Hoquiam, Washington
Tree Inventory and Community Urban Forest Management Plan

Introduction
Historical Perspective

Urban Forestry is the planning and management of trees, forests, and related vegetation within communities to create or add value.

--E. Gregory McPherson

Urban Forestry, a common place term today, has actually been practiced since the late 1700's. In the very early years immigrants brought with them the species of trees and plants reminding them of home. A perspective of early tree care indicates the forester's primary responsibilities were to plant and remove trees and at times provide insect control. Very often the trees of concern were introduced species such as; Lombardy poplar, Norway maple and others.[1]

The concept of Urban Forestry as a management approach, developed into a science in the 1960s and 1970s largely as a result of numerous diseases introduced into the urban environment. Diseases with a serious impact on the urban forest such as Dutch Elm Disease, Oak Wilt, and Phloem Necrosis spurred the development of a systems approach to managing urban trees. Drawing on the knowledge from numerous other disciplines provided the necessary tools for tree professionals and municipal leaders to adopt an integrated management system.[2]

Unlike traditional forestry, with a primary emphasis on the natural forest and Arboriculture with an emphasis on the individual tree, Urban Forestry is concerned and deals with the forest from an urban perspective, in its entirety. With all of the positive and often negative impacts of urbanization it is essential for the urban forester to recognize the value of a multi-disciplinary systems approach to the forest under their charge.

Urban forestry, over the last decade has seen dramatic changes. Moving from a once primarily reactive system to one which is becoming primarily proactive, urban forestry now has become of the driving forces in shaping the fabric of city infrastructure and city growth.

[1] Mcpherson, E. Gregory.2006. Urban Forestry in North America.
[2] Bratkovich, DR. Steve. Urban Forestry: An Evolving Discipline

Rationale

Rooted in the scientific research backed idea that people desire to live in communities with trees and green space, urban and community forests address the need for aesthetic development. With an emphasis of beautification came the realization that trees provide much more to communities than just aesthetics. Wind channeling, flood control, heating expense reduction, reduced cooling costs, reduction in crime, airborne particulate matter capture, aerosolized chemical absorption and the list goes on.

With all of the benefits of urban and community forests there are some consequence as well. To mitigate the negative aspects trees in our communities require a plan, a management direction to prevent tree related disruption, utility conflict and infrastructure damage.

The management plan begins with an inventory of the cities existing urban trees then provides a framework to grow the existing community forest all to the aid in the realization of the benefits while at the same time reducing or eliminating the negative aspects of trees on our communities.

Objective of the Management Plan

The objective of the Hoquiam, Washington; Urban Forestry Management Plan is to address the existing urban forest based on results from data collected during a comprehensive street tree inventory conducted by ArborPro Urban Forest Management Software. Address tree related issues faced by the community of Hoquiam, and provide management guidance to the community in relation to the urban and community forest. The goal is to provide an effective tool for the city to employ sound management guidelines to address the urban and community forestry needs.

Hoquiam, Washington
Tree Inventory and Community Urban Forest Management Plan

Executive Summary

In May of 2011 ArborPro, Inc. began operations of collecting a GPS tree inventory of trees in their neighborhood areas. From May 8th to the 18th the inventory was initiated with the GPS data collection. ArborPro, Inc. assigned a Board Certified Master Arborist , with over 15 years experience, to collect the requested tree attributes and the GPS coordinates of every tree. The objective of this report is to summarize the findings from the survey. Included in the survey are the GPS locations of the trees, species name in botanical nomenclature and common form, general health assessment, maintenance recommendation and species composition.

Statistical Highlights:

There are 933 tree sites recorded in the survey area representing over 71 different species.

Japanese Flowering Cherry, Crabapple and Douglas Fir are the most abundant trees on in the City.

The largest tree in the survey is a 80 inch Redwood located on Chenault Street.

The GPS points were collected for every tree in the survey at an accuracy level of +/- 3 feet also referred to as “Sub-meter”. This is a highly accurate level of precision.

Maintenance recommendations for each tree have been provided to help preserve and enhance the overall health of the tree population and appearance of the HOA.

Abbreviations Used in the Report

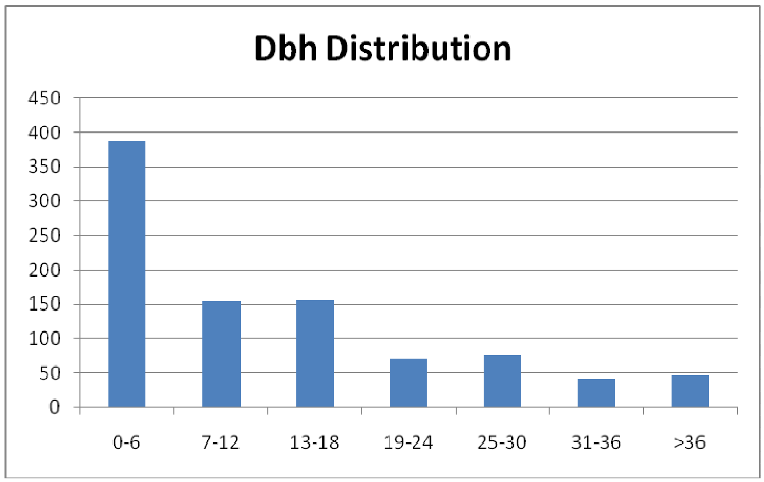
DBH………………………. Diameter at Breast Height (girth of a tree)
GIS……………………….. Geographic Information System
GPS……………………….. Global Positioning System
ID…………………………. Identification
SPP……………………….. Species

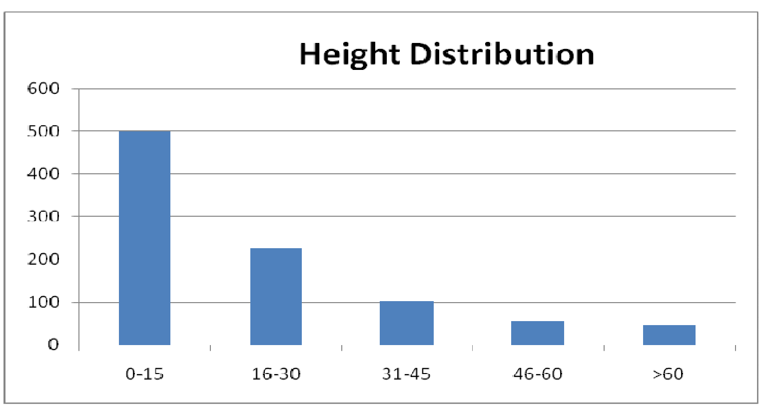
Study Results

Size Characteristics

The size of a tree provides insight into the age and value of the tree. There are two industry-wide recognized size characteristics, height and diameter at breast height. Height was measured utilizing laser range finders and is represented in ranges due to the dynamic growth rate of trees. Diameter is determined by measuring the diameter of the tree at 4.5 feet above grade. The DBH is represented in ranges due to the dynamic growth rate of trees.

Dbh Range	Tree Count
0-6	387
7-12	154
13-18	157
19-24	71
25-30	77
31-36	41
>36	46
Total	**933**





Height Range	Tree Count
0-15	500
16-30	227
31-45	103
46-60	55
>60	48
Total	**933**

Maintenance Recommendations

Based on criteria set forth by our experience in urban forestry management and ISA standards our data collector has provided a maintenance recommendation for each tree or tree site. The ArborPro software program allows the Campus to search for trees recommended for a specific maintenance activity. We have provided a sample map detailing the recommended maintenance in the appendix. The definition for each recommended maintenance activity can be found below.

Recommended Maintenance	Tree Count
Priority 1 Removal	33
Priority 2 Removal	34
Priority 1 Prune	21
Priority 2 Prune	5
Routine Prune	494
Training Prune	346
Total	**933**

Priority 1 Removal
Trees that are dead or have one or more defects that cannot be cost-effectively or practically remedied. Such defects include extensive trunk decay and severely decayed or weakened v-type crotches. These trees should be surveyed by staff and scheduled for removal and replacement if appropriate. This category includes trees that reflect dangerous conditions combined with significant targets such as proximity to high volume sidewalks or play areas.

Priority 2 Removal
Trees that are structurally compromised but may be expected to be removed in 2 to 5 years. These trees should be scheduled for removal over a reasonable time period based on available funds. The removal process should be followed by a replanting program. The appropriate species should be planted based on the Planting Plan provided by ArborPro, Inc.

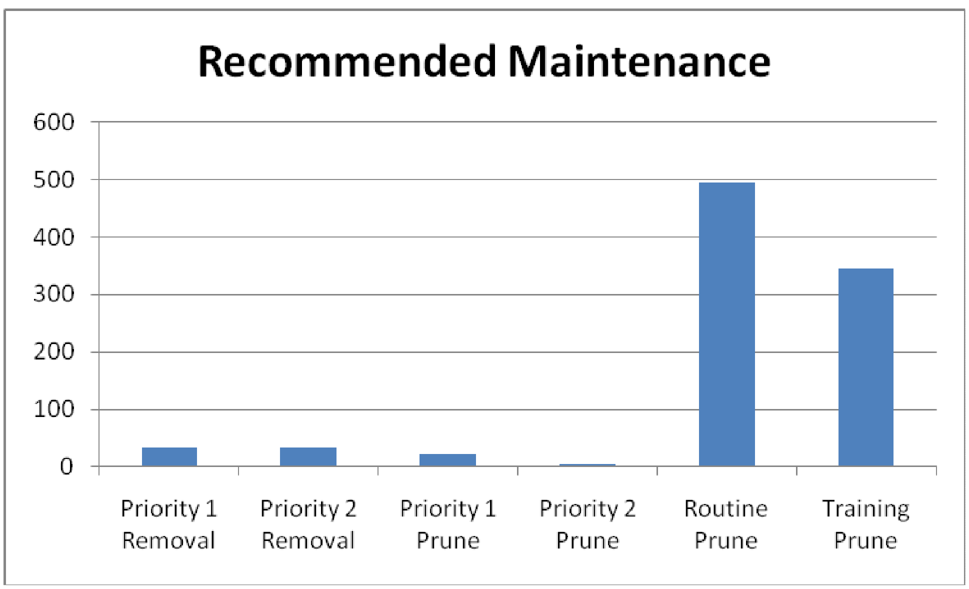
Priority 1 Prune
Trees which require pruning to remove deadwood and/or broken branches that pose an immediate safety risk that could result in personal injury or property damage. Limbs that are more than 3 inches in diameter and pose and immediate safety risk. The trees that have been recommended for a high priority prune should be inspected by staff. These trees are in need of corrective maintenance. The percentages of trees that fall into this category is approximately 2% of the entire tree population. The budget required to prune these trees should be very reasonable and easy to attain.

Priority 2 Prune
Trees having problems and conditions which may affect future safety, health or structure of the tree. This includes primarily large trees (over 20 feet in height) with minor amounts of deadwood and correctable structural problems. It is recommended that these trees are placed on a systematic pruning program. The most cost effective program would include grid pruning. Low-priority pruning cycles can be developed with regard to available funds.

Routine Prune
It is recommended that these trees are placed on a systematic pruning program. The most cost effective program would include grid pruning or arterial pruning. Divide the City evenly into tree maintenance grids or select entire areas. Have the entire area pruned in a budget year. Low-priority pruning cycles can be developed with regard to available funds.

Training Prune
Many of the surveyed trees fall into this category. The trees that have been recommended for training prune have recently been installed or they are trees under 6” DBH. These trees will necessitate pruning for careful establishment of a strong, well placed scaffold branch structure particularly in large canopy species. This in important to resist storm damage, coexist with vehicular or pedestrian traffic, and avoid utility conflicts.

Trees pruned properly within their first two to three years will be healthy trees requiring less maintenance in the future. Young tree maintenance will also prevent tree liability associated with un-maintained trees.



Tree Condition Evaluation

The survey included an evaluation of the trees that have been inventoried with respect to their overall condition of trunks and leaves as well as a risk factor rating. The evaluation performed was a ground-level sight inspection. There are many conditions that can exist in a tree that are not assessed from a ground-level inspection. However, the condition evaluation is helpful in determining the trees that are in the poorest condition. Below are the details of our tree condition notations for review and a chart of the tree conditions of the HOA of Haddonfield

Excellent

Superior branch placement free of codominant leaders. Canopy is full and balanced, free of epicormic shoots, with adequate twig retention to ensure the continued development of correct branch taper. Superior trunk taper and root flare present. Conditions should be ideal for full development of genetic potential.

Good

Good to Excellent branch placement, lack of uncorrectable co-dominant leaders, good pruning history. Canopy generally full and balanced, good foliage color, vigor and shoot elongation typical of species, lack of visible or uncontrollable pests. Conditions ideal to favorable for full development to species potential, sufficient room for canopy and root growth, irrigation and soils exist to sustain development.

Fair

Decent branch placement, less than ideal scaffold spacing, some co-dominance present, past pruning less than ideal but possibly correctable. Canopy relatively thin, foliage chlorotic, vigor and shoot elongation below norm for species, minor pests or possibility of infestation. Some restriction imposed by deficiencies such as proximity to competing species, proximity to sidewalks, grade changes, poor irrigation, overhanging adjacent trees.

Poor

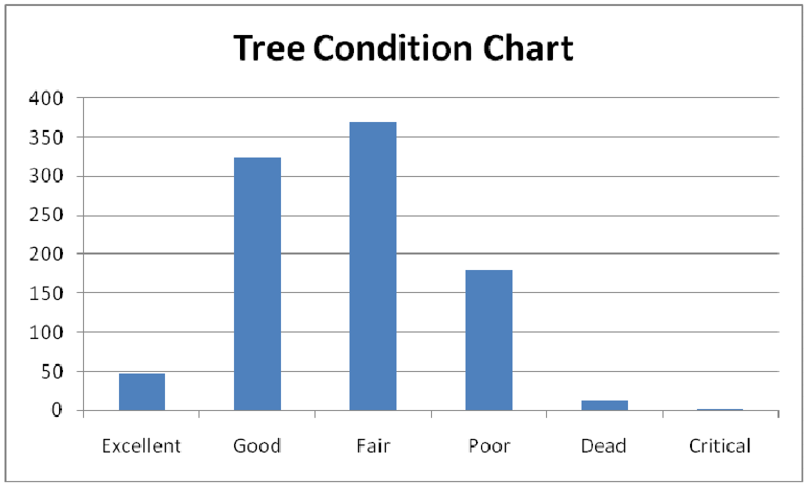
Inferior branch placement, crowded scaffold, co-dominance likely, correction or mitigation necessary and likely extensive, restructuring needed to repair past pruning practices. Canopy sparse, dead twigs, stunted or absent new growth, declining number of growing points, pest presence visible or likely. One or more restrictions severe enough to hamper the ability of the tree to develop fully as listed above. Recent changes to the site may manifest themselves symptomatically in the future.

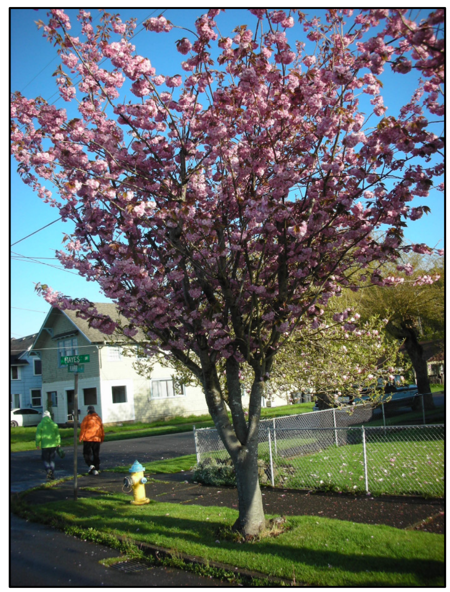
Dead or Critical

Majority of dead limbs and scaffold. Canopy nearly or completely dead. Restrictions to the site likely. to cause failure or death of the tree.

Tree Condition Chart

Tree Condition	Tree Count
Excellent	46
Good	324
Fair	369
Poor	180
Dead	13
Critical	1
Total	**933**





Species Frequency

The species population diversity of the Property is listed on the following pages. The survey identified over 70 tree species in the selected survey areas. The most common tree identified was the *Prunus serrulata* commonly known as the Japanese Flowering Cherry Tree.

Botanical Name	Common Name	Tree Count
Prunus serrulata	Japanese Flowering Cherry	151
Malus floribunda	Crabapple	62
Pseudotsuga menziesii	Douglas Fir	59
Zelkova serrata	Sawleaf Zelkova	49
Calocedrus decurrens	Incense Cedar	45
Prunus cerasifera	Purple-Leaf Plum	38
Acer rubrum	Red Maple	31
Betula papyrifera	Paper Birch	28
Juniperus occidentalis	Western Juniper	27
Acer plantanoides	Norway Maple	26

Pyrus calleryana 'Aristocrat'	Aristocrat Pear	25
Styrax japonicus	Japanese Snowbell Tree	24
Other Tree	Other Tree	21
Crataegus phaenopyrum	Washington Hawthorn	19
Sorbus aucuparia	European Mountain Ash	18
Prunus avium	Sweet Cherry	15
Acer saccharum	Sugar Maple	13
Tilia cordata	Little-Leaf Linden	13
Acer saccharinum	Silver Maple	13
Picea pungens glauca	Colorado Blue Spruce	12
Aesculus glabra	Ohio Buckeye	12
Acer campestre	Hedge Maple	12
Prunus virginiana	Common Chokecherry	12
Acer platanoides 'Crimson King'	Crimson King Maple	11
Cercidiphyllum japonicum	Katsura Tree	9
Alnus oregona	Red Alder	7
Acer palmatum	Japanese Maple	7
Taxus brevifolia	Pacific Yew	6
Acer negundo	Box Elder	5
Thuja occidentalis	American Arborvitae	5
Fraxinus pennsylvanica 'Summit'	Summit Ash	5
Tsuga mertensiana	Mountain Hemlock	5
Quercus palustris	Pin Oak	5
Ulmus americana	American Elm	4
Ilex opaca	American Holly	4
Gleditsia triacanthos inermis	Thornless Honey Locust	4
Acer circinatum	Vine Maple	3
Prunus americana	American Plum	3
Cornus kousa	Kousa Dogwood	3
Thuja standishii x T. plicata 'Green Giant'	Green Giant' Arborvitae	3
Ptelea trifoliata	Wafer Ash	3
Pinus spp	Pine Species	3
Amelanchier canadensis	Canadian Serviceberry	2
Betula utilis jacquemontii	Himalayan White Birch	2
Cedrus deodara	Deodar Cedar	2
Acer macrophyllum	Bigleaf Maple	2
Pinus jeffreyi	Jeffrey Pine	2
Umbellularia californica	California Bay	2
Ulmus glabra camperdownii	Camperdown Elm	2
Fraxinus latifolia	Oregon Ash	2
Syringa reticulata	Japanese Tree Lilac	2
Juglans nigra	Black Walnut	2

Magnolia grandiflora	Southern Magnolia	2
Salix matsudana 'Tortuosa'	Corkscrew Willow	2
Salix babylonica	Weeping Willow	2
Cornus florida	Eastern Dogwood	2
Robinia pseudoacacia	Black Locust	2
Prunus blireiana	Flowering Plum	2
Acacia cultriformis	Knife Acacia	1
Sequoia sempervirens	Coast Redwood	1
Pinus ponderosa	Ponderosa Pine	1
Ilex spp.	Holly Species	1
Aesculus hippocastanum	Common Horsechestnut	1
Aesculus octandra	Yellow Buckeye	1
Ailanthus altissima	Tree of Heaven	1
Abies spp.	Fir Species	1
Ginkgo biloba	Maidenhair Tree	1
Cupressus guadalupensis forbesii	Tecate Cypress	1
Cornus nuttallii	Pacific Dogwood	1
Cercis canadensis	Eastern Redbud	1
Pinus flexilis	Limber Pine	1

Chapter 1: Costs and Benefits of Having Trees in the Urban and Community Environment

Trees are a necessary valuable asset and an integral part of every community's infrastructure. By performing many essential biological functions, trees provide numerous, measurable benefits for the community and environment. In contrast to other community assets, trees have basic biological requirements for survival and growth, and, as a consequence, active tree management and protection is required to maintain healthy tree, function, safety, beauty, and value.

Since the costs and benefits of urban and community forests are quite extensive, it is up to each community to determine if urban and community forest-related projects achieve benefits that out weigh the costs. If the benefits gained from urban and community trees are to be maximized, and the associated costs and risks are to be minimized, the community must have a good understanding of the benefits, costs, structure, and growth requirements of the trees themselves. Examples of variables that need to be considered include wind factors, storm water runoff, property values, pavement degradation, tree removal and replacement costs, aesthetics, and noise issues.

Benefits of Urban and Community Trees

Trees provide a number of environmental, social, and economic benefits that may include, but are not limited to, air quality, annual carbon dioxide absorption, increased annual energy savings, storm water runoff reduction (e.g., reduced flooding), flood water storage, erosion prevention, increased property values, noise reduction, aesthetics, and wildlife benefits. Quite often, these benefits are tangible and measurable in terms of dollar value. Some of the more important benefits are included below:

Improved Air Quality
Urban trees can help to improve air quality in four main ways:

1. Oxygen release through photosynthesis,
2. Gaseous pollutant absorption (e.g., ozone, nitrogen oxide, sulfur dioxide) through leaf surfaces,
3. Particulate matter interception (e.g., dust, ash, pollen, smoke)
4. Water transpiration and surface shading, which lowers local air Temperatures and reduces ozone levels.

During photosynthesis, tree leaves absorb carbon dioxide and produce the oxygen we require to breathe. In fact, a single large, healthy tree can produce enough oxygen daily for up to as many as 18 people.
Additionally, tree leaves absorb other pollutants such as; carbon monoxide, nitrogen dioxide, sulfur dioxide, and dust particulate matter from the air. In fact, tree canopy cover of as little as 24% has been shown to remove up to 89,000 tons of pollutants annually, with an estimated value of $419 million. Many other studies suggest that deciduous and evergreen trees can remove up to 9% and 13% of aerosolized particulates in the air, respectively, with an estimated annual value of pollutant uptake by a typical medium-sized urban tree is between $12 and $20.

Trees also provide direct shading to buildings, parking lots, and road surfaces. Shading not only reduces temperatures but also indirectly reduces ozone and volatile organic compounds (VOCs) released from automobiles and biogenic volatile organic compounds (BVOCs) released from certain tree species.

Reduced Atmospheric Carbon Dioxide
Urban forests can reduce carbon dioxide in two ways:

1. Direct CO2 sequestration in woody and foliar biomass during growth.
2. Reduced demand for heating and air conditioning, resulting in reduced emissions from electric power production.

On average, a mature tree can absorb and store 13 pounds of carbon per year in its roots, trunk, and limbs, and an urban or community forest can sequester or store as much as 2.6 tons of carbon per acre per year. The collective storage capacity of urban and community trees throughout the United States are estimated at 6.5 million tons per year, resulting in a savings of $22 billion in control costs. For each pound of carbon removed, $1.70 is saved, which equates to an annual savings of $22 from carbon storage by each tree.

For each pound of wood grown, a tree absorbs 1.47 pounds of carbon dioxide and emits 1.07 pounds of oxygen. It is therefore possible that an acre of trees might grow 4,000 pounds of wood in a year, absorbing 5,880 pounds of carbon dioxide and emitting 4,280 pounds of oxygen. Alternatively, for every pound of decayed or burned wood, 1.07 pounds of oxygen are absorbed, and 1.47 pounds of carbon dioxide are emitted.

Increased Energy Conservation
Urban trees conserve energy in three principal ways:

1. Shading – reduces amount of radiant energy absorbed by building surfaces,
2. transpiration – converts moisture to water vapor and cools using solar energy that would otherwise result in air heating,
3. wind speed reduction – reduces infiltration of outside air into interior spaces and heat loss where thermal conductivity is high.

Tree crowns create a shade canopy for homes, offices, streets, parking lots, and pavement. This canopy reduces the amount of sunlight reaching our streets, lawns, and parking areas, and results in lower summer temperatures. In fact, air temperatures in trees and green space within individual building sites may be as much as 5°F lower than outside the green space. Trees properly placed for optimal shading of buildings (south and west sides) and air conditioners, can provide a 17 to 75% decrease in summer cooling costs. While properly placed trees generally decrease winter heating costs and serve to buffer a home against cold winter winds (north and west sides).

In a single growing season, the 200,000 leaves typically contained on a healthy 100-foot tree can uptake 11,000 gallons of water from the soil and transpire that water into the air. The cooling effect of transpiration can be equivalent to air conditioning for as many as12 rooms.

Windbreaks composed of urban and community trees reduce wind speed and air infiltration by up to 50%, which potentially leads to annual heating savings of 25% or more. Additionally, heat transfer through conductive materials is decreased as a result of reduced wind speed.

Reduced Storm water Runoff
Urbanization and land development alters and reduces natural vegetation, reduces the natural rain fall infiltration properties within the watershed, significantly increases runoff amounts, and decreases water quality. Development-affected waterways experience a change in form and function. In fact, conversion of forest to impervious cover can result in an estimated 29% increase in runoff during a peak storm event and ultimately result in lost habitat, unstable streams, degraded water quality, and reduced biological diversity.

As the percentage of impervious cover increases, there is a corresponding increase in runoff and decrease in evapo-transpiration and infiltration, which can lead to water pollution, habitat degradation, property damage, and the need for artificial storm water remediation measures. Healthy urban forests can help to counteract urbanization by reducing the amount of storm water runoff and pollutant loading in

Three primary ways:

1. Leaves and branch surfaces intercept and store rainfall, reducing runoff volumes and delaying onset of **peak flows**,
2. Root growth and decomposition increase the capacity and rate of soil infiltration by rainfall and reduce **overland flow**, and
3. Canopies reduce soil erosion by diminishing the impact of raindrops on barren surfaces.

Urban trees are structurally important to communities because their many leaves, branches, stems, and roots aid in rainfall interception, storage, and release to the soil. When trees are present, water flow is spread over a greater amount of time, and the impact on storm water facilities is smaller. By incorporating trees into a city's infrastructure, cities can afford to build smaller, less expensive storm water management systems. Because trees intercept 7 to 22% of precipitation, the value of trees can be measured by the reduction in construction and material costs for storm water control structures and systems. One study has shown that, for every gallon of water intercepted by a tree during a twelve-hour storm, 2 cents in water control costs are saved. This equates to a 17% reduction of 11.3 million gallons, and a savings of $226,000 for a medium-sized city! In an Ohio study, an existing tree canopy with just 22% coverage reduced potential runoff by 7%, and an increase in canopy coverage to 29% reduced runoff by nearly 12%. By reducing runoff, trees function as natural retention-detention structures because increased interception and subsequent water storage greatly reduces the chances of flood damage to property and crops, and eliminates the need for costly storm water treatment and control structures. Furthermore, the amount and velocity of overland flow and **non-point source** (NPS) pollution that occurs during and after heavy rains is greatly decreased when trees are present. Simulations of urban forest effects on storm water report annual runoff reductions of 2 to 7%. Reductions in flow amounts and velocities equate to less erosion and better infiltration and storage, ultimately leading to less damage to the watershed and the surrounding environment. Because of its water storage abilities, retaining, maintaining, and restoring forest land, particularly in riparian and bottomland areas, should be a priority for Mississippi communities. Allowing these areas to undergo development can create a need for expensive drainage projects to alleviate flooding. Simple planning, a little foresight, and help from nature can save communities both time and money in the long-run.

Improved Water Quality
Trees in urban riparian or streamside forests control fluctuations in water temperatures and act as natural filters by absorbing pollutants and other toxins before they can enter underground water systems. This, in effect, reduces the amount of polluted water that runs off urban and community streets, into sewers, and eventually into the groundwater, and also prevents thermal pollution of water resources. Additionally, trees in urban riparian forests maintain light levels that sustain beneficial algae as well as other stream flora and fauna.
Urban and community forests can also help improve water quality through treatment and disposal of wastewater on irrigated nurseries or plantations. Wastewater reuse can help to recharge aquifers, reduce storm water treatment loads, and create income when used for nurseries or wood products. Furthermore, urban wastewater recycled through green spaces provides an economical means of treatment and disposal and provides other environmental benefits.

Reduced Soil Erosion
Streams lacking urban riparian or streamside forest channels are prone to channel widening and bank erosion, and any fundamental change in the dimension, pattern, and profile of a channel results in habitat loss. Numerous studies attest to the ability of urban riparian forests to remove, hold, or transform nutrients from fertilizers, sediments, and other pollutants. In fact, urban and community trees can reduce sediment movement off a site by 95% even before water reaches the riparian forest, effectively keeping our water bodies cleaner and healthier. The amount of soil saved in a medium-sized city annually can be as much as 10,886 tons!

Wildlife Food and Habitat
Although less biologically diverse than rural woodlands, urban and community forests are home to many wildlife species and provide much-needed food and shelter in the urban environment. Flowers, fruits, leaves, buds, and woody parts of urban and community trees are used by many birds, mammals, insects, and other wildlife species. Bacteria and fungi contained in tree parts cause decay and increase soil fertility and structure. Elsewhere, along streams, urban and community trees provide shade, reduce water temperatures, contribute to the overall health of aquatic ecosystems by providing habitat, shelter, and food for aquatic organisms like turtles, otters, beavers, and fish, and often connect a city or community to its surrounding bioregion.

Increased Aesthetic Appeal

Trees placed in urban and community areas create an aesthetically pleasing and comfortable place in which to live, work, and shop. In fact, beautification is one of the most frequently cited reasons for planting trees, and research has shown that street trees are the single strongest positive influence on scenic quality. Trees also attract more Residents and visitors to a community, increasing the community's tax and economic base. Surveys of consumers found that the presence of trees in commercial areas increases preference ratings, results in more frequent and extended shopping, and evokes higher willingness to pay for goods and services. Adding or retaining trees in recreational areas creates a natural setting for activities such as walking, jogging, bicycling, golfing, and bird watching. Studies have found that urban and community park visitors preferred wooded to non-wooded parks. Residents of public housing complexes used outdoor spaces with trees significantly more often than spaces without trees. It has been further suggested that urban and community trees can strengthen social interactions, thereby reducing domestic violence, fostering safer and more sociable neighborhoods, and creating a sense of pride among residents. Others have established a connection between the presence of urban trees and crime reduction.

The presence of trees in cities and communities provides social and psychological benefits by answering the human need for contact with nature, and creating a general sense of human well being through interaction with green space. Studies have shown that trees and views of nature provide pleasure and restorative experiences, ease mental fatigue and aid in concentration, result in reduced sickness and greater job satisfaction, reduce stress response, induce better sleep and reduced medication in hospital patients, and reduce exposure to ultraviolet light.

Urban and community trees can also result in increased property values. Trees can provide an owner of a single home with a 4 to 27% increase in property value, and a single tree can add as much as 9% to the total value of a residential property. Scientists have found that each large front-yard tree increased actual sale prices by 1% each. One study has shown that each hardwood tree on a site adds $333 to the property value and each pine adds $257. Trees soften the glare and hard lines of developed city streets, screen buildings, reduce noise pollution, act as sound barriers or screens, and create natural noise amid city sounds. In cities, noise levels can reach unhealthy levels, with trucks, trains, and airplanes sometimes exceeding 100 decibels, which is two times the level at which noise becomes unhealthy. Thick vegetation strips in conjunction with solid barriers and land forms, can reduce highway noise by 6 to 15 decibels and absorb high frequencies that are most distressing to humans.

Forests, wetlands, meadows, and other natural areas provide essential ecological services such as providing floodwater storage, filtering runoff, moderating outside temperatures, storing carbon emissions, controlling erosion, providing visual and auditory screening, and providing natural aesthetics. When these areas are degraded or destroyed, communities are then forced to spend large sums of money to construct technologies that mimic natural functions.

Costs of Urban and Community Trees
In addition to providing many benefits and being a valuable community asset, urban and community trees have costs associated with their conservation, establishment, and maintenance. These costs usually revolve around tree purchase and planting, annual trimming, tree and stump removal and disposal, pest and disease control, irrigation, infrastructure damage, litter and storm clean-up litigation, and program administration. More specifically, neglected, unprotected, abused, or poorly maintained trees result in poor health, an increased risk for failure, and additional liability for the tree owner. A Tree Management Cost Worksheet is provided in Appendix B to assist in planning for costs associated with tree conservation and management. Additionally, a list of long-term cost saving strategies for tree conservation and management is included in Appendix B. While there are many costs associated with trees, in most cases benefits far outweigh costs.

Planning and Design Costs
Planning and designing an urban and community tree plan, evaluation, or survey project requires a great amount of time and money, but careful planning and quality design can result in a more successful and valuable project achieving high income levels. Some important elements of urban and community tree project planning and design include:

1. quality planting stock – expensive, but purchasing good quality trees reduces future replacement and maintenance costs,
2. tree maintenance – regular pruning insures tree health, safety, and longevity,
3. tree monitoring and protection – reduces chances of damage from construction activities, utility line installation or repair, and pest problems.
4. tree removal – necessary when trees decline beyond the point of improvement or die, can be expensive for large trees.

Tree Hazards

Urban and community trees must not be allowed to grow into zones designated for utility lines, pedestrians' buildings, streets, and vehicles. Excess growth into these zones reduces clearance and sight distance and causes increased costs to maintain public safety. Additionally, portions of or whole trees that, either in the present or in the future, tower over property can cause utility service outages, vehicle, home, fence, or pavement damage, and lead to personal injury. For example, tree roots that surface above ground can be a tripping hazard for humans and can cause damage to lawn mower blades. Additionally, un-pruned branches can cause severe personal injuries or even death.

Infrastructure Conflicts

In many cities across the U.S., communities are spending millions of dollars annually to manage and resolve conflicts between trees and sidewalks, sewers, power lines, and other elements of urban infrastructure. In previous studies, repair costs for sidewalk, curb and gutter repair, tree removal and replacement, prevention methods, and legal/liability costs range from $0.75 to $2.36 per capita and up to $6.98 per resident. When additional expenditures for damaged sewer lines, building foundations, parking lots, and other hardscape elements are included, total costs can soar to $100 million per year in larger cities.

Unfortunately, in some areas, the high costs of infrastructure maintenance and dwindling fiscal budgets have forced municipalities to shift costs of sidewalk and other repairs to residents. This attempt to control costs has had an harmful effect on urban forests as a whole because cities have been forced to downsize urban forests by planting smaller stature trees, remove greater numbers of trees due to sidewalk damage, and remove more trees than are being planted. Most of these problems could easily be avoided by simply matching growth characteristics to conditions at the planting site.

Under favorable soil conditions, tree roots can penetrate underground water and sewer lines through small cracks or pipe joints, proliferate, and cause problems. Repair costs for damaged water and sewer lines are expensive, typically ranging from $100 to $1,000 per pipe.

Throughout the year, urban and community trees drop leaves, flowers, fruit, and branches that collect as debris on city streets and can clog sewers, dry wells, and other elements of flood and storm water control systems. Large expenditures from additional labor needed to remove debris, property damage from localized flooding, and clean-up costs after windstorms can be avoided by employing street sweepers on a regular basis.

Conflicts between trees and power lines often result in increased electric rates and decreased benefits from over-pruning of poorly suited trees. In areas with thousands of trees, pruning costs can be as high as $50 per tree, and this cost is, more often than not, passed on to the consumer. Most of the above problems can be minimized or avoided by simply matching tree species to planting sites.

Chapter 2: Guidelines for Effective Urban and Community Forest Management

Developing a Community Forest Management Strategy

Tree ordinances provide a legal framework for successful urban and community forest management by enabling and authorizing management activities. However, methods for managing urban forest ecosystems are continually evolving, and the input of trained professionals to the management process is critical. Therefore, ordinances should facilitate rather than prescribe management, and communities need to develop or review their overall urban forest management strategy before considering a new or revised urban and community forestry ordinance.

In developing or reviewing an overall management strategy, a community should ask itself four questions and follow seven corresponding steps (all information taken directly from ISA 2001)[3]. Working through the steps is ultimately driven by specific goals and resources of the individual community. By following the process outlined below, a small community like Hoquiam with very modest forest management goals can develop a simple ordinance that addresses its limited goals. Conversely, if Hoquiam is seeking to develop a comprehensive tree management program or further expand their program in years to come, they can do so following the same process. In either case, the ordinances developed will be uniquely suited to Hoquiam's Urban Forest needs.

Question 1. What do you have?

Step A. Assess the tree resource.

The City of Hoquiam's Urban Forest assessment/ inventory has been done, and the results and discussion are contained elsewhere within this document. The data collected during the tree inventory phase was determined and set forth in the RFP.

Step B. Review tree management practices.

Understanding the status of the urban or community forest requires knowing how it has been previously managed. Some information that should be collected on past and current management methods and actions includes:

1. Municipal tree care practices, including planting, maintenance, and removal,
2. Existing ordinances, and level of enforcement practiced.
3. Planning regulations and guidelines pertaining to trees, and numbers of tree-related permits granted, modified, or denied, and
4. Activities of municipal departments and public utilities that impact trees.

[3] ISA. Guidelines for Developing and Evaluating Tree Ordinances. 2001

The purpose of reviewing past and current tree management practices is to identify all activities affecting trees in the community, especially those falling under municipal control. For instance, seemingly unrelated ordinances and planning regulations may directly or indirectly impact forest resources and, therefore, must be taken into account.

Question 2. What do you want (i.e., goal-setting)?

Step C. Identify Needs.

Once information on the status of tree resources and tree management is in hand, a community can assess its urban forestry needs. Urban and community forestry needs can be grouped into three broad categories, with some needs falling into more than one category.

Biological needs (i.e., related to the tree resource itself):

1. increase species and age diversity to provide long-term forest stability,
2. provide sufficient tree planting to keep pace with urban growth and offset tree removal,
3. increase proportion of large-statured trees in the forest for greater canopy effects.
4. guarantee proper compatibility between trees and planting sites to reduce sidewalk damage and conflicts with overhead utilities that lead to premature tree removal.

Management needs (i.e., needs of those involved with the short- and long-term care and maintenance of the urban forest):

1. develop adequate long-term planning to guarantee the sustainability of the urban forest,
2. optimize the use of limited financial and personnel resources,
3. increase training and education for tree program employees to ensure high quality tree care, and
4. coordinate tree-related activities of municipal departments.

Community needs (i.e., those that relate to how the public perceives and interacts with the urban forest and the local urban forest management program):

1. increase public awareness of values and benefits associated with trees,
2. promote better private tree care through better public understanding of the biological needs of trees,
3. foster community support for the urban forest management program, and
4. promote conservation of the urban forest by focusing public attention on all tree age classes, not just large heritage trees.

Although the needs listed above are common in many communities, the specific needs of Hoquiam will vary, and may include others city needs not listed here.

Step D. Establish Goals.

With information on resources and needs collected, goals to address local urban forestry needs can be set and a management strategy formed. To establish realistic goals, it is important to consider limitations posed by the level of support within the community, economic realities, and environmental constraints. Limitations on resources may make immediate addressing of all identified needs impractical and, in this case, it will be necessary to prioritize goals.

Community involvement and support are critical in the establishment of goals since most urban and community forestry ordinances rely heavily upon voluntary compliance by the public, and compliance will only occur if the public supports the goals set. Involving the public in the goal-setting process allows them to reflect on the values of their community as well as educate themselves on how urban forest management affects their community.

Since goals are tangible ends that the management strategy seeks to achieve, it is important for the city to set goals which are quantifiable, so that progress toward achieving these goals can be monitored. Typical tree program goals, as well as corresponding ordinance provisions for each goal, consistent with good urban forest management are discussed in detail in Appendix B.

Question 3. How do you get what you want?

Step E. Select tools and formulate the management strategy.

This step develops a management strategy addressing specific goals. It is important to remember there are many approaches that can be used to address each goal, and the pros and cons of each approach should be considered. Feasibility, practicality, legality, and economics should be considered in selecting appropriate management tools. Some typical tools include:

1. public education programs,
2. assistance and incentive programs,
3. voluntary planting programs,
4. mitigation guidelines,
5. planning regulations and guidelines, including the general plan and specific plans,
6. ordinances.

Community involvement and support continues to be important in this phase of the process; if management approaches and tools are unacceptable to the community, they are unlikely to succeed. Your assessment of current and past management practices should provide ideas about the effectiveness of various methods used in

Hoquiam, and public input and comment should be sought for any new approaches being contemplated or developed.

The role of an ordinance becomes apparent at this stage, when it may become necessary to establish new positions, require development and implementation of a community forest master plan, mandate a program of public education, or outlaw destructive practices. Any provisions placed in ordinances should be directly related to the goals the Hoquiam community has established for its community forest, and all ordinances should include all of the essential components previously listed.

Step F. Implement the management strategy.
No matter how ideal a plan may appear on paper, it cannot achieve its goals until it is implemented. Implementation of the management strategy requires several steps, which may differ between communities, and include:

1. passing an ordinance,
2. budgeting necessary funds,
3. hiring a municipal forester or arborist,
4. appointing a citizen tree advisory board,
5. formulating a master tree management plan, and
6. developing public education programs.

The above steps need not require funding if a volunteer tree board can be formed and ordinances are in place.

It is often useful to map out an implementation schedule to accomplish the steps involved in your community's management strategy. The schedule should show the steps involved and the time frame within which they should be completed. Additionally, progress checks in the form of required progress reports to the city council or county board of supervisors should be built into the schedule to make certain that delays or problems are detected and addressed. Maintaining a high profile for the management program during implementation will help foster public interest and maintain the commitment of local government.

Question 4. Are you getting what you want?

Step G. Evaluate and revise.
Monitoring of your implemented management strategy is essential to make certain that progress is being made and standards are being met. Evaluation provides feedback on the effectiveness of the strategy, provides opportunities to reassess the needs and goals of the community, and allows readjustments and changes to goals before a crisis develops. Specific methods to monitor ordinance effectiveness are included in Appendix B.

Developing Urban and Community Forestry Ordinances

Need for Urban and Community Forestry Ordinances

To many residents, urban and community forests, no matter what their size, are an important and essential part of the community which provides character and beauty, and influences property values and the quality of life enjoyed by community residents.

One proven tool used by communities striving to attain a healthy, vigorous, and well-managed community forest and protect urban and community trees and woodlands is adoption of local laws through the development and establishment of urban and community forestry ordinances. In their most basic form, ordinances generally seek to provide developers with a framework for preserving and restoring as many trees as possible on a site, often placing an emphasis upon older, larger specimens. Urban and community forestry-related ordinances can also serve to protect and establish green space, delineate and protect buffer zones, maintain and protect urban and community trees, and control non-point source pollution, or mitigate storm water.

Planning For Urban and Community Forestry Ordinances

All communities have different needs and values regarding their urban and community forestry resources. To some communities, retention of the urban and community forest resource and the proper specifications and standards of urban and community forest restoration through tree planting is a critical need for which ordinances are established. Ordinances, in effect, generally reflect the individuality and values of a community and its residents, values they believe are worthy of protection and essential to maintain their quality of life and provide an environment that is both pleasant and safe. More specifically, urban and community forestry ordinances encourage neighborhood beautification, tree protection and preservation, regulation of development, and restoration of areas through planting and management. Additionally, ordinances serve the purpose of enabling citizens to prevent the spread of tree diseases and regulate sidewalk replacement and utility line clearing work. Finally, urban and community forestry ordinances can enhance the beauty and safety of a community's urban forest because they often require the use of professionals, specify duties of municipal employees, and help control careless management of this important natural resource.

By themselves, urban and community forestry ordinances cannot assure the improvement or maintenance of urban and community trees. Tree ordinances simply provide authorization and standards for management activities which must be integrated into an overall management strategy. Simply put, tree ordinances can assist in the overall proper management of community tree resources.

Effectiveness of Urban and Community Forestry Ordinances

The effectiveness of urban and community forestry ordinances depends upon numerous factors including resident support, opposition, and awareness; adequacy of ordinance enforcement; provisions for environmental limitations that affect tree health, growth, and survival; and availability of financing from local governments to fulfill ordinance requirements.

Although the form, content, and complexity of ordinances may vary widely, an effective tree ordinance should meet the following criteria:

1. Goals should be clearly stated and ordinance provisions should address stated goals. Goals must be clearly stated because they provide the basis for interpreting ordinances and evaluating their effectiveness. Lack of clear, specific goals is a common shortcoming of many tree ordinances.
2. Responsibility should be designated, and authority granted, commensurate with responsibility. In most cases, the most efficient way to manage an urban forest is to have one individual responsible for overseeing all tree-related activities. In smaller communities, such as Hoquiam it may be necessary to split responsibility between a tree commission, which sets policy and has administrative duties, and city staff, which is responsible for operations and enforcement.
3. Basic performance standards should be set. Effective performance standards address the urban forest as a whole rather than focusing exclusively on individual trees.
4. Flexibility should be designated into the ordinance. Flexible performance standards can allow responsible parties to make decisions on a case-by-case or site-specific basis.
5. Enforcement methods should be specified. Specifying enforcement methods like fines, jail terms, forfeiture of performance bonds, and tree replacement plantings and consistent enforcement of these methods can help deter offenders.
6. The ordinance should be developed as part of a comprehensive management strategy. A comprehensive management strategy assures the inclusion of appropriate and necessary provisions to protect urban and community forestry resources.
7. The ordinance should be developed with community support. Developing the ordinance within the context of community values and priorities can help gain public support. Many ordinances rely on voluntary compliance to guarantee public support.
8. Effective tree ordinances are connected to local land use planning and zoning. They are also part of the building permit process. Information on ordinance requirements and tree care techniques should be available at the planning office and wherever people apply for building permits.

Chapter 3: Guidelines for Pruning and Planting

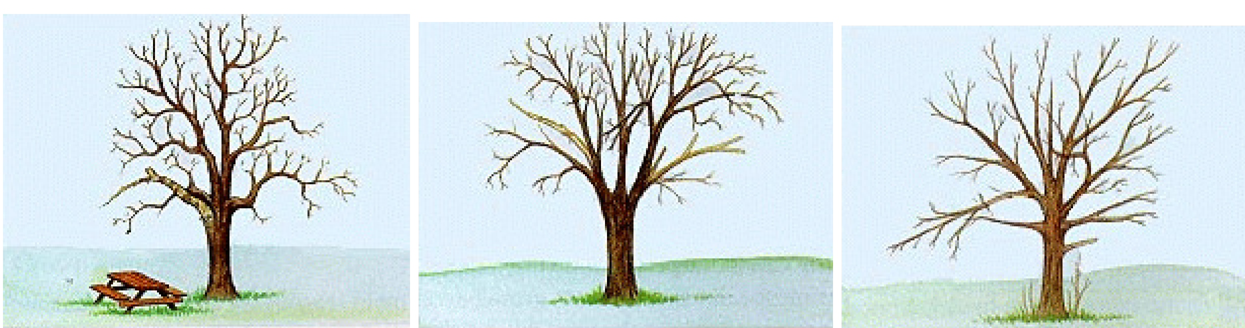
Introduction
The objective of pruning is to produce strong, healthy, attractive plants. By understanding how, when and why to prune, and by following a few simple principles, this objective can be achieved.

Why Prune
The main reasons for pruning ornamental and shade trees include safety, health, and aesthetics. In addition, pruning can be used to stimulate fruit production and increase the value of timber.

Pruning for *safety* (Fig. 1A) involves removing branches that could fall and cause injury or property damage, trimming branches that interfere with lines of sight on streets or driveways, and removing branches that grow into utility lines. Safety pruning can be largely avoided by carefully choosing species that will not grow beyond the space available to them, and have strength and form characteristics that are suited to the site.

Pruning for *health* (Fig. 1B) involves removing diseased or insect-infested wood, thinning the crown to increase airflow and reduce some pest problems, and removing crossing and rubbing branches. Pruning can best be used to encourage trees to develop a strong structure and reduce the likelihood of damage during severe weather. Removing broken or damaged limbs encourage wound closure.

Pruning for *aesthetics* (Fig. 1C) involves enhancing the natural form and character of trees or stimulating flower production. Pruning for form can be especially important on open grown trees that do very little self-pruning. All woody plants shed branches in response to shading and competition. Branches that do not produce enough carbohydrates from photosynthesis to sustain themselves die and are eventually shed; the resulting wounds are sealed by **woundwood** (callus). Branches that are poorly attached may be broken off by wind and accumulation of snow and ice. Branches removed by such natural forces often result in large, ragged wounds that rarely seal. Pruning as a cultural practice can be used to supplement or replace these natural processes and increase the strength and longevity of plants.



A.Safety B. Health C. Aesthetics

Trees have many forms, but the most common types are pyramidal **(excurrent)** or spherical (**decurrent)**. Trees with pyramidal crowns, e.g., most conifers, have a strong central stem and lateral branches that are more or less horizontal and do not compete with the central stem for dominance. Trees with spherical crowns, e.g., most hardwoods, have many lateral branches that may compete for dominance. To reduce the need for pruning it is best to consider a tree's natural form. It is very difficult to impose an unnatural form on a tree without commitment to constant maintenance.

Pruning Approaches

Producing strong structure should be the emphasis when pruning young trees. As trees mature, the aim of pruning will shift to maintaining tree structure, form, health and appearance. Proper pruning cuts are made at a node, the point at which one branch or twig attaches to another. In the spring of the year growth begins at buds, and twigs grow until a new node is formed. The length of a branch between nodes is called an internode.

Crown thinning, primarily for hardwoods, is the selective removal of branches to increase light penetration and air movement throughout the crown of a tree. The intent is to maintain or develop a tree's structure and form. To avoid unnecessary stress and prevent excessive production of epicormic sprouts, no more than one-quarter of the living crown should be removed at a time. If it is necessary to remove more, it should be done over successive years.

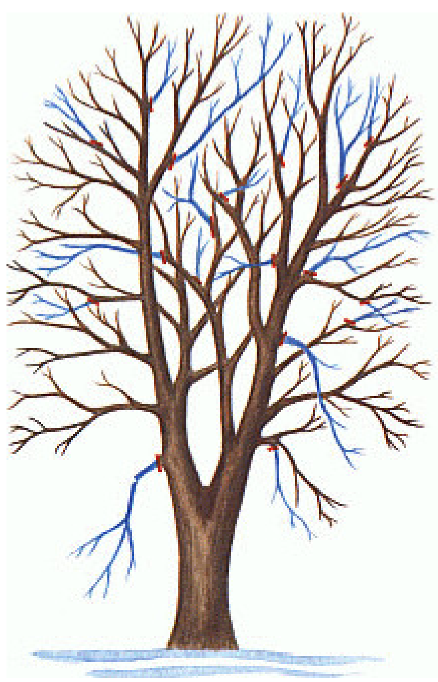


Figure 2. Crown thinning - branches to be removed are shaded in blue; pruning cuts should be made at the red lines. No more than one-fourth of the living branches should be removed at one time

Branches with strong U-shaped angles of attachment should be retained. Branches with narrow, V-shaped angles of attachment often form **included bark** and should be removed. Included bark forms when two branches grow at sharply acute angles to one another, producing a wedge of inward-rolled bark between them. Included bark prevents strong attachment of branches, often causing a crack at the point below where the branches meet. Codominant stems that are approximately the same size and arise from the same position often form included bark. Removing some of the lateral branches from a codominant stem can reduce its growth enough to allow the other stem to become dominant. Lateral branches should be no more than one half to three-quarters of the diameter of the stem at the point of attachment. Avoid producing "lion's tails," tufts of branches and foliage at the ends of branches, caused by removing all inner lateral branches and foliage. Lion's tails can result in sun scalding, abundant **epicormic sprouts**, and weak branch structure and breakage. Branches that rub or cross another branch should be removed. Conifers that have branches in whorls and pyramidal crowns rarely need crown thinning except to restore a dominant leader. Occasionally, the leader of a tree may be damaged and multiple branches may become codominant. Select the strongest leader and remove competing branches to prevent the development of codominant stems.

Crown Raising, is the practice of removing branches from the bottom of the crown of a tree to provide clearance for pedestrians, vehicles, buildings, lines of site, or to develop a clear stem for timber production. Also, removing lower branches on white pines can prevent blister rust. For street trees the minimum clearance is often specified by municipal ordinance. After pruning, the ratio of the living crown to total tree height should be at least two-thirds (e.g., a 12 m tree should have living branches on at least the upper 8 m). On young trees "temporary" branches may be retained along the stem to encourage taper and protect trees from vandalism and sun scald. Less vigorous shoots should be selected as temporary branches and should be about 10 to 15 cm apart along the stem. They should be pruned annually to slow their growth and should be removed eventually.

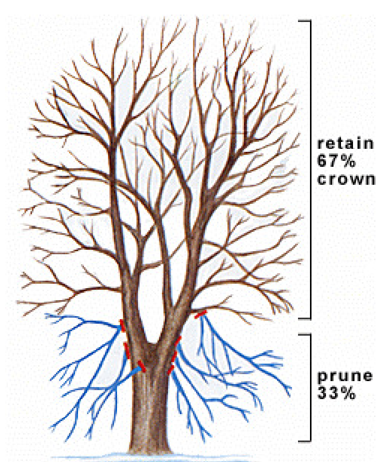


Figure 4. Crown raising - branches to be removed are shaded in blue; pruning cuts should be made where indicated with red lines. The ratio of live crown to total tree height should be at least two-thirds.

Crown reduction pruning is most often used when a tree has grown too large for its permitted space. This method, sometimes called **drop crotch pruning**, is preferred to topping because it results in a more natural appearance, increases the time before pruning is needed again, and minimizes stress (see drop crotch cuts in the next section). Crown reduction pruning, a method of last resort, often results in large pruning wounds to stems that may lead to decay. This method should never be used on a tree with a pyramidal growth form. A better long term solution is to remove the tree and replace it with a tree that will not grow beyond the available space[4].

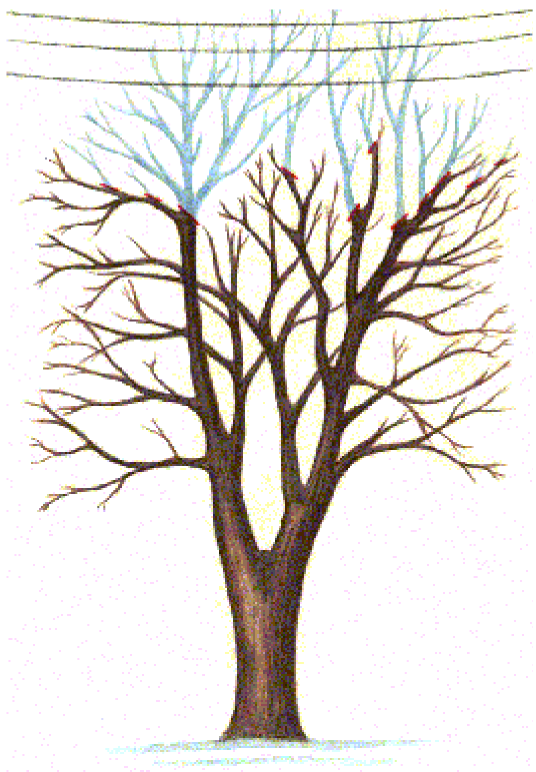


Figure 5. Crown reduction - branches to be removed are shaded in blue; pruning cuts should be made where indicated with red lines. To prevent branch dieback, cuts should be made at lateral branches that are at least one-third the diameter of the stem at their union.

[4] Bedker, J. Peter, O'Brien. G. Joseph. USDA Forest Service. How to Prune Trees.

Guidelines for Tree Planting

Site Factors for Trees on Streets

Trees planted between paved traffic lanes (i.e., medians), streets, parking lots, and shopping centers more than likely will endure harsh conditions. Problems associated with these sites will include compacted soils that often lack appropriate nutrients for tree growth. Additionally, these soils may be excessively drained or poorly drained. Trees that grow naturally in bottomland/lowland conditions are often suited to urban sites because they have adapted to low oxygen and/or compacted soils. Root space is very often the most limiting factor for urban trees. Therefore, ensuring adequate space for roots to grow and expand is critical. Each potential planting site should have an individual assessment and species recommendation since micro-site conditions vary widely, and numerous species are suitable depending on objectives. A list of recommended uses for native and ornamental tree species suitable for urban and community forestry activities in the Pacific Northwest is located in Appendix D

Growing Space for Trees on Streets

Above ground portions of trees must be restricted in size and shape to avoid obstructing pedestrian or driver viewing, and below ground portions must be restricted to a size that will not exceed the available planting area. Upright, vase-like, or oval crowns are preferred over weeping, rounded, spreading, and pyramidal forms. Picking the appropriate tree species and proper placement will avoid higher maintenance costs, such as periodic pruning, or, in some cases, tree removal and replacement.

Environmental Considerations for Trees on Streets

Trees must be resistant to air pollution from vehicles and nearby industries. Planting a variety of trees will increase diversity, with obvious wildlife and aesthetic benefits. Also, a diverse median forest will lessen the chance of widespread losses from insects or diseases. Trees also need to be wind resistant will often be isolated, thereby leaving them vulnerable to wind throw. Trees in urban areas also need to be somewhat drought resistant. Ambient temperatures are known to be higher in developed areas, thus creating additional tree and plant stress. Tolerant species will persist better during dry periods and also require less irrigating by maintenance crews.

By promoting the establishment and growth of trees on medians, maintenance of these sites should be a consideration. With established tree stands, there will be a shading effect on the understory, resulting in the reduction of mowing required on medians. Where hardwoods are planted, problems may occur with leaf litter that carries off the median. However, most of the leaf fall will be recycled back into the site as nutrients for the stand of trees.

Best Management Practices for Tree Selection and Placement on Streets Finally, before the question of which tree to plant can be answered, a number of factors need to be considered. When selecting trees for placement as street trees the following questions should be asked and answered:

1. Why is the tree being planted? Do you want the tree to provide shade, fruit, or seasonal color, or act as a windbreak or screen? Maybe, more than one of the above?
2. What is the size and location of the planting site? Does the space lend itself to a large, medium, or small tree? Are there overhead or below ground wires or utilities in the vicinity? Do you need to consider clearance for sidewalks, patios or driveways? Are there other trees in the area?
3. What type of soil conditions exist? Is the soil deep, fertile, and well-drained or is it shallow, compacted, and infertile?
4. What type of maintenance are you willing to provide? Do you have time to water, fertilize and prune the newly planted tree until it is established or will you be relying on your garden or tree service for assistance?
5. Can trees be planted as a rain garden for the purpose of on-site water treatment? If so, plant at or below grade and create curb cutouts or other inflow mechanisms.

Chapter 4 Tree Growth and Decay

As forest scientists observed how trees respond to wounds, pruning techniques changed and pruning objectives were clarified. This chapter provides background information on how trees grow and decay and therefore the implications of pruning cuts and structural training.

How Trees Grow
Xylem tissues – Each year a tree puts on a new outer ring of wood (xylem tissue) under the bark resulting in the increased diameter of a trunk or branch. The number of rings indicates the limb's age and the width of individual rings indicates that year's growing conditions.
CODIT – How Trees Decay
Unlike animals and people, trees don't replace damaged tissues. Rather, cells in the damaged area undergo a chemical change in an method to seal off or "compartmentalize" the damaged area from the spread of decay. This area of chemical change is called the ***reaction zone***. In most species, a reaction zone appears as darker colored wood.
The spread of decay is related to this compartmentalization of the xylem tubes in a box-like structure created by the annual growth rings and ray cells. In this box-like structure, the four walls differ in their resistance to the spread of decay.

Wall 1 – Resistance to the spread of decay is very weak up and down inside the xylem tubes. Otherwise, the tubes would plug, stopping the flow of water, and kill the plant. From the point of injury, decay moves upwards to a small degree, but readily moves downward. The downward movement may be 20 plus feet and can include the root system.
Wall 2 – The walls into the older xylem tissues (towards the center of the tree) is also rather weak allowing decay to readily move into older annual growth rings.
Wall 3 – The walls created by the *ray cells* (being high in photosynthates) are somewhat resistant to decay organisms. This may help suppress the spread of decay around the tree.
Wall 4 – New annual growth rings that grow in years after the injury are highly resistant to the spread of decay. Resistance to the spread of decay by the new annual growth ring and ray cells creates a pipe-like structure, with a decayed center. This concept of how decay spreads in a tree (as controlled by the *annual growth rings* and *ray cells*) is called CODIT, for Compartmentalization Of Decay In Trees. [Figure 8]

Evaluating Decay
Percent Shell
A trunk or branch with some internal decay is not necessarily at risk for failure. Structural strength is based on 1) the minimum thickness of the healthy wood (xylem tissues) and 2) the structural strength of wood (tree species). In evaluating potential hazards, arborists (tree care professionals) work with a technical term called ***percent shell***. Percent shell is calculated by dividing the thickness of the healthy wood at the thinnest point (not

including bark, reaction wood, or decaying tissue) by the radius of the trunk/branch (not including bark).

33 percent shell = high risk potential – Trees with a 33 percent shell or less are termed "high risk" with a statistically high probability of failure in a storm event. For example, a six inch diameter (3 inch radius) trunk with only a one inch thick ring of healthy wood would have a 33% shell with a hollow center. If injury or property damage would occur upon tree failure, corrective action (such as removal of the defective branch or removal of the tree) should be considered.

20 percent shell = critical risk potential – Trees with a 20 percent shell or less are considered a "critical risk" with a very high probability of failure in storms. For example, a tree with a 10 inch diameter (5 inch radius) trunk with only one inch ring of healthy wood would be considered a "critical risk". If injury or property damage would occur upon tree failure, corrective action (such as removal of the defective branch or removal of the tree) should be taken.

The *Percent Shell Formula* is valid only when the decay column is centered in the trunk/branch. Researchers are developing other formulas to evaluate off-sided decay and open cavities, which are significantly weaker.

Measuring Decay
So, how thick is the healthy wood in a trunk or branch? Researchers are working to address this big question. At the present time, arborists are limited in their ability to measure and evaluate the internal structure of a trunk or limb. The following are procedures with limited potential to evaluate the internal structure of trees.

Visual Indicators of Decay
Large pruning wounds suggest the potential for internal decay. Often decay may be observed within the pruning wound.

Cankers suggest the potential for internal decay. If the canker extends down into the soil, decay organisms will always be active.

Valleys, ridges, cracks, and splits along the trunk/branch suggest the potential for decay.

Wildlife living inside the tree is a sign of decay.

Abnormal swellings or shapes could be a sign that the tree is growing around a decayed area.

Coring Devices
Note: All coring devices have a small potential to spread decay, as the coring tools break the strong exterior wall of a reaction zone and bring decaying tissues out though healthy wood in the removal. Therefore, it is essential for the use of disinfectants on coring tools.

Coring tools should only be used where decay and threat of tree failure is highly suspect, they are generally not used on living trees except when there is a special need to evaluate risk potential. All coring devices only indicate the decay potential at the point of drilling and do not represent the entire trunk or branch.

Increment Borer is a hand tool that removes a small core from a trunk or branch. The relative effort it takes to drill the borer through various layers of the tree and examination of the core removed gives the arborist some idea about the internal structure at this location. Increment borers are rarely used today in arboriculture.

Drill with small drill bit – Drilling the trunk or branch with a 1/8 inch fully fluted drill bit is a tool used by some arborists. Pressure to push the drill through the annual growth rings and examination of the sawdust removed gives the arborist some idea about the internal structure at this location. An experienced arborist can be rather accurate in evaluation by drilling. Drilling has little value, however, for the inexperienced person.

Resistograph is a specialized drill that graphs the pressure needed to push a small drill bit through various layers of annual growth rings. The graph gives a visual indication of internal structure at this location. Due to cost, few arborists have a Resistograph.

Digital Microprobe, a specialized drill bit rotating at 7,000 rpm, measures the pressure needed to drill/burn its way through tissues. Data is fed into a computer database for evaluation and printout. This equipment is new to the industry and cost prohibitive for most arborists.

Listening and Radar Devices

Rubber mallet – Tapping the trunk/branch with a rubber mallet and listening for a hollow sound may give some indication of critical internal decay. It will not give any percent shell to help evaluate risk potential and on thick bark trees (like old cottonwoods) may not be very effective. However, don't totally discount this technique, as may give clues of where to use other tools.

PiCUS Sonic Tomography is a new device that listens to how sound waves move through the trunk/branch. A series of listening devices are attached around the trunk/branch and connected to a computer. When the tree is tapped with a mallet, the computer measures how the sound moves through the wood and creates a graphic cross-section of the trunk/branch interior. Measurements taken at multiple heights up the trunk can generate a three-dimensional image. This type of equipment has the potential to totally change tree care when it becomes available to arborists. Currently the cost is prohibitive for most arborists

.**Electrical Impedance Tomography** is similar to sonic tomography and measures the distortion of the electrical field by wood conditions. Electrical impedance tomography is better at detecting "Y" crevices and cracks and thus is often used in conjunction with sonic tomography.

Tree Radar – A hand held radar device is run around the trunk/branch. The computer database is sent to the company for evaluation. Currently the cost is prohibitive for most arborists.