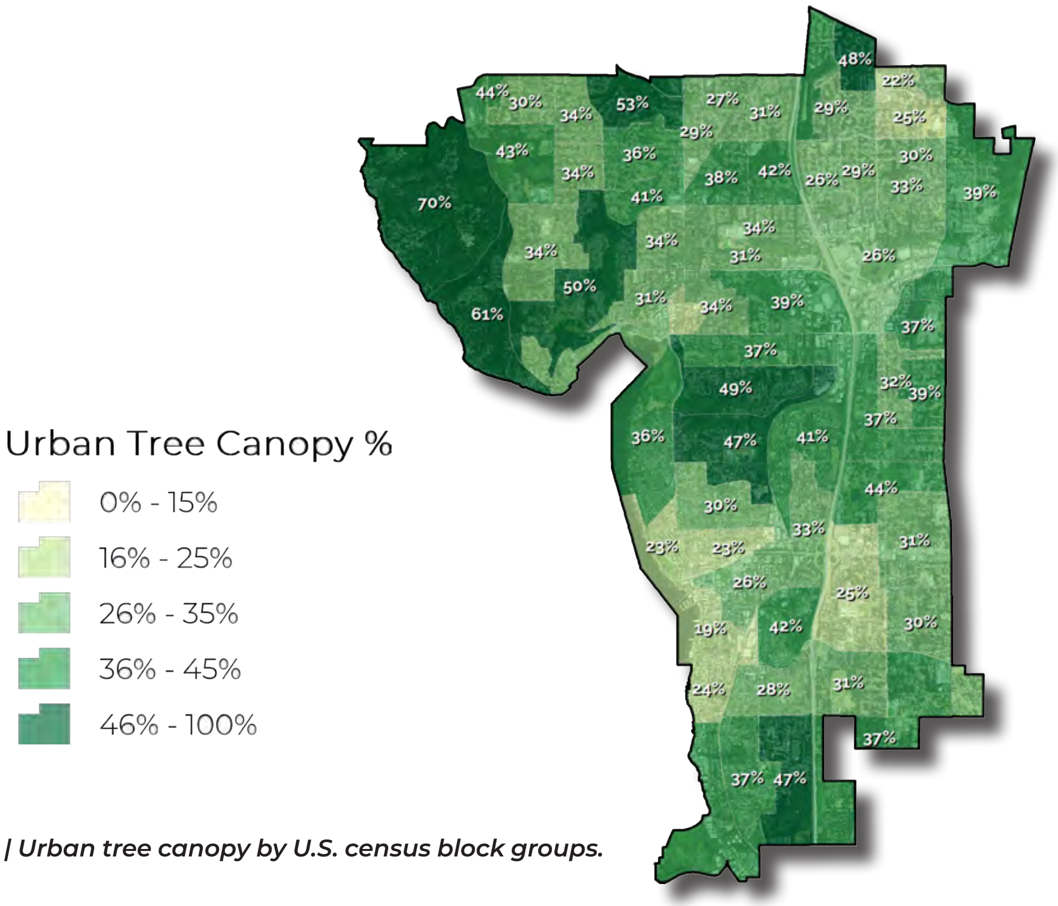


Figure 15. | Urban tree canopy by U.S. census block groups.

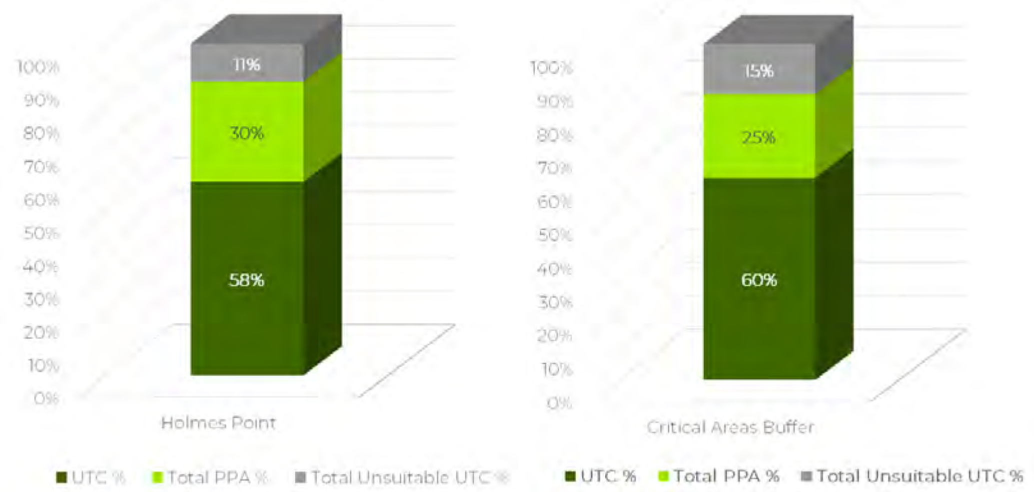
URBAN TREE CANOPY BY HOLMES POINT OVERLAY

UTC and PPA were assessed within the Holmes Point Overlay boundary. Historically, this area is one of the City's most densely forested areas. In 2017, this region contained over 58 percent UTC, 30 percent total PPA (of which 28 percent was PPA-Vegetation and only 2 percent was PPA-Impervious), and 11 percent total unsuitable areas. With 380 acres of canopy, the Holmes Point Overlay contains 9 percent of Kirkland's tree canopy, despite comprising only 6 percent of its land area.

Table 9. | Urban tree canopy in Kirkland's Holmes Point region. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within the overlay (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Holmes Point Overlay	651	6%	380	58%	9%	197	30%	6%

Urban Tree Canopy Potential by Holmes Point Overlay and Citywide Critical Area Buffers



Figures 16 and 17. | Urban tree canopy, possible planting area, and unsuitable areas for UTC in Kirkland's Holmes Point Overlay (left) and citywide 100' critical area buffers (right).

URBAN TREE CANOPY BY CRITICAL AREA BUFFERS

Trees in critical and sensitive environmental areas are also a valuable part of Kirkland's urban forest resource. A buffer of 100 feet was applied to Kirkland's streams, lakes, wetlands, and landslide areas and UTC and PPA metrics were assessed within this area. Results indicated that Kirkland's critical area buffers contained 60 percent existing UTC, 25 percent total PPA (predominantly vegetation), and 15 percent total unsuitable areas. With 2,872 land acres and 1,729 acres of canopy, this region contains 40 percent of Kirkland's citywide canopy while occupying just 25 percent of its land area.

Table 10. | Urban tree canopy in Kirkland's critical area buffers. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within the buffer (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Critical Area Buffers (100')	2,873	25%	1,729	60%	40%	715	25%	21%

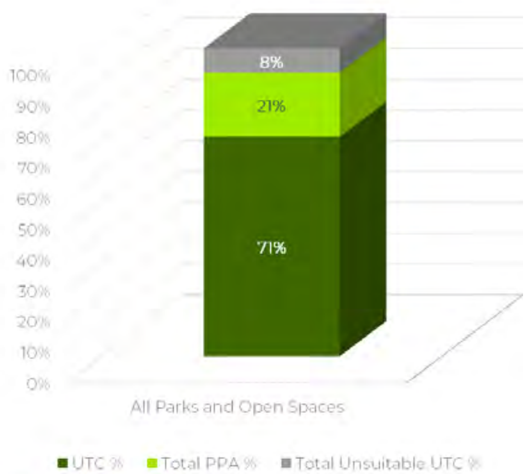
URBAN TREE CANOPY BY PARKS AND OPEN SPACES

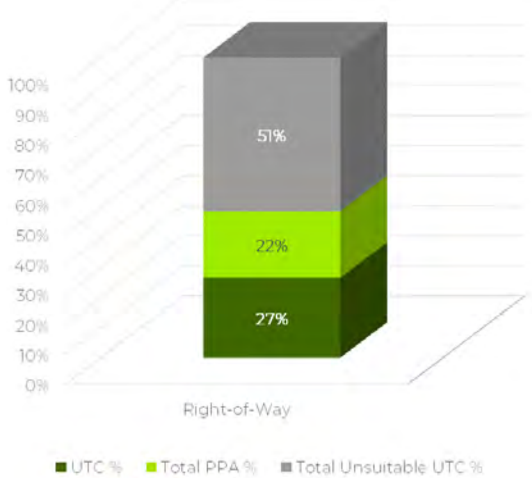
UTC and PPA were assessed within Kirkland's various classes of parks and open spaces: general parks (consisting of parks, swimming pool facilities, and cemeteries), open spaces, and all parks. UTC was 85 percent in open spaces, 70 percent in general parks, and 71 percent overall. General parks contained the majority of total UTC within this assessment scale with 70 percent canopy cover contributing 91 percent of the total canopy. PPA ranged from 13 percent in open spaces to 22 percent in general parks, which also contributed the most to the citywide total with 21 contributing 95 percent of all plantable space in these areas.

Table 11. | Urban tree canopy in Kirkland's parks and open spaces. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within the area (dist.).

Parks and Open Spaces	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
General Parks	943	93%	661	70%	91%	203	22%	95%
Open Spaces	75	7%	63	85%	9%	10	13%	5%
Totals	**1,017**	**100%**	**725**	**71%**	**100%**	**213**	**21%**	**100%**

UTC, PPA, and Impervious Areas in Kirkland's Parks/Open Spaces and Right-of-Way





Figures 18 and 19. | Urban tree canopy, possible planting area, and impervious areas in Kirkland's Parks and Open Spaces (left) and right-of-way (right).

URBAN TREE CANOPY BY RIGHT-OF-WAY

UTC and PPA were assessed for Kirkland's right-of-way or publicly-maintained sidewalk and street areas. Trees in the ROW are especially valuable components of a city's urban forest in terms of air pollution control, shading, and even social benefits. Within these areas, UTC was 27 percent, PPA-Vegetation was 14 percent, PPA-Impervious was 8 percent, and unsuitable areas were 50 percent. UTC and total PPA (22 percent) were lower in the ROW than the citywide average, but much of this area consists of sidewalks or roads where it would be impossible to plant trees.

Table 12. | Urban tree canopy in Kirkland's right-of-way. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within the ROW (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Right-of-Way	2,166	19%	576	27%	13%	481	22%	14%

URBAN TREE CANOPY BY SHORELINE JURISDICTIONS

UTC and PPA were assessed within Kirkland's shoreline jurisdictions. The results were aggregated for reporting. Shoreline jurisdictions in Kirkland had 46% canopy cover or 4% of all canopy citywide. These areas also contained 116 acres of possible planting area (35%) with a majority of that on vegetated surfaces.

Table 13. | Shoreline jurisdiction urban tree canopy assessment results by acres and percent. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within Kirkland's shoreline jurisdictions (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Shoreline Jurisdictions	332	3%	153	46%	4%	116	35%	3%

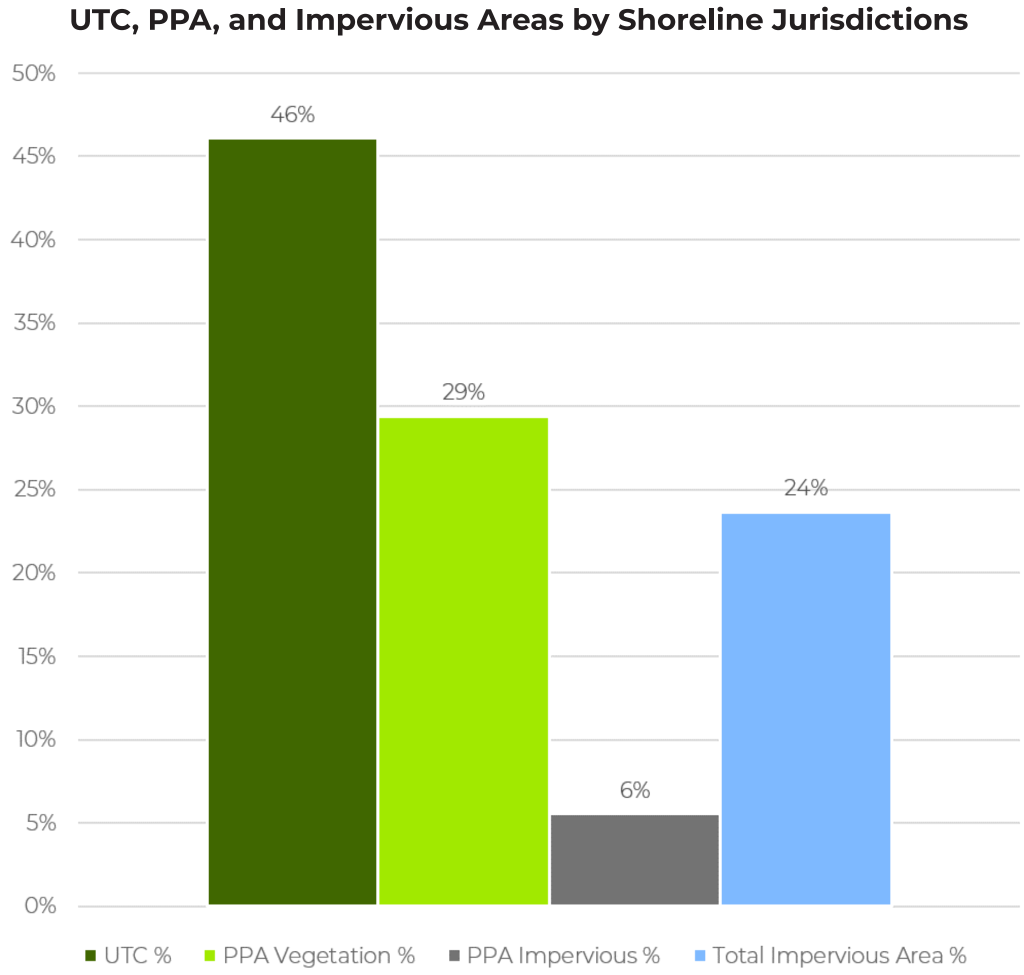


Figure 20. | Urban tree canopy, possible planting area, and impervious areas in Kirkland's shoreline jurisdictions.

URBAN TREE CANOPY CHANGE ANALYSIS

This section presents the change analysis results which were analyzed across the same geographic assessment boundaries described above. In addition to assessing Kirkland's urban tree canopy using 2017 imagery, this study also quantified changes in urban tree canopy since it was last assessed by AMEC Environmental & Infrastructure, Inc. using 2010 Worldview-2 satellite imagery. Although the exact methods used to map land cover varied between the 2017 and 2010 studies, the resulting land cover data are comparable. Both studies used leaf-on, high-resolution aerial imagery as their primary source. The spatial resolution of the imagery in 2010 was 1.5-feet while this study used 1-meter NAIP imagery. Both studies also utilized Feature Analyst remote sensing software and an object-based image analysis (OBIA) as their primary method. To ensure an even comparison, the 2010 land cover data were reanalyzed using the current boundaries of the city, land use, census block groups, etc., and changes since 2010 were assessed at the same geographic assessment scales. Similar to the UTC and PPA assessment above, the urban tree canopy change percentages are based on land area only.

CITYWIDE URBAN TREE CANOPY CHANGE

There was a slight decrease in Kirkland's tree canopy over the 7-year study period from 2010-2017. Throughout the city, the average canopy cover decreased from 40.7 percent in 2010 to 38.3 percent in 2017. Tree canopy decreased by approximately 272 acres, yielding a 2.4 percent raw or 6 percent relative decrease since 2007. New development throughout the city was responsible for a majority of the losses in tree canopy. Some overestimation in the previous assessment was also observed.

Table 14. | Urban tree canopy change results for the City of Kirkland by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
City Boundary	11,394	100%	4,632	41%	4,361	38%	-272	-2%

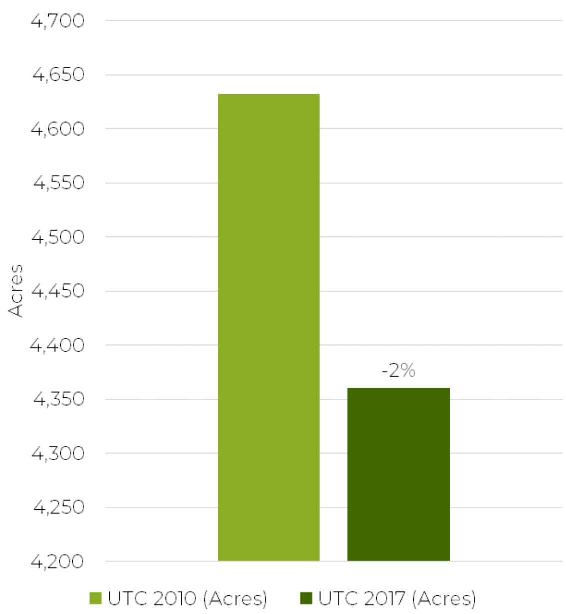


Figure 21. | Urban tree canopy change for the City of Kirkland, 2010-2017.

Figure 22. | Urban tree canopy in 2010 (yellow) compared to 2017 (green) in Downtown Kirkland.

URBAN TREE CANOPY CHANGE BY PRE-ANNEXATION CITY BOUNDARY

UTC within the pre-annexation city boundary decreased slightly. This region lost approximately 77 acres of canopy which equated to a 1 percent decrease from 36 percent to 35 percent between 2010 and 2017. This change result indicates that the majority of canopy lost in Kirkland over the study period (195 acres or 72 percent) occurred within the three annexed neighborhoods of Finn Hill, North Juanita, and Kingsgate, which were more heavily forested to begin with. The recent losses in canopy cover within the pre-annexation city boundary are a reversal of an increasing trend experienced from 2002-2010 when canopy cover increased by approximately 4 percent.

Table 15. | Urban tree canopy change results for the pre-annexation boundary by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Pre-Annexation Boundary	6,802	60%	2,448	36%	2,371	35%	-77	-1%

URBAN TREE CANOPY CHANGE BY WATERSHEDS

UTC change within the Lake-Washington Sammamish River watershed, which occupies 94 percent of the City's land area, closely mirrored the City's change result. This watershed lost approximately 239 acres of canopy which lowered its UTC by 2 percent from 41 percent in 2010 to 38 percent in 2017. The Bear Creek-Sammamish River watershed experienced a larger decrease in relation to its size. It lost approximately 33 acres of canopy, decreasing its UTC by 5 percent from 41 percent in 2010 to 36 percent in 2017. However, this watershed only occupies 6 percent of land area in Kirkland.

Table 16. | Urban tree canopy change results for Kirkland's watersheds by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

Watersheds	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Bear Creek-Sammamish River	699	6%	285	41%	252	36%	-33	-5%
Lake Washington-Sammamish River	10,695	94%	4,347	41%	4,108	38%	-239	-2%
Totals	**11,394**	**100%**	**4,632**	**41%**	**4,361**	**38%**	**-272**	**-2%**

URBAN TREE CANOPY CHANGE BY LAND USES

UTC change varied slightly across Kirkland's ten King County comprehensive plan land use classes. Undesignated areas, primarily the Interstate-405 corridor, experienced the greatest loss in canopy by percentage, decreasing by approximately 4 percent from 25 percent in 2010 to 21 percent in 2017. The greatest loss in citywide canopy by acreage occurred in the Single-Family Residential class, which lost 253 acres or approximately 3 percent of their canopy from 41 to 37 percent. However, several land use classes such as Industrial/Manufacturing, Public Use/Institutional, and Parks/Open Spaces had increases in their tree canopy over the seven-year time period, and several others had little to no change.

Table 17. | Urban tree canopy change results for Kirkland's King County land use classes by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

Land Uses	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
General Commercial	602	5%	109	18%	103	17%	-6	-1%
Industrial/Manufacturing	285	2%	67	23%	72	25%	5	2%
Mixed Use Commercial/Residential	226	2%	73	32%	71	31%	-2	-1%
Multi-Family Residential	414	4%	139	33%	129	31%	-9	-2%
Office/Business Park	178	2%	49	27%	48	27%	-0	-0%
Park/Golf Course/Trail/Open Space	1,132	10%	784	69%	791	70%	7	1%
Public Use/Institutional	154	1%	48	31%	50	33%	2	1%
Single-Family Residential	8,081	71%	3,282	41%	3,029	37%	-253	-3%
Undesignated	323	3%	82	25%	67	21%	-15	-5%
Totals	**11,394**	**100%**	**4,632**	**41%**	**4,360**	**38%**	**-272**	**-2%**

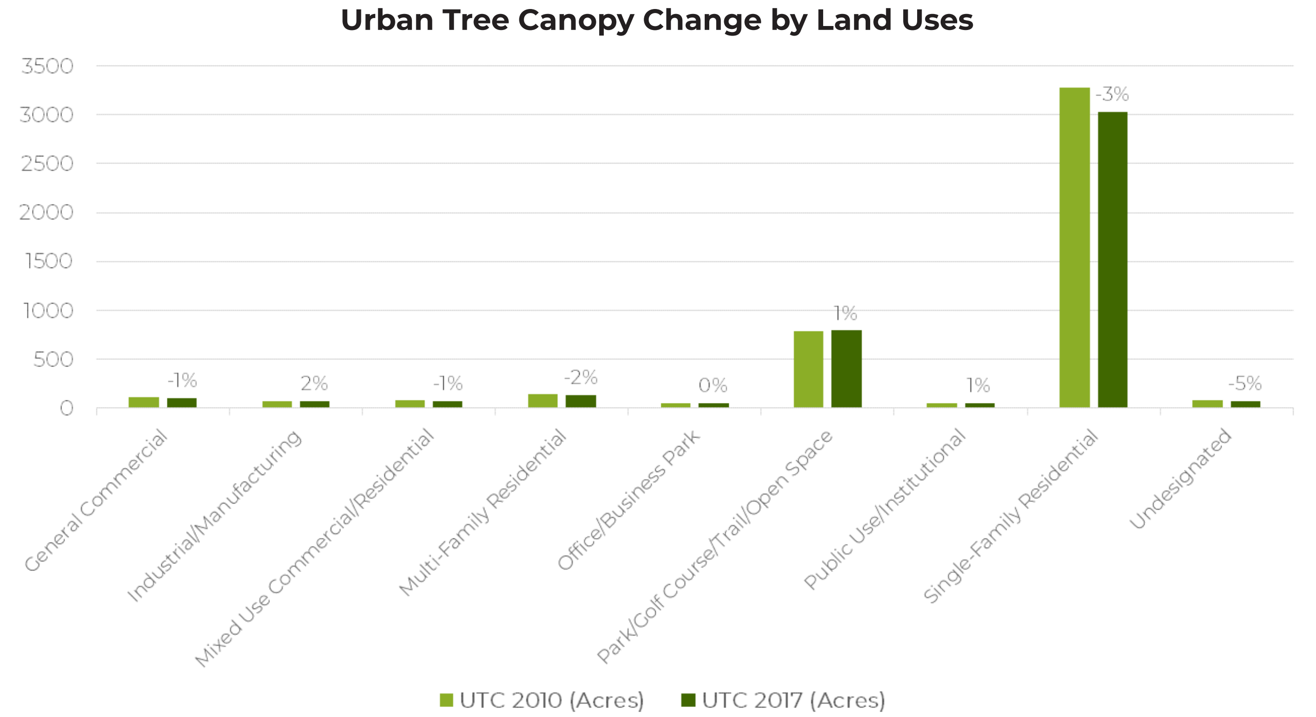


Figure 22. | Urban tree canopy change in Kirkland from 2010-2017 by county land use classes.

URBAN TREE CANOPY CHANGE BY LAND USES (CONTINUED)

Land Use Category

- Public Use/Institutional
- Office/Business Park
- General Commercial
- Industrial/Manufacturing
- Mixed Use Commercial/Residential
- Multi-Family Residential
- Single-Family Residential
- Park/Golf Course/Trail/Open Space
- Undesignated

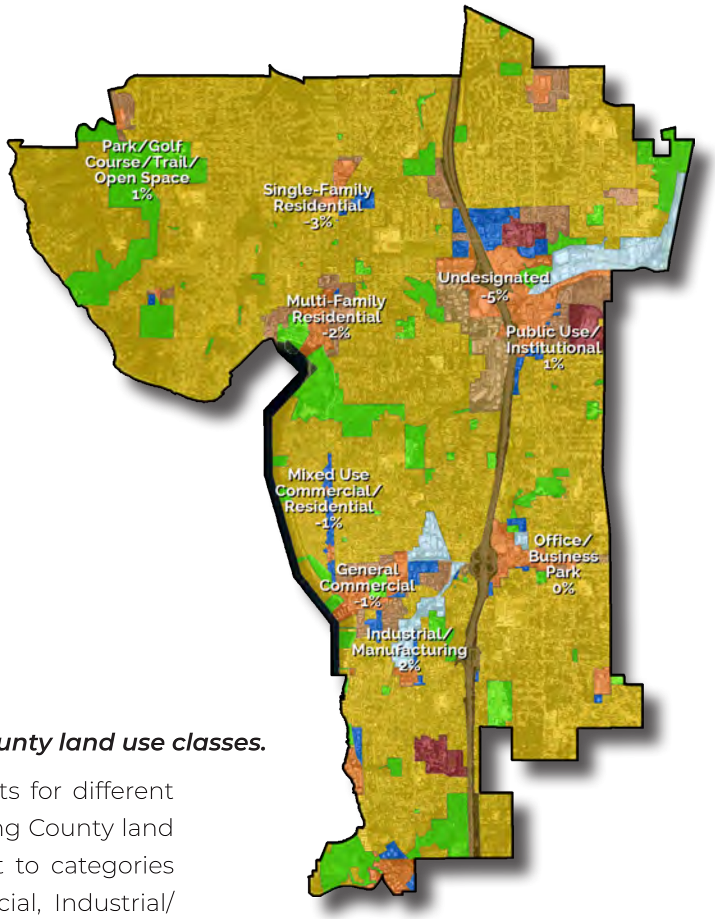


Figure 23. | Urban tree canopy change by King County land use classes.

Canopy goals were established by American Forests for different land uses in the Puget Sound region. Five of the King County land use classes analyzed in this study were equivalent to categories presented by American Forests: General Commercial, Industrial/Manufacturing, Single-Family Residential, Multi-Family Residential, and Park/Golf Course/Trail/Open Space. The City of Kirkland has not adopted American Forests' canopy goals for individual land use classes. However, comparisons between American Forests' individual land use classifications and Kirkland's UTC may provide some insight into future urban forest management decisions. In 2010, only the Park/Golf Course/Trail/Open Space category met or exceeded the American Forests' recommendations for the same land use class. Those areas had a UTC of 69 percent compared to a 25 percent standard. By 2017, another land use had exceeded American Forests' standard: Industrial areas increased from 23 percent UTC to the 25 percent standard. General Commercial, Single-Family Residential, and Multi-Family Residential areas all slightly decreased over the same time period, moving them farther away from the American Forests recommendations for the Puget Sound region. Single-Family Residential areas remained the furthest from the American Forests recommendations with 37 percent UTC compared to the target of 50 percent.

Urban Tree Canopy Change by Land Uses Compared with American Forests Goals

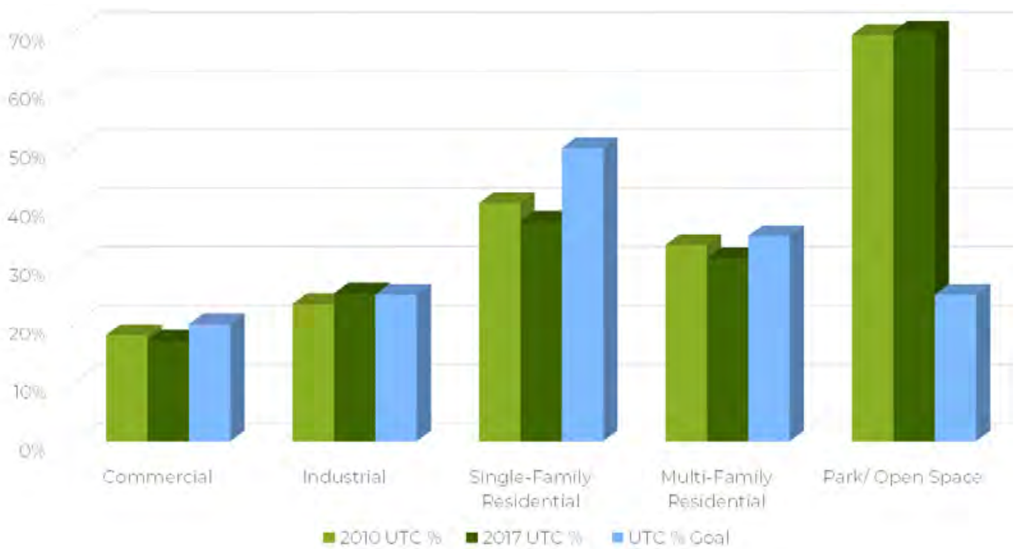


Figure 24. | Urban tree canopy change in Kirkland's five land use classes with UTC goals set in the 2010 study.

URBAN TREE CANOPY CHANGE BY NEIGHBORHOODS

Assessing Kirkland's UTC change by neighborhoods revealed more variation. Neighborhoods that experienced the greatest decreases in canopy included Kingsgate with a 6 percent loss, Juanita with 4 percent, and Finn Hill with 3 percent. Finn Hill also had the greatest decrease in canopy by acreage (85 acres) but maintained the highest UTC of any neighborhood in both 2010 (54 percent) and 2017 (50 percent). The Lakeview, Totem Lake, and Market neighborhoods all showed an increase in canopy by 2-3 percent.

Table 18. | Urban tree canopy change results for Kirkland's neighborhoods. UTC results include acres and percent of area covered by UTC in 2010 and 2017 and change in acres and percent over the seven-year period.

Neighborhoods	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Bridle Trails	610	5%	225	37%	213	35%	-12	-2%
Central Houghton	610	5%	244	40%	233	38%	-12	-2%
Everest	220	2%	87	40%	81	37%	-6	-3%
Finn Hill	2,609	23%	1,398	54%	1,313	50%	-85	-3%
Highlands	363	3%	154	43%	147	40%	-7	-2%
Juanita	1,865	16%	793	43%	712	38%	-81	-4%
Kingsgate	1,279	11%	510	40%	438	34%	-71	-6%
Lakeview	363	3%	136	37%	142	39%	6	2%
Market	291	3%	89	31%	96	33%	8	3%
Moss Bay	314	3%	77	25%	70	22%	-7	-2%
Norkirk	511	4%	171	33%	162	32%	-9	-2%
North Rose Hill	978	9%	356	36%	361	37%	5	0%
South Rose Hill	508	4%	152	30%	139	27%	-13	-3%
Totem Lake	874	8%	239	27%	254	29%	15	2%
Totals	**11,394**	**100%**	**4,632**	**41%**	**4,360**	**38%**	**-272**	**-2%**

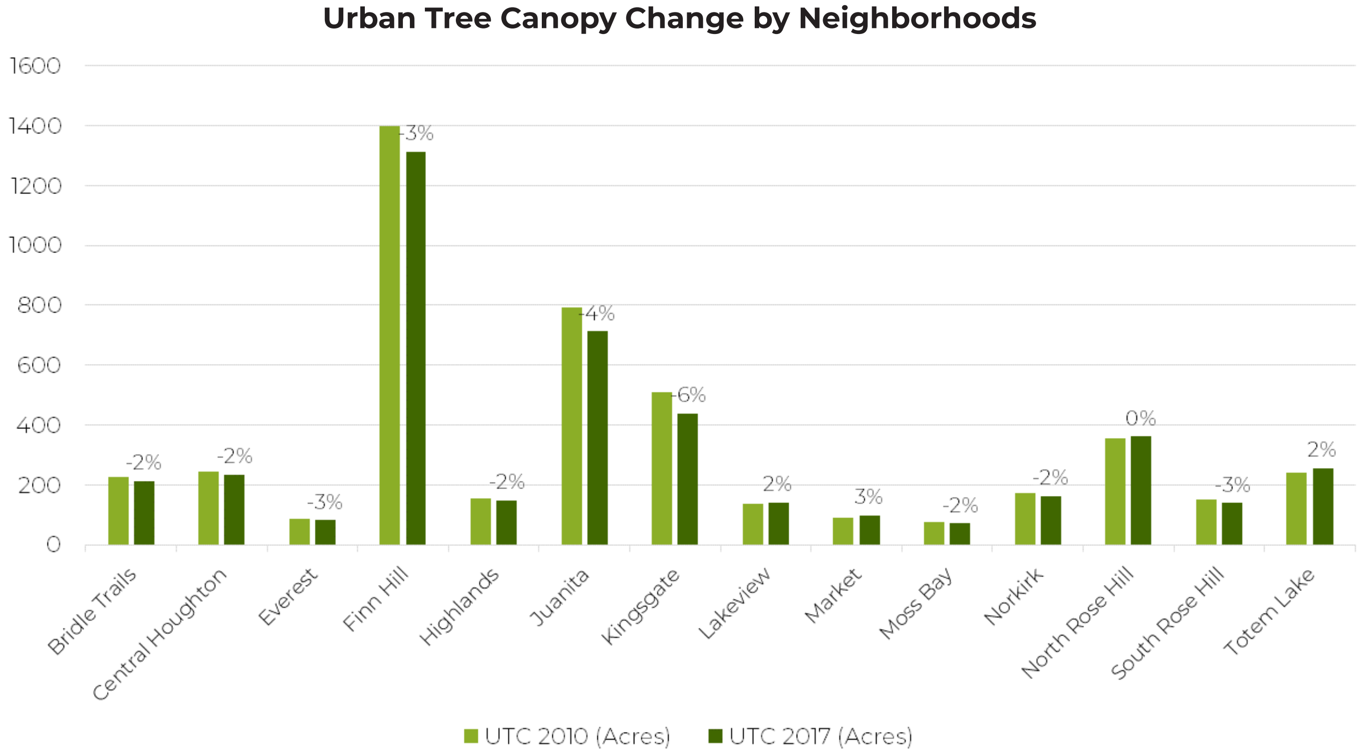


Figure 25. | Urban tree canopy change in Kirkland's neighborhoods.

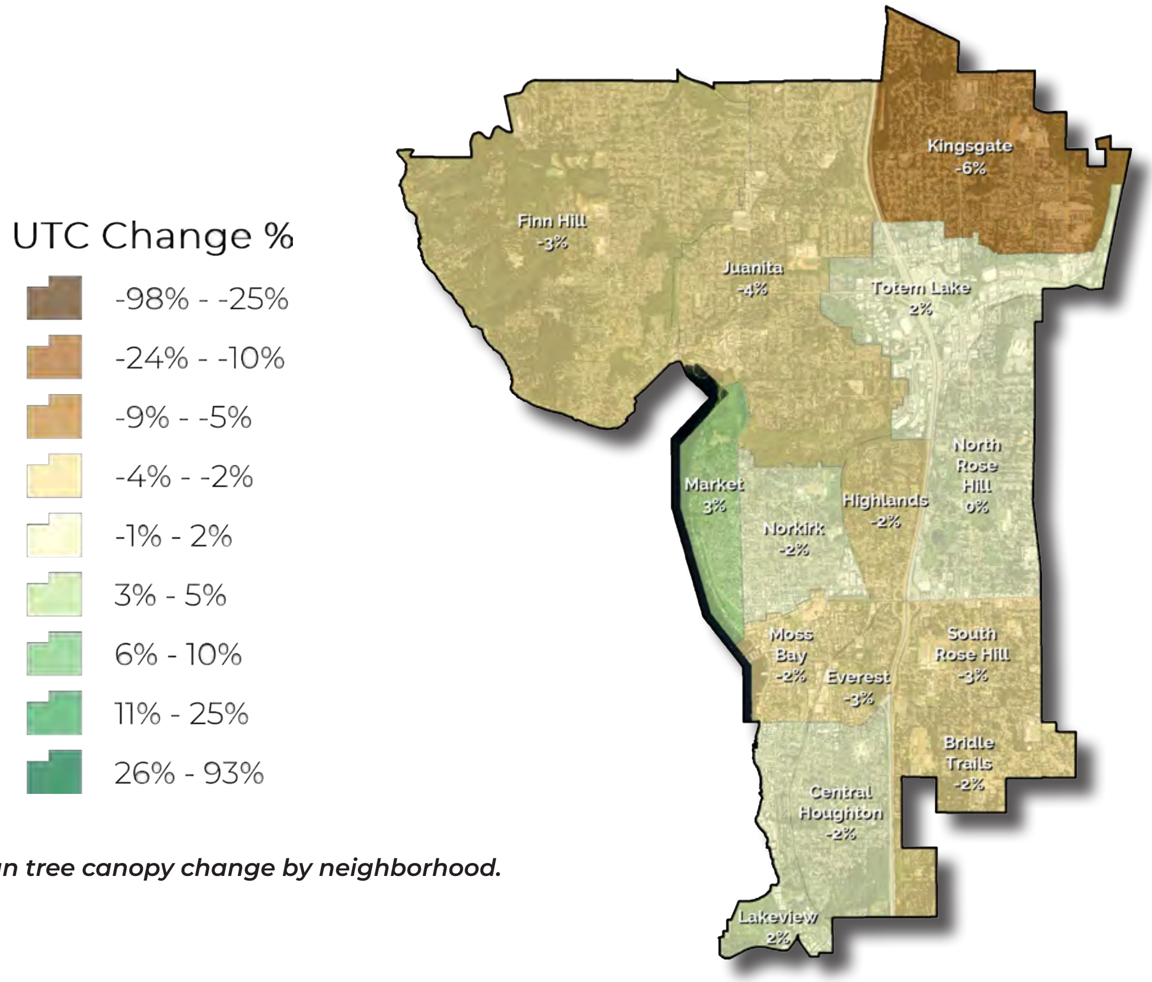


Figure 26. | Urban tree canopy change by neighborhood.

URBAN TREE CANOPY CHANGE BY DRAINAGE BASINS

Between 2010 to 2017, all of Kirkland's 15 drainage basins had a decrease in canopy except for Kirkland Slope which had no change. Holmes Point had the greatest decrease in canopy by percentage, dropping from 67 to 60 percent but maintained the highest UTC of all the drainage basins both years despite that loss. Juanita Creek had the greatest loss in UTC acres, losing 121 acres or 3 percent of its canopy.

Table 19. | Urban tree canopy change results for Kirkland's drainage basins by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

Drainage Basins	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Carillon Creek	106	1%	37	35%	36	34%	-1	-1%
Champagne Creek	621	5%	292	47%	281	45%	-11	-2%
Denny Creek	803	7%	449	56%	429	53%	-20	-3%
Forbes Creek	1,824	16%	717	39%	715	39%	-2	-0%
Holmes Point	457	4%	305	67%	276	60%	-30	-6%
Houghton Slope A	376	3%	102	27%	99	26%	-3	-1%
Houghton Slope B	134	1%	48	36%	44	33%	-4	-3%
Juanita Creek	3,615	32%	1,399	39%	1,279	35%	-121	-3%
Kingsgate Slope	562	5%	239	42%	212	38%	-27	-5%
Kirkland Slope	210	2%	66	31%	66	31%	0	0%
Lower Sammamish River Valley	24	0%	11	46%	10	43%	-1	-3%
Moss Bay	1,486	13%	474	32%	444	30%	-29	-2%
South Juanita Slope	287	3%	105	36%	94	33%	-10	-4%
To Redmond	303	3%	92	30%	84	28%	-7	-2%
Yarrow Creek	577	5%	293	51%	287	50%	-6	-1%
Totals	**11,385**	**100%**	**4,629**	**41%**	**4,356**	**38%**	**-273**	**-2%**

URBAN TREE CANOPY CHANGE BY CHANGE BY CENSUS BLOCK GROUPS

18 percent of Kirkland's 80 CBGs increased their tree canopy between 2010 and 2017 and the remaining 82 percent had decreases.

56 percent of all CBGs had canopy decreases of 5 percent or less, 17 percent had decreases between 5-10 percent, and 9 percent had decreases greater than 10 percent. UTC change ranged from +10 percent in the CBG with the greatest increase to -60 percent in the CBG with the greatest loss.

For the full change analysis results by CBG, refer to the UTC Results spreadsheet.

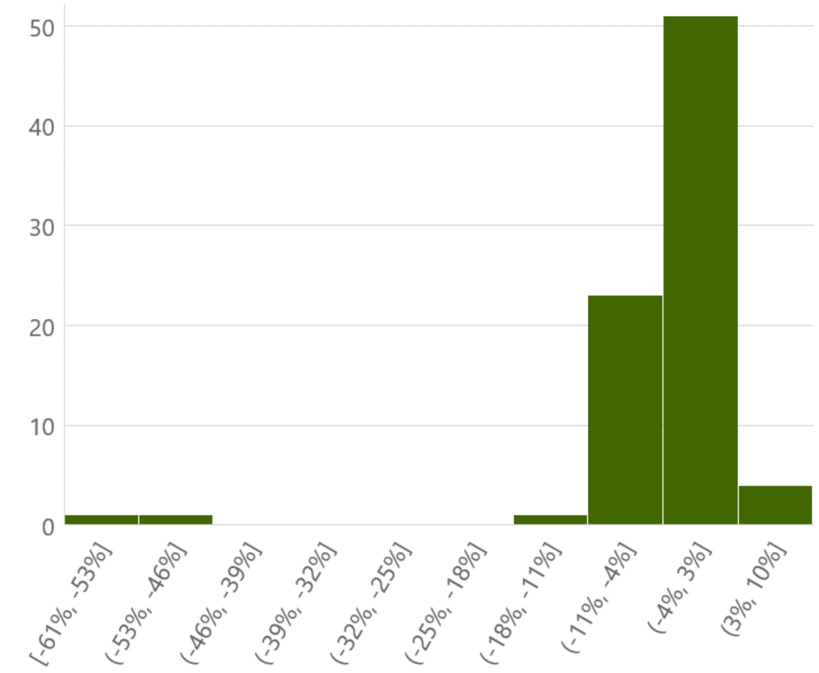
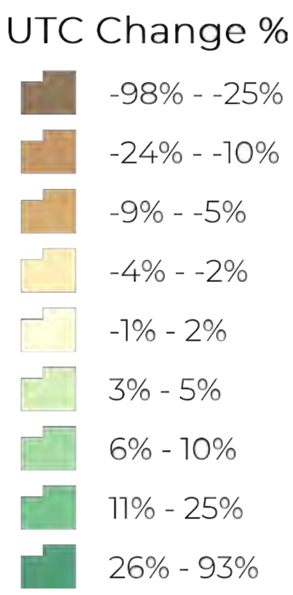


Figure 26. | Number of census block groups within UTC change ranges.



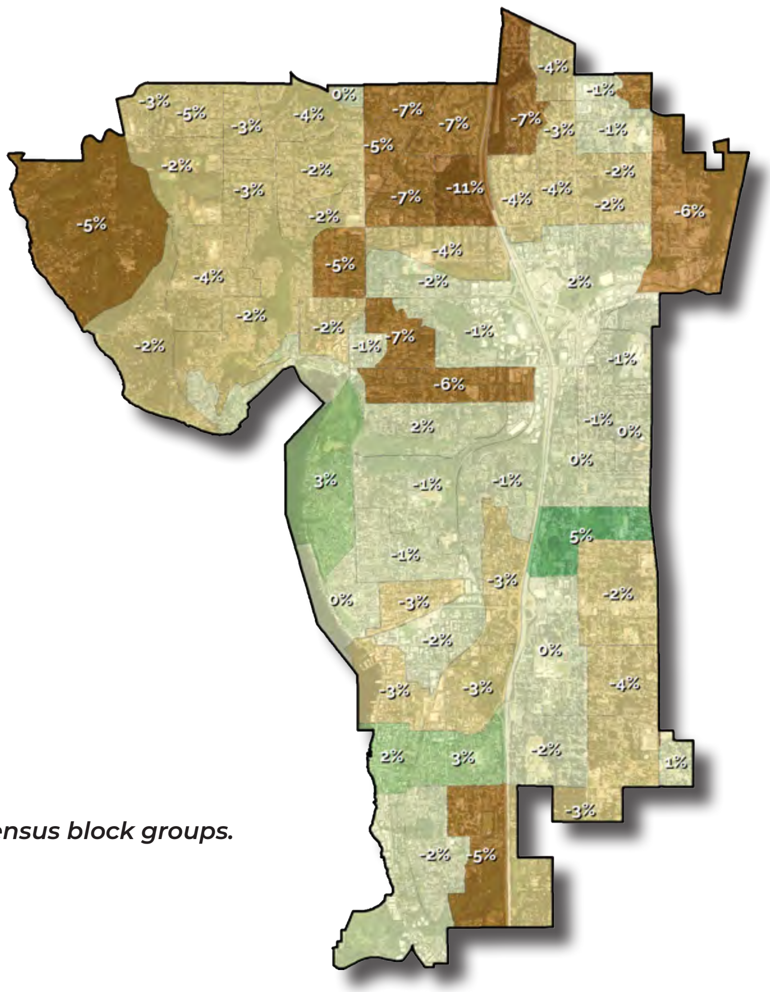


Figure 27. | Urban tree canopy change by U.S. census block groups.

URBAN TREE CANOPY CHANGE BY HOLMES POINT OVERLAY

Kirkland's Holmes Point Overlay region had a decrease in canopy, but its UTC remained among the highest in the City. This region lost 37 acres of canopy between 2010-2017 which decreased its UTC by 6 percent from 64 to 58 percent.

Table 20. | Urban tree canopy change results for the Holmes Point overlay by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Holmes Point Overlay	651	6%	416	64%	380	58%	-37	-6%

URBAN TREE CANOPY CHANGE BY RIGHT-OF-WAY

Kirkland's ROW experienced very little change in canopy over the seven-year assessment period. These areas lost approximately 5 acres of canopy and had a UTC of 27 percent in both 2010 and 2017.

Table 21. | Urban tree canopy change results for Kirkland's right-of-way by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Right of Way	2,166	19%	416	64%	380	58%	-37	-6%

URBAN TREE CANOPY CHANGE BY CRITICAL AREA BUFFERS

The 100-foot buffered region around Kirkland's lakes, streams, wetlands, and landslide areas was one of the few areas of the City that experienced an increase in canopy between 2010 and 2017. This area had an increase of 13 acres, maintaining a UTC of 60 percent throughout both years.

Table 22. | Urban tree canopy change results for Kirkland's critical area buffers by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Critical Area Buffers (100')	2,873	25%	1,716	60%	1,729	60%	13	0%

URBAN TREE CANOPY CHANGE BY PARKS AND OPEN SPACES

UTC change in Kirkland's park and open space classes varied. General parks had an increase of 1 percent from 69 to 70 percent UTC, while UTC in open spaces decreased by 2 percent from 87 to 85 percent. Overall, UTC in all of Kirkland's park and open space areas increased by approximately 12 acres or 1 percent.

Table 23. | Urban tree canopy change results for Kirkland's parks and open space classes by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

Parks and Open Spaces	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
General Parks	943	93%	647	69%	661	70%	14	1%
Open Spaces	75	7%	65	87%	63	85%	-2	-2%
Totals	**1,017**	**100%**	**712**	**70%**	**725**	**71%**	**12**	**1%**

URBAN TREE CANOPY CHANGE BY SHORELINE JURISDICTIONS

In contrast to most of the City's area which had a slight decrease in UTC from 2010-2017, Kirkland's shoreline jurisdictions had an increase in canopy. In total, these areas gained 22 acres of canopy or 7 percent, increasing overall UTC from 39 to 46 percent.

Table 24. | Urban tree canopy change results for Kirkland's shoreline jurisdictions by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Shoreline Jurisdictions	332	3%	131	39%	153	46%	22	7%

RECOMMENDATIONS

It is clear that the City of Kirkland values its urban forest resource and wants to preserve, protect, and maintain it. One way to do this is to have a canopy assessment performed on a regular interval. The City of Kirkland has started this process by assessing their canopy in 2010 and again 2017. As the City changes, they will be able to use these recommendations to ensure that their urban forest policies and management practices continue to prioritize its maintenance, health, and growth.

Tree canopy increased in Kirkland's Industrial, Parks, & Institutional land use classes from 2010-2017.

The City of Kirkland's 2013 Comprehensive Plan set a target of 40%. With its current canopy cover of 38%, Kirkland has fallen below this goal after reaching it in 2010. It is still within 75-100% of its citywide canopy goal which is an "optimal" indicator per the performance indicator model in the 2013 Urban Forestry Strategic Management Plan (UFSMP). The City's vegetated PPA of 21%, over 2,000 acres, provides many opportunities for future canopy expansion. Therefore, the City should put these results to work to preserve and promote its tree canopy in working towards that goal.

The results of this assessment can and should be used to encourage investment in forest monitoring, maintenance, and management; to inform codes and policies for tree retention and tree planting; to prepare supportive information for local budget requests/grant applications; and to develop targeted presentations for city leaders, planners, engineers, resource managers, and the public on the functional benefits of trees in addressing environmental issues. All data created by this study were collected and delivered in a manner that the City's GIS staff may use to conduct further analysis. The results by geographic area (such as census block group) may be particularly helpful for soliciting grant funding since they demonstrate which areas have the greatest need. The land cover data should be disseminated to diverse partners for urban forestry and other applications while the data is current and most useful for decision-making and implementation planning. The information from this study can help establish canopy cover goals for the short- and long-term. A hyperlink to this UTC report should be provided on the City's Urban Forest, Trees and Landscaping, GIS Maps, and Kirkland Green Links and Library webpages to help engage the public. The city should also continue to incorporate tree planting, tree maintenance, and invasive removals which can be supported by these data.

Additionally, the City and its various stakeholders can utilize the results of the UTC, PPA, and change analyses to identify the best locations to focus future tree planting and canopy expansion efforts. While the City has a decent canopy coverage throughout its entire area, breaking up the results by several different geographic boundaries demonstrated that this canopy is not evenly distributed. These results can be used as a guide to determine which

RIGHTS-OF-WAY IN KIRKLAND ARE PRIME AREAS FOR INCREASING URBAN TREE CANOPY

areas would receive the greatest benefits from the investment of valuable time and resources into Kirkland's urban forest.

In terms of expanding Kirkland's canopy, the City has several potential routes to take. For example, Single-family residential areas are a good place to target future canopy expansion as they hold a large amount of PPA (72 percent of the City's total plantable space). Rights-of-way are also good areas to target because of the additional benefits of trees in these areas for stormwater runoff mitigation, air quality improvement, and shading. Meanwhile, the Moss Bay and South Rose Hill neighborhoods have the lowest existing UTC (22 and 27 percent respectively). Therefore, land use and/or ROW could be overlaid with neighborhoods to identify single-family residential areas and rights-of-way within those neighborhoods that are lacking canopy to identify planting opportunities. An approach to review these opportunity areas should be developed including on-the-ground assessments to gauge planting site suitability.

Kirkland must integrate these data into its larger citywide planning efforts and establish set policies and guidelines for the preservation of tree canopy amidst future development. Kirkland's urban forest provides the City with a wealth of environmental, social, and even economic benefits which relate back to greater community interest in citywide initiatives and priorities. The City should use these UTC, PPA, and change metrics in combination with the results of the recent i-Tree Hydro analysis that was also performed in Kirkland to interpret where these gains would be felt most significantly and where there is still work to be done in accordance with the city's broader goals and vision for its future.

The 2013 Urban Forestry Strategic Management Plan, 2014-2019 Urban Forest Work Plan (UFWP), and 2015 Forest and Natural Areas Restoration Plan (FNARP) should be updated to include the 2018 UTC and i-Tree Hydro results. The guidelines established in the existing UFSMP, UFWP, FNARP, and other 2018 pre-approved plans should be utilized and enforced to protect tree canopy. The updated results can also be used to meet the objectives of the existing UFSMP: for example, to identify the best locations for public outreach by comparing areas with low existing canopy and high PPA, or to quantify the values, functions, and benefits of trees. To slow the loss of canopy, Kirkland Zoning Code Chapter 95 can be updated, incentives could be developed, and changes to procedures could be made in response to this study's findings.

Kirkland should also leverage its stormwater plans and regulations to promote and protect tree canopy whenever possible. Some of these include Municipal Codes 15.52.060, "Surface Water Management," which can be used to incorporate trees as best management practices for water flow control and water quality, and 15.56.060, "Qualified Rainwater Harvesting Discount," which can help to increase canopy on private property as an incentive to decrease stormwater utility fees. The UTC and i-Tree Hydro results should be incorporated into the City's Comprehensive Water Plan as they relate to canopy cover, impervious surfaces, etc., and Surface Water Master Plan (SWMP) as they relate to stormwater regulation. The SWMP also states that tree preservation and planting may be used as a low-impact development stormwater management technique (section 2.F.1), and that stormwater utility funds may be used to care for and maintain trees in the public right-of-way, fund the City's Urban Forester position, and implement of the UFMP (sections 5.B.6 and 5.C.8), so the City should continue these practices.

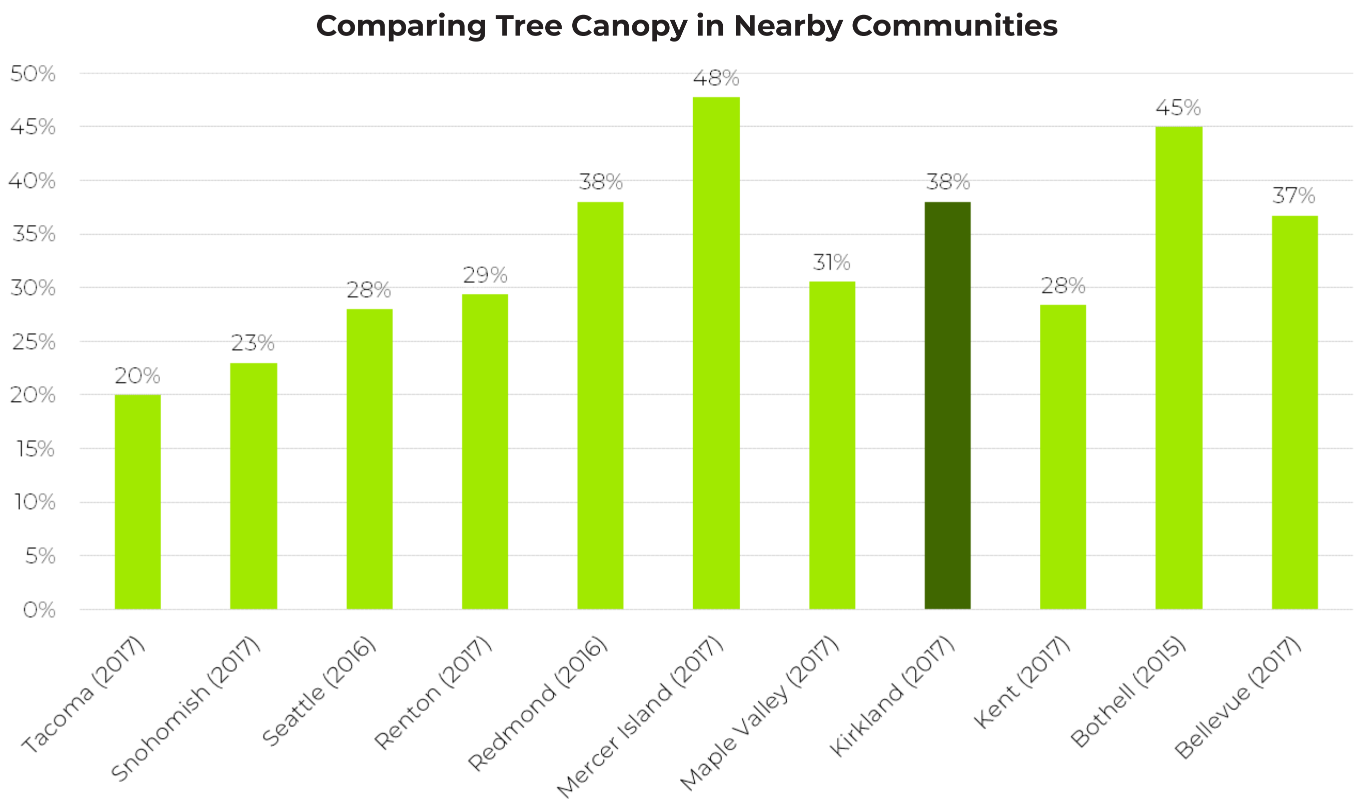


Figure 25. | A comparison of tree canopy in nearby communities.

APPENDIX

ACCURACY ASSESSMENT

Classification accuracy serves two main purposes. Firstly, accuracy assessments provide information to technicians producing the classification about where processes need to be improved and where they are effective. Secondly, measures of accuracy provide information about how to use the classification and how well land cover classes are expected to estimate actual land cover on the ground. Even with high resolution imagery, very small differences in classification methodology and image quality can have a large impact on overall map area estimations.

The classification accuracy error matrix illustrated in Table A1 contain confidence intervals that report the high and low values that could be expected for any comparison between the classification data and what actual, on the ground land cover was in 2017. This accuracy assessment was completed using high resolution aerial imagery, with computer and manual verification. No field verification was completed.

THE INTERNAL ACCURACY ASSESSMENT WAS COMPLETED IN THESE STEPS

1. Two hundred fifty (250) sample points, or approximately 15 points per square mile area in Kirkland (18.2 sq. miles), were randomly distributed across the study area and assigned a random numeric value.
2. Each sample point was then referenced using the NAIP aerial photo and assigned one of five generalized land cover classes ("Ref_ID") mentioned above by a technician.
3. In the event that the reference value could not be discerned from the imagery, the point was dropped from the accuracy analysis. In this case, no points were dropped.
4. An automated script was then used to assign values from the classification raster to each point ("Eval_ID"). The classification supervisor provides unbiased feedback to quality control technicians regarding the types of corrections required. Misclassified points (where reference ID does not equal evaluation ID) and corresponding land cover are inspected for necessary corrections to the land cover.[1]

Accuracy is re-evaluated (repeat steps 3 & 4) until an acceptable classification accuracy is achieved.

SAMPLE ERROR MATRIX INTERPRETATION

Statistical relationships between the reference pixels (representing the true conditions on the ground) and the intersecting classified pixels are used to understand how closely the entire classified map represents Kirkland's landscape. The error matrices shown in Table A1 represent the intersection of reference pixels manually identified by a human observer (columns) and classification category of pixels in the classified image (rows). The gray boxes along the diagonals of the matrix represent agreement between the two-pixel maps. Off-diagonal values represent the

1 Note that by correcting locations associated with accuracy points, bias is introduced to the error matrix results. This means that matrix results based on a new set of randomly collected accuracy points may result in significantly different accuracy values.

number of pixels manually referenced to the column class that were classified as another category in the classification image. Overall accuracy is computed by dividing the total number of correct pixels by the total number of pixels reported in the matrix (82 + 35 + 101 + 3 + 9 = 230 / 250 = 92 percent), and the matrix can be used to calculate per class accuracy percent's. For example, 84 points were manually identified in the reference map as Tree Canopy, and 82 of those pixels were classified as Tree Canopy in the classification map. This relationship is called the "Producer's Accuracy" and is calculated by dividing the agreement pixel total (diagonal) by the reference pixel total (column total). Therefore, the Producer's Accuracy for Tree Canopy is calculated as: (82/84 = .98), meaning that we can expect that ~98 percent of all 2017 tree canopy in the Kirkland, WA study area was classified as Tree Canopy in the 2017 classification map.

Conversely, the "User's Accuracy" is calculated by dividing the total number of agreement pixels by the total number of classified pixels in the row category. For example, 82 classification pixels intersecting reference pixels were classified as Tree Canopy, but 6 pixels were identified as Vegetation in the reference map. Therefore, the User's Accuracy for Tree Canopy is calculated as: (82/88 = 0.93), meaning that ~93 percent of the pixels classified as Tree Canopy in the classification were actual tree canopy. It is important to recognize the Producer's and User's accuracy percent values are based on a sample of the true ground cover, represented by the reference pixels at each sample point. Interpretation of the sample error matrix results indicates this land cover, and more importantly, tree canopy, were accurately mapped in Kirkland in 2017. The largest sources of classification confusion exist between tree canopy and vegetation.

Table A1. | Error matrix for land cover classifications in Kirkland, WA (2017).

Classification Data	Reference Data: Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Tree Canopy	82	6	0	0	0	88
Vegetation	1	35	6	1	0	43
Impervious	1	1	101	0	0	103
Soil / Dry Veg.	0	0	4	3	0	7
Water	0	0	0	0	9	9
Total	84	42	111	4	9	250

Overall Accuracy = 92%

Producer's Accuracy	
Tree Canopy	98%
Veg. / Open Space	83%
Impervious	91%
Bare Ground / Soil	75%
Water	100%

User's Accuracy	
Tree Canopy	93%
Veg. / Open Space	81%
Impervious	98%
Bare Ground / Soil	43%
Water	100%

ACCURACY ASSESSMENT RESULTS

Interpretation of the sample error matrix offers some important insights when evaluating Kirkland's urban tree canopy coverage and how land cover reported by the derived rasters and the human eye. The high accuracy of the 2017 data indicates that Kirkland's current tree canopy can be safely assumed to match the figures stated in this report (approximately 38 percent).

GLOSSARY/KEY TERMS

Land Acres: Total land area, in acres, of the assessment boundary (excludes water).

Non-Canopy Vegetation: Areas of grass and open space where tree canopy does not exist.

Possible Planting Area - Vegetation: Areas of grass and open space where tree canopy does not exist, and it is biophysically possible to plant trees.

Possible Planting Area - Impervious: Paved areas void of tree canopy, excluding buildings and roads, where it is biophysically possible to establish tree canopy. Examples include parking lots and sidewalks.

Possible Planting Area - Total: The combination of PPA Vegetation area and PPA Impervious area.

Shrub: Low-lying vegetation that was classified based on interpretation of shadows and texture in vegetation. Shrubs produce little to no shadow and appeared smooth in texture compared to tree canopy.

Soil/Dry Vegetation: Areas of bare soil and/or dried, dead vegetation.

Total Acres: Total area, in acres, of the assessment boundary.

Unsuitable Impervious: Areas of impervious surfaces that are not suitable for tree planting. These include buildings and roads.

Unsuitable Planting Area: Areas where it is not feasible to plant trees. Airports, ball fields, etc. were manually defined as unsuitable planting areas.

Unsuitable Soil: Areas of soil/dry vegetation considered unsuitable for tree planting. Irrigation and other modifiers may be required to keep a tree alive in these areas.

Unsuitable Vegetation: Areas of non-canopy vegetation that are not suitable for tree planting due to their land use.

Urban Tree Canopy (UTC): The "layer of leaves, branches and stems that cover the ground" (Raciti et al., 2006) when viewed from above; the metric used to quantify the extent, function, and value of Kirkland's urban forest. Tree canopy was generally taller than 10-15 feet tall.

Water: Areas of open, surface water not including swimming pools.

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Attachement 2

OCTOBER | 2018

URBAN TREE CANOPY

ASSESSMENT

KIRKLAND, WASHINGTON

Attachment 3

Citywide Tree Code Amendments
Kirkland Zoning Code Chapter 95

Public Engagement Plan

Contents

1. Purpose

Regularly-occurring code updates allow an opportunity to review code effectiveness, ensure codes remain relevant, are consistent with best available science and align with the community's vision. The purpose of the 2018 tree code revision is to support the goals established in Kirkland's Urban Forestry Strategic Management Plan and the Comprehensive Plan, to address issues and challenges that have arisen since the last tree code revision (2010) and to update the code so that it is effective and practical to use.

2. Approach

As part of scoping the tree code amendment project, the Planning Commission directed staff to develop a schedule and outreach plan that would encompass key milestones and stakeholders. With guidance from David Wolbrecht, the City's Neighborhood Outreach Coordinator, Planning staff developed this approach and sought a wide variety of perspectives for the Planning Commission and ultimately, City Council to consider.

Public engagement occurred through the use of three formats: Stakeholder Groups, City-wide Events and Neighborhood Meetings, and Correspondence submitted to the City. A webpage was created to inform the public on details about the project such as public meeting dates, potential code amendments and links to resources.

Anyone interested in receiving updates on the code amendment project could subscribe to a listserv through the project webpage. As of October 30 there were over 850 subscribers to the tree code amendment listserv.

In late October, the City's Communications Program Manager Kellie Stickney employed the use of press releases, the City's weekly email newsletter, and social media (Facebook, Twitter, Nextdoor) to solicit public comments on proposed code language.

3. Stakeholder Meeting Format

Staff formed two stakeholder groups consisting of citizens that have demonstrated or expressed an interest in urban forestry regulatory issues: citizens concerned with the protection of trees, the rules governing trees on development sites and with tree removal. Recruitment for each group was supplemented by support from the Finn Hill Neighborhood Alliance and the Master Builders Association, although each group did not consist exclusively of members of each affiliation. The separate groups met on September 17 and 21, 2018.

Staff sought to proactively address implicit bias that as individuals, might unconsciously bring to this process. Participants were informed that a facilitator who was not familiar with the tree code would guide discussions to extract simple statements in response to identical questions posed with each group. Aside from a short introduction and a limited amount of clarifying questions provided by the City's Urban Forester, there was little interaction between staff familiar with the tree regulations and the participants.

Participants were given the following prompts:

- What are your concerns with the current tree code?
- "A successful tree code in Kirkland is ____."
- "A successful tree code in Kirkland has ____."

The last 2 questions were formatted to obtain specific attributes or features of a "successful" tree code. Each of the group sessions generally lasted two hours.

Four common themes heard from the first group were:

1. The code is not effective
2. Tree protection, inspections and code enforcement is inadequate on development sites
3. Developers are either unaware of the codes or are exploiting loopholes
4. The codes do not relate to long-range canopy cover goals

Four common themes heard from the second group were:

1. The code is difficult to use
2. The code is too subjective, allowing the City to exercise too much authority with code interpretations such as with 'High Retention Value' trees
3. The code needs to be more prescriptive, with predictable outcomes, yet be flexible enough to accommodate anomalies such as odd-shaped lots
4. Certain definitions such as 'grove' are not clear

Overlapping areas of interest for potential code amendments amongst all groups and correspondence includes:

- Address areas in the code so it is more prescriptive, with predictable outcomes
- Redefine trees of merit/trees worthy of retention to reflect size, condition and location
- Improve tree protection, inspections and code enforcement on development sites

Participants in the stakeholder groups were actively engaged in the exercises, graciously acknowledged staff efforts to accurately capture their perspectives and were genuinely pleased to be involved in the City's tree code amendments.

It was observed that in both groups, there were many incorrect assumptions made about the code, pointing for the need to provide ongoing public education beyond the implementation phase of this code revision. One common area of confusion between the two groups was the categorization of trees of merit, or trees that are considered worthy of retention on development sites.

4. Event/Meeting Participation

In addition to the stakeholder meetings, staff utilized multiple events to inform the public and answer questions on how the current code works, about the code update process and how to get involved. All public engagement events and meetings are listed below:

DATE	EVENT/GROUP	# OF PARTICIPANTS
May 16	*Highlands Neighborhood Meeting*	20
Aug 23	*Master Builders Quarterly Meeting*	14
Aug 31	*Juanita Farmer's Market*	25
Sept 8	*Crossing Kirkland Event*	15
Sept 17	*Stakeholder Meeting #1*	10
Sept 21	*Stakeholder Meeting #2*	8
Sept 25	*Everest Neighborhood Meeting*	6
Oct 6	*City Hall for All Event/Presentation & Conversations*	20
Oct 10	*Kirkland Alliance of Neighborhoods (KAN) Meeting*	22
Oct 17	*Finn Hill Neighborhood Alliance Meeting*	35
		TOTAL: 175

The Juanita Farmer's Market and Crossing Kirkland events involved a pop-up tent and table setup with signage posing the question, "If you were in charge of trees in Kirkland, what kind of rules would you make?" (see Outreach Materials). Writing materials were provided so participants could jot down their responses on index cards, which were placed in a "comment box." Staff fielded many questions about the existing tree code and held conversations with citizens about the potential code revisions.

The City Hall for All event consisted of the same table setup with the addition of a 20-minute presentation on how the current code works, the code update process and how to get involved. At all tabled events, staff handed out postcards that list the project webpage URL so that interested parties could find out more about the tree code update and subscribe to the project listserv (see Outreach Materials).

Generally speaking, participants at these events expressed an appreciation for trees and the natural environment and conveyed a positive reaction that tree protection codes exist in Kirkland. Four main themes from the conversations and comments at these events include:

1. Retain large trees
2. Plant trees
3. General knowledge on the benefits that trees provide
4. How to address tree-sidewalk conflicts

The Neighborhood and Master Builder Quarterly meetings provided an opportunity to describe the code updates and to field questions about the current code, potential changes to the code and the amendment process.

5. Emails & Letters

Emails and letters regarding the city-wide tree code updates addressed to the City Council, Planning Commission, Urban Forester or Planning Department were compiled and attached to the November 8, 2018 Planning Commission staff memo (Attachment 10). There are about 18 letters and emails that were received up to noon October 31, 2018, some of which were sent from key stakeholder groups. The subject matter in the letters and emails generally covered potential code amendments or similar issues that have been previously outlined in Planning Commission memos or discussed in public meetings. Correspondence topics include:

- Tree removal allowances
- Tree planting requirements per lot size
- Tree canopy cover/tree credits
- Tree canopy goals
- Code enforcement
- Exceptional/Heritage/Landmark/High Retention Value trees (trees of merit)
- City authority to require permit applicants to seek variations to development standards for the retention of existing trees
- Integrated Development Plan review (for shortplat/subdivisions)
- Tree protection fencing, signage
- Maintenance requirements for retained and newly-planted trees
- Fines for tree code enforcement
- Native trees and vegetation
- Benefits of trees
- Perceived inequity between allowed tree removal with development and tree removals on private property where no development occurs

6. Public Comments

Question: if you were in charge of trees in Kirkland, what kind of rules would you make?

1. No hurting [trees] unless [they're] weak and going to [be removed] anyway
2. Kirkland's assets are its tall, mature trees – keep our neighborhoods green!
3. Grow More [trees]!
4. More compost bins available ☺
5. I would every time you cut down 1 tree you have to plant 2 native trees
6. I wouldn't cut any of them down!
7. [Plant] as many trees as possible
8. Increase tree canopy coverage goal, [and] maintain, don't cut down mature trees, especially for construction of new mansions. Study urban heat island effect, health data & localized cooling. Lift up sidewalks & trim roots that have heaved the pavement instead of removing and replacing trees.
9. Balance growth/tree retention, [better coordinate] different [City] departments' interests with trees
10. [There should be more] equity between homeowners' [tree removal] allowances vs. developers [tree retention requirements]
11. We need trees for privacy and sound/dust barrier
12. More trees [for their] benefits
13. [Unless] potentially hazardous, save for squirrel habitat
14. Preserve the large old growth, replace with greater than what is taken away (trees)
15. Be more diligent with street/park tree maintenance, especially street/sidewalk clearance
16. I'm all for preservation of trees, but please be open minded that in certain situations, pruning and/or cutting is necessary
17. [Allow] payment in lieu of replacement trees on private property [so that replacements can go somewhere void of trees] like Spinney Park
18. Trees/veg cleared from sidewalk
19. Cut down trees & sell 'em for City $ funds
20. Allow in critical areas [tree] prun[ing] for light
21. If a tree blocks my view, I want it cut down
22. Tree code enforcement [should be] part of the tree code update. [Require] stop work order for people who break code. Suspend or revoke their business license. Fix loopholes
23. More trees and understory plants everywhere. Preserve large trees
24. Clarify the process by which you can have a tree declared unhealthy or unsafe, and therefore you can cut it down without affecting your annual limit

Stakeholder Question: What are your concerns with the current tree code?

25. Tree credit [requirement is] inconsistent with goals for canopy coverage. It incentivizes native forest conversion into a non-native forest. Only way it works is with non-native deciduous trees.
26. Credits/rules don't align with tree growth/biology. Should be using PNW data and survival rate
27. Sidewalk planting strip longevity messing up sidewalk [root growth of street trees in sidewalk strips leads to broken pavement]
28. Unfair processes/double standard between residents and developers
29. Statistics on canopy cover [should] only come from [what's within] City jurisdiction or boundary lines
30. [That] developers [don't] know their role in city-wide canopy goals
31. Developing [occurring] despite consequences of fines, etc. Up front work [occurs such as tree retention plans] but [there's] no follow-through with code enforcement.
32. No protection for adjacent property owners' trees
33. Need better signage for tree protection
34. [Concerned with] preserving trees with trail systems. Walkability and root zone [conflict]
35. [Code is] onerous and expensive for residents [and small contractors] specifically re: [tree protection] fencing. Doesn't make sense. [Even with fencing, there are] impacts [to] tree/plant health

36. [Code] too specific, doesn't achieve general goals
37. There is a lack of:
    - Developer awareness on tree canopy maximization
    - Tree categories (significant, heritage, etc.) and incentives to save them
    - Maintenance bond
    - Enforcement and fines correlated to tree size
    - Understanding of [protected tree] maintenance responsibility of developer/owner
    - IDP [requirement on a citywide basis]
    - Financial support from City for resident tree preservation [City-provided incentive such as a tax break or permit/zoning regulation relaxation for retaining mature trees; this would be the flip side of usual policy that prohibits or penalizes tree removals
38. Tree preservation isn't coordinated between various agencies/utilities
39. Where in the process [is] the tree standard created and applied [questions the basis for the City's current credits requirement and how it's applied to retain trees or plant new trees
40. Interpretation of code language [too lax] ("if feasible" etc)
41. Notice of development doesn't have tree plan, [is] not online.
42. More equality with 2-per 12 months tree removal, specifically regarding larger properties
43. [Code is] inflexible for atypical lot dimensions
44. [Code is] unpredictable:
    - [It's an] outlier from other building codes
    - Updates [are unpredictable]
    - Interpretation/implementation [is not consistent] between different staff and over time
    - [In how tree] credits [are] practice[d]
    - [There's] no objective measure
45. [Needs] clearer definitions and environmental connection [to] "significant" and "exceptional"
46. [Too] subjective standards, especially staff consistency [over time]/training [for new staff]
47. Lack of "grove" definition
48. [Code] minimum[s are] subjective, [result in] additional requirements as opposed to other building code minimums. [Results in unnecessary] one-sided negotiation [that favors staff].
49. Process timing too swift, not enough time for review
50. [In regards to] "canopy" [cover] vs. [trunk diameter at] breast height:
    - DBH is easier to measure
    - Canopy can be manipulated
51. [Concerned with] implementation of [increased] tree replacement [requirements] and [having] arborist on site during [construction]

Stakeholder - complete this statement: a "successful" tree code in Kirkland is…

52. One that helps homeowners plant, replace, manage trees depending on where they are [located]
53. One that provides construction solutions to owners when they have a tree [retention] problem
54. One that consistently meets with 40% canopy goal for City boundaries only
55. One that incentivizes native tree usage via tree credit [requirements]
56. Integrated with rest of development code
57. Accommodating of different neighborhoods' character
58. Integral, connected to policy goal of healthy, sustainable urban forest/tree canopy goals
59. Correlated between lot size and tree code policy with balance between simple and cost effective
60. Objective
61. Accommodating of the original intention of a plat layout
62. Respectful of property rights
63. Takes into account other advancements in environmental tech [such as] water and solar
64. Predictable and consistent
65. Flexible [with a] transparent process to [address] problematic anomalies of code [that are] not really working
66. Equitable
67. Balanced between predictable and flexible

68. Accommodating of a fee program in lieu of [tree] replanting [on site]
69. Accommodating of tree replanting [vs. tree retention]
70. Consistent [with] meaning/definitions for decision-making rationale and construction methods (root zones)
71. Not requiring an on-site arborist

Stakeholder - complete this statement: a "successful" tree code in Kirkland has…

72. Contractors sign [an] affidavit for tree responsibilities over time [after development]
73. Precedence over other development processes
74. Ongoing financial responsibility through HOA or similar [legal] vehicle for maintenance of PNA/required [tree] replanting or a bond for x years [after development]
75. Mandatory education for developers, including [required trees] follow up
76. Clear [tree protection] plans included on [public] notices [and job sites] with [code] enforcement [phone] #
77. Economic incentives for public to do the right thing
78. Acknowledgment of "downstream" consequences of [tree] removal, [tree] removals included in stormwater assessment
79. A proactive city-wide education campaign and partnership with Lake Washington Technical College to increase availability of native plants and shrubs and drought-tolerant varieties to homeowners, city parks and public works departments
80. Clear online resource to identify tree problem and Next Steps [for permits]
81. Maintenance requirements for City-owned property and conservation easements
82. Different tree classifications [for] species, cultural [significance] and heritage [trees], etc.
83. A clear process flowchart similar to LID process, especially for "flexible" situations [such as] difficult lots
84. Third party appeals/arbitration process with option for Hearing Examiner
85. An IDP option [as opposed to requiring it for all shortplat/subdivisions citywide]
86. No IDP requirement [would rather it be an option]
87. "Black and white" clear definitions, standards
88. A better definition of "grove"
    - Science-based qualifications
    - [Has a] legal protection [mechanism that's] not [an] easement
    - When [is it] applied?

7. Outreach Materials

KIRKLAND TREE CODE SUMMARY

	TREE REMOVAL SCENARIO	IS A PERMIT REQUIRED?	DETAILS
PRIVATE PROPERTY	Remove any 2 trees	**No, however…**	Notify Planning Dept. to prevent Code Enforcement response
	Remove additional hazard or nuisance trees	**No, if…**	Condition is obvious in a photo
	Remove hazard or nuisance trees in critical areas	**Yes**	Arborist report, replanting may be required
	Emergency/urgent tree removal	**No**	Contact Planning Dept.
	Prune or trim trees	**No**	No topping allowed
	Tree removal with development	**Yes, with development permit**	-Arborist report required -Tree protection required on site
PUBLIC PROPERTY	Prune/remove street trees	**Yes**	Public Works may prune/remove street trees by request or at their discretion
	Prune/remove park, CKC, and street trees	**No, City service**	Property owner requests may not be granted

If you were in charge of trees in Kirkland…

What kind of rules would you make?

Share with us your thoughts on how to efficiently and sustainably manage Kirkland's urban forest.

September 24, 2018

Scott Moser
2135 112th Ave NE #100
Bellevue, WA 98004
scott@mosercpas.com

Subject: Tree Removal Permit: TRE18-06443, Denial

Scott Moser,

A Tree Removal Permit was submitted to the City of Kirkland Planning Department on 9/12/2018 requesting removal of 107 trees, pursuant to Kirkland Zoning Code (KZC) 95.23 and 70.15. A peer review of the removal request and arborist report was completed for compliance with applicable City regulations.

None of the trees on this property are not approved for removal, as the City has found no evidence that the trees meet the nuisance or hazard criteria listed in KZC 95.10.10 and 95.10.7. The Arborist Report submitted with this permit was an Arborist Report to aid in development, not a tree risk assessment. Tree retention and removal for this project will be determined during the building permit review.

An applicant may appeal an adverse determination to the Hearing Examiner. A written notice of appeal shall be filed with the City within 14 calendar days following the date of distribution of a City's decision. The office of the Hearing Examiner shall give notice of the hearing to the applicant at least 17 calendar days prior to the hearing. The applicant shall have the burden of proving that the City made an incorrect decision. Based on the Hearing Examiner's findings and conclusions, the Hearing Examiner may affirm, reverse or modify the decision being appealed. The appeal fee shall be submitted with the written request.

Please contact me with any questions.

Sincerely,

DEPARTMENT OF PLANNING AND COMMUNITY DEVELOPMENT

Kelly Wilkinson

Kelly Wilkinson
Development Review Arborist
425.587.3264
kwilkinson@kirklandwa.gov

From: Kelly Hardy [mailto:kellyhardy2005@gmail.com]
Sent: Friday, November 02, 2018 10:01 AM
To: Deborah Powers <DPowers@kirklandwa.gov>
Subject: Nov 8 Tree discussion

Hi, I would like to ask that consideration be made to restricting the height of trees. Some of these trees are too tall and unkept. It not only is a risk, but blocks neighbors view of the beautiful landscape we have in Kirkland. Thank you,

Kelly Hardy
123 7th Ave
Kirkland, WA 98033

Sent from Mail for Windows 10

From: Amy Kolve [mailto:amy.kolve@gmail.com]
Sent: Wednesday, November 7, 2018 10:04 AM
To: Planning Commissioners <PlanningCommissioners@kirklandwa.gov>
Subject: Protecting our Trees - Kirkland needs a better Tree Ordinance

Dear Kirkland Planning Commission,
Thank you for taking the time to read my email about protecting Kirkland's trees. I'm a long time Kirkland resident, having lived here over 55 years! Lately, I've seen more and more trees being cut and the city and residential neighborhoods are changing, our tree density has greatly diminished over the years.

Currently, I live near OO Denny Park in the Juanita area. We are fortunate to have a beautiful wooded area that supports birds and other animals. Unfortunately, the trees are being overtaken by english ivy and thinning of nearby trees is causing windfall damage to occur more frequently. When I read about what The City would like to do to curtail tree protection of our Holmes Point Overlay standards I cringe, we need to protect these trees from further cutting, allowing homes but with great protection of current standing trees and plans for future ones as well. These trees soak up our CO_2 and help reduce global warming caused by greenhouse gases, lets let the amazing biodensity (wood and biomass) unique to the Northwest help lead the way in reducing greenhouse gases. No where else on the planet can one square acre produce as much plant material (our Douglas Firs, Western Maples, Western Hemlocks, Cedars to name a few) to help balance the gases in the air.

I support the Finn Hill Neighborhood Alliance when it states:

FHNA has said the following:

- Tree canopy goal: Residential subdivisions and short plats should be landscaped to provide a 50% canopy cover when trees mature (e.g., in 20 years' time). Without such a standard, the City won't be able to maintain a 40% canopy cover overall, because business and multi-family areas don't have high tree canopy percentages.
- Tree planting requirements should be based on expected canopy coverage, not tree credits. FHNA asserts that the tree credit system doesn't work. The City's goal is to establish a robust tree canopy, but a tree credit system doesn't measure canopy; it measures trunk size. Different tree species have different canopies, so canopy results will be vastly different depending on which species are planted, even though the same credits may be awarded in each planting scenario. (Compare the wide crowns of deciduous trees to the narrow, columnar profiles of many conifers.) And the current tree credit requirement of 30 credits per acre doesn't approach a 40% canopy cover. Even for big deciduous trees, a 30 credit/acre standard yields less than 20% canopy coverage.
- Existing trees need better protection during development. The code currently says that high retention value trees must be retained "to the maximum extent possible" and moderate retention value trees must be retained "if feasible". But it doesn't seem like these standards have been applied as written. City planners should do more to require that improvements like sidewalks, driveways and even home site footprints be redesigned to save healthy mature trees.

- Landmark trees should be given special protected status and the planting of native species should be encouraged. We've recommended that 50% of trees that must be planted to meet the City's tree density requirements be native species.
- Newly planted trees must be maintained. Builders are required to maintain new tree plantings for 5 years, but once home sites are sold, the builders are effectively relieved of their responsibilities. Builders should, in cases where significant tree planting has been required, post bonds so that the City can require the installation of replacement trees if plantings die within 5 years.

Thank you,
Amy Kolve
425-283-7019

--
Amy

(425) 283-7019

November 7, 2018

Kirkland Planning Commission
123 – 5th Ave.
Kirkland, WA 98033

Re: Tree Code Update Comments

Honorable Commissioners,

Merit Homes is an active homebuilder in Kirkland. At any given time, we have a dozen or more subdivision applications pending and 25 of our homes are currently under construction in the City. Over the last 12 months, we've paid the City $1,103,000 in subdivision and building-permit-related fees.

We're familiar tree code operation, it is by far our most challenging issue. I attended the September 21 stakeholder meeting and can attest the room's awareness of current practice was fully and properly formed. However, Staff reports that:

> *"It was observed that . . . there were many incorrect assumptions made about the code, pointing for the need to provide ongoing public education beyond the implementation phase of this code revision."*

Nobody at that meeting was making any assumptions, they were universally speaking from experience. To assert the building community needs "ongoing public education" to understand our businesses is misguided.

Further, and more troubling, none of our input translated into the Staff Recommendations. We disagree with the Finn Hill Neighborhood Alliance's position that a 'canopy system' would improve on one based on credits, however Staff goes even further, preferring *no objective measures*. In 25 years as a land use practitioner, I've never seen such an unworkable nor extreme position from any agency Staff.

Stepping back, the record indicates the Commission may have been given a partial impression of Code history and current practice. Last year, I did a research project on tree code history. This is included in Exhibit 10, starting page 160 from the November 8 Staff package. In brief, City decided trees were important, installed a 40% canopy goal in its Comprehensive Plan, then in 2005 negotiated/enacted the basic form of today's Code, with tree credits at the heart of Code operation. This went into effect January 1, 2006.

CREDITS

Initially, credits were used faithfully. I have multiple project decisions clearly reflecting this. Over time, credits faded into the background and today they have been excised in all but a few outlying cases. Today, there is no credit review and nothing has replaced them. Today's practice is predicated on opinion, not measures. Staff simply decides, case-by-case, how Owner rights are balanced with tree retention.

This is how Staff prefers to run project reviews. In the November 8 Recommendations to the Commission, that preference is made clear *(see Quantitative Review Standards Recommendations 40, 75, and 77)*.

From their view, this would allow them to require preservation just short of getting sued for total regulatory taking under Constitutional inverse condemnation. A further recommendation states that Reasonable Use should not be adopted for trees *(see potential change #70)*, but Reasonable Use and inverse condemnation avoidance are the same thing. Reasonable Use, all over the Puget Sound, was created specifically as a safety valve to *avoid getting sued for inverse condemnation*.

Further, the *context* of Reasonable Use is within the Critical Areas framework (wetlands, streams, steep slopes). These are defined in the State GMA [36.70A.030(5)], and faithfully reflected in Kirkland's Zoning Code at 5.10.179.5. Kirkland's Reasonable Use provisions are found at KZC 90.180, within the Critical Areas chapter. Trees are not Critical Areas by State definition, nor Kirkland's, and yet Staff's recommendations lean toward creating a brand-new critical area in treatment, if not definition. It's further notable that actual Critical Areas have objective review standards.

Today's practice toes the line of Reasonable Use already – today – with no code guidance. At page 178, Exhibit 10 in the November 8 package, I sent an example of one of our homes. In that case, we had to modify our application multiple times at considerable cost and delay, with an ultimate requirement of 1,230% of Code requirement on tree credits.

With current practice:

- It is impossible to determine preservation requirement by reading the code;
    - Because of this, some reviewers are more reasonable and others less so;
    - Our early work to vet property (feasibility) can be nearly impossible;
- Properties are not treated equally – adjoining 7,200 SF lots could vary in value $100,000 or more;
- Credits *should* organize the entire code – without them any tree Staff wants to preserve becomes "high priority" or *must save*, regardless of definitional compliance.

City Staff has said repeatedly that existing Code requires the current, unsettled approach and that they wish an objective standard were in place. Everyone wants predictability, measurable success is the goal of every land use rule. Setbacks, FAR, building height, Lot Coverage, insulation standards, etc. etc. Codes are written with repeatable, definitive, and defensible protocols because they work. A code everyone can read, that treats people and properties equally should not be controversial. That should be the expectation here.

IDP

Staff recommends IDP be required City-wide. Late last year, I had a lengthy email exchange with Jeremy McMahon on benefits and downsides of IDP. There is very little code difference between IDP and Phased reviews, limited to a few statements at KZC 95.30.6.

As currently practiced, IDP requires assessing all development at project beginning, which negotiation can't start until survey and arborist report are complete (6 weeks), and the first presubmittal meeting is held (3 weeks). Absent any retention standards, the City then has free rein with project design, potentially ignoring owner wishes, utility needs, access requirements, and anything else not tree-related. On a new project, an applicant has no idea what to expect, what development conditions will be, or how to appraise a property until the 3rd month of work.

Feasibility is the business term for project workability *and whether it is likely to make money*. Our policy avoids survey, arborist, and engineering until we're confident (because those tasks cost thousands of dollars). Without meaningful feedback from the City and especially if they have design influence, the equation becomes unfavorable. Further, property sellers frequently don't allow months for feasibility review. IDP puts us in a bind from multiple angles:

- *Large sites compared to small* – Big projects can require a considerable earth-moving for access and utilities. This doesn't leave much room for saving trees, which Staff generally accepts. In a larger project, there can also be more room to adjust design without major compromise to the product. In these cases, IDP works well.

  By contrast, short plats 1) usually don't mass grade - no immediate need to clear trees; 2) do not have physical space to adjust design without penalty; and 3) any loss of building value, even one compromised lot, can ruin a project as there aren't a number of other lots to defray problems.

- IDPs put Owner-driven and other nonprofessional applicants at a disadvantage. Upfront work is expensive and demands knowledge of (and commitment to) end-product. Owners creating value through subdivision applications usually don't build out, making those negotiations difficult.

- Because of the previous point, transferring applications between controlling interests becomes harder. Merit buys in-process short plats - we don't want another builder's product. From their view, time/money spent on buildings is wasted, and really so is Staff time in those reviews.

- Schedule/cost – The process is already lengthy and expensive. All the feedback we've received is IDP adds to both, sometimes tremendously. Add to that unpredictability of outcome and the business view is quite negative.

In the November 8 Commission package, Staff indicated IDP was preferable, at least in part because the process is more 'prescriptive'. They've also advocated to continue current practice without objective standards. These statements are polar opposites – 'prescriptive' is like a building setback, 5' side yard, 20' front, etc., or building heights – *30' and here's how to calculate*. Prescriptive requirements are those that 5 people can read and arrive at the same interpretation.

I assume what was meant is that tree requirements are settled earlier in the process with IDP, rather than reviewing the issue multiple times. This is not, by itself, a bad goal. Where it goes wrong is in *also* removing any objective standard for retention. Given a blank design slate, and infinite allowance to design around trees, regulatory abuse is inevitable.

IDP is a good alternative but doesn't fit every situation, Phased Review should remain a choice.

Suggestions

IDP would work better if an objective standard were employed, *and* full sites could be reviewed for compliance rather than lot-by-lot as required now. If most great trees are in good locations on one or two lots, and the other lots have poorer quality or placements, why not allow retention to be concentrated?

With some Code changes, applicable to both Phased Review and IDP, fairness could be increased. From our viewpoint, creating a Code with boundless requirements, subject solely to a reviewer's opinion, is unworkable. The credit system which has been deactivated, would work if it were actually used. The Finn

Merit Homes, Inc. 811 Kirkland Ave. #200, Kirkland WA 98033

Hill Neighborhood Alliance proposes a different metric – canopy coverage, to tie into Comprehensive Plan goals.

Another possibility is backstop protections, providing that tree conditions cannot reduce lot count nor prevent construction of homes fully compliant with all other regulations (of which there are many).

I hope a functional system for preparing and reviewing development applications can come out of this process, and look forward to continuing dialog.

Thanks very much for your consideration,

S. Michael Smith,
Development Manager

Merit Homes, Inc. 811 Kirkland Ave. #200, Kirkland WA 98033

From: Scott Morris [mailto:Scott.Morris@trilogy-international.com]
Sent: Friday, November 09, 2018 11:36 AM
To: Deborah Powers <DPowers@kirklandwa.gov>
Cc: Adam Weinstein <AWeinstein@kirklandwa.gov>
Subject: RE: Kirkland tree code

Deb,

Yes, I think you have addressed everything. I was in meetings yesterday up to the time of the Planning Commission meeting and did not see your latest response until I got home.

I would say that your retention is good but that planting to restore canopy should not be overlooked. They are both important. I presume we're in agreement on that point.

BTW, I think the builders can subscribe to more rigorous retention of some existing trees (i.e. clearly defined "landmark" trees and clearly defined "quality" (?) groves) so long as they can determine, before they invest in a land purchase, which trees they will be asked to retain.

Scott Morris
Trilogy International Partners LLC
155 108th Ave NE, Suite 400
Bellevue WA 98004

Email: scott.morris@trilogy-international.com
Desk: 425-458-5955
Cell: 206-972-9493
Fax: 425-458-5998

From: goodwin [mailto:goodwin.hp@gmail.com]
Sent: Wednesday, November 07, 2018 10:06 PM
To: Planning Commissioners <PlanningCommissioners@kirklandwa.gov>
Cc: Scott Morris <Scott.Morris@trilogy-international.com>; City Council <citycouncil@kirklandwa.gov>; Deborah Powers <DPowers@kirklandwa.gov>; Adam Weinstein <AWeinstein@kirklandwa.gov>
Subject: KZC95 meeting 11/8

Dear Commissioners,

Many neighbors understand you have been working on tree agenda items for a long time, thank you. We have to remind ourselves sometimes you guys are volunteers like us. Know what you are doing is making a difference.

Many stakeholders will say 'trees' is Kirkland's #1 most contentious issue. I hope you somehow find the energy to help council tackle this complex issue and find a solution to the problem through this KZC95 revision process.

Tomorrow night (11/8) as we dive into the code I suggest you start the dialogue with staff, before staff launches into their presentation, one question **'What is our tree policy'.** It is very important you ask this question directly to the ranking city leadership person attending the meeting.

Many stakeholders will agree Kirkland's tree policy is unclear. Many will say if there is a policy the city seems to have given up on it.

Thank you for what you do,

Ken Goodwin
FHNA Member

CC'd:
City Council
Adam Weinstein
Deb Powers
Scott Morris

From: Mike Smith [mailto:Mike@merithomesinc.com]
Sent: Wednesday, November 07, 2018 4:57 PM
To: Planning Commissioners <PlanningCommissioners@kirklandwa.gov>; Deborah Powers <DPowers@kirklandwa.gov>
Subject: Tree code update letter from Merit Homes

Good evening,

I've prepared a comment letter on behalf of Merit Homes, and hope it can be added to the record and reviewed before tomorrow night's meeting.

Thanks very much,

Mike

S. Michael Smith
MERIT HOMES

Development Manager
O – 425-578-0604 | M - 206-755-2660
Mike@MeritHomesInc.com | www.MeritHomesInc.com | Facebook
811 Kirkland Ave, Suite 200, Kirkland, WA 98033

From: Scott Morris [mailto:Scott.Morris@trilogy-international.com]
Sent: Wednesday, November 07, 2018 3:06 PM
To: Deborah Powers <DPowers@kirklandwa.gov>

Cc: Adam Weinstein <AWeinstein@kirklandwa.gov>; Susan Lauinger <SLauinger@kirklandwa.gov>
Subject: RE: Kirkland tree code

Thanks so much for the responses, Deb. I appreciate your getting back to me.

I have 3 replies/questions of my own, in yellow below.

Scott Morris
Finn Hill Neighborhood Alliance - President
www.finnhillalliance.org | 206-972-9493
PO Box 682, Kirkland WA 98083

www.facebook.com/finnhillalliance

From: Scott Morris [mailto:Scott.Morris@trilogy-international.com]
Sent: Sunday, November 04, 2018 10:00 PM
To: Deborah Powers <DPowers@kirklandwa.gov>
Cc: Adam Weinstein <AWeinstein@kirklandwa.gov>
Subject: Kirkland tree code

Deb,

I read the staff memos to the Planning Commission about the tree ordinance and the canopy assessment this weekend. There's a lot in the tree ordinance memo that FHNA likes – the IDP, better fencing and inspection requirements, restricting the over-reliance on arbor vitae, better location of new trees. And I think we like where you are going on trees of merit, although I have some questions about the details of your proposal.

While we want to be pragmatic, FHNA has a very difficult time understanding why the Planning Department proposes to relax rules for planting new trees after a short plat or subdivision is developed. It looks like you are saying that no new trees would need to be planted unless the site (the subdivision?, a lot on the subdivision?) is "devoid of trees". This seems to be a loophole that would lead to further declines in Kirkland's tree canopy, not a step towards restoring a 40% canopy cover. Have I misread the staff memo? Perhaps it's not clear in the memo, but per our phone conversation, rather than the 30 credits per acre calculation, there will simply be a number of trees per lot size requirement, shown in a table format. The number of required trees will not be reduced, it will be shown more clearly. [Scott: I don't recall seeing a table in the 11/8 staff memo. Is it being prepared? And are you suggesting that instead of specifying 30 credits/acre you are moving to 6 trees of a minimum size (or 4?)/quarter acre, 15 trees (or 12?)/half acre, 30 trees/acre?] Remember per intern findings and canopy analysis, replacement trees are not the issue, it's tree retention with development that's caused our recent canopy loss, so that's where the heavy lifting code changes focus. [Scott: Yes, but you can't save all that many trees from removal during development, so you still have to include some meaningful replanting requirements to replace/augment what you couldn't save. Right?]

More specifically, I have several focused questions about the tree code and proposed revisions to it. Can we get 10-15 minutes between 10am and 3pm today to run through them?

- Does the current definition of High Retention Value trees cover only those trees that are located in sideyards and required landscape areas or does it extend to specimen trees, trees on slopes, and groves not located in sideyards and required landscape areas? (I honestly don't know how to interpret the code on this point.) Trees required to be retained on slopes are covered by the critical area/geohazard chapters in KZC, regardless of their condition. HRV trees can include what's currently defined as specimen. Right now HRV tree retention applies only in setbacks and required yards. Sometimes trees worthy of retention aren't in a setback so that's why we want to change the language regarding HRV. Currently staff requires retention of groves outside setbacks, but it's not really clear and consequently results in frequent disagreements. That's why we want to clarify grove requirements.
- What is a required landscape area, by the way? Technically, required landscaping applies to commercial/multifamily, and may include buffers. The zoning for particular properties dictates the size of either. Susan, feel free to chime in on this one…
- How would a new standard for retaining trees of merit differ from the standard for retaining moderate retention value trees Per memo – new definition for large trees, etc. ("feasible") or high retention value trees ("maximum extent possible")? (To me, feasible is a high standard, but that doesn't seem to have been the interpretat1ion over the years.) We often can't mandate Moderate Retention Value tree retention, mostly because of the location (see 1st bullet) but also because the language you're describing results in more negotiations, less tree retention. That's why we're addressing it – see the memo for some proposed options based on other cities codes that address the issue.
- Are tree plans required for all development activities that are "major" yes or are short plats and subdivisions? Yes, tree plans are required with SPLs/SUBs – see KZC 95.30.5. Look for the little 'x' marks in the applicable column
- Are tree plans always accompanied by an arborist report? Yes, unless it's a minor addition/remodel If not always, when are arborist reports typically required? When and why are they waived? See KZC 95. See KZC 95.30.5 and the table mentioned above. Let me know if you have any questions after checking the code
- If tree canopy percentage has fallen in residential areas of the City over the last 8 years, why do you conclude that the City doesn't need to worry much about planting new trees following development activity? That's not a conclusion the City is making – see 1st bullet point. *Again, it's loss of canopy resulting from development that's the focus.*
- Is it technically incorrect to assert that the crown diameter of a red maple is bigger than that of a cedar? Yes, see https://www.itreetools.org/streets/resources/Streets_CTG/CUFR_164_Pacific_Northwest_CTG.pdf [Scott: Thanks for the citation. It looks like a very useful document. I see that it has crown diameter figures for maples and a host of other deciduous trees, but I didn't see any data for cedars or conifers. Did I miss something?]

- Do you believe that the volume of the crown of a red maple is equivalent to that of a cedar? i.e. total leaf area ration, no

Thanks!

Scott Morris
Finn Hill Neighborhood Alliance - President
www.finnhillalliance.org | 206-972-9493
PO Box 682, Kirkland WA 98083

www.facebook.com/finnhillalliance

From: Amy Kolve [mailto:amy.kolve@gmail.com]
Sent: Wednesday, November 7, 2018 10:04 AM
To: Planning Commissioners <PlanningCommissioners@kirklandwa.gov>
Subject: Protecting our Trees - Kirkland needs a better Tree Ordinance

Dear Kirkland Planning Commission,
Thank you for taking the time to read my email about protecting Kirkland's trees. I'm a long time Kirkland resident, having lived here over 55 years! Lately, I've seen more and more trees being cut and the city and residential neighborhoods are changing, our tree density has greatly diminished over the years.

Currently, I live near OO Denny Park in the Juanita area. We are fortunate to have a beautiful wooded area that supports birds and other animals. Unfortunately, the trees are being overtaken by english ivy and thinning of nearby trees is causing windfall damage to occur more frequently. When I read about what The City would like to do to curtail tree protection of our Holmes Point Overlay standards I cringe, we need to protect these trees from further cutting, allowing homes but with great protection of current standing trees and plans for future ones as well. These trees soak up our CO2 and help reduce global warming caused by greenhouse gases, lets let the amazing biodensity (wood and biomass) unique to the Northwest help lead the way in reducing greenhouse gases. No where else on the planet can one square acre produce as much plant material (our Douglas Firs, Western Maples, Western Hemlocks, Cedars to name a few) to help balance the gases in the air.

I support the Finn Hill Neighborhood Alliance when it states:

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- Tree canopy goal: Residential subdivisions and short plats should be landscaped to provide a 50% canopy cover when trees mature (e.g., in 20 years' time). Without such a standard, the City won't be able to maintain a 40% canopy cover overall, because business and multi-family areas don't have high tree canopy percentages.
- Tree planting requirements should be based on expected canopy coverage, not tree credits. FHNA asserts that the tree credit system doesn't work. The City's goal is to establish a robust tree canopy, but a tree credit system doesn't measure canopy; it measures trunk size. Different tree species have different canopies, so canopy results will be vastly different depending on which species are planted, even though the same credits may be awarded in each planting scenario. (Compare the wide crowns of deciduous trees to the narrow, columnar profiles of many conifers.) And the current tree credit requirement of 30 credits per acre doesn't approach a 40% canopy cover. Even for big deciduous trees, a 30 credit/acre standard yields less than 20% canopy coverage.
- Existing trees need better protection during development. The code currently says that high retention value trees must be retained "to the maximum extent possible" and moderate retention value trees must be retained "if feasible". But it doesn't seem like these standards have been applied as written. City planners should do more to require that improvements like sidewalks, driveways and even home site footprints be redesigned to save healthy mature trees.
- Landmark trees should be given special protected status and the planting of native species should be encouraged. We've recommended that 50% of trees that must be planted to meet the City's tree density requirements be native species.
- Newly planted trees must be maintained. Builders are required to maintain new tree plantings for 5 years, but once home sites are sold, the builders are effectively relieved of their responsibilities. Builders should, in cases where significant tree planting has been required, post bonds so that the City can require the installation of replacement trees if plantings die within 5 years.

Thank you,
Amy Kolve
425-283-7019

From: Kelly Hardy [mailto:kellyhardy2005@gmail.com]
Sent: Friday, November 02, 2018 10:01 AM
To: Deborah Powers <DPowers@kirklandwa.gov>
Subject: Nov 8 Tree discussion

Hi, I would like to ask that consideration be made to restricting the height of trees. Some of these trees are too tall and unkept. It not only is a risk, but blocks neighbors view of the beautiful landscape we have in Kirkland. Thank you,

Kelly Hardy
123 7th Ave
Kirkland, WA 98033

Sent from Mail for Windows 10

From: Deborah Powers
Sent: Friday, November 09, 2018 4:44 PM
To: Scott Moser <scott@mosercpas.com>
Cc: Adam Weinstein <AWeinstein@kirklandwa.gov>; Jeremy McMahan <JMcMahan@kirklandwa.gov>; Kelly Wilkinson <KWilkinson@kirklandwa.gov>
Subject: RE: Tree Removal Permit TRE18-06443

Hi Scott,

I don't review development permits so I'm as not familiar with your site as Kelly, who's out of the office today. Based on GIS imagery, your site is quite affected by critical areas. From our permit database, it looks like you received a Tree Removal Guide explaining the conditions of tree removal in Kirkland, so you would know that critical areas are a major limiting factor. I assume your consultant let you know they also limit clearing, grading and development of the site too. Clearing/grading permits do not allow site-wide tree removal, which I'm sure you know from yours that it's not the mechanism if that's what you are seeking.

Outside of critical areas (which are relatively small portions of your property), tree removal - no development - is limited to 2 per 12 months, with the addition of hazard and nuisance trees. I haven't read your arborist report but would guess that maybe none of the trees in those areas fit the criteria, possibly another reason for your permit denial. Kelly is correct in that the rules for tree removal with development are different. So as your project moves forward, tree removal removal/retention will be a part of the review and approval of your building permit.

I understand the assumption that you'd be able to simply remove trees preemptively for development, but not in Kirkland - the tree code here is focused on slowing the loss of tree canopy. The discussion at last night's Planning Commission meeting pertains to developers removing trees under the 2-per/12 months allowance right before submitting their development permit just to avoid tree retention. You didn't mention last night if you had, but from what I can tell, removal of the "2 per" is the extent of allowable tree removal until you're farther along in the development process. The discussion about early review of tree plans pertains to short plats and subdivisions.

I would encourage you to contact Kelly directly or a Planner if you feel I haven't addressed your questions completely. Planners are extremely helpful with determining development potential of specific sites, which may be really helpful for you or your consultant. I hope I helped clarify the intent of Kirkland's tree policy/code.

Take care, and have a great weekend.

Best,

Deb Powers
Urban Forester
ISA Certified Arborist
ISA Tree Risk Assessment Qualified
City of Kirkland Planning & Building Department
p: 425-587-3261
hrs: Mon-Fri 8am-4:30pm

From: Scott Moser [mailto:scott@mosercpas.com]
Sent: Thursday, November 08, 2018 11:51 PM
To: Deborah Powers <DPowers@kirklandwa.gov>
Subject: Tree Removal Permit TRE18-06443

11/8/2018

RE: TRE18-06443

Dear Ms. Powers,

After attending the 11/8 planning commission meeting and reviewing the priorities for revisions to the City tree code, I have a number of questions for you. Several participants pointed out to the commission the lack of clarity in the current code and I noted the difficulty that my consultants have expressed in predicting what constitutes an acceptable tree plan. I requested a tree permit in order to gain clarity and address this issue at an early stage to keep my project on schedule and received the attached response which provided little insight. I was clearly re-buffed with a response of no tress can be removed absent development.

In reviewing the current goals in front of the planning commission, it appears to me that my permit request was not given a proper review. One of the goals of the current revisions state "Limiting tree removals prior to development permit application submittal". This suggests that current code allows for the removal of trees ahead of development yet the attached response suggest the City already has that power! If that is the case, why are you now asking for the power to limit tree removal ahead of development? There is clearly a disconnect here. It seems to me that it is everyone's interest to address the tree retention plan as early as possible to get the best possible result, something the City is also now requesting with current revisions.

https://www.kirklandwa.gov/depart/planning/Code_Updates/Projects/Tree_Code_Updates.htm

As noted during the planning meeting, there in fact is a process for removing tress now on my property that could have been addressed in response to my permit request. The lack of helpful consideration in the response from the city serves to extend the time and cost of development for my project and it's not at all clear to what purpose this serves. The current tree code revisions now propose that the tree requirements be addressed earlier in the development process. Yet you have elected to defer early consideration of the trees on my project.

I look forward to your response.

Scott Moser, CPA/PFS, MST
Moser Wealth Advisors, LLC
2135 112th Avenue N.E., #100
Bellevue, WA 98004
(425) 818-9400 Fax (425) 818-9440
MoserCPAS.com

Attachment 5

Update #	KZC 95.__	Subsection	POTENTIAL KZC 95 CODE AMENDMENTS with NO/MINOR POLICY IMPACT*	Policy Level	Agree with Approach?
1	21	2	~~Add 'per ANSI standard...'~~ added 'topping' definition per ANSI standard to 95.10	None	yes
2	23	2	Add to end of sentence '...without permission.'	None	yes
3	23	3	Clarify "notification" in 3, 5 rather than repeating 2x	None	yes
4	30	4	Delete 'tree type' replace with 'Identify by tree species and/or common name.' Confusing - applicants think they need to type tree by retention value	None	yes
5	30	4	Clarify requirements between 2-5 for LOD, CRZ, fence location, tree protection zone, etc.	None	yes
6	30	4	Add language on project sequencing, IDPs. Include landscaping/other activity within CRZ	None	yes
7	50	5	Typo - revise 1st sentence to read: 'plants listed in the Kirkland Prohibited Plant list shall not be planted in required landscaping areas.	None	yes
8	51	1	~~Revise last sentence for consistency with 95.21 (ROW tree maintenance responsibilities, adjacent property owners)~~	None	n/a
9	51	2	Distinguish between a) and b) 3 (housing/development types). ~~Add to b 'part of an IDP'~~	None	yes
10	23		~~Typo in 2nd sentence, "and" should be "or". See Susan's email of 10/31/14~~	~~Minor~~	n/a
11	10	14	Multiple trunk tree measurement - codify?	Minor	yes
12	5	2	Add 'manage trees and other vegetation consistent with industry standards' (ISA, ANSI, etc.)	Minor	yes
13	10	9	Clarify tree protection definitions per ISA/ANSI standards	Minor	yes
14	10	12	Replace 'TRACE' with 'TRAQ' for qualified professional standards	Minor	yes
15	10		Add topping definition per ISA/ANSI standards	Minor	yes
16	23	5	~~Add 'Holmes Point Overlay Zone' after shoreline jurisdiction and critical areas~~	Minor	n/a
17	23	5	Revise 'is not obvious' to 'is evident in a photograph'	Minor	yes
18	23	5	Delete 'street,' replace with 'public' trees, add '...including streets, Parks...'	Minor	yes
19	30	1	3rd paragraph - clarify minimum tree density is in addition to High Retention Value trees	Minor	yes
20	30	3	~~Include lot line adjustments and applicable rezone process~~	Minor	yes
21	30	5	~~Under "Req'ments in KZC..." 1st row inconsistent with 95.30.4a(1) - address in either section~~	Minor	yes
22	30	5	Clarify IDP vs. phased review modifications if not addressed by Sean's code revision	Minor	yes
23	32		Revise 1st paragraph, 1st sentence to incentivize applicants	Minor	yes
24	33	4	Remove Arborvitae (LID/O-4547 added Thuja/Arborvitae to code, which was inconsistent with department practice). See e-mail "Arborvitae...", PC 8/9/18	Minor	yes
25	34		1st paragraph - reference ISA/ANSI standards for tree protection during development activity	Minor	yes
26	34	2	Revise LOD/critical root zone for consistency in 1 and 2	Minor	yes
27	34	3	Revise LOD/critical root zone for consistency in a-d	Minor	yes

28	40	2	Add at end of last sentence '...with preference to native vegetation species'.	Minor	yes
29	41	2	~~Add '...with preference to native vegetation species.~~' Add to last sentence 'i.e. mulch'	Minor	yes
30	51	5	Reference Prohibited Plant List, King County and WA Weed Agencies. Per GKP, add 'remove ivy'	Minor	yes
31	52		Revise 1st sentence to '...listed on the Kirkland Prohibited Plant List shall not be...'	Minor	yes
32			Simplify or rename 'tree density credits'/point system so it's not as confusing	Minor	unsure
33	50	5	Delete 'Natural Resource Management Team', replace with 'on the PBD webpage'. Add language to encourage species diversity by planting other than listed with Planning Official approval.	Minor	yes
34	30	6	Clearly specify IDP areas for tree retention (i.e.: "building envelope") MB 8/23/18	Minor	unsure
35	23	3	Clarify public and street tree removal requirements HCC 8/27/18	Minor	yes
36	30		Update to reflect current types of housing HCC 8/27/18	Minor	yes
37	50	5	Add language to avoid planting large trees under/within proximity to overhead utilities	Minor	yes
39	30	6	IDP modifications explanation (addressed with Minor Code Amendment #34	Minor	yes
50	20	1	First sentence add "...without previously obtaining a permit." Revise section for clarity/simplicity	Minor	yes
51	21	1	Address inconsistency with KMC 1.12. Add "within reason" and "allows" language. (Define) minor pruning OK for adjacent property owners	Minor	yes

~~Lined out entries~~ - were addressed by the Planning & Building Department under previously-completed minor code amendments

**No Impact* - amendments that clarify or further define something already in the code, address redundancies and typos, or involve reformatting or removal of outdated references. They do not change the meaning of the code.

Minor Impact - amendments resulting from updates to Best Available Science, Best Management Practices, industry standards, etc. that do not result in changes to code intent or an increase in requirements.

Moderate Impact - relatively uncontroversial restructuring of code sections, and any of the above that result in new, increased or eliminated requirements.

Major Impact - substantially prohibit/ban or add new requirements to what's currently allowed. These may result in significant changes to procedures, additional cost to permit applicants or change the intent of the code.

Potential Code Amendments with No/Minor Policy Impact - only relevant code sections are shown below:

95.05.2 (h)

2. Tree and vegetation removal in urban areas has resulted in the loss to the public of these beneficial functions. The purpose of this chapter is to establish a process and standards to provide for the protection, preservation, replacement, proper maintenance, and use of significant trees, associated vegetation, and woodlands located in the City of Kirkland.

The intent of this chapter is to:

h. Manage trees and other vegetation in a manner consistent with the City's Urban Forest Strategic ~~Natural Resource~~ Management Plan and industry standards and best management practices established by the International Society of Arboriculture (ISA) and the American National Standards Institute (ANSI).

i. Preserve and protect street trees, trees in public parks and trees on other City property.

95.10 Definitions

The following definitions shall apply throughout this chapter unless the context clearly indicates otherwise. Definitions that apply throughout this code are also located in Chapter 5 KZC.

1. Caliper – The industry~~American Association of Nurserymen~~ standard for trunk measurement of nursery stock, applicable to supplemental required trees. Caliper ~~of the trunk~~ shall be ~~the trunk diameter~~ measured six (6) inches above the ground for up to and including 4-inch caliper trunk sizes~~ and 12 inches above the ground for larger sizes~~.

2. Critical Root Zone – The area extending ~~surrounding a tree at a distance from the trunk, which is equal to~~ one (1) foot beyond the trunk for every inch of DBH per the International Society of Arboriculture standard. Example: a 24-inch DBH tree has a 24-foot Critical Root Zone.~~trunk diameter measured at 4.5 feet from grade or otherwise determined by a qualified professional (example: one (1) foot radius per one (1) inch DBH).~~

9. Limit of Disturbance – The boundary between the Tree Protection Zone ~~protected area around a tree~~ and the allowable site disturbance as determined by a qualified professional, measured in feet from the trunk. Limit of Disturbance denotes the location of tree protection fencing.

12. Qualified Professional – An individual with relevant education and training in arboriculture or urban forestry, having two (2) or more of the following credentials:

- International Society of Arboriculture (ISA) Certified Arborist;
- Tree Risk Assessor Qualification~~Certification~~ (TRAQ~~CE~~) as established by the ~~Pacific Northwest Chapter of~~ ISA (or equivalent);
- American Society of Consulting Arborists (ASCA) registered Consulting Arborist;
- Society of American Foresters (SAF) Certified Forester for Forest Management Plans;

For tree retention associated with a development permit, a qualified professional must have, in addition to the above credentials, a minimum of three (3) years' experience working directly with the protection of trees during construction and have experience with the likelihood of tree survival after construction. A qualified professional must also be able to prescribe appropriate measures for the preservation of trees during land development.

14. Significant Tree – A tree that is at least six (6) inches in diameter at breast height (DBH) as measured at 4.5 feet from the ground. Trees with multiple trunks shall be measured per the industry standard outlined in the Guide for Plant Appraisal 10th Edition, Council of Tree and Landscape Appraisers.

xx. Topping – The reduction of a tree's size using heading cuts that shorten limbs or branches back to a predetermined crown limit. Topping is not an acceptable pruning practice and is not appropriate on established trees.

xx. Tree Protection Zone (TPZ) is an arborist-defined area surrounding a tree trunk intended to protect individual trees, groups of trees, vegetation, roots and soil from construction-related activities. Determining TPZ size may include Critical Root Zone, dripline, or root plate diameter methodologies or exploratory root excavations.

95.21 Tree Pruning

2. Tree Pruning on Private Property. A permit is not required to prune trees on private property. Topping or ~~P~~pruning which results in the removal of at least half of the live crown will be considered tree removal and subject to the provisions in KZC 95.23.

95.23 Tree Removal – Not Associated with Development Activity

1. Introduction. Tree and vegetation removal in urban areas has resulted in the loss of beneficial functions provided by trees to the public. The majority of tree canopy within the City of Kirkland is on private property. The purpose of this section is to establish a process and standards to slow the loss of tree canopy on private property, contributing towards the City's canopy goals and a more sustainable urban forest.

2. Permit Required for Removal of Trees on Private Property and~~or~~ City Right-of-Way. It is unlawful for any person (other than City crews) to remove, prune, trim, modify, alter or damage a tree in a public park or on any other City property without permission.

   No person, directly or indirectly, shall remove any significant tree on any private property within the City, or any public tree in parks and in the public right-of-way, without first obtaining a tree removal permit as provided in this chapter, unless the activity is exempted in KZC 95.20 or subsection (5) of this section.

3. Tree Removal Permit Application Form. The applicable City ~~Planning and Building Department and Public Works~~ Department shall establish and maintain a tree removal permit application form. The form shall be used for ~~to allow~~ property owners to request City review of tree removal for compliance with applicable City regulations. The tree removal application form shall include at a minimum the following:

5. Tree Removal Allowances.

   a. Except in the Holmes Point Overlay zone, any private property owner of developed property may remove up to two (2) significant trees from their property within a 12-month period without having to apply for a tree removal permit; provided, that:

      1) There is no active application for development activity for the site;

      2) The trees were not required to be retained or planted as a condition of previous development activity; and

      3) All of the additional standards for tree removal and tree removal permits as described in subsections (5)(b) through (e) of this section are met.

      The Planning and Building Department shall establish and maintain a tree removal notification ~~request~~ form. The form may be used by property owners to request Department review of tree removal for compliance with applicable City regulations and to notify the Department of allowable tree removal.

   d. Removal of Hazard or Nuisance Trees. Any private property owner seeking to remove any number of significant trees which are a hazard or nuisance from developed or undeveloped property or the public right-of-way shall first obtain approval of a tree removal permit and meet the requirements of this subsection.

1) Tree Risk Assessment. If the nuisance or hazard condition is not evident in a photograph~~obvious~~, a tree risk assessment prepared by a qualified professional explaining how the tree(s) meet the definition of a nuisance or hazard tree is required. Removal of nuisance or hazard trees does not count toward the tree removal limit if the nuisance or hazard is supported by a report prepared by a qualified professional and approved by the City.

2) Trees in Critical Areas or Critical Areas Buffers. See Chapter 90 KZC.

3) The removal of any tree in the Holmes Point Overlay Zone requires the planting of a native tree of a minimum of six (6) feet in height in close proximity to where the removed tree was located. Selection of native species and timing of installation shall be approved by the Planning Official.

~~4~~) Public~~Street~~ Trees. Public~~Street~~ trees may only be removed if determined to be a hazard or nuisance. If the removal request is for public~~street~~ trees, including trees in rights of way, parks and other City facilities, the appropriate Department ~~Public Works~~ Official may consider whether the tree(s) are now, or may be in the future, part of the City's plans for the right-of-way or other capital projects. The City shall require a one-for-one tree replacement in a suitable location.

95.30 Tree Retention Associated with Development Activity

1. Introduction. The City's objective is to retain as many viable trees as possible on a developing site while still allowing the development proposal to move forward in a timely manner. To that end, the City requires approval of a tree retention plan in conjunction with all development permits resulting in site disturbance and for any tree removal on developed sites not exempted by KZC 95.20. This section includes provisions that allow development standards to be modified in order to retain viable significant trees.

A minimum tree density approach is being used in combination with priorities for retention to retain as many viable trees as possible with new development activity. The requirement to meet a minimum tree density applies to new single-family homes, cottages, carriage units, two/three-unit homes, and new residential subdivisions and short subdivisions. If such a site falls below the minimum density with existing trees, supplemental planting is required. A tree density for existing trees to be retained is calculated to see if new trees are required in order to meet the minimum density for the entire site. Supplemental tree location priority is set as well as minimum size of supplemental trees to meet the required tree density.

Priorities for retention are assessed in subsection 3 of this section and in KZC 95.10, Definitions. The importance of effective protection of retained trees during construction is emphasized with specific protection standards in the last part of this section. These standards must be adhered to and included on demolition, grading and building plans as necessary.

4. Tree Retention Plan Components. The tree retention plan shall contain the following information as specified in the chart in subsection (5) of this section, unless waived by the Planning Official:

a. A tree inventory with ~~containing~~ the following:

~~1~~) A numbering system of all existing significant trees on the subject property (~~with~~ corresponding to tags on trees).~~:~~ T~~t~~he inventory must also include significant trees on adjacent properties~~y~~ that appear to have ~~with~~ Critical Root Zones (CRZ)~~driplines~~ extending onto~~over~~ the subject property line;

2) The distance in feet for Critical Root Zones (CRZ) and proposed Limits of D~~d~~isturbance (LOD) of all existing significant trees (including approximate distance in feet for CRZ and LOD of off-site trees with ~~overhanging~~ CRZs extending onto the subject property ~~driplines)~~;

3) Size (DBH);

4) Proposed tree status (trees to be removed or retained);

5) Brief general health or condition rating of these trees (i.e.: poor, fair, good, excellent, etc.);

6) Tree ~~type or~~ species and/or common name.

b. A site plan showing~~depicting~~ the following:

2) Accurate location of significant trees on the subject property (surveyed locations may be required). The site plan must also show~~include~~ the approximate trunk location ~~and critical root zone~~ of significant trees that are on adjacent propert~~y~~ies with CRZs~~driplines~~ extending over the subject property line;

3) Trees labeled corresponding to the tree inventory numbering system;

~~4) Location of tree protection measures;~~

5) Indicate the proposed L~~l~~imits of D~~d~~isturbance and the Critical Root Zone drawn to scale around all trees potentially impacted by site disturbances resulting from grading, demolition, or construction activities (including approximate LOD of off-site trees with CRZs extending over property lines~~overhanging driplines~~);

6) Trees P~~p~~roposed ~~tree status (trees~~ to be removed~~, or retained)~~ noted by an 'X' or by ghosting out;

7) Proposed locations of any existing or supplemental trees ~~and any~~ required ~~trees in order~~ to meet tree density or minimum number of trees as outlined in KZC 95.33.

c. An arborist report to include ~~containing~~ the following:

1) A complete description of each tree's health, condition, and viability (including off-site trees that may be potentially impacted by site disturbances);

2) A description of the method(s) used to determine the L~~l~~imits of D~~d~~isturbance (i.e., C~~c~~ritical R~~r~~oot Z~~z~~one formula, root plate diameter, exploratory root excavations or a case-by-case basis description for individual trees);

3) Any special instructions specifically outlining any work proposed within the Critical Root Zone~~limits of the disturbance protection area~~ (i.e., hand-digging, tunneling, root pruning, any grade changes, clearing, monitoring, and aftercare);

4) For trees not viable for retention, a description of the reason(s) for removal based on poor health, high risk of failure due to structure, defects, unavoidable isolation (wind firmness), or unsuitability of species, etc., and for which no reasonable alternative action is possible must be given (pruning, cabling, etc.);

5) Describe the impact of necessary tree removal to the remaining trees, including those in a grove or on adjacent properties;

6) For development applications, a description~~discussion~~ of project sequencing related to the timing and installation of tree protection measures, including landscaping and other activity within the Critical Root Zone of retained trees that must include fencing and be in accordance with the tree protection standards as outlined in KZC 95.34; and

5. Tree Retention Plan. The applicant shall submit a Tree Retention Plan that includes the components identified in the following chart based on the proposed development activity.

TREE RETENTION PLAN

Development Activity / Required Components	Minor (1)(3) – Single-Family, or two attached, detached, or stacked dwelling units, and related demolition and land surface modification applications	Major (2)(3) Single-Family, or two attached, detached, or stacked dwelling units, and related demolition and land surface modification applications	Multifamily, Commercial, any other use other than residential, and related demolition and land surface modification applications	Short Plat, Subdivisions, cottages, carriage units, two/three-unit homes, and related demolition and land surface modification applications (see KZC 95.30(6)(a), Phased Review, for additional standards)
TREE INVENTORY AS DESCRIBED IN KZC 95.30(4)(a) FOR:				
All significant trees on the subject property		X	X	X
Significant trees potentially impacted by proposed development activity	X			
SITE PLAN AS DESCRIBED IN KZC 95.30(4)(b) TO INCLUDE:				
Surveyed tree locations if required by the Planning Official		X	X	
Surveyed tree locations				X
A final landscape plan showing retained trees			X	
REQUIREMENTS IN KZC 95.30(4)(c) SHALL BE PREPARED BY A QUALIFIED PROFESSIONAL AND APPLY TO:				
Significant trees within required yards or within 10 feet of any side property line		X		
Significant trees potentially impacted by proposed development activity as determined by the Planning Official			X	
Proposed removal of trees with a high retention value in required landscaping areas			X	
All significant trees				X
TREE RETENTION STANDARDS				
Applicant is encouraged to retain viable trees	X(4)			

Development Activity Required Components	Minor (1)(3) – Single-Family, or two attached, detached, or stacked dwelling units, and related demolition and land surface modification applications	Major (2)(3) Single-Family, or two attached, detached, or stacked dwelling units, and related demolition and land surface modification applications	Multifamily, Commercial, any other use other than residential, and related demolition and land surface modification applications	Short Plat, Subdivisions, cottages, carriage units, two/three-unit homes, and related demolition and land surface modification applications (see KZC 95.30(6)(a), Phased Review, for additional standards)
Retain and protect trees with a high retention value to the maximum extent possible		X(4)	X(4)	X(4)
Retain and protect trees with a moderate retention value if feasible		X	X	X
Preservation and maintenance agreements pursuant to KZC 95.51 are required for all remaining trees on the subject property	X	X	X	X(5)
TREE DENSITY				
Tree density requirements shall apply as required in KZC 95.33		X		X
A minimum of two trees must be on the lot following the requirement set forth in KZC 95.33(4)	X			
LANDSCAPING PER ZONING/LAND USE				
Preserved trees in required landscaping areas shall apply toward required landscaping requirements			X	

6. Additional Tree Retention Plan Standards for Short Plats and Subdivisions.

a. Phased Review.

~~1~~) If the location of all proposed improvements, including the building footprint, utilities, and access was not established ~~during the short plat or subdivision review process the location of all proposed improvements, including the building footprint, utilities, and access, was not able to be established~~, the applicant may submit a Tree Retention Plan that addresses trees only affected by the ~~known~~ improvements known at the time of application. Proposed t~~T~~ree removal shall be limited to those affected areas.

2) A new Tree Retention Plan shall be required at each subsequent phase of the project as more information about the location of the proposed improvements is known subject to all of the requirements in this section.

3) Phased review of Tree Retention Plans is not permitted in the Holmes Point Overlay zone. In the HPO zone, subdivision or short plat applications shall provide a comprehensive review of Tree Retention Plans as outlined in subsections (2) through (5) of this section.

4) Modifications. A Tree Retention Plan modification request for Phased Review shall contain information as determined by the Planning Official based on the requirements in subsection (5) of this section, Tree Retention Plan. The fee for processing a modification request shall be established by City ordinance.

~~b~~. Integrated Development Review.~~Modifications to Tree Retention Plan for Short Plats and Subdivisions. A Tree Retention Plan modification request shall contain information as determined by the Planning Official based on the requirements in subsection (5) of this section, Tree Retention Plan. The fee for processing a modification request shall be established by City ordinance.~~

1) ~~For~~ Tree Retention Plans ~~approved during the short plat or subdivision review process that~~ establishing~~ed~~ the location of all proposed improvements, including the building footprint, utilities, and access with an approved short plat or subdivision review process allow tree removal to occur throughout the site.~~, a modification to the Tree Retention Plan may be approved as follows:~~

2~~1~~) Modification – General. The Planning Official may approve minor modifications to the approved Integrated Development Review Tree Retention Plan in which the minimum tree density credits associated with trees identified for retention are not decreased.

2~~2~~) Modification Prior to Tree Removal. The Planning Official may approve a modification request to the approved Integrated Development Review Tree Retention Plan to decrease the minimum number of tree density credits associated with trees previously identified for retention if:

a) Trees inventoried in the original Tree Retention Plan have not yet been removed; and

b) The Planning Official shall not approve or deny a modification pursuant to this section without first providing notice of the modification request consistent with the noticing requirements for the short plat.

4~~3~~) Modification after Tree Removal. A modification request is required to decrease the minimum number of tree density credits associated with trees previously identified for retention after which trees inventoried in the original Integrated Development Review Tree Retention Plan have already been removed. Such a request may be approved by the Hearing Examiner only if the following are met:

95.32 ~~Incentives and~~ Variations to Development Standards and Incentives to Retain Trees

Applicants are encouraged to ~~In order to retain trees, the applicant should~~ pursue provisions in Kirkland's codes that allow development standards to be modified to retain trees. Examples include but are not limited to number of parking stalls, right-of-way improvements, lot size reduction under Chapter 22.28 KMC, lot line placement when subdividing property under KMC Title 22, Planned Unit Developments, and required landscaping, including buffers for lands use and parking/driving areas.

95.33 Tree Density Requirement

The required minimum tree density is 30 tree credits per acre for single-family homes, cottages, carriage units, two/three-unit homes, short plats, and/or subdivisions and associated demolition and land surface modification. For individual lots in a short subdivision or subdivision with an approved Tree Retention Plan, the tree density shall be calculated for each lot within the short plat or subdivision. The tree density shall~~may~~ consist of existing trees pursuant to the tree's retention value, supplemental trees or a combination of existing and supplemental trees pursuant to subsection (2) of this section. Existing trees transplanted to an area on the same site shall not count toward the required density unless approved by the Urban Forester based on transplant specifications provided by a qualified professional that will ensure a good probability for survival.

4. Minimum Size and Tree Density Value for Supplemental Trees. The required minimum size of the supplemental tree worth one (1) tree credit shall be ~~six (6) feet tall for Thuja/Arborvitae or~~ four (4) feet tall for native or other conifers and 2-inch caliper for deciduous or broad-leaf evergreen tree. Additional credits may be awarded for larger supplemental trees. The installation and maintenance shall be pursuant to KZC 95.50 and 95.51 respectively.

95.34 Tree and Soil Protection during Development Activity

Prior to development activity or initiating tree removal on the site, vegetated areas, individual trees and soil to be preserved shall be protected from potentially damaging activities per ISA and ANSI standards for tree protection during development activity as follows:~~pursuant to the following standards:~~

1. Placing Materials near Trees. No person may conduct any activity within the protected area of any tree designated to remain, including, but not limited to, operating or parking equipment, placing solvents, storing building material or stockpiling any materials, or dumping concrete washout or other chemicals. During construction, no person shall attach any object to any tree designated for protection.

2. Tree Protection Fence~~Protective Barrier~~. Before development, land clearing, filling or any land alteration, the applicant shall:

   a. Erect and maintain immovable, readily visible temporary protective tree fencing at ~~along~~ the L~~l~~imits of D~~d~~isturbance which completely surrounds the protected area of all retained trees, groups of trees, vegetation and native soil. Fences shall be constructed of chain link and be at least six (6) feet high, unless other type of fencing is authorized by the Planning Official.

   b. Install highly visible signs spaced no further than 15 feet along the entirety of the Tree Protection Fence~~protective tree fence~~. Said signs must be approved by the Planning Official and shall state at a minimum “Tree and Soil Protection Area, Entrance Prohibited” and provide the City phone number for code enforcement to report violations.

   c. Prohibit excavation or compaction of soil or other potentially damaging activities within the fence: ~~barriers;~~ provided, that the Planning Official may allow such activities approved by a qualified professional and under the supervision of a qualified professional retained and paid for by the applicant.

   d. Maintain the Tree Protection Fence~~protective barriers~~ in place for the duration of the project until the Planning Official authorizes their removal.

   e. Ensure that any approved landscaping done in the protected zone subsequent to the removal of the barriers shall be accomplished with machinery from outside the protected zone or by hand.

   f. In addition to the above, the Planning Official may require the following:

      1) If equipment is authorized to operate within the Tree Protection ~~protected z~~Zone, the soil and C~~c~~ritical R~~r~~oot Z~~z~~one of a tree must be covered with mulch to a depth of at least six (6) inches or with plywood, steel plates or similar material in order to protect roots and soil from damage caused by heavy equipment.

      2) Minimize root damage by hand-excavating a 2-foot-deep trench, at edge of C~~c~~ritical R~~r~~oot Z~~z~~one, to cleanly sever the roots of trees to be retained. Never rip or shred roots with heavy equipment.

3. Grade.

   a. The grade shall not be elevated or reduced within the critical root zone of trees to be preserved without the Planning Official’s authorization based on recommendations from a qualified professional. The Planning Official may allow coverage of up to one-half (1/2) of the area of the tree’s C~~c~~ritical R~~r~~oot Z~~z~~one with light soils (no clay) to the minimum depth necessary to carry out grading or landscaping plans, if it will not imperil the survival of the tree. Aeration devices may be required to ensure the tree’s survival.

   b. If the grade adjacent to a preserved tree is raised such that it could slough or erode into the tree’s C~~c~~ritical R~~r~~oot Z~~z~~one, it shall be permanently stabilized to prevent soil erosion and suffocation of the roots.

95.40 Required Landscaping per Zoning

1. User Guide. Chapters 15 through 56 KZC containing the use zone or development standards tables assign a landscaping category to each use in each zone. This category is either “A,” “B,” “C,” “D,” or “E.” If you do not know which landscaping category applies to the subject property, you should consult the appropriate use zone or development standards tables.

95.41 Supplemental Plantings per Zoning Requirements

2. Standards. The applicant shall provide the following at a minimum:

   a. Living plant material which will cover 80 percent of the area to be landscaped within two (2) years. If the material to be used does not spread over time, the applicant shall re-plant the entire area involved immediately. Any area that will not be covered with living plant material must be covered with nonliving groundcover, i.e.: mulch. Preference is given to using native plant species. See Kirkland Native Tree/Plant Lists.

   b. One (1) tree for each 1,000 square feet of area to be landscaped. At the time of planting, deciduous trees must be at least two (2) inches in caliper and coniferous trees must be at least five (5) feet in height, with preference to native vegetation species.

95.42 ~~Minimum~~ Zoning & Land Use Buffer Requirements

The applicant shall comply with the provisions specified in the following chart and with all other applicable provisions of this chapter. Land use buffer requirements may apply to the subject property, depending on what permitted use exists on the adjoining property or, if no permitted use exists, depending on the zone that the adjoining property is in.

95.46 Modifications to Zoning/Land Use Landscaping Standards

1. Modification to Land Use Buffer Requirements. The applicant may request a modification of the requirements of the buffering standards in KZC 95.42. The Planning Official may approve a modification if:

95.47 Nonconforming Zoning/Land Use Landscaping and Buffers

1. The landscaping requirements of KZC 95.41, Supplemental Plantings, KZC 95.43 Outdoor Use, Activity and Storage, KZC 95.44, Internal Parking Lot Landscaping, and KZC 95.45, Perimeter Landscape Buffering for Driving and Parking Areas, must be brought into conformance as much as is feasible, based on available land area, in either of the following situations:

95.50 Installation Standards for Required Plantings

All required trees, landscaping and soil shall be installed according to sound horticultural practices in a manner designed to encourage quick establishment and healthy plant growth. All required landscaping shall be installed in the ground and not in above-ground containers, except for landscaping required on the top floor of a structure.

5. Plant Selection.

   a. Plant selection shall be consistent with the appropriate Kirkland Plant Lists, which are shown on the Planning Department webpage~~is produced by the City's Natural Resource Management Team~~ and available in the Planning and Building Department. Species diversity is encouraged by planting species other than those listed, with Planning Official approval.

   b. Plants shall be selected and sited to produce a hardy and drought-resistant landscape area. Selection shall consider soil type and depth, the amount of maintenance required, spacing, exposure to sun and wind, the slope and contours of the site, and compatibility with existing native vegetation preserved on the site. Preservation of existing vegetation is strongly encouraged. Planting large trees under/within proximity to overhead utilities shall be avoided.

   c. ~~Prohibited Materials.~~ Plants listed ~~as prohibited~~ in the Kirkland Prohibited Plant List shall not be planted ~~are prohibited~~ in required landscape areas. Additionally, there are other plants that may not be used if identified in the Kirkland Plant List as potentially damaging to sidewalks, roads, underground utilities, drainage improvements, foundations, or when not provided with enough growing space.

95.51 Tree and Landscape Maintenance Requirements per Land Use/Zoning

The following maintenance requirements apply to all trees~~including street trees,~~ and other vegetation required to be planted or preserved by the City:

1. Responsibility for Regular Maintenance. Required trees and vegetation, fences, walls, and other landscape elements shall be considered as elements of the project in the same manner as parking, building materials, and other site details. The applicant, landowner, or successors in interest shall be responsible for the regular maintenance of required landscaping elements.~~ Plants that die must be replaced in kind~~. It is also the responsibility of the property owner to maintain street trees abutting their property pursuant to KZC 95.21.

2. Maintenance Duration. Maintenance shall be ensured in the following manner except as set forth in subsections (3), (4) and (5) of this section:

   a. Commercial, Industrial and Multifamily Development. All required landscaping shall be maintained throughout the life of the development. Plants that die must be replaced in kind. Prior to final inspection/issuance of a certificate of occupancy, the proponent shall provide a final as-built landscape plan and an agreement to maintain and replace all landscaping that is required by the City.

   b. Single Family Residential Development. Any existing tree or other existing vegetation designated for preservation in a tree retention plan shall be maintained for a period of five (5) years following issuance of the certificate of occupancy for the individual lot or development. After five (5) years, all trees on the property are subject to KZC 95.23 unless:

      1) The tree and associated vegetation are in a grove that is protected pursuant to subsection (3) of this section; or

      2) The tree or vegetation is considered to be a public benefit related to approval of a P~~p~~lanned U~~u~~nit D~~d~~evelopment; or

      3) The tree or vegetation was retained to partially or fully meet requirements of KZC 95.40 through 95.45, R~~r~~equired L~~l~~andscaping per Zoning.

3. Maintenance of Preserved Grove. Any applicant who has a grove of trees identified for preservation on an approved Tree Retention Plan pursuant to KZC 95.30(2) shall provide prior to occupancy the legal instrument acceptable to the City to ensure preservation of the grove and associated vegetation in perpetuity, except that the agreement may be extinguished if the Planning Official determines that preservation is no longer appropriate.

4. Maintenance in Holmes Point Overlay Zone. Vegetation in designated Protected Natural Areas in the Holmes Point Overlay Zone is to be protected in perpetuity pursuant to KZC 70.15(8)(a). Significant trees in the remainder of the lot shall be protected in perpetuity pursuant to KZC 70.15(8)(b).

5. Nonnative Invasive and Noxious Plants. It is the responsibility of the property owner to remove nonnative invasive plants and noxious plants per the City's Prohibited Plant List, King County and Washington Weed Agencies from the vicinity of any tree or other vegetation that the City has required to be planted or protected. Removal must be performed in a manner that is not injurious to~~will not harm the tree or other vegetation that the~~ City-~~ has~~ required trees and vegetation.~~to be planted or protected~~.

6. Landscape Plans and Utility Plans. Landscape plans and utility plans shall be coordinated. In general, the placement of trees and large shrubs should adjust to the location of required utility routes both above and below ground. Location of plants shall be based on the plant's mature size both above and below ground. See the Kirkland Plant List for additional standards.

95.52 Prohibited Vegetation

Plants listed ~~as prohibited~~ in the Kirkland Prohibited Plant List shall not be planted in the City or required to be retained.

Update #	KZC 95.__	Subsection	POTENTIAL KZC 95 CODE AMENDMENTS with MODERATE/MAJOR POLICY IMPACT*	Policy Level	Agree with Approach or Staff Rec?
Definitions					
47	10	12	Add ISA Municipal Specialist Certification to credentials	Moderate	yes
48	10	7	Define 'Hazard' consistent with TRAQ standards/course of action	Moderate	yes
Tree Removal Allowances					
53	23	5	Adjust tree removal allowance in proportion to varying lot sizes - PC 7/12/18	Moderate	yes
67			Allow removal of hedges (trees >6” DBH) with replacement, no hedge height regs - PC 8/9/18	Major	yes
76			Address hazard/nuisance tree removal resulting from contagious pests/diseases - CAO	Major	yes
38	30		Add language to prevent tree girdling (see #56, #58)	Moderate	yes
56	23		Prevent tree girdling/removals that occur to avoid ‘High Retention Value’ tree requirements - PC 8/9/18	Moderate	yes
58	23	2	Address tree girdling in 2nd paragraph (see #38, #56)	Major	yes
Landscape Requirements per Zoning (applies to Multifamily, Commercial, etc.)					
44	33	3	Add language regarding appropriate locations for newly-planted trees	Moderate	yes
49	34	5	Add “including aftercare” and include current arboricultural practices	Moderate	yes
62	44		Add language regarding tree retention in parking lots. Coordinate with PW on LID features	Major	yes
74			Promote retention of tree groves, particularly with parking lot design/development - HCC 8/27/18	Major	yes
Tree Retention with Development (applies primarily to short plats, subdivisions and Single Family Residential)					
40	33	1	Limit maximum tree density credits allowed in Table 95.33.1	Moderate	unsure
~~41~~	~~42~~	-	~~Clarify intent of buffer (no issue found, most likely addressed by a previous code amendment~~	~~Moderate~~	n/a
~~42~~	-	-	~~Authority to require tree removal based on species~~ (addressed with prior code update, Prohibited Plant List)	~~Moderate~~	n/a
43	25		Reference Low impact Development (LID), LEED, Green Building Design, etc.	Moderate	yes
45	34	2	Revise tree protection fence requirements - HPO	Moderate	yes
46	34	2	Revise tree protection sign standards and inspection procedures – per HPO	Moderate	yes
~~52~~	~~42~~	~~2~~	~~Replace '10 feet apart' with 20 feet or use street tree list for small-medium trees~~	~~Moderate~~	n/a
54	50	7	List aftercare options such as gator bags, irrigation, soil drenches, etc. PC 8/9/18 (see #49 Minor)	Moderate	yes
55	33	4	Address overuse of arborvitae (allow certain # or % tree credits) - PC 8/9/18	Moderate	unsure
57	50		Specify appropriate locations for trees required to be planted - PC 8/9/18	Moderate	yes

59	23	5	Prevent girdling/tree removal in anticipation of development permit submittal to avoid 'High Retention Value' tree requirement compliance. Add 'intent to develop' language/time period requirement (see #38, #56)	Major	yes
60	30		Streamline tree retention/replanting requirements for greater compliance	Major	yes
61	33	3	Clarify the section on payment in lieu of planting new trees	Major	yes
63	51	3	Clarify the grove definition and maintenance requirements	Major	yes
64	10		Clearly designate trees of merit - HPO, PC 7/12/18	Major	yes
65	10		Require Landscape Architect review of Tree Retention Plans - HPO, PC 7/12/18 (see #44, #57 alternatives)	Major	yes
66			Address poorly located required tree plantings - PC 8/9/18 (same issue as #44 and #57)	Major	yes
68			Incentivize tree species diversity - PC 8/9/18		yes
69	10	13	Revise Low Retention Value tree definition to avoid tree removal loophole - PC 8/9/18 (see #60, #64)	Major	yes
70	30	5.3	Strengthen retention requirements for trees of merit - HPO, PC 8/9/18 (see #60, #64)	Major	unsure
73			Determine tree retention early in SPL/SUB design process (city-wide IDP) - PC 8/9/18	Major	yes
75	30		Use a canopy-based methodology (vs tree credits) for retention/planting requirements - HPO	Major	unsure
77			Increase tree density credit requirements for retention/replanting city-wide - HPO	Major	unsure

Miscellaneous/New					
71			Address renewable energy system conflicts with trees - PC 8/9/18, MB 8/23	?	yes
72	23		Reference tree removal in critical areas – PBD email 10/26/18 (Delete KZC 90.135)	?	yes
79			Clarify how to measure DBH with multi-trunked trees - staff	Minor	yes
80			Address multiple references to City authority	No	yes
81	34		Require permit applicants post a bond instead of the current 5 Year Maintenance Agreement	Major	yes

~~Lined out entries~~ - were addressed by the Planning & Building Department under prior code amendments

**No Impact* - amendments that clarify or further define something already in the code, address redundancies and typos, or involve reformatting or removal of outdated references. They do not change the meaning of the code.

Minor Impact - amendments resulting from updates to Best Available Science, Best Management Practices, industry standards, etc. that do not result in changes to code intent or an increase in requirements.

Moderate Impact - relatively uncontroversial restructuring of code sections, and any of the above that result in new, increased or eliminated requirements.

Major Impact - substantially prohibit/ban or add new requirements to what's currently allowed. These may result in significant changes to procedures, additional cost to permit applicants or change the intent of the code.

Attachment 7

CITY OF KIRKLAND
Planning and Building Department
123 5th Avenue, Kirkland, WA 98033
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MEMORANDUM EXCERPTS

To: Planning Commission

From: Deb Powers, Urban Forester
Adam Weinstein, AICP, Deputy Planning Director
Jeremy McMahan, Planning Manager – Development Services

Date: June 28, 2018

Subject: Introduction to Code Amendments for Kirkland Zoning Code Chapter 95, Tree Management and Required Landscaping
File Number CAM18-00408

PAGES 2-3

What is Canopy Cover?

Put simply, tree canopy cover is the outline of leaf surface seen from above. It is typically expressed in acreage or by percentage in relation to other land cover such as impervious surfaces or land use such as zoning. Information from canopy assessments is used to

- Establish canopy goals
- Prioritize locations for tree planting efforts
- Establish master plans
- Inform code development or updates

When overlaid with other mapping data (census data for example), canopy data can inform social, economic, and ecological policies ranging from stormwater management, environmental equity and public health issues. It's important to note what canopy cover is not. It does not provide a "boots-on-the-ground" detailed level of information. For example, canopy cover data does not inventory tree species or health/condition. It is a 2-dimensional *quantitative* value.

This short video provides a brief overview of canopy cover: what it is and what it's used for. A basic understanding of tree canopy cover is needed to make decisions on whether the City should change its code requirement methodology to a canopy-based system or to make adjustments to code requirements. How the data is collected is relevant to either.

Canopy data is typically obtained using three common methods. See Attachment 4 (below) for a comparison summary, noting that Kirkland utilized the third method, High Resolution Imagery for its 2002, 2010 and 2018 canopy studies (as a clarification, the Kirkland 2011 Urban Tree Canopy Report was based on 2010 imagery).

Some key differences between canopy data-collecting methods are the range in cost, accuracy and the level of complexity involved. The Planning Commission will have an opportunity to discuss tree canopy cover in greater detail at the June 28, 2018 Study Session, particularly in regards to using canopy cover as a tree code requirement metric. The canopy data information presented herein will facilitate that and future discussions.

With the HPO code revision process, the Finn Hill Neighborhood Alliance (FHNA) has suggested that the City use the first method ("iTree") to analyze canopy cover data on a lot-by-lot basis rather than use the City's current tree density credit system to guide tree protection efforts. As shown in Attachment 4 (below), the iTree method of obtaining tree canopy data is more suitable for quick estimations over very large areas. The level of accuracy and imagery quality are not appropriate for parcel-sized analysis, which is evident with online iTree Canopy tool use.

As explained at the May 24, 2018 Planning Commission meeting, the second method using "fly-over" ortho-photography imagery, currently employed by the City of Lake Forest Park, can be problematic when used as a basis for code requirements due to the subjective nature and experience level when each user (homeowner, developer, permit applicant, staff, etc.) delineates canopy cover. For example, it's fairly common for shrubs, meadow grass and sometimes turf to be accidentally included as canopy cover, skewing the canopy cover data.

[Another issue with using ortho-flyovers is that the images are collected in the winter or early spring, during leaf-off conditions so that buildings, roads and other urban features are visible. This adds another element of subjectivity when tracing the branch tips, not canopy outline, of deciduous trees.

Making canopy cover determinations even more complicated, not all trees have symmetrically uniform canopies, so a fair manner of accounting for odd-shaped tree canopies must be determined. For example, Snohomish County requires the radius from the center of the tree to the tip of the shortest branch and the radius from the center of the tree to the tip of the longest branch to be added together and divided by 2 to get the *average canopy cover for each tree*.]

If the canopy data derived from ortho-flyovers is the basis for retention/replanting requirements, an acceptable margin of error needs be defined so that the requirements can be applied in a fair and consistent manner, enforced and in some cases, appealed.

ATTACHMENT 4

From The Sustainable Urban Forest, A Step-by-Step Approach. 2016. Leff, Davey Institute, USDA Forest Service pp 23-25. Note - contributors to this publication include Pacific Northwest regional expertise.

Top-Down: Tree Canopy Assessments

The top-down approach is used to determine the amount and distribution of tree canopy cover, potential planting space, and prioritizing planting needs. As it is aerial-based, it does not obtain data on individual trees, such as species, size, and condition. So the top-down approach is valuable for broad-scale mapping, planning, prioritizing, and monitoring land cover – as well as for providing information about canopy cover on private property – but not as well-suited to assessing ecosystem services of individual trees.

There are three common methods for assessing urban tree canopy cover. While all three will map estimated tree canopy and other cover types in an area, they differ greatly in process, resolution, costs, and accuracy. As a result, there are various advantages and disadvantages to each method, as outlined below, in order of increasing cost and accuracy.

1) **National Land Cover Database (NLCD) satellite imagery –** Free maps and data for entire contiguous 48 states showing estimated percentage of tree canopy and impervious land cover.

   Advantages: The most recent NLCD data (2011) comes pre-loaded into **i-Tree Landscape** (www.itreetools.org/landscape) along with other data layers, including those acquired through Urban Tree Canopy (UTC) Assessments where available and various other base map layers. This allows mapping and planning tree cover distribution based on ecological and socio-economic factors. (For more on **i-Tree Landscape,** see **Part V, Constructing the Community Framework, Tools and Strategies for Engaging the Community**.)

   Disadvantages: Low resolution (30-meter pixels, or segments) cannot detect individual trees. ♦ Available only in the U.S.

   Accuracy: Typically underestimates tree cover in urban areas by approximately 10 percent.

   Cost: None, other than small amount of staff time, if experienced with GIS.

   Recommendation: Useful for cities and broader-scale regional analyses where canopy and land cover data are needed quickly and at little to no cost. ♦ Excellent engagement tool.

2) **Aerial photo interpretation –** Randomly generated points on digital aerial images are interpreted to determine cover type at each point center, resulting in estimates with a known degree of statistical error. Accuracy can be easily increased by sampling more points (see below).

Figure 5. Photo interpretation involves classifying random points within preselected cover classes (e.g., tree, impervious, water).

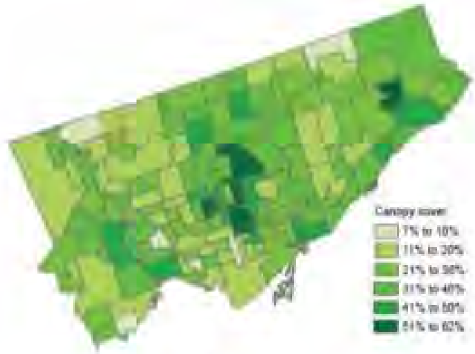


Figure 6. Neighborhood tree cover in Toronto, determined through photo interpretation

Advantages: The **i-Tree Canopy** program (www.itreetools.org/canopy) can be used to photo-interpret a statistically valid sample of cover points anywhere high-quality images are available in Google Maps. (This can also be done manually by GIS-experienced staff using other digital images supplied by municipal or other regional sources.) ♦ Allows quick assessment of land cover types (e.g., tree canopy, available planting space, impervious surfaces) and can produce analyses and maps by defined strata (e.g., neighborhoods, census blocks). ♦ Changes in land cover over time can be assessed by matching paired images from different dates.

Disadvantages: Cannot produce finely detailed maps of cover types, estimate full range of ecosystem services, or summarize data at multiple, finely defined scales. ♦ Available image quality may be poor in some locations.

Accuracy: A sample of 100 points (which can be interpreted in about 1 hour) will yield an estimate with a standard error of about 4.6 percent in an area with 30 percent canopy cover; increasing the sample to 1,000 points would reduce the error to 1.4 percent. ♦ To minimize errors introduced by misclassifying cover types, photo-interpreters must be trained and checked. Leaf-off imagery in particular can be difficult to interpret. ♦ Can also be useful for checking accuracy of other top-down methods.

Cost: Images are generally available for free or at low cost. ♦ Staff time depends on sample size, as noted above.

Recommendation: A good low-cost option for getting an initial top-down perspective on a city's urban forest and tracking change over time. Can be highly accurate, though not very detailed or flexible. Best method to estimate tree cover if you do not need to map it.

3) High-resolution aerial or satellite imagery – Automated techniques extract land cover features from high-resolution imagery (typically less than 1-meter pixels), yielding detailed maps of tree canopy and other cover types in a given area. (Source imagery for the entire United States is available from USDA.)

Figure 7. High-resolution (bottom) vs. 30-m NLCD imagery (top).

Figure 8. High-resolution land cover map.

Advantages: Data can be summarized at a broad range of scales (e.g., parcel to watershed), enabling user to relate tree canopy cover to a host of demographic, planning, and biophysical data. ♦ Among other purposes, can be used to locate and prioritize potentially available spaces to plant trees, and to monitor locations where cover is changing. ♦ Integrates well with GIS.

Disadvantages: Analysis and reporting requires highly trained personnel, specialized image analysis software, and significant time and effort. ♦ Requires additional modeling in order to estimate ecosystem services.

Accuracy: Accuracy varies but is typically 90 percent accurate for tree cover. ♦ Utilizing advanced remote-sensing technology, such as LIDAR (Light Detection and Ranging, or laser radar), and/or making manual corrections can increase the accuracy to over 95 percent.[12] ♦ Unless corrected, map inaccuracies can show false changes in tree cover over time.

Cost: Overall costs vary widely, depending on the size of the study area and the availability and quality of source data. ♦ Citywide assessments by professional consultants can cost anywhere from $5,000 to $60,000 or more.

Recommendation: Best method to map urban tree cover when expertise and financial resources are available; used for various Urban Tree Canopy (UTC) studies. For more information: www.nrs.fs.fed.us/urban/utc/.

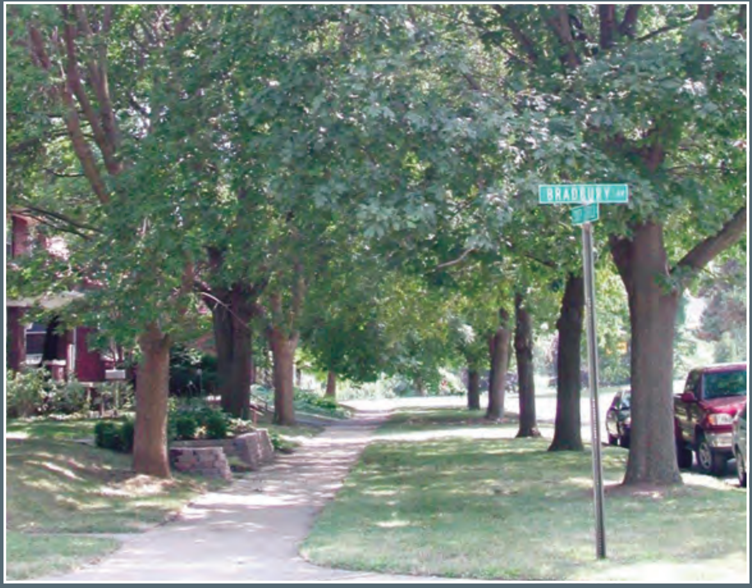
Attachment 8

USDA

United States Department of Agriculture

Urban Tree Database and Allometric Equations

E. Gregory McPherson, Natalie S. van Doorn, and Paula J. Peper



Forest Service

Pacific Southwest Research Station

General Technical Report PSW-GTR-253

October 2016

Authors

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Cover photos: top—Mature street trees frame a view down a residential street in Bismarck, North Dakota. Bottom right—Young street trees shade a sidewalk and parked cars in Glendale, Arizona. Bottom left—Street and front yard trees join to provide continuous shade in this Indianapolis, Indiana, neighborhood. (Photos courtesy of Pacific Southwest Research Station.)

Abstract

McPherson, E. Gregory; van Doorn, Natalie S.; Peper, Paula J. 2016. Urban Tree Database and Allometric Equations. Gen. Tech. Rep. PSW-GTR-235. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 86 p.

Information on urban tree growth underpins models used to calculate the effects of trees on the environment and human well-being. Maximum tree size and other growth data are used by urban forest managers, landscape architects, and planners to select trees most suitable to the amount of growing space, thereby reducing costly future conflicts between trees and infrastructure. Growth data are used to examine relationships between growth and influencing factors such as site conditions and stewardship practices. Despite the importance of tree growth data to the science and practice of urban forestry, our knowledge in this area is scant. Over a period of 14 years, scientists with the U.S. Forest Service Pacific Southwest Research Station recorded data from a consistent set of measurements on over 14,000 trees in 17 U.S. cities. Key information collected for each tree species includes bole and crown size, location, and age. From this Urban Tree Database, 365 sets of tree growth equations were developed for the 171 distinct species. Appendices contain field data collection protocols, foliar biomass data that are fundamental to calculating leaf area, tree biomass equations for carbon storage estimates, and a user guide that illustrates application of the equations to calculate carbon stored over many years for tree species that were measured in multiple cities. An online database at http://dx.doi.org/10.2737/RDS-2016-0005 includes the raw data, growth equations, coefficients, and application information for each species' volume and dry-weight-biomass equations for urban and rural forest trees; and an expanded list of biomass density factors for common urban tree species.

Keywords: Allometry, growth models, predictive equations, tree growth, urban trees.

Contents

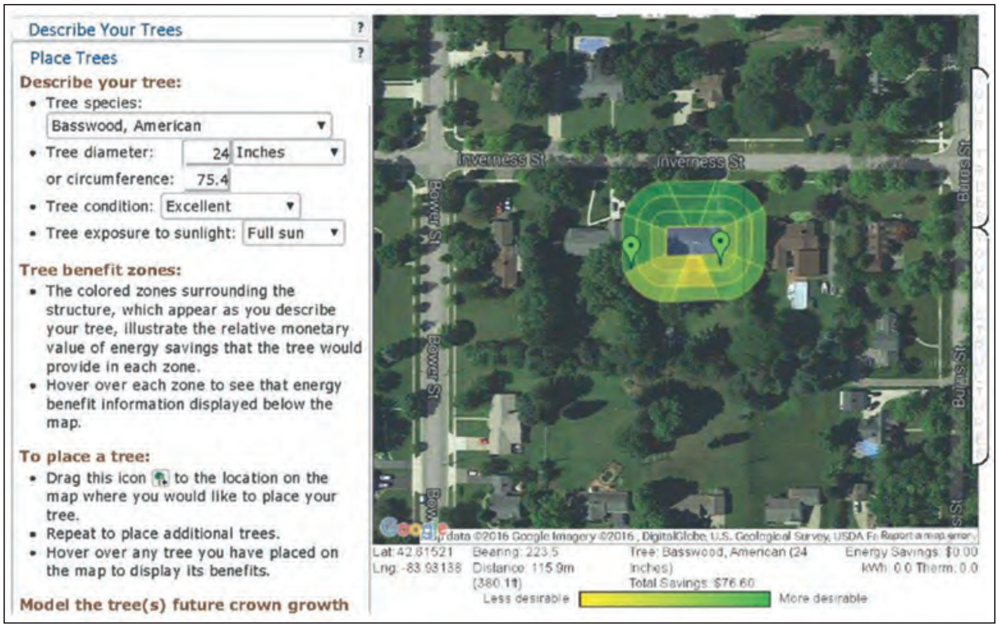
Chapter 1: Introduction

Tree size and age influence management costs and ecosystem services derived from urban trees. Urban forest researchers have developed allometric equations for trees in urban environments, but their range of application and predictive power are limited owing to small sample sizes, few species, young trees only, excellent-condition trees only, and narrow geographic region. This research overcomes many of these limitations. Based on measurements of 14,487 urban street and park trees, an Urban Tree Database (UTD) was constructed. From the UTD, 365 sets of allometric equations were developed for tree species from around the United States. Each "set" consists of eight equations for each of the approximately 20 most abundant species in each of 16 climate regions. Tree age is used to predict species diameter at breast height (d.b.h.), and d.b.h. is used to predict tree height, crown diameter, crown height, and leaf area. Diameter at breast height is also used to predict age. For applications with remote sensing, average crown diameter is used to predict d.b.h. There are 171 distinct species represented within this database. Some species grow in more than one region and tend to grow differently from one region to another owing to environmental and management differences. Thus, there are multiple equations for the same species that reflect those differences, and it is important to select the equation for the appropriate region. The UTD contains foliar biomass data that are fundamental to calculating leaf area, as well as tree biomass equations for carbon storage estimates. Also, a user guide illustrates application of the equations to calculate carbon stored over many years for tree species that were measured in multiple cities. The raw data and equations may be accessed and downloaded at http://dx.doi.org/10.2737/RDS-2016-0005.

Uses of Urban Tree Growth Equations

Information on urban tree growth is indispensable to modeling urban forest function and value. The economic, social, and ecological benefits of trees are directly related to their size, as indicated by leaf area, crown volume, and biomass (Scott et al. 1998, Stoffberg et al. 2010, Xiao et al. 2000a). Growth equations underpin the calculations produced by many computer models used in urban forestry, such as i-Tree, National Tree Benefit Calculator, OpenTreeMap, and ecoSmart Landscapes (fig. 1).

Urban tree growth and size data can assist municipal foresters because the costs for pruning and removing trees tends to increase with tree size (O'Brien et al. 1992). For example, accurate projections of size-related costs for pruning species that require frequent care can improve budgeting. Sanders et al. (2013) noted that managers are hindered in developing tree removal and replacement plans and obtaining public acceptance when they lack empirical data on each species' useful



i-Tree.org

Figure 1—Computer programs such as i-Tree use tree growth equations when calculating annual carbon dioxide sequestration by trees.

service life. Without maximum size end points that are linked to constraints posed by the designed space, it is difficult to plan for phased removal and replacement that minimizes liability and maintains continuous tree canopy cover.

Knowledge of maximum tree size can inform tree selection to avoid conflicts between tree roots and nearby sidewalks or between crowns and utility lines (Randrup et al. 2001). Conversely, field-based predictions of crown projection area at 10, 15, and 20 years after planting can help designers select species to achieve targeted tree canopy cover in parking lots (McPherson 2001). Other examples of design and management issues influenced by tree growth and size include spacing between trees and in relation to building infrastructure, soil volumes required, irrigation demands, and pest-control and fertilization dosages (fig. 2). A better understanding of tree allometry by landscape architects and arborists can potentially reduce management costs, improve functional performance, and increase the benefits derived from healthy and sustainable urban forests (Clark et al. 1997).

Allometric equations that describe the bole and crown growth of different urban tree species can be used to create more realistic animations that compress years of growth into seconds (Peper et al. 2007). Landscape architects and planners are increasingly using three-dimensional models to visualize alternative landscapes (fig. 3). Incorporating empirically derived allometric equations to simulate development of the tree canopy can allow designers to anticipate spatial impacts and potential conflicts between maturing trees and other design elements (Larsen and Kristoffersen 2002).

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Figure 2—Urban tree growth equations can be used to estimate the maximum trunk diameter of different aged trees to help managers reduce infrastructure repair costs.

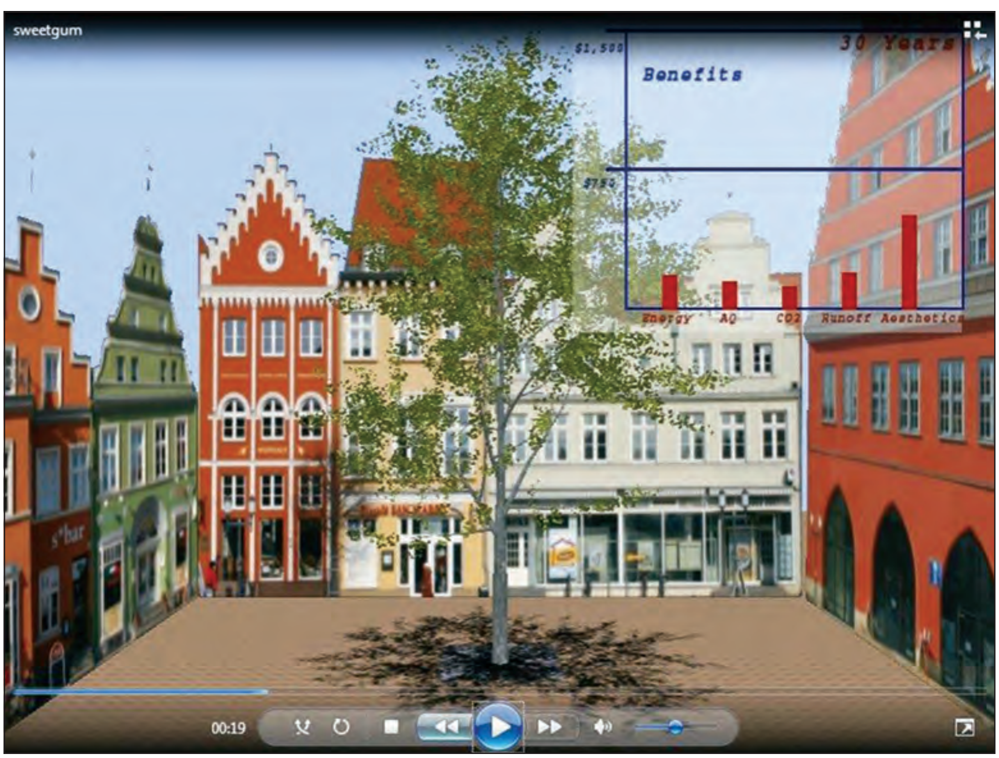

Figure 3—Tree growth equations underpin three-dimensional models that are used to visualize the spatial and economic impacts of alternative landscapes. (Linsen et al. 2005)

Analyses of allometric and site data can find correlations between variables that will inform management (Grabosky and Gilman 2004). Moreover, tree size and age data can be used to form local baselines for cities. Repeated measurements of the same trees can identify trends in growth, survival, and replacement. By building upon these baseline data, long-term tree growth and demographic studies could fill important knowledge gaps in urban forestry.

Development of Urban Tree Growth Equations

Although tree growth is the result of very complex processes, growth equations capture changes in tree size with age in a surprisingly simple and accurate way. Growth equations contain two components that reflect the interaction of two opposing biological forces. The expansion component is responsible for the increase in the increment with age, and growth expansion is proportional to the current size of the tree (Zeide 1993). The growth-decline component is responsible for the decrease in the increment with age from constraints imposed by internal (aging) and external (stress) factors. Hence, growth equations bring together these two biological forces over the entire lifespan of a species. Because tree growth reflects the unique genetic traits of trees, as well as their responses to environmental trends and management, no one growth equation suits all species, sites, or growth processes. Growth equations are best applied when the scope of analysis includes many individual trees over long time periods.

Growth equations are traditionally associated with rural forests, where they provide quantitative guidelines for planting, thinning, and harvesting. Growth equations for forest trees may not be directly transferable to open-grown urban trees because they grow and partition bole, branch, twig, and leaf biomass differently (Anderegg et al. 2015, Nowak 1994a, Peper and McPherson 1998) (fig. 4). For example, in forests, tree crowns compete for limited space and may not reach their maximum expansion potential (Martin et al. 2012).

The development of allometric equations for urban open-grown trees has been sporadic. Fleming (1988) measured trees in New Jersey having full healthy crowns to develop linear relationships between d.b.h., height, crown spread, and age. Frelich (1992) measured only healthy trees (12 species, 221 trees total) growing in Minneapolis and St. Paul, Minnesota, to predict linear size relationships. Nowak (1994b) developed an allometric equation for leaf area based on data from park trees in Chicago. Tree dimensions and leaf area were predicted

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Figure 4—The form of red maple trees (*Acer rubrum*) can vary from relatively upright in forest stands (left) (Zimmerman 2011) to spreading when growing in the open (right).

for the most abundant street tree species in Modesto and Santa Monica, California (Peper et al. 2001a, 2001b). In New Haven, Connecticut, Troxel et al. (2013) developed allometric equations for predicting d.b.h. from age and height, crown diameter, and crown volume from d.b.h. for early growth (15 years) of 10 street tree species.

Outside of North America, growth equations have been developed for street-side *Tilia* species in Copenhagen, Denmark (Larsen and Kristoffersen 2002), and *T. cordata* Mill., *Fraxinus excelsior* L. and *Aesculus hippocastanum* L. in Warsaw, Poland (Lukaszkiewicz and Kosmala 2008, Lukaszkiewicz et al. 2005). Predictive models were developed from allometric data for five street tree species in northeastern Italy by Semenzato et al. (2011). Stoffberg et al. (2008) used allometric relationships between age and d.b.h., height, and crown diameter to estimate dimensions at 10, 15, and 30 years after planting for three street tree species in Tshwane, South Africa. The allometric equations from all these studies reflect the effects of local site conditions, management practices, and growing season on growth, limiting application outside their region of origin (fig. 5).

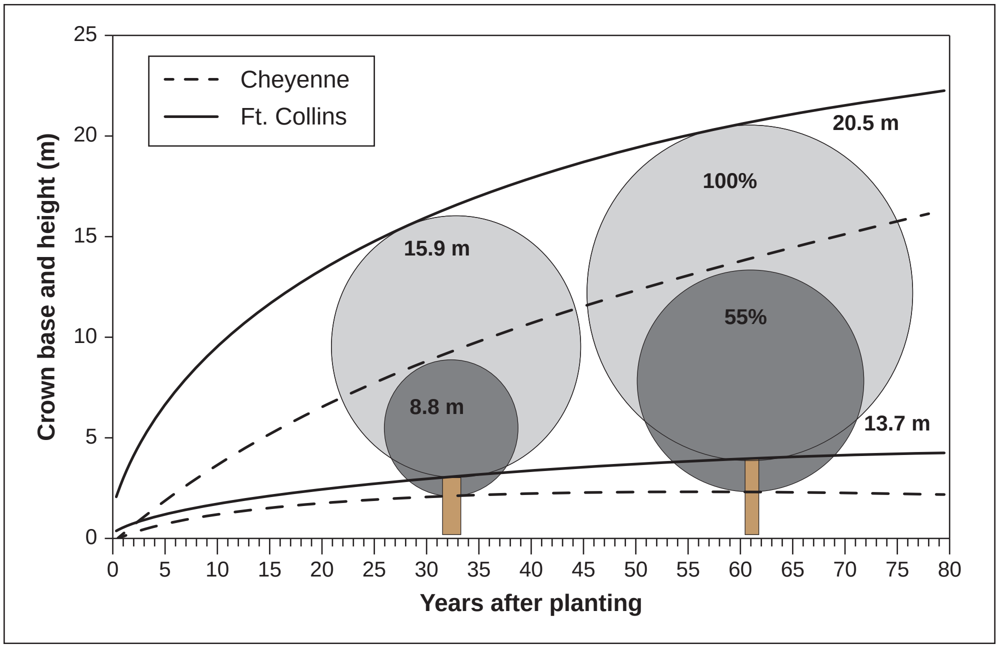

Figure 5—Urban tree growth modeling has shown how crown dimensions for trees of the same age and species can vary due to differences in climate and management practices (McPherson and Peper 2012). Upper and lower lines represent height and height to first branch, respectively. Cheyenne green ash (*Fraxinus pennsylvanica*) have 55 percent of the Fort Collins' ash leaf area after 60 years.

Origin of These Urban Tree Growth Equations

For this report, the need to develop urban tree growth equations was first prompted by a grant that required calculating the 40-year annual stream of carbon stored by urban trees across the United States (McPherson and Simpson 1999). Measured data were lacking for most regions. Following Frelich (1992), d.b.h. was predicted using a power function with age and two constants (fig. 6). Coefficients were adjusted for different regions based on the number of frost-free days, and calibrated with the few data points that were available. This absence of reliable data led the U.S. Forest Service to undertake a 14-year campaign that measured more than 14,000 trees in cities across the United States. Crews began systematically sampling street and park trees in 1998. The initial tree growth equations were used with numerical models to calculate the annual stream of benefits associated with energy effects, air pollutant uptake and emissions, carbon storage, rainfall interception, and effects on property values (Maco and McPherson 2003, McPherson et al. 2005).

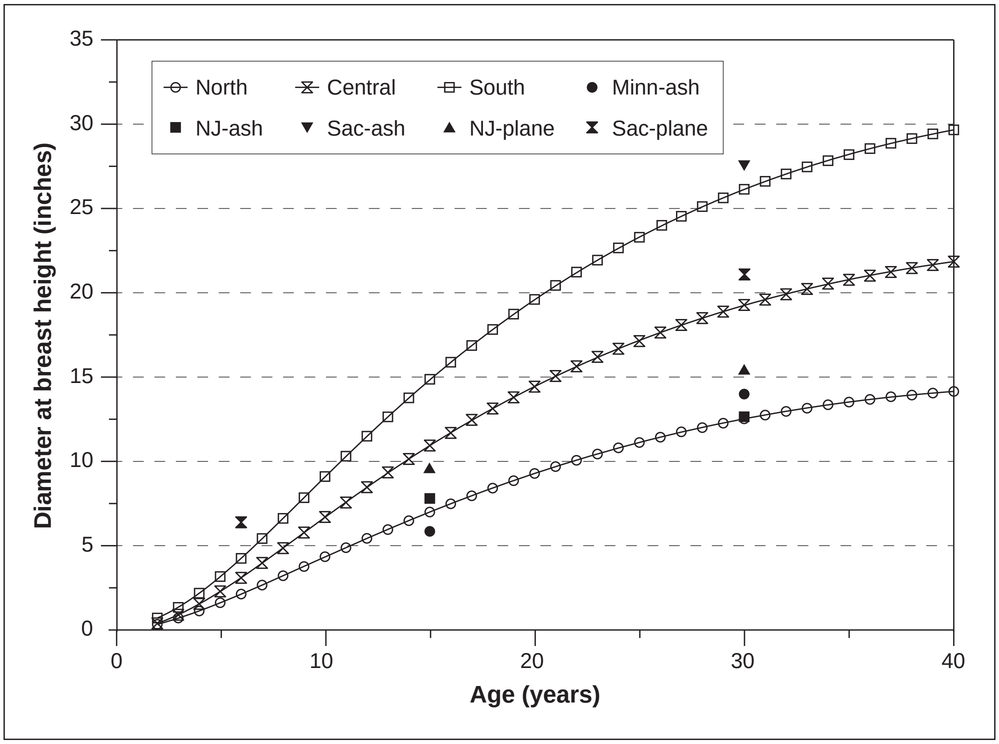

Figure 6—Initial efforts to model tree growth to calculate carbon storage were limited by a scarcity of measured data (McPherson and Simpson 1999).

This work evolved into the i-Tree Streets (formerly STRATUM) software program and a series of related products that are highlighted below.

- **Sixteen regional tree guides** quantified the long-term benefits and costs for trees and provided information on program design and implementation, optimal configurations of trees, tree species for different situations, techniques for successful establishment of new trees, and sources of funding and technical assistance. These technical reports provide regionally specific science-based information for elected officials, planners, landscape architects and contractors, urban foresters, arborists, and nonprofit tree organizations (McPherson et al. 2000, 2010; Peper et al. 2009; Vargas et al. 2007) (http://www.fs.fed.us/psw/topics/urban_forestry/products/tree_guides.shtml).
- **Seventeen municipal forest resource assessments** combined results of citywide street/park tree inventories with benefit-cost modeling to describe structure, function, and value, along with resource management needs (McPherson and Simpson 2002, McPherson et al. 1999) (http://www.fs.fed.us/psw/topics/urban_forestry/products/mfra.shtml).

- **Trees in Our City PowerPoint presentations** (http://www.fs.fed.us/psw/topics/urban_forestry/TreesInOurCity/index.shtml) **and Trees Pay Us Back brochures** (http://www.fs.fed.us/psw/topics/urban_forestry/products/treebrochures.shtml) translated regional results into customized images and figures for audiences such as city councils and homeowners (McPherson et al. 2011).

In 2008, the U.S. Forest Service Pacific Southwest Research Station received funding from CAL FIRE to develop a tree carbon calculator to predict carbon stored by tree planting, following guidance in the Urban Forest Greenhouse Gas Reporting Protocol (Climate Action Reserve 2008). The Center for Urban Forestry Research (CUFR) Tree Carbon Calculator was released in 2010 and incorporated revised tree growth equations for the most abundant tree species in each of 16 U.S. climate zones (http://www.fire.ca.gov/resource_mgt/resource_mgt_urbanforestry).

This report presents the third, most recent and most complete sets of growth equations. The equations presented in this report were developed using more sophisticated statistical methods than before. For example, in the first studies, logarithmic regression and exponential models predominantly provided the best fits to measured data (Peper et al. 2001a, 2001b). In these equations, the best model fits ranged from polynomials (from simple linear to quartic) to logarithmic and exponential models (Peper et al. 2014). The newest equations have been integrated with numerical models of tree benefits in the ecoSmart Landscapes software (McPherson et al. 2014).

Limitations of Urban Tree Growth Equations

The biophysical, social, and economic forces that influence tree growth are highly variable within and among cities. Consequently, large sample sizes are required to fully capture overall growth trends within a species. In rural forests, relatively uniform growing conditions allow foresters to create site indices and generate site-specific growth equations for each species in the stand. This has not been done for trees in the urban forest because of their heterogeneity and limited resources for measurements.

Management practices can differ widely among the arborists and amateurs who plant and maintain trees. For example, pruning practices such as topping trees to reduce their height can affect tree growth and size (fig. 7). Crown damage from storms, pests, drought, and other stressors can result in highly variable height and diameter dimensions among trees of the same species and age. The presence of trees with dimensions that deviate from the norm can result in growth equations that produce less reliable size predictions.

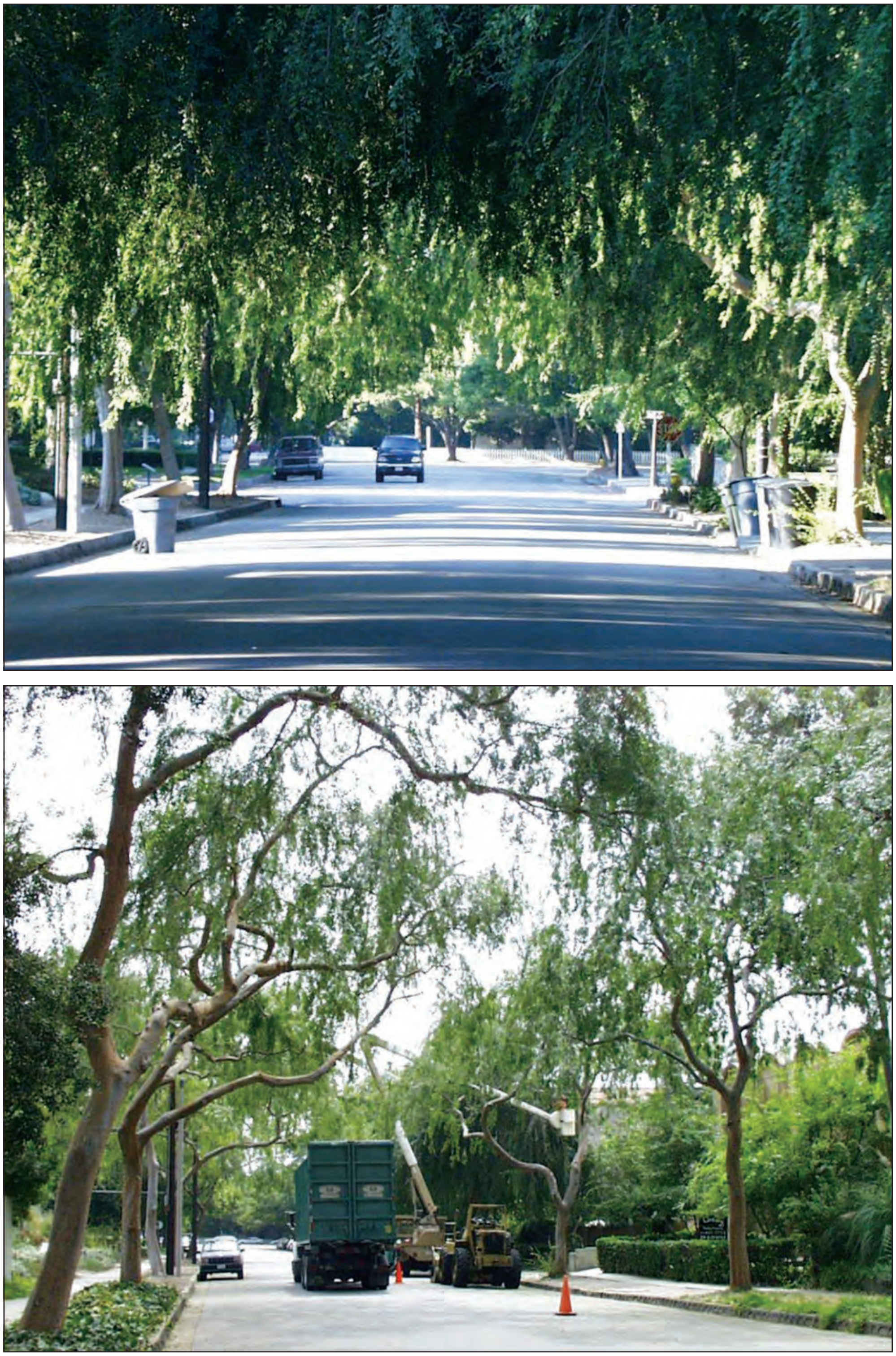

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Figure 7—Tree management practices, especially pruning, can affect crown size. The two Chinese elms (*Ulmus parvifolia*) before (above) and after (below) pruning in Claremont, California.

Another limitation to the development of robust growth equations for urban trees is the difficulty of obtaining accurate age data for older trees. In the context of this research, tree age refers to years after planting, not after germination or propagation. Records of planting dates seldom extend beyond 30 to 40 years. Similarly, detecting the presence and size of individual trees using high-resolution aerial imagery becomes difficult prior to 1990. As a result, predictions of urban tree dimensions reflect the increasing uncertainty about true tree age compounded by naturally increasing variability associated with aging (fig. 8).

Allometric equations for urban tree species have many valuable uses. Although researchers have developed such equations, their range of application and predictive power are limited by small sample sizes, few species, young and excellent-condition trees only, and narrow geographic range. This research overcomes some of these limitations by presenting 365 sets of allometric equations for the most abundant tree

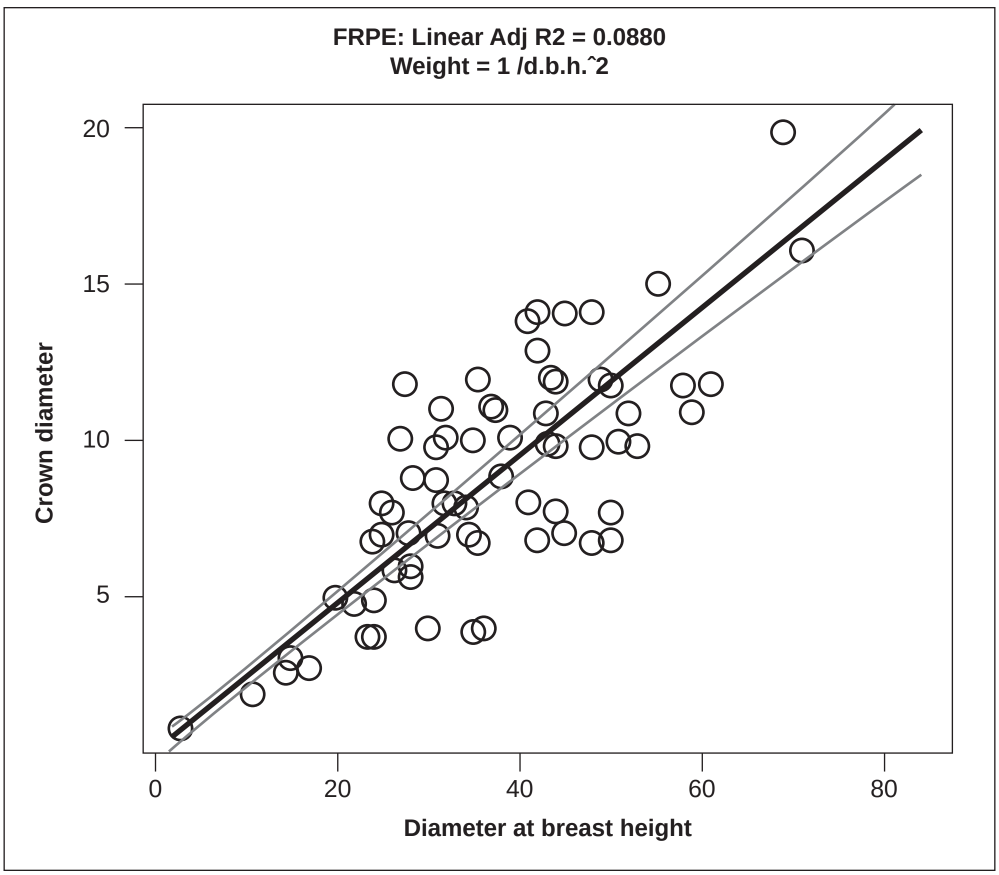

Figure 8—Tree crown measurements typically reflect increased variability with age. In this scatter plot of green ash diameter at breast height (d.b.h.) (in centimeters) and crown-diameter data (in meters) the variability is greatest for trees with d.b.h. in the 20-to 60-cm range. Accordingly, the prediction interval increases with d.b.h. size (Peper et al. 2014).

species in cities from around the United States. Also, this report illustrates application of these growth equations by calculating the predicted amounts of carbon dioxide stored over 50 years by the same species of trees growing in cities with different climates, soils, and management practices.

Foliar Biomass

Accurate estimates of leaf area are fundamental to modeling physiological and functional processes of urban forests. For example, the volume of rainfall intercepted by a tree crown is related to the amount of leaf area as well as the foliage surface saturation storage capacity, both of which are species dependent (Xiao et al. 2000b). Leaf area is used to calculate dry deposition rates of air pollutants and emissions of biogenic volatile organic compounds (BVOC) for different tree species (Benjamin and Winer 1998). Hirabayashi et al. (2012) used a regression equation to estimate leaf area that uses crown dimensions and a species-specific shade factor (Nowak 1996). Bottom-up modeling approaches such as this calculate interception, uptake, and emissions of individual trees and scale-up these estimates to the region. This approach allows for modeling future effects of different management strategies.

The accuracy, precision, efficiency, and other practical considerations associated with four methods of estimating leaf area of open-grown urban trees were evaluated with a completely destructive sample of 50 trees (Peper and McPherson 2003). The color digital image processing method was the only method to produce estimates within 25 percent of mean true leaf area and meet additional requirements for precision and efficient use in urban settings. The regression equation that is currently applied in the i-Tree Eco dry deposition model (Cabaraban et al. 2013, Nowak et al. 2014) had the lowest correlation of the four approaches.

Isoprene and other BVOC emission factors are important components of air quality models because tree emissions can occur at levels that influence atmospheric composition (Geron et al. 2001). Isoprene emission rates of different plant species range from <0.1 to $>100\ \mu g \cdot m^{-2} \cdot h^{-1}$. Species-specific emission factor data have been summarized and measurement techniques detailed (Ortega et al. 2008). Allometric relationships between leaf area, fresh and dry leaf weight make it possible to estimate values of these important model parameters from measurements on a related parameter. For example, emission factors are expressed in units for dry foliar weight ($g\text{-}C \cdot kg^{-1} \cdot$ dry leaf day^{-1}). To scale-up the emission calculation to an entire tree, one can estimate its total dry foliar weight if the kilogram of dry leaf to square meter leaf area is known, as well as total tree leaf area. Similarly, if total tree foliar dry weight is unknown but the foliar dry weight to fresh weight ratio is known, total tree foliar dry weight can be estimated by sampling and weighing leaves in quadrats within the crown volume.

The UTD described in this report contains allometric equations that can be used to calculate tree leaf area by d.b.h. for selected species. Also, it contains species-specific ratios for foliar dry weight to fresh weight and dry weight to leaf area. The UTD is the most extensive compilation of these ratios for urban trees published to date.

Woody Biomass

Tree species, wood density, moisture content, and size data (d.b.h. and height) are used with biomass equations and other information (e.g., condition) to calculate tree wood volume and stored carbon. Because wood densities and moisture contents can vary within and among species, there is error associated with the use of average values in allometric equations (Yoon et al. 2013). Volumetric equations calculate the aboveground green wood volume of a tree using species d.b.h. and height. Total biomass and carbon stored are estimated by converting green volume to dry weight using density conversion factors, adding the biomass stored belowground, and converting total biomass to carbon.

Direct equations, a second type of equation, yield the aboveground dry weight of a tree, eliminating the need for density conversion factors. Direct equations are very site specific, and they assume that wood density value does not change. This is a limitation if the equations are to be applied across a variety of trees, sites, and climate zones because wood density varies within a tree and by site. Our focus has been on using volume equations and species-specific wood density factors obtained from the Global Wood Density Database (Zanne et al. 2009). This allows the user to select a volume equation from a species whose structure most resembles the structure of the subject tree, then apply the density factor for the subject tree's species.

Destructive sampling methods used to develop biomass equations in forests are occasionally used in urban forests, such as for *Quercus virginiana* Mill. and *Q. laurifolia* Michx. in Florida (Timilsina et al. 2014). Pillsbury et al. (1998) took nondestructive manual measurements of 15 species of street and park trees in California. Terrestrial LiDAR was used to develop biomass equations for 11 species in Fort Collins, Colorado (Lefsky and McHale 2008). A laser dendrometer was used for measurements on the five most abundant street tree species in Daegu, Korea (Yoon et al. 2013).

Application of forest-based biomass equations for tree species is less desirable than applying urban-based equations because of differences in tree architecture (McHale et al. 2009, Yoon et al. 2013). Nowak (1994c) recommended multiplying forest-based equation results by a correction factor of 0.80 because they overestimated actual biomass. However, McHale et al. (2007) found that standard application of the correction factor may lead to underestimates of biomass at the city scale. Yoon et al. (2013) found that the urban-based biomass equation for *Zelkova serrata* (Thunb.) Makino produced estimates 4.7 to 6.0 times lower than one from plantation-grown trees, but was similar to the equation for urban *Zelkova* in California (Pillsbury et al. 1998). However, the allometric equations for open- and plantation-grown *Ginkgo biloba* L. were similar, implying greater architectural and genetic uniformity for this species.

Urban general equations have been developed as an alternative to applying species-specific equations when many species do not have an equation. Aguaron and McPherson (2012) compiled urban general equations from 26 urban-based equations that were species specific. They found that these direct general equations underestimated carbon storage relative to species-specific equations at the city scale. Differences between the structure of the species used to generate the urban general equations and the city's tree population may be responsible. Yoon et al. (2013) compiled species-specific urban equations into a general equation and found that the difference in values estimated using species-specific values was less than 1 percent at the citywide scale. However, Aguaron and McPherson's (2012) general equation for urban broadleaf species overestimated aboveground biomass by 50 percent. The uncertainty associated with application of urban general equations underscores the need for more urban equations that are species specific. For improved accuracy, the urban general equations in this UTD are volume equations that allow users to apply species-specific dry weight density factors.

Chapter 2: Sampling Design and Data Collection

Climate Zones and Reference Cities

The United States was divided into 16 national climate zones by aggregation of 45 Sunset climate zones (Brenzel 1997). The climate zone map demarcates each zone (fig. 9). Sunset zones were aggregated based on factors that influence plant distribution, such as length of growing season and minimum temperature, as well as cooling degree days (CDD) and heating degree days (HDD), which are indicators of the potential effects of trees on building heating and cooling loads (table 1). The CDD and HDD values are the summation of degrees of the average temperature per day above and below 18.5 °C (65 °F) for the year, respectively (McPherson 2010).

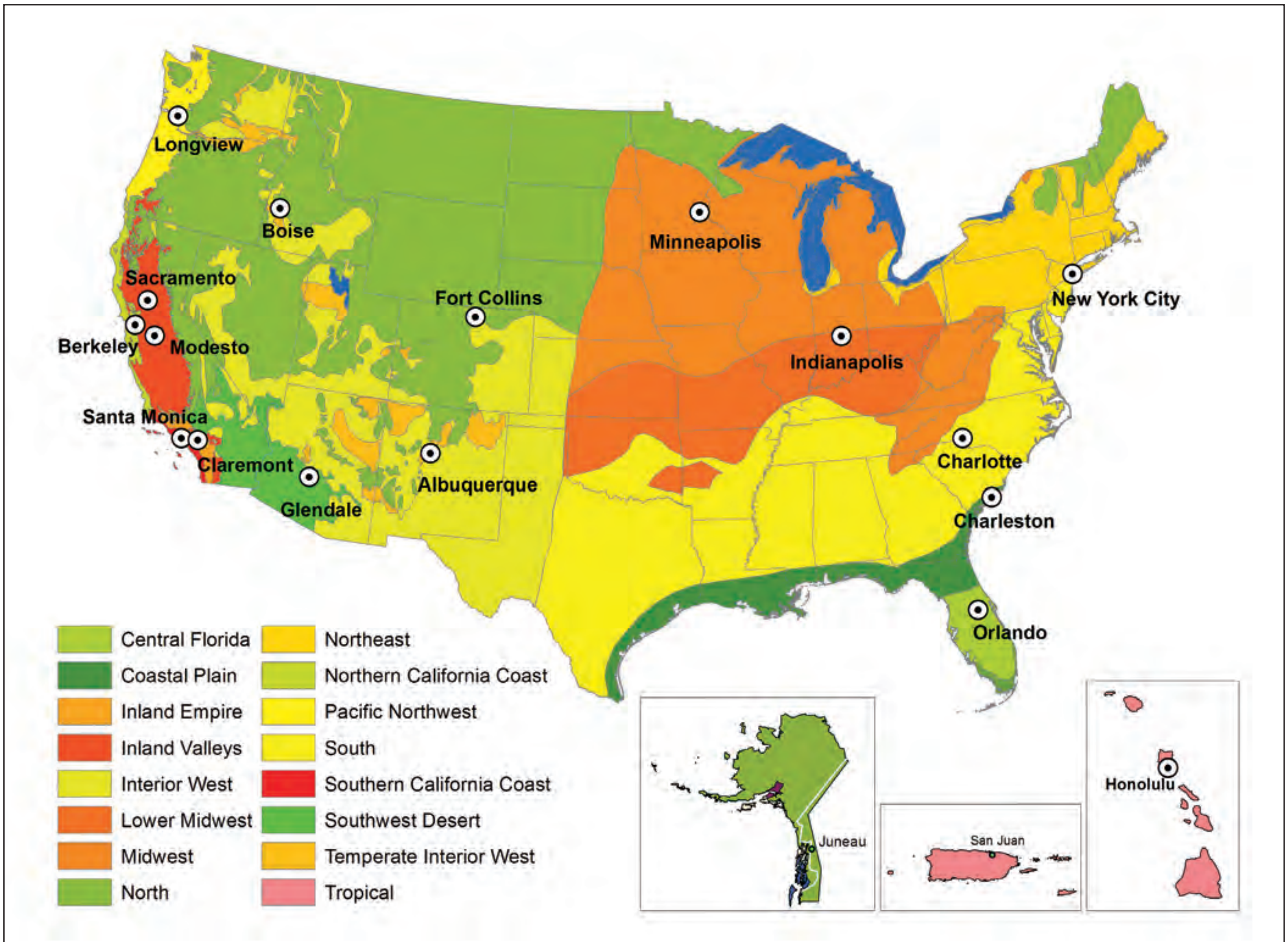

Figure 9—Climate zones were aggregated from 45 Sunset climate zones into 16 zones. Each zone has a reference city where tree growth data were collected. Sacramento, California, was added as a second reference city (with Modesto) to the Inland Valleys zone.

Table 1—Information on the reference city in each climate zone

Climate zone (code)	Reference city	Years data collected	Reference city code	Sunset zones[a]	USDA hardiness zones[b]	CDD[c]	HDD[c]	Annual precipitation
								Millimeters
Central Florida (CenFla)	Orlando, FL	2008	ORL	26	9-10	1,806	289	1367
Coastal Plain (GulfCo)	Charleston, SC	2004	CHS	27, 28	8-9	1,124	1,221	1555
Inland Empire (InlEmp)	Claremont, CA	2000	CLM	18, 19, 20, 21	9	134	872	523
Inland Valleys (InlVal)	Modesto, CA Sacramento, CA	1998 2010 2012	MOD SMF	7, 8, 9, 14,	8-9	1,052 773	1,439 1,718	315 470
Interior West (InterW)	Albuquerque, NM	2005	ABQ	2, 10	5-6	677	2,416	250
Lower Midwest (LoMidW)	Indianapolis, IN	2006	IND	35	6-7	510	3,153	392
Midwest (MidWst)	Minneapolis, MN	2004	MSP	36, 41, 43	4-6	355	4,436	622
North (NMtnPr)	Fort Collins, CO	2002	FNL	1, 44, 45	1-4	349	3,332	452
Northern California Coast (NoCalC)	Berkeley, CA	2003	JBK	15, 16, 17	9-10	39	1,786	564
Northeast (NoEast)	Queens, New York city, NY	2005	JFK	34, 37, 38, 39, 40, 42	2-5	560	2,819	1041
Pacific Northwest (PacfNW)	Longview, WA	2001	LOG	4, 5, 6	8-9	157	2,468	1059
South (Piedmt)	Charlotte, NC	2004	CLT	29, 30, 31, 32, 33	6-8	847	1,891	1426
Southern California Coast (SoCalC)	Santa Monica, CA	1999	SMA	22, 23, 24	10-11	266	710	570
Southwest Desert (SWDsrt)	Glendale, AZ	2003	GDL	11, 12, 13	9-10	2,128	637	174
Temperate Interior West (TpIntW)	Boise, ID	2005	BOI	3	7	387	3,325	417
Tropical (Tropic)	Honolulu, HA	2005	HNL	25	11	2,416	0	2206

[a] From Brenzel (1997).
[b] From http://planthardiness.ars.usda.gov/PHZMWeb/.
[c] From McPherson (2010), cooling degree days (CDD) and heating degree days (HDD) are the summation of degrees of the average temperature per day above and below 18.5 °C for the year, respectively.

"Reference city," refers to one city selected for intensive study within each climate zone (McPherson 2010). Data were collected for a second reference city in the Inland Valleys climate zone, Sacramento, California, because tree growth data were required for several ongoing studies. Criteria for selecting a reference city included (1) an updated computerized tree inventory with location information for each tree (20,000 to 250,000 street/park trees); (2) information to accurately age a sample of about 900 trees by the city forester; (3) large, old trees present in the community; and (4) an aerial lift truck available for 1 week to sample foliage.

Species and Tree Sampling

The trees sampled in each reference city were obtained from the computerized tree inventory. First, the inventory was cleaned to remove stumps, dead trees (shown as scheduled for removal), and vacant sites. It was sorted by species to identify the most abundant species for sampling. About 20 of the most abundant species were selected for sampling in each city. Appendix 1 lists the number of trees of each species sampled in each city (available for download as table S2). The sampled species accounted for 50 to 95 percent of all trees in the municipal tree inventories. To obtain information spanning the life cycle of each of the predominant tree species, a stratified random sample was drawn. The sample was stratified into nine diameter at breast height (d.b.h.) classes (0 to 7.6, 7.6 to 15.2, 15.2 to 30.5, 30.5 to 45.7, 45.7 to 61.0, 61.0 to 76.2, 76.2 to 91.4, 91.4 to 106.7, and >106.7 cm). Thirty to 70 trees of each species were randomly selected to survey, about 5 to 10 trees in each d.b.h. class. Smaller samples of 30 trees were drawn for small-growing species such as *Prunus* spp. and *Malus* spp. Seventy trees were drawn for species with individuals represented in all size classes. An equal number of alternative trees were selected as replacement trees in the event that the originally sampled trees could not be located.

Although 30 to 70 trees were randomly selected for sampling each species, the final samples ranged from 22 to 79 trees. The lower number resulted when the original and replacement trees could not be located. The higher numbers occurred when the sample trees were actually in a different size class than reported in the inventory. These trees were measured in case viable replacements could not be found. In fact, replacements were found and sample numbers became greater than expected.

Tree Data Collection

Each variable in the UTD, as well as its definition, abbreviation, and potential use, is listed in table 2. Protocols for data collection are in appendix 2. Metrics recorded for each tree sampled included species, address/location, d.b.h. (to nearest 1.0 cm by tape), tree crown, and bole height (to nearest 0.5 m by clinometer or sonar measuring device), crown diameter in two directions (parallel and perpendicular to nearest street to nearest 0.5 m by sonar measuring device) (table 2). Observational information was recorded on crown shape, land use, distance and direction from nearest air-conditioned/heated building, car shade, and conflicts with utility lines. Other data are presently being analyzed and will be added to the UTD upon publication including sidewalk damage, site type, the amount of planting space, condition of wood and foliage, whether the tree is city or privately managed, maintenance needs, and photograph numbers for the one or two photographs that were taken of each tree and processed in the laboratory to calculate leaf area and crown volume. This photographic method is described in Peper and McPherson (2003) and was found more accurate than other techniques (±25 percent of actual leaf area) for open-grown trees. The tree growth equations and raw data collected for each tree are available for download in the online supplement http://dx.doi.org/10.2737/RDS-2016-0005.

Tree age was determined from local residents, the city's urban forester, street and home construction dates, historical planting records, and aerial and historical photos. In two cases, extra effort was required to obtain age information. Tree coring was used in Queens, New York City, to estimate planting dates instead of relying solely on historical research. Unlike other cities, where streets are lined with trees of the same age because they were all planted at the time of development, street trees in Queens were of all ages because several episodes of planting had ocurred. Dendrologists at the Lamont-Doherty Earth Observatory's Tree Ring Laboratory cored 150 randomly sampled trees to establish mean tree age. These trees represented a subsample of the original 910 sample trees. One to two trees in size classes 2 through 9 were cored for each species. Cores were analyzed in the lab and tree age established. Urban foresters provided tree ages for an additional 104 sample trees in d.b.h classes 8 and 9 (91.4 to 106.7 cm and >106.7 cm), based on building records, and 34 trees in d.b.h. classes 1 and 2 based on planting records. These data were pooled with ring-count data to develop regressions based on the mean age for each d.b.h. size class. Thus, the online data for Queens, New York City, shows two sets of data, one for data directly collected from each tree and one for tree ages collected from a combination of coring a subsample of the measured trees and aging information provided by New York City Parks and Recreation. Although more accurate aging of trees is required for that region, equations relationships between d.b.h. and parameters other than age reflect actual measured data.

Table 2—Abbreviations, names, descriptions, and uses for each variable in the Urban Tree Database (UTD)

Abbreviation	Name	Description	Use
DbaseID	UTD ID number	Unique ID number for each tree	To track tree
Region	Climate region	16 U.S. climate regions, abbreviations are used (see table 1)	To identify geographic region and climate
City	Reference city/state	City/state names where data were collected	To identify city where data were collected, associated management practices, climate, etc.
Source	Original file name	.xls file name	To identify locations of original data sets
TreeID	Inventory ID number	Number assigned to each tree in inventory by city	To link to other tree inventory data
Zone	Inventory management or nursery number	Number of the management area or zone that the tree is located in within a city or nursery if young tree data are collected there	To identify where data were collected
Park/street	Inventory data for park, street, or nursery trees	Data listed as park or street or nursery (for young tree measurements)	To identify where data were collected
SpCode	Species code	Four- to six-letter code consisting of the first two letters of the genus name and the first two letters of the species name followed by two optional letters to distinguish two species with the same four-letter code	To have a stable abbreviation for each species name
ScientificName	Scientific name	Botanical name	To group by taxon
CommonName	Common name	Common name	To group by taxon
Treetype	Tree type	Three-letter code where first two letters refer to life form (BD = broadleaf deciduous, BE = broadleaf evergreen, CE = coniferous evergreen, PE = palm evergreen), and the third letter is mature height (S = small [<8 m], M = medium [8 to 15 m], (L = large [>15 m])	To assist with matching species that were not measured
Address	Address number	From inventory, street number of the building where the tree is located	To relocate the tree
Street	Street name	From inventory, the name of the street on which the tree is located	To relocate the tree
Side	Side of building or lot	From inventory, side of building or lot on which the tree is located: F = front, M = median, S = side, P = park	To relocate the tree
Cell	Tree number when multiple trees are at the same address	From inventory, the cell number (i.e., 1, 2, 3, …), where protocol determines the order trees at same address are numbered (e.g., driving direction or as street number increases)	To relocate the tree
OnStreet	Name of the street the tree is on	From inventory (omitted if not a field in city's inventory), for trees at corner addresses when tree is on cross street rather than addressed street	To relocate the tree

Table 2—Abbreviations, names, descriptions, and uses for each variable in the Urban Tree Database (UTD) (continued)

Abbreviation	Name	Description	Use
FromStreet	Name of cross street where first tree is inventoried	From inventory, the name of the first cross street that forms a boundary for trees lining unaddressed boulevards. Trees are typically numbered in order (1, 2, 3 …) on boulevards that have no development adjacent to them, no obvious parcel addresses	To relocate the tree
ToStreet	Name of last cross street	From inventory, the name of the last cross street that forms a boundary for trees lining unaddressed boulevards	To relocate the tree
Age	Tree age	Number of years since planted	For allometric equations
DBH (cm)	Trunk diameter at breast height (d.b.h.)	D.b.h. (1.37 m) measured to nearest 0.1 cm (tape). For multistemmed trees forking below 1.37 m measured above the butt flare and below the point where the stem begins forking, as per protocol	For allometric equations
TreeHt (m)	Tree height	From ground level to tree top to nearest 0.5 m (omitting erratic leader)	For allometric equations
CrnBase (m)	Height to crown base	Average distance between ground and lowest foliage layer to nearest 0.5 m (omitting erratic branch)	For allometric equations
CrnHt (m)	Height of crown from crown base to top	Calculated as TreeHT minus Crnbase to nearest 0.5 m	To calculate crown volume
CdiaPar (m)	Crown diameter measured parallel to the street	Crown diameter measurement taken to the nearest 0.5 m parallel to the street (omitting erratic branch)	For average crown diameter
CDiaPerp (m)	Crown diameter measured perpendicular to the street	Crown diameter measurement taken to the nearest 0.5 m perpendicular to the street (omitting erratic branch)	For average crown diameter
AvgCdia (m)	Average crown diameter	The average of crown diameter measured parallel and perpendicular to the street	For allometric equations
Leaf (m^2)	Leaf surface area (one side)	Estimated using digital imaging method to nearest 0.1 m^2	Air pollutant and property value effects
Setback	Tree distance from conditioned building	Distance from tree to nearest airconditioned/heated space (may not be same address as tree location): 1 = 0 to 8 m, 2 = 8.1 to 12 m, 3 = 12.1 to 18 m, 4 = >18 m.	Energy effects
TreeOr	Tree orientation (compass bearing)	Taken with compass, the coordinate of tree taken from imaginary lines extending from walls of the nearest conditioned space (may not be same address as tree location)	Energy effects
CarShade	Number of parked vehicles in tree shade	Number of parked automotive vehicles with some part under the tree's drip line. Car must be present: 0 = no autos, 1 = 1 auto, etc.	Air pollutant effects

Table 2—Abbreviations, names, descriptions, and uses for each variable in the Urban Tree Database (UTD) (continued)

Abbreviation	Name	Description	Use
LandUse	Land use type where tree is located	Predominant land use type where tree is growing: 1 = single-family residential, 2 = multifamily residential (duplex, apartments, condos), 3 = industrial/institutional/large commercial (schools, government, hospitals), 4 = park/vacant/other (agric., unmanaged riparian areas of greenbelts), 5 = small commercial (minimart, retail boutiques, etc.), 6 = transportation corridor.	Energy and property value effects
Shape	Crown shape	Visual estimate of crown shape verified from each side with actual measured dimensions of crown height and average crown diameter: 1 = cylinder (maintains same crown diameter in top and bottom thirds of tree), 2 = ellipsoid, the tree's center (whether vertical or horizontal) is the widest, includes spherical), 3 = paraboloid (widest in bottom third of crown), 4 = upside down paraboloid (widest in top third of crown).	For crown volume and energy effects
WireConf	Tree crown conflict with overhead wires	Utility lines that interfere with or appear above tree: 0 = no lines, 1 = present and no potential conflict, 2 = present and conflicting, 3 = present and potential for conflicting.	Pruning owing to conflicts may affect crown dimensions
d.b.h.1 to d.b.h.8	Trunk d.b.h.	D.b.h. (cm) for multistemmed trees; for non-multistemmed trees, d.b.h.1 is same as d.b.h.	For d.b.h. calculation

Note: "-1" for all fields except leaf area, and "-100" for leaf area indicate no data collected.

In the Lower Midwest zone, the age of 337 of the 911 sampled trees was identified across d.b.h. ranges through local resources. This represented enough data to develop age to d.b.h equations for 12 of the 20 species sampled. For the remaining eight species, analysis was run testing available measured data with the same species measured in the other 15 climate regions to find the closest relationships. Closest relationships were found for *Catalpa speciosa* and *Juglans nigra* with same species in Boise, Idaho; with *Magnolia grandiflora, Picea pungens, Pyrus* sp.*, and Ulmus pumila* in Fort Collins, Colorado; with *Celtis occidentalis* in Minneapois, Minnesota; and with *Pinus strobus* in Queens, New York City. However, these relationships were based on a comparison of minimal data from Indianapolis and should not be construed to be accurate until additional data are available for analysis from Indianapolis. These data are presented in the online UTD database and annotated in the "Notes" column as to origin. Age to d.b.h. equations shown here for these eight species, therefore, should be regarded as first-order approximations until more definitive data are available. For these reasons, tree age is probably the least accurate metric in this database.

Foliar Sampling and Data Collection

For each species, one to three trees—typical of species in age, size, and condition—were selected for foliar sampling. Sampling was done from a bucket truck that required room to maneuver to reach the areas of the crown to be sampled. Foliar samples were taken at different locations within each tree crown to capture differences between sun and shade, as well as juvenile and mature foliage. By sampling leaves of different size and maturity, it was possible to obtain relationships between leaf area and dry weight that were representative of the tree's foliar biomass over time. One set of 10 random quadrat (a cube 30 by 30 by 30 cm) samples were clipped from each tree—three from the lower one-third of the crown, four from the middle section, and three from the top one-third. Within each crown stratum, at least one sample was from the outer, middle, and inner portions. Leaves and stems were clipped along the outside of the cube, and each sample was stored in a labeled ziplock bag. The bags were stored in an ice chest and shipped by overnight delivery to the cold-storage site in Davis, California.

The foliar samples were processed to develop relationships between leaf area and foliar biomass for each tree species. The leaves in each bag were separated from stems and twigs, then weighed (fresh weight) and run through the leaf area meter to obtain the sample's total surface area (leaf area). The foliage was returned to the paper bag and dried in an oven at 65 °C (149 °F) for 3 days (72 hours minimum). On the fourth day, the bag was removed from the oven and weighed (dry weight). The bag was returned to the oven and dried 24 hours then removed from the oven and weighed. If the bag weighed less than its previous weight, it was returned to the oven and dried. This process was repeated until the weight no longer changed. The fresh weight, dry weight, and leaf area were recorded for the foliar samples in each of the 10 bags per species. Leaf area to dry weight and fresh weight to dry weight relationships were calculated for each species using standard descriptive statistics. Resulting data are shown in appendix 3.

Chapter 3: Development of Tree Growth Equations

Six models were tested for seven parameters at four weights. Predicted parameters included the following: using tree age to predict diameter at breast height (d.b.h.); and using d.b.h. to predict tree height, crown height, crown diameter, and leaf area. In addition, crown diameter was used to predict d.b.h. for use with remote sensing imagery and age predicted from d.b.h. for use in backcasting. Prior to analysis, raw data points from each region were plotted to examine potential outliers. Following methods described by Martin et al. (2012), we eliminated from our analysis those observations identified on residual plots that were greater than two units larger than the general spread of observations for that parameter. Models tested included four polynomial models (linear, quadratic, cubic, and quartic), as well as log-log and exponential:

Linear $$y_i = a + bx_i + \frac{\in_i}{\sqrt{w_i}} \quad (1)$$

Quadratic $$y_i = a + bx_i + cx_i^2 + \frac{\in_i}{\sqrt{w_i}} \quad (2)$$

Cubic $$y_i = a + bx_i + cx_i^2 + dx_i^3 + \frac{\in_i}{\sqrt{w_i}} \quad (3)$$

Quartic $$y_i = a + bx_i + cx_i^2 + dx_i^3 + ex_i^4 + \frac{\in_i}{\sqrt{w_i}} \quad (4)$$

Log-log $$\text{In}(y_i) = a + b\text{In}(\text{In}(x_i + 1)) + \frac{\in_i}{\sqrt{w_i}} \quad (5)$$

Exponential $$\text{In}(y_i) = a + bx_i + \frac{\in_i}{\sqrt{w_i}} \quad (6)$$

Where y_i is the measurement of tree *i*, *a* is the mean intercept, *b* is the mean slope, x_i is the d.b.h. or age of tree *i*, $\in_i$ is the random error for tree *i* with $\in_i\, j \sim N(0,\sigma^2)$, σ^2 is the variance of the random error, and w_i is a known weight that takes on one of the following forms: $w_i = 1$, $w_i = 1/\sqrt{x_i}$, $w_i = 1/x_i$, $w_i = 1/x^2$.

Analysis was conducted using SAS® 9.2 MIXED procedure (SAS 2008). The bias-corrected Aikaike's information criterion (AIC_c) was used to compare and rank the models because of smaller sample sizes (Akaike 1974). The models with the "best" fit as indicated by having the smallest AIC_c were selected. Additional steps were needed to obtain comparable AIC_c values for log-log and exponential models (eqs. 7 and 8). Otherwise AIC_c values would not be comparable across all models. Multiplying by the geometric mean allows the AIC_c values to be compared with the models where y_i is not transformed (Draper and Smith 1998).

Log-log $$\dot{y}\ln(y_i) = a^* + b^*\ln(\ln(x_i + 1)) + \frac{\epsilon^*_i}{\sqrt{w_i}} \qquad (7)$$

Exponential $$\dot{y}\ln(y_i) = a^* + b^* x_i + \frac{\epsilon^*_i}{\sqrt{w_i}} \qquad (8)$$

Where $\dot{y}$ is the geometric mean of the y_i values.

All weightings for polynomials are built into the coefficients (unlike the exponential and log-log formulas). The equations are translated to Excel format in table 3 (available for download as table S4).

The resulting best fitting model is listed for each measured species and region in the online supplement, table S6 (an example is shown in app. 4), with the measured parameter, predicted tree component, model weight, equation name, the coefficients to use in each model, the minimum and maximum values to estimate between, mean square error, sample size, adjusted R^2, the raw data range, and the degrees of freedom. The model weights are already accounted for in the equation coefficients. The equation name represents the general form of the equation, the details of which are in table 3. Note that log-log and exponential models require an input for mean-squared error (mse), which is listed in table 7 (app. 4) column "c or mse" (i.e., do not calculate and use sigma^2).

For palms, there is no discernable relationship between age and d.b.h. In contrast, age is an adequate predictor of tree height. Therefore, equations were developed to predict palm height from age, and subsequently, to predict other parameters such as biomass from palm height.

Table 3—Excel-formatted equations for predicting open-grown tree growth parameters

Model name	Equation
lin	a + b × (age or dbh)
quad	a + b × x + c ×x^2
cub	a + b × x + c ×x^2 + d × x^3
quart	a + b × x + c ×x^2 + d × x^3 + e × x^4
log-logw1	EXP(a + b × LN(LN(age or dbh +1) + (mse/2)))
log-logw2	EXP(a + b × LN(LN(age or dbh +1)) + (SQRT(age or dbh) + (mse/2)))
log-logw3	EXP(a + b × LN(LN(age or dbh +1)) + (age or dbh) + (mse/2))
log-logw4	EXP(a + b × LN(LN(age or dbh +1)) + (age^2 or dbh^2) + (mse/2))
expow1	EXP(a+ b × (age or dbh) + (mse/2))
expow2	EXP(a + b × (age or dbh) + SQRT(age or dbh) + (mse/2))
expow3	EXP(a + b × (age or dbh) + (age or dbh) + (mse/2))
expow4	EXP(a + b × (age or dbh) + (age^2 or dbh^2) + (mse/2))

An important constraint to consider when applying the growth equations to measured tree data is that equations predicting d.b.h. from age may produce negative values for young ages. Negative values in d.b.h. estimates may cause continued problems for predicting tree height and other variables from d.b.h. These values should take on the first instance of a positive value.

In the Urban Tree Database (UTD), two sets of data ranges are reported. One shows the actual range of the data collected and is labelled “Data min” and “Data max.” To reduce the risk of overextending the application of the equations, we report application ranges for the equations used to predict each parameter. The “Apps min” and “Apps max” range informs users on a reasonable range for use of the equations—sometimes extending beyond collected data points, and sometimes not reaching those points. Values extending beyond the range of collected data were considered because there was sufficient knowledge of how large trees grow from measurements taken in local parks and neighborhoods.

Database Description

The core of the UTD consists of two large data tables that can be downloaded in ASCII format through the online supplement. The first table (app. 3 and available for download as table S5) shows summarized results from the foliar sampling for each species and region. The second table displays equations and coefficients for predicting tree-growth parameters by species and predicted parameter (table S6). An excerpt from table S6 for two species in one climate zone is shown in appendix 4. A User Guide (app. 5) provides step-by-step instructions and examples for applying the growth equations to trees of interest using the core data tables. In addition, appendix 5 demonstrates how to estimate dry weight biomass and carbon using allometric equations (tables S7 and S8). Table S9 provides an expanded list

Table 4—Percentage of best fitting model types for tree growth parameters by measured and predicted parameters

Relationship	cub	expow	lin	log-log	quad	quart
			Percent			
Age to diameter at breast height (d.b.h.)	27	0	31	13	28	0
Crown diameter to d.b.h.	26	1	23	35	15	0
D.b.h. to age	38	1	22	14	25	0
D.b.h. to crown diameter	22		16	23	38	0
D.b.h. to crown height	13	4	26	24	33	0
D.b.h. to leaf area	15	2	1	72	10	0
D.b.h. to tree height	16	3	14	30	35	2
Total	22	2	19	31	26	0

of dry-weight biomass density factors for common urban species. Lastly, a case study demonstrates differences in d.b.h., tree height, and total carbon across the different climate zones, highlighting the importance of developing region-specific growth models.

Data Limitations and Future Research Needs

Accurately predicting d.b.h and tree height leads to better estimates of total carbon storage and carbon sequestration. This section describes where uncertainty is greatest and additional research is needed to improve estimates.

Tails—
In the context of estimating tree size, as well as carbon storage and sequestration for applications such as calculating tree benefits, it is important to continue to improve the accuracy of the equations at the extreme ends of the age spectrum. With limited measurements at the extreme ends of the age spectrum, there is the risk of a few extreme points driving the equation form selection. It is particularly important to sample from larger/older trees because small changes in growth equations can cause large absolute differences in carbon estimates. As trees age, the differences typically increase owing to temporal autocorrelation and differences in equation form. Each additional data point obtained at the upper age range is therefore critical for increasing accuracy of growth and volumetric equations.

Age—
Sampling from large trees does not guarantee the addition of old trees to the database. One practical limitation of the age-to-d.b.h.-regression approach (from size curves instead of real growth curves) is that age data are often difficult to acquire. The lack of age information can limit the use of predictions in applications. For example, not all of the large trees randomly selected for coring in New York City were successfully cored. The length of the coring instrument and pockets of decay inside the tree limited the effectiveness of coring and thus makes this research dependent on people recording tree planting dates. Predictions for d.b.h. from the best model for *Platanus* × *acerifolia* in New York City estimated an end d.b.h. growth at and end d.b.h. of 61 cm as predicted from age, even though the largest tree measured was 165 cm d.b.h. This occurred because the largest tree was not cored successfully. Until additional data are collected to represent a larger and more robust sample of tree ages and sizes for each species, the level of inference drawn from these model fits should be limited by staying within the Apps min and Apps max ranges listed in the database.

Size—

Selecting a robust sample of trees that captures a range of sizes is important for smaller-growing species as well. We found that smaller-growing species, particularly *Prunus* and *Lagerstroemia* were problematic for model-fitting. Typically, there were few specimens smaller than 7.6 cm d.b.h. and many in the 15.2 to 30.5 cm d.b.h. range. In addition, because these trees were often pruned by homeowners, crowns rarely followed a more natural form, resulting in a large variety of forms and heights. This problem of form manipulation was even greater with *Lagerstroemia*, which also might be present as either a single- or multistemmed plant. *Lagerstroemia* were often pollarded every year, affecting height and crown measurements as well as slowing d.b.h. growth.

It was also more difficult to find good model fits for several of the small- and medium-growing conifers like *Pinus brutia*, *P. edulis*, and *P. contorta* because there were few representatives in the 0 to 15.2 cm size class or, as in the case of *P. edulis*, most representatives were in the 10.2 to 30.5 cm d.b.h. range with few samples available below or above that.

Palms—

Palms represent another sampling gap. In the UTD (app. 4), palms do not have mse or adjusted R^2 because the equations were not calculated from measurements, but from information provided by palm nurseries and experts in the region. This was done because the majority of palms were transplanted at anywhere from 5 to 40 years of age, and d.b.h. recorded in tree inventories showed no relationship to other crown dimensions. Also, city foresters had very little information on the ages of palms at time of planting. Although the UTD contains measurements for more species than ever reported, much more information is needed for truly accurate growth representation within regions of the country.

Volumetric equations—

The results from the case study (app. 5) demonstrate the differences in growth patterns among climate zones/regions. Besides improving on the growth equation database, there is work to be done to expand volumetric equations. As described in the user guide (app. 5), the volumetric equations used to predict tree volume from measured parameters are not region specific, because differences between regions have not yet been tested and localized equations have not been developed. Developing a more extensive database of volumetric equations for open-grown urban tree species is a high-priority research need.

Chapter 4: Conclusions

Information on urban tree growth underpins models such as i-Tree that calculate effects of trees on the environment and human well-being. Data about tree growth are used to create realistic animations that depict landscape change over decades. Maximum tree size and other growth data are used by urban forest managers, landscape architects, and planners to select trees most suitable to the amount of growing space, thereby reducing costly future conflicts between trees and infrastructure. Growth data may be used to characterize relationships between growth and influencing factors such as site conditions and stewardship practices. Despite the importance of tree growth data to the science and practice of urban forestry, our knowledge is scant. For example, data have been lacking to specify the range of bole and crown dimensions for an open-grown red oak (*Quercus rubra*) tree exhibiting "normal" growth in New York City.

Over a period of 14 years, the U.S. Forest Service recorded data from a consistent set of measurements on over 14,000 trees in 17 U.S. cities. This network of cities represents municipal forests with different climates, forest structures, and management histories and practices. Key information collected for each tree species includes bole and crown size, location, and age. From this Urban Tree Database (UTD), 365 sets of tree-growth equations were developed for the predominant species. Although the UTD contains measurements for more species than ever reported, much more information is needed to better model tree growth within regions of the country. Tree planting dates are seldom recorded but remain fundamental to establishing relations between age and size. Capturing the range of ages that exist within the population promises to improve the lower and upper ends of the growth predictions where most of the uncertainty currently resides. Also, the value of the UTD can be expanded with new information on site conditions (e.g., soil type, microclimate, amount of growing space) and management practices (e.g., pruning dose, irrigation regime). With such information, analysts can better predict the effects of practices on tree growth and the services their trees provide.

The UTD is not a static repository. Already remeasurements have been conducted on originally measured trees in two cities (Claremont and Santa Monica, California) to update these equations and better understand the long-term demographics of street tree populations. These new data, as well as contributions from other researchers, will be incorporated into the UTD. Continued updating will ensure that the UTD remains a valuable resource for urban and community forestry.

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English Equivalents

When you know:	**Multiply by:**	**To find:**
Millimeters (mm)	0.0394	Inches (in)
Centimeters (cm)	0.394	Inches (in)
Meters (m)	3.281	Feet (ft)
Square meter (m^2)	10.76	Square feet
Cubic meters (m^3)	35.315	Cubic feet (ft^3)
Grams (g)	35.315	Ounces (oz)
Micrograms or microns (µg)	3.527×10^8	Ounces (oz)
Kilograms (kg)	2.205	Pounds (lb)
Kilograms per square meter (kg/m^2)	0.205	Pounds per square foot (lb/ft^2)
Metric tonne (t)	1.102	Tons (ton)
Degrees Celsius (°C)	°C × 1.8 + 32	Degrees Fahrenheit (°F)

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Appendix 1: Trees Sampled by Species and Region

Table 5—Numbers of trees sampled by species and region

Scientific name	Common name	SpCode	Samples
Central Florida (CenFla):			
Acer rubrum L.	red maple	ACRU	56
Cinnamomum camphora (L.) J. Presi	camphor tree	CICA	63
Eriobotrya japonica (Thunb.) Lindl.	loquat tree	ERJA	31
Juniperus virginiana L.	southern redcedar	JUSI	50
Koelreuteria elegans (Seem.) A.C. Sm.	Chinese rain tree	KOELFO	43
Lagerstroemia indica L.	common crapemyrtle	LAIN	35
Liquidambar styraciflua L.	sweetgum	LIST	48
Magnolia grandiflora L.	southern magnolia	MAGR	51
Pinus elliottii Engelm.	slash pine	PIEL	37
*Platanus occidenta*lis L.	American sycamore	PLOC	44
*Platycladus orien*talis (L.) Franco	Oriental arborvitae	THOR	37
Prunus caroliniana (Mill.) Aiton	Carolina laurelcherry	PRCA	39
Quercus laurifolia Michx.	laurel oak	QULA2	67
Quercus shumardii Buckley	Shumard oak	QUSH	37
Quercus virginiana Mill.	live oak	QUVI	65
Sabal palmetto (Walter) Lodd. ex Schult. & Schult. f.	cabbage palmetto	SAPA	45
Syagrus romanzoffiana (Cham.) Glassman	queen palm	SYRO	30
Triadica sebifera (L.) Small	tallowtree	TRSE6	40
Ulmus parvifolia Jacq.	Chinese elm	ULPA	37
Washingtonia robusta H. Wendl.	Mexican fan palm	WARO	40
Coastal Plain (GulfCo):			
Acer rubrum L.	red maple	ACRU	36
Butia capitata (Mart.) Becc.	jelly palm	BUCA	33
Carya illinoinensis (Wangenh.) K.Koch	pecan	CAIL	36
Celtis laevigata Willd.	sugarberry	CELA	37
Cornus florida L.	flowering dogwood	COFL	34
Gleditsia triacanthos L.	honeylocust	GLTR	37
Ilex opaca Aiton	American holly	ILOP	37
Juniperus virginiana L.	eastern red cedar	JUVI	43
Lagerstroemia indica L.	common crapemyrtle	LAIN	42
Liquidambar styraciflua L.	sweetgum	LIST	50
Magnolia grandiflora L.	southern magnolia	MAGR	40
Pinus taeda L.	loblolly pine	PITA	47
Platanus occidentalis L.	American sycamore	PLOC	56
Pyrus calleryana Decne.	Callery pear	PYCA	36
Quercus laurifolia Michx.	laurel oak	QULA2	79

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Quercus nigra L.	water oak	QUNI	68
Quercus phellos L.	willow oak	QUPH	45
Quercus virginiana Mill.	live oak	QUVI	76
Sabal palmetto (Walter) Lodd. ex Schult. & Schult. f.	cabbage palmetto	SAPA	40
Inland Empire (InlEmp):			
Brachychiton populneus (Schott & Endl.) R.Br.	kurrajong	BRPO	37
Cinnamomum camphora (L.) J. Presl	camphor tree	CICA	57
Eucalyptus sideroxylon A. Cunn. ex Woolls	red ironbark	EUSI	37
Fraxinus uhdei (Wenz.) Lingelsh.	evergreen ash	FRUH	37
Fraxinus velutina ‘Modesto’ Torr.	Modesto ash	FRVE_G	36
Ginkgo biloba L.	ginkgo	GIBI	37
Jacaranda mimosifolia D. Don	jacaranda	JAMI	63
Lagerstroemia indica L.	common crapemyrtle	LAIN	61
Liquidambar styraciflua L.	sweetgum	LIST	38
Liriodendron tulipifera L.	tulip tree	LITU	37
Magnolia grandiflora L.	southern magnolia	MAGR	37
Pinus brutia Ten.	Turkish pine; east Mediterranean pine	PIBR2	37
Pinus canariensis C. Sm.	Canary Island pine	PICA	39
Pistacia chinensis Bunge	Chinese pistache	PICH	40
Platanus racemosa Nutt.	California sycamore	PLRA	37
Platanus × acerifolia (Aiton) Willd.	London planetree	PLAC	38
Pyrus calleryana Decne.	Callery pear	PYCA	39
Quercus agrifolia Née	coastal live oak; California live oak	QUAG	37
Quercus ilex L.	holly oak	QUIL2	35
Schinus molle L.	California peppertree	SCMO	37
Schinus terebinthifolius Raddi	Brazilian pepper	SCTE	36
Washingtonia robusta H. Wendl.	Mexican fan palm	WARO	36
Inland Valleys (InlVal):			
Acer saccharinum L.	silver maple	ACSA1	29
Betula pendula Roth	European white birch	BEPE	29
Celtis sinensis Pers.	Chinese hackberry	CESI4	30
Cinnamomum camphora (L.) J. Presl	camphor tree	CICA	31
Fraxinus angustifolia ‘Raywood’ Vahl	Raywood ash	FRAN_R	31
Fraxinus excelsior ‘Hessei’ L.	Hesse ash	FREX_H	27
Fraxinus holotricha Koehne	Moraine ash	FRHO	29

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Fraxinus pennsylvanica Marshall	Marshall ash	FRPE_M	28
Fraxinus velutina Torr.	Modesto ash	FRVE_G	28
Ginkgo biloba L.	ginkgo	GIBI	32
Gleditsia triacanthos L.	honeylocust	GLTR	27
Koelreuteria paniculata Laxm.	goldenrain tree	KOPA	29
Lagerstroemia indica L.	common crapemyrtle	LAIN	26
Liquidambar styraciflua L.	sweetgum	LIST	30
Magnolia grandiflora L.	southern magnolia	MAGR	29
Pinus thunbergii Parl.	Japanese black pine	PITH	26
Pistacia chinensis Bunge	Chinese pistache	PICH	30
Platanus × *acerifolia* (Aiton) Willd.	London planetree	PLAC	27
Prunus cerasifera Ehrh.	cherry plum	PRCE	27
Pyrus calleryana ‘Bradford’ Decne.	Callery pear ‘Bradford’	PYCA_B	30
Quercus ilex L.	holly oak	QUIL2	28
Zelkova serrata (Thunb.) Makino	Japanese zelkova	ZESE	31
Interior West (InterW):			
Chilopsis linearis (Cav.) Sweet	desert willow	CHLI	30
Elaeagnus angustifolia L.	Russian olive	ELAN	30
Fraxinus americana L.	white ash	FRAM	28
Fraxinus angustifolia ‘Raywood’ Vahl	Raywood ash	FRAN2	30
Fraxinus pennsylvanica Marshall	green ash	FRPE	31
Fraxinus velutina Torr.	velvet ash	FRVE	69
Gleditsia triacanthos L.	honeylocust	GLTR	68
Koelreuteria paniculata Laxm.	goldenrain tree	KOPA	28
Malus sp.	apple	MA2	30
Pinus edulis Engelm.	pinyon pine	PIED	29
Pinus nigra Arnold	Austrian pine	PINI	28
Pinus ponderosa Douglas ex P. Lawson & C. Lawson	ponderosa pine	PIPO	30
Pinus sylvestris L.	Scotch pine	PISY	30
Pistacia chinensis Bunge	Chinese pistache	PICH	30
Platanus × *acerifolia* (Aiton) Willd.	London planetree	PLAC	70
Populus angustifolia E. James	narrowleaf cottonwood	POAN	70
Populus fremontii S. Watson	Fremont cottonwood	POFR	70
Prunus cerasifera Ehrh.	cherry plum	PRCE	30
Pyrus calleryana Decne.	Callery pear	PYCA	32
Ulmus pumila L.	Siberian elm	ULPU	70

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Lower Midwest (LoMidW):			
Acer platanoides L.	Norway maple	ACPL	34
Acer rubrum L.	red maple	ACRU	35
Acer saccharinum L.	silver maple	ACSA1	54
Acer saccharum Marsh.	sugar maple	ACSA2	37
Catalpa speciosa (Warder) Warder ex Engelm.	northern catalpa	CASP	49
Celtis occidentalis L.	northern hackberry	CEOC	56
Cercis canadensis L.	eastern redbud	CECA	33
Fraxinus americana L.	white ash	FRAM	55
Fraxinus pennsylvanica Marshall	green ash	FRPE	49
Gleditsia triacanthos L.	honeylocust	GLTR	35
Juglans nigra L.	black walnut	JUNI	34
Malus sp.	apple	MA2	36
Morus sp.	mulberry	MO	48
Picea pungens Engelm.	blue spruce	PIPU	35
Pinus strobus L.	eastern white pine	PIST	39
Populus deltoides Bartram ex Marsh	eastern cottonwood	PODE	59
Pyrus calleryana 'Bradford' Decne.	Callery pear 'Bradford'	PYCA_B	39
Quercus rubra L.	northern red oak	QURU	60
Tilia cordata Mill.	littleleaf linden	TICO	36
Ulmus pumila L.	Siberian elm	ULPU	54
Midwest (MidWst):			
Acer negundo L.	Boxelder	ACNE	43
Acer platanoides L.	Norway maple	ACPL	48
Acer rubrum L.	red maple	ACRU	46
Acer saccharinum L.	silver maple	ACSA1	41
Acer saccharum Marsh.	sugar maple	ACSA2	48
Celtis occidentalis L.	northern hackberry	CEOC	49
Fraxinus americana L.	white ash	FRAM	38
Fraxinus pennsylvanica Marshall	green ash	FRPE	46
Ginkgo biloba L.	ginkgo	GIBI	48
Gleditsia triacanthos L.	honeylocust	GLTR	48
Malus sp.	apple	MA2	50
Quercus palustris Münchh.	pin oak	QUPA	47
Quercus rubra L.	northern red oak	QURU	45
Tilia americana L.	American basswood	TIAM	46
Tilia cordata Mill.	littleleaf linden	TICO	38
Ulmus americana L.	American elm	ULAM	42

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Ulmus pumila L.	Siberian elm	ULPU	37
North (NMtnPr):			
Acer platanoides L.	Norway maple	ACPL	60
Acer saccharinum L.	silver maple	ACSA1	66
Acer saccharum Marsh.	sugar maple	ACSA2	22
Celtis occidentalis L.	northern hackberry	CEOC	67
Fraxinus americana L.	white ash	FRAM	31
Fraxinus pennsylvanica Marshall	green ash	FRPE	65
Gleditsia triacanthos L.	honeylocust	GLTR	64
Gymnocladus dioicus (L.) K. Koch	Kentucky coffeetree	GYDI	31
Malus sp.	apple	MA2	31
Picea pungens Engelm.	blue spruce	PIPU	34
Pinus nigra Arnold	Austrian pine	PINI	33
Pinus ponderosa Douglas ex P. Lawson & C. Lawson	ponderosa pine	PIPO	31
Populus sargentii Dode	plains cottonwood	POSA	54
Prunus sp.	plum	PR	25
Pyrus sp.	pear	PY	29
Quercus macrocarpa Michx.	bur oak	QUMA1	34
Tilia americana L.	American basswood	TIAM	33
Tilia cordata Mill.	littleleaf linden	TICO	34
Ulmus americana L.	American elm	ULAM	61
Ulmus pumila L.	Siberian elm	ULPU	62
Northern California Coast (NoCalC):			
Acacia melanoxylon R. Br.	black acacia	ACME	35
Acer palmatum Thunb.	Japanese maple	ACPA	38
Cinnamomum camphora (L.) J. Presl	camphor tree	CICA	70
Eucalyptus globulus Labill.	blue gum eucalyptus	EUGL	67
Fraxinus velutina Torr.	velvet ash	FRVE	33
Ginkgo biloba L.	ginkgo	GIBI	36
Liquidambar styraciflua L.	sweetgum	LIST	37
Liriodendron tulipifera L.	tulip tree	LITU	34
Magnolia grandiflora L.	southern magnolia	MAGR	38
Pinus radiata D. Don	Monterey pine	PIRA	35
Pistacia chinensis Bunge	Chinese pistache	PICH	37
Pittosporum undulatum Vent.	Victorian box	PIUN	31
Platanus × *acerifolia* (Aiton) Willd.	London planetree	PLAC	70

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Prunus cerasifera Ehrh.	cherry plum	PRCE	31
Pyrus calleryana Decne.	Callery pear	PYCA	30
Pyrus kawakamii Hayata	evergreen pear	PYKA	35
Quercus agrifolia Née	coastal live oak; California live oak	QUAG	66
Robinia pseudoacacia L.	black locust	ROPS	34
Sequoia sempervirens (Lamb. ex D. Don) Endl.	coast redwood	SESE	62
Ulmus americana L.	American elm	ULAM	60
Ulmus parvifolia Jacq.	Chinese elm	ULPA	33
Northeast (NoEast):			
Acer platanoides L.	Norway maple	ACPL	42
Acer rubrum L.	red maple	ACRU	46
Acer saccharinum L.	silver maple	ACSA1	53
Acer saccharum Marsh.	sugar maple	ACSA2	31
Aesculus hippocastanum L.	horsechestnut	AEHI	33
Fraxinus pennsylvanica Marshall	green ash	FRPE	44
Ginkgo biloba L.	ginkgo	GIBI	33
Gleditsia triacanthos L.	honeylocust	GLTR	34
Liquidambar styraciflua L.	sweetgum	LIST	41
Malus sp.	apple	MA2	32
Pinus strobus L.	eastern white pine	PIST	32
Platanus × *acerifolia* (Aiton) Willd.	London planetree	PLAC	53
Pyrus calleryana Decne.	Kwanzan cherry	PRSE2	34
Quercus palustris Münchh.	Callery pear	PYCA	33
Quercus phellos L.	pin oak	QUPA	54
Quercus rubra L.	willow oak	QUPH	33
Tilia cordata Mill.	northern red oak	QURU	51
Tilia tomentosa Moench	littleleaf linden	TICO	48
Ulmus americana L.	silver linden	TITO	30
Zelkova serrata (Thunb.) Makino	American elm	ULAM	40
Acer platanoides L.	Japanese zelkova	ZESE	34
Pacific Northwest (PacfNW):			
Acer macrophyllum Pursh	bigleaf maple	ACMA	40
Acer platanoides L.	Norway maple	ACPL	74
Acer rubrum L.	red maple	ACRU	39
Acer saccharum Marsh.	sugar maple	ACSA2	37
Betula pendula Roth	European white birch	BEPE	41

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Calocedrus decurrens (Torr.) Florin	incense cedar	CADE2	38
Carpinus betulus ‘Fastigiata’ L.	columnar hornbeam	CABEF	39
Crataegus × *lavallei* Hérincq ex Lavallée	Carriere hawthorn	CRLA	74
Fagus sylvatica L.	European beech	FASY	38
Fraxinus latifolia Benth.	Oregon ash	FRLA	39
Liquidambar styraciflua L.	sweetgum	LIST	73
Malus angustifolia (Aiton) Michx.	southern crabapple	PYAN	39
Morus alba L.	white mulberry	MOAL	38
Pinus contorta var. *bolanderi* (Parl.) Vasey	Bolander beach pine	PICO5	39
Populus balsamifera subsp. *Trichocarpa* L.	black cottonwood	POTR2	36
Prunus cerasifera Ehrh.	cherry plum	PRCE	74
Prunus serrulata Lindl.	Kwanzan cherry	PRSE2	38
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir	PSME	39
Quercus rubra L.	northern red oak	QURU	39
Tilia americana L.	American basswood	TIAM	39
Tilia cordata Mill.	littleleaf linden	TICO	40
Ulmus americana L.	American elm	ULAM	41
South (Piedmt):			
Acer rubrum L.	red maple	ACRU	44
Acer saccharinum L.	silver maple	ACSA1	48
Acer saccharum Marsh.	sugar maple	ACSA2	41
Betula nigra L.	river birch	BENI	39
Cornus florida L.	flowering dogwood	COFL	34
Ilex opaca Aiton	American holly	ILOP	34
Juniperus virginiana L.	eastern red cedar	JUVI	39
Lagerstroemia sp.	common crapemyrtle	LA6	40
Liquidambar styraciflua L.	sweetgum	LIST	43
Magnolia grandiflora L.	southern magnolia	MAGR	42
Malus sp.	apple	MA2	29
Pinus echinata Mill.	shortleaf pine	PIEC	36
Pinus taeda L.	loblolly pine	PITA	37
Prunus sp.	plum	PR	36
Prunus yedoensis Matsum.	Yoshino flowering cherry	PRYE	39
Pyrus calleryana Decne.	Callery pear	PYCA	34
Quercus alba L.	white oak	QUAL	47
Quercus nigra L.	water oak	QUNI	45
Quercus phellos L.	willow oak	QUPH	49
Quercus rubra L.	northern red oak	QURU	40

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Ulmus alata Michx.	winged elm	ULAL	32
Inland Valleys (SacVal):			
Cedrus deodara (Roxb. ex D. Don) G. Don	deodar cedar	CEDE	61
Celtis occidentalis L.	northern hackberry	CEOC	37
Celtis sinensis Pers.	Chinese hackberry	CESI4	60
Cinnamomum camphora (L.) J. Presl	camphor tree	CICA	63
Fraxinus velutina Torr.	Modesto ash	FRVE_G	40
Ginkgo biloba L.	ginkgo	GIBI	60
Lagerstroemia indica L.	common crapemyrtle	LAIN	28
Liquidambar styraciflua L.	sweetgum	LIST	44
Liriodendron tulipifera L.	tulip tree	LITU	64
Magnolia grandiflora L.	southern magnolia	MAGR	67
Pistacia chinensis Bunge	Chinese pistache	PICH	38
Platanus × *acerifolia* (Aiton) Willd.	London planetree	PLAC	54
Prunus cerasifera Ehrh.	cherry plum	PRCE	34
Pyrus calleryana Decne.	callery pear	PYCA	31
Quercus agrifolia Née	coastal live oak; California live oak	QUAG	65
Quercus lobata Née	valley oak	QULO	53
Quercus rubra L.	northern red oak	QURU	41
Sequoia sempervirens (Lamb. ex D. Don) Endl.	coast redwood	SESE	52
Ulmus parvifolia Jacq.	Chinese elm	ULPA	62
Zelkova serrata (Thunb.) Makino	Japanese zelkova	ZESE	47
Southern California Coast (SoCalC):			
Callistemon citrinus (Curtis) Skeels	lemon bottlebrush	CACI	31
Cedrus deodara (Roxb. ex D. Don) G. Don	deodar cedar	CEDE	28
Ceratonia siliqua L.	algarrobo Europeo	CESI3	31
Cinnamomum camphora (L.) J. Presl	camphor tree	CICA	29
Cupaniopsis anacardioides (A. Rich.) Radlk.	carrotwood	CUAN	30
Eucalyptus ficifolia F.Muell	red flowering gum	EUFI81	32
Ficus thonningii Blume	figueira benjamin	FIMI	34
Jacaranda mimosifolia D. Don	jacaranda	JAMI	33
Liquidambar styraciflua L.	sweetgum	LIST	33
Magnolia grandiflora L.	southern magnolia	MAGR	33
Melaleuca quinquenervia (Cav.) S.T. Blake	punk tree	MEQU	31
Metrosideros excelsa Sol. ex Gaertn.	New Zealand christmas tree	MEEX	32
Phoenix canariensis Chabaud	Canary Island date palm	PHCA	32

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Pinus canariensis C. Sm.	Canary Island pine	PICA	30
Pittosporum undulatum Vent.	Victorian box	PIUN	36
Podocarpus macrophyllus (Thunb.) Sweet	yew podocarpus	POMA	31
Prunus caroliniana (Mill.) Aiton	Carolina laurelcherry	PRCA	32
Schinus terebinthifolius Raddi	Brazilian pepper	SCTE	31
Tristaniopsis conferta L.A.S.Johnson & K.D.Hill	Brisbane box	TRCO	28
Washingtonia robusta H. Wendl.	Mexican fan palm	WARO	30
Southwest Desert (SWDsrt):			
Acacia farnesiana L.	sweet acacia	ACFA	31
Acacia salicina Lindl.	willow acacia	ACSA3	37
Brachychiton populneus (Schott & Endl.) R.Br.	kurrajong	BRPO	35
Chilopsis linearis (Cav.) Sweet	desert willow	CHLI	34
Eucalyptus microtheca F. Muell.	coolibah tree	EUMI2	36
Fraxinus uhdei (Wenz.) Lingelsh.	evergreen ash	FRUH	32
Fraxinus velutina Torr.	velvet ash	FRVE	59
Morus alba L.	white mulberry	MOAL	39
Olea europaea L.	olive	OLEU	36
Parkinsonia aculeata L.	Jerusalem thorn	PAAC	34
Parkinsonia florida (Benth. ex A. Gray) S. Watson	blue paloverde	CEFL	32
Phoenix dactylifera L.	date palm	PHDA4	56
Pinus eldarica Medw.	Afghan pine	PIEL2	30
Pinus halepensis Mill.	Aleppo pine	PIHA	34
Pistacia chinensis Bunge	Chinese pistache	PICH	33
Prosopis chilensis (Molina) Stuntz	algarrobo	PRCH	31
Quercus virginiana Mill.	live oak	QUVI	36
Rhus lancea L.f.	African sumac	RHLA	32
Ulmus parvifolia Jacq.	Chinese elm	ULPA	36
Washintonia filifera (Linden) Wendl.	California palm	WAFI	71
Washingtonia robusta H. Wendl.	Mexican fan palm	WARO	63
Temperate Interior West (TpIntW):			
Acer platanoides L.	Norway maple	ACPL	62
Acer saccharinum L.	silver maple	ACSA1	58
Acer saccharum Marsh.	sugar maple	ACSA2	30
Catalpa speciosa (Warder) Warder ex Engelm.	northern catalpa	CASP	59
Crataegus sp.	hawthorn	CR	33
Fraxinus americana L.	white ash	FRAM	32
Fraxinus pennsylvanica Marshall	green ash	FRPE	60

Table 5—Numbers of trees sampled by species and region (continued)

Scientific name	Common name	SpCode	Samples
Gleditsia triacanthos L.	honeylocust	GLTR	33
Juglans nigra L.	black walnut	JUNI	57
Liquidambar styraciflua L.	sweetgum	LIST	33
Malus sp.	apple	MA2	30
Picea pungens Engelm.	blue spruce	PIPU	29
Pinus sylvestris L.	Scotch pine	PISY	29
Platanus × *acerifolia* (Aiton) Willd.	London planetree	PLAC	64
Platanus occidentalis L.	American sycamore	PLOC	48
Pyrus calleryana Decne.	Callery pear	PYCA	34
Quercus rubra L.	northern red oak	QURU	56
Robinia pseudoacacia L.	black locust	ROPS	62
Tilia americana L.	American basswood	TIAM	59
Ulmus pumila L.	Siberian elm	ULPU	55
Tropical (Tropic):			
Bauhinia × *blakeana* Dunn	Hong Kong orchid tree	BABL	37
Calophyllum inophyllum L.	kamani	CAIN4	62
Cassia × *nealiae* H. S. Irwin & Barneby	rainbow shower tree	CANE33	41
Casuarina equisetifolia L.	Australian pine	CAEQ	62
Citharexylum spinosum L.	fiddlewood	CISP2	35
Cocos nucifera L.	coconut palm	CONU	34
Conocarpus erectus L. var. *argenteus* Millsp.	silver buttonwood	COERA2	37
Cordia subcordata Lam.	kou	COSU2	33
Delonix regia (Bojer) Raf.	royal poinciana	DERE	59
Elaeodendron orientale Jacq.	false olive	ELOR2	34
Ficus benjamina L.	Benjamin fig	FIBE	60
Filicium decipiens (Wight & Arn.) Thwaites	fern tree	FIDE6	35
Ilex paraguariensis A. St.-Hil.	Paraguay tea	ILPA2	36
Lagerstroemia speciosa (L.) Pers.	giant crapemyrtle	LASP	37
Melaleuca quinquenervia (Cav.) S.T. Blake	punk tree	MEQU	59
Samanea saman (Jacq.) Merr.	monkeypod	PISA2	62
Swietenia mahagoni (L.) Jacq.	West Indian mahogany	SWMA	54
Tabebuia aurea (Silva Manso) Benth. & Hook. f. ex S.	silver trumpet tree	TAAR	37
Tabebuia heterophylla (DC.) Britton	pink trumpet tree	TAPA	36
Tabebuia ochracea (Cham.) Standl. subsp. *neochrysantha* (A.H. Gentry) A.H. Gentry	golden trumpet tree	TACH	36
Veitchia merrillii H.E. Moore	Christmas palm	VEME	32
Total			14,487

SpCode = four- to six-letter code consisting of the first two letters of the genus name and the first two letters of the species name followed by two optional letters to distinguish two species with the same four-letter code.

Appendix 2: Field Data Collection Protocols

The following data will be recorded for each tree (note: highlighted fields 1 through 9 will be uploaded from inventory onto your palmtop and are for locating trees. You will collect data for the remaining items:

1. TreeID—from inventory, unique number assigned to each tree by city in inventory.
2. SpCode—four- to six-letter code consisting of the first two letters of the genus name and the first two letters of the species name followed by two optional letters to distinguish two species with the same four-letter code.
3. AddressNum–from inventory, street number of building where tree is located.
4. Street–from inventory, the name of the street on which the tree is located–from inventory.
5. Side—from inventory, indicates side of building or lot on which the tree is located (see fig. 10):
   F = front
   M = median
   S = side
   P = park
6. Cell—from inventory, the cell number where the tree is located (1, 2, 3, etc). Obtain city inventory protocols to determine what order the trees are numbered in (e.g., sometimes they are assigned in driving direction or, alternatively, as street number increases, depending upon city).
7. OnStree—from inventory (omit if not included as a field in city's inventory), for trees at corner addresses when the tree is actually on a cross street rather than the addressed street (see fig. 10).
8. FromStreet/ToStreet—from inventory, the names of the cross streets that form boundaries for trees lining unaddressed boulevards. For example, on boulevards that have no development adjacent to them, therefore no obvious parcel addressing, trees are typically numbered in order. By including closest cross streets in the inventory, one will not have to begin counting trees from No. 1 in order to locate No. 333, which is 10 blocks up the boulevard from No. 1.

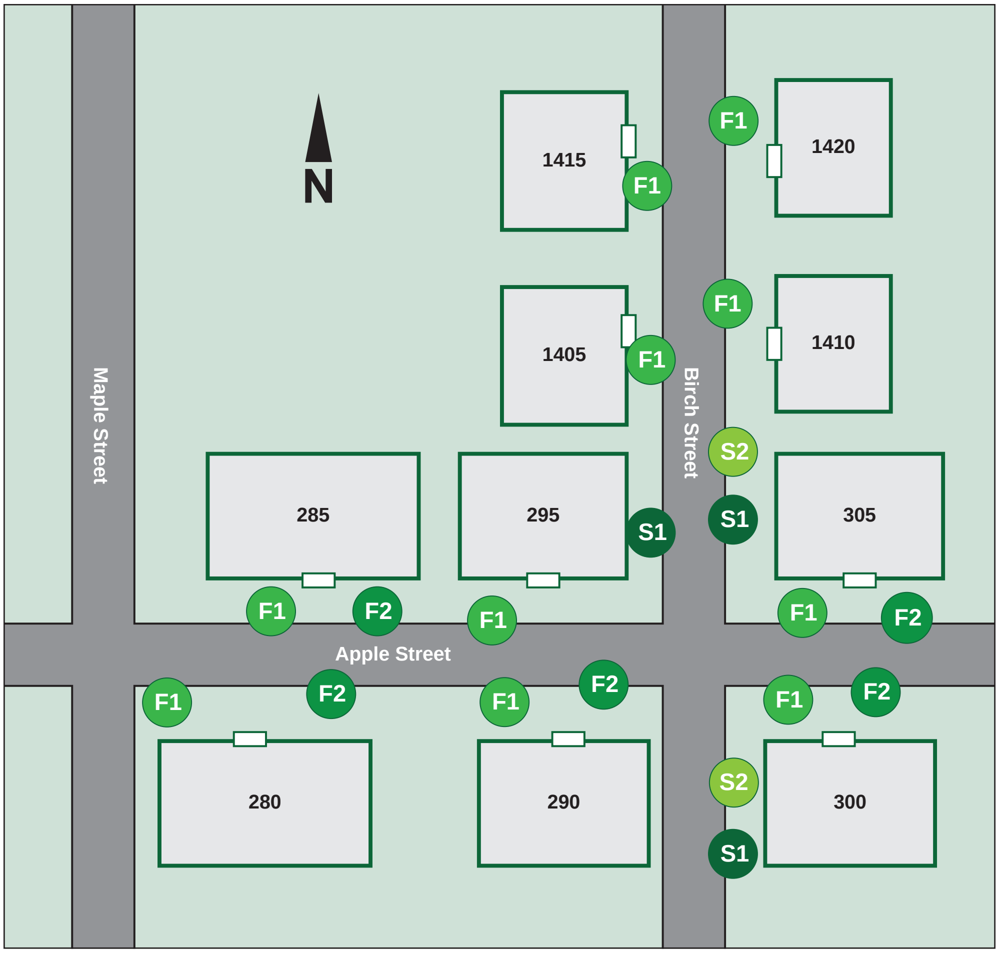

Figure 10—Treeloc tree 295 Apple S1 is actually the first tree (in driving direction) on Birch Street side of house.

9. DBHinv—the diameter at breast height (d.b.h.) from the city inventory, usually expressed as classes from one to nine, but class system specific to city. Sometimes expressed as d.h.h. to nearest inch or centimeter. Data are used to help locate the desired size of tree in the field for sampling.
10. Diameter at breast height—measure the d.b.h. (1.37 m) to nearest 0.1 cm (tape). Where possible for multistemmed trees forking below 1.37 m, measure above the butt flare and below the point where the stem begins forking. When this is not possible, measure diameter root collar (DRC) as described below. Saplings (d.b.h./DRC 2.54 to 12.5 cm) will be measured at 1.37 m unless falling under multistemmed/unusual stem categories requiring DRC measurements (per Forest Health Monitoring (FHM) Field Methods Guide).

DIAMETER at ROOT COLLAR–adapted from Forest Health and Monitoring (FHM) Field Methods Guide:
For species requiring DRC, measure the diameter at the ground line or at the stem root collar, whichever is higher. For these trees, treat clumps of stems having a unified crown and common rootstock as a single tree; examples include mesquite and juniper. For multistemmed trees, compute and record a cumulative DRC (see below); record individual stem diameters and a stem status (live or dead) on a separate form or menu as required.

Measuring DRC: Before measuring DRC, remove the loose material on the ground (e.g., litter) but not mineral soil. Measure just above any swells present, and in a location where the diameter measurements are reflective of the volume above the stems (especially when trees are extremely deformed at the base).

Stems must be at least 0.3 m in length and 2.54 cm in diameter at breast height to qualify for measurement; stems that are missing owing to cutting or damage are not included in measurement.

Additional instructions for DRC measurements are illustrated in figure 11.

Computing and recording DRC: For all tally trees requiring DRC, with at least one stem 2.54 cm in diameter or larger at the root collar, DRC is computed as the square root of the sum of the squared stem diameters. For a single-stemmed DRC tree, the computed DRC is equal to the single diameter measured.

Use the following formula to compute DRC:

DRC = SQRT [SUM (stem diameter^2)]

Round the result to the nearest 2.54 cm. For example, a multistemmed woodland tree with stems of 12.2, 13.2, 3.8, and 22.1 would be calculated as:

DRC = SQRT ($12.2^2 + 13.2^2 + 3.8^2 + 22.1^2$)

= SQRT (825.93)

= 28.74

= 28.7

11. TreeHt—from ground level to treetop to nearest 0.5 m (omit erratic leader as shown in fig. 12 with rangefinder).
12. CrnBase—with rangefinder, average distance between ground and lowest foliage layer (omitting erratic branch) to nearest 0.5 m.
13. CDiaPar—(crown diameter) crown diameter measurement taken to the nearest 0.5 m parallel to the street. The occasional erratic branch should not be included (see fig. 13).
14. CDiaPerp—(crown diameter) crown diameter measurement taken to the nearest 0.5 m perpendicular to the treet. The occasional erratic branch should not be included (see fig. 13).

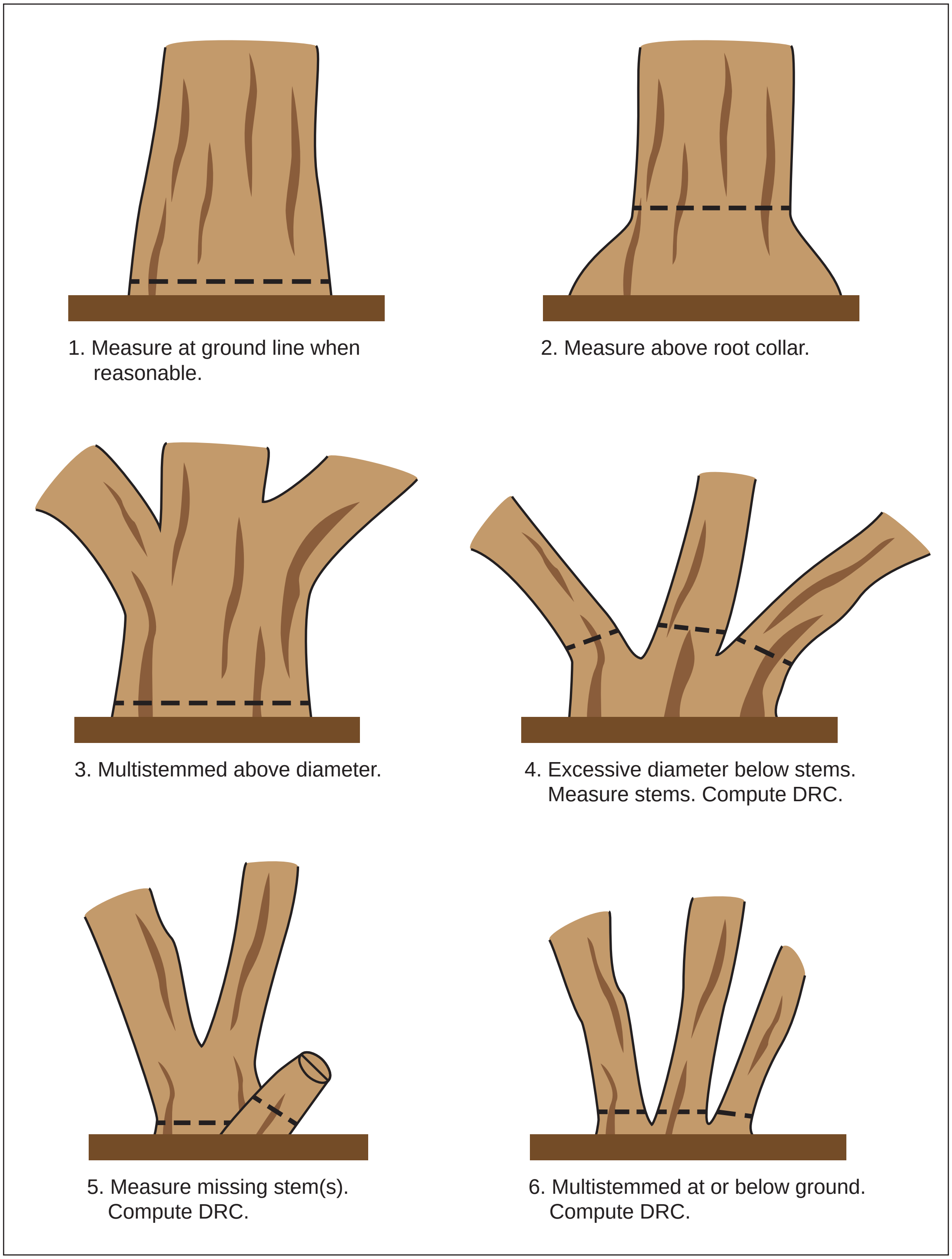

Figure 11—How to measure Diameter at Root Collar (DRC) in a variety of situation.

Pacific Southwest Research Station

Figure 12—Tree with erratic leader that should not be included in height measurement.

Pacific Southwest Research Station

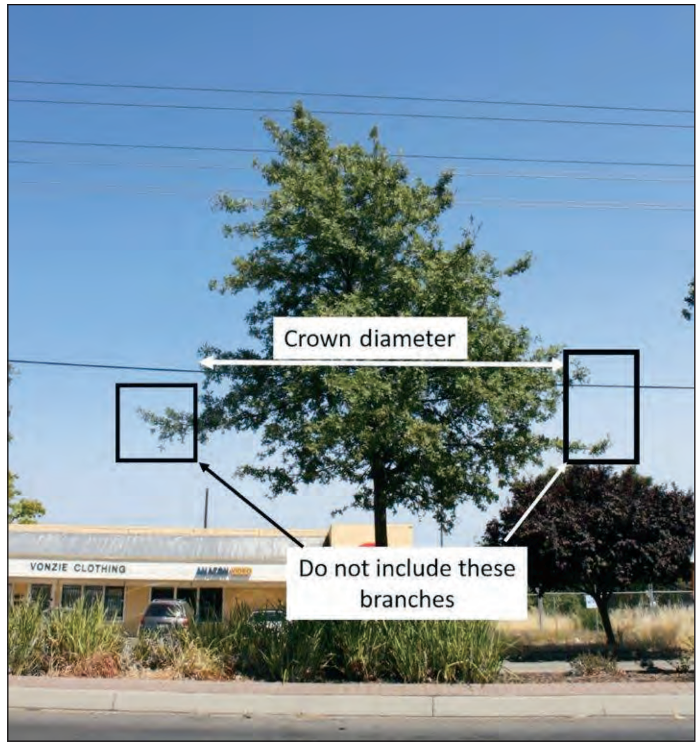

Figure 13—Erratic branch (in box at left) is omitted from crown diameter measurement. Distance measured is represented by white line.

15. Setback—distance from the tree to the nearest air conditioned/heated space (be aware that this may not be the same address as the tree location).
    Evaluate as:
    1 = 0 to 8 m
    2 = 8.1 to 12 m
    3 = 12.1 to 18 m
    4 = >18 m
    Use: assess effects of shade on energy use.
16. TreeOr—Tree orientation—taken with compass, as in figure 14 the coordinate of tree taken from imaginary lines extending from walls of the nearest conditioned space (heated or airconditioned space—may not be same address as tree location):
17. CarShade—Number of autos where any portion of any parked automotive vehicle is under the tree's drip line. Car must be present:
    0 = no autos
    1 = one auto
    2 = two autos, etc.
    Use: vehicle hydrocarbon emissions reduction.

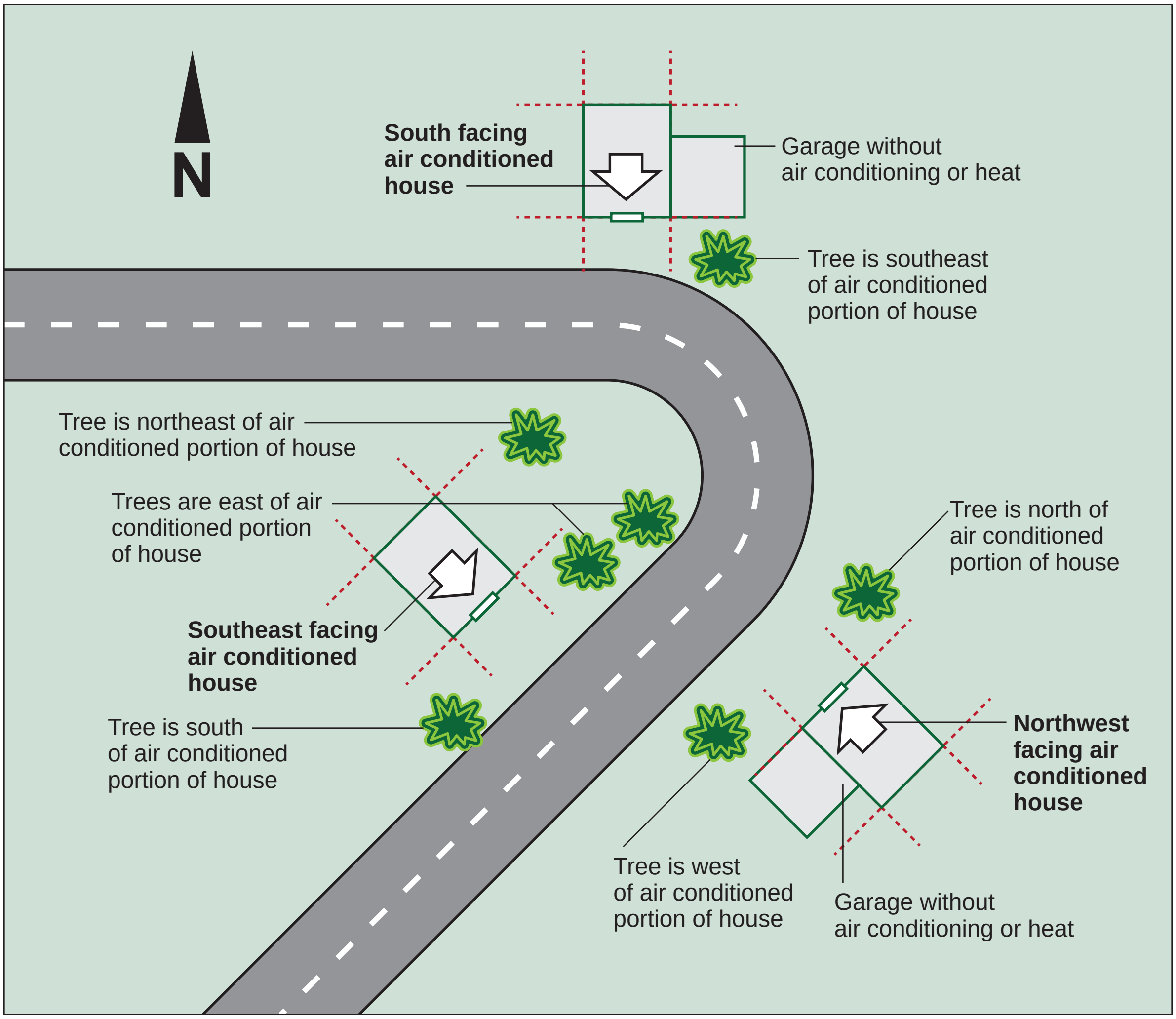

Figure 14—Shows imaginary lines extending from walls and associated tree orientation

18. Land use—Area where tree is growing:
    1 = single-family residential
    2 = multifamily residential (duplex, apartments, condos)
    3 = industrial/institutional/large commercial (schools, government, hospitals)
    4 = park/vacant/other (agricultural, unmanaged riparian areas of greenbelts)
    5 = small commercial (minimart, retail boutiques, etc.)
    6 = transportation corridor.
    Use: energy, property value.

19. Shape–visual estimate of crown shape verified when different from each side with actual measured dimensions of crown height and average crown diameter. If in doubt, determine shape using average crown diameter and crown height measurements. See figure 15. Use: energy (shadow patterns)
20. 1 = cylinder = maintains same crown diameter in top and bottom thirds of tree
21. 2 = ellipsoid (horizontal or vertical; also includes spherical)—for ellipse the tree's center (whether vertical or horizontal) should be the widest)
22. 3 = paraboloid—widest in bottom third of crown
23. 4 = upside down paraboloid—widest in top third of crown
24. WireConf—utility lines that interfere with or appear above tree
    0 = no lines
    1 = present and no potential conflict
    2 = present and conflicting
    3 = present and potential for conflicting
25. Image1—select position for best possible photo of tree crown, keeping in mind that you must try to obtain two perpendicular views of the tree that are as free of background noise as possible. Try to position yourself so the tree crown is as isolated as possible from neighboring tree crowns and other crowns in background:
26. Distance from tree that photo is taken at increments of 5 m (5, 10, 15, 20 m, etc) and accurate within 0.05 m.
27. Camera zoom should be set to full wide angle
28. First image must include entire tree (bole and crown) for backup measurements and should fill as much of viewfinder as possible
29. Kneel to take images so more sky is included in background
30. Dist1—Measure distance from camera back (the point where image is actually recorded) to point equivalent to center of tree bole (fig. 16). Measure accurately within 0.05 m.
31. Image2—taken as perpendicularly (90°) as possible to Image 1.
32. Dist2—distance as per Dist1 for Image 2.
33. PlantDate—Date tree was planted. As you collect data, talk with residents and see if you can find name and address of the oldest person on street or in neighborhood, or if residents know age of tree. We will review methods for aging trees during training.
34. Notes: any pertinent notes—if tree is replacement and what tree was replaced—give address of replacement tree.
35. dbh1, dbh2, dbh3, etc., are for individual stem diameter entries for multi-stemmed trees being recorded using DRC methods. These cells are linked to the formula in field #10 (d.b.h.) column calculating the final d.b.h.

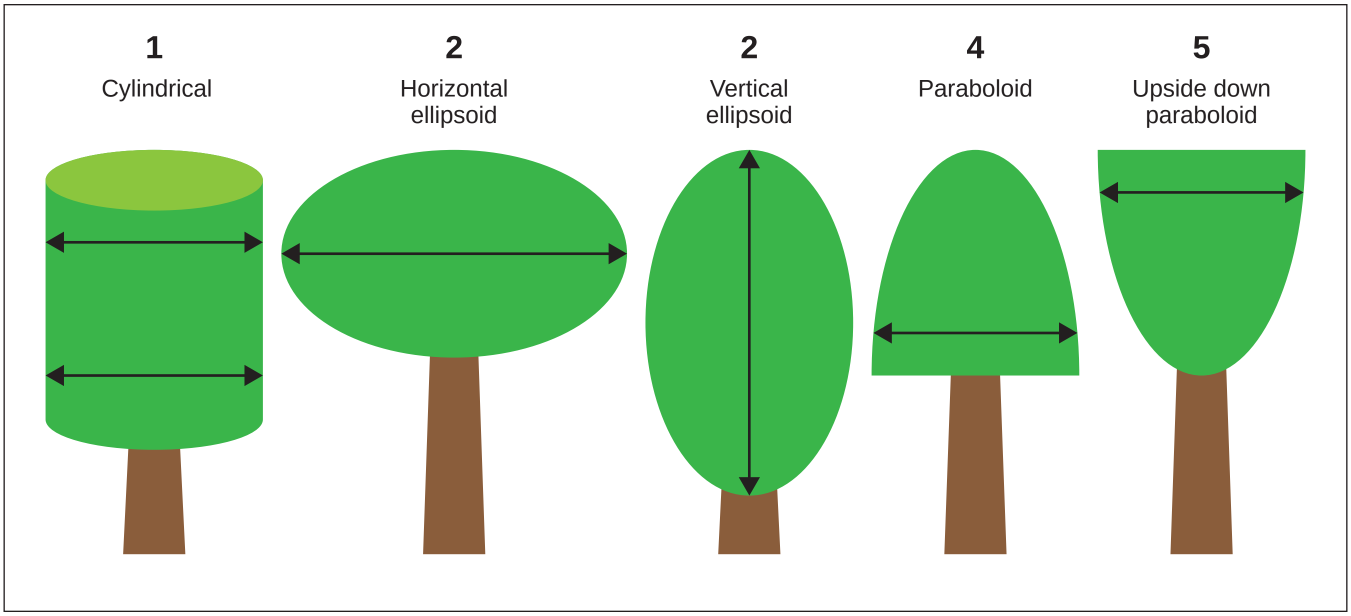

Figure 15—Shapes of tree crowns.

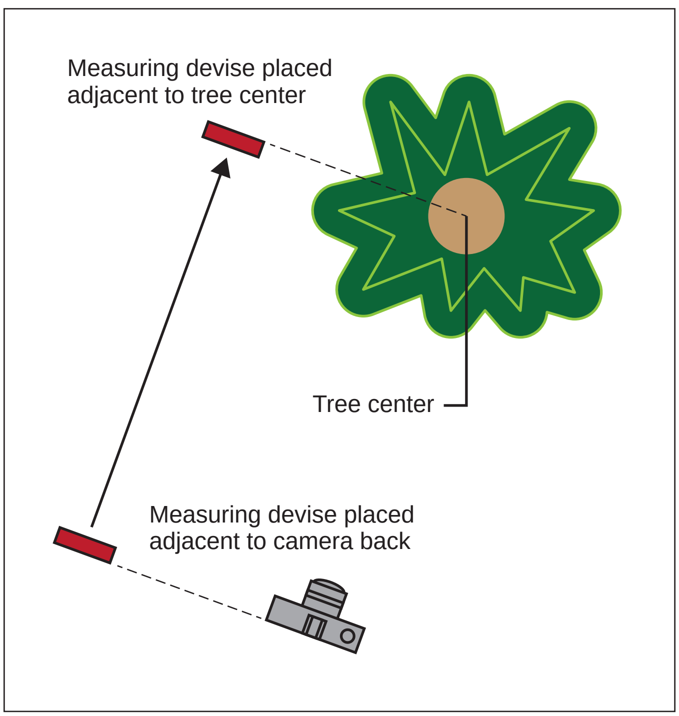

Figure 16—Showing how to measure distance (in 5-m increments) between camera back and tree center.

Appendix 3: Foliar Biomass

Table 6 shows the mean and standard deviations for dry-weight to fresh-weight ratios for foliar biomass and the average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region. Average foliar biomass factors range from a low of 76.1 g/m^2 for climate zone MidWst to a high of 222.7 g/m^2 for TpIntW. Across climate zones, there is a range of average foliar biomass factor values by species tree type from a high of 481.9 g/m^2 in large conifer evergreen species to a low of 99.3 g/m^2 in large broadleaf deciduous species. Within climate zones, there is also high variability, influenced by tree type. For example, although the average foliar biomass factor for NoCalC is 214.4 g/m^2, the range is from a high of 659.7 g/m^2 (driven by *Sequoia sempervirens* and *Pinus radiata*, both factors over 500.0 g/m^2) to a low of 73.2 g/m^2 *Prunus cerasifera*. It is important to note the sample number (n) and documented sampling notes when applying these data. Foliar samples were not collected in four of the reference cities (InlVal, InterW, PacfNW, SacVal).

Table 6—Average dry-weight to fresh-weight (dw:fw) ratios for foliar biomass and average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region

Region[a]	SpCode[b]	Avg dw/fw (g)	dw/fw SD	Avg dw g/m^2	dw g/m^2 SD	No.
CenFla	ACRU	0.46	0.04	102.75	12.28	10
CenFla	CICA	0.48	0.04	116.42	6.64	10
CenFla	ERJA	0.41	0.06	162.48	26.87	10
CenFla	JUSI	0.50	0.03	405.68	48.08	10
CenFla	KOELFO	0.49	0.04	68.35	12.55	10
CenFla	LAIN	0.34	0.03	81.38	18.16	10
CenFla	LIST	0.31	0.02	93.74	15.48	10
CenFla	MAGR	0.35	0.03	144.87	22.25	10
CenFla	PIEL	0.44	0.01	107.74	11.50	10
CenFla	PLOC	0.38	0.04	74.60	13.45	10
CenFla	THOR	0.42	0.01	207.09	29.85	10
CenFla	PRCA	0.45	0.05	118.66	19.20	10
CenFla	QULA2	0.48	0.01	117.81	37.87	10
CenFla	QUSH	0.50	0.02	110.12	16.49	10
CenFla	QUVI	0.49	0.04	135.18	51.85	10
CenFla	SAPA	0.41	0.16	207.21	83.86	7
CenFla	SYRO	0.46	0.03	132.76	59.85	7
CenFla	TRSE6	0.36	0.03	73.87	10.81	10
CenFla	ULPA	0.42	0.04	130.78	37.30	10

Table 6—Average dry-weight to fresh-weight (dw:fw) ratios for foliar biomass and average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region (continued)

Region[a]	SpCode[b]	Avg dw/fw (g)	dw/fw SD	Avg dw g/m^2	dw g/m^2 SD	No.
CenFla	WARO	0.42	0.07	149.50	18.68	4
GulfCo	ACRU	0.32	0.02	72.68	14.58	10
GulfCo	BUCA	0.71		331.74		1
GulfCo	CAIL	0.45	0.03	104.35	16.85	10
GulfCo	CELA	0.33	0.04	58.41	11.16	10
GulfCo	COFL	0.39	0.03	78.34	21.27	10
GulfCo	GLTR	0.40	0.03	159.31	142.22	10
GulfCo	ILOP	0.52	0.02	206.95	13.51	10
GulfCo	JUVI	0.45	0.02	357.56	46.51	10
GulfCo	LAIN	0.30	0.03	78.58	13.71	10
GulfCo	LIST	0.35	0.04	98.90	24.22	10
GulfCo	MAGR	0.43	0.02	221.77	17.98	10
GulfCo	PITA	0.39	0.01	572.86	25.14	10
GulfCo	PLOC	0.40	0.06	71.94	15.67	10
GulfCo	PYCA	0.49	0.02	154.87	22.36	10
GulfCo	QULA2	0.53	0.02	135.55	14.41	10
GulfCo	QUNI	0.53	0.01	147.77	14.32	10
GulfCo	QUPH	0.50	0.03	100.79	10.68	10
GulfCo	QUVI	0.52	0.01	255.19	197.58	10
GulfCo	SAPA	0.63		303.42		1
InlEmp	BRPO	0.35		122.79		20
InlEmp	CICA	0.46		176.12		20
InlEmp	EUSI	0.47		179.20		20
InlEmp	FRUH	0.45		164.23		20
InlEmp	FRVE	0.53		144.64		20
InlEmp	GIBI	0.41		176.63		20
InlEmp	JAMI	0.36		114.76		20
InlEmp	LAIN	0.46		256.51		20
InlEmp	LIST	0.46		145.46		20
InlEmp	LITU	0.34		89.61		20
InlEmp	MAGR	0.54		289.27		20
InlEmp	PIBR2	0.36		446.89		20
InlEmp	PICA	0.50		342.79		20
InlEmp	PICH	0.45		118.87		20
InlEmp	PLAC	0.55		128.41		20
InlEmp	PLRA	0.56		139.39		20
InlEmp	PYCA	0.59		186.43		20
InlEmp	QUAG	0.52		358.25		20

Table 6—Average dry-weight to fresh-weight (dw:fw) ratios for foliar biomass and average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region (continued)

Region[a]	SpCode[b]	Avg dw/fw (g)	dw/fw SD	Avg dw g/m^2	dw g/m^2 SD	No.
InlEmp	QUIL2	0.60		202.39		20
InlEmp	SCMO	0.31		166.69		20
InlEmp	SCTE	0.43		153.77		20
InlEmp	WARO	0.47	0.05	271.45	52.90	4
LoMidW	ACPL	0.31	0.12	101.52	53.63	10
LoMidW	ACRU	0.32	0.05	108.69	16.68	10
LoMidW	ACSA1	0.29	0.07	85.92	15.37	10
LoMidW	ACSA2	0.38	0.06	122.58	30.86	10
LoMidW	CASP	0.25	0.03	72.01	16.29	10
LoMidW	CEOC	0.31	0.05	72.60	13.00	10
LoMidW	CECA	0.27	0.04	95.05	9.89	10
LoMidW	FRAM	0.37	0.02	102.43	16.89	10
LoMidW	FRPE	0.33	0.04	116.06	22.56	10
LoMidW	GLTR	0.32	0.07	114.58	29.89	10
LoMidW	JUNI	0.30	0.03	87.52	10.82	10
LoMidW	MA2	0.23	0.07	105.13	21.14	10
LoMidW	MO	0.26	0.04	99.88	22.03	10
LoMidW	PIPU	0.42	0.04	340.97	169.38	10
LoMidW	PIST	0.34	0.03	250.60	32.06	10
LoMidW	PODE	0.28	0.03	122.01	20.47	10
LoMidW	PYCA	0.30	0.03	115.70	25.59	10
LoMidW	QURU	0.34	0.05	109.22	21.66	10
LoMidW	TICO	0.28	0.06	100.13	37.61	10
LoMidW	ULPU	0.26	0.05	106.42	13.37	10
MidWst	ACNE	0.30	0.03	52.94	10.21	10
MidWst	ACPL	0.39	0.03	49.84	7.50	10
MidWst	ACRU	0.46	0.02	83.29	11.79	10
MidWst	ACSA1	0.44	0.03	85.83	14.78	10
MidWst	ACSA2	0.42	0.04	53.62	11.55	10
MidWst	CEOC	0.40	0.02	68.23	6.79	10
MidWst	FRAM	0.40	0.03	71.40	15.16	10
MidWst	FRPE	0.34	0.03	68.62	13.05	10
MidWst	GIBI	0.31	0.03	91.24	14.10	10
MidWst	GLTR	0.39	0.02	89.52	12.86	10
MidWst	MA2	0.40	0.05	67.53	20.50	10
MidWst	QUPA	0.44	0.02	84.97	10.85	10
MidWst	QURU	0.45	0.02	85.06	16.44	10

Table 6—Average dry-weight to fresh-weight (dw:fw) ratios for foliar biomass and average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region (continued)

Region[a]	SpCode[b]	Avg dw/fw (g)	dw/fw SD	Avg dw g/m^2	dw g/m^2 SD	No.
MidWst	TIAM	0.37	0.03	77.04	22.04	10
MidWst	TICO	0.35	0.03	57.33	15.11	10
MidWst	ULAM	0.36	0.02	82.30	9.63	10
MidWst	ULPU	0.41	0.02	124.67	18.41	10
NMtnPr	ACPL	0.40	0.03	68.23	19.36	10
NMtnPr	ACSA1	0.48	0.09	83.03	29.01	10
NMtnPr	ACSA2	0.36	0.06	75.73	11.58	10
NMtnPr	CEOC	0.45	0.04	76.18	16.71	10
NMtnPr	FRAM	0.42	0.06	74.91	11.40	10
NMtnPr	FRPE	0.39	0.08	84.76	20.89	10
NMtnPr	GLTR	0.44	0.03	96.98	21.79	10
NMtnPr	GYDI	0.36	0.03	58.25	13.26	10
NMtnPr	MA2	0.31	0.09	54.94	13.70	10
NMtnPr	PIPU	0.45	0.01	428.00	29.51	10
NMtnPr	PINI	0.43	0.04	411.32	41.37	10
NMtnPr	PIPO	0.44	0.02	399.01	31.95	10
NMtnPr	POSA	0.27	0.04	70.73	12.52	10
NMtnPr	PR	0.41	0.09	71.12	15.74	10
NMtnPr	PY	0.42	0.02	120.06	14.26	10
NMtnPr	QUMA1	0.53	0.11	122.42	14.97	10
NMtnPr	TIAM	0.33	0.03	69.46	8.30	10
NMtnPr	TICO	0.33	0.07	57.75	14.78	10
NMtnPr	ULAM	0.43	0.04	84.33	22.85	10
NMtnPr	ULPU	0.33	0.04	70.29	15.34	10
NoCalC	ACME	0.56	0.05	219.54	23.17	10
NoCalC	ACPA	0.51	0.02	90.67	10.69	10
NoCalC	CICA	0.53	0.05	167.57	18.93	9
NoCalC	EUGL	0.55	0.03	338.48	28.62	10
NoCalC	FRVE	0.60	0.05	184.02	18.19	10
NoCalC	GIBI	0.38	0.02	156.00	60.01	10
NoCalC	LIST	0.48	0.04	125.75	18.38	10
NoCalC	LITU	0.36	0.01	83.00	5.16	10
NoCalC	MAGR	0.48	0.02	232.77	15.65	10
NoCalC	PIRA	0.52	0.03	762.71	127.18	10
NoCalC	PICH	0.51	0.04	143.94	25.88	10
NoCalC	PIUN	0.49	0.01	149.41	11.55	10
NoCalC	PLAC	0.42	0.14	107.74	12.69	10

Table 6—Average dry-weight to fresh-weight (dw:fw) ratios for foliar biomass and average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region (continued)

Region[a]	SpCode[b]	Avg dw/fw (g)	dw/fw SD	Avg dw g/m^2	dw g/m^2 SD	No.
NoCalC	PRCE	0.45	0.02	73.19	27.38	10
NoCalC	PYCA	0.57	0.03	175.06	34.38	10
NoCalC	PYKA	0.58	0.09	243.93	48.81	10
NoCalC	QUAG	0.60	0.02	251.98	9.65	10
NoCalC	ROPS	0.42	0.03	86.20	8.34	10
NoCalC	SESE	0.52	0.03	556.77	94.40	10
NoCalC	ULAM	0.79	1.19	160.98	243.30	9
NoCalC	ULPA	0.46	0.01	192.29	16.69	10
NoEast	ACPL	0.41	0.04	62.05	18.87	10
NoEast	ACRU	0.37	0.13	72.68	16.10	10
NoEast	ACSA1	0.41	0.04	89.82	18.86	10
NoEast	ACSA2	0.44	0.02	80.77	13.07	10
NoEast	AEHI	0.43	0.06	85.38	10.89	10
NoEast	FRPE	0.44	0.02	109.44	12.42	10
NoEast	GIBI	0.35	0.08	130.59	31.82	10
NoEast	GLTR	0.44	0.03	124.66	21.56	10
NoEast	LIST	0.35	0.08	93.78	25.84	10
NoEast	MA2	0.50	0.05	109.68	23.11	10
NoEast	PIST	0.38	0.10	717.94	376.53	10
NoEast	PLAC	0.41	0.01	110.02	20.02	10
NoEast	PRSE2	0.43	0.03	99.32	19.35	10
NoEast	PYCA	0.46	0.06	130.15	35.72	10
NoEast	QUPA	0.45	0.05	88.17	28.31	10
NoEast	QUPH	0.46	0.03	183.61	278.65	10
NoEast	QURU	0.46	0.03	96.79	24.42	10
NoEast	TICO	0.38	0.04	141.78	236.15	10
NoEast	TITO	0.38	0.01	73.85	8.99	10
NoEast	ULAM	0.40	0.01	99.77	20.85	10
NoEast	ZESE	0.45	0.05	73.05	39.55	10
Piedmt	ACRU	0.44	0.04	86.92	21.30	10
Piedmt	ACSA1	0.40	0.03	84.77	9.26	10
Piedmt	ACSA2	0.36	0.12	57.99	30.52	10
Piedmt	BENI	0.35	0.07	69.63	15.32	10
Piedmt	COFL	0.35	0.05	54.49	14.71	10
Piedmt	ILOP	0.34	0.05	124.53	32.68	10
Piedmt	JUVI	0.40	0.02	559.08	78.10	10
Piedmt	LA6	0.32	0.03	112.76	18.18	10

Table 6—Average dry-weight to fresh-weight (dw:fw) ratios for foliar biomass and average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region (continued)

Region[a]	SpCode[b]	Avg dw/fw (g)	dw/fw SD	Avg dw g/m^2	dw g/m^2 SD	No.
Piedmt	LIST	0.33	0.04	80.11	20.74	10
Piedmt	MAGR	0.40	0.04	165.31	26.11	10
Piedmt	MA2	0.28	0.06	57.71	19.52	10
Piedmt	PIEC	0.38	0.02	706.35	201.79	10
Piedmt	PITA	0.39	0.03	525.79	98.03	10
Piedmt	PR	0.29	0.05	57.86	17.15	10
Piedmt	PRYE	0.40	0.05	116.85	28.23	10
Piedmt	PYCA	0.37	0.08	113.74	41.72	10
Piedmt	QUAL	0.42	0.05	73.03	17.37	10
Piedmt	QUNI	0.44	0.08	91.73	20.63	10
Piedmt	QUPH	0.42	0.04	86.21	18.50	10
Piedmt	QURU	0.42	0.06	71.81	16.01	10
Piedmt	ULAL	0.50	0.03	84.65	16.63	10
SoCalC	CACI			204.01		10
SoCalC	CEDE			390.93	11.19	3
SoCalC	CESI3			233.23	22.20	3
SoCalC	CICA			129.86		1
SoCalC	CUAN			178.53	20.01	3
SoCalC	FIMI			141.50	7.04	3
SoCalC	JAMI			115.85		1
SoCalC	LIST			124.00	4.85	3
SoCalC	MAGR			235.45	13.78	3
SoCalC	MEQU			201.99		1
SoCalC	MEEX			219.06		1
SoCalC	PHCA			226.15		1
SoCalC	PIBR2	0.36		446.89		1
SoCalC	PICA			371.31		1
SoCalC	PIUN			143.46		1
SoCalC	POMA			200.41	13.34	2
SoCalC	SCTE			121.99		1
SoCalC	TRCO			174.30		1
SoCalC	WARO			216.16		1
SWDsrt	ACFA	0.48	0.08	178.75	42.23	10
SWDsrt	ACSA3	0.32	0.02	187.23	16.85	10
SWDsrt	BRPO	0.37	0.02	86.14	6.40	10
SWDsrt	CHLI	0.40	0.02	159.62	25.89	10
SWDsrt	EUMI2	0.48	0.08	145.29	12.16	10

Table 6—Average dry-weight to fresh-weight (dw:fw) ratios for foliar biomass and average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region (continued)

Region[a]	SpCode[b]	Avg dw/fw (g)	dw/fw SD	Avg dw g/m^2	dw g/m^2 SD	No.
SWDsrt	FRUH	0.47	0.02	126.35	11.21	10
SWDsrt	FRVE	0.44	0.02	120.11	13.48	10
SWDsrt	MOAL	0.49	0.04	153.46	30.14	10
SWDsrt	OLEU	0.52	0.02	256.39	18.88	10
SWDsrt	PAAC	0.40	0.06	586.32	126.61	10
SWDsrt	CEFL	0.51	0.05	181.85	40.64	10
SWDsrt	PHDA4	0.68	0.02	309.49	5.62	2
SWDsrt	PIEL2	0.43	0.02	452.68	142.21	10
SWDsrt	PIHA	0.47	0.02	515.04	199.92	10
SWDsrt	PICH	0.47	0.06	132.31	27.57	10
SWDsrt	PRCH	0.45	0.03	177.36	21.06	10
SWDsrt	QUVI	0.52	0.10	185.64	29.68	10
SWDsrt	RHLA	0.46	0.04	132.57	15.47	10
SWDsrt	ULPA	0.53	0.01	203.71	20.19	10
SWDsrt	WAFI	0.52	0.01	193.01	27.01	2
SWDsrt	WARO	0.54	0.06	192.46	2.98	2
TpIntW	ACPL	0.43	0.02	68.37	13.43	10
TpIntW	ACSA1	0.46	0.12	83.03	11.59	7
TpIntW	ACSA2	0.43	0.03	59.23	12.41	10
TpIntW	CASP	0.32	0.05	81.09	35.25	10
TpIntW	CR	0.48	0.03	113.36	25.49	10
TpIntW	FRAM	0.41	0.03	101.97	12.78	10
TpIntW	FRPE	0.39	0.02	78.97	15.26	10
TpIntW	GLTR	0.45	0.03	113.71	30.52	10
TpIntW	JUNI	0.41	0.03	97.23	21.33	10
TpIntW	LIST	0.38	0.03	99.82	17.96	10
TpIntW	MA2	0.42	0.06	81.29	21.26	10
TpIntW	PIPU	0.49	0.03	562.63	28.25	10
TpIntW	PISY	0.46	0.02	477.71	70.45	10
TpIntW	PLAC	0.40	0.02	101.34	18.50	10
TpIntW	PLOC	0.38	0.03	91.63	21.75	10
TpIntW	PYCA	0.42	0.03	93.42	14.80	10
TpIntW	QUAL	0.47	0.02	91.68	16.86	10
TpIntW	QURU	0.47	0.06	89.61	13.81	10
TpIntW	ROPS	0.42	0.11	64.84	14.25	10
TpIntW	TIAM	0.37	0.03	60.00	13.58	10
TpIntW	TICO	0.39	0.03	63.38	16.17	10

Table 6—Average dry-weight to fresh-weight (dw:fw) ratios for foliar biomass and average foliar biomass factors (gram of dry weight per square meter of leaf area) for each species and region (continued)

Region[a]	SpCode[b]	Avg dw/fw (g)	dw/fw SD	Avg dw g/m^2	dw g/m^2 SD	No.
TpIntW	ULPU	0.40	0.02	118.79	27.30	10
Tropic	BABL	0.43	0.03	121.05	10.66	10
Tropic	CAIN4	0.41	0.06	173.82	16.25	10
Tropic	CANE33	0.45	0.03	99.05	10.73	10
Tropic	CAEQ	0.45	0.17	1466.27	561.35	10
Tropic	CISP2	0.35	0.02	109.36	19.44	10
Tropic	CONU	0.45	0.06	200.91	28.09	2
Tropic	COERA2	0.34	0.02	194.06	87.11	10
Tropic	COSU2	0.20	0.02	50.06	9.58	10
Tropic	DERE	0.38	0.02	125.06	26.21	10
Tropic	ELOR2	0.44	0.01	216.18	14.57	10
Tropic	FIBE	0.39	0.02	130.09	22.03	10
Tropic	FIDE6	0.42	0.02	151.57	27.80	10
Tropic	ILPA2	0.42	0.02	164.33	12.96	10
Tropic	LASP	0.31	0.04	99.35	26.17	10
Tropic	MEQU	0.40	0.14	189.66	48.45	10
Tropic	PISA2	0.41	0.03	118.04	21.74	10
Tropic	SWMA	0.45	0.02	110.92	15.42	10
Tropic	TAAR	0.34	0.02	155.75	18.22	10
Tropic	TAPA	0.36	0.02	136.29	21.70	10
Tropic	TACH	0.48	0.03	154.16	31.80	10
Tropic	VEME	0.41	0.02	170.11	10.17	2

SD = standard deviation.

[a] CenFla = Central Florida, GulfCo = Coastal Plain, InlEmp = Inland Empire, LoMidW = Lower Midwest, MidWst = Midwest, NMtnPr = North, NoCalC = Northern California Coast, NoEast = Northeast, Piedmt = South, SoCalC = Southern California Coast, SWDsrt = Southwest Desert, TpIntW = Temperate Interior West, Tropic = Tropical.

[b] SpCodes = Four- to six-letter code consisting of the first two letters of the genus name and the first two letters of the species name followed by two optional letters to distinguish two species with the same four-letter code.

Appendix 4: Growth Equation Coefficients and Application Information

Appendix 4 and the corresponding online supplement report the growth equation coefficients from the best fitting models for each species and region. Table 7 illustrates the parameters predicted by the growth equations for two species, ACME and ACPA, in the Northern California Coast climate zone. The full table of coefficients for all species measured in each reference city is available in table S6 of the online supplement.

Twelve combinations of equation forms and model weights were tested for predicting seven parameters for each species and region. Thirty-one percent of all region-species combinations are best-fit (as measured by AIC_c values) by log-log (primarily unweighted) equations, followed closely by polynomial quadratic (26 percent), cubic (22 percent), and linear (19 percent) equations (app. 4, table 8). However, there is considerable variation in best-fit equation form among measured and predicted parameter types. For example, d.b.h. to leaf area relationship are typically best described by a log-log relationship (72 percent of the best-fit models across species are log-log equations), while d.b.h. to age relationships are most frequently described by cubic equations (38 percent). There is also variation in best-fit model frequency based on tree type, such as evergreen or deciduous, large, medium or small, and broadleaf, conifer, or palm. For example, the relationship between d.b.h. and tree height is most frequently best fit with quadradic models (50 percent) in medium coniferous evergreen species, but small coniferous evergreen species are best fit with linear models (83 percent). Meanwhile, log-log models are the most frequently chosen models for medium broadleaf deciduous species (43 percent).

Table 7—Example of equations for predicting tree-growth parameters by species and predicted parameter in Northern California Coast climate zone

Species	Ind. var.	Pred.[a]	Model weight[b]	EqName[c]	A	b	c or mse	d	e	Apps min	Apps max	Sigma	No.	adj R2	DF
ACME	dbh	age	1/dbh	quad	-0.07717	1.03847	-0.00387			1	74	1.13403	35	0.941	32
ACME	cdia	dbh	1/cdia^2	quad	0.48486	2.88322	0.17048			2.78	99.02	1.28772	31	0.927	28
ACME	dbh	crown dia	1/sqrt(dbh)	quad	0.72517	0.23255	-0.00072			1.37	16.71	0.31444	31	0.941	28
ACME	dbh	crown ht	1/sqrt(dbh)	log-logw2	0.33845	1.43614	0.01374			2.14	13.47	0.1172	31	0.911	29
ACME	age	dbh	1/age^2	cub	2.85114	-0.12224	0.05596	-0.0005		2.78	99.03	0.11337	35	0.907	31
ACME	dbh	leaf area	1	log-logw1	0.38175	3.72792	0.30567			6.38	491.2	0.55287	25	0.895	23
ACME	dbh	tree ht	1/sqrt(dbh)	log-logw2	0.50713	1.54757	0.00894			2.6	18.45	0.09454	31	0.948	29
ACPA	dbh	age	1/dbh	cub	-2.14827	1.39244	0.00738	-0.00021		0	64	0.70595	38	0.97	34
ACPA	cdia	dbh	1/cdia^2	lin	-0.767	4.15225				2.85	47.38	0.67011	35	0.931	33
ACPA	dbh	crown dia	1	log-logw1	-1.01932	2.48188	0.03998			0.78	10.57	0.19994	35	0.928	33
ACPA	dbh	crown ht	1/dbh	lin	0.90353	0.11475				1.23	6.34	0.05462	35	0.771	33
ACPA	age	dbh	1/age^2	cub	2.84767	0.23083	0.02511	-0.00028		2.85	47.39	0.02437	38	0.944	34
ACPA	dbh	leaf area	1	log-logw1	-2.21556	5.79413	0.37159			1.3	368.78	0.60958	33	0.888	31
ACPA	dbh	tree ht	1/sqrt(dbh)	lin	2.02054	0.15818				2.47	9.52	0.36403	35	0.819	33

ACME, ACPA = *Acacia melanoxylon* and *Acer palmatum*, respectively.
[a] Units of predicted components: age = years, dbh = centimeters, crown dia = meters, crown height = meters, la = m^2.
[b] Model components: dbh = diameter at breast height, crown dia = crown diameter, crown ht = crown height, tree ht = tree height, la = leaf area, Ind.var. = independent variable; Pred. = predicts component; EqName = equation name referring to equations in table 3.
[c] Log-log and exponential models require an input for mean-squared-error (mse), which is listed in column "c or mse" (do not calculate and use $sigma^2$).

Table 8—Percentage frequency of best-fit equation forms by measured/predicted parameter and tree type

Relationship	BDL	BDM	BDS	BEL	BEM	BES	CEL	CEM	CES	PEL	PEM	PES	Total
							Percent						
Age to d.b.h.:													
cub	33	26	16	33	25	5	12	67	6				27
expow	0	2	0	0	0	0	0	0	0				0
lin	24	35	50	33	36	58	36	6	12				31
log-log	9	11	18	3	3	0	16	22	82				13
quad	34	26	16	30	36	37	36	6	0				28
quart	0	0	0	0	0	0	0	0	0				0
Total													100
Crown diameter to d.b.h.:													
cub	35	25	8	21	33	21	28	22	0				26
expow	1	0	5	0	0	0	0	0	0				1
lin	11	21	39	24	33	26	36	50	12				23
log-log	35	33	34	42	28	37	28	17	82				35
quad	19	21	13	12	6	16	8	11	6				15
quart	0	0	0	0	0	0	0	0	0				0
Total													100
D.b.h. to age:													
cub	43	37	32	27	42	32	28	6	94				38
expow	1	0	5	0	0	0	4	0	0				1
lin	23	19	29	21	17	21	24	28	6				22
log-log	7	14	18	12	17	26	12	50	0				14
quad	26	30	16	39	25	21	32	17	0				25
quart	0	0	0	0	0	0	0	0	0				0
Total													100
D.b.h. to crown diameter:													
cub	29	21	24	12	3	0	16	0	0	14	93	33	22
expow	0	0	0	3	0	0	0	0	0	0	0	0	0
lin	6	25	26	9	25	32	36	28	18	7	0	0	16
log-log	31	26	24	15	25	47	24	17	0	0	0	0	23
quad	34	28	26	61	47	21	24	56	82	79	7	53	38
quart	0	0	0	0	0	0	0	0	0	0	0	13	0
Total													100

Table 8—Percentage frequency of best-fit equation forms by measured/predicted parameter and tree type (continued)

Relationship	BDL	BDM	BDS	BEL	BEM	BES	CEL	CEM	CES	PEL	PEM	PES	Total
							Percent						
D.b.h. to crown height													
cub	13	9	3	15	6	0	8	22	0	14	73	33	13
expow	0	2	8	0	8	21	8	0	12	0	0	0	4
lin	17	25	45	18	36	42	40	22	82	7	0	0	26
log-log	29	35	29	36	25	26	16	6	6	0	0	0	24
quad	40	30	16	30	25	11	28	50	0	79	27	53	33
quart	0	0	0	0	0	0	0	0	0	0	0	13	0
Total													100
D.b.h. to leaf area:													
cub	5	5	5	9	3	0	8	39	0	100	73	93	15
expow	1	2	0	3	6	5	0	0	12	0	0	0	2
lin	1	2	5	3	0	0	0	0	0	0	0	0	1
log-log	85	75	87	67	81	89	84	44	88	0	0	0	72
quad	8	16	3	18	11	5	8	17	0	0	27	7	10
quart	0	0	0	0	0	0	0	0	0	0	0	0	0
Total													100
D.b.h. to tree height:													
cub	18	12	5	15	6	0	24	17	0	7	93	33	16
expow	0	0	8	3	8	21	0	6	0	0	0	0	3
lin	10	12	29	9	8	5	16	22	82	0	0	0	14
log-log	33	33	42	36	36	47	28	6	18	7	0	0	30
quad	39	42	16	36	42	26	32	50	0	86	7	20	35
quart	0	0	0	0	0	0	0	0	0	0	0	47	2
Total													100

Tree types: BDL = broadleaf deciduous large, BDM = broadleaf deciduous medium, BDS = broadleaf deciduous small, BEL = broadleaf evergreen large, BEM = broadleaf evergreen medium, BES = broadleaf evergreen small, CEL = conifer evergreen large, CEM = conifer evergreen medium, CES = conifer evergreen small, PEL = palm evergreen large, PEM = palm evergreen medium, PES= palm evergreen small.

Appendix 5: User Guide

This guide provides step-by-step instructions on how to use the allometric equations to estimate tree component dimensions. Predicted parameters included using tree age to predict diameter at breast height (d.b.h.); using d.b.h. to predict tree height, crown height, crown diameter, and leaf area. In addition, crown diameter was used to predict d.b.h., and age from d.b.h. The guide is divided into sections based on the tree components that are to be estimated. In the first section, we show tree diameter, height, crown dimensions, and leaf area from d.b.h. and/or tree height. In the second section, we demonstrate how to estimate dry-weight biomass and carbon using the table of equations presented in appendix 5. Lastly, we present a case study that illustrates the importance of developing region-specific growth models.

Calculating Bole Diameter and Height, Crown Dimensions, and Leaf Area

Example 1. Calculating d.b.h. and tree height from tree age (d.b.h. and height not measured).

In this example, we aim to predict tree dimensions d.b.h., tree height, crown diameter, crown height, and leaf area for a 33-year-old *Liquidambar styraciflua* (American sweetgum) in the Northern California Coast (NoCalC) region.

Step 1. Look up the species and region specific age to d.b.h. equation in table S5 in the online supplement at http://dx.doi.org/10.2737/RDS-2016-0005. The equation name is "quad" for which the equation form is listed in table 3:

d.b.h. (*Liquidambar styraciflua* in NoCalC) = a + b × age + c × age^2

d.b.h. = 2.80359 + 1.29151 × 33 + 0.00299 × (33)^2 = 42.2 cm

Step 2. Calculate tree height (ht) from d.b.h. by looking up the equation name and coefficients in table S5 and equation form (cubic) in table 3:

ht (*Liquidambar styraciflua* in NoCalC) = a + b × dbh + c × dbh^2 + d × dbh^3

ht = 0.57478 + 0.62687 × 42.16 + (-0.00837) × (42.2)^2 + 0.00004 × (42.2)^3 = 15.1 m

Having calculated tree d.b.h (and in some cases tree height), it is now possible to skip ahead to section 2 if the goal is to estimate dry-weight biomass and carbon storage/sequestration. To estimate other tree dimensions, continue with steps 3 through 6.

Step 3. Calculate crown diameter (cdia) from d.b.h. by looking up the equation name and coefficients in table S5 and equation form (cubic) in table 3:

cdia (*Liquidambar styraciflua* in NoCalC) = a + b × dbh + c × dbh^2

cdia = 0.42238 + 0.29796 × 42.2 +(-0.00131) × 42.2^2 = 10.7 m

Step 4. Calculate crown height (cht) from d.b.h. by looking up the equation name and coefficients in table S5 and equation form in table 3:

cht (*Liquidambar styraciflua* in NoCalC) = a + b × dbh + c × dbh^2 + d × dbh^3

cht = (-0.54095) + 0.53287 × 42.2 + (-0.00872) × 42.2^2+0.00005 × 42.2^3 = 10.2 m

Step 5. Calculate leaf area (la) from d.b.h. by looking up the equation name and coefficients in table S5 and equation form (log-log) in table 3:

la = $e^{(a + b \times \ln (\ln (dbh +1) + (mse/2))}$

la = $e^{(-1.47634) + 5.49634 \times LN(LN(42.2+1) + (0.29671/2))}$ = 413.2 m^2

where e is a mathematical constant equal to 2.71828182845904, the base of the natural logarithm.

Step 6. To calculate foliar biomass (fb), multiply leaf area (m^2) from step 4 by the average foliar biomass factor (g/m^2 leaf area) in appendix 3:

fb = leaf area × average foliar biomass factor

fb = 413.2 m^2 × 125.75 (g/m^2) = 51959.9 g

Estimating Dry-Weight Biomass and Carbon

To estimate the aboveground volume of wood in a tree, measured tree size data are used with biomass equations. While the growth equations are region-specific, biomass equations are not. Biomass equations are presented for 26 open-grown urban trees species (table 9). Most of these equations are compiled from literature sources described in the table, while the general equations (Urb Gen Broadleaf and Urb Gen Conifer) were developed through data collection and analyses. To be consistent with equations used in the Urban Forest Project Protocols (Climate Action Reserve 2008) for carbon projects, mass is not included in the formulations. All urban equations predict aboveground volume in square meters per tree. To convert from volume to dry-weight (DW) biomass, the predicted volume is multiplied by a DW density factor (table 9).

In addition to equations developed specifically for urban trees, biomass equations have been adapted from literature on rural forest biomass and applied for use in the urban setting (table 10). These equations may produce either volume or DW biomass directly. Equations predicting DW biomass directly do not need to be multiplied by a DW density factor.

Complete listings of equations are available in tables 9 and 10 (downloadable as tables S6 and S7). All equations are listed in an Excel-ready form so they may be copied and pasted into an Excel cell. Measurements required for using the biomass equations are either d.b.h. and tree height, or d.b.h. alone. If data availability permits, it is recommended that users select the d.b.h. and height equations over the d.b.h. only equations as they tend to produce more accurate results, particularly for trees with crowns that have been heavily pruned or topped.

Table 9—Volume equations for 26 urban tree species requiring diameter at breast height (d.b.h.) (cm) only or d.b.h. (cm) and height (m) measurements to calculate volume

Equation species	SpCode	D.b.h. range	Equation[a]	Predicts[b]	DW density	Equation source[c]
D.b.h. and height:		*Centimeters*				
Acacia longifolia	ACLO	15 to 57	=0.0000904 × dbhcm^2.18649 × htm^0.46736	V	510	3
Acer platanoides	ACPL	10 to 102	=0.001011 × dbhcm^1.533 × htm^0.657	V	520	2
Acer saccharinum	ACSA1	13 to 135	=0.0002383 × dbhcm^1.998 × htm^0.596	V	440	2
Celtis occidentalis	CEOC	11 to 119	=0.0022451 × dbhcm^2.118 × htm^ to 0.447	V	490	2
Ceratonia siliqua	CESI3	16 to 74	=0.0001368 × dbhcm^1.79584 × htm^0.92667	V	520	3
Cinnamomum camphora	CICA	13 to 69	=0.0000807 × dbhcm^2.1348 × htm^0.63404	V	520	3
Cupressus macrocarpa	CUMA	16 to 147	=0.0000419 × dbhcm^2.2604 × htm^0.6301	V	410	3
Eucalyptus globulus	EUGL	116 to 130	=0.0000318 × dbhcm^2.15182 × htm^0.83573	V	620	3
Fraxinus pennsylvanica	FRPE	15 to 123	=0.0004143 × dbhcm^1.847 × htm^0.646	V	530	2
Fraxinus velutina 'Modesto'	FRVE_G	15 to 85	=0.0000385 × dbhcm^1.76296 × htm^1.42782	V	510	3
Gleditsia triacanthos	GLTR	9 to 98	=0.0004891 × dbhcm^2.132 × htm^0.142	V	600	2
Gymnocladus dioicus	GYDI	10 to 37	=0.000463 × dbhcm^1.545 × htmet^0.792	V	530	2
Jacaranda mimosifolia	JAMI	17 to 60	=0.0000801 × dbhcm^2.18578 × htm^0.548045	V	490	3
Liquidambar styraciflua	LIST	14 to 54	=0.0000631 × dbhcm^2.31582 × htm^0.41571	V	460	3
Magnolia grandiflora	MAGR	15 to 74	=0.0000504 × dbhcm^2.07041 × htm^0.84563	V	460	3
Pinus radiata	PIRA	17 to 105	=0.0000419 × dbhcm^2.226808 × htm^0.668993	V	400	3
Pistacia chinensis	PICH	13 to 51	=0.0000329 × dbhcm^2.19157 × htm^0.94367	V	685	3
Platanus × *acerifolia*	PLAC	16 to 74	=0.0000485 × dbhcm^2.43642 × htm^0.39168	V	500	3
Populus sargentii	POSA	6 to 137	=0.0019055 × dbhcm^1.806 × htm^0.134	V	370	2
Quercus ilex	QUIL2	13 to 52	=0.0000789 × dbhcm^1.82158 × htm^1.06269	V	820	3
Quercus macrocarpa	QUMA1	11 to 100	=0.0001689 × dbhcm^1.956 × htm^0.842	V	580	2
Tilia cordata	TICO	11 to 65	=0.0009453 × dbhcm^1.617 × htm^0.59	V	420	2
Ulmus americana	ULAM	18 to 114	=0.0012 × dbhcm^1.696 × htm^0.405	V	460	2
Ulmus parvifolia	ULPA	17 to 56	=0.0000609 × dbhcm^2.32481 × htm^0.49317	V	730	3
Ulmus pumila	ULPU	16 to 132	=0.000338 × dbhcm^0.855 × htm^2.041	V	540	2
Zelkova serrata	ZESE	15 to 86	=0.0000401 × dbhcm^2.36318 × htm^0.5519	V	520	3
Urban Gen broadleaf	UGEB	6 to 135	=0.0001967 × dbhcm^1.951853 × htm^0.664255	V	Jenkins, DRYAD[d]	1
Urban Gen conifer	UGEC	16 to 147	=0.0000426 × dbhcm^2.24358 × htm^0.64956	V	Jenkins, DRYAD[d]	1

Table 9—Volume equations for 26 urban tree species requiring diameter at breast height (d.b.h.) (cm) only or d.b.h. (cm) and height (m) measurements to calculate volume (continued)

Equation species	SpCode	D.b.h. range	Equation[a]	Predicts[b]	DW density	Equation source[c]
D.b.h. only:						
Acacia longifolia	ACLO	15 to 57	=0.000154 × dbhcm^2.34725	V	510	3
Acer platanoides	ACPL	10 to 102	=0.0019421 × dbhcm^1.785	V	520	2
Acer saccharinum	ACSA1	13 to 135	=0.000363 × dbhcm^2.292	V	440	2
Celtis occidentalis	CEOC	11 to 119	=0.0014159 × dbhcm^1.928	V	490	2
Ceratonia siliqua	CESI3	16 to 74	=0.0002579 × dbhcm^2.128861	V	520	3
Cinnamomum camphora	CICA	13 to 69	=0.0000839 × dbhcm^2.53466	V	520	3
Cupressus macrocarpa	CUMA	16 to 147	=0.0000985 × dbhcm^2.495263	V	410	3
Eucalyptus globulus	EUGL	116 to 130	=0.000161 × dbhcm^2.43697	V	620	3
Fraxinus pennsylvanica	FRPE	15 to 123	=0.0005885 × dbhcm^2.206	V	530	2
Fraxinus velutina 'Modesto'	FRVE_G	15 to 85	=0.000054 × dbhcm^2.633462	V	510	3
Gleditsia triacanthos	GLTR	9 to 98	=0.0005055 × dbhcm^2.22	V	600	2
Gymnocladus dioicus	GYDI	10 to 37	=0.0004159 × dbhcm^2.059	V	530	2
Jacaranda mimosifolia	JAMI	17 to 60	=0.0001005 × dbhcm^2.486248	V	490	3
Liquidambar styraciflua	LIST	14 to 54	=0.0000799 × dbhcm^2.560469	V	460	3
Magnolia grandiflora	MAGR	15 to 74	=0.0000559 × dbhcm^2.622015	V	460	3
Pinus radiata	PIRA	17 to 105	=0.0000469 × dbhcm^2.666079	V	400	3
Pistacia chinensis	PICH	13 to 51	=0.0000392 × dbhcm^2.808625	V	685	3
Platanus × *acerifolia*	PLAC	16 to 74	=0.000059 × dbhcm^2.673578	V	500	3
Populus sargentii	POSA	6 to 137	=0.0020891 × dbhcm^1.873	V	370	2
Quercus ilex	QUIL2	13 to 52	=0.0000627 × dbhcm^2.607285	V	820	3
Quercus macrocarpa	QUMA1	11 to 100	=0.0002431 × dbhcm^2.415	V	580	2
Tilia cordata	TICO	11 to 65	=0.0009359 × dbhcm^2.042	V	420	2
Ulmus americana	ULAM	18 to 114	=0.0018 × dbhcm^1.869	V	460	2
Ulmus parvifolia	ULPA	17 to 56	=0.000069 × dbhcm^2.639347	V	730	3
Ulmus pumila	ULPU	16 to 132	=0.0048879 × dbhcm^1.613	V	540	2
Zelkova serrata	ZESE	15 to 86	=0.0000502 × dbhcm^2.674757	V	520	3
Urban Gen broadleaf	UGEB	6 to 135	=0.0002835 × dbhcm^2.310647	V	Jenkins, DRYAD[d]	1
Urban Gen conifer	UGEC	16 to 147	=0.0000698 × dbhcm^2.578027	V	Jenkins, DRYAD[d]	1

[a] dbhcm = diameter at breast height in centimeters; htm = tree height in meters; dwdensity = dry weight-density factor.
[b] DWdensity = dry weight biomass in kg/ m^3 ; V = aboveground volume in cubic meters per tree.
[c] Equation source: 1 = Aguaron and McPherson 2012; 2 = Lefsky and McHale 2008; 3 = Pillsbury et al. 1998.
[d] Look up the dw density factor in McHale et al. (2009) first, but if not available, then the Global Wood Density Database (Zeng 2003).

Table 10—Dry-weight biomass and volume equations derived from rural forests

Equation species	SpCode	D.b.h. range (cm)	Equation[a]	Predicts[b]	Dry-weight density	Equation source[c]
Acer rubrum	ACRU	0 to 35	=0.1970 × dbhcm^2.1933	DW	N/A	6
Fagus grandifolia	FAGR	1 to 60	=0.1957 × dbhcm^2.3916	DW	N/A	6
Fraxinus americana	FRAM	5 to 50	=0.1063 × dbhcm^2.4798-EXP(-4.0813+5.8816/dbhcm)	DW	N/A	6,A
Juniperus virginiana	JUVI	14 to 43	=dbhcm+0.1632 × dbhcm^2.2454-(dbhcm+0.1244 × dbhcm^1.5549)	DW	440	4,B
Liriodendron tulipifera	LITU	5 to 50	=0.0365 × (dbhcm)^2.7324-EXP(-4.0813+5.8816/dbhcm)	DW	N/A	6,A
Melaleuca quinquenervia	MEQU	0.5 to 39	=EXP(-1.83+2.01 × LN(dbhcm))	DW	N/A	7
Quercus agrifolia	QUAG	20 to 140	=0.0000447 × (dbhcm)^2.31958 × (htm)^0.62528	V	590	5
Quercus garryana	QUGA4	20 to 140	=0.0000674 × (dbhcm)^2.14321 × (htm)^0.74220	V	640	5
Quercus lobata	QULO	20 to 140	=0.0000763 × (dbhcm)^1.94165 × (htm)^0.86562	V	550	5
Quercus rubra	QURU	5 to 50	=0.1130 × (dbhcm)^2.4572-EXP(-4.0813+5.8816/dbhcm)	DW	N/A	6,A
Umbellularia californica	UMCA	20 to 140	=0.0000763 × (dbhcm)^1.94553) × (htm)^0.88389	V	510	5
Gen Hdwd aspen/alder/cottonwood/ willow	GNHDAA	12 to 50	=EXP(-2.2094+2.3867 × LN(dbhcm))-EXP(-4.0813+5.8816/dbhcm)	DW	N/A	4,B
Gen Hdwd Harris	GNHDH	>10	=EXP(-2.437+2.418 × LN(dbhcm))+EXP(-3.188+2.226 × LN(dbhcm))	DW	N/A	3
Gen Hdwd maple/oak/hickory/beech	GNHDHM	14 to 34	=EXP(-2.0127+2.4342 × LN(dbhcm))-EXP(-4.0813+5.8816/dbhcm)	DW	N/A	4,B
Gen Hdwd soft maple/birch	GNHDSM	12 to 42	=EXP(-1.9123+2.3651 × LN(dbhcm))-EXP(-4.0813+5.8816/dbhcm)	DW	N/A	4,B
Gen Sftwd cedar/larch	GNSWCL	3 to 61	=EXP(-2.0336+2.2592 × LN(dbhcm))-EXP(-2.9584+4.4766/dbhcm)	DW	N/A	4,B
General Sftwd doug-fir	GNSWDF	3 to 190	=EXP(-2.2304+2.4435 × LN(dbhcm))-EXP(-2.9584+4.4766/dbhcm)	DW	N/A	4,B
Gen Sftwd pine	GNSWP	3 to 99	=EXP(-2.5356+2.4349 × LN(dbhcm))-EXP(-2.9584+4.4766/dbhcm)	DW	N/A	4,B
Gen Sftwd spruce	GNSWS	3 to 78	=EXP(-2.0773+2.3323 × LN(dbhcm))-EXP(-2.9584+4.4766/dbhcm)	DW	N/A	4,B
Gen Sftwd truefir/hemlock	GNSWTF	3 to 111	=EXP(-2.5384+2.4814 × LN(dbhcm))-EXP(-2.9584+4.4766/dbhcm)	DW	N/A	4,B
Gen Trop Chave	GNTRC	4 to 148	=0.112 × ((dw density/1000) × dbhcm^2 × htm)^0.916	DW	Jenkins, DRYAD[d]	1
Gen Wdlnd juniper/oak/mesquite	GNWDJO	NA	=EXP(-0.7152+1.7029 × LN(dbhcm))-EXP(-4.0813+5.8816/dbhcm)	DW	N/A	4,B
Genl palms	GNP	to 17 m ht	=(6 × htm+0.8)+(0.8 × htm+0.9)	DW	N/A	2
Gen spiny dry climate	GNHDV	2 to 32	=EXP(-1.103+1.994 × LN(dbhcm)+0.317 × LN(htm)+1.303 × LN(dwdensity/1000))	DW	Jenkins, DRYAD[d]	8

N/A = not applicable.

[a] dbhcm = diameter at breast height in centimeters; htm = tree height in meters; dwdensity = dry-weight density factor.

[b] DW density = dry-weight biomass in kiligrams per cubic meter; V = aboveground volume in cubic meters per tree.

[c] Equation source: 1 = Chave et al. 2005, 2 = Frangi and Lugo (1985), 3 = Harris et al. (1973), 4 = McHale et al. (2009), 5 = Pillsbury and Kirkley (1984), 6 = Ter-Mikaelian and Korzukhin 1997, 7 = Van et al. 2000, 8 = Vieilledent et al. 2012, A = minus Jenkins foliage, B = minus foliage ratio.

[d] Look up the dry-weight density factor in McHale et al. (2009) first, but if not available, then look it up in the Global Wood Density Database (Zeng 2003).

We developed two general volume equations from the urban species equations, one for urban broadleaf species and one for conifers. These equations can be used if the species of interest cannot be matched taxonomically or through wood form to the species listed in the tables of biomass equations derived from urban or rural forests (table 10). The general equations predict cubic meters of fresh-wood volume. Fresh-wood volume is then multiplied by the species' DW density factor to obtain aboveground DW biomass. The urban general equations require looking up a dry-weight density factor (in Jenkins et al. 2004 first, but if not available then the Global Wood Density Database).

To estimate total carbon and stored carbon dioxide (CO_2) equivalents, dry-weight biomass (either calculated directly or from fresh-wood volume) is converted using constants. The DW biomass is multiplied by 1.28 to incorporate belowground biomass (Husch et al. 2003, Tritton and Hornbeck 1982, Wenger 1984), multiplied by the constant 0.5 to convert to total carbon stored (Leith 1963, Whittaker et al. 1973), and multiplied by the constant 3.67 (molecular weight of CO_2) to convert to total CO_2 stored.

Dry-weight densities are unique to each tree species and can vary extensively among species. Volume equations can be applied to other species based on taxonomy if a species-specific DW density factor is not known. For example, because many of the species measured in each of the reference cities were not represented in tables 9 and 10, it was necessary to assign biomass equations to species for which there were no available data. Table 11 provides examples of species matching for volume or biomass estimation (see column "Equation Species Code" for species to which species without information are matched). If the form of the tree is completely different than any species listed, we recommend using the general equations for urban broadleaf and conifer trees and look up the species-specific dry-weight-wood density value in DRYAD, the Global Wood Density Database (Chave et al. 2005, Frangi and Lugo 1985, Harris et al. 1973, Higuchi et al. 2005, Jenkins et al. 2004, Pillsbury and Kirkley 1984, Ter-Mikaelian and Korzuhkhin 1997, Van et al. 2000, Vieilledent et al. 2012, Zanne et al. 2009, Zeng 2003) available as a downloadable Excel spreadsheet at http://datadryad.org/repo/handle/10255/dryad.235.

Table 11— Expanded list of biomass density factors for common urban species

SpCode	Scientific name	DW density[a]	Matched equation SpCode	Equation source[b]
ACFA	*Acacia farnesiana*	520	ACLO	8
ACLO	*Acacia longifolia*	520	ACLO	8
ACMA	*Acer macrophyllum*	440	ACPL	6
ACME	*Acacia melanoxylon*	573	ACLO	8
ACNE	*Acer negundo*	420	ACPL	6
ACPA	*Acer palmatum*	450	ACPL	6
ACPL	*Acer platanoides*	520	ACPL	6
ACRU	*Acer rubrum*	490	ACRU	9
ACSA1	*Acer saccharinum*	440	ACSA1	6
ACSA2	*Acer saccharum*	560	ACPL	6
ACSA3	*Acacia salicina*	473	ACLO	8
AEHI	*Aesculus hippocastanum*	500	UGEB	1
BABL	*Bauhinia* x *blakeana*	527	GNTRC	2
BENI	*Betula nigra*	490	UGEB	1
BEPE	*Betula pendula*	530	UGEB	1
BRPO	*Brachychiton populneus*	387	UGEB	1
BUCA	*Butia capitata*	370	PRACM	3
CABEF	*Carpinus betulus* 'Fastigiata'	598	UGEB	1
CACI	*Callistemon citrinus*	690	UGEB	1
CADE2	*Calocedrus decurrens*	350	GNSWCL	5,B
CAEQ	*Casuarina equisetifolia*	728	GNTRC	2
CAIL	*Carya illinoinensis*	600	UGEB	1
CAIN4	*Calophyllum inophyllum*	560	GNTRC	2
CANE33	*Cassia* x *nealiae*	670	GNTRC	2
CASP	*Catalpa speciosa*	380	UGEB	1
CECA	*Cercis canadensis*	520	UGEB	1
CEDE	*Cedrus deodara*	410	GNSWCL	5,B
CEFL	*Parkinsonia florida*	619	GNHDV	11
CELA	*Celtis laevigata*	490	CEOC	6
CEOC	*Celtis occidentalis*	490	CEOC	6
CESI3	*Ceratonia siliqua*	520	CESI3	8
CESI4	*Celtis sinensis*	490	CEOC	6
CHLI	*Chilopsis linearis*	600	GNHDV	11
CICA	*Cinnamomum camphora*	520	CICA	8
CISP2	*Citharexylum spinosum*	700	GNTRC	2
COERA2	*Conocarpus erectus* var. *argenteus*	690	GNTRC	2
COFL	*Cornus florida*	640	UGEB	1
CONU	*Cocos nucifera*	520	PRACM	3
COSU2	*Cordia subcordata*	640	GNTRC	2

Table 11— Expanded list of biomass density factors for common urban species (continued)

SpCode	Scientific name	DW density[a]	Matched equation SpCode	Equation source[b]
CR	*Crataegus* species	520	UGEB	1
CRLA80	*Crataegus laevigata*	620	UGEB	1
CUAN	*Cupaniopsis anacardioides*	520	UGEB	1
CUMA	*Cupressus macrocarpa*	410	CUMA	8
DERE	*Delonix regia*	479	GNTRC	2
ELAN	*Elaeagnus angustifolia*	520	UGEB	1
ELOR2	*Elaeodendron orientale*	676	GNTRC	2
ERJA	*Eriobotrya japonica*	520	UGEB	1
EUFI81	*Eucalyptus ficifolia*	794	EUGL	8
EUGL	*Eucalyptus globulus*	620	EUGL	8
EUMI2	*Eucalyptus microtheca*	994	EUGL	8
EUSI	*Eucalyptus sideroxylon*	932	EUGL	8
FAGR	*Fagus grandifolia*	585	FAGR	9
FASYAT	*Fagus sylvatica* ‘Atropunicea’	585	FAGR	9
FIBE	*Ficus benjamina*	460	GNTRC	2
FIDE6	*Filicium decipiens*	805	GNTRC	2
FIMI	*Ficus thonningii*	432	GNTRC	2
FRAM	*Fraxinus americana*	550	FRAM	9,A
FRAN_R	*Fraxinus angustifolia* ‘Raywood’	510	FRVE_G	8
FRAN2	*Fraxinus angustifolia*	510	FRVE_G	8
FREX_H	*Fraxinus excelsior* ‘Hessei’	560	FRVE_G	8
FRHO	*Fraxinus holotricha*	510	FRVE_G	8
FRLA	*Fraxinus latifolia*	500	FRAM	9,A
FRPE	*Fraxinus pennsylvanica*	530	FRPE	6
FRPE_M	*Fraxinus pennsylvanica* ‘Marshall’	530	FRPE	6
FRUH	*Fraxinus uhdei*	510	FRPE	6
FRVE	*Fraxinus velutina*	510	FRVE_G	8
FRVE_G	*Fraxinus velutina* ‘Modesto’	510	FRVE_G	8
GIBI	*Ginkgo biloba*	520	UGEB	1
GLTR	*Gleditsia triacanthos*	600	GLTR	6
GNHDAA	General hardwood jenkins	N/A	GNHDAA	5,B
GNHDH	General hardwood harris	N/A	GNHDH	4
GNHDHM	General hardwood jenkins	N/A	GNHDHM	5,B
GNHDSM	General hardwood jenkins	N/A	GNHDSM	5,B
GNHDV	General spiny dry vieilledent	N/A	GNHDV	11
GNSWCL	General softwood jenkins	N/A	GNSWCL	5,B
GNSWDF	General softwood jenkins	N/A	GNSWDF	5,B
GNSWP	General softwood jenkins	N/A	GNSWP	5,B
GNSWS	General softwood jenkins	N/A	GNSWS	5,B

Table 11— Expanded list of biomass density factors for common urban species (continued)

SpCode	Scientific name	DW density[a]	Matched equation SpCode	Equation source[b]
GNSWTF	General softwood jenkins	N/A	GNSWTF	5,B
GNTRC	General tropical chave	N/A	GNTRC	2
GNWDJO	General woodland jenkins	N/A	GNWDJO	5,B
GYDI	*Gymnocladus dioicus*	530	UGEB	1
ILOP	*Ilex opaca*	500	UGEB	1
ILPA2	*Ilex paraguariensis*	565	GNTRC	2
JAMI	*Jacaranda mimosifolia*	490	JAMI	8
JUNI	*Juglans nigra*	510	UGEB	1
JUSI	*Juniperus virginiana* var. *silicicola*	420	JUVI	5,B
JUVI	*Juniperus virginiana*	440	JUVI	5,B
KOEL	*Koelreuteria elegans*	595	UGEB	1
KOPA	*Koelreuteria paniculata*	620	UGEB	1
LA6	*Lagerstroemia* species	571	UGEB	1
LAIN	*Lagerstroemia indica*	571	UGEB	1
LASP	*Lagerstroemia speciosa*	612	GNTRC	2
LIST	*Liquidambar styraciflua*	460	LIST	8
LITU	*Liriodendron tulipifera*	400	LITU	9,A
MA2	*Malus* species	610	UGEB	1
MAGR	*Magnolia grandiflora*	460	MAGR	8
MEEX	*Metrosideros excelsa*	1150	UGEB	1
MEQU	*Melaleuca quinquenervia*	520	MEQU	10
MO	*Morus* species	520	UGEB	1
MOAL	*Morus alba*	520	UGEB	1
OLEU	*Olea europaea*	700	UGEB	1
PAAC	*Parkinsonia aculeata*	610	GNHDV	11
PHCA	*Phoenix canariensis*	370	PRACM	3
PHDA4	*Phoenix dactylifera*	370	PRACM	3
PIBR2	*Pinus brutia*	430	UGEC	1
PICA	*Pinus canariensis*	610	UGEC	1
PICH	*Pistacia chinensis*	685	PICH	8
PICO5	*Pinus contorta* var. *bolanderi*	380	UGEC	1
PIEC	*Pinus echinata*	470	UGEC	1
PIED	*Pinus edulis*	500	UGEC	1
PIEL2	*Pinus eldarica*	540	UGEC	1
PIHA	*Pinus halepensis*	460	UGEC	1
PINI	*Pinus nigra*	430	UGEC	1
PIPO	*Pinus ponderosa*	380	UGEC	1
PIPU	*Picea pungens*	360	UGEC	1
PIRA	*Pinus radiata*	400	PIRA	8

Table 11— Expanded list of biomass density factors for common urban species (continued)

SpCode	Scientific name	DW density[a]	Matched equation SpCode	Equation source[b]
PISA2	*Samanea saman*	520	GNTRC	2
PIST	*Pinus strobus*	340	UGEC	1
PISY	*Pinus sylvestris*	430	UGEC	1
PITA	*Pinus taeda*	470	UGEC	1
PITH	*Pinus thunbergiana*	430	UGEC	1
PIUN	*Pittosporum undulatum*	745	UGEB	1
PLAC	*Platanus* × *acerifolia*	500	PLAC	8
PLOC	*Platanus occidentalis*	480	PLAC	8
PLRA	*Platanus racemosa*	480	PLAC	8
POAN	*Populus angustifolia*	350	POSA	6
PODE	*Populus deltoides*	370	POSA	6
POFR	*Populus fremontii*	410	POSA	6
POMA	*Podocarpus macrophyllus*	470	UGEB	1
POSA	*Populus sargentii*	370	POSA	6
POTR2	*Populus balsamifera* ssp. *trichocarpa*	310	POSA	6
PR	*Prunus* species	560	UGEB	1
PRACM	*Prestoea montana*	370	PRACM	3
PRCA	*Prunus caroliniana*	560	UGEB	1
PRCE	*Prunus cerasifera*	470	UGEB	1
PRCEKW	*Prunus cerasifera* ‘Thundercloud’	560	UGEB	1
PRCH	*Prosopis chilensis*	740	GNHDV	11
PRSE2	*Prunus serrulata*	560	UGEB	1
PRYE	*Prunus yedoensis*	470	UGEB	1
PSME	*Pseudotsuga menziesii*	450	GNSWDF	5,B
PY	*Pyrus* species	600	UGEB	1
PYAN	*Malus angustifolia*	610	UGEB	1
PYCA	*Pyrus calleryana*	600	UGEB	1
PYCA_B	*Pyrus calleryana* ‘Bradford’	600	UGEB	1
PYKA	*Pyrus kawakamii*	600	UGEB	1
QUAG	*Quercus agrifolia*	590	QUAG	7
QUAL	*Quercus alba*	600	QUGA4	7
QUGA4	*Quercus garryana*	640	QUGA4	7
QUIL2	*Quercus ilex*	820	QUIL2	8
QULA2	*Quercus laurifolia*	560	QULO	7
QULO	*Quercus lobata*	550	QULO	7
QUMA1	*Quercus macrocarpa*	580	QUMA1	6
QUNI	*Quercus nigra*	560	QUAG	7
QUPA	*Quercus palustris*	580	QUAG	7
QUPH	*Quercus phellos*	560	QUAG	7

Table 11— Expanded list of biomass density factors for common urban species (continued)

SpCode	Scientific name	DW density[a]	Matched equation SpCode	Equation source[b]
QURU	*Quercus rubra*	560	QURU	9,A
QUSH	*Quercus shumardii*	590	QUAG	7
QUVI	*Quercus virginiana*	800	QUGA4	7
RHLA	*Rhus lancea*	540	GNHDV	11
ROPS	*Robinia pseudoacacia*	660	GLTR	6
SAPA	*Sabal palmetto*	520	PRACM	3
SCMO	*Schinus molle*	650	UGEB	1
SCTE	*Schinus terebinthifolius*	650	UGEB	1
SESE	*Sequoia sempervirens*	360	GNSWCL	5,B
SWMA	*Swietenia mahagoni*	750	GNTRC	2
SYRO	*Syagrus romanzoffiana*	370	PRACM	3
TAAR	*Tabebuia aurea*	520	GNTRC	2
TACH	*Tabebuia ochracea* subsp. *neochrysantha*	960	GNTRC	2
TAPA	*Tabebuia heterophylla*	520	GNTRC	2
THOR	*Platycladus orientalis*	527	UGEC	1
TIAM	*Tilia americana*	320	TICO	6
TICO	*Tilia cordata*	420	TICO	6
TITO	*Tilia tomentosa*	320	TICO	6
TRCO	*Tristaniopsis conferta*	750	UGEB	1
TRSE6	*Triadica sebifera*	520	UGEB	1
UGEB	Urban general broadleaf	DRYAD[c]	UGEB	1
UGEC	Urban general conifer	DRYAD[c]	UGEC	1
ULAL	*Ulmus alata*	600	ULPU	6
ULAM	*Ulmus americana*	460	ULAM	6
ULPA	*Ulmus parvifolia*	730	ULPA	8
ULPU	*Ulmus pumila*	540	ULPU	6
UMCA	*Umbellularia californica*	510	UMCA	7
VEME	*Veitchia merrillii*	370	PRACM	3
WAFI	*Washingtonia filifera*	370	PRACM	3
WARO	*Washingtonia robusta*	370	PRACM	3
ZESE	*Zelkova serrata*	520	ZESE	8

Notes: Species without a specific equation or dry-weight density factor are matched to known species. N/A = not applicable.

[a] DW density = dry-weight biomass kilograms per cubic meter.

[b] Equation source: 1 = Aguaron and McPherson 2012, 2 = Chave et al. 2005, 3 = Frangi and Lugo 1985, 4 = Harris et al. 1973, 5 = Jenkins et al. 2004, 6 = Lefsky and McHale 2008, 7 = Pillsbury and Kirkley 1984, 8 = Pillsbury et al. 1998, 9 = Ter-Mikaelian and Korzukhin 1997, 10 = Van et al. 2000, 11 = Vieilledent et al. 2012, A = minus Jenkins foliage, B = minus foliage ratio.

[c] For equations UGEC and UGEB, look up correct dry-weight density factor for species of interest in DRYAD (the Global Wood Density Database).

Example 2. Calculating dry-weight biomass and carbon stored based on either calculated or measured d.b.h. and/or tree height.

Once d.b.h. and height have been measured or calculated (as in example 1), the next step entails using either d.b.h. or d.b.h. and height to calculate the dry-weight biomass. For species assigned biomass equations, skip to example 3. For species assigned volumetric equations, follow this example.

In this example, we continue with a sample tree *Liquidambar styraciflua* (sweetgum) located in the Northern California Coast region. It is 33 years of age and has an estimated d.b.h. equal to 42.2 cm and tree height equal to 15.3 m, as calculated in example 1.

Step 1. Select the equation for d.b.h. and height to calculate aboveground fresh wood volume (table 9). Fresh-wood volume in cubic meters (V) for a 15.3-m tall sweetgum with a 42.2-cm d.b.h. is calculated as:

$$V = 0.0000631 \times (42.2)^{2.31582} \times (15.1)^{0.41571} = 1.13\ m^3$$

Note that the volumetric equations are not region specific, so the fact that our sample tree is located in the Northern California Coast region does not play a role in this example. If the tree had not been measured and we were predicting d.b.h. and/or ht from age or d.b.h., we would need to select a region-specific growth equation.

Step 2. Convert from fresh-wood volume to dry-weight biomass by multiplying V by the species-specific DW density factor, which for sweetgum is 460 kg/m^3 (from table 9)

$$DW = 1.13\ m^3 \times 460\ kg/m^3 = 519.80\ kg$$

Step 3. Thus far, we have calculated the biomass for the aboveground portion of the tree. To convert from DW biomass to carbon stored, the belowground biomass should be incorporated. The biomass stored belowground is calculated by multiplying the DW biomass by 1.28:

$$\text{Total DW} = 519.80\ kg \times 1.28 = 665.34\ kg$$

Step 4. Next, the DW biomass is converted into kilograms of carbon (C) by multiplying by the constant 0.5:

$$C = 665.34\ kg \times 0.5 = 332.67\ kg$$

Step 5. Convert stored carbon into stored carbon dioxide (CO_2) by multiplying by the constant 3.67 as follows:

$$CO_2 = 332.67\ kg \times 3.67 = 1220.89\ kg$$

Note that in this case, results were rounded at each step. Users will achieve slightly different results when using Excel or programming language to calculate the final amounts.

Example 3. Estimating DW biomass directly from tree size parameters.

In this variation of example 2, we measure a *Liriodendron tulipifera*, which has a d.b.h. of 35.0 cm. Select the equation from table 10 for estimating the direct DW biomass of this species. The calculation is as follows:

$DW = 0.0365 \times (35.0)^{2.7324} - e^{(-4.0813+5.8816/35.0)} = 604.4$ kg

where e is a mathematical constant equal to 2.71828182845904.

To estimate total DW, total carbon stored, and CO_2 stored, continue with steps 3 through 5 in example 2.

Error in Predicting Future Growth, Carbon, and Biomass

The volume equations were developed from trees that may differ in size from the trees in the user's sample or inventory. The d.b.h. ranges for trees sampled to develop the volume and biomass equations are listed in columns labelled "Dbh lower (cm)" and "Dbh upper (cm)" (tables 9 and 10). Applying the equations to trees with d.b.h. outside of this range may increase the prediction error. Tree growth as modelled or estimated by the user may deviate significantly from tree growth models generalized here. In general, it is better to err on the side of underestimating carbon stocks rather than overestimating. Recommended ways of evaluating the growth data presented here include contacting local arborists and other tree experts (e.g., university extension offices, city tree managers) or from repeated measurements of inventoried trees.

Case Study

To demonstrate the species-level differences in d.b.h., tree height, and total carbon across regions, we selected the top three species most commonly measured in the 17 reference cities (16 reference cities and SacVal): *Acer saccharinum* (silver maple), *Liquidambar styraciflua (*sweetgum), and *Magnolia grandiflora* (southern magnolia). We estimated the d.b.h., tree height, and total carbon at 10-year intervals up to the maximum age recommended for the application of the developed equations (i.e., "AppMax"). Silver maple was measured in 7 reference cities, southern magnolia in 8 cities, and sweetgum in 12 cities.

At age 40, the oldest age for which data were available across regions, the estimated total carbon stored in silver maple was between 378.1 kg in the Northeast and 4505.6 kg in the Midwest regions, an 11-fold difference (fig. 17). Estimated d.b.h range was between 34.8 cm in Northeast and 101.6 cm in the Midwest; tree height ranged from 13.3 m in Northeast and 23.4 m in Midwest (table 12). The growth patterns of silver maple are similar in three regions: Inland Valley, North, Tropical Interior West and Lower Midwest, where there is only a twofold difference at age 40. Over the same time period, the quickest accumulation of carbon in silver

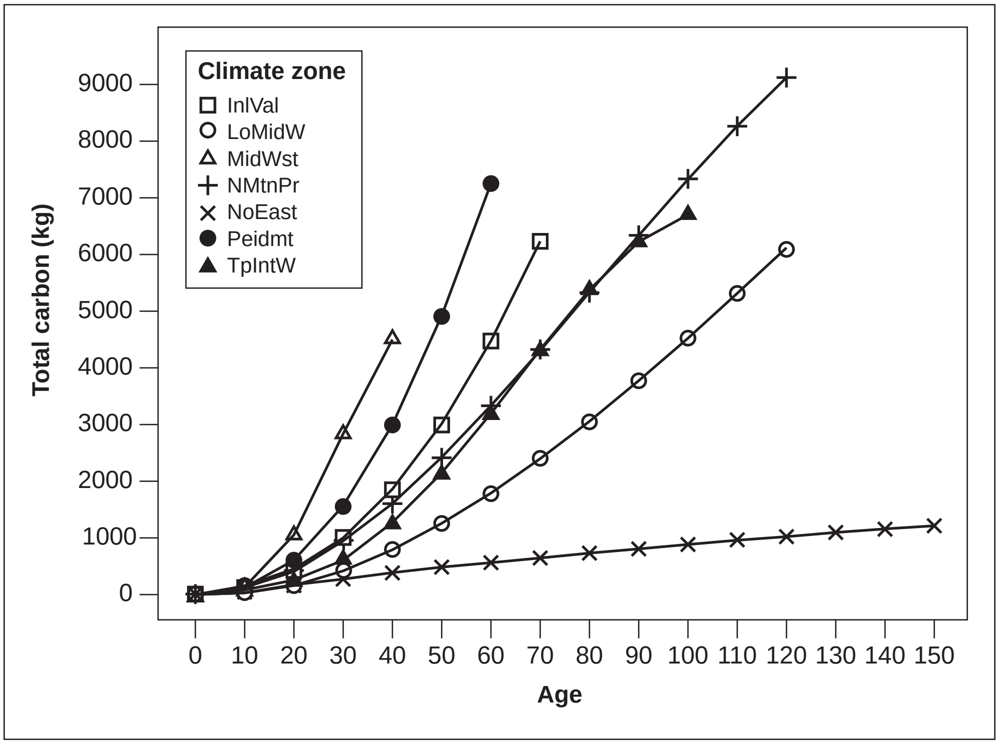

Figure 17—Total stored carbon by age for silver maple in regions where it was measured.

maple occurred in the Midwest and South. Silver maple growing in the Northeast is on the lowest trajectory for carbon stored, amounting to only 1222.3 kg at the oldest age for which the growth equations could be applied, age 150.

Of the regions and reference cities in which sweetgum is planted abundantly, the highest amount of carbon stored was in the southeastern region of the United States followed by regions in California (Northern California Coast; Inland Valleys including Sacramento Valley; Inland Empire) (fig. 18). Sweetgum in the Northeast and Southern California Coast stored noticeably less carbon than in the other regions as trees grew older. At age 60, the difference between highest and lowest estimates of carbon storage was ninefold, ranging from 238.6 kg in Southern California Coast (d.b.h. = 37.3; tree height = 13.3 m) to 5451.5 kg in the South region (d.b.h. = 121.4 cm; tree height = 34.8 m (fig. 18; table 13).

The regional differences in total carbon stored by magnolia become evident within 30 years of planting, with trees in Central Florida, South (Piedmont), Coastal Plain, and Sacramento Valley increasing at a faster rate than in Southern California Coast, Northern California Coast, and Inland Valleys (fig. 19). It takes magnolia approximately 30 additional years in Northern California Coast to attain similar levels of total carbon storage amount as in Central Florida and South regions. By age 50, the oldest age for which estimates were available across regions, magnolia is

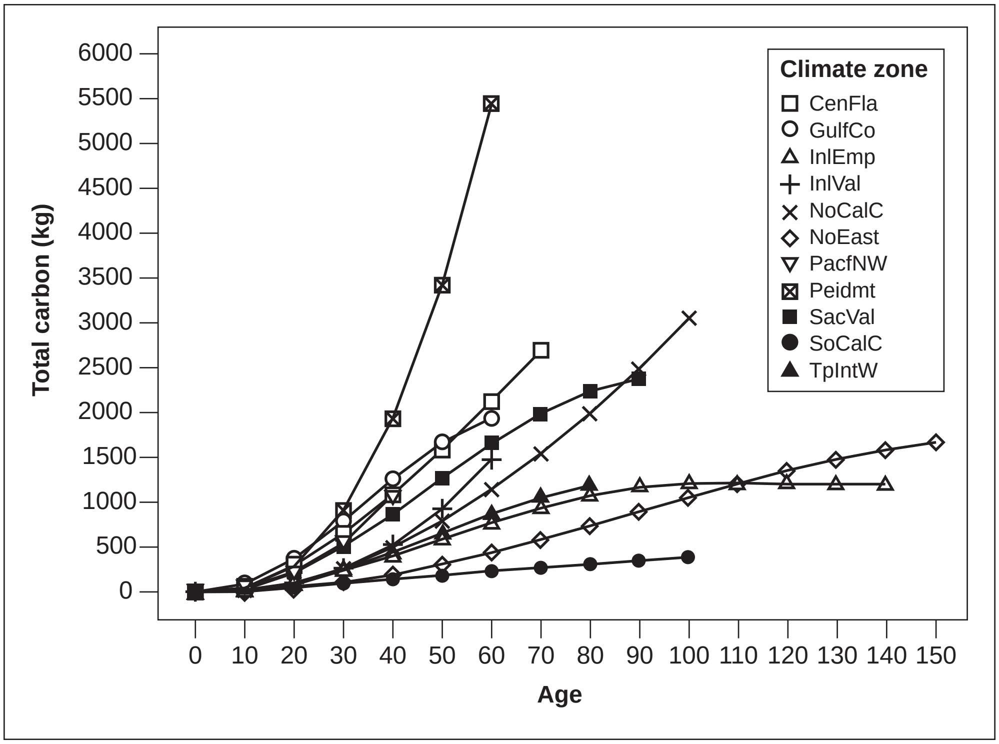

Figure 18—Total stored carbon by age for sweetgum in regions where it was measured.

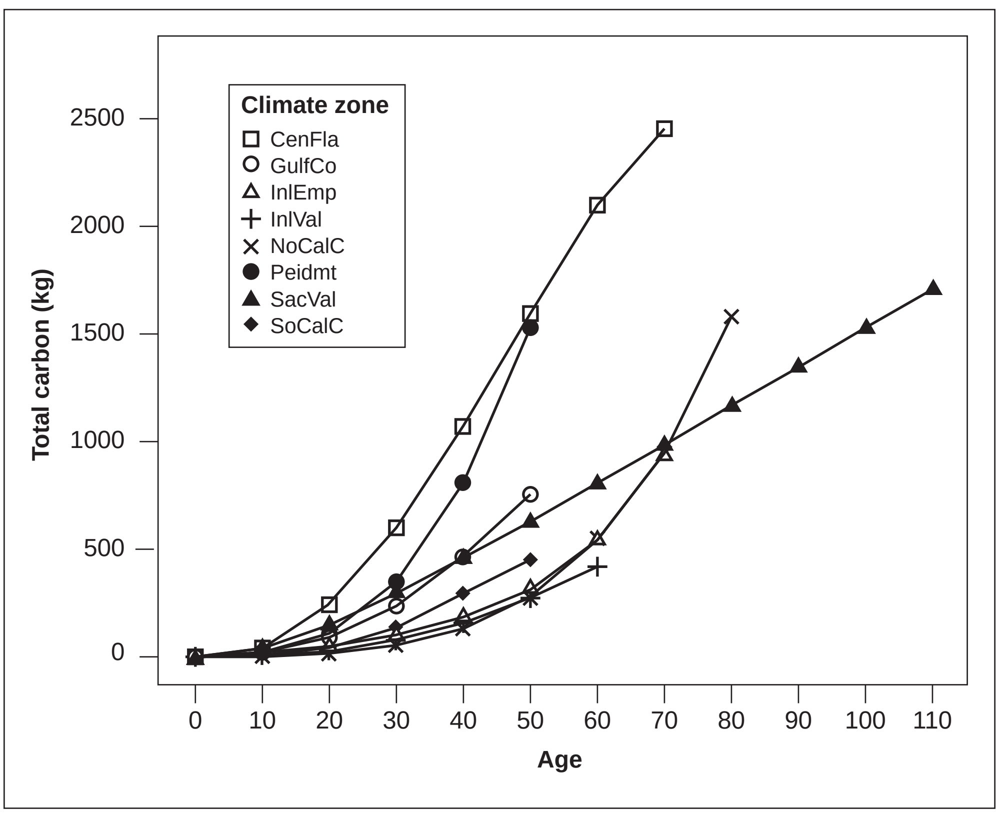

Figure 19—Total stored carbon by age for southern magnolia in regions where it was measured.

expected to accumulate six times more carbon in the Central Florida (1596.2 kg) than in the Inland Valleys region (271.9 kg), nearly a sixfold difference. Estimated d.b.h ranged from 41.2 cm (tree height = 12.2 m) in the Inland Valleys to 97.8 cm in Central Florida region (tree height = 15.7 m) (table 14).

Species that are highly abundant in the reference cities (i.e., silver maple, sweetgum, and magnolia) accumulated carbon at a higher rate in the southeastern regions of the Unites States, namely South, Central Florida, and Coastal Plain regions. The ability of trees to store a large amount of carbon in the southeastern United States is likely due in part to the combination of high precipitation (>1300 mm per year), high temperatures in the summer and relatively warm temperatures in the winter (cooling degree days [CDD] > 847; heating degree days [HDD] < 2000), and long growing seasons. Central Florida, for example, has low HDD and high CDD, signifying a warm climate year round, where cooling would be required in the summers, but heating would not be needed as much in the winter.

Another region in which our case study species have accumulated relatively large amounts of carbon is the Midwest. This is surprising owing to the shorter growing seasons and cooler temperatures. One factor that likely played a role was the lack of limitations on growing space in Minneapolis, Minnesota. Very few sites had visible limitations on growth. In contrast, in Queens, New York city, only 44 percent of the sites had no apparent limitations. The species analyzed in our case study accumulated consistently less carbon in Queens than in the other reference cities. Santa Monica, reference city for the Southern California Coast region, also had lower estimates of carbon storage by sweetgum, likely resulting from too heavy pruning owing to hazard potentials (e.g., trees planted very close to curbs on busy commercial boulevards) (personal communication, P. Peper). Additional regions that had lower total carbon storage were the Inland Empire, Inland Valleys, and Lower Midwest. Although the inland regions of California have many warm days conducive to plant growth, low precipitation can result in high evaporative demand. Prolonged drought stress can restrict tree growth and carbon storage (Anderegg et al. 2015). For example, in the Inland Valleys region, CDD is 3153 mm, but annual precipitation is only 315 mm, most of which comes during the leaf-off season.

Table 12—Diameter at breast height (d.b.h.) and tree height estimates for *Acer saccharinum* in regions where these species were measured

Age	Inland Valleys	Lower Midwest	Midwest	North	Northeast	South	Temperate Interior West
Year	*Diameter at breast height (cm)*						
0	2.5	1.4	2.2	2.8	2.2	1.3	4
10	19	10	22.5	19.6	16.5	22.4	15.2
20	35.5	23.5	52.6	35.5	24.8	43.5	28.4
30	52	36.2	81.4	50.3	30.4	64.6	42.8
40	68.5	48	101.6	64.2	34.8	85.7	57.9
50	85	58.9		77.2	38.4	106.7	72.8
60	101.5	69.1		89.1	41.5	127.8	87
70	118	78.7		100.1	44.1		99.7
80		87.8		110.2	46.5		110.3
90		96.4		119.2	48.7		118
100		104.7		127.3	50.6		122.2
110		112.6		134.4	52.4		
120		120.1		140.6	54.1		
130					55.7		
140					57.1		
150					58.5		
	Tree height (m)						
0	2.2	1.3	3	2.8	2	2.6	6.4
10	10.6	6.9	10.4	11.2	9.1	8.7	9.3
20	14.7	11.2	18.3	15	11.3	13.7	12.4
30	17.5	13.8	22.5	17.5	12.5	17.8	15.4
40	19.8	15.7	23.4	19.3	13.3	20.9	18.1
50	21.6	17.1		20.8	13.9	23	20.4
60	23.2	18.2		21.9	14.4	24.2	22.1
70	24.5	19.2		22.9	14.8		23.3
80		20		23.7	15.2		24
90		20.7		24.4	15.5		24.4
100		21.3		24.9	15.7		24.6
110		21.9		25.4	16		
120		22.4		25.8	16.2		
130					16.4		
140					16.6		
150					16.7		

Table 13—Diameter at breast height (d.b.h.) and tree height estimates for *Liquidambar styraciflua* in regions where these species were measured

Age	Central Florida	Coastal Plain	Inland Empire	Inland Valleys	Northeast	Northern CA Coast	Pacific Northwest	Sacramento Valley	South	Southern CA Coast	Temperate Interior West
Year	*Diameter at breast height (cm)*										
0	0.9	2.6	2.5	2.5	3.4	2.8	2	3.7	2.3	1.8	2.8
10	21.9	24.5	15.1	14.5	12.1	15.4	18.4	20.4	18.7	14.9	13.7
20	41	42.9	26.4	26.4	20.2	27.4	34.8	35.3	39.3	22.3	26.1
30	56.2	58	36.3	38.4	27.8	38.9	51.3	48.4	59.8	27.4	36.8
40	68.9	69.7	45	50.3	35	49.7	67.7	59.6	80.3	31.4	46.1
50	80.1	77.9	52.4	62.3	41.6	59.9		69	100.8	34.6	53.8
60	90	82.8	58.4	74.2	47.7	69.5		76.5	121.4	37.3	60
70	99		63.2		53.4	78.5		82.2		39.7	64.7
80			66.6		58.5	87		86		41.9	67.9
90			68.8		63.1	94.8		88.1		43.8	
100			69.6		67.2	102				45.5	
110			69.6		70.8						
120			69.6		73.9						
130			69.6		76.5						
140			69.6		78.6						
150					80.1						
	Tree height (m)										
0	0.6	1.8	2.9	4.8	2.7	2.3	2.4	3.5	1.8	2.6	1.6
10	9.9	12.7	9.2	7.9	5.9	8.4	9.5	10	12.6	7.3	8.1
20	13.6	17.7	12.9	11.1	8.5	12.4	14.5	15.2	19.9	9.6	12.9
30	15.7	20.7	15.2	14.2	10.6	14.8	17.6	19.2	24.9	11	16.2
40	17.2	22.7	16.6	17.4	12.3	16.3	18.6	22.2	28.8	12	18.6
50	18.3	23.9	17.7	20.5	13.7	17.3		24.5	32	12.7	20.3
60	19.2	24.6	18.6	23.7	14.9	18		26.1	34.8	13.3	21.6
70	19.9		19.4		15.9	18.8		27.3		13.8	22.5
80			20		16.8	19.8		28		14.2	23.1
90			20.5		17.6	21.1		28.3		14.6	
100			20.6		18.3	22.7				14.9	
110			20.6		18.9						
120			20.6		19.4						
130			20.6		19.9						
140			20.6		20.2						
150					20.5						

Table 14—Diameter at breast height (d.b.h.) and tree height estimates for *Magnolia grandiflora* in regions where these species were measured

Age	Central Florida	Coastal Plain	Inland Empire	Inland Valleys	Lower Midwest	Midwest	North	Northeast	Northern California Coast	Sacramento Valley	South
Year	*Diameter at breast height (cm)*										
0	3	2.5	2.2	2.5	3.1	3.1	3.1	3.1	3	1.2	3.1
10	21.2	14.7	13.3	10.3	14.5	14.5	14.5	14.5	7.7	18.8	14.5
20	41.6	26.9	21.9	18	27.9	27.9	27.9	27.9	14.1	32.4	27.9
30	59.4	39.1	29.3	25.7	43.2	43.2	43.2	43.2	22.3	42.6	43.2
40	74.7	51.3	36.7	33.5	60.5	60.5	60.5	60.5	32.3	50.9	60.5
50	87.5	63.5	45.6	41.2	79.6	79.6	79.6	79.6	44.1	57.9	79.6
60	97.8		57.1	49					57.6	64.1	
70	105.5		72.6						72.9	69.6	
80									90.1	74.6	
90										79.2	
100										83.4	
110										87.4	
	Tree height (m)										
0	1.1	1.2	2.8	1.8	1.6	1.6	1.6	1.6	1.9	0.7	1.6
10	6.6	5.7	5.6	4.4	6.1	6.1	6.1	6.1	4.1	8	6.1
20	10.3	9.2	7.5	6.8	10.5	10.5	10.5	10.5	6	10.8	10.5
30	12.7	11.8	8.9	8.9	14.4	14.4	14.4	14.4	7.8	12.4	14.4
40	14.4	13.5	10.2	10.7	17.3	17.3	17.3	17.3	9.4	13.4	17.3
50	15.7	14.2	11.4	12.2	18.7	18.7	18.7	18.7	10.8	14.3	18.7
60	16.5		12.5	13.5					12.1	14.9	
70	16.5		13.2						13.3	15.5	
80									14.5	15.9	
90										16.3	
100										16.7	
110										17	

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Holmes Point Overlay Code Revision

Tree Density Credits & Canopy Cover

ATTACHMENT 9

City of Kirkland Planning and Community Development Department February 2018

The purpose of the Holmes Point Overlay code revision is to support the policy direction and intent established in the new Finn Hill Neighborhood Plan, to address issues and challenges that have risen since HPO adoption and to integrate the code in a manner that is both effective and practical to use.

This summary paper outlines staff analysis of tree density credits to tree canopy cover.

Preserve tree canopy: a key policy direction

One important aspect of the Finn Hill Neighborhood Plan is retaining its woodland character. To that end, municipalities use urban tree canopy (UTC), a metric that quantifies tree cover as a tool for goal-setting and establishing tree protection codes. Tree canopy is the outline of leaf surface seen in aerial imagery, typically expressed in relation to other land cover.

Prior to annexation, Kirkland's 2002 canopy analysis indicated a 32% tree canopy cover. In 2010, Kirkland's 36% canopy cover showed effective tree codes had contributed towards increasing canopy cover. Citywide canopy cover became 40% with annexation due to the larger single-family properties and parks with higher canopy percentages[1]. Excluding parks, analysis indicates about 60% canopy cover within the HPO boundary. Taking a 'no net loss' approach, the Finn Hill Neighborhood Plan establishes a 60% canopy goal within the HPO to retain community character.

How do tree credits relate to canopy cover over time?

Kirkland's tree code uses a point system for tree retention and replanting requirements. It's based on the premise that a credit defined by trunk diameter is a general indicator of tree size, which translates (albeit indirectly) to canopy cover over time. Credits are straightforward for permit applicants, planners and code enforcement to use; which is why other cities such as Olympia, Vancouver, WA, Issaquah, Medina, Kenmore, and Woodinville use tree credits. Like Kirkland, other cities monitor canopy cover and adjust their tree codes to address trends in canopy cover.

During the Holmes Point Overlay code revision, citizens asked staff to show how a credit system translates into tree canopy. Staff started with research findings correlating trunk growth to canopy cover. Since a multitude of variables affect canopy cover: enormous differences in tree growth rates, species size and growing conditions, staff applied *a rule of averages* for the exercise. A red maple (Acer rubrum) was selected because

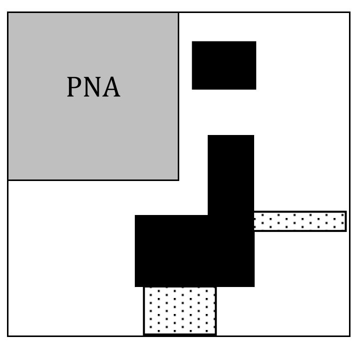
- Data on red maples is commonly found in research findings
- It is moderately-sized at maturity (an "average" sized tree, relatively speaking)
- It has an average growth rate

ATTACHMENT 9

Note the selected tree species has little relevance to the exercise other than representing an "average" tree.

A 2" caliper tree is the equivalent of one credit according to Kirkland's tree code. Based on i-Tree data, red maples develop a 10.5" diameter trunk over 20 years' time.[2] Soil volume research correlates an 11" trunk diameter at breast height (DBH) with an estimated 450 square foot canopy coverage[3], while Virginia Tech research shows red maple canopy in urban settings ranges from 177 to 314 square feet in 20 years.[4] So, an "average tree" has an estimated 245 square foot canopy cover in 20 years.

Staff used average canopy growth estimates to a hypothetical empty one-acre lot (43,560 square feet). In the HPO, 25% of the lot must be designated as a Protected Natural Area (PNA). That means on a 1 acre lot, a 10,890 square foot PNA is required. The remaining area outside the PNA equates to 32,670 square feet.



Per code, each area has a different tree density credit requirement:

- 150 tree credits per acre are required in the PNA
- 30 credits per acre are required on the rest of the lot, outside the PNA

The minimum size of a required replacement tree in Kirkland is a 2" caliper deciduous tree, which is equal to one tree credit. Tree density credits requirements for a 1 acre lot in the HPO are calculated in this manner:

- PNA (10,890/43,560) x 150 credits = 25% x 150 = 37.5, which rounds up to 38 tree credits.
- Non-PNA (32,670/43,560) x 30 credits = 75% x 30 = 22.5, which round up to 23 tree credits.

Using 245 square feet of tree canopy cover per every credit (one 2" caliper tree) over 20 years, a 1 acre lot in the HPO would be expected to provide:

- 86% canopy coverage in the PNA (245 x 38 = 9,310/10,890)
- 17% canopy coverage in the non-PNA (245 x 23 = 5,635/32,670)
- 34% canopy cover on the entire lot (.25 acre PNA x 86% canopy cover + .75 acre non-PNA x 17% canopy cover = 34.25% canopy cover average for the entire lot

Holmes Point Overlay Code Revision

Tree Density Credits & Canopy Cover

ATTACHMENT 9

This exercise in allometry[5] shows Kirkland's tree density credit system equates to an overall 34% canopy cover on a one acre lot in the HPO over 20 years, which then raises the question:

What are fair and equitable tree codes towards a canopy goal?

Examining what constitutes HPO's 60% overall canopy cover reveals an interesting diversity in canopy cover on a lot-by-lot basis. Of the 1,200 parcels in the Holmes Point Overlay area, half have less than 50% tree canopy cover and the majority are under ½ acre in size.[6] Over 200 parcels have less than 25% canopy cover. The wide range of individual parcels' canopy cover raises equity issues when considering fair and effective codes. Some citizens suggest establishing minimum canopy requirements on a lot-by-lot basis as development occurs instead of using tree credits. Regardless of the metric, increasing tree retention requirements for lots under development target fewer properties in the HPO since it was downzoned. One objection to focusing on quantitative tree code requirements is that a qualitative approach towards a healthy, sustainable urban forest is ignored. Other measures, or "tools in the toolbox" could be considered as effective means to maintain tree canopy in the HPO such as

- Using current canopy data as a basis for changes to code requirements
- Develop incentives, change procedures, and use opportunities for education and outreach
- Efforts to increase canopy on properties not under development

These and other issues are some of the challenges with the Holmes Point Overlay code revision project currently underway.

References

[1] City of Kirkland, 2011. Urban Tree Canopy Assessment Report

[2] i-Tree Streets' data for tree species growth in the Pacific Northwest

[3] James Urban, *Up by Roots, page 205;* research on adequate soil volumes per tree size

[4] Virginia Tech online tool, *Tree Canopy Spread & Urban Landscapes*

[5] Wikipedia entry on Tree allometry: https://en.wikipedia.org/wiki/Tree_allometry

[6] Kirkland IT-GIS Department analysis, October 2017

Additional Resources

For additional information, see the following:

- City of Kirkland Comprehensive Plan, 2015 Revision
- Kirkland Zoning Code Chapter 95, Trees and Landscaping
- Kirkland Zoning Code Chapter 70, Holmes Point Overlay Zone
- Kirkland Urban Forestry Strategic Management Plan

Snohomish County
Planning and Development Services

Urban Tree Canopy Coverage Requirements

Assistance Bulletin
#105

Revised March 2015

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This Assistance Bulletin only applies to property within unincorporated Snohomish County and does not apply to property within incorporated city limits.

Introduction

In order to balance environmental goals and planned density goals, the County has shifted its approach of tree retention from regulating individual trees to the conservation of the overall unincorporated urban forest canopy. In the past, tree retention and replacement regulations only applied to sites with significant trees, while sites without significant trees were not subject to the tree retention and replacement requirements. Recognizing the functional importance of a mixed-age, mixed-species urban tree canopy, new regulations were adopted to treat urban residential sites without tree canopy the same as urban residential sites with tree canopy.

Applicability of Tree Canopy Requirements

The tree canopy requirements are primarily contained in SCC 30.25.016 and apply to all new residential development located within unincorporated Urban Growth Areas whether or not tree canopy exists on the parcel.

Tree Canopy and Significant Trees Defined

Tree canopy shall include all evergreen and deciduous trees six feet in height or greater, excluding invasive species or noxious weeds, within the gross site area. Significant tree means a tree with a caliper of at least 10 inches. Dogwoods and vine maples are significant trees if they have a caliper of at least seven inches. Alders are not significant trees. For multiple stem trees such as vine maples, the caliper of the individual stems are added together to determine if a tree meets the minimum caliper for a significant tree.

Exemptions to Tree Canopy Requirements

- Removal of any hazardous, dead, or diseased trees, and as necessary to remedy an immediate threat to person or property as determined an arborist
- Construction of a single-family dwelling, duplex, accessory or non-accessory storage structure on an individual lot created prior to April 21, 2009, or created by a subdivision or short subdivision for which a complete application was submitted prior to April 21, 2009
- Construction or maintenance of public or private road network elements and public or private utilities including utility easements not related to development subject to chapters 30.23A, 30.34A, 30.41G, or 30.42E SCC
- Construction or maintenance of public parks and trails when located within an urban residential zone
- Pruning and maintenance of trees

Tree Canopy Coverage Requirements

Tree canopy requirements are set to a sliding scale based on the type of residential development and the number of lots or units. The following table is taken from SCC 30.25.016 and shows the minimum required tree canopy for all new residential development within unincorporated urban growth areas.

Type of Development	**Minimum Required Tree Canopy Coverage of Development Site (gross site area)**
Subdivisions for Single Family Residential 10 or more lots	30 percent
Short Subdivisions for Single Family Residential 4 to 9 lots	25 percent
Short Subdivisions for Single Family Residential Less than 4 lots	20 percent
Single Family Detached Units, Cottage Housing, Townhouse, Multi-family 10 or more units	20 percent
Single Family Detached Units, Cottage Housing, Townhouse, Multi-family Less than 10 units	15 percent
Urban Center (residential and mixed use projects only)	15 percent

Tree Canopy Coverage versus Lot Coverage

Tree canopy coverage is different than lot coverage. Tree canopy can extend over structures and buildings like an umbrella. The photo to the right illustrates this. Note the large deciduous tree which has branches extending over the roof of the home. Lot coverage by comparison means that portion of the total area of a lot that is covered by buildings.

Measuring Tree Canopy

Existing tree canopy may be measured by surveying the canopy for each tree located on a project site and summing the canopy area of each tree to calculate the total existing canopy. Alternatively, for heavily forested sites, sites with critical areas, or sites not proposing to utilize one of the incentives to save existing significant trees, canopy area can be estimated using a recent aerial photo. For sites proposing to plant new tree canopy, the canopy area of each tree to be planted at 20-years maturity must be calculated. The table below illustrates the methods for calculating existing and new tree canopy.

Existing Canopy		**New Canopy**
Option 1 Tree Survey	**Option 2 Aerial Estimation**	**20-Year Canopy Calculation**
Measure average canopy radius *(r)* for each tree to be retained Calculate existing canopy area using the formula: Canopy Area ($CA)=\pi r^2$ Total the sum of tree canopy areas and divide by gross site area to obtain canopy coverage percentage	Obtain aerial imagery of site Measure site boundaries Measure canopies of individual trees or stand area using leading edges as the forest boundary Divide total canopy measurement by the gross site area to obtain canopy coverage percentage	For each proposed species: Calculate radius (*r*) of canopy at 20 years maturity Calculate canopy coverage using the formula: $CA=\pi r^2$ Multiply by the proposed quantity to be planted to obtain total species canopy area Total the sum of species canopy area for all proposed species and divide by gross site area to obtain 20-year canopy coverage percentage

Tree Calculation Worksheet and Tree Species Database

To assist applicants with the calculation of tree canopy for development applications, a worksheet has been developed. This worksheet is required to be submitted with a landscaping plan. Additionally, a database of tree species has been developed and includes estimated 20-year canopy coverage and whether it can be used as a street tree or is utility safe. Applicants shall consult the tree species database when determining the proposed canopy. An applicant may request the PDS director include additional tree species in the database or a change to the 20-year canopy coverage in the database when they provide written documentation from an arborist or nursery. The worksheet and database are available on the county's website at www.snohomishcountywa.gov/2737.

Incentives to Retain Significant Trees

In an effort to retain significant trees and existing tree canopy, several incentives are available and may be incorporated into a development application. These include:

- Canopy bonuses for retaining individual significant trees, stands of five or more trees, stands of five or more significant trees, and significant trees qualified to receive flow control credits for drainage
- Reductions in required on-site open space in exchange for preserving 40 percent of the existing tree canopy
- Exemption from landscape requirements when at least 45 percent of the gross site area's existing tree canopy is retained and the majority retained are evergreen species
- Reducing the minimum lot area required in subdivisions and short subdivisions when at least 20 percent of the site, not including any critical area protection areas and perimeter buffers, is put into a separate tract or tracts that have at least 20 significant trees per acre and where at least 60 percent of the significant trees within the tract or tracts are retained

Reducing the Tree Canopy Coverage Requirements

An applicant may request a landscape modification to reduce the tree canopy coverage requirements by five percentage points when certain criteria are met. For example, a short subdivision of less than four lots could request a landscape modification to reduce the tree canopy coverage requirement from 20% to 15%. The applicant would need to demonstrate they have made every effort to retain as much tree canopy as possible, plant additional understory vegetation and, if applicable, enhance underperforming critical area protection area buffers.

On sites without existing tree canopy, the director may reduce the tree canopy coverage requirements by five percentage points when the applicant provides a 25 percent increase in the area of required open space. Certain developments are not eligible for this reduction.

Option to Opt-in to Tree Canopy Regulations for Vested Development Applications

Applicants with a development application that was vested between April 21, 2009 and October 27, 2014, may request the application be reviewed under Amended Ordinance No. 14-073. All other development regulations in effect as of the date the original application was vested shall apply. Applicants shall have 12 months from October 27, 2014, in which to apply. Public notice to parties of record is required.

Definitions of Tree and Clusters or Stands of Trees

Title 30 SCC does not include a general definition of a tree. Pursuant to code the customary meaning of a tree is used. According to the Merriam-Webster dictionary a tree is a woody perennial plant having a single usually elongated main stem generally with few or no branches on its lower part.

Title 30 SCC does not define the phrase "clusters or stands of trees." In general, a stand or cluster is five or more uniform mature trees that form a continuous canopy, however, each site will be reviewed on a case-by-case basis to determine what constitutes a cluster or stand.

Frequently Asked Questions

Q: What can be counted as existing tree canopy?

A: Tree canopy shall include all evergreen and deciduous trees six feet in height or greater, excluding invasive species or noxious weeds, within the gross site area. This can include existing trees located within critical areas and buffers.

Q: Do street trees planted within required frontage improvements count towards the tree canopy coverage requirements?

A: Yes.

Q: What significant trees are required to be saved?

A: All significant trees within critical area protection areas and required buffers. If applicable, all significant trees within required perimeter landscaping buffers required under SCC 30.25.020.

Q: Can the incentives to save existing trees be combined?

A: Yes. It is possible to combine incentives, however, as a practical matter not all of the incentives will work together.

Q: What does "counted at 125, 150, or 200 percent of its actual canopy area" mean?

A: It means the existing tree is given extra credit for its canopy, making it more attractive to be retained rather than cut down. To calculate this incentive the existing tree canopy is multiplied by 1.25, 1.5, or 2. For example, if an applicant wants to take advantage of the incentive to retain one existing significant tree with a canopy of 500 square feet. The applicant would multiply the tree canopy of 500 square feet by 1.25, resulting in an effective canopy of 625 square feet. The 625 square feet would be deducted from the overall tree canopy coverage requirements. The net effect is the applicant may need to plant less trees on the project site because they chose to retain existing trees.

Q: Can the owner of a single family home remove an existing significant tree located in their yard?

A: Yes. Unless the tree was part of a development application submitted after October 27, 2014, then it cannot be removed unless determined in writing by an arborist to constitute a hazard.

Q: Can the owner of a single family home remove a retained or replacement tree located in their yard?

A: No. Retained significant trees, trees planted as replacements for significant trees, and trees planted to meet the canopy coverage requirements may not be removed except when determined in writing by an arborist to constitute a hazard. Removal of a replacement or significant tree without proper documentation is subject to a fine under chapter 30.85 SCC.

Q: Does a property without trees have to comply with the tree canopy requirements?

A: Yes. The tree canopy requirements apply to all new residential development located within unincorporated Urban Growth Areas whether or not tree canopy exists on the parcel.

Q: What are the notice requirements for opting in to the tree canopy requirements?

A: SCC 30.25.013(3) requires public notice pursuant to chapter 30.70 SCC. Any development application requesting to opt-in is required at a minimum to provide notice to parties of record.

Q: Where can I get more information?

A: More tree canopy resources are available at www.snohomishcountywa.gov/2737.

Snohomish County Tree Canopy Calculation Sheet

Name of Project: Paradise Lake Garden Apartments

Permit File Number: Assigned at submittal

Project Manager/Planner: Clay White

Applicant Name: Snohomish Garden Development Company LLC

Development Type: Multi-family residential apartments

Required Tree Canopy Coverage per SCC Table 30.25.016(3): 147,334 sf

Resubmittal under 30.25.013*? ☒Yes ☐No

1. Is project exempt from Tree Canopy Requirements pursuant to SCC 30.25.016(1)(b)(c)or(d)?
   ☐Yes
   ☒No
2. Is there existing tree canopy on site (consult latest Snohomish County, Google Earth or Bing aerial imagery)?
   ☒Yes
   ☐No
3. Type of existing canopy calculation applicant is using pursuant to SCC 30.25.016(4)
   ☐Option 1 – Tree Survey (eligible for all canopy credits under SCC 30.25.016(5)
   ☐Option 2 – Aerial Estimation (only eligible for canopy credits under SCC 30.25.016(5)(f))
4. Type of canopy calculation or combination of canopy calculations used below:
   ☐Existing Canopy only (indicate Option 1 or 2 above)
   ☒New Canopy only
   ☐Combination of Option 1 and New Canopy (eligible for all canopy credits under SCC 30.25.016(5)
   ☐Combination of Option 2 and New Canopy (only eligible for canopy credits under SCC 30.25.016(5)(f))

* Resubmittal eligibility ends after October 26, 2015 pursuant to SCC 30.25.013

Snohomish County Tree Canopy Calculation Sheet

Existing Canopy: Option 1 – Tree Survey

Tree Number	Tree Species	Taxonomic Family	Species Type (Evergreen/ Deciduous)	Native Species (Yes/No)	SCC 30.25.016(5)(a)	SCC 30.25.016(5)(b)	SCC 30.25.016(5)(c)	SCC 30.25.016(5)(d)	SCC 30.25.016(5)(e)	Existing Average Canopy Radius*(*r*)	Average Canopy Calculation (CA=pr^2)	Existing Canopy Bonus**	Total Existing Tree Canopy Area
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0
											0		0

*** Calculate Existing Average Canopy Radius by measuring the longest and shortest branches radiating from trunk, summing the measurements and dividing by 2**
**** Only one type of Existing Canopy Bonus may be given – use largest canopy bonus applicable under SCC 30.25.016(5)(a)(b)(c)(d)or (e)**

Species Type Mix	Total Existing Canopy Area	Gross Site Area	Canopy Coverage %
% Evergreen**:** % Deciduous			

Snohomish County Tree Canopy Calculation Sheet

Existing Canopy: Option 2 – Aerial Imagery

*

Total Existing Canopy Area	Gross Site Area	Canopy Coverage %

* Required imagery includes most recent Snohomish County aerial imagery, Google Earth or Bing aerials and gross site perimeter displayed
** Required measurements include perimeter measurements of gross site, perimeter measurements of canopy coverage areas

Snohomish County Tree Canopy Calculation Sheet

New Canopy

Tree Species	Taxonomic Family	Species Type (Evergreen/Deciduous)	Native Species (Yes/No)	20 Year Canopy Calculation**	Height at Planting (min 6 ft)	Deciduous Diameter at Planting (min 1.5 in. combined)	Quantity to Plant	Total 20 year Tree Canopy Area
Acer circinatum	Aceraceae	deciduous	yes	240	7-8'	2'	56	13440
Acer circinatum 'Pacific Fire'	Aceraceae	deciduous	yes	240	8-10'	2.5'	29	6960
Betula papyrifera	Betulaceae	deciduous	yes	480	10-12'	2'	132	63360
Calocedrus decurrens	Cupressaceae	evergreen	yes	175	7-8'	2'	52	9100
Chamecyparis lawsoniana	Cupressaceae	evergreen	yes	175	7-8'	2'	56	9800
Cornus nuttallii 'Eddie's White Wo	Cornaceae	deciduous	yes	240	8-10'	2'	19	4560
Picea omorika	Pinaceae	evergreen	no	110	7-8'	2'	40	4400
Psudotsuga menziesii	Pinaceae	evergreen	yes	480	7-8'	2'	51	24480
Thuja plicata	Cupressaceae	evergreen	yes	480	7-8'	2'	40	19200

**** 20 year calculations for some species available from Snohomish County PDS Landscaping Database – any other 20 year coverages must be submitted by Qualified Landscape Designer with documented annual growth rates for species height and width (canopy coverage estimate must not exceed Mature Canopy calculation within Snohomish County PDS Landscaping Database**

Species Type Mix	Total 20 year Canopy Area	Gross Site Area	Canopy Coverage %
50.3% Evergreen**:** 49.7% Deciduous	**155,300**	**736,671**	**21**

** Landscaping Database Sources: United States Department of Agriculture - Natural Resources Conservation Service Plants Database, Washington Native Plant Society Native Plant Database, SelecTree - Cal Poly Urban Forest Ecosystems Institute, Washington State University - PNW Plants Database, University of Florida Environmental Horticulture Plant Information Database, Woodbrook Native Plant Nursery Native Plant Descriptions, J.Frank Schmidt & Son Co. Reference Guide

Snohomish County Tree Canopy Calculation Sheet

5. Is applicant proposing to retain 40% of gross site area in tree canopy retention tracts, including understory and groundcover vegetation? If yes, applicant is exempt from all on-site recreation requirements of SCC 30.23A.080.
   ☐Yes
   ☒No
6. If applicant is retaining significant tree canopy and using Option 1, does the significant tree canopy coverage meet or exceed 45% of the gross site area and is the Species Mix Type majority Evergreen? If yes, applicant is exempt from all other requirements of SCC 30.25.015 and 30.25.016.
   ☐Yes
   ☒No
7. Is applicant reducing lot areas by 20% using SCC 30.25.016(5)(h)? If yes, then at least 20 percent of the site, not including any critical area protection areas and perimeter buffers, must be placed into a separate tract or tracts that have at least 20 significant trees per acre and where at least 60 percent of the significant trees within the tract or tracts are retained (does not change the tree canopy requirements).
   ☐Yes
   ☒No
8. Is applicant using Lot Size Averaging pursuant to SCC 30.23.210?
   ☐Yes
   ☒No
9. Is applicant reducing lot sizes by 20% using Lot Size Averaging bonus in SCC 30.25.016(5)(i)? If yes, then at least 20 percent of the site, not including any critical area protection areas and perimeter buffers, must be placed into a separate tract or tracts that have at least 20 significant trees per acre and where at least 60 percent of the significant trees within the tract or tracts are retained (does not change the tree canopy requirements).
   ☐Yes
   ☒No
10. Is applicant reducing canopy requirements of SCC Table 30.25.016(3) using the 5% reduction allowed in SCC 30.25.16(8)? If yes, applicant must submit landscape modification including understory planting plan and critical area and buffer enhancement plan, if applicable.
   ☐Yes
   ☒No

Snohomish County Tree Canopy Calculation Sheet

11. For sites without existing canopy, is applicant reducing canopy requirements of SCC Table 30.25.016(3) using the 5% reduction allowed in SCC 30.25.016(9)? If yes, on-site recreation space must exceed requirements in SCC 30.23A.080(2) by 25% (short subdivisions less than seven lots, single family detached units, cottage housing, townhouse, multi-family less than 10 units, and urban center developments are not eligible for this reduction).
    ☐Yes
    ☒No
12. Does the applicant meet the evergreen planting requirements in SCC 30.25.016(6)(a)? If no, applicant must qualify for exception in SCC 30.25.016(6)(a)(i) or (ii) or re-submit a corrected Tree Canopy Calculation Sheet.
    ☒Yes
    ☐No
13. If the applicant is using the Evergreen Species mix exceptions available in SCC 30.25.016(6)(a)(i) or (ii) indicate which below:
    ☐ SCC 30.25.016(6)(a)(i) Native Deciduous Option – 37.5% Evergreen mix required
    ☐ SCC 30.25.016(6)(a)(ii) Street Tree Option
14. Does the applicant meet the planting species mix requirements in SCC 30.25.016(6)(b)? If no, applicant must re-submit a corrected Tree Canopy Calculation Sheet.
    ☒Yes
    ☐No

The following calculations are for Internal Reporting Use Only

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Total square footage of Canopy Bonuses applied in Option 1 if used:

Total reduced canopy percentage under exceptions pursuant to SCC 30.25.016(8) or (9) if used:

Total Actual Tree Canopy Coverage after all bonuses and exceptions subtracted: