Urban Watershed Forestry Manual

Part 1: Methods for Increasing Forest Cover in a Watershed

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Chesapeake Bay Program
A Watershed Partnership

ABOUT THIS MANUAL SERIES

This manual is one in a three-part series on using trees to protect and restore urban watersheds. A brief description of each part follows.

Part 1: Methods for Increasing Forest Cover in a Watershed introduces the emerging topic of urban watershed forestry. This part also presents new methods for the watershed planner or forester to systematically measure watershed forest cover and select the best methods for maintaining or increasing this cover by protecting, enhancing, and reforesting large parcels of primarily public land across the watershed. These methods are based on extensive review of the latest research and input from experts in a wide range of related fields.

Part 2: Conserving and Planting Trees at Development Sites presents specific ways to enable developers, engineers, or landscape architects to incorporate more trees into a development site. The proposed approach focuses on protecting existing trees, planting trees in storm water treatment practices, and planting trees in other open spaces at a development site. This part introduces conceptual designs for storm water treatment practices that utilize trees as part of the design (referred to as storm water forestry practices). These designs were developed with input from experts in storm water engineering, forestry, and a range of related fields.

Part 3: Urban Tree Planting Guide provides detailed guidance on urban tree planting that is applicable at both development site and watershed scales. Topics covered include site assessment, planting design, site preparation, and other pre-planting considerations, and planting and maintenance techniques. An Urban Tree Database is included for use in selecting the best tree and shrub species for the planting site.

Urban watershed forestry is a new practice that draws from multiple disciplines, including forestry, hydrology, engineering, landscape architecture, mapping, planning, and soil science. Consequently, some ideas drawn from each discipline have been simplified in this manual in order to be easily understood by a diverse audience. In addition, the latest and most relevant research from each discipline has been used to support the new practice. The research summarized in this manual, however, is not intended to provide a comprehensive literature review.

This manual draws heavily upon research and examples from the Chesapeake Bay watershed and the northeastern region of the United States. The manuals primarily apply to these regions, and may also apply in other humid regions of the country where the natural vegetative cover is predominately forest. Finally, several elements in the manuals are brand new and will require additional testing, research, and analysis. We welcome future additions to the methodology and techniques presented.

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The preparation of the manual was greatly influenced by two design workshops held in Annapolis, MD, in winter 2004. The first workshop focused on developing conceptual designs for integrating trees and storm water treatment practices, while the second workshop developed guidelines for planting trees in specific urban locations. More than 40 local, regional, and national experts participated in the workshops, including foresters, storm water engineers, landscape architects, arborists, urban soil scientists, watershed planners, and representatives from parks, and transportation and utility companies.

The Center for Watershed Protection project team included:

- Karen Cappiella
- Tom Schueler
- Ted Brown
- Chris Swann
- Tiffany Wright

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Chapter 1: Introduction to Urban Watershed Forestry

This chapter introduces urban watershed forestry concepts, and makes the case as to why communities should integrate trees and forests into their planning practice in both developed and developing watersheds. Included are a discussion of terminology, principles, goals, objectives, and techniques related to urban watershed forestry; a review of the impacts of urbanization on forests and watershed health; a review of the watershed benefits of forest cover; and unique considerations for reforesting urban areas.

What Is Urban Watershed Forestry?

Since the 1980's, urban forest research and new technical analysis tools have defined a wider role and value for urban trees. There is greater recognition of how urban trees and forests improve air and water quality, reduce storm water runoff, conserve energy, and protect public health. Increasingly, these benefits are being better defined and quantified through scientific research. At the same time, the loss of trees and forests in developing watersheds continues, and urban tree canopy in inner cities deteriorates through removal or lack of replacement. The rate of conversion of forests to urban uses increased twofold from 1982 to 2001 in the United States, reinforcing the need for greater integration of forest and land use planning (NRCS, 2001).

The magnitude of impacts due to the loss of green space in urban watersheds, such as increased runoff and impervious cover, demonstrates the vital role of forestry in urban watershed management. Past approaches to restoring urban watersheds that have relied on structural solutions have failed to protect and restore urban streams. Many practitioners in the engineering community are now turning to vegetation and natural systems as a critical part of the solution; however, bringing these approaches together has not always been easy.

Urban watershed forestry is an integration of the fields of urban and community forestry and watershed planning. ***Urban and community forestry*** is the management of the urban forest for environmental, community, and economic benefits, while ***watershed planning*** promotes sound land use and resource management to improve water resources within a watershed. Therefore, urban watershed forestry sets watershed-based goals for managing the urban forest as a whole rather than managing forest resources on a site-by-site or jurisdictional basis, and provides strategies for incorporating forests into urban watershed management.

This integration of urban forestry techniques into urban watershed management acknowledges the importance of trees and forests in protecting water resources. This approach encourages watershed managers and urban foresters to systematically assess existing urban forests to determine how best to manage them to meet watershed protection and restoration goals. Several important terms related to the concept of urban watershed forestry are defined in the next section.

Terminology of Urban Watershed Forestry

It is important to distinguish the terms "forest," "forest cover," "urban forest cover," and "urban tree canopy." The terms are similar, yet each is defined, measured, and classified in a different manner by different authorities. These terms have confounding definitions and may even be used interchangeably. Box 1 gives examples.

BOX 1. SEEING THE FOREST FOR THE TREES

The Pacific Forest Trust defines a **forest** as "a biological community of plants and animals that is dominated by trees and other woody plants" (PFT, 2004). While at first glance this definition appears adequate, it may be difficult to use it to define which portions of an urban watershed are covered by forest.

Forest cover can be defined as the total area of land that is classified as forest. Just because an area is classified as forest, however, does not necessarily mean that it is 100% covered by trees. So how many trees constitute a forest? By delving deeper into the existing literature and resources on the mapping and classification of forests, one discovers a diverse array of operational definitions, such as the following examples:

1. "Dense forest" includes areas with **more than 70% canopy cover,** while "fragmented forest" includes areas with 40% to 70% cover. – *The Tropical Ecosystem Environment Observations by Satellite (TREES) project (Center for International Forestry Research, 2004).*

2. "Forest" consists of areas dominated by trees with a total **canopy cover of 61% or more**, tree crowns usually interlocking. – *National GAP Analysis (USGS, 2000).*

3. "Forest" consists of trees with their crowns overlapping, generally forming **60% to 100% cover** (as opposed to "woodlands" which have 25% to 60% cover). – *The U.S. National Vegetation Classification System (TNC, 1998).*

4. "Closed forest" includes areas with **more than 40% canopy cover**, while "open or fragmented forest" includes areas with 10% to 40% cover. – T*he United Nations Environment Programme (Center for International Forestry Research, 2004)*.

Since the sources cited above define tree cover as ranging from 40% to more than 70%, estimates of watershed forest cover will vary greatly depending on which classification system is used.

Since the methods in this manual apply to urban watersheds, what we are really concerned with measuring is **urban forest cover**. This manual deals primarily with forests, trees and shrubs, and does not address planting herbaceous vegetation. "Urban forest" is defined as trees growing individually, in small groups or under forest conditions, on public and private lands, in cities and towns and their suburbs (CBP, 2004). Therefore, our working definition of urban forest cover includes individual trees and groups of trees, as well as forests. The best measure of urban forest cover is attained by mapping the urban tree canopy.

Urban tree canopy is defined as the layer of tree leaves, branches, and stems that cover the ground when viewed from above (CBP, 2004). Measuring tree canopy is also important because it is the tree canopy that provides such benefits as rainfall interception, pollutant removal, and shading of streams and impervious surfaces (Box 2).

The term "forest cover" will be used throughout this manual when describing the recommended methodology (e.g., measure forest cover in the watershed, set numerical goals for forest cover in the watershed). **For the purposes of this manual, our operational definition of forest cover is the total area of land that is classified as forest by the land cover data source you are using.** The ideal land cover data recommended for this analysis is urban tree canopy, which includes individual trees and groups of trees, as well as forest. We recognize, however, that this level of detail may not be attainable for all communities. Therefore, communities conducting an assessment of their urban forests should use the best available data.

BOX 2. MEASURING URBAN TREE CANOPY

Exhibit A. Forest cover derived from land use data

Exhibit B. Urban tree canopy derived from satellite imagery

Measurement of forest cover in an urban watershed is further confounded by forest fragmentation. Small forest fragments may not meet the canopy coverage requirements for forest cover and thus may be classified as nonforest cover. Therefore, the scale at which forest cover is measured and the resolution of the data are also important. Exhibits A and B illustrate this point. Note the presence of small patches of trees in Exhibit B compared with the lower resolution forest cover data in Exhibit A.

An assessment of urban tree canopy may be obtained from existing data or images such as USGS digital orthoquads or IKONOS satellite imagery. Minimum standards for measuring urban tree canopy include a resolution of 1 meter and imagery that is no more than 3 years old (CBP, 2004). One difficulty with mapping urban tree canopy in urban areas is that these assessments may underestimate tree cover where buildings cast shadows over the trees.

Urban tree canopy generally gives a more accurate representation of forest cover in an urban watershed than a forest cover layer. The assessment approach used by a community, however, will be driven by the funds and technical capacity of the staff, as well as by the availability of modeling applications for the data. If it is not feasible to map urban tree canopy, the highest-resolution forest cover data available should be used. Be sure to check the metadata to determine the scale, resolution, and recency of the data.

Watersheds are land areas that drain surface water and ground water to a downstream water body or outlet, such as a river, lake, or estuary. Watershed drainage areas vary in size, but urban watershed forestry generally deals with watersheds ranging from 20 to 100 square miles or more. Given their size, they may encompass many political jurisdictions, contain a mix of land uses (forest, agricultural, rural, suburban, urban), and have a broad range of pollution sources. Each watershed is composed of a number of smaller watersheds called subwatersheds.

Subwatersheds, as a general rule of thumb, have a drainage area less than 10 square miles and include streams ranging from first to third order. Ideally, each step in the urban watershed forestry methodology outlined in this manual would be conducted at the *subwatershed* scale. However, this may not be feasible or desirable for communities that wish to conduct urban forest assessments or land use planning at a larger scale. For this reason, and for simplicity, this manual presents each step at the *watershed* scale. Many of the techniques related to urban watershed forestry are actually implemented at the parcel scale. A ***parcel*** is a contiguous plot of land that is owned by a single entity.

Urban watersheds or subwatersheds are defined for the purposes of this manual, as having more than 10% total impervious cover. ***Impervious cover*** includes any surface that does not allow water to infiltrate, such as roads, buildings, parking lots, and driveways. Natural channels and hydrologic processes in urban watersheds are often altered by the creation of impervious cover as well as by structural features such as storm drains, channelized streams, and retention basins.

Storm water treatment practices (STPs) include a suite of structural practices that treat storm water runoff before it enters local receiving waters. STPs treat runoff by capturing and temporarily detaining water, allowing pollutants to settle out. Major categories of STPs include ponds, wetlands, infiltration systems, filtering systems, and open channel systems. Additional detail on specific STPs and how trees can be incorporated is provided in Part 2 of this manual series.

Principles of Urban Watershed Forestry

Urban watershed forestry takes a new approach to watershed protection and restoration by systematically tracking and managing forest cover at the watershed level. The basic aim is to *reduce forest loss and maximize forest gains over time*. Some of the core principles of this emerging practice are listed below.

1. Forest cover is the highest and best use of land in a watershed, and is superior to turf grass as a vegetative cover in terms of water storage, groundwater recharge, runoff reduction, pollutant reduction, and habitat (see Watershed Benefits of Forest Cover later in this chapter, for a description of benefits).

2. Forest cover provides additional environmental benefits by reducing ozone and other air quality problems, reducing the “urban heat island effect” and providing habitat for urban wildlife.

3. Urban forests are a dynamic mosaic of forest, impervious, and turf cover, are highly impacted by outside stressors, such as air pollution, invasive species, and construction damage.

4. The constant changes in watershed forest, impervious, and turf cover needs to be carefully analyzed over time to track gains and losses as a result of development, forest conservation and afforestation.

5. Special management techniques are needed to improve urban forest quality, measured in terms of diversity, structure, canopy, maturity, species composition, and relationship to natural ecosystems.

6. Existing forest tracts should be investigated to identify those that have the greatest priority for permanent conservation or need for special management techniques.

7. Forest loss during land development can be sharply reduced by employing local planning and forest conservation tools.

8. Forest cover gains can be sharply increased through systematic reforestation of larger parcels of public or corporate lands, and by tree planting on smaller privately owned individual parcels. Forest canopy can also be enhanced through the addition of trees to the built environment, such as within storm water treatment practices and along streets and other engineered settings.

9. Land use plans should contain explicit goals with respect to watershed forest cover and impervious cover. The two are interrelated and the ultimate impervious cover expected in the watershed can be used to define realistic forest cover goals.

10. Urban watershed forestry should be integrated with other watershed restoration practices, such as stream repair and restoration, storm water retrofits, and pollution prevention practices.

11. Urban reforestation efforts should focus on improving conditions at the planting site, selecting appropriate species, and designing the reforestation plan to maximize long-term survival of the forest.

Goals of Urban Watershed Forestry

Based on the preceding principles, urban watershed forestry has three goals:

1. ***Protect*** undeveloped forests from human encroachment and the impacts of land development by creating and applying various planning techniques, regulatory tools, and incentives. This includes conservation easements that protect forested land from being developed, land use planning that directs development away from forested areas and reduces imperviousness, ordinances that require developers to physically protect selected forests during construction, and financial incentives--such as storm water credits--that encourage developers to conserve more forest at a development site.

2. ***Enhance*** the health, condition, and function of urban forest fragments. This includes the use of various techniques for increasing and improving structure, hydrologic function, diversity, and wildlife habitat, and improving conditions for tree growth to ensure long-term sustainability of the forest.

3. ***Reforest*** open land through active replanting or natural regeneration to regain some of the functions and benefits of a forest and to increase overall watershed forest cover and increase forest canopy.

Objectives of Urban Watershed Forestry

The three goals of urban watershed forestry are achieved by pursuing the major objectives described in Table 1.

Table 1. Urban Watershed Forestry Objectives, by Goal		
Goal	Objective	Description
1. Protect	A. Protect Priority Forests	Select large tracts of currently unprotected and undeveloped forest to protect from future development.
	B. Prevent Forest Loss During Development and Redevelopment	Directly or indirectly reduce forest clearing during construction.
	C. Maintain Existing Forest Canopy	Prevent clearing and encroachment on existing protected and unprotected forest fragments on developed land.
2. Enhance	D. Enhance Forest Fragments	Improve the structure and function of existing protected forests.
3. Reforest	E. Plant Trees During Development and Redevelopment	Require on-site reforestation as a condition of development.
	F. Reforest Public Land	Systematically reforest feasible planting sites within public land, rights-of-way, or other priority sites.
	G. Reforest Private Land	Encourage tree planting on feasible locations within individual yards or property.

Techniques of Urban Watershed Forestry

Chapter 3 provides detailed information on 29 specific techniques that can be implemented to meet the goals and objectives of urban watershed forestry. Considerations for planting trees during development and redevelopment are covered in more detail in Part 2 of this manual series, Conserving and Planting Trees at Development Sites.

Why Is Urban Watershed Forestry Important?

Over 75% of the U.S. population lives in cities (Nowak and others, 2000). As a result, more and more people are disconnected from natural resources such as forests that support them and the watersheds in which they live. As a result, urban residents may take for granted the important benefits provided by urban trees. Urban watershed forestry represents an important management approach, given the many benefits provided by urban forests and impact of development on forest structure and function and watershed health. Managing urban forests in ways that explicitly address watershed health can mitigate some of the negative impacts of forest fragmentation, soil compaction, and increased impervious cover in urban watersheds.

An overview of the watershed benefits of urban forests, the impacts of impervious cover on watershed health, the impacts of urbanization on forests, and the unique properties of the urban planting environment is provided below.

Watershed Benefits of Forest Cover

Forests provide numerous benefits that can be divided into those that affect watershed health and those that are more apparent at the individual parcel scale. These benefits can be further categorized into economic, environmental, and community benefits. These benefits are summarized in Table 2.

Table 2. Economic, Environmental, and Community Benefits of Trees		
Scale	Category	Benefit
Watershed	Environmental	• Reduce storm water runoff • Improve regional air quality • Reduce stream channel erosion • Improve soil and water quality • Provide habitat for terrestrial and aquatic wildlife • Reduce summer air and water temperatures
Parcel	Economic	• Decrease heating and cooling costs • Reduce construction and maintenance costs (by decreasing costs related to clearing, grading, paving, mowing, and storm water management) • Increase property values • Positively influence consumer behavior
	Environmental	• Reduce urban heat island effect • Enhance function of storm water treatment practices
	Community	• Increase livability • Improve health and well-being • Block UV radiation • Provide shade • Buffer wind and noise • Increase recreational opportunities • Provide esthetic value

Part 2 of this manual series addresses the benefits trees provide at the individual parcel scale (e.g., development sites). A description of the watershed benefits of forest cover follows and is summarized in Table 3. Box 3 introduces methods to place an economic value on these watershed benefits, while Box 4 describes various forest conditions that maximize these watershed benefits.

BOX 3. CALCULATING THE VALUE OF TREES

Recent studies have attempted to place a value on the watershed benefits provided by urban trees. American Forests has conducted more than 20 studies known as Regional Ecosystem Analyses. These analyses use satellite imagery to estimate forest loss over time and CITYgreen software to place an economic value on lost forest. American Forests analyzed the Baltimore-Washington area and estimated a decline in tree cover from 51% to 37% from 1973 to 1997. The loss in forest cover produced an estimated 19% increase in storm water runoff (from each 2-year peak storm event) (American Forests, 1999). The cost to construct storm water treatment practices to intercept this runoff would cost $1.08 billion (American Forests, 1999). The lost tree canopy would have removed about 9.3 million pounds of pollutants from the atmosphere annually, at a value of approximately $24 million per year (American Forests, 1999).

Table 3. Watershed Benefits of Forest Cover	
Benefit	**Description**
Reduce storm water runoff and flooding	• Trees intercept rainfall in their canopy, reducing the amount of rain that reaches the ground. A portion of this intercepted rainwater evaporates from tree surfaces. This effect is greater in low rainfall events. • Trees take up water from the soil through their roots during transpiration, which increases soil water storage potential and lengthens the amount of time before rainfall becomes runoff • Trees promote infiltration by attenuating runoff and by increasing soil drainage due to the creation of macropores by tree roots. The addition of organic matter (e.g., leaf litter) also increases storage of water in the soil, further reducing runoff. • Reduced runoff from forested land reduces the frequency and volume of downstream flood events.
Improve regional air quality	• Trees absorb nitrogen dioxide, carbon monoxide, ozone, and particulate matter from the atmosphere. • Trees reduce air temperature which reduces formation of pollutants that are temperature dependent, such as ozone • Trees indirectly improve air quality by cooling the air, storing carbon, and reducing energy use, which reduces power plant emissions
Reduce stream channel erosion	• Trees growing along a stream bank prevent erosion by stabilizing the soil with root systems and the addition of organic matter, and by substantially dispersing raindrop energy • Reduced runoff volume due to forests upstream can reduce downstream flood flows that erode the stream channel
Improve soil and water quality	• Trees prevent erosion of sediment by stabilizing soil with root systems and the addition of organic matter, and by substantially dispersing raindrop energy • Trees take up nutrients such as nitrogen from soil and groundwater • Forested areas can filter sediment and associated pollutants from runoff • Certain tree species break down pollutants commonly found in urban soils, groundwater, and runoff, such as metals, pesticides and solvents
Provide habitat for terrestrial and aquatic wildlife	• Forests (and even single trees) provide habitat for wildlife in the form of food supply, interior breeding areas, and migratory corridors • Streamside forests provide habitat in the form of leaf litter and large woody debris, for fish and other aquatic species • Forest litter, such as branches, leaves, fruits, and flowers, form the basis of the food web for stream organisms
Reduce summer air and water temperatures	• Riparian forests shade the stream and regulate summer air and water temperatures, which is critical for many aquatic species • Trees and forests shade impervious surfaces, reducing temperature of storm water runoff, which can ameliorate the thermal shocks normally transmitted to receiving waters during storms.

BOX 4. MAXIMIZING WATERSHED BENEFITS

While trees and shrubs provide watershed benefits, certain forest conditions maximize the benefits. The location of forests within headwater riparian areas in the watershed is one of these conditions. Headwater streams (e.g., first or second order) are often the most sensitive to development as well as the least protected. Cumulatively, headwater streams make up 75% of the total stream and river mileage in the country (Schueler, 1995); therefore, having an intact forested riparian corridor along headwater streams can provide significant benefits to overall watershed health.

At the site level, large, mature trees and a continuous canopy provide the most benefit in terms of storm water reduction, cooling, and wildlife habitat (Metro, 2002). Proper site preparation, planting, and management techniques are essential to ensure that newly planted trees live long enough to mature and provide these benefits. Tree selection and strategic placement can also be critical to attaining benefits. Urban watershed forestry goals should seek to expand the forested riparian corridor along headwater streams, conserve existing tracts of contiguous forest, connect existing forest parcels, increase canopy cover in urban areas, and maintain long-term forest health.

Reduce storm water runoff

Forests improve stream quality and watershed health primarily by decreasing the quantity of storm water runoff and pollutant loads that reach surface waters. Trees reduce storm water runoff through **rainfall interception** by the tree canopy (Box 5), by releasing water into the atmosphere through **evapotranspiration** (Box 6), and by promoting **infiltration** of water through the soil and storage of water in the soil and forest litter (Box 7). Figure 1 illustrates these hydrological processes.

Reducing storm water runoff improves watershed health by recharging groundwater and improving baseflow in streams, decreasing flooding and erosion, and reducing the pollutants that are washed into streams from impervious surfaces. Forests can absorb or store the majority of rainfall from most storms and, therefore, have lower runoff coefficients than do turf grass or impervious cover (see Appendix A). The **runoff coefficient** is the proportion of rainfall that is converted to storm water runoff.

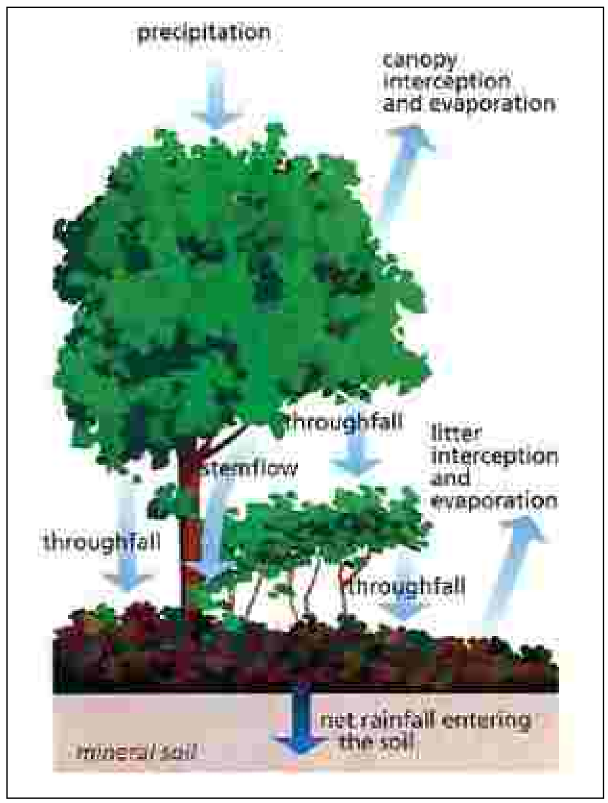


Figure 1. Schematic of a Tree's Hydrologic Cycle (Source: FISRWG, 1998, p. 2-5)

BOX 5. RAINFALL INTERCEPTION

Rainfall interception is the capture of rainwater by leaves, branch surfaces, mosses, and bark. Interception decreases throughfall of rain and reduces runoff volume and velocity. **Throughfall** is the portion of precipitation that reaches the ground directly through gaps in the tree canopy, or dripping from leaves, twigs, and stems (Metro, 2002). Intercepted rainwater is either evaporated directly into the atmosphere, absorbed by the canopy surfaces or transmitted to the ground via stems, branches, and other tree surfaces (referred to as **stemflow)**. The ability of a

(continued)

RAINFALL INTERCEPTION (CONT'D)

tree to intercept rainfall is influenced by its branching structure, canopy density, leaf texture, and bark texture (Metro, 2002). A key factor in determining the amount of leaf coverage or canopy density of trees is the **Leaf Area Index**, the ratio of leaf area to ground area (ITRC, 2001).

Studies of rainfall interception for individual trees indicate that a mature deciduous tree can intercept from 500 to 760 gallons of water per year (Envirocast, 2003; CUFR, 2001), and a mature evergreen can intercept more than 4,000 gallons per year (Portland BES, 2000; CUFR, 2001). Rainfall interception for individual trees ranges from 10% to 68% of a rainfall event (CMHC, no date; ITRC, 2001; Passmore, no date), and is dependent on the tree species and rainfall characteristics. Studies of rainfall interception by forests estimate that between ten and 40% of incoming rainfall is intercepted by forest canopy (Watershed Science Center, 2000). Canopy interception in conifer stands ranges from 15% to 40% of annual precipitation, and interception in hardwood stands ranges from 10% to 20% (Xiao and others, 2000). Rainfall interception is higher for evergreens because they have the ability to intercept rainfall all year round.

BOX 6. EVAPOTRANSPIRATION

Evapotranspiration (ET) represents the combined water loss due to evaporation from soil and plant surfaces and transpiration by plants. **Transpiration** is the process by which plants take up water from the soil through their root system and release moisture in the form of water vapor from their leaves. The uptake of soil water by tree roots increases soil water storage potential, effectively lengthening the amount of time before rainfall becomes runoff. Many factors influence transpiration rates, including leaf shape, size, number of pores (stomata), and waxiness of the leaf surface (Metro, 2002). Generally speaking, evergreens have lower transpiration rates because they are more efficient than deciduous trees at retaining moisture, due to the structure of their leaves (Metro, 2002). Chart 1 presents typical ET rates for different types of trees in an urban environment (adapted from Perry, 1994).

In general, a mature tree can transpire 100 gallons per day (Akbari and others, 1992; Metro, 2002). Water-loving species such as bald cypress can absorb 880 gallons per day, depending on soil type and saturation (Keating, 2002). An acre of mature forest can take up more than 1,800 gallons of water every day (Envirocast, 2003).

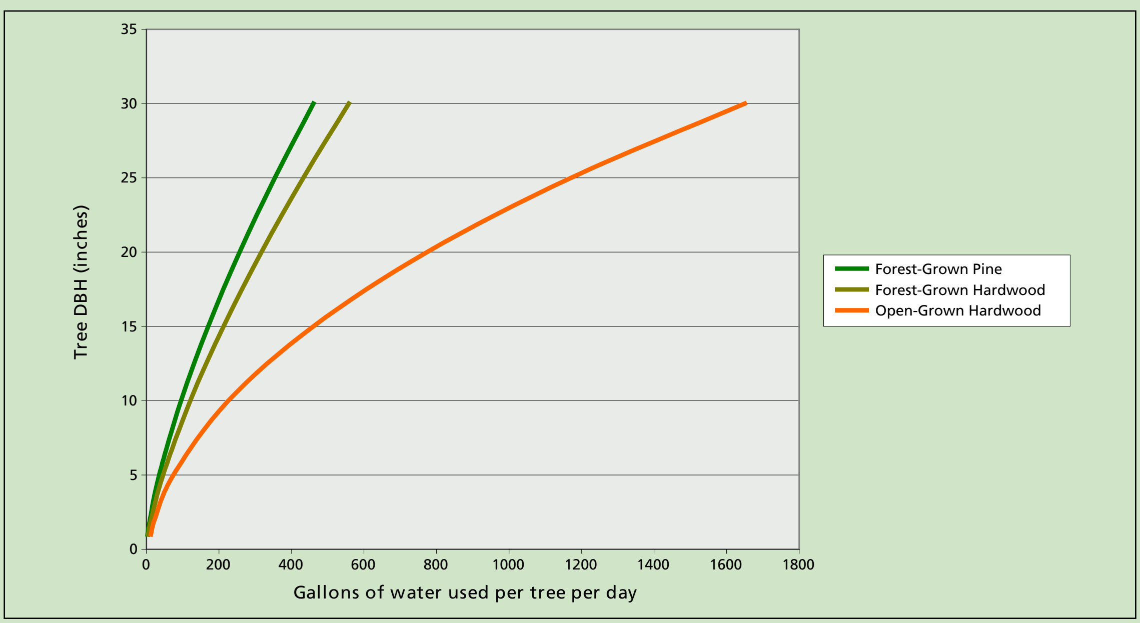


Chart 1: Evapotranspiration Rates for Various Tree Types (adapted from Perry, 1994)

BOX 7. INFILTRATION

The presence of trees helps to slow down or attenuate storm water runoff, which promotes infiltration of water through the soil. In addition, tree roots and organic matter from leaf litter create soil conditions that increase the capacity to infiltrate rainfall, which further reduces the volume of water that runs off the land surface. Tree roots increase infiltration by creating interconnected pathways in the soil called macropores. The depth, size, and number of these macropores, as well as the storm event characteristics, determine how much macropores aid infiltration during storms. Leaf litter and other organic matter produced by trees also work to reduce the amount of runoff by holding water and promoting infiltration rather than allowing rainfall to run off the surface as overland flow. This organic matter provides a good environment for earthworms, which also improve infiltration through the creation of additional macropores.

Infiltration tests conducted across a North Carolina watershed on various land types found that a medium aged pine-mixed hardwood forest had a mean final constant infiltration rate of 12.42 inches per hour. When the forest understory and leaf litter were removed, the resultant lawn had a mean infiltration rate of 4.41 inches per hour (Kays, 1980). Four additional types of disturbed land were tested and had infiltration values around two orders of magnitude less than for the native forest conditions (Kays, 1980).

Improve regional air quality

Trees improve air quality by directly removing pollutants, including nitrogen dioxide, carbon monoxide, sulfur dioxide, ozone, and particulate matter such as dust, ash, pollen, and smoke (MD DNR, 2002; Nowak, 1999). One study estimates the pollutant removal rate is 10 to 14 grams per square meter of canopy per year in eastern cities (Nowak, 1999). Trees also reduce air temperature, which indirectly reduces the emissions of some pollutants that are temperature dependent, such as hydrocarbons released through gasoline evaporation from parked cars (Nowak, 1999; McPherson and others, 1997; Scott and others, 1998). The cooling provided by urban trees can reduce smog levels by up to 6% (Wolf, 1998), and the reduced energy demand in turn reduces the amount of carbon dioxide produced by fossil-fuel power plants. Urban forests in the United States store millions of tons of carbon annually, helping to reduce the level of carbon dioxide in the atmosphere (Rowntree and Nowak, 1991).

One source estimates that a large front yard tree annually absorbs 10 pounds of air pollutants (including 4 pounds of ozone and 3 pounds of particulates), and prevents 330 pounds of carbon dioxide from entering the atmosphere through direct sequestration in the tree's wood and reduced power plant emissions from energy savings due to cooling (CUFR, 2001). While these numbers may be impressive, stands of trees are even more effective at reducing air pollution than individual trees. Even modest increases of 10% canopy cover in the New York City area were shown to reduce peak ozone levels by 3% of the maximum and by 37% of the amount by which the region exceeded its air quality standard (Casey Trees Endowment Fund, no date). Similar results were found in other eastern cities.

Reduce stream channel erosion

Trees in the riparian zone help to reduce stream channel erosion by stabilizing the soil with their root systems and by adding organic matter. Vegetative cover also prevents erosion by substantially dispersing raindrop energy. Long-term loss of riparian vegetation can result in bank erosion and channel widening, increasing the width/depth ratio of the channel (Hartman and others, 1987; Oliver and Hinckley, 1987; Shields and others, 1994). Trees outside riparian areas indirectly reduce stream channel erosion by attenuating runoff and reducing the total runoff volume that would otherwise contribute to downstream channel erosion.

Improve soil and water quality

Trees improve soil and water quality through uptake of soil nutrients (primarily nitrogen), filtering of sediment and associated pollutants from runoff, and removal of pollutants commonly found in runoff and urban soils (see Box 8 on phytoremediation). Over time, trees also increase the amount of organic matter in the soil, which binds many pollutants. Appendix A summarizes the effect of land cover on water quality in terms of nutrient loads. Sediment loads from forests are estimated at 50 tons of soil per square mile per year, compared with developing areas, which can lose 25,000 to 50,000 tons per square mile per year (Urban Forestry South Expo, no date).

BOX 8. PHYTOREMEDIATION

Phytoremediation is the process of using plants to remove contamination from soil and water. Plants can be used to clean up metals, pesticides, solvents, explosives, crude oil, polycyclic aromatic hydrocarbons, and landfill leachates from contaminated soils (U.S. EPA, 1998). Tree species typically used for phytoremediation include willow, poplar (cottonwood hybrids), and mulberry, because they have deep root systems and are able to control migration of pollutants by consuming large amounts of water (Puckette, 2001; Metro, 2002). Forested buffer strips are one common example of phytoremediation technology that is applied in agricultural settings to filter out pollutants from agricultural runoff before it reaches a stream. Forested buffer strips can also be applied in urban settings, although pollutant removal rates are not as well documented (Schueler, 1995).

Pollutant removal rates for phytoremediation technologies vary greatly, but one study estimated that one sugar maple growing along a roadway removed 60 mg of cadmium, 140 mg of chromium, 820 mg of nickel, and 5,200 mg of lead from the environment during a single growing season (Coder, 1996). More information about phytoremediation can be found in U.S. EPA (1999).

Provide habitat for terrestrial and aquatic wildlife

Forests serve as wildlife habitat that supplies food, water, and cover for a variety of birds, mammals, amphibians, reptiles, and invertebrates. Large areas of contiguous forest are important habitat for interior dwelling species, while narrow strips of forest may connect larger forest tracts. Large forest areas and narrow strips both can serve as migratory corridors for wildlife.

Riparian forests provide multiple benefits for aquatic life. Trees provide leaf litter and large woody debris, which create habitat for fish, macroinvertebrates, amphibians, and reptiles. Leaf litter is also an important source of energy to streams as it is the basis for aquatic community food webs. A typical acre of mature forest will drop between 2 and 3 tons of leaves, twigs, and branches every fall (Envirocast, 2003). When these leaves blow into a stream, they form “packs” that are gradually broken down by fungi and bacteria, dependent on temperature and current velocity (Envirocast, 2003). The fungi are a major food source for insects such as caddisflies and stoneflies, which in turn are a food source for small fish and other aquatic life (Envirocast, 2003).

In urban watersheds, much of the organic matter inputs to streams are from upland areas such as roadsides, where leaves fall onto curb areas and are washed through the storm drain system to the stream. Therefore, upland forests may be as important as riparian forests in urban watersheds, in terms of organic matter inputs to the stream.

Reduce summer air and water temperatures

Riparian forests regulate surface water temperatures for fish and aquatic insects through the shade they provide along stream channels. Temperature is important because it plays a central role in the rate and timing of biotic and abiotic reactions in streams (FISRWG, 1998). The increased impervious cover and lack of forest cover in urban watersheds can increase summer stream temperatures by 2 to 10 degrees Fahrenheit (Galli, 1991). In some regions, summer stream warming can even shift a cold-water stream to a cool-water or a warm-water stream, and this change can be irreversible (FISRWG, 1998). Trees and forests that shade impervious surfaces can reduce the temperature of storm water runoff. Therefore, urban forests can mitigate the thermal shocks that would otherwise be transmitted to urban streams during storms.

Impacts of Impervious Cover on Watershed Health

Most watersheds in the eastern United States were once primarily forested. Today, many of these forests have been cleared to make way for farmland or urban development. As forests are cleared for development in urbanizing watersheds, they are replaced with paved surfaces such as roads, driveways, parking lots, and sidewalks. These paved surfaces combined with rooftops make up impervious cover. All surfaces in a watershed that are not considered impervious cover are generally lumped under the category “pervious cover,” and constitute most of the green space in the watershed (Box 9).

Impervious cover has recently been identified as an excellent indicator of stream quality in small watersheds. CWP (2003) summarized recent research findings and has integrated them into a watershed planning tool known as the Impervious Cover Model (ICM). The ICM predicts that most stream quality indicators decline when watershed impervious cover exceeds 10%, with severe degradation expected beyond 25% (CWP, 2003). The ICM predicts the *average* behavior of a group of indicators over a *range* of impervious cover and should not be used to predict the fate of individual species (e.g, trout, mussels).

The impacts of impervious cover on the health of small streams are reflected in four different indicators: hydrologic, physical, water quality, and biological. Impervious cover fundamentally alters the hydrology of urban watersheds by generating increased storm water runoff and reducing the amount of rainfall that soaks into the ground (Figure 2). Storm drain networks are created to efficiently deliver this runoff away from a development site, which increases downstream flooding and channel erosion, and delivers pollutants entrained in storm water runoff. Pollutants commonly found in urban storm water include sediment, nutrients, bacteria, metals, pesticides, and hydrocarbons. Urban storm water runoff also has thermal impacts on the stream, as the water is heated by impervious surfaces during the warm summer months. These increases in pollutant loads and temperature, combined with increases in flood frequency and peaks, have a detrimental effect on water quality, the stability of small stream channels, and the abundance and diversity of aquatic species living in these streams. More information on the impacts of impervious cover on stream health, the ICM, and specific indicators that measure watershed health can be found in CWP (2003).

The impacts of impervious cover described above can be mitigated by “disconnecting” impervious areas so that they are no longer hydraulically connected to the drainage system as well as by increasing tree canopy over the impervious cover. Disconnection can involve redirecting runoff from rooftops or individual parking lots to storm water treatment practices or vegetated areas and allowing the runoff to infiltrate. In fact, infiltrating storm water on-site is the goal of many storm water treatment practices and low-impact development approaches, particularly those that use vegetative cover and amended soil media and are sited to break up and treat runoff from what would otherwise be large expanses of impervious surface.

While some mitigation of impervious cover impacts is possible, conserving existing forests is still the best defense against the deterioration of watershed health from urbanization impacts. Planting new forests can help to mitigate the effects of prior development.

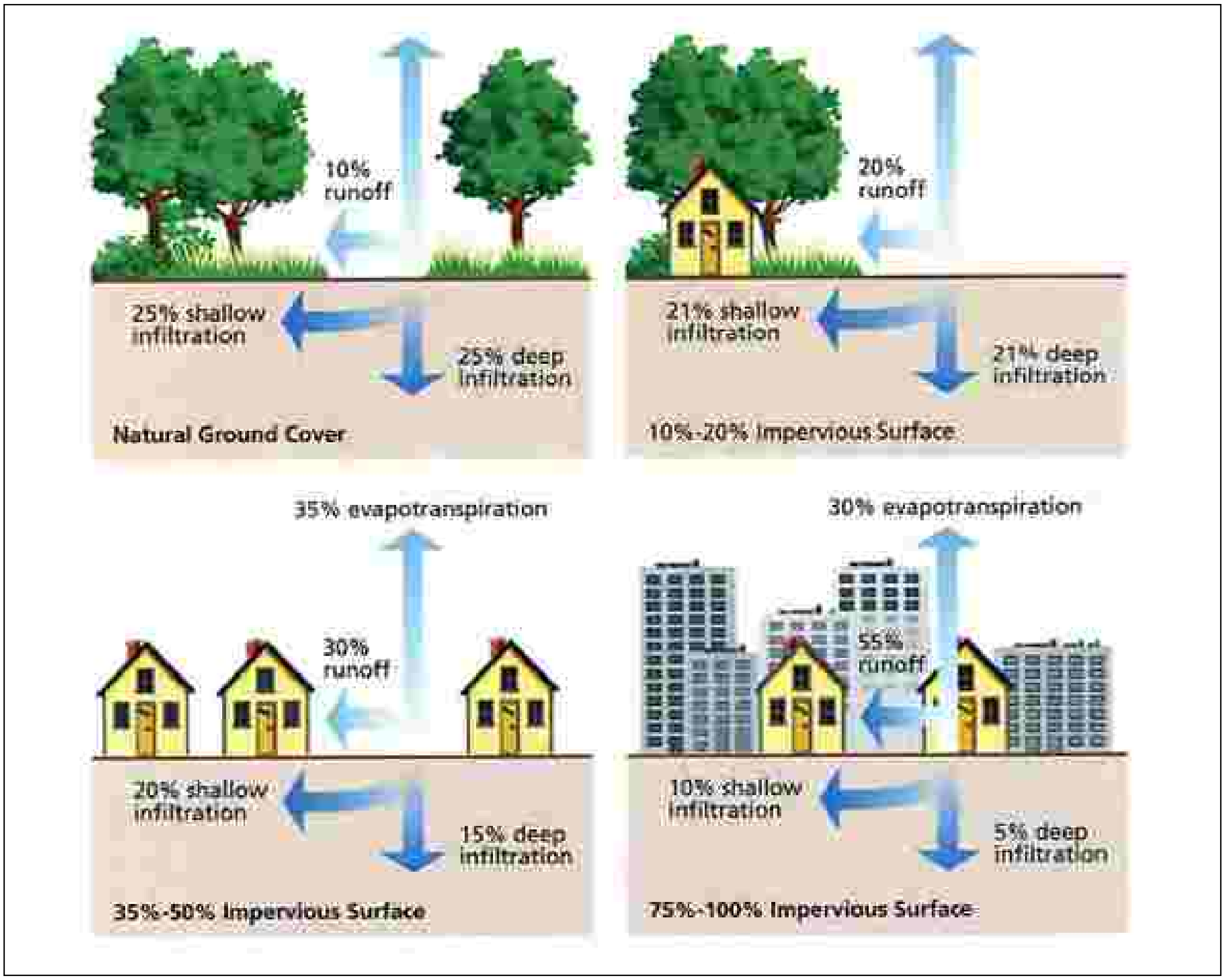


Figure 2. The Impacts of Impervious Cover on the Hydrologic Cycle (Source: FISRWG, 1998, p. 3-21)

BOX 9. ALL PERVIOUS COVER MATTERS

The vegetative cover of urban pervious areas ranges from bare earth to urban forest, but the majority is often turf grass or lawn. Forests are the most beneficial type of pervious cover in terms of watershed health because they reduce storm water runoff by intercepting and storing rainfall. On average, forests produce 30% to 50% less runoff than do grass lawn areas (Pitt and others, 1986), which produce significantly less runoff than impervious surfaces (see Appendix A).

Several studies have found that watershed forest cover may be as important as impervious cover in predicting stream health. One Puget Sound study found that watersheds with at least 65% forest cover usually had a healthy aquatic insect community (Booth, 2000). A Montgomery County, MD, study that used IKONOS imagery to map forest and impervious cover in relation to stream health ratings found similar results (Goetz and others, 2003). For watersheds to have a stream health rating of excellent required at least 65% tree cover in the riparian zone, and a stream health rating of good required at least 45% tree cover overall (Goetz and others, 2003).

Impacts of Urbanization on Forests

As land in a watershed is developed parcel by parcel, formerly continuous forests are divided into smaller patches. This process is referred to as ***forest fragmentation***. As forests are divided into smaller fragments, the proportion of edge to interior habitat increases, creating an "***edge effect***." Edge habitat occurs at the boundaries between different types of land cover, while interior forest habitat is defined as large tracts of continuous forest cover (Jones and others, 1997). Fragmentation diminishes habitat for forest interior dwelling species (e.g., interior-dwelling migratory birds), although the amount of interior forest habitat needed varies for different species (Jones and others, 1997; ELI, 2000). In general, habitat quality declines in relation to the size of the forest fragment.

American Forests estimates that tree cover in urban areas east of the Mississippi has declined by about 30% over the last 20 years, while the footprint of urban areas has increased by 20% (American Forests, no date). In fact, tree canopy cover across the United States averages only 27% in urban areas and 33% in metropolitan areas (Dwyer and Nowak, 2000). As forest cover within a watershed falls below 75%, fragmentation effects, such as changes in species composition and diversity, become more pronounced (U.S. EPA, 1997). The pattern of forest loss is as important as the amount of forest loss. For example, a checkerboard pattern exhibits more fragmentation than a clumped pattern of the same amount of forest (Jones and others, 1997; ELI, 2000). Figure 3 illustrates the loss and fragmentation of forest cover over six decades in the Gwynns Falls watershed in Baltimore County, MD.

Forest Cover in Gwynns Falls Watershed

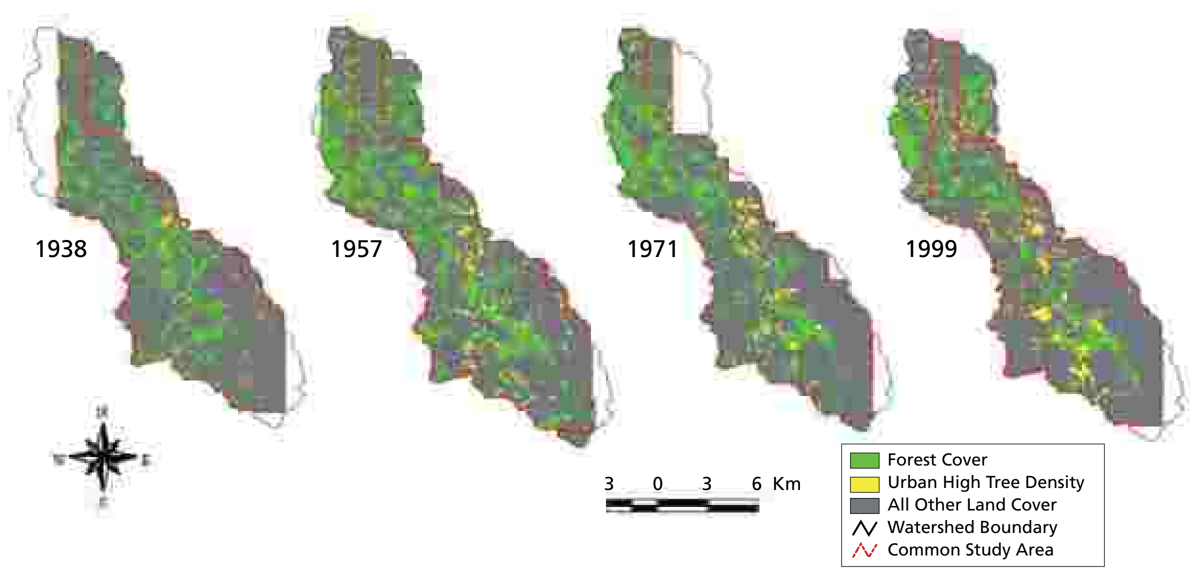


Figure 3. Forest cover was lost in the Gwynns Falls Watershed, Baltimore County, MD, from 1938 to 1999 (Source: Jim Dyer)

Edge effects

Fragmentation can also change the microclimate of the forest, altering species composition and opening the forest to invasive species. The forest interior has very different characteristics from the edge of the forest, and these differences become more pronounced with increased distance between the interior and the edge (Figure 4). The forest interior is more shaded, has higher humidity, and is less exposed to wind than is the forest edge, while the edge has more exposure to light, wind, and rain and contains more sun-loving species (Hanssen, 2003; FISRWG, 1998). The interior and edge habitats may also have different soil characteristics. Wildlife in forest edges are also more vulnerable to external competition, predation, and nest parasitism because they are more accessible to predators (e.g., house cats) and parasites (e.g., cowbirds) (Hanssen, 2003).

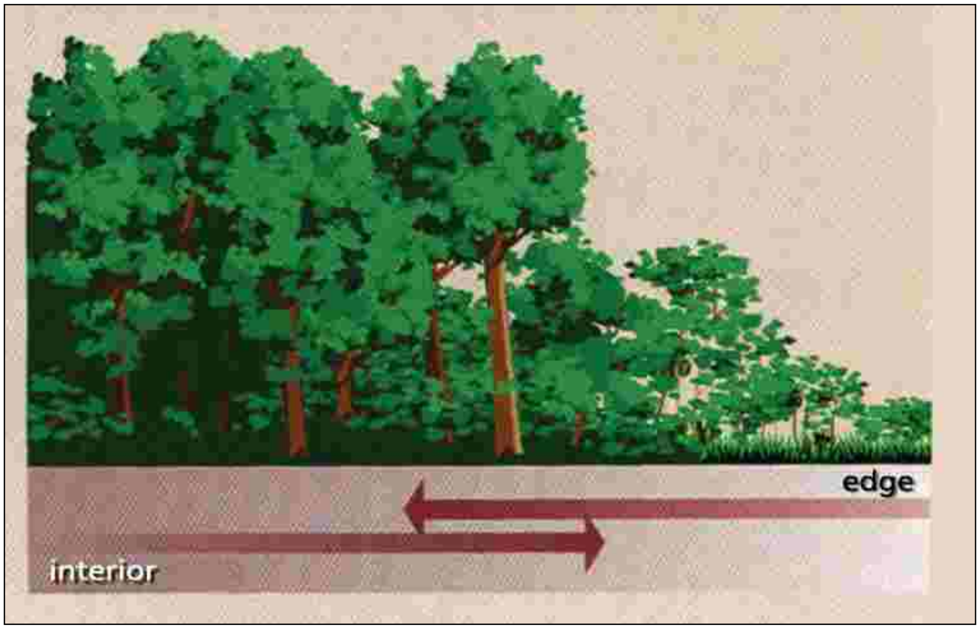


Figure 4. Differences between edge and interior become more pronounced with increased distance (Source: FISRWG, 1998, p. 2-81)

Due to the increased ratio of edge to interior forest habitat in urban watersheds, urban forest remnants are particularly susceptible to invasions of nonnative edge-loving plants such as ailanthus, kudzu, English ivy, and Japanese honeysuckle, and it is not uncommon for these invasive species to become dominant (Figure 5). Herbivory effects from whitetailed deer also tend to increase with increasing edge habitat. Deer browse primarily on woody plants and can thrive in transitional edge habitats that provide plenty of food and ample shelter (MD DNR, 1998). The lack of natural predators in urban areas combined with the effects of fragmentation can also concentrate large populations of deer in small forest fragments by restricting movement, which further magnifies the effects of browsing.

Figure 5. Typical urban forest fragment with invasive species, illegal dumping, and lack of vertical structure

Stresses from nearby development

Remaining urban forest fragments tend to be located in areas that are difficult to develop, such as stream valleys and steep slopes, or in places where trees have been allowed to grow up over time, such as parks and vacant lands. Many stresses are placed on these remaining fragments from nearby development and land use activities. Construction activities can compact root zones and alter drainage patterns around remaining forest patches and groups of trees. Air pollutants such as ozone damage tree foliage and impair photosynthesis, making trees more susceptible to pest outbreaks, disease, and drought (MD DNR, 2002). Urban forests are exposed to higher temperatures than their rural counterparts because of the urban heat island effect, making them more vulnerable to drought. Forest remnants are also stressed by deer overbrowsing and often lack the structure and understory of a healthy forest. Urban forests are also subject to clearing, excessive dumping of trash and rubble, and compaction and erosion from foot traffic and ATVs (Box 10).

BOX 10. TYPICAL CHARACTERISTICS OF URBAN FOREST FRAGMENTS

- Lack of vertical structure
- Populations of invasive plants may dominate
- Fewer native species are present
- Trash and other illegally dumped material is present
- Lack of species diversity (often a monoculture)
- High proportion of edge habitat to interior habitat
- Lack of understory or herbaceous layer
- Poor, compacted soils
- Subject to clearing and encroachment
- Subject to erosion and excessive storm water runoff
- Subject to overbrowsing by deer due to uncontrolled populations
- Large populations of exotic earthworms
- Soil nitrogen present primarily as nitrate.

Changes to riparian areas

Impacts to the riparian forest have their own particular pattern. Urbanization often results in encroachment, tree clearing, and mowing of the vegetated buffer along stream channels. These changes can interrupt the continuity of the stream buffer corridor and undermine its many benefits, such as stream shading and bank stabilization. Urban stream buffers may also be fragmented by road and utility crossings, and are often short circuited by storm water pipes. In commercial settings, buffers are often cleared and replaced with parking lots and riprap directly adjacent to the stream. Homeowners may replace natural buffer cover with turf grass that lacks the root depth needed to maintain bank stability. Finally, stream incision from increased flows in urban streams effectively cuts off the remaining riparian forest from its water source because floodwaters cannot make it up over the banks onto the floodplain.

Unique Properties of the Urban Planting Environment

In addition to the stresses placed on urban trees from surrounding development and land use activities, further difficulties may be caused by past land use activities when attempting to reforest an urban site. Most urban planting sites are highly disturbed, and the most fundamental change is caused by the disturbance of native soils. Progressive cycles of development and redevelopment involve wholesale earthmoving, erosion or removal of topsoil, compaction of subsoils, and the filling of depressions, wetlands, and natural rainfall storage areas (Figure 6). Consequently, the soils of urban pervious areas often lack the fertility, tilth, and recharge characteristics of their non-urban counterparts (CWP, 2000a), even if they have not been drastically disturbed.

Figure 6. Native soils disturbed during construction are compacted and contain building rubble

Figure 7. Stripping of topsoil during construction removes most of the nutrients and organic matter vital to plant growth (Source: Derek Booth)

Urban or made soils are typically very compacted, which physically impedes root development and suffocates the tree by limiting available oxygen (VCE, 2002; Coder, 2002). Compacted soils typically become limiting to root growth at soil bulk densities around 1.4 to 1.6 grams/cm^2 or greater (Craul, no date; CWP, 2000a). Compacted soils also have poor drainage, which can cause the tree roots to drown. From a practical standpoint, the hydrology of many urban pervious areas is more similar to impervious areas than to natural ones.

The quality of most urban soils is poor and is usually not ideal for plant growth. Most of the soil organic matter is removed along with the topsoil during construction (Figure 7). Turf is often established after construction, which does not contribute much organic matter to the soil. In addition, the soil pH in urban areas is often elevated from excessive building rubble, which contains calcium.

Soil surveys actually change the classification of the native soil to the ubiquitous moniker “urban soils” after a site is developed because they differ so drastically from the native soil and because they are so highly variable within an individual site that classifying the new soil is not feasible. This extreme variability necessitates some basic sampling and characterization of soil prior to restoration efforts.

Other considerations in the urban planting environment include these: exposure to extreme temperatures from surrounding pavement, conflicts with infrastructure, limited soil volume. More detail on preparing the urban planting environment is provided in Part 3 of this manual series.

Chapter 2: Planning Methods for Increasing Forest Cover in a Watershed

This chapter guides the watershed planner or forester through a six-step method for increasing forest cover in a watershed, defining watershed-based forest cover goals, and identifying priority sites for protection, restoration, and reforestation. Figure 8 presents the six-step method for increasing watershed forest cover, which is explained in detail in this chapter. These methods are only one component of the larger urban watershed restoration process, and should be coordinated with other restoration practices such as those outlined in Schueler (2004). For example, the baseline and sentinel monitoring of watershed conditions recommended in Schueler (2004) are essential to evaluate the effect of increasing forest cover through urban watershed forestry techniques.

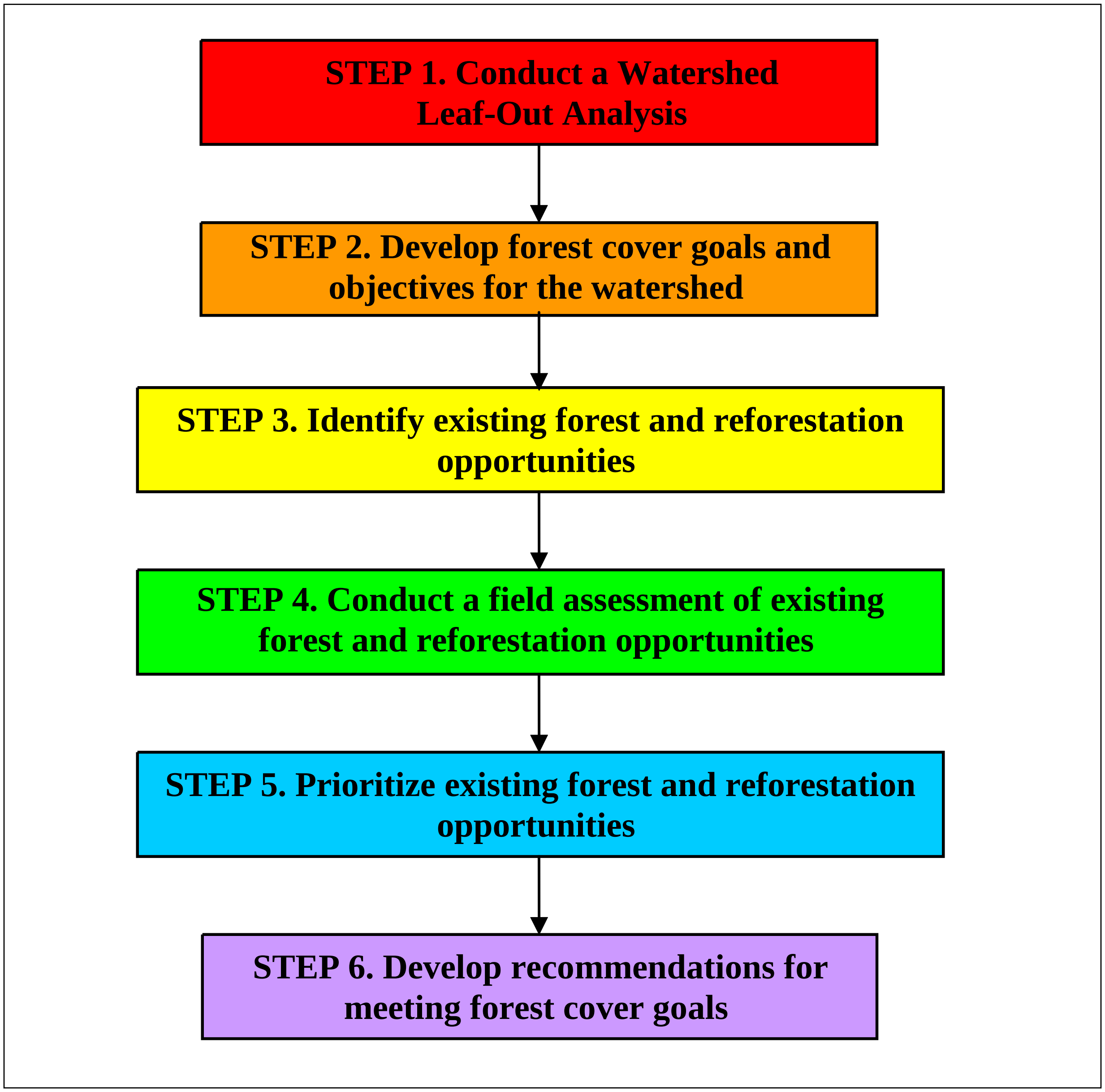


Figure 8. Six-step process for increasing forest cover in a watershed

This method is based on the assumption that a municipal or community program has mapping and other resources and the ability to conduct the method. The method is typically conducted across an entire watershed or subwatershed, but could easily be applied to a different scale, such as a small urban catchment or an entire metropolitan area. In addition, the actual implementation of several of the steps occurs at the individual parcel scale (e.g., evaluating reforestation sites, implementing reforestation projects). The use of Geographic Information Systems (GIS) is required, and the resolution of data should be appropriate for the scale of analysis.

The six-step method described here focuses on *planning* to increase forest cover in the watershed. Detailed guidance on *implementation* of techniques to increase forest cover is outside the scope of this manual; however, specific references direct the reader to the best implementation resources.

Step 1: Conduct a Watershed "Leaf-Out" Analysis

Watersheds are constantly gaining and losing forest cover at the same time due to the clearing of forests for land development, homeowner landscaping, abandonment of farm land or open space, reforestation, or other activities. The first step in planning to increase forest cover entails an inventory of existing and future watershed land cover to systematically account for forest losses and gains. The inventory method described here is referred to as the "Leaf-Out" Analysis because it is similar to a build-out analysis, which predicts future impervious cover with development based on zoning categories. The Leaf-Out Analysis focuses on future forest cover rather than on impervious cover. This analysis can be used to identify and evaluate the location, distribution, average size, future use, and ownership of forest fragments and reforestation sites. This information can then be used to determine which types of projects (protection, restoration, or reforestation) and what types of lands (public, private, residential turf, parks) will yield the greatest return in terms of increasing forest cover in the watershed. This step requires the use of GIS (see Box 11).

These substeps of the Leaf-Out Analysis are described in detail below:

Step 1.1 Estimate the Distribution of Current Land Cover in the Watershed

Step 1.2 Identify Protected and Unprotected Lands in the Watershed

Step 1.3 Determine Whether Parcels are Developed or Undeveloped

Step 1.4 Determine Allowable Zoning on Undeveloped Land

Step 1.5 Summarize Watershed Data

Step 1.6 Acquire Forest Cover Coefficients

Step 1.7 Estimate Future Forest Cover in the Watershed.

BOX 11. USING GEOGRAPHIC INFORMATION SYSTEMS FOR THE LEAF-OUT ANALYSIS

A Geographic Information System (GIS) is a computer-based tool for mapping and analyzing all sorts of geographically referenced (spatial) data. GIS is a common tool by which local governments manage property data, map natural resources, plan future transportation corridors, and provide efficient emergency response. Maintaining a GIS can require extensive resources for data collection, staff training, hardware and software acquisition, and more.

The inventory of current and future land cover described in this section requires the use of GIS; therefore, some basic understanding of GIS is helpful to navigate this section. Since a wide variety of GIS software is available, the steps described in this section refer only to general procedures rather than software-specific manipulations. The data layers created in this analysis have applicability and utility across a wide variety of local departments and analyses. Following are the minimum GIS layers required for the inventory of land cover in a watershed.

- Watershed and subwatershed boundaries (delineation methods available at the Storm Water Manager's Resource Center: www.storm watercenter.net)
- Open water and wetlands
- Topography
- Land cover (e.g, impervious, forest, turf)
- Protected lands (e.g., conservation easements)
- Parcel boundaries
- Land use (e.g., schools, parks)
- Zoning
- Natural resources (e.g., stream buffers, steep slopes, floodplains)
- Monitoring data (e.g., water quality, habitat, biological)
- Cultural, recreational, or historical sites
- Storm water treatment practices and other drainage features.

Many of these layers are available for free download from State Web sites such as in Maryland, the State Geographic Committee's Technology Toolbox: www.msgic.state.md.us. De la Cretaz, and others (2003) provide guidance on compiling and analyzing watershed GIS data, and Appendix B provides a list of additional data resources.

Step 1.1 Estimate the Distribution of Current Land Cover in the Watershed

The first step is to create or acquire a GIS layer of current land cover in the watershed that distinguishes between three cover types: impervious cover, forest cover, and nonforest vegetative cover. Open water and non-forested wetlands are not included in the land cover analysis.

- *Impervious cover* is defined as any surface that does not allow water to infiltrate and typically includes roads, buildings, parking lots, driveways, sidewalks, and decks.

- *Forest cover* includes all land that is primarily covered by trees and shrubs, although the actual classification of forest cover can vary greatly with the data source (see Box 1 on page 2). The ideal forest cover layer in this scenario is actually urban tree canopy, which includes the canopy of individual trees, groups of trees, and forests.

- *Non-forest vegetative cover* can include turf, bare ground, landscaping, meadow, and crops. In urban watersheds, the majority of non-forest vegetation is usually turf. Since it is difficult to distinguish between these cover types from aerial photos, and because all of these cover types are potential reforestation candidates, any land cover that is not forest or impervious is considered turf for the purposes of this analysis.

Depending on current GIS data, staff expertise, and resources available, there are three options for obtaining a current land cover layer:

1. Use existing local or regional land cover GIS layers (see Appendix B for potential sources).
2. Derive land cover from high-resolution imagery using GIS and remote sensing techniques.
3. Use GIS to digitize land cover from recent aerial photos.

If recent land cover maps of an appropriate scale and resolution are not available, one option is to acquire high-resolution satellite or aerial imagery and use remote sensing software to interpret and classify the images into the three land cover categories. Existing imagery that may be used includes USGS digital orthoquads and IKONOS satellite imagery. Minimum standards for measuring urban tree canopy include a resolution of 1 meter and imagery that is no more than 3 years old (CBP, 2004). Two techniques that utilize image classification to derive forest cover are American Forests CITYgreen (www.americanforests.org) and the Baltimore Strategic Urban Forests Assessment (Irani and Galvin, 2002).

In the CITYgreen analysis, high resolution satellite and aerial imagery is used to create a tree canopy layer for input into the CITYgreen software. American Forests has developed a method of classifying the imagery to create this 'green data' layer. This layer is used to calculate the benefits of the canopy in terms of runoff reduction, air quality, carbon storage and energy savings. For more information about CITYgreen, see www.americanforests.org.

The Baltimore Strategic Urban Forests Assessment (SUFA) was modified from the Maryland Strategic Forest Land Assessment (SFLA) (MD DNR, 2003) for application to an urban area. The SUFA method involved acquiring high resolution satellite imagery of the study area and using remote sensing software and techniques to interpret the image by creating "masks" of the tree canopy cover, non-tree vegetation, and impervious surfaces within the jurisdiction. These masks were then overlaid with local land use, zoning, and resource management data to create an "opportunity mask" of potential planting sites prioritized based on local need. For a detailed description of the methods used, see Irani and Galvin (2002) or the SFLA Web site at www.dnr.state.md.us/forests/download/sfla_report.pdf.

A third option for deriving land cover is to acquire aerial photos and directly digitize land cover layers from these photos (see Appendix B for sources of aerial photos). This method can be time-consuming but may be more affordable than using satellite imagery, particularly if some of the land cover layers already exist in GIS format.

Once the GIS layer of current land cover has been acquired or developed, the area of each cover type in the watershed should be quantified (Figure 9, Step 1.1).

Step 1.2 Identify Protected and Unprotected Lands in the Watershed

The next step is to create or acquire a GIS layer of protected and unprotected lands, in both public and private ownership. Protected lands are defined as land protected from future development through the application of conservation easements or by local regulations that protect specific natural resources. The types of protected land vary in each watershed, but may include wetlands, floodplains, stream corridors or buffers, steep slopes, hydric or erodible soils, parkland, land in conservation easements, karst features, and historic or cultural sites. Protected lands can be digitized from paper maps or from aerial photos if they do not currently exist in GIS format. The final GIS layer should indicate which lands are protected. All remaining lands are designated as unprotected (Figure 9, Step 1.2).

Step 1.3 Determine Whether Parcels Are Developed or Undeveloped

The next step is to create or acquire a GIS layer of developed and undeveloped parcels in the watershed to identify which parcels have already been developed, or "built-out" to the maximum extent allowed by zoning (Figure 9, Step 1.3). The development status (developed or undeveloped) of a parcel may be readily available in the associated data table of a good parcel boundary GIS layer. Ideally, this layer will contain ownership data to be used later to prioritize sites based on ownership and to contact landowners about potential projects. If this is not the case, the development status of each parcel can be estimated by initially classifying all parcels containing buildings as developed. Aerial photos and local knowledge of the area can be used to verify this classification. Parcel boundaries can be digitized from paper maps if they do not currently exist in GIS format.

Alternatively, state planning agencies or the municipal department that handles land development permits may have a composite set of parcel maps in a digital format or a database of developed and undeveloped parcels (e.g., property tax maps) that can be linked to a GIS layer. One example is the Maryland PropertyView Database available from the State Planning Department: www.mdp.state.md.us/data/index.htm.

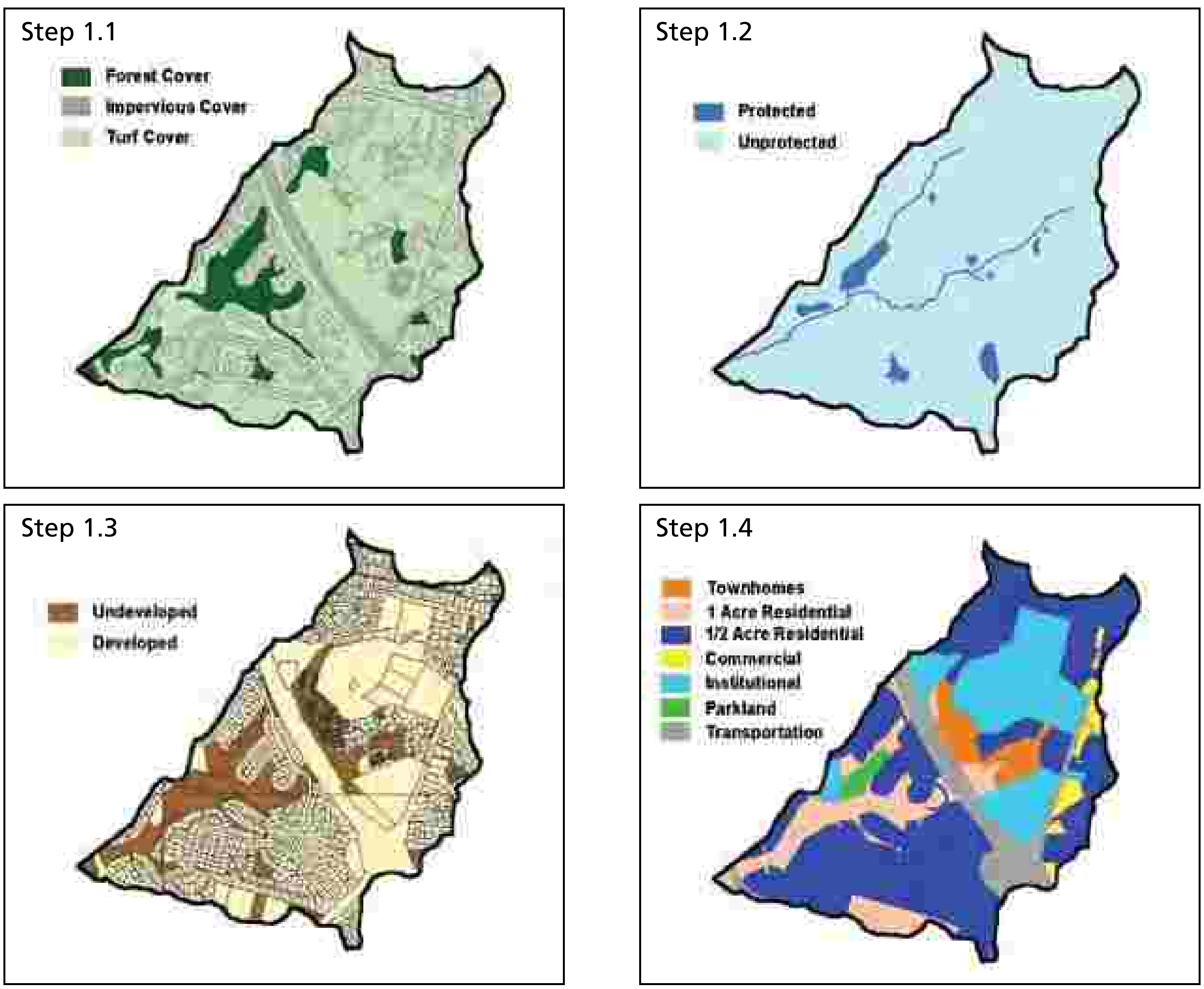


Figure 9. Example maps created as a result of the Leaf-Out Analysis: Step 1.1 – current land cover (upper left), Step 1.2 – protected lands (upper right), Step 1.3 – development status (lower left), and Step 1.4 – zoning (lower right).

Step 1.4 Determine Allowable Zoning on Undeveloped Land

Most local planning and zoning departments maintain a GIS or paper map of zoning categories, or both. A zoning map dictates the allowable land uses and development densities within the community and provides a snapshot of what land use will look like with future build-out. If a GIS layer of zoning does not exist, one can be digitized from the paper zoning map. If the watershed spans more than one community, zoning information from each community must be acquired and combined (Figure 9, Step 1.4).

Step 1.5 Summarize Watershed Data

In this step, the data collected in the four previous steps is used to develop a summary table that provides the necessary variables for estimating future forest cover (Table 4). This can be done using GIS by merging the four layers created in Steps 1.1 through 1.4 and querying the resulting data table. The variables highlighted in Table 4 are inserted into a worksheet designed to estimate future forest cover in Step 1.7.

Table 4. Summary of Watershed Data

Zoning Category	Current Impervious Cover (acres)	Current Forest Cover (acres)		Current Turf Cover (acres)		
				Developed		
		Protected/ Developed	Buildable (unprotected/ undeveloped)	Public	Private	Undeveloped
Agriculture	100	1,000	50	0	3,000	50
Open urban land	150	2,000	100	4,000	0	0
2 acre residential	500	500	200	0	4,000	1,000
1 acre residential	1,000	500	2,000	0	2,000	500
½ acre residential	1,000	500	3,000	0	1,500	1,000
¼ acre residential	2,000	500	1,000	0	1,000	500
⅛ acre residential	2,000	0	50	0	150	100
Townhomes	4,000	0	500	0	100	400
Multifamily	3,000	0	100	0	100	0
Institutional	1,000	0	500	3,000	500	0
Light industrial	5,000	0	500	0	50	100
Commercial	5,000	0	2,000	0	500	500
Total	24,750	5,000	10,000	7,000	2,950	4,150

Each of the variables quantified in this step serves some function in estimating future forest cover:

- The *total amount of current impervious cover* in the watershed will limit the potential for future forest cover (unless impervious cover is removed in order to reforest).
- *Forested land that is already either protected or developed* is assumed to remain forested with future watershed development.
- *Forested land that is both unprotected and undeveloped* is considered "buildable," and some proportion of that forest will be cleared during future development (Step 1.6 will estimate that proportion).
- *Developed turf* probably provides the best opportunities for reforestation, especially public land; however, only some proportion of public turf will actually be available for reforestation. Privately owned developed turf is likely to be residential lawns or commercial or industrial land and has the potential to greatly increase forest cover by reforestation, but will require extensive education, outreach, and possibly incentives to be implemented.

- *Undeveloped turf* may also provide some opportunity for reforestation; however, land should always be reforested in conjunction with protection measures, to ensure long-term sustainability of the forest.

Step 1.6 Acquire Forest Cover Coefficients

Forest cover coefficients represent the fraction of developed land that is forest. These coefficients are applied to specific zoning categories to estimate the amount of future forest cover on all buildable land in the watershed. Little data exist for forest cover or turf cover coefficients; however, some data is available that represent the fraction of developed land that is impervious. The methods used to derive these impervious cover coefficients may be used to estimate forest cover and turf cover coefficients.

Impervious cover coefficients for 12 urban and suburban land uses are available from Cappiella and Brown (2001) and are presented in Table 5. These coefficients were derived from recently developed urban-suburban areas in the Chesapeake Bay region and are applicable to areas with similar types of development. Where possible, local or regional estimates of impervious cover should be used. If none are available, communities should derive their own from local data (see Cappiella and Brown, 2001, for methods). Communities should also derive their own forest and turf cover coefficients by analyzing limits of disturbance on site plans or by analyzing turf cover or forest cover at the parcel scale as a sample of actual development sites. Appendix C and Cappiella and Brown (2001) provide detailed methods for deriving land cover coefficients.

Impervious, forest, and turf cover percentages are also provided in Table 5 for three forest conservation scenarios. These percentages are examples only and are based on a number of assumptions and data sources described below. Conversion of these percentages to coefficients for use in worksheets requires division by 100. Additional data sources that may be used to develop land cover coefficients are provided in Appendix D.

Table 5. Example Land Cover Percentages for Three Forest Conservation Scenarios[1]

Zoning Category	Impervious Cover (%)[2]	Turf Cover (%)[3]			Forest Cover (%)[3]		
		NFC	IFC	DFC	NFC	IFC	DFC
Agriculture	2	93	83	78	5	15	20
Open urban land	9	86	76	41	5	15	50
2 acre residential	11	84	74	39	5	15	50
1 acre residential	14	81	71	36	5	15	50
½ acre residential	21	74	64	54	5	15	25
¼ acre residential	28	67	57	47	5	15	25
⅛ acre residential	33	62	52	47	5	15	20
Townhomes	41	54	44	39	5	15	20
Multifamily	44	51	41	36	5	15	20
Institutional	34	61	51	46	5	15	20
Light industrial	53	42	32	32	5	15	15
Commercial	72	23	13	13	5	15	15

[1]*Forest Conservation Scenarios:*
NFC — No Forest Conservation = clearing can proceed anywhere at the site except protected wetlands.
IFC — Indirect Forest Conservation = some site areas cannot be cleared because of steep slopes, wetland buffers, stream buffers, floodplains, or other local clearing restrictions.
DFC — Direct Forest Conservation = additional site areas cannot be cleared because of explicit forest conservation or afforestation requirements at the site (e.g., Maryland Forest Conservation Law).
[2]*Impervious cover percentages are from Cappiella and Brown (2001).*
[3]*Turf cover and forest cover percentages are example values only.*

The turf and forest cover percentages presented in Table 5 are representative of three tiers of local forest conservation regulations: no forest conservation, indirect forest conservation, and direct forest conservation.

The *No Forest Conservation (NFC)* scenario applies to communities that have no forest conservation or other natural resource conservation regulations that apply during land development. Under NFC, the entire site can be graded, except for state or federally delineated wetlands. For the forest cover percentages presented in Table 5, the assumption was made that a minor fraction of forest cover (5%) may be retained during construction.

The *Indirect Forest Conservation (IFC)* scenario applies to communities that have some additional regulations that prevent clearing on portions of a development site containing stream buffers, steep slopes, floodplains, or other sensitive natural area. These areas often contain forest fragments, and therefore indirectly contribute to forest conservation, although they may represent a very small fraction of the site. The amount of forest conserved will vary depending on how much of the site is currently forested and located within areas such as floodplains, steep slopes, and stream buffers. For the forest cover percentages presented in Table 5, the assumption was made that approximately 15% of any given site would be preserved as forest.

The *Direct Forest Conservation (DFC)* scenario applies to communities with defined forest conservation or afforestation requirements at the development site, in addition to the environmental criteria listed under the indirect forest conservation scenario. The forest cover percentages presented in Table 5 were primarily based on the Maryland Forest Conservation Act criteria, which require a certain percentage of a development site to be preserved as forest or reforested during development.

The turf cover percentages presented in Table 5 reflect the remaining land after impervious cover and forest cover are subtracted from the total land area.

Figure 10. Effect of forest conservation regulations at the development site

Figure 10 illustrates the three tiers of forest conservation regulations. Prior to development, the parcel shown in Figure 10 had 45% forest cover (dark green). With development under the NFC scenario, only a small portion of forest on the site was preserved, with a net forest cover of 10%. Under the IFC scenario, a stream buffer ordinance that restricts disturbance of native vegetation within 100 feet of all streams resulted in the developer conserving additional forest along the stream that runs through the property. The net forest cover for this scenario was 25%. Under the DFC scenario, a forest conservation ordinance that required preservation of 40% of the site as forest resulted in a net forest cover of 40% and total forest loss of only 5%.

Most communities fall into one of these three tiers of forest conservation. Communities should select the appropriate forest cover coefficients depending on their prevailing regulations. As illustrated in Table 5, land cover coefficients vary with the zoning category and the forest conservation scenario; however, one variable not reflected in this table is the prior land use of the site. Land in agricultural use will have less forest cover to start with compared with a forested parcel and so will likely have lower forest cover coefficients. In addition, forest cover coefficients that are derived for older developments may tend to be higher than for more recently developed areas because trees have been planted or allowed to grow up over time in older developments. This variability and the current lack of data on forest and turf cover coefficients points to the derivation of land cover coefficients as a major data gap in this analysis and an area for future research.

Forest cover coefficients will be used in Step 1.7 to estimate future forest cover on buildable lands in the watershed. The percentages shown in Table 5 can be converted to default coefficients by dividing them by 100. Data provided in Appendix D may also be used until detailed studies are conducted to derive more precise information.

Step 1.7 Estimate Future Forest Cover in a Watershed

The final step in the Leaf-Out Analysis is to estimate future forest cover in the watershed under full build-out conditions. This initial estimate of future forest cover is intended to quantify forest cover under a worst-case or "do-nothing" approach and does not account for any future or planned forest conservation or reforestation efforts or regulations. Step 2, Develop Forest Cover Goals and Objectives, models the effect of various forest protection and reforestation techniques on future forest cover.

Box 12 summarizes the assumptions used in estimating future forest cover. These assumptions should be modified when more detail is available regarding future development patterns in a particular watershed. The Leaf-Out Analysis worksheet can be used to estimate future forest cover in the watershed under a worst-case scenario (no additional reforestation or conservation efforts). An example is shown in Box 13, and a blank worksheet is provided in Appendix E. Data summarized in Table 4 on page 24 (Step 1.5) and forest cover coefficients derived from local information (in Step 1.6) should be used to fill in the blanks in the worksheet.

BOX 12. ASSUMPTIONS USED IN ESTIMATING FUTURE FOREST COVER IN A WATERSHED

1. All developed land will remain in its current land cover.
2. All protected land will remain in its current land cover.
3. All impervious cover will remain impervious (e.g., no removal of pavement).
4. All land that is unprotected and undeveloped is considered "buildable" and is subject to future development under allowable zoning.
5. Full buildout of the watershed will occur based on allowable zoning (e.g., no re-zoning).
6. Future land cover of all buildable land can be estimated by applying the appropriate land cover coefficients for each zoning category.
7. The land cover coefficients chosen should reflect the current status of forest conservation regulations in the watershed.

BOX 13. LEAF-OUT ANALYSIS WORKSHEET FOR ESTIMATING FUTURE FOREST COVER IN A WATERSHED--WORST-CASE SCENARIO (e.g., no additional reforestation or conservation efforts)

Section 1. Future Forest Cover

Current Protected or Developed Forest Cover:	*5,000*	acres
From Table 4. All protected or developed forest will remain forested.	+	
Priority Forest Area Protected	*0*	acres
See section 2 of this worksheet. Default value is zero.	+	
Area of Forest Conserved During Development	*2,780*	acres
See section 2 of this worksheet.	+	
Area Reforested	*0*	acres
Default value is zero.	=	
Total Future Forest Cover	*7,780*	acres

Section 2. Forest Conserved During Development

Zoning Category	Buildable Forest (acres)		Priority Forest Protected (acres)		Buildable Forest Remaining (acres)		Forest* Cover Coefficient		Forest Conserved During Development (acres)
Agriculture	50	-	0	=	50	x	.50	=	25
Open urban land	100	-	0	=	100	x	.50	=	50
2 acre residential	200	-	0	=	200	x	.50	=	100
1 acre residential	2,000	-	0	=	2,000	x	.50	=	1,000
½ acre residential	3,000	-	0	=	3,000	x	.25	=	750
¼ acre residential	1,000	-	0	=	1,000	x	.25	=	250
⅛ acre residential	50	-	0	=	50	x	.20	=	10
Townhomes	500	-	0	=	500	x	.20	=	100
Multifamily	100	-	0	=	100	x	.20	=	20
Institutional	500	-	0	=	500	x	.20	=	100
Light industrial	500	-	0	=	500	x	.15	=	75
Commercial	2000	-	0	=	2,000	x	.15	=	300
Total	10,000		0						2,780

* Use forest cover coefficients that represent forest conservation requirements in your area

Section 3. Results Summary

Total Current Forest Cover	*15,000*	acres		
From Table 4.	-			
Total Future Forest Cover	*7,780*	acres		
From Section 1 above.	=			
Future Forest Loss	*7,220*	acres	*48*	%

The worksheet result gives an estimate of future forest loss (%) in the watershed with no additional forest conservation or reforestation efforts. In the example shown, 48% of existing forest in the watershed is lost to development.

The USDA Forest Service's Northeastern Research Station is developing a new tool to project future forest canopy cover that may facilitate the Leaf-Out Analysis. The tool involves a GIS-integrated management decision program that is a component of the Urban Forest Effects (UFORE) Model. This tool is called UFORE Future Effects and is designed to project future canopy cover over a 30-year period based on estimated growth and mortality rates. More information about UFORE is available at www.fs.fed.us/ne/syracuse/Tools/UFORE.htm and www.ufore.org/.

Step 2: Develop Forest Cover Goals and Objectives for the Watershed

The second step is to develop overall goals for increasing forest cover in both the watershed and the community, and to identify specific objectives for attaining these goals. Forest cover goals should be specific, measurable, and realistic, and have an associated timeline for attainment.

Step 2.1 Set Numerical Targets for Forest Cover

A numerical target for forest cover should be defined first for the entire community, and then for each individual watershed within the community. American Forests recommends 40% cover for most metropolitan areas, and a number of communities have already adopted this as a goal (see Appendix F). Across the United States, tree canopy cover currently falls below this standard, averaging 27% in urban areas and 33% in metropolitan areas (Dwyer and Nowak, 2000).

A recent Chesapeake Bay Program directive encourages communities to adopt canopy goals (Box 14) and recommends that goals should represent an increase in overall tree cover, be set for a 10-year horizon, and establish targets for percent increase in forest cover at specified intervals (CBP, 2004). Goals should also take into account current forest cover, current and planned development patterns and regulations, and resources available for reforestation and protection efforts. The Urban Forest Effects (UFORE) Web site provides data on current canopy cover for 21 U.S. cities that may be used as a starting point for developing community forest cover targets: www.fs.fed.us/ne/syracuse/Data/data/htm.

BOX 14. CHESAPEAKE BAY PROGRAM URBAN CANOPY GOALS

In 2003, the Chesapeake Executive Council signed Directive #04-01 expanding the Chesapeake Bay Program goals for riparian forest buffers. The Directive clearly recognized the importance of maintaining and increasing urban tree canopy as a way to extend the watershed functions of the forest in these developed areas. Furthermore, the directive established two specific urban tree canopy goals:

- By 2010, work with at least five local jurisdictions and communities in each state to complete an assessment of urban forests, adopt a local goal to increase urban tree canopy and encourage measures to extend forest buffer functions in urban areas.
- Encourage increases in the amount of tree canopy in all urban and suburban areas by promoting the adopting of tree canopy goals as a tool for communities in watershed planning.

Because most metropolitan areas contain multiple watersheds that often have varying land use and development patterns, a numerical target should be defined for each watershed, based on community-wide targets but taking into account specific watershed protection or restoration goals and using the results of the Leaf-Out Analysis. It may not be realistic for some watersheds to meet the community-wide forest cover goal, while other watersheds may surpass them. To date, few communities have adopted numerical targets for forest cover at the watershed scale; however, some data indicate that watershed forest cover of at least 45% to 65% is most beneficial in terms of stream health (Appendix F). These studies provide a starting point for setting watershed-wide forest cover goals. Table 6 provides some example forest cover goals for four watershed scenarios.

Table 6. Example Forest Cover Goals for Four Watershed Scenarios			
Watershed Type	Impervious Cover %	Forest Cover Goal	Benefits of Forest Cover
Suburban-Forested	< 25	60% minimum with 70% riparian forest cover	• Maintain aquatic ecosystem • Improve filtering capacity • Wildlife habitat • Stream protection
Suburban-Agricultural	< 25	40-50% minimum	• Maintain aquatic ecosystem • Improve filtering capacity • Wildlife habitat • Stream protection
Urban-Suburban	26 to 60	25-40% minimum	• Storm water runoff reduction • Reduce urban heat island • Wildlife habitat • Increase esthetic value • Provide recreational opportunities
Urban	> 60	15-25% minimum	• Reduce urban heat island • Storm water runoff reduction • Public health and air quality • Community livability

The forest cover goals presented in Table 6 are examples only and should be refined based on individual watershed characteristics, modeling, or literature review, to directly address storm water, air quality, or other outcomes. Current forest cover should be used as a starting point for goal setting. Current watershed impervious cover may also help determine the maximum limit of forest cover that it is possible to achieve without removal of impervious surfaces. Numerical forest cover targets should be revisited periodically and revised if necessary. Cost estimates for implementing forest conservation and reforestation objectives are necessary for communities to determine what is a realistic forest cover increase to achieve given a specific timeframe and budget. Two examples are presented in Box 15.

BOX 15. QUANTIFYING REALISTIC FOREST COVER GOALS

A study of the urban forest in Syracuse, NY, found that the current forest cover in the city was 26.6% for the 25.1 square mile area. A specific recommendation was made in the city's Urban Forest Management Plan to increase overall canopy cover to 30%. Assuming that existing forest cover was maintained, this **increase of 3.4%** could be implemented over **25 years** by planting 1,360 new trees each year (Nowak and O'Connor, 2001). Annual costs for implementation are estimated at $272,000 (based on cost of $200 per tree for planting and maintenance from Connecticut Climate Change, 2004).

A similar study by the North East State Foresters Association (Luley and Bond, 2002) used a model to determine that a 1**0% increase in canopy cover** was realistic for the New York City metropolitan region (an area of 1,950 square miles) to achieve over a **30-year time period.** This increase would bring the total tree canopy cover up to 41%. To achieve this goal, more than 1 million trees would need to be planted each year at an annual cost of $212 million (using the above cost estimate).

Step 2.2 Define Priority Objectives to Meet Goals

Forest cover goals for a watershed should represent an increase in the existing percentage of forest cover. The specific objectives utilized to meet forest cover goals may vary with each watershed and should be based on the data derived from the Leaf-Out Analysis (e.g., current impervious cover, area of protected forest, area of buildable forest, proportion of public and private developed turf).
Table 7 provides guidance on identifying priority objectives to meet forest cover goals in specific types of watersheds.

Table 7. Linking the Leaf-Out Analysis With Forest Cover Goals and Priority Objectives

Urban Watershed Forestry Objective	Characteristics of Watersheds Where Objective is Prioritized
A. Protect Priority Forests	Significant proportion of buildable forest, significant forest lost to development in Leaf-Out analysis scenario, large tracts of forest owned by single landowners
B. Prevent Forest Loss During Development and Redevelopment	Significant proportion of buildable forest, significant forest lost to development in Leaf-Out analysis scenario, current forest cover regulations do not directly or indirectly protect forests
C. Maintain Existing Forest Canopy	Highly developed watershed with little or no buildable forest remaining, majority of forest is on developed land
D. Enhance Forest Fragments	Significant protected forest exists, little remaining buildable forest
E. Plant Trees During Development and Redevelopment	Significant proportion of buildable land, current conservation regulations do not provide much protection of trees (and is not feasible or acceptable to change), or most of buildable land is turf (prior agricultural land)
F. Reforest Public Land	Significant proportion of public turf
G. Reforest Private Land	Significant proportion of private turf, private turf is held by a few large landowners, or private turf is held by many small landowners but represents the best opportunity for increasing forest cover (e.g., very little forest exists to protect, little buildable forest left, little public turf)

Step 2.3 Evaluate Effect of Objectives on Future Forest Cover

The Leaf-Out Analysis provides a baseline estimate of future land cover under a worst case or "do nothing" scenario. Based on priority forest cover objectives, alternative scenarios can be evaluated to determine their impact on future forest cover. The Leaf-Out Analysis worksheet in Box 16 illustrates an example scenario in which future forest loss was reduced from a 48% loss to a 7% gain in watershed forest cover.

BOX 16. LEAF-OUT ANALYSIS WORKSHEET FOR ESTIMATING FUTURE FOREST COVER IN A WATERSHED (FOREST CONSERVATION AND REFORESTATION SCENARIO)

Section 1. Future Forest Cover

Current Protected or Developed Forest Cover:	*5,000*	acres
From Table 4. Protected or developed forest will remain forested.	+	
Priority Forest Area Protected	*2,000*	acres
See section 2 of this worksheet. Select area to protect as part of an urban watershed forestry program.	+	
Forest Conserved During Development	*5,000*	acres
See section 2 of this worksheet.	+	
Area Reforested	*4,000*	acres
Select area to reforest as part of an urban watershed forestry program.	=	
Total Future Forest Cover	*16,000*	acres

Section 2. Forest Conserved During Development

Zoning Category	Buildable Forest (acres)		Priority Forest Protected (acres)		Buildable Forest Remaining (acres)		Forest* Cover Coefficient		Forest Conserved During Development (acres)
Agriculture	*50*	-	*500*	=	*50*	x	*.50*	=	*25*
Open urban land	*100*	-	*500*	=	*100*	x	*.50*	=	*50*
2 acre residential	*200*	-	*50*	=	*200*	x	*.50*	=	*100*
1 acre residential	*2,000*	-	*250*	=	*2,000*	x	*.50*	=	*1,000*
½ acre residential	*3,000*	-	*0*	=	*3,000*	x	*.50*	=	*1,500*
¼ acre residential	*1,000*	-	*0*	=	*1,000*	x	*.50*	=	*500*
½ acre residential	*50*	-	*0*	=	*50*	x	*.50*	=	*25*
Townhomes	*500*	-	*0*	=	*500*	x	*.50*	=	*250*
Multifamily	*100*	-	*0*	=	*100*	x	*.50*	=	*50*
Institutional	*500*	-	*500*	=	*500*	x	*.50*	=	*250*
Light industrial	*500*	-	*0*	=	*500*	x	*.50*	=	*250*
Commercial	*2,000*	-	*200*	=	*2,000*	x	*.50*	=	*1,000*
Total	*10,000*		*2,000*						*5,000*

* Use forest cover coefficients that represent the amount of forest conserved at a site with adoption of forest conservation or afforestation requirements.

(continued)

Section 3. Results Summary				
Total Current Forest Cover	*15,000*	acres		
From Table 4.				
Total Future Forest Cover	*16,000*	acres		
From Section 2.				
Future Forest Increase	*1,000*	acres	7	%

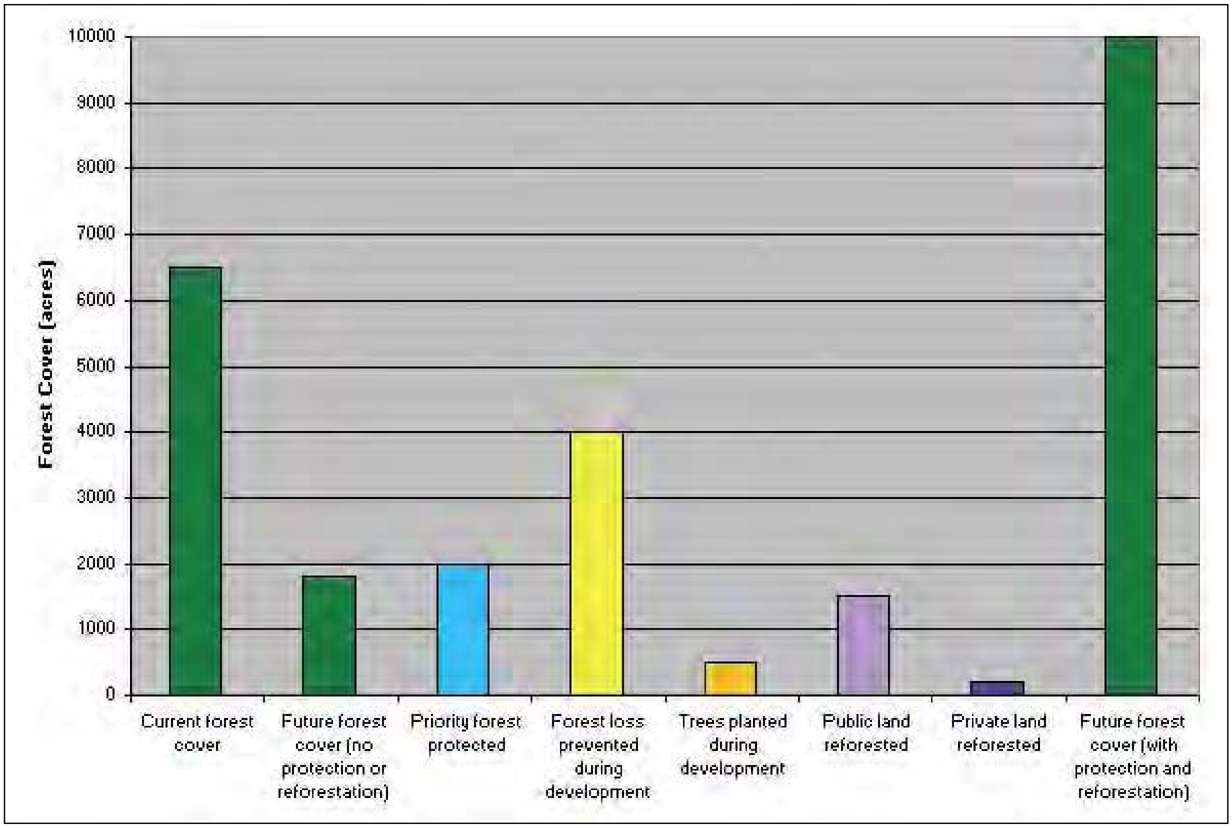


Figure 11. The effect of forest conservation and reforestation on future forest cover

Figure 11 illustrates the effect of priority forest cover objectives on future forest cover compared with future forest cover with no protection or reforestation efforts.

Step 3: Identify Existing Forest and Reforestation Opportunities

Once numerical targets for protection of existing forest and reforestation are identified, the next step involves locating the best sites in the watershed for these activities. In this step, priority forest and reforestation sites are selected for further evaluation in the field based on the inventory of current land cover in the watershed. Due to factors such as budget and land ownership, however, it is not desirable or feasible to pursue each and every forested site for protection, or each and every open area for reforestation. Using the information generated through the inventory of current and future land cover, as well as some additional land use and land owner information, a select number of sites can be identified through the use of a GIS. Table 8 identifies what are typically the best opportunities for each of the seven urban watershed forestry objectives.

Table 8. Types of Land Best Pursued for Urban Watershed Forestry Objectives	
Urban Watershed Forestry Objective	**Best Opportunities**
A. Protect Priority Forests	Large tracts of contiguous, unprotected forest
B. Prevent Forest Loss During Development and Redevelopment	Forest on parcels to be developed
C. Maintain Existing Forest Canopy	Forest on parcels that are already developed
D. Restore Forest Fragments	Protected forests
E. Plant Trees During Development and Redevelopment	Turf areas on parcels to be developed, including streetside planting areas, storm water treatment practices (STPs), property lines
F. Reforest Public Land	Turf areas on publicly owned parcels that are already developed (e.g., parks, schools, stream buffers, STPs, rights-of-way) or undeveloped turf areas (provided reforestation is done in conjunction with protection measures)
G. Reforest Private Land	Turf areas on privately owned parcels that are already developed (e.g, residential lawns, stream buffers, institutional and commercial land)

GIS layers created in Step 1 (current land cover, protection status, development status, zoning and future land cover) are combined with the following layers in this step:

- Property boundaries/land owner information
- Public lands (e.g., schools, parks, rights-of-way)
- Storm water treatment practices
- Vacant land
- Aerial photos
- Natural resource data (e.g., streams, wetlands, floodplains, critical habitats, karst features, steep slopes, erodible soils, monitoring data)
- Cultural, recreational, or historical areas.

Step 3.1 Identify Existing Forests for Further Assessment

To identify existing forests for further assessment, a watershed map that also identifies forested land that may be lost to future development (e.g., unprotected and undeveloped forest land) should be analyzed (Figure 12). It may also be useful to overlay the map with other GIS layers on the map that define constraints on site selection, such as land ownership, transportation corridor or utility restrictions, prior site use (e.g., potential for soil or groundwater contamination), and natural, cultural, and historical resources.

Forests selected for further evaluation are assessed in the field to determine whether they are good candidates for protection or restoration and to select appropriate protection or restoration techniques. In highly urban watersheds where few remaining forests exist, it may not be necessary to whittle down the forested sites to a more manageable number. Criteria for selecting forested parcels for further evaluation include the following:

- Currently unprotected
- Publicly owned or willing land owner
- Contiguous forest greater than a specified acreage (set by municipality, dependent on average size of forest fragments)
- Strategic location in watershed (e.g, is adjacent to existing forest parcel, reforestation site, or protected land; connects or has the potential to connect two existing contiguous forest parcels; has significant natural, historic, cultural or recreational value).

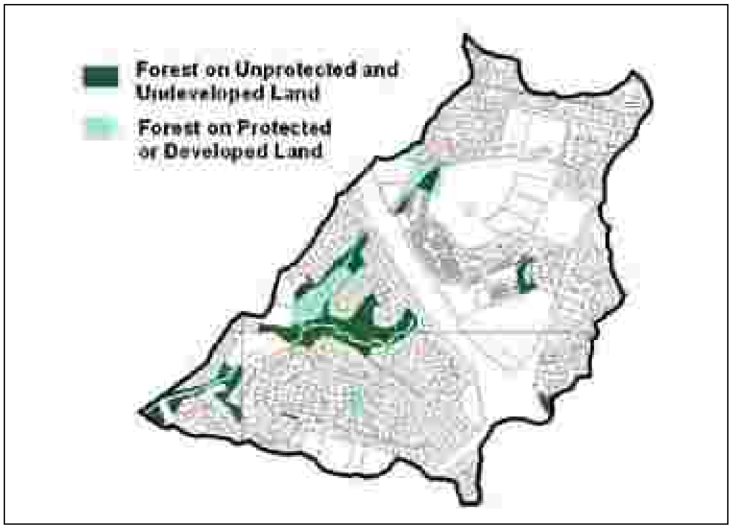


Figure 12. Buildable forest land with potential for future forest loss.

Each community should tailor these criteria for selecting forest parcels to take into account the specific characteristics of their watersheds. The possibility of expanding forested areas or linking them to the stream corridor or other remnants should always be considered when selecting priority forest sites. Owners of large forested tracts may be contacted at this stage to gauge their interest in forest conservation efforts, and to get permission to evaluate their land further.

Step 3.2 Identify Reforestation Opportunities for Further Assessment

To select reforestation sites for further assessment, a map that displays the existing non-forest vegetative cover in the watershed should be analyzed along with property boundaries, vacant lands, public lands, storm water treatment practices, and natural cultural and historical resource information.

Sites with turf cover typically present the best reforestation opportunities because they do not involve extensive removal of vegetation or impervious cover. If the GIS layer of land cover does not distinguish between turf and other types of non-forest vegetation, aerial photos may be used to verify which parcels contain turf. Turf cover typically represents the largest portion of non-forest vegetative cover and can comprise up to 80% of urban pervious cover (CWP, 2000b). Figure 13 shows the distribution of turf cover at the state level across various land uses (composite of MTC, 1996; VASS, 1998; and PTC, 1989).

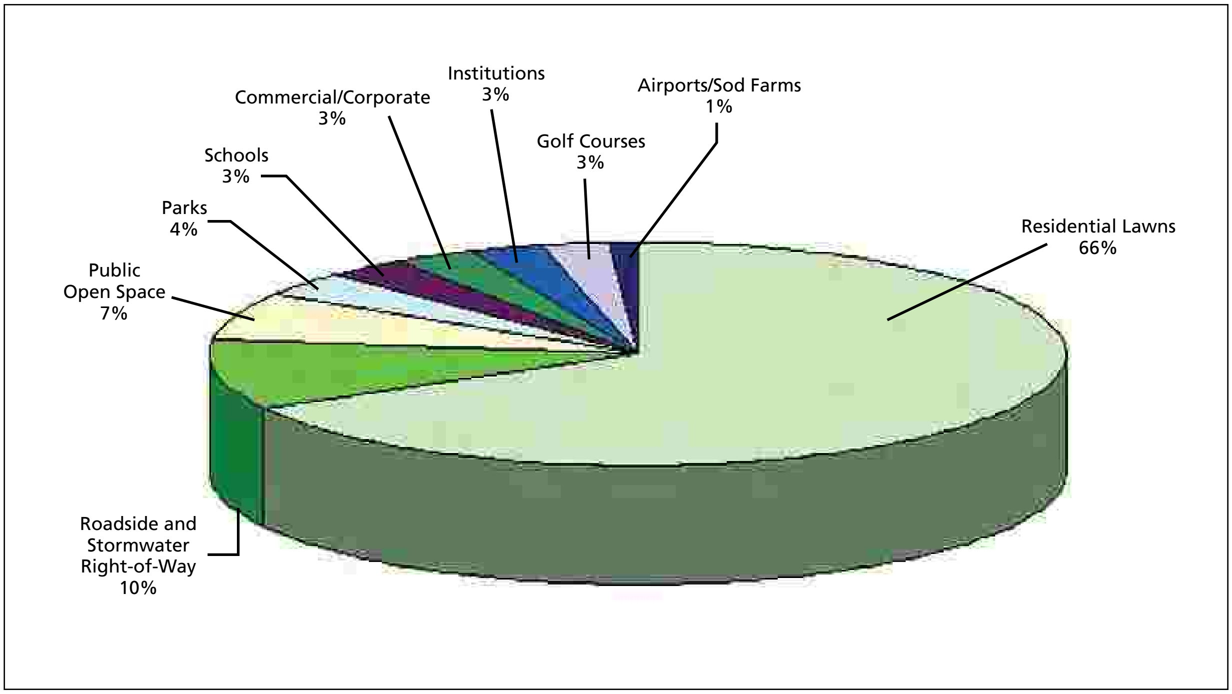


Figure 13. Distribution of turf cover at the state level (composite of MTC, 1996; VASS, 1998; and PTC, 1989)

Figure 13 clearly shows that residential lawns constitute the largest single share of turf cover (about 67%). Public land, such as rights-of-way, open space, parks, and schools, constitute about a quarter of the total turf cover. This distribution will vary from watershed to watershed, but residential lawns and public land are typically the major components.

While reforesting residential lawns may yield the largest increase in watershed forest cover, this can be difficult to accomplish because of the sheer number of landowners involved and potentially small number of homeowners who are willing to convert their turf to forest. If residential lawns do comprise a significant portion of turf cover in the watershed, an education program geared towards homeowners about the benefits of planting trees, combined with a community tree planting or cost-share program, may be the most effective tool for increasing forest cover on residential lots (GFC, 2001). The same approach may be used for private institutions, commercial land, and multifamily housing complexes, which may also have large turf areas that can be reforested. Figure 14 illustrates that while private turf may present opportunities for extensive reforestation, the land is typically in the hands of multiple owners.

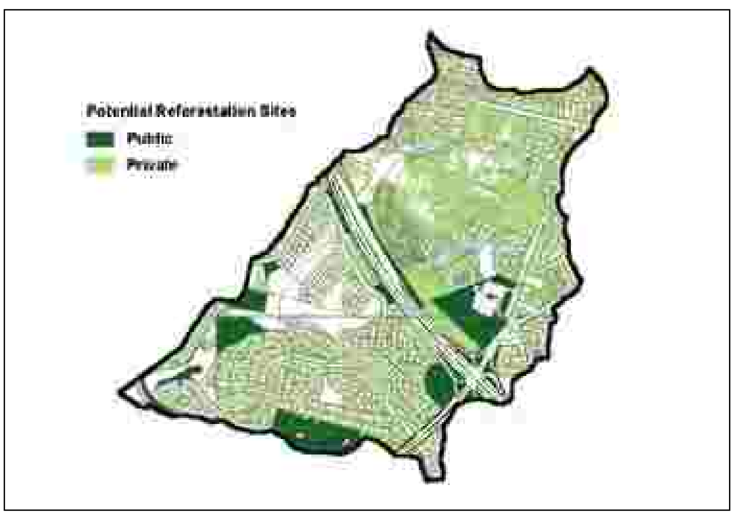


Figure 14. Public and private land with potential for reforestation

Public lands are attractive from the standpoint of reforestation because of their large size and ownership. These include highway cloverleafs and buffers, parks, schools, storm water dry ponds, and utility corridors. Vacant lands and stream corridors provide additional opportunities to reforest the watershed. Criteria for selecting reforestation opportunities for further evaluation include the following:

- Turf cover
- Developed or vacant land
- Publicly owned (e.g., highway cloverleafs, highway buffers, parks, schools, storm water dry ponds, utility corridors)
- Strategic location in watershed (e.g, stream corridor, adjacent to existing forest parcel, reforestation site, or protected land; connects or has the potential to connect two contiguous forest parcels; has significant natural, historic, cultural or recreational value).

Each community should tailor these criteria to select reforestation opportunities that take into account the specific characteristics of their watersheds. For example, a community with a very large number of sites that meet the above criteria may elect to evaluate only turf parcels larger than 2 acres. The possibility of expanding existing forested areas or linking two forest fragments should always be considered when selecting priority reforestation sites.

Step 4: Conduct a Field Assessment of Existing Forest and Reforestation Opportunities

The next step is to select existing individual forest and/or potential reforestation sites for further evaluation in the field to verify their existence and use, determine if they are good candidates for protection, restoration or reforestation, and to collect some basic screening information to rank the sites.

Step 4.1 Conduct a Field Assessment of Existing Forest Fragments

Many methods exist for evaluating the quality of existing forests; however, few are specifically tailored to urban forests. Several forest assessment methods are summarized in Table 9, which address at least some of the potential impacts of development on forests. The priority forests selected in Step 3 should be assessed using one of these methods or an equivalent. The choice of which method to use and how many forested parcels to initially evaluate in the field will ultimately be driven by staff, budget, resources and the level of detail desired.

Table 9. Summary of Forest Assessment Methods			
Forest Assessment Method	**Applicability**	**Description**	**Source**
Unified Subwatershed and Site Reconnaissance (USSR)	Urban upland forests	The Pervious Area Assessment form of the USSR is used to collect basic information about existing forest remnants	Wright and others, (2004)
Woodland Buffer Habitat Assessment	Riparian forest	Evaluates the value of riparian forest for wildlife habitat	Hanssen (2003)
Upland Contiguous Forest Assessment	Upland forests	Designed to evaluate large parcels of contiguous forest to determine which are priorities for conservation	CWP (unpublished)
Maryland's Green Infrastructure Assessment	Regional application	Evaluates hubs and corridors in terms of ecological significance for the purpose of land acquisition	Weber (2003)
Maryland Forest Conservation Act Stand Assessment	Parcel scale	Evaluates forest stands on an individual development site to identify conservation areas	Greenfeld and others, (1991)

Each method collects similar types of information at forest fragments to evaluate the quality of the forest, identify potential restoration opportunities, and rank each site in terms of conservation priorities. These forest characteristics are presented in Table 10.

Table 10. Forest Characteristics Evaluated in Field Assessments	
Characteristic	**Description**
Basic site information	Landowner and use, parcel size, location, protection and development status
Surrounding land uses	Observe adjacent forest or open areas and evaluate potential for connection with these nearby fragments
Dominant species	Dominant tree species or forest association
Forest age	Indicated by successional stage or size class of dominant trees
Vertical structure	Presence of different vertical layers of vegetation such as ground cover, understory, mid-story, and canopy trees. Measure of habitat complexity.
Canopy density and condition	Percentage of forest covered by tree canopy, canopy condition and health.
Herbaceous vegetation	Density and species of herbaceous vegetation, presence of duff layer
Understory vegetation	Density and species of understory vegetation
Invasive species	Density, extent, and species of invasive plant species
Indicator or rare, threatened, or endangered (RTE) species	Species and specific location. Indicator species are intolerant of a decline in habitat quality and are therefore indicators of high quality habitat
Evidence of disturbance	Clearing, trash dumping, erosion, pollution, overbrowsing
Presence of food, water, cover, and habitat	Includes streams, wetlands, snags and cavity trees, large woody debris, conifers, mast species, vernal pools, leaf litter

Basic site information and surrounding land uses are evaluated to assess the feasibility of protecting or restoring the site and to use in ranking the site in terms of its potential to connect other forest fragments or habitat corridors. The remaining characteristics provide an overall indicator of the ecological significance or value of the forest. Most forest assessment methods will include a system for interpreting data collected in the field that results in an actual score or classification of the forest in terms of ecological value.

Step 4.2 Conduct a Field Assessment of Potential Reforestation Sites

Most potential reforestation sites are public or private turf. Turf areas should be assessed in the field to verify their condition, evaluate the feasibility of reforestation, and collect information to prioritize candidate sites. If desired, additional information may be collected at this time to use in developing a reforestation plan for the sites (e.g, detailed soil characteristics). Table 11 summarizes three assessment methods for evaluating urban reforestation sites. Additional information on evaluating planting sites is provided in Part 3 of this manual series, and in Reynolds and Ossenbruggen (1991) and WFC and Morgan (1993).

Table 11. Summary of Reforestation Site Assessment Methods

Reforestation Site Assessment Method	Applicability	Description	Source
Unified Subwatershed and Site Reconnaissance (USSR)	Urban upland pervious areas	The Pervious Area Assessment form of the USSR is used to collect basic information about potential planting sites	Wright and others, (2004)
Unified Stream Assessment	Urban riparian areas with inadequate stream buffer	The Inadequate Buffer form is used to collect basic information about potential planting sites with < 25 foot forested stream buffer	Kitchell and Schueler (2004)
Site Assessment for Urban Tree Planting	Urban planting sites	Detailed site assessment for urban tree planting to use in selecting species and developing a planting plan	Bassuk and others, (2003)

The types of information collected with each assessment method vary with the purpose of the assessment and location(s) in which they apply (upland or riparian). Table 12 provides a summary of the three types of information typically collected during a reforestation site assessment: feasibility factors, ranking factors, and factors to use in creating a reforestation plan.

Table 12. Factors Evaluated in Field Assessment of Reforestation Sites

Factor Type	Description
Feasibility	Landowner and use, site access, potential soil contamination, lack of sun or water, severe and widespread invasive species or overbrowsing, conflicts with infrastructure
Ranking	Size and dimensions of planting area, location in watershed, surrounding land use, potential for connection to nearby forest or protected land, presence of nearby streams, wetlands, RTE species or other sensitive resource
Reforestation Planning	Current vegetative cover, invasive species, trash dumping, soil pH, soil texture, soil compaction, soil drainage, soil salinity, soil depth, distance to water table, light exposure, heat exposure, wind exposure, slope, and potential for damage from vandalism, automobiles, deer, lawnmowers, etc.

The feasibility and ranking factors collected will be used to prioritize sites for reforestation (Step 5) and the reforestation planning factors collected will be used to determine exactly what to plant, where to plant, and when to plan at the site (Step 6).

Step 5: Prioritize Existing Forest and Reforestation Opportunities

The next step in planning to increase forest cover is to prioritize the candidate sites identified in Step 4 for protection, enhancement, and reforestation. The ranking system should take into account the forest cover goals for the watershed, as well as any larger watershed protection or restoration goals that have been defined. The ranking system should also be driven by the resources available for implementing watershed forestry projects, and will be based on results of both the inventory of watershed land cover and the field assessments. Therefore, some factors may be weighted more heavily than others. While the exact ranking system should be defined by the user, some important ranking factors to include are presented in Table 13.

Table 13. Common Ranking Factors to Prioritize Parcels for Protection, Enhancement, and Reforestation

Ranking Factor	Description
Feasibility Ranking Factors	
Land ownership	Prioritize public land, then private land with willing landowners
Access to site	Project may be infeasible if access to site is not adequate for any necessary foot traffic, vehicles, or heavy equipment.
Prohibitive site characteristics	Certain site characteristics may make a project infeasible, such as potentially contaminated soils or insufficient sunlight for plant growth
Environmental Ranking Factors	
Continuity (if forest)	Prioritize sites with uninterrupted cover
Connectivity	Prioritize sites that link or have the potential to link adjacent forest, reforestation sites, or protected lands
Contiguity	Prioritize sites with greater than a specified acreage
Ecological significance	Prioritize sites with high habitat scores, high fish and bug Index of Biotic Integrity (IBI) scores, mature vegetation, rare, threatened, or endangered species, or other sensitive natural resources, or streams identified as restoration priorities
Location in watershed	Prioritize sites located in riparian areas, wetlands, floodplains, steep slopes, erodible soils, recharge areas, or other locations important to watershed hydrology and water quality.
Community Ranking Factors	
Recreational value	Prioritize sites with recreational value
Community acceptance	Prioritize sites that received community support and have a potential base of volunteers to help with tree planting or maintenance (this may entail a public meeting to get community input on projects)
Historic or cultural value	Prioritize sites with significant cultural or historical value
Difficulty Ranking Factors	
Cost	Prioritize sites with the lowest cost per acre
Level of effort	Prioritize sites that require minimal site preparation (soil amendments, removal of invasive species) over those requiring extensive site preparation

Separate prioritization methods may be developed to rank forested sites and reforestation sites. Several examples of detailed prioritization methods for protection, enhancement, and reforestation projects are summarized in Table 14.

Table 14. Summary of Prioritization Methods for Protection, Enhancement, and Reforestation

Prioritization Method	Applicability	Description	Source
Maryland's Green Infrastructure Assessment	Regional application	Prioritizes hubs and corridors for land acquisition based on ecological significance	Weber (2003)
Urban Riparian Restoration Project	Urban riparian areas	Three-tiered ranking system for prioritizing riparian sites for reforestation	Virginia Department of Forestry (1993)
Watershed Analysis Extension for ArcView	Watershed scale	Provides tools for quantitatively ranking land in a watershed by estimated surface water quality impact	de la Cretaz and others, (2003)
Chesapeake Bay Resource Lands Assessment	May be applicable at a variety of scales	GIS-based methods for identifying forests in the Chesapeake Bay watershed that are important for protecting water quality and watershed integrity	Painton-Orndorff and others, (2004)
Forest Areas of Local Importance	County or regional application	GIS-based decision tool to identify critical forest areas for protection	NEGRDC (2004)
Urban Forest Effect (UFORE) Model	Site level	GIS-based tool for selecting the best locations to plant trees to improve air quality and building energy conservation	USDA Forest Service (2004)

Step 6. Develop Recommendations for Meeting Forest Cover Goals

The last step in planning to increase forest cover is to integrate forest cover goals for the watershed in the context of a watershed plan. This plan should include specific recommendations for implementing protection, enhancement, and reforestation techniques at priority sites.

Watershed planning is a unique forest protection tool in that it takes a landscape-level approach to conserving forests based on natural features rather than focusing on jurisdictional boundaries or an individual development site. A watershed plan ideally should be created for every watershed within a jurisdiction that seeks to maintain or increase forest cover and incorporates specific recommendations for how to do this. CWP (1998b) and Schueler (2004) provide detailed guidance on how to create watershed protection plans and subwatershed restoration plans.

A watershed plan should incorporate the forest cover goals developed in Step 2 as well as the priority objectives identified and any related numerical targets. The watershed plan should also include priority sites identified for protection, restoration, and reforestation. Detailed information should be provided for the top priority sites, including the following:

- Specific techniques recommended for protection, enhancement, or reforestation
- Cost estimates for implementation and maintenance
- Potential funders, partners, and other entities who will be involved in project implementation and long-term maintenance (e.g., watershed organizations, homeowners associations or HOAs)
- Implementation schedule.

Step 6 will involve some decisionmaking as to what types of protection, enhancement, or reforestation techniques to use at each priority site. Protection, enhancement, and reforestation techniques are described in detail in Chapter 3.

Chapter 3: Techniques for Maintaining and Increasing Forest Cover in a Watershed

This chapter provides a summary of techniques and further resources for the protection and enhancement of forests and the reforestation of open lands in a watershed. Table 15 lists the techniques according to the corresponding goals and objectives.

Table 15. Summary of Protection, Enhancement, and Reforestation Techniques

Goals	Objectives	Techniques
Protect	A. Protect Priority Forests	1. Conservation easements 2. Land acquisition 3. Transfer of development rights
	B. Prevent Forest Loss During Development and Redevelopment	4. Bonus and incentive zoning 5. Clearing and grading requirements 6. Forest conservation regulations 7. Open space design 8. Overlay zoning 9. Performance-based zoning 10. Storm water credits 11. Stream buffer ordinances
	C. Maintain Existing Forest Canopy	12. Protection of significant trees 13. Tree removal restrictions for developed areas
Enhance	D. Enhance Forest Fragments	14. Increase forest area where possible 15. Increase habitat diversity 16. Manage deer 17. Protect soils from erosion and compaction 18. Provide food, cover, and nesting sites for wildlife 19. Reduce or eliminate invasive species 20. Remove trash and prevent dumping
Reforest	E. Plant Trees During Development and Redevelopment	21. Landscaping requirements 22. Planting trees in storm water treatment practices 23. Planting trees in other open areas 24. Shading and canopy requirements
	F. Reforest Public Land	25. Allow natural regeneration 26. Actively reforest public lands
	G. Reforest Private Land	27. Education 28. Incentives for tree planting 29. Stewardship and neighborhood action

Techniques for Protecting Forests

Different techniques are used to protect existing forests. Generally, these fall into three categories depending on the stage of development. Techniques related to Objective A, Protect Priority Forests, focus on techniques to protect large tracts of forest that are currently undeveloped. Techniques related to Objective B, Prevent Forest Loss During Development and Redevelopment, focus on limiting the clearing of forests during the actual construction process. Techniques related to Objective C, Maintain Existing Forest Canopy, include techniques that prevent landowners from clearing forests on land that has already been developed. Most techniques are regulatory tools that local governments can adopt to protect forests during each stage of development. One exception is the urban forestry management plan, which is described in Box 17.

This section briefly describes each technique and includes relevant links to model regulations, example ordinances (see Box 18), and comprehensive references. Additional information about many of these techniques can be found in ELI (2000), Palone and Todd (1998), Georgia Forestry Commission (2001), and Wenger and Fowler (2000).

BOX 17. URBAN FORESTRY MANAGEMENT PLANS

Urban forestry management plans are comprehensive plans for managing the urban forest within a particular jurisdiction. These plans can be used to set goals for forest canopy cover, conduct tree inventories, make recommendations for new tree plantings, provide species lists, and outline methods for managing the urban forest. While these plans may not be regulatory per se, they are similar to comprehensive plans in that they provide the framework upon which specific ordinances and other regulations may be built. The City of Roanoke, Virginia has an Urban Forestry Plan that contains many of these elements and is a good example of comprehensive urban forest management. This plan is available online at www.roanokegov.com/WebMgmt/ywbase61b.nsf/vwContentFrame/N254GHSJ053LWODEN.

BOX 18. A NOTE ABOUT ORDINANCES

When developing a forestry ordinance, it is always important to ensure that the language clearly defines the following factors: the purpose of the ordinance, who is subject to it, penalties for violation, who is responsible for enforcement of penalties, and allowable enforcement actions. General guidance on how to design tree-related ordinances or evaluate existing ordinances is provided in the following references:

- International Society of Arboriculture Guidelines for Developing and Evaluating Tree Ordinances:
  http://phytosphere.com/treeord/index.htm
- International Society of Arboriculture. 1990. *Municipal Tree Manual. Urbana, IL*
  Comprehensive guide to drafting and revising a municipal tree planting and care ordinance. Discusses management standards and includes sample ordinances.
- Urban Forestry South Urban Tree Ordinance Index:
  www.urbanforestrysouth.org/ordinances/index.asp
- TREEORD Software: www.mnstac.org/RFC/treeord_software.htm
- McElfish, J. M., Jr., 2004. Nature-Friendly Ordinances. Environmental Law Institute. www.eli.org
- Louisiana State University Greenlaws Web site: www.greenlaws.lsu.edu/

Protecting Priority Forests

Large tracts of high quality forest or those potentially valuable to watershed functions can be protected from future development through conservation easements, land acquisition, or transfer of development rights.

1. Conservation easements

Conservation easements are conveyances of development rights from a property's landowner to a municipality, land trust, or other nonprofit organization. The easement may be purchased or donated and typically grants the seller a reduction in taxes. The landowner still retains use, occupancy, and ownership of the land itself, but is limited in the ability to develop the land for the term of the easement (which may be permanent or may expire after a specified number of years). The terms of the easement may also dictate what types of activities are allowable on the land, and the easement is transferable with the land if sold.

- Land Trust Alliance (LTA): www.lta.org
- Model Conservation Easement: www.stormwatercenter.net/Model%20Ordinances/model_conservation_easement.htm.

2. Land acquisition

Land acquisition is outright acquisition of title to forested lands by a municipality, land trust, or other nonprofit organization. This is an expensive way to protect forested lands, but it guarantees long-term protection from development. As owners of the land, land trusts have control of management and use of the land (unlike conservation easements). The Nature Conservancy and the Trust for Public Land are two national organizations that act as land trusts.

- The Nature Conservancy: www.tnc.org
- Trust for Public Land: www.tpl.org
- The Conservation Fund: www.conservationfund.org.

3. Transfer of development rights

Transfer of development rights (TDRs) is a land use management technique that transfers development potential from environmentally sensitive areas such as forests to specific areas designated for growth. TDRs are based on a market-driven incentive program where it is possible to sell development potential without actually buying or selling land. Once a TDR occurs for a property, further development can never occur on that land. Landowners in preservation areas are compensated for lost development potential (CWP, 1998a).

- Sarasota, FL,Transfer of Development Rights Ordinance: www.stormwatercenter.net/Model%20Ordinances/misc_sarasota.htm

Preventing Forest Loss During Development and Redevelopment

Several regulatory tools can be applied to directly or indirectly reduce forest clearing during construction as well as to prevent inadvertent injury to trees. Techniques include these: bonus or incentive zoning, clearing and grading requirements, forest conservation and protection regulations, open space design, overlay zoning, performance-based zoning, storm water credits, and stream buffer ordinances. Each technique is described below.

4. Bonus and incentive zoning

Bonus and incentive zoning encourages developers to conserve environmental resource areas such as forests. In this technique, a developer is granted the right to build more intensively on a property or is given some other bonus in exchange for conserving a portion of the site in natural vegetation or providing an amenity, such as trails or a park that the community feels would be beneficial (CWP, 1998a). For more information on bonus and incentive zoning, consult McElfish (2004).

5. Clearing and grading requirements

Regulations that limit the maximum amount of clearing that can occur at a development site can be an effective forest conservation technique. For example, a developer may be restricted to clearing no more than 25% of a site. Alternatively, the ordinance might state that the grading contractor or developer must use site fingerprinting, a technique in which clearing and grading is reduced by limiting disturbance to the minimum necessary for the construction of buildings and roadways. At a minimum, clearing and grading may be restricted within a specified distance (e.g., 25 to 50 feet) of all streams. In addition, soil from forested areas that are cleared during development should be stockpiled and replaced so that new vegetation will have healthy soil in which to grow. Part 2 of this manual series contains more detailed information on site fingerprinting and other techniques to protect trees at a development site.

- City of Olympia, WA, Clearing and Grading Ordinance: www.stormwatercenter.net/Model%20Ordinances/esc_clearing_ordinance.htm.

6. Forest conservation regulations

Forest conservation and protection regulations require the retention and protection of trees and forests on a development site. These regulations establish specific criteria for identifying which trees and forests should be conserved, and prescribe methods to protect these stands during the construction process.

Criteria for conserving forests on a development site are often expressed as a minimum percentage of existing forest (e.g., conserve at least 25% of any existing forest on the site), a minimum percentage of the site (e.g., at least 25% of the site must be forested—reforestation may be necessary to meet these goals), or as a tree size threshold (e.g., conserve all trees greater than 6 inches in diameter at breast height outside of the building and pavement footprint). Trees to be protected can also be identified based on age, species, historic significance, ecological value, esthetics, location, or other factor. Special trees such as heritage, champion, or specimen trees are often protected through these ordinances.

Forest protection regulations typically require the contractor for a development site to create a tree protection plan. The plan delineates forest stands, defines the limits of disturbance, requires protective barriers be installed around trees to be protected, and posts signs to inform contractors of the tree protection area (Figure 15). These regulations protect trees from unnecessary damage during construction, such as mechanical injury to roots, trunks, or branches; compaction of soil; or changes to existing grade that may expose or suffocate roots.

To ensure long-term protection of trees, forest conservation and protection regulations may require permits for removal, encroachment, or pruning of trees. They may also require posting of signs to inform residents of the tree protection areas and should include enforceable penalties for encroachment on tree protection areas.

- American National Standards Institute Tree Protection Standards: http://webstore.ansi.org/ansidocstore/dept.asp?dept_id=30
- Frederick County, MD, Forest Conservation Ordinance: www.stormwatercenter.net/Model%20Ordinances/buffer_model_ordinance.htm
- Maryland Forest Conservation Act: www.dnr.state.md.us/forests/programs/urban/explained.html
- City of Pasadena, CA, Tree Protection Guidelines: www.ci.pasadena.ca.us/publicworks/PNR/TreeOrdinance/protectionGuidelines.asp
- International Society of Arboriculture. Avoiding Tree Damage During Construction: www.isa-arbor.com/consumer/avoiding.html
- Minnesota Department of Natural Resources. Conserving Wooded Areas in Developing Communities: Best Management Practices in Minnesota: http://files.dnr.state.mn.us/forestry/urban/bmps.pdf
- Tree Protection Ordinance for Chapel Hill, NC: http://ourworld.compuserve.com/homepages/DoanePerry/ChapelHillNC.htm.

Figure 15. Sign posted at construction site informs workers of forest protection area.

7. Open space design

Open space design is a compact form of development that concentrates density on one portion of the site in exchange for reduced density elsewhere. Open space design allows for the preservation of forests, using less space for streets, sidewalks, parking lots, and driveways (Figure 16). Requirements in an open space design ordinance generally set aside a percentage of the site for active or passive open space area (e.g., ballfields or trails). Minimum lot sizes, setbacks, and frontage distances are relaxed to provide this common open space. Open space regulations can protect existing forests, provided the regulations identify allowable types of vegetation, minimum area, native species, allowable uses, and maintenance responsibilities. An open space design ordinance should also specify that the open space be maintained in a natural condition.

- Stormwater Manager's Resource Center. Open Space Design Model Ordinance: www.stormwatercenter.net/Model%20Ordinances/open_space_model_ordinance.htm.

Figure 16. This open space design contains areas of preserved forest (Source: Randall Arendt)

8. Overlay zoning

Overlay zoning superimposes additional regulatory standards or development criteria onto existing zoning provisions. Overlay zones can be created to protect particular resources, such as forests, wetlands, or historic sites. The provisions of the overlay zone incorporate mandatory requirements that restrict development in some way to reach the desired level of forest conservation or other goal. This land use management technique gives a community legal control without having to purchase land (CWP, 1998b; Palone and Todd, 1998; McElfish, 2004).

9. Performance-based zoning

Performance-based zoning is designed to ensure an acceptable level of performance within a given zoning district, such as providing a certain open space/development ratio, an impervious area target, or a desirable density. Performance factors include storm water runoff quality and quantity criteria, protection of wildlife and vegetation, or traffic and noise generation limits. The developer is given flexibility and control over development as long as these criteria are met (CWP, 1998a; Palone and

Todd, 1998). Performance-based zoning can be used to protect a specified percentage of forested land. For more information on performance-based zoning, see McElfish (2004).

10. Storm water credits

A storm water credit system provides incentives to developers, designers, and builders, to implement site design techniques that cause less impact to aquatic resources by conserving forests, reducing impervious cover, and reducing storm water runoff. By taking advantage of the credit system, developers can reduce the storm water management requirements for quantity or quality or both. The credit system directly translates into cost savings to the developer by reducing the size of storm water storage and conveyance systems required.

Credits may be given for conservation of natural areas, reforestation, stream buffers, forested filter strips, green rooftops, and nonstructural techniques that help to reduce storm water runoff. Storm water credits for conservation of natural areas rewards protection of natural vegetation or critical resource areas on a development site. Under this credit, the developer may subtract forest conservation areas from the total site area when computing the water quality volume and the recharge volume.

- Maryland Stormwater Design Manual: www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp.

11. Stream buffer ordinances

Stream buffer ordinances require the conservation and protection of existing forested stream buffers on a development site, and may also require reforestation of stream corridors that are currently lacking tree cover. Forested buffers provide shade for the stream, protection from erosion, habitat for wildlife, and recreational opportunities. Stream buffer ordinances should set criteria for buffer width, vegetation, allowable uses, and long-term maintenance. More information about buffer ordinances can be found in CWP (2000a), Wenger (1999), and Cappiella and Schueler (2001).

- Storm Water Manager's Resource Center Stream Buffer Model Ordinance: www.stormwatercenter.net/Model%20Ordinances/buffer_model_ordinance.htm

- Center for Watershed Protection. 2000. The Architecture of Urban Stream Buffers. www.stormwatercenter.net/Library/Practice/39.pdf

- Wenger, S. J.; L. Fowler, 2000. Protecting Stream and River Corridors: Creating Effective Local Riparian Buffer Ordinances. Athens: University of Georgia. www.cviog.uga.edu/pprs/paper-streams.pdf

- Montgomery County, PA, Model Ordinance for Riparian Corridor Conservation District: www.pawatersheds.org/techresources/bufferordinance.pdf.

Maintaining Existing Forest Canopy

In neighborhoods that have already been built-out, existing tree canopy may decline over time if trees are removed or ruined by topping or other poor maintenance practices. While regulation of forest stands on developed private lands may not be practical or desirable, individual trees can be protected by awarding special status to significant trees, such as champion trees, or by regulating the removal and replacement of existing trees.

12. Protection of significant trees

By explicitly providing special status to significant trees such as specimen or champion trees, communities may be able to provide a higher level of protection to such trees. The Cape Cod Commission (2003) defines a specimen tree as "a native, introduced or naturalized tree, which is important because of its impacts on community character, its significance in the cultural landscape or its value in enhancing the function of wildlife habitat." A champion tree is the largest tree of its species within a particular county, state, or other jurisdiction (TERRA, 2003; Figure 17).

Other significant trees may be defined by characteristics such as size, species, age, historical significance, ecological value, esthetics, or location. Alternative ways that are used to identify significant trees include: "heritage," "historic," "landmark," and "legacy."

Significant trees can be protected by identifying and registering them with the local natural heritage department or registrar of champion trees. Registration will keep them from being removed (if the land is not already protected through some other means). Another protection measure is designating an area of no disturbance around a tree. An ordinance may also be created to specifically protect these valuable trees by defining penalties associated with unauthorized damage or removal of an individual tree.

While protecting individual trees probably does not maintain a significant amount of canopy, a good champion tree program can serve to create public enthusiasm about conserving trees, educate citizens about trees, promote awareness of tree benefits and foster respect for the beauty and historical significance they possess.

- Defining Special Trees: Heritage, Historic and Landmark Trees: http://phytosphere.com/treeord/heritage.htm
- National Register of Big Trees: www.americanforests.org/resources/bigtrees/.

Figure 17. Specimen tree protected during construction. (Photo: Al Todd)

13. Tree removal restrictions for developed areas

Tree removal restrictions are ordinances or other regulatory measures that require a permit to remove, relocate, prune or otherwise damage trees within a specified area or of a specified size or species. These ordinances may also require replacement of any trees that are removed.

Recognizing that trees reduce runoff and provide other watershed benefits, the Council of the City of Takoma Park, MD, has instituted tree removal regulations. The Takoma Park ordinance requires a permit to remove "urban forest trees," and requires residents to replace any urban forest tree removed or excessively damaged. This ordinance also requires the replacement of trees that were initially recorded as trees to protect during construction but were subsequently damaged or cut down. All replacement trees must be equal or superior to the original tree with respect to species quality, shade potential, and other characteristics, and it must be from nursery stock with a 1-year guarantee. Enforcement is an important factor to consider when implementing tree removal restrictions.

- City of Takoma Park, MD, Tree Ordinance: www.207.176.67.2/pw/treeordinance.html.

Techniques for Enhancing Remaining Forest Fragments

While regulatory tools can prevent a forest from being cleared, enhancement may still be needed to improve its value for wildlife (provide food, water, cover, and nesting sites), improve tree growth and canopy condition, and guarantee the long-term perpetuation of forest vegetation. Urban forest fragments present many opportunities to restore the condition and function of an urban forest. Enhancement techniques increase and improve wildlife habitat and improve conditions for tree growth to ensure long-term sustainability of the forest. This section summarizes techniques for restoring and enhancing forest fragments and includes links to relevant resources. Much of the information in this section was adapted from Hanssen (2003) and Adams (1994).

Existing urban forest fragments on protected lands in the watershed can be enhanced by expanding the forest area, increasing habitat diversity, managing deer, providing food, cover and nesting sites for wildlife, reducing or eliminating invasive species, protecting soils from erosion and compaction, and by removing trash and preventing dumping.

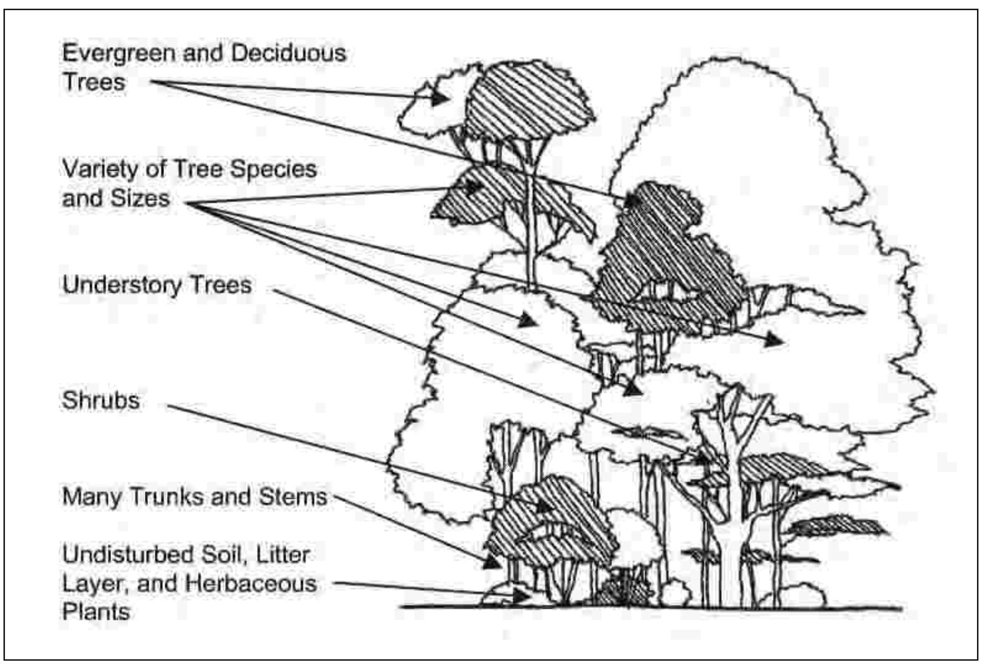


Figure 18. Example of forest with good habitat diversity and vertical structure (Adapted from Head and others, 2001, p. 41)

14. Increase forest area where possible

Forest area can be increased incrementally over time by strategically reforesting areas around remnants or gaps within remnants, or by simply shrinking the edges that are routinely mowed. These small, gradual increases will increase contiguity and benefit wildlife and will not significantly reduce the amount of usable land for the landowner. Cumulatively, these small increases in forest area can significantly increase watershed forest cover.

15. Increase habitat diversity

Urban forest fragments often lack the diversity of habitat common to their rural counterparts. One measure of habitat diversity is vertical structure, which evaluates the variety of vertical vegetative layers in a forest such as overstory, mid-story, understory, and herbaceous vegetation. Figure 18 illustrates a forest with high habitat and species diversity. Urban forest fragments often lack an understory, either due to deer overbrowsing or removal by landowners who want easy access through the forest. Planting understory species in these areas is one way to increase the diversity of habitat in a forest, and native wildlife will be best accommodated by using native tree species. Simply allowing the understory to come back naturally is an even better approach, provided steps are taken to protect the new plants from deer browse, invasives and encroachment, and trampling.

Another opportunity for increasing habitat diversity occurs at the forest edge, where edge habitat exists at the border between the forest and an adjacent land use. If the adjacent land use is pervious (e.g., field or lawn), the edge habitat can be improved by creating a soft edge or transition rather than a hard edge or abrupt change from forest to field. The soft edge can be achieved by removing specific trees along the inside edge of the forest, planting new shrubs and small trees just outside the forest edge, or allowing a strip of land just outside the forest edge to regenerate. This will provide a gradual transition from herbaceous cover to shrubs and small trees to tall trees (Figure 19). This gradual transition provides a greater diversity of habitat types and also reduces predation and nest parasitism along the forest edge (Hanssen, 2003).

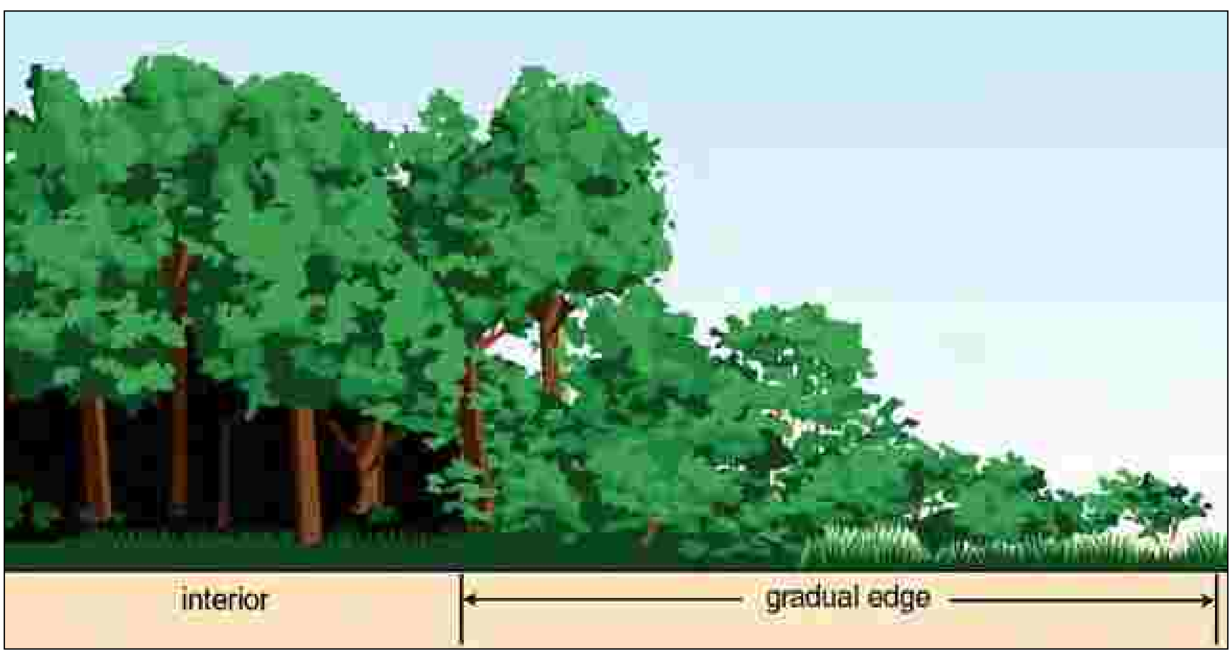


Figure 19. A soft or gradual forest edge provides a gradual transition from forest to field and benefits wildlife . (Source: FISRWG, 1998, p. 8-21)

Woody debris and leaf litter also provide unique habitat features within a natural forest, but may be eliminated in urban forest fragments because landowners wish to "clean up" the debris. A simple method to restore habitat diversity is to leave the woody debris and leaf litter. Woody debris from downed trees or fallen branches should be left in place as they are a source of food for insects and fungi and provide habitat for amphibians, reptiles, and small mammals. Woody debris and leaf litter also contribute organic matter to the soil, which improves water retention and infiltration, and recharges groundwater.

Vernal pools and spring seeps provide two additional types of aquatic habitat within a forest. Vernal pools are small depressions within a forest that temporarily pond water, typically during winter (Figure 20). They provide habitat for amphibians, waterfowl, insects, and crustaceans. Spring seeps are areas where water from below ground flows to the surface to form small streams. These are important for wildlife because they provide a fresh source of water year round. A 50 foot undisturbed buffer is needed to protect vernal pools and spring seeps. Enhancing the buffer around these natural features is another restoration method that improves habitat. Alternatively, vernal pools can be created if none exists.

- The Vernal Pool Association: www.vernalpool.org.

Figure 20. A vernal pool in winter
(Source: Tiner and others, 2002)

16. Manage deer

Deer overpopulation is common in urban and suburban areas where there are no natural predators for deer, and hunting is restricted due to safety concerns. Urban forests also tend to have a large proportion of edge habitat, in which deer thrive (MD DNR, 1998).

Figure 21. Deer exclosure shows heavy browsing of unprotected understory vegetation in forest on right.

Deer browse primarily on woody plants, so a large deer population can essentially deplete the forest of native understory or midstory vegetation. An overbrowsed forest may have a characteristic browse line about 4 to 5 feet high, under which no green leaves are present (evident only during the growing season) or may have all unprotected understory vegetation removed. (Figure 21). Several methods exist to control deer populations and manage their impacts on forests, including hunting, sterilization, fencing, and other barriers and repellents

- Deer in Maryland: www.dnr.state.md.us/wildlife/deerhunting.asp

- Montgomery County Deer Management Work Group 2004. Comprehensive Management Plan for White-Tailed Deer in Montgomery County, Maryland: Goals, Objectives, Implementation. Silver Spring, MD. www.mc-mncppc.org/Environment/deer/DEERPLAN%20update%208-2004.pdf.

17. Protect soils from erosion and compaction

Forest soils can be protected from erosion and compaction by restricting access and use. One example is to limit access to designated trails only and to restrict ATV use entirely. Trails should be designed properly to prevent erosion, and special care must be taken in areas with steep terrain. For more information on trail design, see TCF (1993). Another way to improve forest soils is to ensure that the leaf litter layer is not disturbed. Leaf litter contains organic matter that improves water retention and infiltration. Finally, significant inputs of storm water to the forest fragment should be managed to prevent erosion from high flows.

18. Provide food, cover, and nesting sites for wildlife

To encourage desirable wildlife in the urban forest, such as woodpeckers, wood ducks, owls, bluebirds, chipmunks, and foxes, adequate food, cover, and nesting sites must be present. Plant species that provide food, cover, or habitat for specific wildlife species can be planted, or artificial structures that provide cover or nesting sites can be created. These include mast species, brush piles, evergreens, snags and cavity trees, and nesting structures.

Mast species are tree species that produce fruits, nuts, seeds, and other sources of food for wildlife. A healthy forest should have a continuous supply of 40- to 80-year-old healthy mast-producing species (Hanssen, 2003). Examples of mast species are oak, cherry, hickory, beech, and walnut. Many other native plants provide food or habitat for specific wildlife species, and these should be planted or encouraged wherever possible. The growth of desirable species, such as mast species that already have a foothold in the forest, can be encouraged by releasing them from competition. This means removing any nearby competing vegetation on at least three sides. Mast species can also be encouraged by planting new trees.

Figure 22. Brush pile

Brush piles (Figure 22) are made of brush, tree branches, and cut shrubs and serve as cover for wildlife such as rabbits, squirrels, chipmunks, foxes, and songbirds (Hanssen, 2003). Brush piles are particularly important in a forest that lacks understory because they may provide the only shelter for these animals. Brush piles should be built close to a water or food source. Evergreens also serve as cover for wildlife in winter.

- Maryland DNR Wild Acres Program. Brush Piles: www.dnr.state.md.us/wildlife/wabrush.asp
- National Wildlife Federation. Backyard Habitat: www.nwf.org/backyardwildlifehabitat/logpile.cfm.

Snags and cavity trees are dead or partially dead trees that are still standing. Unless they pose a safety hazard, snags should be left standing because they provide habitat for certain species, such as woodpeckers, wood ducks, bluebirds, hawks, and owls. These animals typically feed on insects and can help control insect infestation in the forest.

- How is a Dead Tree Good? www.fs.fed.us/r6/nr/wildlife/animalinn/goodtree.htm
- Maryland DNR Wild Acres Program. Snags and Logs: www.dnr.state.md.us/wildlife/wasnags.asp.

Nesting structures can be built and installed in the forest for species of birds that nest in cavities such as bluebirds. There are various types of nesting structures specifically designed for particular bird species.

- Maryland DNR Wild Acres Program. Eastern Bluebirds: www.dnr.state.md.us/wildlife/wabluebird.asp
- Ducks Unlimited: www.ducks.org/conservation/duck_box_plans.pdf
- Bat Conservation International: www.batcon.org.

19. Reduce or eliminate invasive species

Another method of restoring forest fragments is to improve the conditions for existing desirable vegetation, to ensure their long-term survival. This includes releasing trees and shrubs from competition by thinning, managing deer populations, and controlling invasive plant species.

An invasive species is defined as a species that is nonnative (alien) to the forest ecosystem and whose introduction causes or is likely to cause economic or environmental harm. Control of invasive plant species includes prevention, removal, and monitoring. Introduction of invasive species can be prevented through education programs and good housekeeping practices that prevent the inadvertent introduction or spread of plant seeds and parts by humans. Another prevention method is to minimize disturbance, which may make forests more susceptible to invasion. If invasive species are present, they can be removed through mechanical, chemical, or biological methods. The method selected will depend on the species characteristics, level of infestation, site characteristics, and resources available. The site should be monitored closely so any new invasives can be removed immediately. For more information on specific methods to control invasive species, see Part 3 of this manual series.

- Invasive Species: www.invasivespecies.gov
- Plants Database: http://plants.usda.gov
- The Nature Conservancy's Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas: http://tncweeds.ucdavis.edu/handbook.html.

Figure 23. Urban forest fragment with illegal dumping

20. Remove trash and prevent dumping

Urban forest fragments often become dumping grounds for trash, building rubble, and unwanted furniture or appliances. Illegal dumping often occurs in these poorly lit areas, particularly along the forest edges and near access trails (Figure 23). Forest fragments can be improved simply by removing the trash and rubble, provided measures are taken to prevent future dumping. These include installing lighting and posting *No Dumping* signs with fines for violation. Cleanup of trash and rubble can be done with volunteers if the volume of trash is minimal and if access and safety are not a concern. Heavy equipment or a hazardous materials (HAZMAT) crew may be needed to remove larger volumes of trash or potentially hazardous material.

Techniques for Reforesting Watersheds

Forest gains can be sharply increased through systematic reforestation of open lands throughout the watershed. Techniques to increase watershed forest cover can be used to meet three of the seven objectives of urban watershed forestry. Objective E, Plant Trees During Development and Redevelopment, either requires or encourages developers to plant trees at development sites, often in places not typically considered for reforestation. Objective F, Reforest Public Land, primarily focuses on reforesting large parcels of public lands that have already been developed, such as schools, parks, and highway and storm water rights-of-way (Figure 24). Objective G, Reforest Private Land, includes techniques to encourage widespread tree planting on feasible locations within individual yards or property that have already been developed.

Figure 24. Highway and local road rights-of-way provide opportunities for reforestation on public land

Each technique is summarized in the ensuing section, including any relevant resources. More guidance on implementing reforestation projects, including site preparation, species selection and maintenance, is provided in Part 3 of this manual series. Specific guidance on reforesting the following land uses is provided in Chapter 4:

1. Highway rights-of-way
2. Residential lawns
3. Parks
4. School grounds
5. Storm water dry ponds
6. Streams and shorelines
7. Utility corridors
8. Vacant lots.

Planting Trees During Development and Redevelopment

Four techniques can be applied to encourage developers to plant trees during development and redevelopment projects. Two are regulatory in nature and are adopted by local governments to either directly or indirectly require tree planting in new developments. The other two techniques are simply opportunities that can be applied by the developer to increase tree cover at the development site. These techniques are summarized below and include landscaping requirements, shading and canopy ordinances, planting trees in storm water treatment practices, and planting trees in other open spaces.

21. Landscaping requirements

Landscaping ordinances regulate how much of a nonresidential development site must be landscaped. Most commercial and industrial areas are required to have some type of landscaping, and it may be set as a percentage of the site, an area per number of parking stalls, a number of trees per street length, or other designation. Landscape ordinances typically provide guidance on species selection; plant spacing; setbacks from buildings, pavement, and utilities; planting plan development; and maintenance schedules. While landscaping ordinances do not specifically require the protection of trees and forests, they can act as incentive for developers to conserve existing trees to avoid having to plant new ones to meet landscaping requirements.

- City of Chicago, IL, Landscape Ordinance: www.cityofchicago.org/Environment/CityTrees/LandscapeOrdinance.html
- San Antonio,TX, Landscape Ordinance: www.sanantonio.gov/dsd/pdf/tree_landscapeOrdinanceBrochure.pdf.

22. Shading and canopy ordinances

Shading or canopy ordinances are essentially landscaping ordinances that define planting requirements by the amount of shade created rather than the area planted. These regulations require that a certain portion of a parking lot or street be shaded by tree canopy after a specified time period (typically 15 years). These regulations are popular in arid regions where shading can significantly reduce heat effects. In Sacramento, Davis, and Los Angeles, California, the shade tree ordinance requires 50% of the total paved area to be shaded within 15 years of issuing the development permit. A recent assessment found that these requirements are not actually being met, however, which means that additional planning must be put into how these ordinances are implemented and enforced (McPherson, 2001). Shading ordinances often provide recommended species lists and 15-year crown projection areas of these species to assist site planners in calculating the future shaded area.

- Sacramento, CA, Shade Tree Ordinance: www.energy.ca.gov/coolcommunity/plshade.html
- City of Sacramento, CA, Parking Lot Shading Design and Maintenance Guidelines: www.cityofsacramento.org/planning/longrange/shading_guide.pdf.

23. Planting trees in storm water treatment practices

Urban development sites provide many opportunities to plant new trees, such as storm water treatment practices, which provide water quality treatment and storage of storm water runoff from impervious surfaces. Many storm water treatment practices have not traditionally been considered appropriate locations for planting trees. Research on the benefits of trees, however, shows they have enormous potential to improve the efficiency of these practices through nutrient uptake and runoff reduction.

To encourage tree planting in storm water treatment practices, guidance must be provided to developers on selecting appropriate species, identifying areas suitable for planting, and making any necessary modifications to the design or planting environment. Part 2 of this manual series includes detailed guidance on planting trees in storm water treatment practices.

24. Planting trees in other open spaces

Other open spaces at a development site that make good candidates for tree planting and are often underutilized include local road rights-of-way, landscaped islands in cul-de-sacs or traffic circles, and parking lots. Private lawn areas also provide space for tree planting, but developers typically have no incentives to plant new trees there. Developers are usually required, however, to landscape certain portions of roadside strips and parking lots and can meet these landscaping regulations while increasing tree canopy at the same time. Part 2 of this manual series provides detailed guidance on planting trees at development sites.

Reforesting Public Land

Public lands often present the best opportunities for reforestation in a watershed, either through natural regeneration or active reforestation. Reforesting public lands allows the entire community to enjoy the recreational, educational, and esthetic benefits of forests. Undeveloped public lands may also be reforested, provided some measures are taken to ensure long-term protection of the land from development. Public parks also afford a measure of long-term protection to the newly planted forest.

25. Allowing natural regeneration

Natural regeneration is a passive method of reforesting a site that entails restricting mowing by posting signs or installing fencing to restrict access and allowing trees to regenerate naturally. This method can take a long time to show results. It may also result in a site covered with invasive species or other undesirable plants, since it is difficult to tell what types of vegetation will grow on a site that is currently being mowed. Good candidate sites for natural regeneration include those with a nearby seed source for the tree species desired at the site, sites with minimal problems with invasive species, and less visible areas of a park, school, or other public land. Natural regeneration is a low-cost, low-effort way to reforest a site.

The most important aspects of using natural regeneration are educating the public and reducing weed competition. No-mow areas should be clearly marked to inform the public or staff of the project and reduce human disturbance (Figure 25). For areas such as public parks or schools, mow a strip just outside the regeneration area to let the public know it is an intentional planting site that is being maintained. Consistent monitoring and removal of invasive plants can also provide a better growing environment for young trees.

- Natural Regeneration: Principles and Practices. 1999. Land for Wildlife Note No. 8. South-east Queensland. www.epa.qld.gov.au/publications/p00254aa.pdf/Natural_regeneration_principles_and_practice.pdf.

Figure 25. Restricting mowing and posting signs will allow forest in this area to regenerate naturally.

26. Actively reforesting public lands and rights-of-way

Actively reforesting public lands throughout a watershed is a more labor-intensive way to create new forests, but allows more control over what types of vegetation become established. Prior to reforesting a site, a detailed assessment should be made of the soils and site conditions to determine what types of trees to plant and to identify any planting constraints. A planting plan should be developed for the site and include the following elements:

- Site preparation (e.g., trash cleanup, removal of invasive plants, soil amendments)
- Species and stock selection (size and species of planting materials)
- Planting zones and layout (where to plant, arrangement and spacing of plants)
- Implementation plan (schedule, equipment and plant materials needed, volunteer recruitment plan)
- Maintenance.

Some general goals of reforestation include maximum canopy coverage, connection with adjacent forested land, a diverse mix of native species, vegetative layers, and habitats. These goals may not all be feasible or desirable for each reforestation site, depending on the current function of the site and existing soil and vegetative conditions. It is also important to maximize the survival of any new plantings by protecting against herbivory and plant competition. To address these unique issues, guidance on planting trees on priority public lands is provided in Chapter 4. More information on planting trees is provided in Part 3 of this manual series.

Reforesting Private Land

Regional GIS analyses of urban areas conducted by American Forests (2001) reveal that about 60% of neighborhoods in the metropolitan areas studied have less than 50% forest canopy cover. The actual rate of tree planting is poorly understood in residential areas. A survey in the Chesapeake Bay watershed indicated that 71% of residents had planted a tree within the last 5 years (CBP, 2002). Lower tree planting rates (about 50%) were reported in urban metropolitan areas such as Baltimore, MD, and Washington, DC.

Reforesting private land may significantly increase forest cover in watersheds, particularly in areas with a high proportion of residential lawns or other privately owned turf. Effective techniques to encourage widespread planting of trees, shrubs, and hedgerows on feasible locations within individual yards or property include these three: developing public education programs that focus on tree planting benefits and techniques, providing financial incentives to plant trees on private property, and promoting public stewardship through the creation and support of citizen action groups that focus on tree planting and preservation. Chapter 4 provides guidance on planting trees in residential lawns to maximize energy savings.

27. Education

Public education is critical in changing public attitudes towards trees. A surprisingly large number of citizens object to having large trees on their property and should be educated about their benefits (GFC, 2001). Public education programs can be designed to convince private landowners and other citizens of the benefits of tree planting and preservation, and to provide guidance on proper techniques for tree planting and maintenance. These programs may include creation of educational workshops, videos, or pamphlets, or distribution of more technical materials such as native plant guidebooks. Education programs are voluntary and are usually geared towards a wide audience.

28. Incentives for tree planting

Financial incentives can encourage private landowners to plant trees on their property. These incentives can take many forms, ranging from free or low cost seedlings or other native tree stock to financial rebates or reduced fees offered by utilities or local governments. Tree seedling giveaways may be coupled with educational programs and may also coincide with nationally recognized days such as Arbor Day or Earth Day (GFC, 2001). Various utilities across the country offer incentives to preserve or plant trees in certain areas of the yard to maximize their cooling benefits. Other communities offer a partial rebate on tree removal permits within 1 year of completed construction. Some examples of incentive programs are available online:

- Slinger,WI, Residential Tree Power Incentive Program: www.slinger-wi-usa.org/utilityprograms.htm
- Tucson, AZ, Electric Power (TEP). Planting Incentives for Residents: http://swenergy.org/programs/arizona/utility.htm
- City of Woodinville, WA, Tree Preservation Incentive Program: www.ci.woodinville.wa.us/documents/Tree%20Incentives%20and%20Regulations.pdf
- City of Hays, KS, Tree Rebate Program: www.haysusa.com/Departments/Parks_Department/Tree_Rebate_Program/tree_rebate_program.html.

29. Stewardship and neighborhood action

Creating or supporting citizen action groups that focus on tree planting and preservation promotes public stewardship of the urban forest. These action groups are typically non-profit, volunteer organizations, and may focus solely on tree planting or may have a wider scope such as watershed stewardship. Members can be drawn from homeowners associations, garden clubs, school groups, or environmental groups. These organizations raise community awareness of the benefits of trees and can also raise funds for tree planting. Citizen tree groups can provide assistance to private landowners on tree planting, particularly when the community does not have a forester or arborist on staff. These groups are vital to community acceptance of trees and can encourage private landowners to plant trees on their property.

- American Forests Global Releaf: www.americanforests.org/global_releaf/
- Trees Atlanta: www.treesatlanta.org
- Iowa State University Extension. Establishing a Community Tree Program. www.extension.iastate.edu/Publications/PM1429a.pdf
- Environmental Law Institute. 2000. Forests for the Bay. Research Report. Washington, DC. www.elistore.org/reports_detail.asp?ID=531&topic=Conservation.

Chapter 4: Planting Guidelines for Priority Reforestation Sites

This chapter provides detailed guidelines for planting trees on these priority reforestation sites in a watershed:

1. Highway rights-of-way
2. Residential lawns
3. Parks
4. School grounds
5. Storm water dry ponds
6. Streams and shorelines
7. Utility corridors
8. Vacant lots.

The guidance is presented in a series of fact sheets that describe the basic reforestation concept and address the following topics:

Pre-Planting Considerations — potential conflicts with planting trees at the site or unique features that drive plant selection and planting procedures. Most of these considerations are addressed under the topics of Species Selection, Site Preparation, Planting Guidance, or Maintenance.

Species Selection — desirable characteristics of species to be planted at the site.

Site Preparation — recommendations for preparing the site for planting.

Planting Guidance — recommendations for stock selection, planting zones, plant spacing, and arrangements and planting methods.

Maintenance — recommendations for tree maintenance.

Potential for Storm Water Treatment — potential for integrating trees and storm water treatment practices in this location.

Further Resources — documents or Web sites referenced in the fact sheet and other relevant resources.

Planting Trees in Highway Rights-of-Way

Description

Larger highways often have fairly large parcels of unused land in the form of cloverleafs and diamonds near interchanges, median strips, and buffers. These rights-of-way can be ideal locations for reforestation because they generally serve no other purpose.

Planting trees along highways can reduce air pollution and stormwater runoff, provide habitat for wildlife such as birds, reduce air temperatures, stabilize the soil, provide a visual screen and buffer from noise and highway fumes, and create a visually pleasing environment for the highway driver.

Pre-Planting Considerations

- ☐ Do highway planting guidelines prohibit or restrict trees?
- ☐ How do I address potential conflicts between trees and utilities?
- ☐ Do I need to use different methods for planting trees on steep slopes?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I provide unobstructed vehicle recovery areas, clear lines of sight, safe travel surfaces, and access to maintenance structures?
- ☐ Can I make the area more attractive with plantings?
- ☐ How do I address soil conditions such as severe compaction or fill soils?
- ☐ How do I manage invasive plants?
- ☐ How do I address illegal dumping?
- ☐ How do I address exposure of trees to auto emissions, polluted runoff, wind, and drought?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Other desirable species characteristics include the following:

- ☐ Tolerates urban stormwater pollutants (oil and grease, metals, chloride)
- ☐ Tolerates air pollution
- ☐ Tolerates poor, highly compacted soils
- ☐ Tolerates drought (rainfall may be the only source of water)
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Provides food, cover, or nesting sites for wildlife
- ☐ Has fall color, spring flowers, or other esthetic benefit.

Site Preparation	☐	Clean up trash and rubble
	☐	Remove invasive plants such as Tree of Heaven (may involve mowing, cutting, and stump treatment)
	☐	Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance	☐	Plant trees in groups to provide shared rooting space and allow mowing around trees to control invasive species
	☐	Use groupings of species that provide fall color, flowers, evergreen leaves, and varying heights to create an esthetically pleasing landscape
	☐	Provide gradual transitions between cover types (e.g., soft edges) to benefit wildlife
	☐	Provide setbacks of 17-50 feet between tree planting areas and edge of pavement to reduce limb and leaf fall onto the roadway (Figure 26), prevent trees from falling into the road, allow for vehicle recovery in high speed areas, and prevent icy spots on shaded roadways (Metro, 2002; MD SHA, 2000; NC DOT, no date). Consider ultimate road widening when determining setbacks. Consider planting wildflowers within setback zones.
	☐	Seedlings may be preferable to large nursery stock since they will be watered infrequently (Gilman, 1997)
	☐	Maintain clear line of sight within 25 feet of overhead lights, within 500-1,000 feet of large signs and traffic control devices, and in the area between 2 to 6 feet above roadway elevations. Maintain vertical clearance of 16 feet above roadways (MD SHA, 2000).
	☐	Provide a setback of 5 to 17 feet to allow maintenance access to roadside structures, such as traffic barriers, cabinet devices, noise walls, drainage structures, and utility poles (MD SHA, 2000).
	☐	When planting on slopes, create small earthen berms around trees to help retain moisture. For very steep slopes, use terraces, bioengineering, or consider alternatives to tree planting.

Specific Planting Guidance

Highway Cloverleaves

Provide a setback of 30 to 50 feet between tree planting areas and the edge of pavement, and plant trees or allow natural regeneration in the center of the cloverleaf. The setback ensures adequate sight lines, allows for vehicle recovery and prevents tree branches in roadways (NC DOT, no date).

Highway Buffers

Provide a setback between tree planting areas and the edge of pavement of 20-50 feet for flat areas (or slopes of 3:1 or less) and 17 feet for slopes of 3:1 or steeper (MD SHA, 2000). This setback generally restricts trees in the area between the edge of the pavement and the toe of the slope (swale) to allow adequate sight lines and vehicle recovery and to prevent tree branches in roadways. Create a gradual transition from grasses to trees on cut slopes.

Highway Medians

Medians greater than 25 feet wide can support two rows of trees spaced 20-40 feet apart (GFC, 2002). Provide adequate setbacks to keep utilities clear (if present) and to prevent downed trees or limbs in the roadway. Consider planting large shrubs in median strips if utilities are an issue or if space is limited.

Maintenance

- ☐ Plan for minimal maintenance of trees (watering may not be feasible)
- ☐ Use mulch to retain moisture. Do not mulch deeper than 3 inches or build up mulch around trunks.
- ☐ Mow setback zones and remove any fallen trees or limbs
- ☐ Manage height of volunteer trees to prevent falling during storms
- ☐ Monitor and control invasive species
- ☐ Use integrated pest management to control insects.

Potential for Stormwater Treatment

Trees planted in highway cloverleaves, medians, and buffers can be used to provide treatment of stormwater runoff, since these areas typically already receive polluted runoff from the highway. Cloverleaves are generally large enough to locate most stormwater treatment practices, while median strips and buffers lend themselves to the use of more linear practices such as bioretention, filter strips and swales. Ideas for integrating trees and stormwater treatment in these areas are provided below.

Highway Cloverleaves	Trees can be planted on side slopes and islands in a wooded stormwater wetland (see Part 2 of this manual series for wooded wetland design) constructed in the center of the cloverleaf. Trees should be restricted on embankments, maintenance access areas, and setback zones.
Highway Medians	Trees can be incorporated into swales within highway medians by using tree mounds as check dams (see Part 2 for tree check dam design) or planting trees on side slopes (provided they are not within the setback zone).
Highway Buffers	Trees can be incorporated into a filter strip on flat areas or fill slopes along a highway buffer. The filter strip can either be forested or incorporate multiple vegetative zones that provide a gradual transition from grass to trees.

Further Resources

Maryland State Highway Administration (MDSHA). 2000. Woody Vegetation Management Standards. In *Integrated Vegetation Management Manual for Maryland Highways*.
Online: www.sha.state.md.us

Maryland State Highway Administration (MDSHA) Partnership Planting Program. Contact: Mr. Leroy Jonas, MD SHA Landscape Operations Division C-304, 707 N. Calvert Street, Baltimore, MD 21202.
Online: www.sha.state.md.us/ImprovingOurCommunity/oed/partner.asp

North Carolina Department of Transportation (NCDOT) Division of Highways. *Guidelines for Planting within Highway Right-of-Way*. Raleigh, NC.
Online: www.doh.dot.state.nc.us/operations/dp_chief_eng/roadside/design/PlantingGuid/pdf/PlantingGuidelines.pdf.

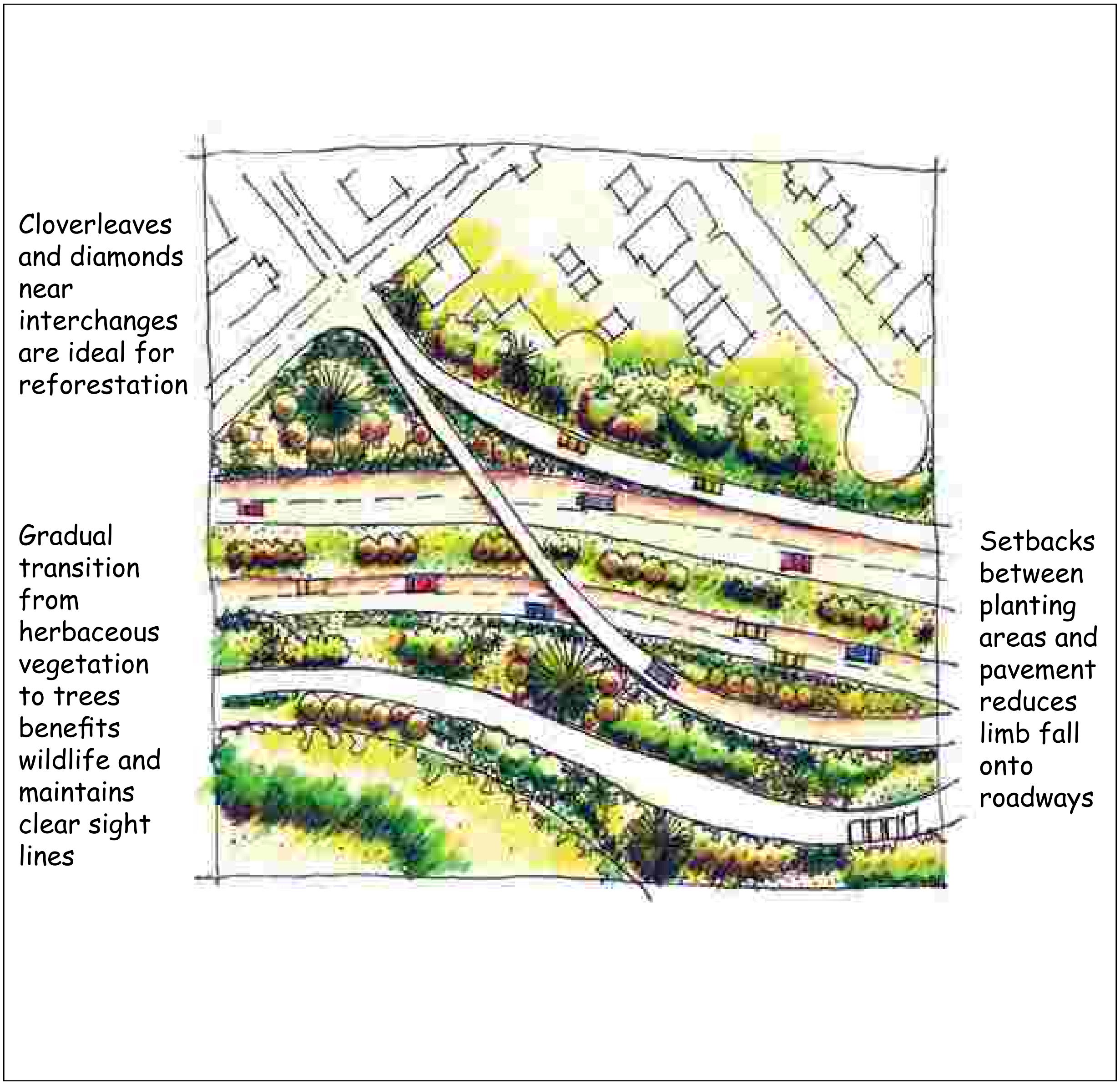


Figure 26. Planting trees in highway rights-of-way

Planting Trees on Residential Lawns

Description

Residential lawns are ideal tree planting locations, particularly in former agricultural areas where few trees exist. Planting trees on home lawns can significantly increase the overall tree cover in the watershed since residential lawns typically constitute a large portion of the plantable area. The key is to educate homeowners about the benefits of trees and provide incentives and assistance with tree planting and care so that the number of trees planted is significant.

Trees on residential lawns provide many benefits, including energy cost savings, shade, habitat for wildlife, esthetic value, privacy, and reduction of stormwater runoff. Trees planted next to buildings can reduce summer air conditioning costs by 40% (Akbari and others, 1992).

Pre-Planting Considerations

- ☐ How can I improve the energy efficiency of my home with tree plantings?
- ☐ How can I integrate trees with open turf areas?
- ☐ Can I make the area more attractive with plantings?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and utilities, pavement, and structures?
- ☐ How do I prevent damage to trees from lawnmowers?
- ☐ How do I utilize plantings for visual screening and buffer from wind and noise?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Use evergreens for screening and to block winter winds. Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates urban pollutants
- ☐ Tolerates poor or compacted soils
- ☐ Provides food, cover, or nesting sites for wildlife.

Site Preparation	☐	Remove invasive plants such as multiflora rose (may include mowing, cutting, or stump treatment)
	☐	Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).
General Planting Guidance	☐	Plant a tree to shade the area over your air conditioner and reduce energy use (Figure 27).
	☐	Plant deciduous trees on the west, south, and east sides of the building to block the summer sun (Figure 28).
	☐	Plant a row of evergreens on the north side of the building to block cold winter winds.
	☐	Provide adequate setbacks between trees and buildings, utilities, and pavement.
	☐	Cluster trees to provide shared rooting space and an even canopy, using species that grow at about the same rate so they don't shade each other out. Use mulch rings and mow around the clusters.
	☐	Use trees to delineate borders or provide visual screens.
	☐	Use trees to provide a buffer from noise. To be effective, the buffer should be dense, tall, and wide, and planted close to the source of the noise. Contiguous rows of trees in widths of 16 feet or more are especially effective (TreesAtlanta, no date).
Maintenance	☐	Plan for low maintenance of trees (frequent watering may not be feasible)
	☐	Use mulch to retain moisture and protect trees from mowers and foot traffic
	☐	Monitor and control invasive plants
	☐	Prune trees where necessary to maintain visibility and safety.
Potential for Stormwater Treatment		Trees on residential lawns are not likely to have high potential for stormwater treatment since most homeowners are not responsible for providing treatment of runoff from their property. In cases where homeowners are responsible for swales located on their properties, alternating side slope plantings or tree check dams could be used. (See Part 2 of this manual series for tree check dam design.)

Further Resources

Akbari, H., Davis, S., Dorsano, S., Huang, J. and S. Winnett. 1992. *Cooling Our Communities. A Guidebook on Tree Planting and Light-Colored Surfacing*. U.S. EPA. Lawrence Berkeley Laboratory Report LBL-31587.

Planting Trees Around Your Home. Fact Sheet available on The Forest Where We Live Web site: www.lpb.org/programs/forest/plantguide.html

Trees Atlanta. No Date. *Facts*. Website: www.treesatlanta.org/facts.html

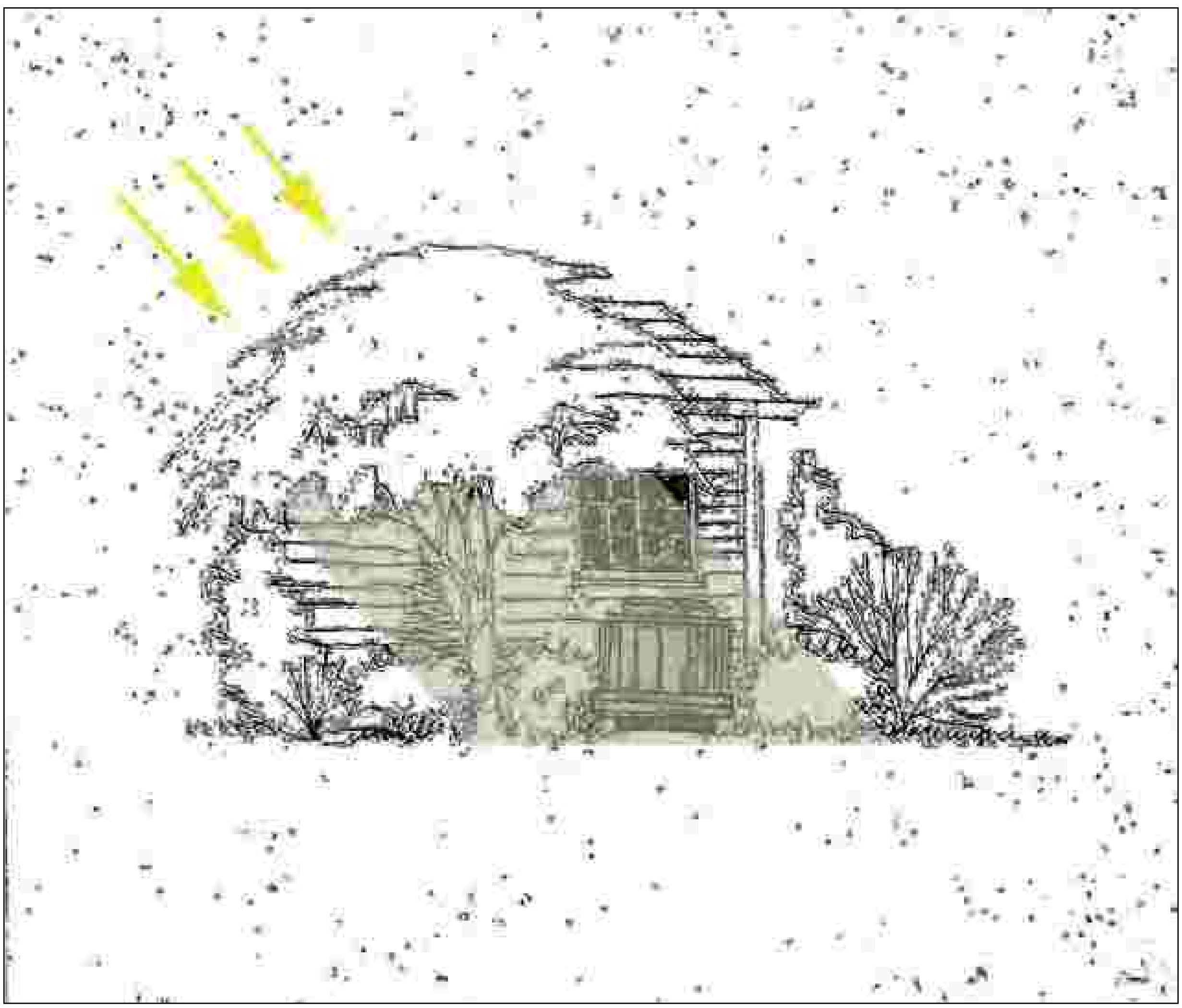


Figure 27. Strategically placed trees shade the air conditioning unit, providing energy savings

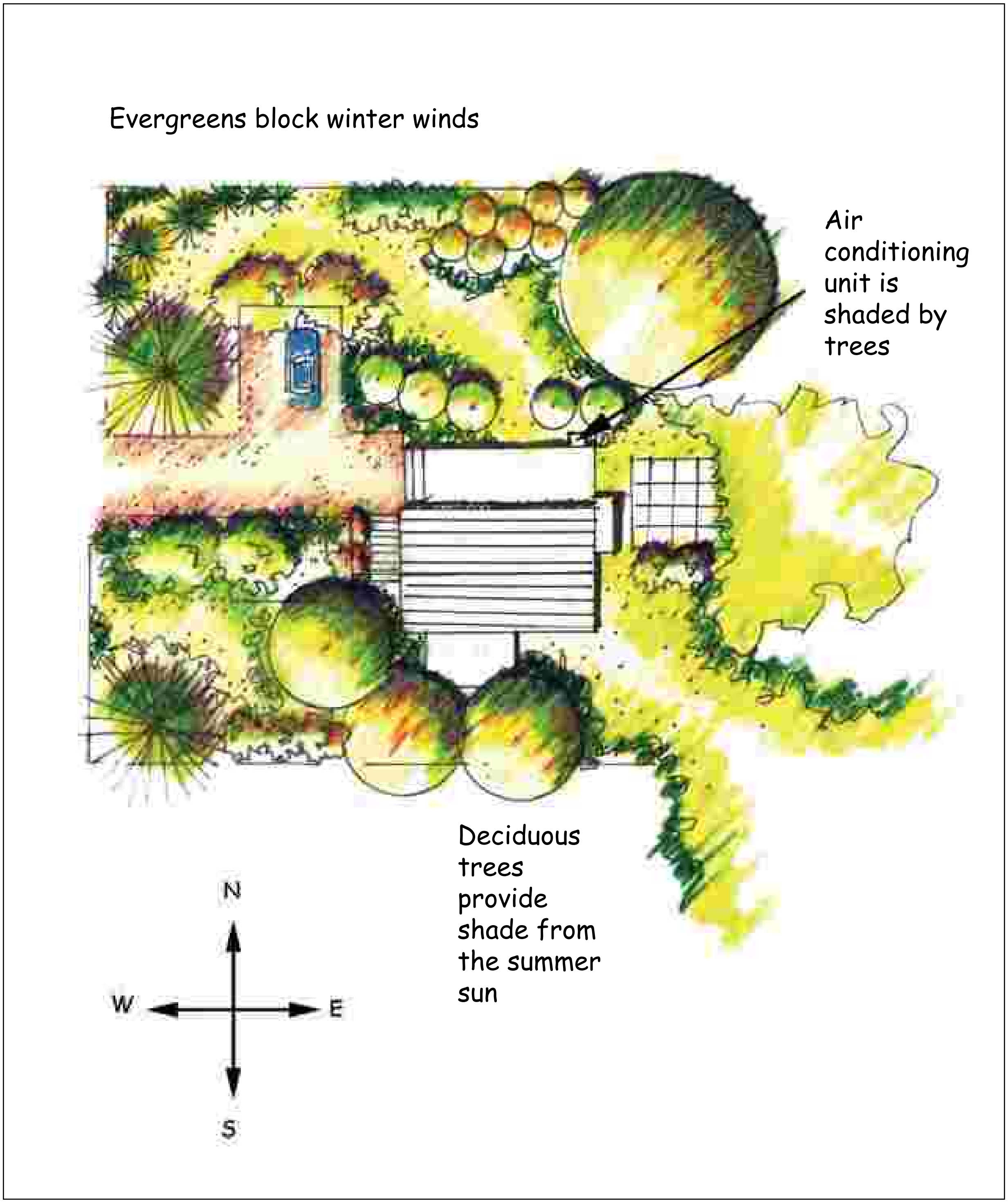


Figure 28. Planting trees on residential lawns

Planting Trees in Parks

Description

Parks provide ideal locations for reforestation since they often have large underutilized open areas for planting trees and are publicly owned. Benefits of planting trees in parks include wildlife habitat, shading, soil stabilization, reduced storm water runoff, and improved recreational opportunities, quality of life, and air quality.

Pre-Planting Considerations

- ☐ How do I address concerns about vandalism, safety, liability, and visibility?
- ☐ How do I integrate trees with recreational uses, such as ballfields and trails?
- ☐ How do I prevent soils in the planting area from being compacted by foot traffic?
- ☐ Can I make the area more attractive with plantings?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I address illegal dumping?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and street lights, utilities, and pavement?
- ☐ How do I prevent damage to trees from lawnmowers?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Select species with similar growth rates when planting in groves (so they do not shade each other out). Limit use of understory trees and shrubs in areas where visibility and safety are important. Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates urban pollutants
- ☐ Tolerates poor or compacted soils
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Large shade tree with a single leader that can be limbed up to 6 feet
- ☐ Provides food, cover, or nesting sites for wildlife
- ☐ Reflects local character and culture.

Site Preparation	☐	Clean up trash or other illegally dumped material
	☐	Remove invasive plants such as multiflora rose (may include mowing, cutting, or stump treatment)
	☐	Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).
General Planting Guidance	☐	Trees can be incorporated when developing landscaping plans for new parks. Select planting areas that are adjacent to existing forest or other natural areas or protect natural features such as streams (Figure 29).
	☐	Plant to provide shade around bleachers and ballfields. Use trees to create screens and boundaries between different areas.
	☐	Allow natural regeneration in less visible areas. Mow a strip outside the regeneration area and clearly mark with signs to educate the public and let them know it is intentional.
	☐	Plant street trees or specimen trees around the perimeter of the site at a spacing of 30 to 45 feet on center, to allow mowing in between for invasive species control.
	☐	Cluster trees to provide shared rooting space and an even canopy, using species that grow at about the same rate so they don't shade each other out. Use mulch rings and mow around the clusters.
	☐	Post signs to identify intentional plantings.
	☐	Use small plant materials (e.g., seedlings, whips) where foot traffic is not an issue and larger stock elsewhere. Mix stock where both understory and canopy trees will be planted (smaller understory stock and larger canopy stock), or in tree clusters to protect whips (plant large stock around perimeter and whips in center).
	☐	Where potential liability due to tree climbing is a concern, prune mature trees to the shoulder height of an adult and plant low shrubs or ground cover at tree base.
	☐	Use tree cages or benches to protect trees from vandalism, or plant species with inconspicuous bark or with thorns to discourage vandalism (Palone and Todd, 1998).
	☐	Plant only low growing herbaceous vegetation in areas where visibility is important for safety reasons. Do not plant evergreens, understory, or ornamental trees or shrubs in these areas. This includes within 10 feet of the centerline of trails, near seating areas, intersections and approaches to trails. Prune or limb trees in these areas up to 8 feet to maintain visibility (TCF, 1993). Provide trail breaks in case of emergency (TCF, 1993).
	☐	Plant trees where traffic is minimal, such as along fencelines. Protect trees and their critical root zone (generally a 25-foot radius) from foot traffic (soil compaction) by using recycled rubber or by directing foot traffic to certain areas using low metal fences, curbs, posts and chains, or porous pavers (Patterson, 1995)

Maintenance

- ☐ Plan for low maintenance of trees (frequent watering may not be feasible)
- ☐ Use mulch to retain moisture and protect trees from mowers and foot traffic. Do not mulch deeper than 3 inches or build up mulch around trunk.
- ☐ Mow around tree clusters, in setback areas, and in other areas that require access, safety, and visibility
- ☐ Monitor and control invasive plants
- ☐ Prune trees where necessary to maintain visibility and safety.

Potential for Stormwater Treatment

Trees planted in parks may be used to provide treatment of stormwater runoff since these areas often have large open areas available for stormwater treatment practices. Depending on available space, site conditions, and runoff volume, the following types of practices may be used: stormwater wetlands, bioretention and bioinfiltration, swales and filter strips. Trees can be incorporated into all of these treatment practices, and design and planting guidance for each is presented in Part 2 of this manual series.

Further Resources

Northeastern Illinois Planning Commission (NIPC). 1997. *Natural Landscaping for Public Officials*. Chicago, IL.

Parks and People Foundation. Online: www.parksandpeople.org

The Conservation Fund (TCF). 1993. *Greenways: A Guide to Planning, Design and Development*. Island Press. Washington, DC.

Figure 29. Planting trees in parks

Planting Trees on School Grounds

Description

Schools provide ideal locations for reforestation since they are publicly owned and often have large underutilized open areas for planting trees. Benefits of planting trees on school grounds include wildlife habitat, shading, soil stabilization, improved recreational opportunities and quality of life, educational opportunities, improved air quality, and reduced stormwater runoff.

Pre-Planting Considerations

- ☐ How do I address concerns about vandalism, safety, liability and visibility?
- ☐ Is there an opportunity to provide educational value?
- ☐ How do I integrate trees with recreational uses such as ballfields and trails?
- ☐ How do I prevent soils in the planting area from being compacted by foot traffic?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I address illegal dumping?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and street lights, utilities, and pavement?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Select species with similar growth rates when planting in groves (so they do not shade each other out). Limit use of understory trees and shrubs in areas where visibility and safety are important.

Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates urban pollutants
- ☐ Tolerates poor or compacted soils
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Large shade trees with a single leader that can be limbed up to 6 feet
- ☐ Provides food, cover, or nesting sites for birds, squirrels, and other wildlife
- ☐ Reflects local character and culture.

Site Preparation

- ☐ Clean up trash or other illegally dumped material
- ☐ Remove invasive plants such as multiflora rose (may include mowing, cutting, or stump treatment)
- ☐ Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance

- ☐ Trees can be incorporated when developing landscaping plans for new schools. Select planting areas that are adjacent to existing forest or other natural areas or protect natural features such as streams.
- ☐ Plant to provide shade around bleachers and ballfields (Figure 30). Use trees to create screen and boundaries between different areas.
- ☐ Plant street trees or specimen trees around the perimeter of the site at spacing of 30 to 45 feet on center to allow mowing in between for invasive control.
- ☐ Cluster trees to provide shared rooting space and an even canopy, using species that grow at about the same rate so they don't shade each other out. Do not include turf in tree clusters. Instead, use mulch rings and mow around the clusters.
- ☐ Post signs to identify intentional plantings
- ☐ Use small plant materials (e.g., seedlings, whips) where foot traffic is not an issue and larger stock elsewhere. Mix stock where both understory and canopy trees will be planted (e.g., use small understory stock and large canopy stock), or in tree clusters to protect seedlings (e.g., plant large stock around perimeter and seedlings in center).
- ☐ Where potential liability from tree climbing is a concern, prune mature trees to the shoulder height of an adult and plant low shrubs or ground cover at tree base.
- ☐ Plant only low growing herbaceous vegetation in areas where visibility is important for safety reasons or limb trees up to 8 feet in these areas to maintain visibility.
- ☐ Plant trees where traffic is minimal, such as along fencelines. Protect trees and their critical root zone (generally a 25-foot radius) from foot traffic (soil compaction) by using recycled rubber or by directing foot traffic to certain areas using low metal fences, curbs, posts and chains, or porous pavers (Patterson, 1995)

Maintenance

- ☐ Plan for low maintenance of trees (frequent watering may not be feasible)
- ☐ Use mulch to retain moisture and protect trees from mowers and foot traffic. Do not mulch deeper than 3 inches or build up mulch around tree trunks.
- ☐ Mow around tree clusters, in setback areas, and other areas to maintain access, safety, and visibility
- ☐ Monitor and control invasive plants
- ☐ Prune trees where necessary to maintain visibility and safety.

Potential for Stormwater Treatment

Trees planted at schools may be used to provide treatment of stormwater runoff since school grounds often have large open areas available for stormwater treatment practices. Depending on available space, site conditions, and runoff volume, the following types of practices may be used: stormwater wetlands, bioretention and bioinfiltration, swales, and filter strips. Trees can be incorporated into all of these treatment practices, and design guidance for each is provided in Part 2 of this manual series. Safety concerns may limit the use of stormwater wetlands or other practices with standing or deep water.

Further Resources

Martin, D., D. Lucas, S. Titman and S. Hayward. 1996. *The Challenge of the Urban School Site.* Green Brick Road. 800-471-3638. $27 Cdn.

Maryland State Department of Education. 1999. *Conserving and Enhancing the Natural Environment: A Guide for Planning, Design, Construction, and Maintenance on New and Existing School Sites*. Baltimore, MD.

National Wildlife Federation (NWF). 2001. *Schoolyard Habitats: A How To Guide for K-12 School Communities*. www./nwf.org/bookstore

Northeastern Illinois Planning Commission (NIPC). 1997. *Natural Landscaping for Public Officials*. Chicago, IL.

U.S. Fish and Wildlife Service (USFWS). Schoolyard Habitat Program. Online: www.fws.gov/r5cbfo/schoolyd.htm

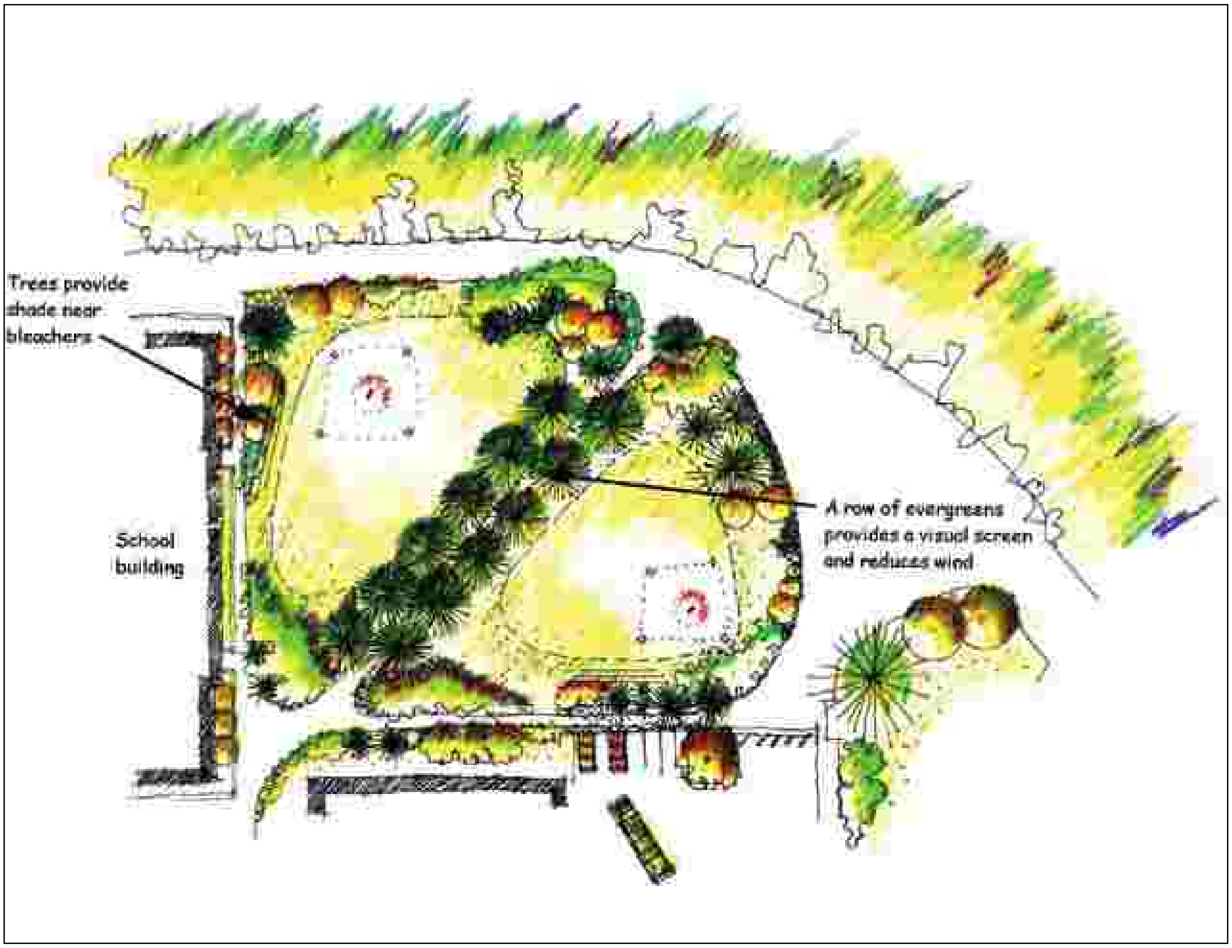


Figure 30. Planting trees on school grounds

Planting Trees in Stormwater Treatment Dry Ponds

Description

In urban areas, lands devoted to treating urban stormwater runoff and septic effluent can comprise up to 3% of the total land area in the watershed (CWP, 2000b). Stormwater dry ponds are one such type of land and are typically maintained as turf. Planting trees in existing dry ponds increases their esthetic value in the community (particularly if they are highly visible) and may increase pollutant removal. Few engineering constraints exist with planting trees in dry ponds as they may be planted anywhere within the practice.

Pre-Planting Considerations

- ☐ Can I make the pond more attractive with plantings?
- ☐ How do I prevent damage to trees from lawnmowers?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address soil conditions such as severe compaction and fluctuations in soil moisture?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates inundation
- ☐ Tolerates urban pollutants (sediment, nutrients, metals, bacteria, pesticides)
- ☐ Tolerates poor or compacted soils
- ☐ Has fall color, spring flowers, or other esthetic benefit.

Site Preparation

- ☐ Remove invasive plants such as multiflora rose (may include mowing or cutting)
- ☐ Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance

- [ ] Plant trees in groups to provide shared rooting space and allow mowing around trees to control invasive species
- [ ] Use groupings of species that provide fall color, flowers, evergreen leaves, and varying heights to create an esthetically pleasing landscape (Figure 31)
- [ ] When planting on pond side slopes, create small earthen berms around trees to help retain moisture.
- [ ] Where soils are compacted and amendments are not possible, provide adequate soil volume in planting hole.

Maintenance

- [ ] Plan for little maintenance of trees (regular watering may not be feasible)
- [ ] Mow around tree clusters to control invasive plants. Do not mulch deeper than 3 inches or build up mulch around trunks.
- [ ] Use mulch to retain moisture

Potential for Stormwater Treatment

A dry extended detention pond provides treatment of stormwater primarily through settling. After storms, stored runoff is gradually released over a period of 1 to 3 days, allowing an opportunity for pollutants to settle out to the floor of the pond. Trees may increase the pollutant removal ability of a dry pond through nutrient uptake.

Further Resources

Shaw, D. and R. Schmidt. 2003. *Plants for Stormwater Design*. Minnesota Pollution Control Agency. Saint Paul, MN.

Figure 31. Planting trees in storm water treatment dry ponds

Planting Trees Along Streams and Shorelines

Description

Trees planted along streams and shorelines provide many benefits, including regulation of stream temperature, stabilization of streambanks, enhancement of habitat for both aquatic and terrestrial species, and pollutant removal. The urban stream corridor is an ideal place for reforestation because of these many benefits, and because it often includes land that cannot otherwise be developed due to its location within the floodplain or inclusion of steep ravines. Three typical urban stream corridor scenarios and related reforestation goals are described below.

Natural forested stream buffer	Provides habitat for wildlife, stream shading, pollutant removal, large woody debris, leaf litter, bank stabilization
Landscaped buffer (residential backyards, parks, and other managed spaces)	Provides access to stream, passive recreation and water views for residents and park users, stream shading and bank stabilization, some pollutant removal
Highly modified buffer (ultra-urban channelized stream)	Provides beautification opportunities even though the forestable area may be limited. Daylighting or removal of impervious cover may increase tree planting opportunities.

Pre-Planting Considerations

- ☐ Do floodway regulations prohibit trees?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and utilities?
- ☐ Do I need to use different methods for planting trees on steep slopes?
- ☐ How do I address illegal dumping?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I address concerns about safety, nuisance rodents, weeds, esthetics, and wildlife?
- ☐ How do I address urban stream impacts, such as lowered baseflow?

Species Selection	Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions. Use large trees for small streams with shallow banks, and shrubs or small trees to provide stability for steep banks or larger streams with high flows. Mix canopy and understory species to create vertical structure. Other desirable species characteristics include the following: ☐ Tolerates inundation (although upland species may do well where the riparian zone is drying out) ☐ Wide, spreading canopy ☐ Provides food, cover, or nesting sites for wildlife.
Site Preparation	☐ Remove any trash or other illegally dumped material ☐ Remove invasive plants such as multiflora rose (may include mowing, cutting, or spraying with aquatic-use herbicide) ☐ Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).
General Planting Guidance	☐ Use three-zone buffer design (Welsch, 1991) with the following zones: streamside, middle, and outer. Each zone should have different vegetative targets, widths, and allowable uses that are progressively more restrictive as you move towards the stream (Figure 32). ☐ Focus on providing a forested strip immediately adjacent to the stream if land use limits reforestation of the entire site (Figure 33) ☐ Select a mix of stock so trees do not all die at the same time. Use larger trees next to the stream and seedlings elsewhere. Bare root stock may be easier for volunteers to plant and require less water. ☐ Random spacing is preferred but can make survival counts difficult ☐ If mowing between trees is necessary, provide enough space for mowers to avoid damaging trees.
Maintenance	☐ Design for little or no maintenance (watering may not be feasible) ☐ Use mulch to retain moisture. Do not mulch deeper than 3 inches or build up mulch around trunks. ☐ Use tree shelters to protect seedlings from deer ☐ Continually monitor for and remove invasive species (mowing in between trees may be necessary).

Potential for Stormwater Treatment

If stormwater runoff crosses the stream buffer in a pipe, potential for stormwater treatment is low. Runoff from adjacent land uses may be directed to the buffer as sheetflow for stormwater treatment. Linear stormwater treatment practices such as filter strips and bioretention may work best here, although depending on space available, stormwater wetlands could also be used. Guidance for incorporating trees into these practices is provided in Part 2 of this manual series.

Further Resources

Alliance for the Chesapeake Bay (ACB). 2002. *Pennsylvania Stream ReLeaf Forest Buffer Toolkit*. Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation.
www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/StreamReLeaf

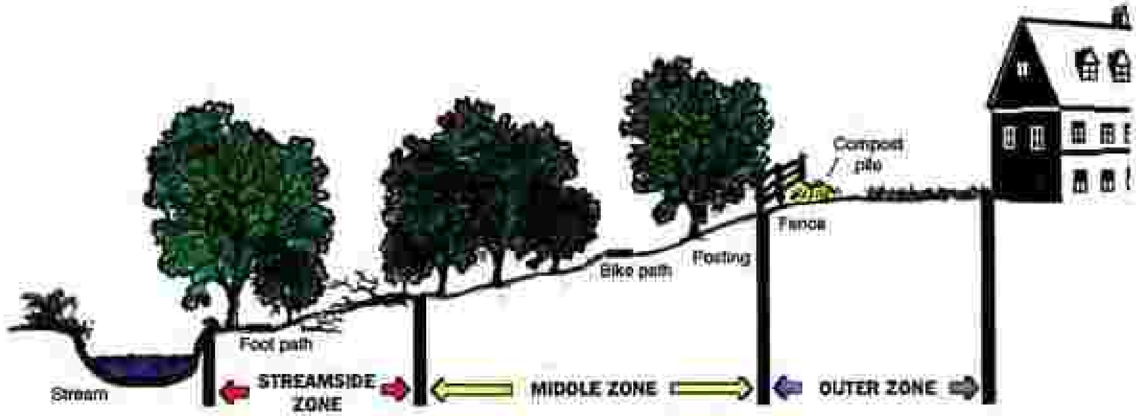
Native Plants by Region for Riparian Forest Buffers:
www.rce.rutgers.edu/njriparianforestbuffers/nativeALL.htm

Palone, R. and A. Todd. 1998. *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*. USDA Forest Service, Northeastern Area State and Private Forestry.
www.chesapeakebay.net/pubs/subcommittee/nsc/forest/handbook.htm

Schueler, T. 1995. *Site Planning for Urban Stream Protection*. Center for Watershed Protection and the Metropolitan Washington Council of Governments.

Standard for Riparian Forest Buffer from the New Jersey BMP Manual:
www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/chapter5_reparian_buffer.PDF

Welsch, D. 1991. *Riparian Forest Buffers – Function and Design for Protection and Enhancement of Water Resources*. 28 pp. USDA Forest Service NA-PR-07-91. Radnor, PA. www.na.fs.fed.us/spfo/pubs/n_resources/buffer/cover.htm



CHARACTERISTICS	STREAMSIDE ZONE	MIDDLE ZONE	OUTER ZONE
FUNCTION	Protect the physical integrity of the stream ecosystem	Provide distance between upland development and streamside zone	Prevent encroachment and filter backyard runoff
WIDTH	Min. 25 feet, plus wetlands and critical habitats	50 to 100 feet, depending on stream order, slope, and 100 year floodplain	25 foot minimum setback to structures
VEGETATIVE TARGET	Undisturbed mature forest. Reforest if grass	Managed forest, some clearing allowable	Forest encouraged, but usually turfgrass
ALLOWABLE USES	***Very Restricted*** e.g., flood control, utility right of ways, footpaths, etc.	***Restricted*** e.g., some recreational uses, some stormwater BMPs, bike paths, tree removal by permit	***Unrestricted*** e.g., residential uses including lawn, garden, compost, yard wastes, most stormwater BMPs

Figure 32. The three-zone stream buffer system (Source: Schueler, 1995, p. 111)

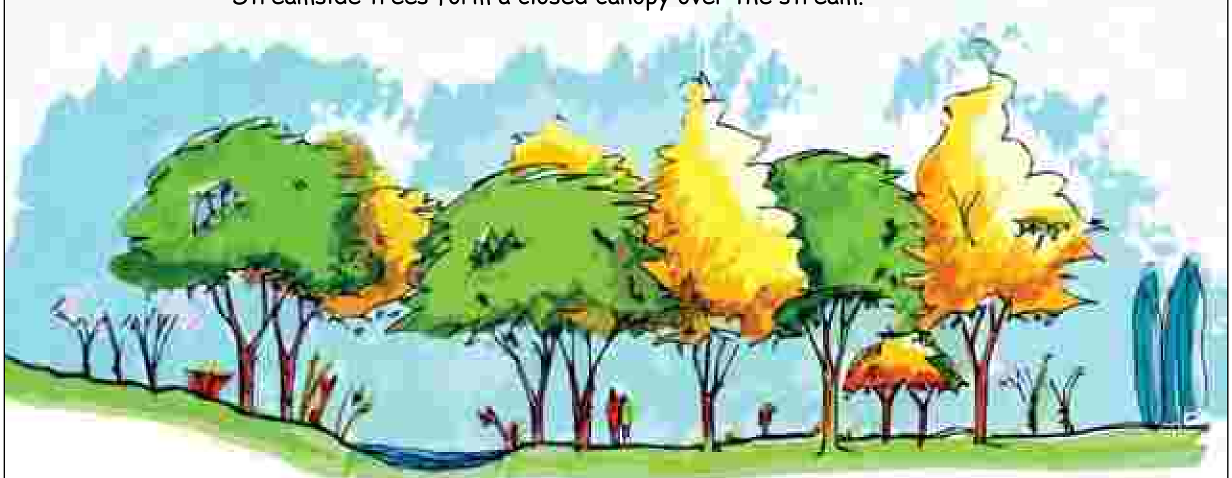


Figure 33. Planting trees along streams and shorelines

Planting Trees in Utility Corridors

Description

Utility corridors are linear features that contain power and gas transmission lines. These corridors can be up to 150 feet wide and contain above- and below-ground utility lines. Most utility corridors are privately owned; therefore, their reforestation potential will depend on the vegetation management policy of the utility company. Planting trees in utility corridors can create wildlife habitat corridors, and improves air quality, stabilizes soil, reduces runoff, and reduces air temperature.

Pre-Planting Considerations

- ☐ Do I have permission of utility company to plant trees?
- ☐ How do I address potential conflicts between trees and utilities?
- ☐ How do I manage invasive plants?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I provide maintenance access to utility structures and visibility for fly-over inspections?
- ☐ How do I address security concerns?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.
Other desirable species characteristics include the following:

- ☐ Is a shrub or small tree less than 10 feet high when mature
- ☐ Provides food, cover, or nesting sites for desired wildlife
- ☐ Tolerates drought (rainfall may be the only source of water)
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Tolerates urban pollutants and poor soils.

Site Preparation

- ☐ Clean up trash and other illegally dumped material
- ☐ Remove invasive or unwanted plants such as multiflora rose (may include mowing, cutting, or spraying with herbicide approved for aquatic use)
- ☐ Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance	☐	Do not plant trees or shrubs along gas transmission lines since canopy limits ability to inspect lines for leaks. Establish meadow vegetation instead.
	☐	Promote the growth of low-growing, shrub or scrub plant communities within electric transmission corridors. Do not plant trees greater than 10 feet mature height within 75 feet of electric transmission lines (Head and others, 2001). Instead, plant small trees, shrubs, or meadow vegetation (Figure 34).
	☐	Create soft edges between the utility corridor and adjacent vegetation by providing a gradual transition from herbaceous vegetation to shrubs to trees as you move away from the power lines. These edges provide a diversity of habitat for wildlife.
	☐	Provide setbacks from utility structures to provide maintenance access.
Maintenance	☐	Plan for minimal maintenance of trees and shrubs (watering may not be feasible)
	☐	Use mulch to retain moisture. Do not mulch deeper than 3 inches or build up mulch around trunks.
	☐	Monitor and control invasive plants
	☐	Use Integrated Vegetation Management (IVM) to maintain low-growing vegetative community (less than 10 feet in height). This includes mowing, hand removal of vegetation, and selective spraying of individual trees in early growing stage (Genua, 2000).
	☐	Where utility corridor crosses the stream, do not mow within 50 feet and use only herbicides approved for aquatic use.
Potential for Stormwater Treatment		Trees and shrubs planted in utility corridors may be used to provide treatment of stormwater runoff from nearby impervious surfaces. Linear stormwater treatment practices such as swales, bioretention, and filter strips are most applicable in a utility corridor. Perhaps the most appropriate use of trees for stormwater treatment in a utility corridor is a filter strip incorporating multiple vegetative zones to provide a gradual transition from herbaceous vegetation to trees. Design guidance for these practices is provide in Part 2 of this manual series.

Further Resources

Genua, S. M. 2000. *Converting Power Easements into Butterfly Habitats*. Potomac Electric Power Company (PEPCO). Online: www.butterflybreeders.org/pages/powerease_sg.html

Wildlife Habitat Council. Online: www.wildlifehc.org/spotlight/index.cfm

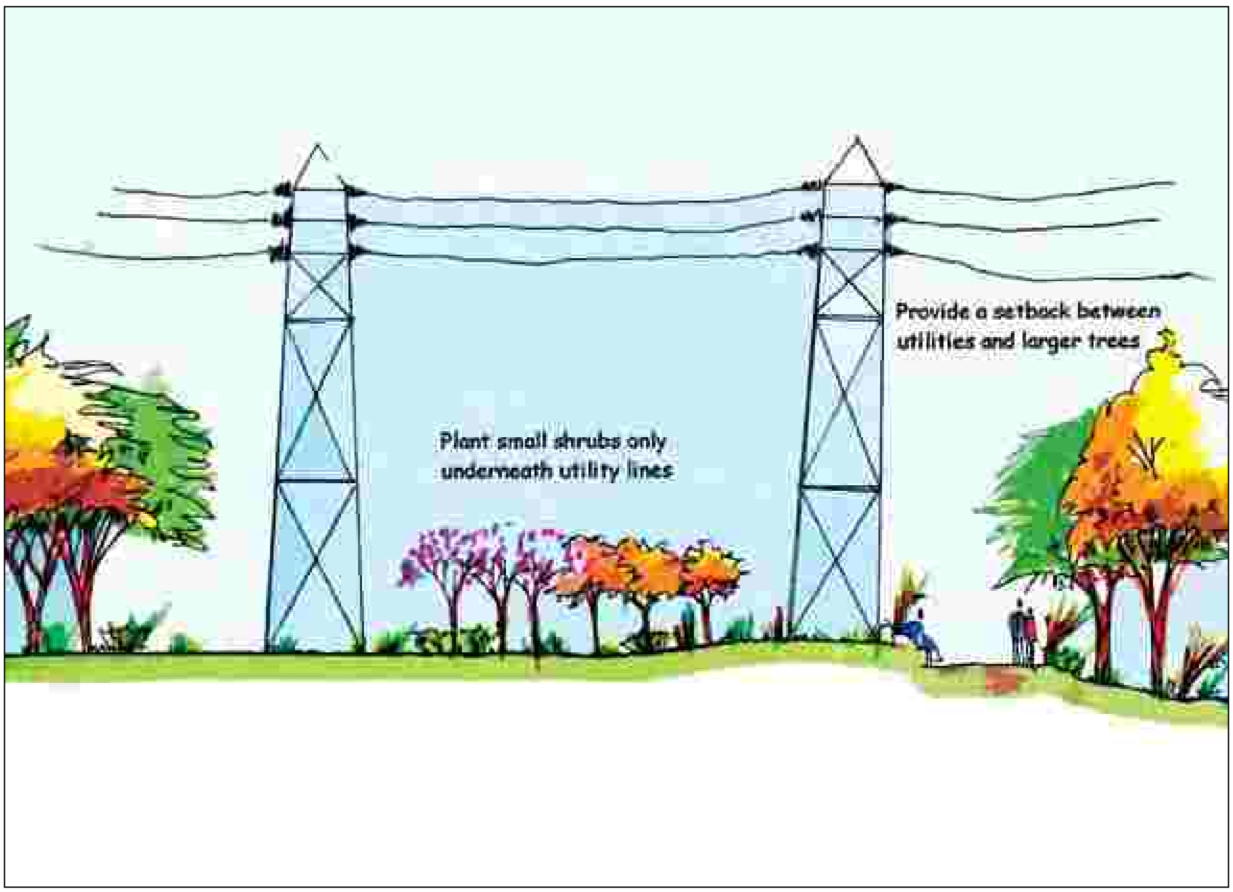


Figure 34. Planting trees in utility corridors

Planting Trees in Vacant Lots

Description

Many older urban areas have numerous vacant lots that cumulatively can increase watershed forest cover through reforestation. Planting trees in vacant lots can also provide much needed community green space for local residents. Other benefits of planting trees in vacant lots include wildlife habitat, shading, soil stabilization, improved air quality, and reduced stormwater runoff.

Pre-Planting Considerations

- ☐ Do I have landowner permission to plant trees?
- ☐ How do I address concerns about vandalism, crime, vagrants, visibility, and safety?
- ☐ Is there an opportunity to create wildlife habitat?
- ☐ How do I address illegal dumping?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and street lights, utilities, and pavement?
- ☐ How do I address soil conditions such as severe compaction, building rubble, and potential contamination?
- ☐ Is there an opportunity to provide a visual identity for the community?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates urban pollutants (lead)
- ☐ Tolerates poorly drained, compacted soils
- ☐ Tolerates alkaline soils
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Fast-growing
- ☐ Not an ornamental
- ☐ Provides food, cover, or nesting sites for birds, squirrels and other wildlife.

Site Preparation

- ☐ Clean up trash, rubble, or other illegally dumped material
- ☐ Remove invasive plants such as multiflora rose (may include mowing, cutting, or stump treatment)
- ☐ Bring in new soils or improve existing soil drainage (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance

- ☐ A defined edge shows the lot is being cared for. Install a border of street trees, fencing, or bollards around the perimeter to create this defined edge (Figure 35). Plant street trees or specimen trees around the perimeter of the site at spacing of 30-45 feet on center to allow mowing in between for invasive control.
- ☐ Provide clear sight lines around the site perimeter for pedestrian safety. This may involve mowing, limbing trees up to 6 feet, or planting only very low growing vegetation.
- ☐ Post signs, incorporate design elements into the site, and consider curb appeal to provide a visual identity for the community.
- ☐ Use trees to provide shade or screens where appropriate.
- ☐ Cluster trees in center of lot to provide shared rooting space and an even canopy, using species that grow at about the same rate so they do not shade each other out. Do not include turf in tree clusters. Instead, use mulch rings and mow around the clusters.
- ☐ Use small plant materials (e.g., seedlings, whips) where foot traffic is not an issue and larger stock elsewhere. Mix stock where both understory and canopy trees will be planted (e.g., use small understory stock and large canopy stock), or in tree clusters to protect seedlings (e.g., plant large stock around perimeter and seedlings in center).
- ☐ Install lighting and post signs to prevent illegal dumping and vandalism (Figure 36).
- ☐ Use tree cages or benches to protect trees from vandalism. Or plant species with inconspicuous bark or thorns to discourage vandalism (Palone and Todd, 1998).

Maintenance

- ☐ Plan for low maintenance of trees (frequent watering may not be feasible)
- ☐ Use mulch to retain moisture and protect trees from mowers and foot traffic. Do not mulch deeper than 3 inches or build up mulch around trunks.
- ☐ Mow around tree clusters, in setback areas, and other areas to maintain access, safety, and visibility
- ☐ Monitor and control invasive plants
- ☐ Prune trees where necessary to maintain visibility and safety.

Potential for Stormwater Treatment

Trees planted in vacant lots may be used to provide treatment of stormwater runoff if soils and the water table allow. Vacant lots may have significant area available for stormwater treatment practices, but if soils are highly disturbed and poorly drained, or water table is close to surface, treatment may be limited (or underdrain may be needed) to prevent soggy basements next door or standing water. Depending on available space, site conditions and runoff volume, the following types of practices may be used: stormwater wetlands, bioretention and bioinfiltration, swales, and filter strips. Trees can be incorporated into all of these treatment practices.

Further Resources

Palone, R. and A. Todd. 1998. *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*. USDA Forest Service, Northeastern Area State and Private Forestry. www.chesapeakebay.net/pubs/subcommittee/nsc/forest/handbook.htm

Pennsylvania Horticultural Society. 2002. *Reclaiming Vacant Lots*. Philadelphia, PA.

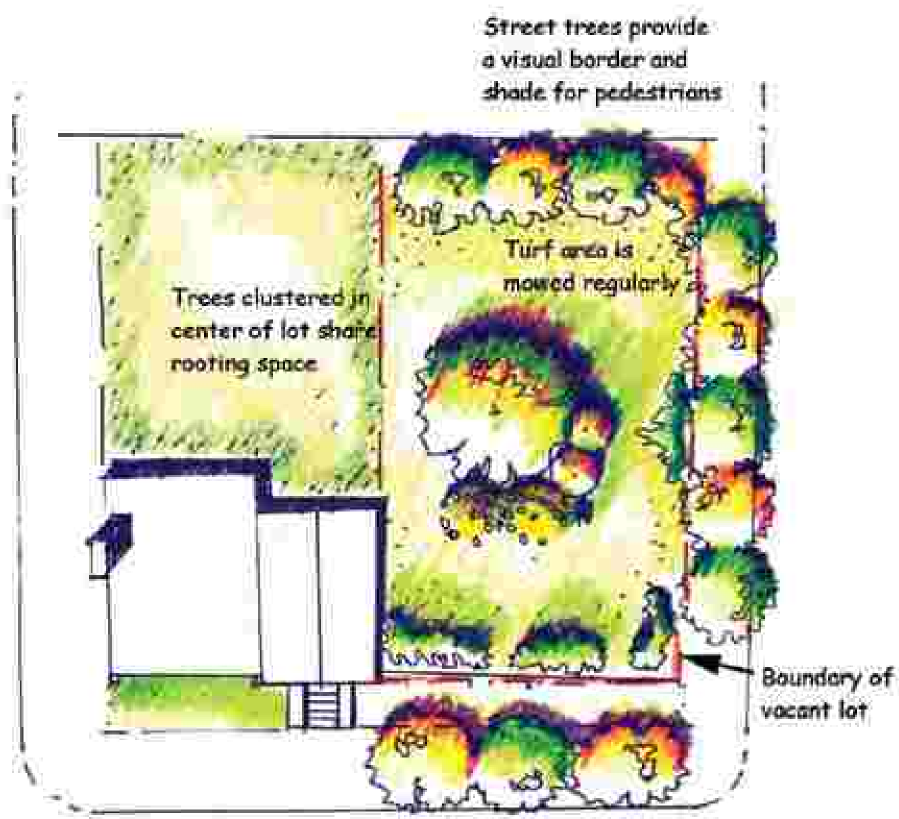


Figure 35. Planting trees in vacant lots—plan view

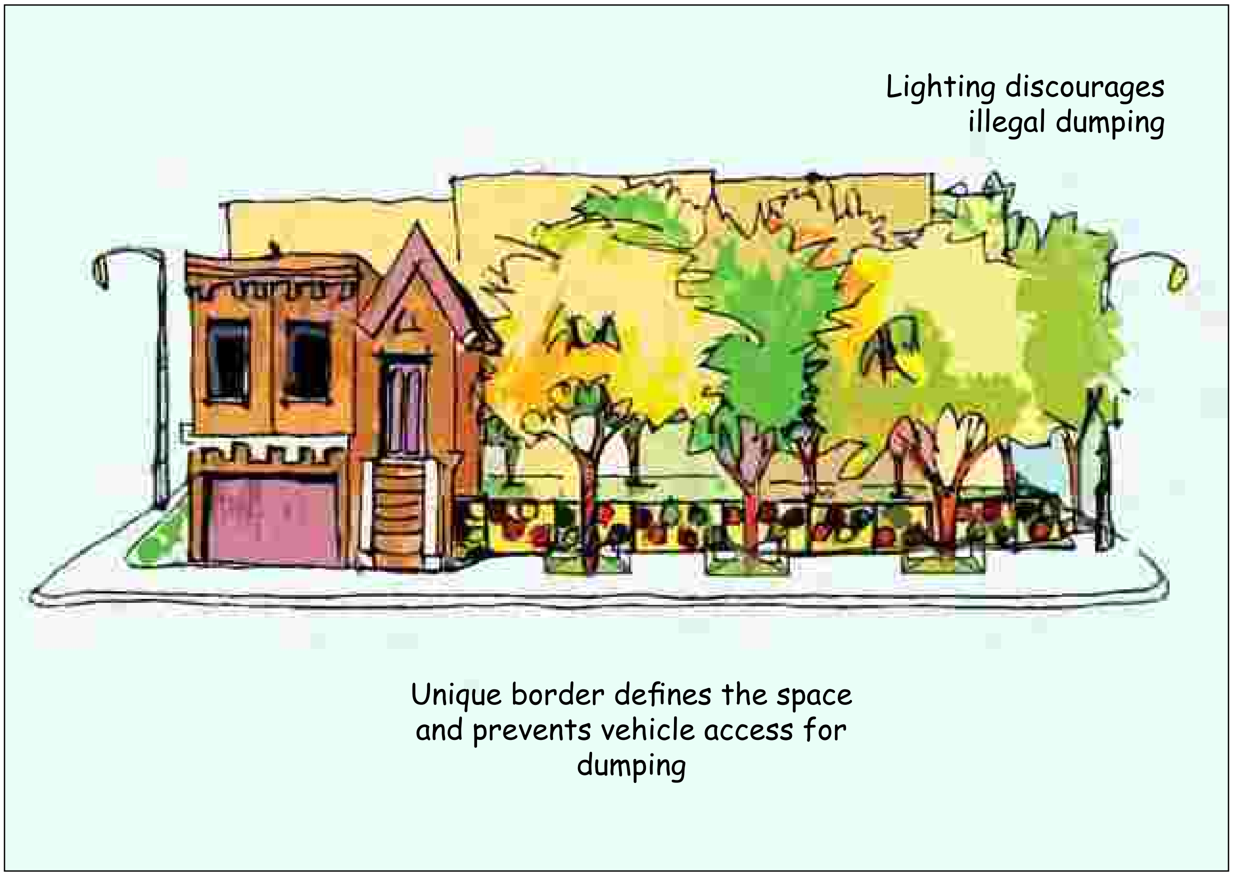


Figure 36. Planting trees in vacant lots--profile

Appendix A. Effect of Land Cover on Runoff and Nutrient Loads in a Watershed

Most urban watersheds are a mosaic of forest, turf, and impervious cover. Traditional monitoring efforts have been unable to distinguish the relative contribution of each type of cover to nutrient loading. With the advent of source area monitoring, however, it is now possible to estimate how much each cover type contributes to nutrient loading in urban watersheds.

As noted earlier, forest cover is the highest and best use of land in a watershed, in terms of reducing excess nutrient runoff. Forests act as a sink for nutrients and lock them up in live and dead biomass, as well as soils. As a result, measured nutrient concentrations in forest runoff are quite low (Table A-1). Turf, on the other hand, generates much higher nutrient levels, according to source area monitoring of both fertilized and unfertilized lawns. Impervious cover produces intermediate nutrient concentrations that reflect the washoff of nutrients deposited from the atmosphere, car exhaust, or household pets.

Table A-1. Median Nutrient Concentrations in Storm Water (milligrams per liter)		
Land Cover	Total Phosphorus	Total Nitrogen
Forest[1]	0.25	1.5
Turf[2]	1.90	9.7
Impervious[3]	0.40	1.9

[1]From Mostaghimi and others (1994) and USGS (1999).
[2]Grand mean of Garn (2002), Waschbusch and others (2000), Steuer and others (1997), and Bannerman and others (1993) turf runoff monitoring data.
[3]Grand mean of all reported impervious cover source area monitoring data in Table 19, page 59 of CWP (2003).

Nutrient concentrations are only part of the story. Forests act as a sponge for rainfall and produce very little, if any, storm water runoff. The forest canopy intercepts rainfall, and the remainder soaks into the forest floor. Forest monitoring has shown that less than 5% of rainfall falling on a forest is converted into runoff, which is referred to as the runoff coefficient:

Land Cover	Runoff Coefficient
Forest	[1]0.05
Turf	[2]0.10
Impervious	[3]0.95

[1]Measured runoff coefficient from Mostaghimi and others (1994).
[2]Average for B and C soil types from Legg and others (1996) and Pitt (1987).
[3]Regression of 40 sites nationally in Schueler (1987).

Turf cover, on average, has a runoff coefficient twice as high as forest, although the coefficient tends to vary considerably depending on the soil type, age, and compaction of the lawn (range = 0.05 to 0.30). As might be expected, nearly all the rain that lands on impervious cover is converted into storm water runoff.

The product of runoff volume and concentration yields the annual nutrient load (Table A-2). Clearly, forests are the most desirable form of watershed cover when it comes to nutrient loading. For example, an acre of turf is calculated to produce 15 times more nutrients than an acre of forest cover. The difference is even more significant when forest cover is compared with impervious cover—over 25 times more nitrogen and phosphorus are lost from impervious cover. The nutrient benefits of maintaining forest cover (or increasing it by converting turf to forest) can be impressive at the watershed scale.

Table A-2. Annual Nutrient Loads in Storm Water (pounds per acre per year)[1]		
Land Cover	Total Phosphorus	**Total Nitrogen**
Forest[2]	0.1	0.6
Turf[3]	1.6	7.9
Impervious[4]	2.8	14.7

[1]As computed by Simple method, 40 inches of annual rainfall, using EMCs and Rvs from part 1 and 2, Schueler (1987).

[2]Within range of measured loadings from Gardner and others (1996); Mostaghimi and others (1994); Blackburn and Wood (1990); and McClurkin and others (1985).

[3]No annual nutrient loading data for turf cover available for comparison.

[4]Within range reported by Schueler and Caraco (2002).

Appendix B. Sources of GIS Data for Watershed Forestry

One of the most important questions to ask when beginning mapping for small watershed restoration is "What GIS data is available for my watershed?" Typical data you will use for watershed forestry planning are listed in Table B-1.

Table B-1. Useful Mapping Data for Watershed Planning		
Category	Data Layers	
Hydrogeomorphic Features	• Topography • Perennial streams • Surface water features	• Wetlands • 100-yr floodplain • Soils
Boundaries	• Watershed boundaries • Subwatershed boundaries	• Municipal boundaries • Parcel boundaries
Land Use and Land Cover	• Aerial photos • Land use • Zoning • Impervious cover (roads, buildings, parking)	• Forest cover • Turf cover • Stream buffers • Protected land
Utilities	• Sanitary sewer lines • Storm drain network • Storm water treatment practices	• Storm water outfalls • Sewer service areas • Other utilities
Special Areas	• Historic and cultural sites • Rare, threatened or endangered species	• Other critical natural resource or conservation areas
Stream Condition	• Monitoring stations	• Impaired stream segments

Lack of available data can be a huge limitation in using GIS mapping for urban watershed restoration. Some GIS data is available free either online or from local sources, such as county planning offices, which are a great data resource. Two important pieces of data that are typically difficult to find or expensive to purchase are aerial photos and impervious cover layers. If the cost of purchasing high-resolution aerial photography is prohibitive, you may wish to hold off on purchasing any photos until you have chosen priority subwatersheds for further assessment. Then you can purchase just the aerial photos for those subwatersheds. Another option is using inexpensive lower resolution photos (Digital Orthophoto Quadrangles) from the U.S. Geological Survey. Impervious cover layers may not exist for your watershed but can be digitized from aerial photos or estimated based on land use. Online sources of GIS data and other products follow.

National Data

EPA Better Assessment Science Integrating point and nonpoint Sources (BASINS)
www.epa.gov/waterscience/basins/b3webdwn.htm Order CD (free) or download software from Web site. Contains various natural resource data, base map layers, environmental monitoring data (station locations), and point source data (Superfund sites, industrial facilities discharge sites, toxic releases).

EPA STORage and RETreival (STORET)
www.epa.gov/storet/ Repository for national water quality, biological and physical monitoring data. Includes a training exercise to help with downloading data and importing into Excel. Data is downloadable in tabular format and may be input into GIS.

EPA Watershed Assessments, Tracking and Environmental Results (WATERS)
www.epa.gov/waters/data/downloads.html
Download GIS layers of 303(d) listed waters (impaired waters) and 305(b) water quality assessments (monitoring data).

ESRI
www.esri.com/data/download/index.html
Contains a wealth of technical resources for GIS software, downloadable data layers, and downloadable GIS software called ArcExplorer.

Federal Emergency Management Agency (FEMA) Flood Map Store
www.msc.fema.gov/ordrinfo.shtml
Digital Q3 flood data available to order for $50 per county.

GIS Data Depot's GeoCommunity
http://data.geocomm.com
Download 1:24,000 Digital Elevation Models (DEMs), Digital Orthophoto Quadrangles (DOQs) and other data at state or county level for free or very low cost.

MapMart
www.mapmart.com
Download or order USGS products at very low cost, also order high resolution aerial photos and other data at reasonable cost.

National Atlas
www.nationalatlas.gov/atlasftp.html
Download various national data layers in the following categories: agriculture, biology, boundaries, climate, environment, geology, history, map reference, people, transportation, and water. May be useful for more obscure layers such as extent of invasive species habitat.

National Wetlands Inventory (NWI)
http://wetlands.fws.gov/downloads.htm
Download wetlands data. NWI is available digitally for 40% of the conterminous United States.

Natural Resources Conservation Service (NRCS) State of the Land
www.nrcs.usda.gov/technical/land/aboutmaps/coverages.html
Download 8-digit Hydrologic Unit Code (HUC) watershed boundaries and various other boundary layers such as counties, Federal lands, and congressional districts.

NRCS State Soil Geographic Database (STATSGO)
www.ftw.nrcs.usda.gov/stat_data.html
Download soil layers for U.S. states. This layer is most useful for counties with no SSURGO data available.

NRCS Soil Survey Geographic Database (SSURGO)
www.ftw.nrcs.usda.gov/ssur_data.html
Download soils layers for counties. Not available for all counties.

Space Imaging
www.spaceimaging.com
Purchase high-resolution Ikonos satellite imagery. Can be very expensive.

U.S. Bureau of the Census Topologically Integrated Geographic Encoding and Referencing System (TIGER)
www.census.gov/geo/www/tiger/index.html
Download TIGER/Line files from the year 2000 and earlier by state. These files include roads, railroads, rivers, lakes, legal boundaries, and census statistical boundaries. Requires special conversion tools to use in GIS.

USGS Geographic Data Download
http://edc.usgs.gov/geodata
Download the National Hydrography Dataset, 1:24,000 Digital Line Graphs and national scale Land Use/Land Cover, Digital Elevation Models, and Digital Line Graphs. Contains information on obtaining other USGS map products.

USGS Seamless Data Distribution
http://seamless.usgs.gov/website/Seamless/
Download high-resolution orthophotos, National Elevation Dataset, National Land Cover Database, and various other layers using interactive map.

USGS Earth Explorer
http://edcsns17.cr.usgs.gov/EarthExplorer/
Purchase reasonably priced satellite imagery, aerial photos, Digital Line Graphs, elevation data, and Digital Raster Graphics.

Chesapeake Bay Regional and Local Data

Canaan Valley Institute
http://canaanvi.org/gis/gis_links.asp
Contains links to downloadable GIS layers for Maryland, Pennsylvania, West Virginia, and Virginia.

Chesapeake Bay Program FTP Site
ftp://ftp.chesapeakebay.net/pub/Geographic/
Download Arc/Info export files for the Mid-Atlantic, Chesapeake Bay, or individual states, including hydrography, land cover, political boundaries, transportation and watershed boundaries (HUC 8, HUC 11).

Chesapeake Bay Program (CBP) Resource Lands Assessment
www.chesapeakebay.net/rla.htm
Download Bay-wide GIS data results of CBP model scenarios. Data includes ranking of lands by importance to: Prime Farmland, Ecological Network, Water Quality Protection, Forest Economics, Cultural Assessment and Vulnerability to Development.

Maryland Department of Natural Resources Geospatial Data
http://dnrweb.dnr.state.md.us/gis/data/data.asp
Download 4-meter Digital Orthophoto Quadrangle Quarters (DOQQs), floodplains, wetlands, protected lands, and other data layers for Maryland by county.

Pennsylvania Spatial Data Access
www.pasda.psu.edu/
Download various GIS layers for Pennsylvania by county or watershed.

Radford University Department of Geography Geoserver
www.radford.edu/~geoserve/main_page.html
Contains downloadable Digital Raster Graphics and Digital Elevation Models for Virginia, Maryland, Washington, DC, and West Virginia.

Towson University Center for GIS
http://chesapeake.towson.edu/data/download/
Download satellite imagery and other GIS data for the northeastern United States.

West Virginia GIS Data Clearinghouse
http://wvgis.wvu.edu/data/data.php
Download various GIS layers for West Virginia.

Mapping Tools

EPA Surf Your Watershed
www.epa.gov/surf/

Terraserver
www.terraserver.com

TIGER Map Service
http://tiger.census.gov/cgi-bin/mapbrowse-tbl

Appendix C. Methods for Deriving Land Cover Coefficients

This Appendix describes the general methods to derive land cover coefficients for use in the Leafout Analysis. Table C-1 presents impervious cover coefficients for various land uses, for four urban and suburban counties in the Chesapeake Bay Watershed: James City County, VA, Baltimore County, MD, Howard County, MD, and Lancaster County, PA (Cappiella and Brown, 2001). These coefficients can be generalized beyond the individual counties in which they were derived, and they are broadly transferable to other Chesapeake Bay communities with similar development patterns.

Table C-1. Impervious Cover Coefficients

Land Use Category	Number of Samples	Mean Impervious Cover (%)
Agriculture	8	2
Open Urban Land	11	9
2-Acre Lot Residential	12	11
1-Acre Lot Residential	23	14
½-Acre Lot Residential	20	21
¼-Acre Lot Residential	23	28
⅛-Acre Lot Residential	10	33
Townhome Residential	20	41
Multifamily Residential	18	44
Institutional	30	34
Light Industrial	20	53
Commercial	23	72

Source: Cappiella and Brown (2001)

The methods used to derive these impervious cover coefficients are described below. These methods can be modified for use in deriving land cover coefficients for forest or turf.

Methodology

The primary question investigated in this study was this: What is the impervious cover level of various land uses at the development level and at the zoning area level? A specific sampling protocol was needed to address this and other questions. The following major steps comprised the protocol:

Step 1. Select the targeted land use categories and number of sampling units.
Step 2. Delineate land use polygons.
Step 3. Measure impervious cover.

Step 1. Select the Targeted Land Use Categories and Number of Sampling Units

Table C-2 lists the selected land use categories and number of sampling units chosen, as well as a description of each land use category. These categories were chosen based on typical zoning categories within the Chesapeake Bay Region, as well as the variety of land uses within the study areas. In addition, there was a direct attempt to target and derive impervious cover coefficients for land uses that had little or no previous research associated with it (e.g., open urban land, institutional land).

Table C-2. Selected Land Use Categories and Sampling Target		
Land Use	Description	Sample Units
Agriculture	Cropland and pasture lands	10
Open Urban Land	Developed park land and recreation areas, golf courses, and cemeteries	10
Residential		
2-Acre Lots	Ranges from 1.70 to 2.30 acres	10
1-Acre Lots	Ranges from 0.75 to 1.25 acres	20
½-Acre Lots	Ranges from 0.40 to 0.60 acres	20
¼-Acre Lots	Ranges from 0.20 to 0.30 acres	20
⅛-Acre Lots	Ranges from 0.10 to 0.16 acres, includes duplexes	10
Townhomes	5-10 units/acre, attached single family units that include a lot area	20
Multifamily	10-20 units/acre, residential condominiums and apartments with no lot area associated with the units	10
Light Industrial	Developed areas associated with light manufacturing, distribution, and storage of products	20
Commercial	Areas primarily used for the sale of products and services including strip malls and central business districts, does not include regional malls	20
Institutional		
Churches	Churches and other places of worship	10
Schools	Public and private elementary, middle, and high schools	10
Municipal	Hospitals, government offices and facilities, police and fire stations	10
Total		200

The number of polygons sampled for each land use were chosen based on the frequency and variability of land uses or zoning categories. For example, over 120 sample polygons were needed to characterize the range of housing densities within residential zoning. Given the limited resources available for the study, sample targets were kept to 10 or 20 for each land use. Rigorous statistical analysis was conducted to demonstrate that the sample size would still yield information, particularly across certain land use types. Standard statistics of the results, such as the standard error, were used as measures of the reliability of the results. Based on this study design, between two and five polygons were sampled for each land use within each jurisdiction.

Step 2. Delineate Land Use Polygons

The criteria used when selecting land use polygons in the GIS are listed below.

For single family residential polygons:

- For residential land uses, the parcel boundary information was used to first classify parcels based on acreage (shown in the description in Table C-2). Development patterns that most closely matched the land use category (e.g., ¼-acre lots) were selected for sampling. Because most subdivisions do not have uniform lot sizes, subdivisions were selected if the majority of lots or average lot size met the general criteria for the land use category.
- Because of difficulty in finding subdivisions that met the above criteria for polygon delineation, no minimum area was set for the polygon size for residential areas. Instead, it was decided that each residential polygon must include a minimum of five lots.
- Polygons were drawn by following the lot lines of contiguous parcels and excluding areas of "unbuildable" land located in the interior of the polygon. Stream valleys that did not originate within the subdivision were excluded from the land use polygons, as were other "unbuildable" lands, such as floodplains, wetlands, and conservation areas. The basis behind this rule is that not all development sites include these types of characteristics. When predicting future impervious cover, a planner could estimate the areas based on existing mapping and based on local codes and ordinances that determine "unbuildable" acreage. This acreage could then be removed from the total acreage of the planning area.

For other land use polygons:

- Stormwater ponds and open water were not considered to be impervious cover because they generally occupy a small area and are not always associated with a single land use. While water surfaces do act as impervious surfaces in a hydrologic sense, they generally do not have similar consequences on stream quality, watershed health, or pollutant loading, as do more conventional types of impervious cover, such as roads, parking lots, and rooftops.
- Minimum lot sizes were set for agriculture (50 acres), commercial (1 acre), industrial (5 acres), and multifamily (5 acres) categories.

Once a development area was selected, generally the following criteria were used to delineate the polygons:

- Parcel lines were used as guides for drawing the polygon boundaries.
- "Unbuildable" land, such as floodplains, steep slopes, and conservation areas, were not included in the polygons.
- Subdivision lots that were not built out were not included in the polygons.
- Large forested areas located outside parcel boundaries were not included in the polygons.
- Local and arterial roads were included in the polygons if the parcels bordering each side of the road had the same land use.
- If a local or arterial road bordering a parcel had a different land use bordering the other side of the road, only half the road was included in the polygon.

- Interstate and state highways were not included in the polygons.
- Parcel data, such as a business or owner name, was used to verify the land use.
- Orthophotos were also used to verify the land use.

Step 3. Measure Impervious Cover

The methods used to calculate impervious cover are listed below. More specific details on using ArcView for this process are provided in Cappiella and Brown (2001). The general impervious cover calculation steps are as follows:

1. Set up a project in ArcView that includes each impervious cover theme, digital orthophotos, and parcel data.
2. Create a new theme for each land use and digitize polygons based on criteria.
3. Check the polygons against the orthophotos.
4. Calculate the acreage of each polygon in its corresponding data table.
5. Intersect each land use polygon with each impervious cover theme (e.g., commercial roads, commercial parking lots, commercial buildings).
6. Calculate the area of each impervious cover type for each land use polygon.
7. Export the data tables to Excel and sum impervious cover within each polygon and divide by polygon area to get percent impervious cover.

Assumptions

Although the methods used provide an accurate direct measure of impervious cover, there were some assumptions made due to lack of data. Specifically, residential driveways and sidewalks were estimated using the orthophotos for Lancaster County, Baltimore County, and James City County. Using the orthophotos as a guide, a parking lot layer was created for James City County, and a parking lot layer and roads layer were created for Howard County. Additionally, an impervious cover theme was digitized for each jurisdiction that represented any impervious surface not included in the other layers, such as tennis courts, garages, and other paved areas. The major assumptions made for the analysis are listed and described below.

For single family residential polygons:

Sidewalk Estimation

Orthophotos were used to measure the length of sidewalks in each polygon, which was then multiplied by 4 feet (assumed sidewalk width). The resulting numbers were added to the data table for calculation of total impervious cover.

Driveway Estimation

Orthophotos were used to determine an average driveway size for each polygon, which was then multiplied by the number of homes within the polygon. The resulting numbers were added to the data table for calculation of total impervious cover.

For other land uses:

Parking Lots

James City County, VA, was the only jurisdiction without a parking lot layer. Therefore, a parking lot layer was created for the chosen land use polygons, and this layer was included in the processing and calculation of total impervious cover.

Other Impervious Surfaces

Orthophotos were used to digitize an impervious cover layer that included tennis courts, garages, and other impervious surfaces not included in the buildings, parking lots, roads, driveways, or sidewalks layers. This impervious cover layer was included in the processing and calculation of total impervious cover.

Appendix D. Sources of Data for Forest Cover Coefficients

The Leaf-Out Analysis method described in Chapter 2 requires the input of forest cover coefficients that represent the fraction of land that is forest for a given land use. Data is currently lacking for forest cover coefficients; however, it can be assumed that the amount of forest cover for a given land use will vary with development intensity, age of development, prior land use, and local forest conservation or natural resource protection regulations. In Table 5 in Chapter 2, the forest cover coefficients presented for the Direct Forest Conservation Scenario were loosely based on the Maryland Forest Conservation Act Forest Cover Requirements shown in Table D-1.

Table D-1. Maryland Forest Conservation Act Forest Cover Requirements (Source: Greenfeld and others, 1991)

Land Use	Recommended % Forest Cover
Agricultural and Resource Areas	20-50
Medium Density Residential	20-25
Institutional	15-20
High Density Residential	15-20
Mixed Use and Public Utility District	15
Commercial and Industrial	15

Other potential sources of data for forest cover coefficients were found for Baltimore, MD, the Philadelphia/New Jersey Metropolitan area, Garland, TX, and Brooklyn, NY. These data came from American Forests CITYgreen analyses and the USDA Forest Service, Northeastern Research Stations's Urban Forest Effects (UFORE) model. These data are presented in Tables D-2, D-3, D-4 and D-5.

Table D-2. Baltimore, MD, Urban Forest Effects (UFORE) Analysis (Source: Nowak and others, 2002a)

Land Use	% Tree Cover
Forest	59.3
Urban Open	48.8
Commercial and Industrial	11.8
Medium and Low Density Residential	32.4
High Density Residential	22.2
Institutional	12.4
Transportation	10.0
Barren	0.8

Table D-3. Philadelphia/New Jersey Metro Area CITYgreen Analysis (American Forests, 2003)	
Land Use	% Tree Cover
Single Family Residential	20
Commercial	2
Multi Family Residential	25
Industrial	6
Transportation	8

Table D-4. Garland, TX, Metro Area CITYgreen Analysis (American Forests, 2000)	
Land Use	% Forest Cover
Medium Density Residential	26
Low Density Residential	13
High Density Residential	7
Commercial	1
Industrial	4

Table D-5. Brooklyn, NY, Urban Forest Effects (UFORE) Analysis (Nowak and others, 2002b)	
Land Use	% Forest Cover
Open Space	21.4
One and Two Family Residential	17.0
Vacant	2.8
Multi-Family Residential	9.2
Public Facilities	8.7
Commercial/Industrial	1.9

Further research is needed to examine relationships between forest cover for various land uses and factors, such as prior land use, age of development, and local conservation regulations, in order to develop more accurate forest cover coefficients that can be applied in the Leaf-out Analysis.

Appendix E. Blank Worksheet for Leaf-Out Analysis

Leaf-Out Analysis Worksheet For Estimating Future Forest Cover in a Watershed

Section 1. Future Forest Cover

Current Protected or Developed Forest Cover:			acres
All protected or developed forest will remain forested.		+	
Priority Forest Area Protected			acres
See section 2 of this worksheet. Default value is zero.		+	
Area of Forest Conserved During Development			acres
See section 2 of this worksheet.		+	
Area Reforested			acres
Default value is zero.		=	
Total Future Forest Cover			acres

Section 2. Forest Conserved During Development

Zoning Category	Buildable Forest (acres)		Priority Forest Protected (acres)		Buildable Forest Remaining (acres)		Forest* Cover Coefficient		Forest Conserved During Development (acres)
Agriculture		-		=		×		=	
Open urban land		-		=		×		=	
2 acre residential		-		=		×		=	
1 acre residential		-		=		×		=	
½ acre residential		-		=		×		=	
¼ acre residential		-		=		×		=	
⅛ acre residential		-		=		×		=	
Townhomes		-		=		×		=	
Multifamily		-		=		×		=	
Institutional		-		=		×		=	
Light industrial		-		=		×		=	
Commercial		-		=		×		=	
Total									

** Use forest cover coefficients that represent forest conservation requirements in your area*

continued

Section 3. Results Summary

Total Current Forest Cover		acres		
	-			
Total Future Forest Cover		acres		
From Section 1 above.	=			
Future Forest Loss		acres		%

Appendix F. Resources for Setting Urban Canopy Goals

In this manual, numerical goals are recommended for forest cover (or, ideally, canopy cover) in urban watersheds. Chapter 2 provides some general guidelines as to what these numerical goals should be for different types of watersheds. These recommendations are based on the data summarized below and should be tailored to the needs of each community.

The first recommendation made in Chapter 2 was to set a numerical target for forest cover for the entire community. Table E-1 lists various canopy goals for metropolitan areas. The 40% goal set by American Forests (2003) is used by a number of communities. This recommendation comes from extensive analysis of urban tree coverage. American Forests measured tree cover in 440 communities and found that most communities in the southeastern United States have more than 60% canopy cover. The potential for tree cover in urban areas was determined to be 60% to 80% canopy cover. Therefore, the 40% goal should be attainable for most communities. Different goals are recommended for metropolitan areas in the southwest and dry west. Total tree cover for these areas should be 25%, while residential areas should have 18% to 35% and commercial areas should have 9%. These are general guidelines only, and each community should set goals that take into account the specific characteristics of their area (American Forests, no date).

Across the United States, tree canopy cover currently falls below this 40% threshold, averaging 27% in urban areas and 33% in metropolitan areas (Dwyer and Nowak, 2000). The Urban Forest Effects (UFORE) web site provides data on current canopy cover for 21 U.S. cities that may be used as a starting point for developing community forest cover targets: www.fs.fed.us/ne/syracuse/Data/data/htm.

Table F-1. Forest Canopy Goals for Metropolitan Areas

Source	Forest Canopy Goal (% cover)
American Forests (2003)	40*
Nowak and O'Connor (2001)	30
USDA Forest Service (1993)	50

*American Forests recommends 40% canopy cover for metropolitan areas east of the Mississippi and the Pacific Northwest.

To date, we are not aware of any communities that have set a numerical target for forest cover at the watershed scale; however, the two studies summarized in Table F-2 do provide a preliminary basis for the recommendations made in Chapter 2. Further research is needed to make more specific forest cover recommendations for urban watersheds.

Table F-2. Forest Canopy Goals for Watersheds

Source	Forest Canopy Goal (% cover)	Summary
Booth (2000)	65	Watersheds with at least 65% forest cover usually had a healthy aquatic insect community (Puget Sound, WA, region)
Goetz and others (2003)	45	Watershed tree cover greater than 45% was correlated with good and excellent stream health, as measured by biological indicators (Montgomery County, MD)

The most extensive data found on canopy goals included recommendations for canopy cover for individual land uses. This is important because although goals may be defined for a larger area such as a watershed or city, the implementation of these goals will often occur at the site level. Table F-3 summarizes recommended or adopted canopy goals for various zoning categories.

Table F-3. Forest Canopy Goals for Various Zoning Categories

Source	Forest Canopy Goal (% cover)			
	Residential	Commercial/ Industrial/ Institutional	Streets and Rights-of-Way	Natural Areas and Stream Corridors
American Forests (2003)	25-50	15	None	None
Botetourt County, VA (2002)	15	10	None	None
City of Chesapeake, VA (2002)	15-20	10	None	None
City of Georgetown, TX (2002)	None	10-25	None	None
City of Manassas, VA (2002)	15-20	10	None	None
City of Suffolk, VA (2002)	10-20	10	None	None
Fauquier County, VA (2002)	15	10	None	None
Georgia Department of Community Affairs (2002)	20	15	None	None
Goetz and others (2003)	None	None	None	65
Greenfeld et al. (1991)	15-25	15-20	None	20-50
Head et al (2001)	40-60	0-40	None	70
Jefferson County, KY (2002)	10-20	0-15	None	None
Portland, OR, Parks and Recreation (2003)	35-40	15	35	30
Prince William County, VA (2002)	10-20	10	None	None
Smithfield County, VA (1998)	10-20	10	None	None
USDA Forest Service (1993)	None	None	50	None

Meteorological models have also been used in determining realistic goals for canopy cover (Luley and Bond, 2002). Table F-4 summarizes the results of one such model (MM5) in estimating current forest cover, proposed (realistic) forest cover, and the maximum possible forest cover for three urban land uses in the New York City area.

Table F-4. Existing, Proposed and Maximum Tree Cover for Urban Land uses Based on a Meteorological Model (Source: Civerolo and others, 2000)			
Land Use	Forest Cover %		
	Existing	Proposed	Maximum
Commercial, Industrial and Transportation	14	24	48
Low-Density Residential	33	43	68
High-Density Residential	25	35	41

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Urban Watershed Forestry Manual

Part 2: Conserving and Planting Trees at Development Sites

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Urban Watershed Forestry Manual

Part 2. Conserving and Planting Trees at Development Sites

Second in a Three-Part Manual Series on Using Trees to Protect and Restore Urban Watersheds

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ABOUT THIS MANUAL SERIES

This manual is the second in a three-part series on using trees to protect and restore urban watersheds. A brief description of each part follows.

Part 1. Methods for Increasing Forest Cover in a Watershed introduces the emerging topic of urban watershed forestry. This part also presents new methods for the watershed planner or forester, to systematically measure watershed forest cover and select the best methods for maintaining or increasing this cover by protecting, enhancing, and reforesting large parcels of primarily public land across the watershed. These methods are based on extensive review of the latest research and input from experts in a wide range of related fields.

Part 2. Conserving and Planting Trees at Development Sites presents specific ways to enable developers, engineers, or landscape architects to incorporate more trees into a development site. The proposed approach focuses on protecting existing trees, planting trees in storm water treatment practices, and planting trees in other open spaces at a development site. This part introduces conceptual designs for storm water treatment practices that utilize trees as part of the design (referred to as storm water forestry practices.) These designs were developed with input from experts in storm water engineering, forestry, and a range of related fields.

Part 3. Urban Tree Planting Guide provides detailed guidance on urban tree planting that is applicable at both development site and watershed scales. Topics covered include site assessment, planting design, site preparation and other pre-planting considerations, and planting and maintenance techniques. An Urban Tree Selection Guide is included for use in selecting the best tree and shrub species for the planting site.

Urban watershed forestry is a new practice that draws from multiple disciplines, including forestry, hydrology, engineering, landscape architecture, mapping, planning, and soil science. Consequently, some ideas drawn from each discipline have been simplified in this manual series in order to be easily understood by a diverse audience. In addition, the latest and most relevant research from each discipline has been used to support the new practice. The research summarized in these manuals, however, is not intended to provide a comprehensive literature review.

This manual series draws heavily upon research and examples from the Chesapeake Bay watershed and the northeastern region of the United States. The manuals primarily apply to these regions, and may also apply in other humid regions of the country where the natural vegetative cover is predominately forest. Finally, several elements in the manuals are brand new and will require additional testing, research, and analysis. We welcome future additions to the methodology, techniques, and designs presented.

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Acronyms Used

CRZ	Critical root zone
FSD	Forest stand delineation
HOA	Homeowners' association
IVM	Integrated vegetation management
LOD	Limits of disturbance
SFP	Storm water forestry practice
STP	Storm water treatment practice

Chapter 1: Introduction

The purpose of this manual is to present specific strategies and practices that developers, engineers or landscape architects can use to incorporate trees into the design of development sites. This manual outlines three approaches for doing so:

1. Conserving existing trees during construction
2. Integrating trees into storm water treatment practices
3. Planting trees along local roads and in parking lots

Developers, contractors, and landscape architects can conserve and plant trees at new development and redevelopment or infill projects. On forested sites, it is most important to conserve existing forests, particularly high quality stands or large, mature trees (Figure 1). To conserve existing forests, developers should inventory the site to identify the best forested areas to protect, design the development to prevent loss of these trees, and take measures to ensure the protection of remaining trees during and after construction.

Where tree conservation is not an option, development sites provide many opportunities to plant new trees, such as in storm water treatment practices (STPs) and other pervious areas of the site. STPs treat storm water runoff by capturing and temporarily detaining water, allowing pollutants to settle out before entering local receiving waters. While some STPs are not traditionally considered appropriate for tree planting, incorporating trees and shrubs in certain areas of STPs can enhance their esthetic appeal and improve their performance. For the purposes of this manual, STPs that incorporate trees into their design are referred to as **storm water forestry practices (SFPs)**.

The remaining pervious areas of a site that are good but often overlooked candidates for tree planting include local road rights-of-way, landscaped islands in cul-de-sacs or traffic circles, and parking lots. Private lawn areas may also constitute a significant portion of green space at development sites, and developers should certainly strive to conserve or plant trees in lawns as well. Many development sites may have harsh soil and environmental conditions that need to be overcome through appropriate tree selection and proper site preparation before planting.

Figure 1. Large tracts of forest (left) and mature trees (right) can be conserved during development.
Photos: Left—Maryland Department of Natural Resources; Right—District of Columbia Department of Forestry

Why Conserve and Plant Trees at Development Sites?

Conserving or planting trees can address forest conservation, landscaping, or other site design requirements. Forest conservation and tree planting enhance the appeal of a development, increase land and housing values, and can reduce costs for construction and storm water management. Trees also provide a wide range of environmental, economic, and community benefits (such as air and water quality improvement, reduction of storm water runoff, and wildlife habitat). These additional benefits of trees at development sites are summarized below.

BOX 1. BENEFITS OF TREES AT DEVELOPMENT SITES

Economic benefits
- Decrease heating and cooling costs
- Reduce construction and maintenance costs
- Increase property values
- Positively influence consumer behavior

Community benefits
- Improve health and well-being
- Provide shade and block ultraviolet radiation
- Buffer wind and noise

Environmental benefits
- Reduce urban heat island effect
- Enhance function of STPs

Benefits of Trees at Development Sites

Part 1 of this manual series summarizes urban forest benefits that affect watershed health. This part reviews the benefits that urban trees provide at the parcel scale, particularly those realized by the developer or homeowner. An important note is that some benefits may not be fully realized until the trees reach maturity. Benefits of trees at development sites are listed in Box 1.

Economic benefits

The values of houses in neighborhoods with abundant trees are usually higher than those of comparable houses in neighborhoods without trees (Morales, 1980; Morales and others, 1983; Anderson and Cordell, 1988) (Table 1 and Figure 2). Neighborhood natural areas also increase the value of properties located nearby (Kitchen and Hendon, 1967; More and others 1983; Correll and others, 1978) (Table 1). Additional cost benefits to the developer and ultimately the homeowner can result from conserving existing trees at a development site. Tree conservation can reduce the amount of clearing and grading, paving, and storm water management needed at sites, reducing infrastructure costs as well as reducing mowing costs in the future. Table 1 summarizes the economic benefits of trees at development sites.

Figure 2. Healthy trees can increase property values and aid home sales.

Table 1. Economic Benefits of Trees at Development Sites		
Benefit	**Supporting Information**	**Source**
Decrease heating and cooling costs	• Properly placed trees can reduce heating and cooling costs by 10% to 20% on average within 10-15 years after planting • Trees properly planted next to buildings can reduce summer air conditioning costs by 40%. Direct shading of an air conditioner can increase efficiency up to 10% • Energy use in a house with a treed lot can be 20% to 25% lower per year than for the same house in an open area	Heat Island Group (1996) Parker (1983) Heisler (1986)
Reduce construction and maintenance costs	• Developers who conserve trees can save up to $5,000 per acre for clearing, grading, and installing erosion control practices • Developers who conserve trees can save $2,000 to $50,000 to treat the quality and quantity of storm water from a single impervious acre • Developers who conserve trees can save $270 to $640 per acre on annual mowing and maintenance costs	Schueler (1995) Schueler (2000) WHEC (1992)
Increase property values	• Property values of homes with trees are an average of 5% to 7% and as much as 20% higher than equivalent properties without trees • Two regional economic surveys document that conserving forests on residential and commercial sites can enhance property values by an average of 6% to 15% and increase the rate at which units are sold or leased.	MD DNR (n.d.) Morales (1980) and Weyerhaeuser Company (1989)
Positively influence consumer behavior	• Consumer ratings of retail establishments was up to 80% higher for business districts with street trees and other landscaping • Survey results indicated that consumers were more willing to travel farther, visit more frequently, stay longer, and pay for parking in business districts that have trees • Survey participants priced goods an average of 11% higher in landscaped business districts than in districts with no trees	University of Washington (1998)

Environmental benefits

Trees reduce air temperatures due to the shading effect provided by their canopy and the release of water vapor through evapotranspiration. Even relatively sparse parking lot canopies can exert a significant cooling effect on parking lot climate and vehicle temperatures (Scott and others, 1998). This temperature reduction reduces the volatilization of smog precursors formed in parking lots and also translates into energy savings when trees are planted in appropriate locations near buildings (e.g., the south and west sides of the building and near air conditioning units).

Trees further increase comfort by blocking harmful ultraviolet radiation, reducing windspeed, and reducing noise from lawnmowers, traffic, and other urban sounds. To be effective at reducing noise, a dense, tall, and wide forested buffer should be planted close to the source of the noise. Contiguous rows of trees in widths of 16 feet or more are especially effective (Trees Atlanta, n.d.). Trees also create background noise, such as rustling leaves and wind through the branches, that help to muffle other more offensive noises (Harris, 1992).

Planting trees in storm water treatment practices can increase nutrient uptake, reduce storm water runoff through rainfall interception and evapotranspiration (ET), enhance soil infiltration, provide bank stabilization, increase esthetic appeal, provide wildlife habitat, provide shading, discourage geese, and reduce mowing costs (Shaw and Schmidt, 2003). While few studies exist that directly quantify these benefits, research is available on rainfall interception and ET rates, as well as pollutant removal for individual trees. This data, presented in Box 2, suggests that incorporating trees into STPs may increase their pollutant removal efficiencies. Median pollutant removal efficiencies for standard STPs are presented in Chapter 3. The environmental benefits of trees at development sites are summarized in Table 2.

BOX 2. HYDROLOGIC AND WATER QUALITY BENEFITS OF TREES

This box summarizes data on rainfall interception, evapotranspiration, and nutrient uptake for a single tree. Based on this data, the potential reduction of storm water runoff by each tree planted in an STP is 860 gallons per year, and the potential nitrogen reduction by each tree is 0.05 pounds per year.

Hydrologic and Water Quality Benefits of Trees		
Benefit	**Per Tree Annual Quantification of Benefit**	**Source and Description**
Rainfall interception	760 gallons of water per tree per year	Annual rainfall interception by a large deciduous front yard tree* (CUFR, 2001)
Evapotranspiration	100 gallons of water per tree per year	Transpiration rate of poplar trees for one growing season (EPA, 1998)
Nutrient uptake	0.05 pounds nitrogen per tree per year	Based on daily rate of nitrogen uptake by poplar trees (Licht, 1990)

*A 40-year-old London plane tree growing in a semi-arid climate

Trees also show enormous potential to remove other pollutants, such as metals, pesticides, and organic compounds. The process of using plants to remove contamination from soil and water is called **phytoremediation.** This process has mainly been applied to soil and groundwater but could easily be applied to storm water runoff. Trees such as poplars that can absorb large quantities of water through evapotranspiration are typically used for phytoremediation because this type of consumption contains and controls the migration of contaminants (EPA, 1998). Many other plants have the ability to absorb excess nutrients, filter sediments, and break down pollutants commonly found in storm water runoff. One sugar maple (1 foot in diameter) along a roadway was shown to retain 60 milligrams (mg) cadmium, 140 mg chromium, 820 mg nickel and 5,200 mg lead from the environment in one growing season (Coder, 1996).

Table 2. Environmental Benefits of Trees at Development Sites		
Benefit	**Supporting Information**	**Source**
Reduce urban heat island effect	• Air temperatures can be 4 to 8 degrees Fahrenheit (°F) cooler in well-shaded parking lots than in unshaded parking lots. Similarly, air temperatures in neighborhoods with mature canopy were 3 to 6 °F lower in daytime than in newer neighborhoods with no trees. • Trees reduce surface asphalt temperatures by up to 36 °F, and vehicle cabin temperatures by 47 °F	McPherson (1998), Akbari and others (1992) CUFR (2001)
Enhance function of STPs	• Trees in storm water treatment practices influence evapotranspiration and capacity for nutrient uptake, aid infiltration, provide bank stabilization, increase esthetic appeal, provide wildlife habitat, provide shading, and reduce mowing costs	Shaw and Schmidt (2003)

Community benefits

Trees at development sites also provide benefits to the community that are equally important but difficult to quantify. These benefits include increased physical comfort due to reduction of wind and noise and provision of shade, esthetic and sentimental value, improved physical and psychological well-being, enhanced sense of community, and increased opportunities for recreation (Figure 3). Overall, trees increase the livability of a community. Trees create a sense of privacy in urban environments, reduce stress, and have been linked to less crime. Table 3 summarizes some of the research on community benefits of trees in neighborhoods.

Figure 3. Trees and natural areas provide many recreational opportunities. *Photo: NRCS photo gallery*

Table 3. Community Benefits of Trees at Development Sites		
Benefit	**Supporting Information**	**Source**
Improve health and well-being	• Recuperation rates were faster for patients whose windows offered views of a wooded landscape. • Less violence occurred in urban public housing where there were trees.	Ulrich (1984) Sullivan and Kuo (1996)
Provide shade and block ultra-violet radiation	• Trees with the right shade and density can block up to 95% of incoming radiation. • Even leafless trees can intercept up to 50% of the sun's energy.	Akbari and others (1992)
Buffer wind and noise	• Depending on housing density, an added 10% tree cover can reduce windspeed by 10% to 20%, while an added 30% tree cover can reduce windspeed by 15% to 35%. Even in winter, trees can reduce windspeeds by as much as 50% to 90% of summer values. • A belt of trees 98 feet wide and 49 feet tall has been shown to reduce highway noise by 6 to 10 decibels, a rate of almost 50%.	Heisler (1989) Akbari and others (1992)

Regulatory Considerations for Trees at Development Sites

Conserving existing trees and planting new ones at development sites can have regulatory implications, in the form of both incentives and barriers. Depending on local codes and ordinances regulating site design, several regulations may be met by preserving or planting trees at a development site. Additional voluntary or incentive programs may exist that can provide even more reasons to conserve trees, such as tax breaks or density bonuses. Part 1 of this manual series provides details and examples of these regulatory and incentive programs that relate to forest conservation. Table 4 summarizes regulations related to conserving and planting trees at development sites.

The same local codes and ordinances governing site development can also limit tree preservation or tree planting in particular areas of a development site, whether intentional or not. For example, guidelines provided for design of planting strips, such as medians and islands, may not produce an environment conducive to supporting healthy, mature trees. Table 5 summarizes the potential barriers to conserving and planting trees at development sites. While these barriers can sometimes be addressed, it is important to become familiar with local codes before planting.

Table 4. Regulations Related to Conserving and Planting Trees at Development Sites

Regulation	Description
Landscaping	Landscaping is typically required in parking lots in the form of a minimum percentage of the total area. Landscaped buffers may also be required to screen parking lots and other land uses from adjacent roads and developments. Street trees may be required along local roads. Conserving existing trees within these locations or planting new ones will meet most landscaping requirements.
Storm water management	Through a storm water credit program, developers can get credits for conserving tracts of forest and may be allowed to subtract this area from the total site area when computing storm water runoff volumes to treat. In addition, required landscaped areas can also be used for storm water treatment, meeting both landscaping and storm water management requirements.
Forest conservation and protection	Regulations may state that a certain percentage of forest must be preserved at each site or that trees of a certain size must be protected.
Conservation of natural areas	Certain regulations, such as stream buffer ordinances and floodplain ordinances, may exist that require natural areas such as stream buffers, floodplains, steep slopes, or otherwise unbuildable areas be protected and preserved during development.
Open space design for subdivisions	Requires clustering of homes on a development site to conserve a certain percentage of natural area such as forest.
Canopy requirements	Typically apply to parking lots or street trees and require a certain percentage of canopy cover to be met within a specified time frame.
Erosion and sediment control	Temporary tree protection devices installed before construction can be combined with erosion and sediment control devices, and can potentially save money.

A recommended approach to address regulatory barriers to tree conservation is to conduct a local site planning roundtable in the community. As part of the local site planning roundtable process, an audit of codes and ordinances governing site development is conducted to identify potential barriers to implementing environmental-friendly site design techniques, such as forest conservation and tree planting. In addition, roundtables help identify language that discourages the use of environmentally friendly techniques by requiring extra costs or a longer review process, even though the technique may not specifically be prohibited. The goal of the site planning roundtable is to make recommendations for revising the codes and ordinances to allow and encourage the use of the desired site design practices. Additional guidance on site planning roundtables is provided in CWP (1998).

Table 5. Potential Regulatory Barriers to Tree Conservation, Planting, and Growth at Development Sites

Regulation	Description
Street trees	Required width of planting area may not provide adequate soil volume for trees. Buffer strip is typically required to be located between the sidewalk and street, further limiting potential rooting space. Setbacks between trees and infrastructure may not be adequate to prevent damage to trees.
Parking lot landscaping	Required size of parking lot islands may not provide adequate soil volume for trees. Setbacks between trees and infrastructure may not be adequate to prevent damage to trees.
Lot design	Required building setbacks and frontages may limit placement of buildings and pavement on the site and decrease the feasibility of conserving remaining forest areas.
Septic systems	Regulations may require clearing of reserve fields at the time of development.
Landscaping for STPs	Guidance may prohibit trees in some or all practices, or within certain areas of practices, such as pond embankments.
Floodplain	Within designated floodways, trees may be prohibited (usually regulated by U.S. Army Corps of Engineers).
Subdivision design	Conventional subdivision design standards may not allow for conservation of natural areas such as forest. Road design standards for subdivision may prohibit use of landscaped island in cul-de-sac.
Parking ratios	Excessive minimum parking ratios can create large unused parking areas that limit potential for tree conservation.
Utilities, signs, and lighting	Regulations may not allow tree planting within utility easements or rights-of-way. In urban environments, adequate space for necessary setbacks between infrastructure and trees may not exist, which can result in limited growing space for trees and potential conflicts between trees and infrastructure.

Unique Properties of the Urban Planting Environment

The average life expectancy of newly planted urban trees has been reported to be 10 to 15 years (Urban, 1999). Urban street trees may have an even lower life expectancy of 7 to 10 years (Appleton and others, 2002). Planted in a better environment, these same trees would have a life expectancy of 60 to 200 years. Why is there such a significant difference? One reason is the harsh planting environment in urban areas that often provides poor conditions for tree growth (Figure 4).

Another major reason for lowered tree life expectancy can be the lack of maintenance provided for urban street trees. Many municipalities actually find it easier and cheaper to replace street trees on a regular cycle rather than to provide adequate conditions and care needed to allow for long-term tree survival. Replacing urban street trees, however, does not offset the additional loss of trees from land development and mortality due to a harsh urban microclimate. A study of tree mortality rates in Baltimore found an annual rate of 6.6%. Even when combined with reforestation efforts, this mortality rate resulted in a net loss of 4.2% in the number of city trees (Nowak and others, 2004). This reality reinforces the need to prioritize retention of existing established urban trees rather than relying on replanting.

Figure 4. Stress from harsh urban conditions can kill a street tree. *Photo: Edward F. Gilman*

Some common causes of urban tree mortality are listed in Box 3 and described below. While not presented in any particular order, one study of urban tree mortality concluded that drought was the most common factor (Foster, 1978). Causes of tree mortality are often difficult to pinpoint because the decline from many impacts can take years to appear.

BOX 3. COMMON CAUSES OF URBAN TREE MORTALITY

- Limited soil volume
- Poor soil quality
- Air pollution
- Construction activities
- Physical damage from lawnmowers, vandalism, or vehicles
- Damage from insects or animals
- Soil compaction from heavy foot traffic
- Exposure to pollutants in storm water runoff
- Soil moisture extremes
- Exposure to wind and high temperatures
- Competition from invasive plant species
- Improper planting and maintenance techniques
- Conflicts with infrastructure
- Disease
- Poor nursery production practices

Limited soil volume

Urban areas often have limited space available for planting due to the presence of infrastructure. Highly compacted soils also effectively prevent tree roots from growing outside the tree pit (Figure 5). The average urban tree pit contains only 40 cubic feet of soil; however, a large tree needs at least 400 cubic feet—and optimally 1,000 cubic feet—of soil to thrive (Urban, 1999).

Figure 5. A typical urban tree pit is about 4 feet by 4 feet and does not provide adequate soil volume for most trees.

Poor soil quality

Most urban soils are highly compacted, have poor drainage, and are low in organic matter and nutrients (Craul, n.d.). The pH is often elevated from calcium deposits from building rubble, irrigation water, and road salt (Craul, n.d.). Soil compaction from construction and heavy use limits root growth and starves the tree of oxygen, nutrients, and water.

Air pollution

Air pollutants such as ozone damage tree foliage and impair photosynthesis (MD DNR, n.d.). Ozone levels as low as 40 to 60 parts per billion have been shown to be harmful to sensitive plant species (Stormcenter Communications, Inc., 2003).

Construction activities

During construction, trees can be damaged by soil compaction, grade changes, root crushing and pruning, damage to the bark, improper pruning of branches, incorrect storage of construction material, and dumping of construction wastes (PSU, 1999; Figure 6). Even if the tree does not appear to be physically harmed, underground root damage may kill the tree later on, which is why protecting the root zone is so important. Some trees will decline slowly over a number of years after construction damage occurs, while others may die quickly. An indirect impact to trees from construction activities results from changing conditions when exterior or interior trees are removed from a group of trees. Trees growing in groups are adapted to each other and to their light, wind, and soil conditions. After a removal, the remaining trees are subject to windthrow, sunscald, and altered soil conditions.

Physical damage from lawnmowers, vandalism, or vehicles

Damage to trees caused by mowers is common, particularly where turf is planted around trees. Vandalism may be common in highly urban areas. Damage to trees from vandalism was found to be highest in areas of high child use, such as playgrounds, or near pubs and bars (Foster, 1978). This same study found that the most common injury to curbside trees was caused by automobiles. Autos may damage 81%

Figure 6. Improper disposal of construction materials and inadequate protection negatively impact trees at a construction site.

Figure 7. Deer browsing damages seedlings.

Figure 8. Urban heat island effect—Because this tree is surrounded by pavement, it is exposed to high temperatures.

of sidewalk trees in a business area, particularly those located near the curb (Foster, 1978). Injury leads to fungal decay, which can kill a tree.

Damage from insects or animals

Damage to trees from deer overbrowsing is common in urban or suburban areas where deer populations are uncontrolled (Figure 7). Where beavers are present, they may cut down many trees in urban riparian areas to build dams. Rodents and other animals may chew on bark, effectively girdling a tree. Poor planting conditions and other urban stressors can make urban trees more susceptible to disease and to pests such as insects.

Soil compaction from heavy foot traffic

Heavy foot traffic in tree planting areas can compact soils, and limit soil drainage and root growth. Street trees are particularly susceptible to trampling damage if appropriate measures are not taken to restrict foot traffic over tree roots.

Exposure to pollutants in storm water runoff

Urban storm water runoff can contain moderate to high levels of pollutants such as salt and other de-icers, metals, bacteria, pesticides, and nutrients. Many tree species cannot tolerate elevated levels of these constituents.

Soil moisture extremes

Paved surfaces are engineered to quickly shed water, often in directions that either deprive trees of adequate soil moisture or leave their roots submerged in excess water (Appleton and others, 2002). An increase in impervious surfaces has also been linked to a decline in baseflow and groundwater (CWP, 2003), which further reduces available water for trees. Poor soil drainage, clogged drainage systems, lack of proper tree maintenance, and significant variation in properties of rootball soil, backfill soil, and site soil can also contribute to soil moisture extremes (Hammerschlag and Sherald, 1985). Damage to trees from flooding and drought is most pronounced during the growing season and includes decline in tree growth, disruption of food production, and poor nutrient uptake (Coder 1994, 1999).

Exposure to wind and high temperatures

Urban trees are often planted in the open and lack protection. Increased exposure to wind affects tree stability and increases susceptibility to drought. Air temperatures in urban areas are generally higher than those in non-urban areas due to the urban heat island effect (Figure 8). Urban trees also have increased exposure to solar radiation when planted alone because they receive sunlight from all sides. Urban trees are exposed to lighting at night, which further increases temperature.

Competition from invasive plant species

Invasive plants are common in disturbed urban areas, such as roadsides and riparian areas, and can outcompete desirable trees by using up already limited water and nutrients.

Improper planting and maintenance techniques

Improper planting and maintenance techniques or lack of maintenance can damage or even kill a tree. For example, improper pruning techniques can make trees more susceptible to disease and pests. Improper use of stakes can also cause tree damage or death.

Figure 9. A common infrastructure conflict results in tree roots lifting or cracking pavement due to inadequate setbacks between trees and pavement. *Photo: Edward F. Gilman*

Conflicts with infrastructure

When trees come in contact with pavement or utilities, they can cause damage such as downed powerlines, sidewalk cracking (Figure 9), and heaving or clogged sewer pipes. Preventative or remedial measures to correct such damage may injure the tree or cause the offending tree to be removed.

Disease

Poor planting conditions and other urban impacts place urban trees under stress and can make them more susceptible to disease and to pests such as insects.

In addition to the above-mentioned constraints of urban environments, planting trees in STPs presents a unique set of considerations, such as increased exposure to urban pollutants and frequent and extended inundation. These conditions are described and addressed further in Chapter 3. Part 3 of this manual series provides additional detail on identifying and addressing limitations of specific planting environments.

Chapter 2. How to Conserve and Plant Trees at Development Sites

This chapter describes in detail the steps that can be taken to conserve existing trees during construction and to plant trees at development sites.

Conserving Existing Trees During Construction

The preferred method for increasing tree cover at a development site is to conserve existing trees during construction, particularly where mature trees are present. Existing trees are conserved during construction through a five-step process:

1. Inventory existing forest.
2. Identify trees to protect.
3. Design the development with tree conservation in mind.
4. Protect trees and soil during construction.
5. Protect trees after construction.

More guidance on conserving trees at development sites can be found in MN DNR (2000), Greenfeld and others (1991), PSU (1999), and Johnson (2005).

1. Inventory Existing Forest

A natural resource professional such as a forester or arborist should conduct an inventory of existing trees and forested areas at the development site before any site design, clearing, or construction takes place. Some communities may require a forest inventory, while it may be optional in others. The extent of the inventory will depend on local regulations, lot size, vegetative cover, and the extent of development activity. In some cases, the inventory may survey each individual tree, while in others, it may entail a limited sampling of forest stands. Tree preservation ordinances will often dictate the size and types of trees that must be inventoried.

The inventory begins with a site map that includes legal, infrastructure, physical, ecological, cultural, and historical features listed in Box 4.

BOX 4. MAPPING DATA FOR FOREST INVENTORY

- Property boundaries
- Roads
- Utilities
- Easements and covenants
- Topography
- Streams
- Soils
- Steep slopes
- Stream buffers
- Critical habitats
- Adjacent land uses
- Cultural and historical sites
- 100-year floodplains
- Non-tidal wetlands

The next step in the inventory is to survey existing trees and determine their species, condition, and ecological value. Locations of trees and forest stands are marked on maps, along with sampling points, and tree and forest health data are recorded on appropriate field sheets.

The State of Maryland is unique in that it requires an inventory of existing forest at certain development sites under the Forest Conservation Act (Box 5). This inventory, called the Forest Stand Delineation (FSD), is used to characterize and map the existing forest on a development site. The FSD results in a map of existing forest, a site vicinity map, forest stand summary sheets, and a narrative of forest stand conditions.

The site inventory process required in Maryland provides a useful model for evaluating forest conservation priorities at development sites elsewhere. Additional guidance on other methods to inventory existing forest conditions is presented in Table 6. Figure 10 presents a typical FSD map, while copies of FSD forms and field methods are provided in Appendix A.

BOX 5. MARYLAND'S FOREST CONSERVATION ACT

The Forest Conservation Act of 1991 was enacted to protect the forests of Maryland by making the identification and protection of forests and other sensitive areas an integral part of the site planning process. The Act provides guidelines for the amount of forested land retained or planted after the completion of development projects. These guidelines vary for each development site and are based on land-use categories. Where little or no forest exists, the Conservation Act requires that new forests be established by planting trees.

To meet these requirements, information on the condition of the existing forest and a plan for conserving the most valuable portions of the forest are required. Therefore, a qualified resource professional must conduct a Forest Stand Delineation (FSD) and create a forest conservation plan for all development disturbing more than 40,000 square feet.

Table 6. Forest and Tree Inventory Guidance

Forest Inventory Method/Guidance	Applicability	Source
Maryland Forest Stand Delineation	Method used to delineate and characterize forests on a development site	Greenfeld and others (1991)
Trees Approved Technical Manual	Methods for natural resources inventory and forest stand delineation used in Montgomery County, MD	MNCPPC (1992)
Volunteer Training Manual	Method used to inventory and evaluate the health of street trees	USDA Forest Service (1998)
A Guide to Preserving Trees in Development Projects	Provides guidance for conducting a tree inventory at a development site	PSU (1999)
Conducting a Street Tree Inventory	Method used to inventory and evaluate the health of street trees	Cornell University (2004)
Conserving Wooded Areas in Developing Communities	Provides guidance for conducting a natural resources assessment at the landscape, subdivision, and lot level	MN DNR (2000)

The inventory of existing forest has three goals: to comply with local tree preservation or other ordinances, to identify the highest quality trees and forest stands on the site for protection, and to identify and address problems such as invasive species and pest or disease outbreaks. The field assessment portion of the inventory typically collects basic information about the tree species, size, and age, as well as the condition of individual trees and suitability for preservation of forest stands.

If the site contains large forest stands, sample individual points at a sampling intensity sufficient to characterize the entire stand. Select sampling site locations at random and draw them on the map before going to the site, and then flag them in the field. Specific forest stand information collected may include dominant species and forest association, size class of dominant trees, total number of tree species, number of trees per acre, common understory trees, and a forest structure rating. Appendix A contains forest stand summary sheets and methods for calculating forest structure rating from the Maryland FSD.

The results of the forest inventory should be provided to site engineers and landscape architects before site design and layout.

2. Identify Trees to Protect

The forest inventory identifies priority trees or forest stands to conserve and protect during site development. Trees and forest identified for protection should include the minimum needed to comply with local tree preservation regulations and trees located within easements, covenants, or other protected areas. Additional selection criteria include tree species, size, condition, and location (Table 7). Greenfeld and others (1991) provide additional guidance on prioritizing forest areas to retain during development.

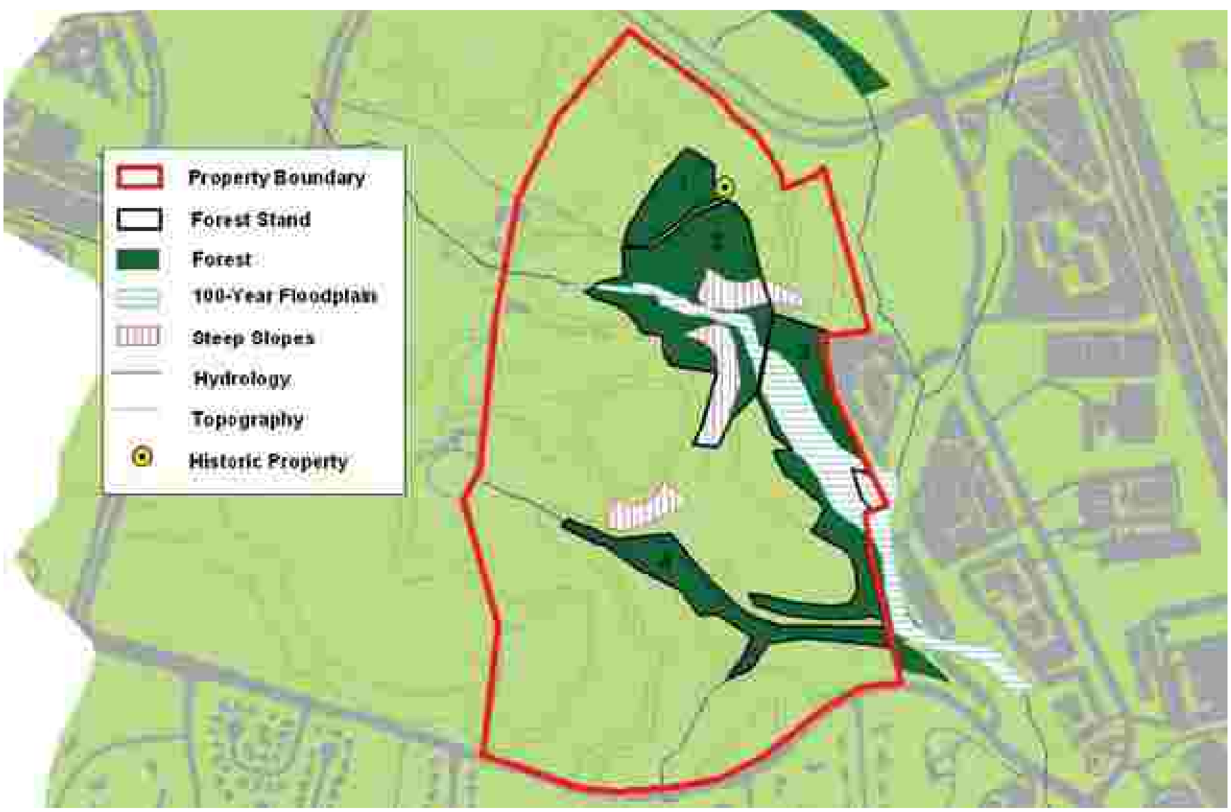


Figure 10. A map of existing forests on a development site is one product of Forest Stand Delineation—a required inventory in the State of Maryland.

Table 7. Selecting Priority Trees and Forests for Conservation	
Selection Criteria for Tree Conservation	**Examples of Priority Trees and Forests to Conserve**
Species	Rare, threatened, or endangered species Specimen trees High quality tree species (e.g., white oaks and sycamores because they are structurally strong and live longer than trees such as silver maple and cottonwood) Desirable landscaping species (e.g., dogwood, redbud, serviceberry) Species that are tolerant of specific site conditions and soils
Size	Trees over a specified diameter at breast height (d.b.h.) or other size measurement Trees designated as national, state, or local champions Contiguous forest stands of a specified minimum area
Condition	Healthy trees that do not pose any safety hazards High quality forest stands with high forest structural diversity
Location	Trees located where they will provide direct benefits at the site (e.g., shading, privacy, windbreak, buffer from adjacent land use) Forest stands that are connected to off-site forests that create wildlife habitat and corridors Trees that are located in protected natural areas such as floodplains, stream buffers, wetlands, erodible soils, critical habitat areas, and steep slopes. Forest stands that are connected to off-site nonforested natural areas or protected land (e.g., has potential to provide wildlife habitat)

Trees and forests selected for protection should be clearly marked both on construction drawings and at the actual site. Flagging or fencing are typically used to protect trees at the construction site. Areas of trees to save should be marked on the site map and walked during preconstruction meetings.

If it is not feasible to conserve all of the desired trees at a site, one option to consider is transplanting some of the trees to another location on the site. Transplanting should be done by a licensed arborist or natural resource professional and may be done with equipment that is already available at the site. Guidance on transplanting trees is provided in Bassuk and others (2003).

3. Design the Development With Tree Conservation in Mind

Once trees and forests are identified for protection, the layout of the site should be designed to conserve these areas, using:

- Open space design techniques to minimize impervious cover and conserve a larger proportion of forest
- Site fingerprinting to minimize clearing and land disturbance
- Setbacks from the critical root zone of trees to be conserved.

Developments should be designed to conserve the maximum amount of forest possible by locating buildings and roads away from priority forest conservation areas and by reducing the total area of graded surfaces. One technique that both reduces grading and conserves forested areas is open space design. Also known as cluster development, open space design is a compact form of development that concentrates density on one portion of the site by clustering lots in exchange for reduced density elsewhere (Figure 11). Minimum lot sizes, setbacks, and frontage distances are relaxed to provide conservation of natural areas such as forests. Open space developments cost less to build because of reduced clearing, paving, storm water management, and infrastructure costs. Open space subdivisions can also bring in higher premiums since people will typically pay more to have a wooded lot or live next to a natural area (see Chapter 1). Open space designs reduce impervious cover by 40% to 60%, thereby conserving significant portions of forest on a site (Schueler, 1995). More guidance on open space design can be found in Schueler (1995), CWP (1998), and Arendt (1996).

Site designers should be creative. For example, houses do not always have to be located in the center of the lot, and the design can take advantage of trees and forests for window views and focus of outdoor decks and recreational spaces. If open space design is not allowed under existing local site development codes, other techniques can still be applied to reduce impervious cover (CWP, 1998). Some examples of Better Site Design techniques to reduce impervious cover and maximize conservation potential are listed in Box 6.

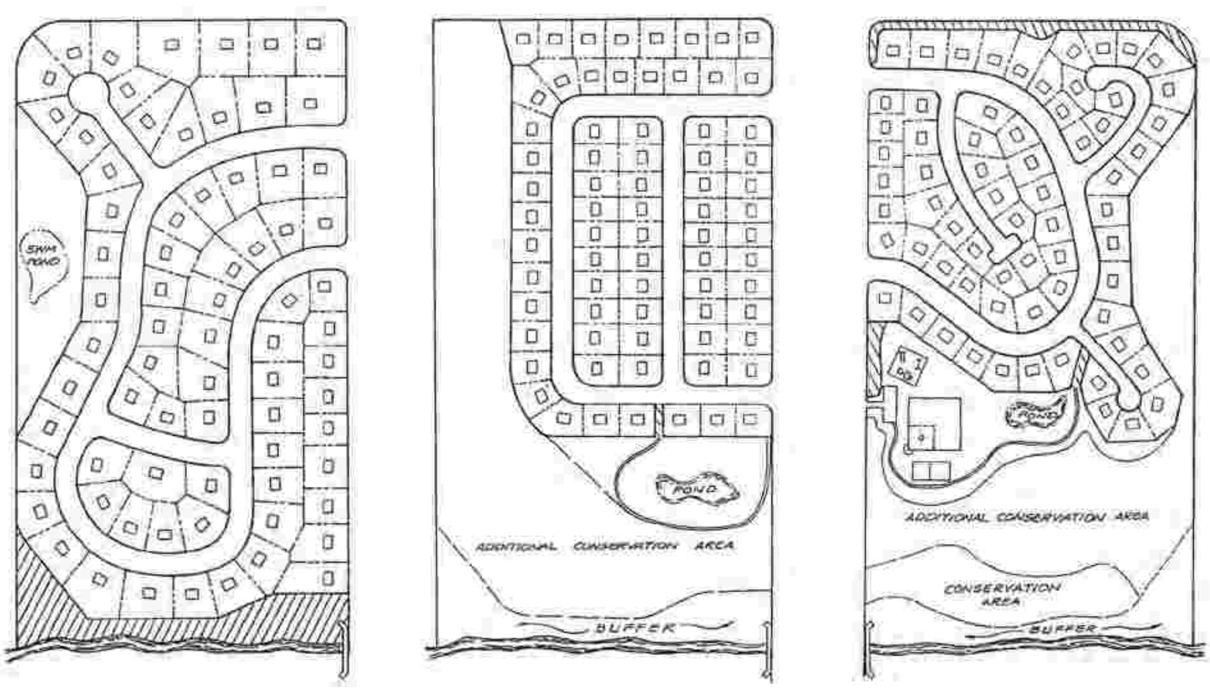


Figure 11. An open space design with 72 lots (center) uses less land than a conventional subdivision with the same number of lots (left). Floodplains and wetlands (hatched lines) are considered unbuildable and must be subtracted from gross density. An alternative design (right) provides 66 lots.
(Source: Schueler, 1995, p. 57-58)

BOX 6. BETTER SITE DESIGN TECHNIQUES TO CONSERVE FORESTS

- Design structural elements such as roads and utilities to minimize soil disturbance and take advantage of natural drainage patterns.
- Where possible, place several utilities in one trench in order to minimize soil disturbance.
- Reduce building footprints by building up, not out.
- Use the minimum required street and right-of-way widths.
- Use alternative turnarounds instead of cul-de-sacs.
- Use efficient street layouts.
- Consider shared driveways for residential lots.
- Use the minimum required number of parking spaces instead of creating additional spaces.

Another method to conserve forests during site design is called site fingerprinting. Also known as site footprinting, site fingerprinting minimizes the amount of clearing and grading conducted at a site by limiting disturbance to the minimum area needed to construct buildings and roadways (Figure 12). A suggested limit of disturbance (LOD) around structures is 5 to 10 feet outward from the building pad (Greenfeld and others, 1991). No clearing, grading, or siting and construction of utility lines, access roads, staging, storage or temporary parking areas, storm water management practices or impervious surfaces should be located within the LOD. This requires that designated areas for temporary parking, material storage, and construction spoil, and holding areas for vegetation and topsoil be established outside the LOD. Designing the site to have only one access point, which coincides with planned roadways, driveways, or utilities also limits the amount of clearing necessary. The LOD should be clearly marked both on site plans and at the site.

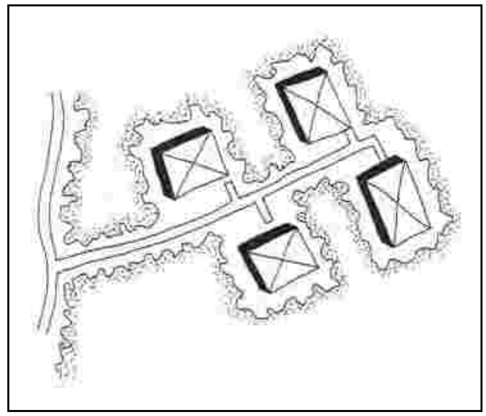


Figure 12. Site fingerprinting limits site disturbance to the minimum necessary for building. *(Source: Greenfeld and others, 1991, p. 51)*

The LOD should incorporate a field delineation of the critical root zone (CRZ) for trees to be conserved. The CRZ, also called the protected root zone, is a circular region measured outward from a tree trunk representing the essential area of the roots that must be maintained or protected for the tree's survival (Greenfeld and others, 1991). In order to adequately protect the tree, no disturbance should occur within the CRZ. There are four methods for delineating the critical root zone:

1. *Trunk diameter method* – Measure the tree diameter in inches at breast height (54 inches above the ground). For every inch of tree diameter, the CRZ is 1 foot of radial distance from the trunk, or 1.5 feet for specimen or more sensitive trees (Greenfeld and others, 1991; Coder, 1995). Figure 13 illustrates the trunk diameter method.

2. *Site occupancy method* – Predict the tree diameter at breast height in inches for that tree at 10 years old. Multiply the number by 2.25 and convert the result into feet to obtain the radius of the CRZ (Coder, 1995).

3. *Minimum area method* – Protect an area of approximately 6 feet in radius around the trunk of the tree as the CRZ (MN DNR, 2000).

4. *Dripline method* – Measure the distance of the branch that extends horizontally farthest from the trunk and multiply by 1.5 to obtain the CRZ radius. Another option is to project the dripline downward to the ground and delineate the area beneath the tree branches or crown as the CRZ (MN DNR, 2000).

The natural resource professional should select the method of delineation. In general, the trunk diameter method is best for trees growing in a forest or with a narrow growth habitat, the minimum area method is preferred for very young trees, and the dripline method is preferred for protecting mature open-growing trees (MN DNR, 2000). These methods do not protect the tree's entire root system but represent a good compromise between tree survival or growth and available space. Other considerations when delineating protected root zone include the following (Greenfeld and others, 1991):

- *Species sensitivity* – Certain species are more tolerant to disturbance or compaction than others. For sensitive species, delineate the CRZ based on species and site evaluation.

- *Tree age* – Younger trees are generally more tolerant of disturbance than older ones. For mature trees, delineate a slightly larger CRZ.

4. Protect Trees and Soil During Construction

Physical barriers must be properly installed around the LOD to protect trees to be conserved and their associated CRZ. The barriers should be maintained and enforced throughout the construction process. Tree protection barriers include highly visible, well-anchored temporary protection devices, such as 4-foot fencing, blaze orange plastic mesh fencing (see Figure 14), two- to three-strand barbed wire fence, or snow fencing (Figure 15) (Greenfeld and others, 1991). Specifications for tree protection methods are provided in Appendix B.

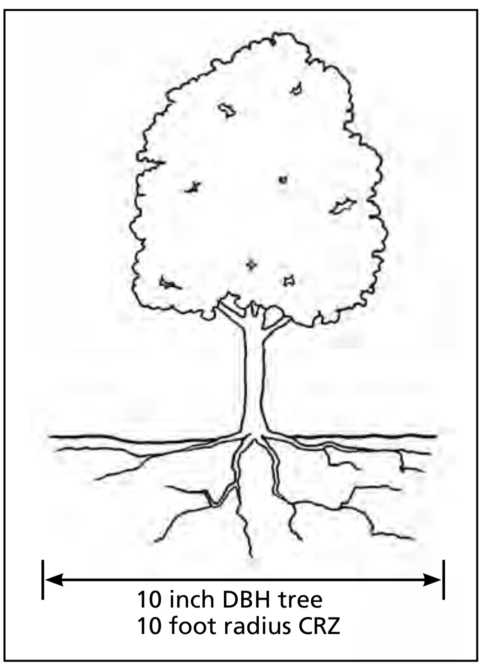


Figure 13. The trunk diameter method is one of four ways to define the critical root zone (CRZ). *(Source: Greenfeld and others, 1991, p. 62)*

Figure 14. Orange plastic mesh fencing delineates tree protection areas.

All fencing should have highly visible flags and include posted signs clearly identifying the tree protection area. No equipment, machinery, vehicles, materials, excessive pedestrian traffic, or trenching for utilities should be allowed within protection areas. It may be necessary to install temporary drainage and irrigation for trees and other plants to be preserved.

All protection devices should remain in place throughout construction, and penalties for violation should be enforced. A landscape protection contract signed by the builder, developer, contractor, and all subcontractors will help ensure compliance.

Tree conservation begins by preserving the native soils throughout the site, especially in areas that will be used for planting. Soil stockpiling and mulching can be used to protect the infiltration capacity of these native soils. Soil stockpiling is the temporary storage of topsoil that has been excavated from a construction site. This soil is then reused on the site in planting areas to provide a higher quality growing medium for new vegetation, which also saves the builder from having to purchase and haul in new topsoil. Applying a layer of mulch at least 6 inches thick over areas that will be used for traffic or material storage during construction also helps to prevent soil compaction in areas that will be used for future planting of trees and other vegetation.

Figure 15. Fencing surrounds a mature tree that is to be preserved.

5. Protect Trees After Construction

Developers should educate both current and new residents about the existence and benefits of trees in their development. Developers should ensure that a responsible entity is created to maintain forest conservation areas and enforce their boundaries. Some methods used to educate residents include posting of signs and constructing fences to serve as boundary markers; use of covenants that define homeowners' associations (HOA) as being responsible for maintenance of trees; enforcement mechanisms to protect forests from encroachment; and incorporating individual tree maintenance agreements into real estate plats and deeds.

HOAs can distribute pamphlets and other educational materials about the benefits and location of protected forests in their neighborhoods; inform residents of forest protection policies at HOA meetings; organize urban forest walks or inspections to monitor the condition of the urban forest and to search for pests and invasive species; and organize planting days to engage residents in tree planting. HOAs can also enforce forest protection policies by inspecting forest conservation areas and mailing correction notices requiring reforestation or other measures, depending on the type of violation. As a last resort, civil fines can be used if notices do not result in cooperation.

Local governments also play an important role in protecting forests after construction by ensuring that appropriate ordinances are enforced to adequately protect forest conservation areas. For example, a community's open space design or forest conservation ordinance should provide specific criteria for the long-term protection and maintenance of natural areas (e.g., restrictions on tree clearing except for safety reasons), and should establish appropriate enforcement measures. A third party, such as a local land trust, may be designated responsible to hold and manage forest conservation easements. Land trusts are effective groups to monitor the site and enforce its boundaries, and the third party land trust option should be specifically allowed in the local ordinance. Model ordinances for open space design and tree protection are provided at the links below:

- Open Space Design Model Ordinance:
  www.stormwatercenter.net/Model%20Ordinances/open_space_model_ordinance.htm

- Forest Conservation Ordinance from Frederick County, MD:
  www.stormwatercenter.net/Model%20Ordinances/misc__forest_conservation.htm

Planting Trees at Development Sites

New development sites provide many opportunities to plant new trees, such as in STPs, along local roads, and in parking lots. While some STPs are not traditionally considered appropriate for tree planting, planting trees and shrubs in certain areas of specific STPs can enhance their attractiveness and improve their performance. Planting trees at new development sites is done in three steps:

1. Select planting sites.
2. Evaluate and improve planting sites.
3. Plant and maintain trees.

1. Select Planting Sites

Potential planting sites in a new development or redevelopment site include portions of local road rights-of-way, such as buffer areas, islands and median strips, parking lot interiors and perimeters, and certain types of storm water treatment practices (Figure 16). In many communities, some type of landscaping is required in and around parking lots and along residential streets. As such, the developer may have to meet these requirements anyway. Other areas of a development site that may be a priority for planting trees include stream valleys and floodplains, areas adjacent to existing forest, steep slopes, and portions of the site where trees would provide buffers, screening, noise reduction, or shading.

2. Evaluate and Improve Planting Sites

It is important to evaluate and record the conditions at proposed planting sites to ensure they are suitable for planting, select the appropriate species, and determine if any special site preparation techniques are needed. A method for evaluating urban tree planting sites is The Urban Reforestation Site Assessment (URSA). Box 7 lists the factors evaluated using the URSA, while Part 3 of this manual series contains the full field form and accompanying guidance for completing it.

Figure 16. Development sites offer several potential planting areas.

BOX 7. FACTORS ASSESSED DURING THE URBAN REFORESTATION SITE ASSESSMENT

- General site information
- Climate
- Topography
- Vegetation
- Soils
- Hydrology
- Potential planting conflicts
- Planting and maintenance logistics
- Site sketch

Site characteristics determine what tree species will flourish there and whether any of the conditions, such as soils, can be improved through the addition of compost or other amendments. Improvements to the planting site generally apply only to smaller spaces. Therefore, when reforesting large tracts of land, it is probably not feasible from a cost and labor standpoint to apply soil amendments over the entire planting area. Table 8 presents methods for addressing common constraints to urban tree planting. Part 3 of this manual series provides more detail on each method.

In general, the best way to address urban planting constraints is to ensure each planting project meets the design principles in Box 8, which are adapted from Urban (1999) and GFC (2001).

Table 8. Methods for Addressing Urban Planting Constraints

Potential Impact	Potential Resolution
Limited soil volume	Use planting arrangements that allow shared rooting space Provide at least 400 cubic feet of soil per tree
Poor soil quality	Test soil and perform appropriate restoration Select species tolerant of soil pH, compaction, drainage, etc. Replace very poor soils if necessary
Air pollution	Select species tolerant of air pollutants
Damage from lawnmowers	Use mulch or tree shelters to protect trees
Soil compaction from heavy foot traffic	Use mulch to protect trees Plant trees in low-traffic areas
Damage from vandalism	Use tree cages or benches to protect trees Select species with inconspicuous bark or thorns Install lighting nearby to discourage vandalism
Damage from vehicles	Provide adequate setbacks between vehicle parking stalls and trees
Damage from animals such as deer, rodents, rabbits, and other herbivores	Use tree shelters, protective fencing, or chemical retardants
Exposure to pollutants in storm water and snowmelt runoff	Select species that are tolerant of specific pollutants, such as salt and metals
Soil moisture extremes	Select species that are tolerant of inundation or drought Install underdrains if necessary Select appropriate backfill soil and mix thoroughly with site soil Improve soil drainage with amendments and tillage if needed
Increased temperature	Select drought tolerant species
Increased wind	Select drought tolerant species
Abundant populations of invasive species	Control invasive species prior to planting Continually monitor for and remove invasive species
Conflict with infrastructure	Design the site to keep trees and infrastructure separate Provide appropriate setbacks from infrastructure Select appropriate species for planting near infrastructure Use alternative materials to reduce conflict
Disease or insect infestation	Select resistant species

BOX 8. DESIGN PRINCIPLES FOR URBAN TREE PLANTING

Adapted from Urban (1999) and GFC (2001)

Provide adequate soil volume to support the tree at maturity. A general guideline is to provide 2 cubic feet of usable soil for every square foot of mature canopy. Design soil volumes of planting areas to be interconnected so trees can share rooting space.

Preserve and improve soil quality. Limit use of heavy equipment in planting areas to protect native soils from compaction. Soil volume should be accessible to air, water, and nutrients. This is best achieved by separating paving from the tree's rooting area, which also allows for periodic inspection of the planting area. Soils should be amended if necessary to improve drainage and fertility.

Provide adequate space for tree to grow. Design surrounding infrastructure to accommodate long-term growth of tree. Space trees to allow for long-term growth and management, including thinning and replacement of the stand.

Select trees for diversity and site suitability. Plant a variety of species that are tolerant of the climate and soil conditions as well as any urban impacts at the site.

Protect trees from other impacts. Develop designs that protect the tree over its entire life from pedestrian traffic, toxic runoff, high temperatures, and other urban impacts.

Part 3 of this manual series provides guidance on tree species selection in the form of an Urban Tree Selection Guide. A useful source for tree selection is the USDA PLANTS database, which can be accessed at http://plants.usda.gov.

3. Plant and Maintain Trees

Planting trees at new development sites requires prudent species selection, design modifications, a maintenance plan, and careful planning to avoid impacts from nearby infrastructure, runoff, vehicles or other urban elements. Chapter 3 provides specific guidance on planting trees in various storm water treatment practices—storm water wetlands, swales, bioretention and bioinfiltration facilities, and filter strips.

Chapter 4 provides specific guidance for planting trees at development sites in pervious areas along local roads and in parking lots.

Part 3 of this manual series provides additional detail on tree planting, site preparation, and maintenance techniques.

Chapter 3. Design and Planting Guidelines for Storm Water Forestry Practices

This chapter provides detailed guidance for planting trees in storm water treatment practices (STPs), known as storm water forestry practices (SFPs). Guidelines are presented with conceptual designs for the following SFPs:

- Wooded wetland
- Bioretention and bioinfiltration facilities
- Alternating side slope plantings (swale)
- Tree check dams (swale)
- Forested filter strip
- Multi-zone filter strip
- Linear storm water tree pit.

The SFP concept designs presented in this chapter are graphical representations only and do not necessarily incorporate all of the items needed for the final design and engineering. Those will require additional testing, research, and analysis; and we welcome future additions to the designs presented here.

SFPs incorporate trees and shrubs into the design of storm water wetlands, swales, bioretention or bioinfiltration facilities, and filter strips. Alternatively, conventional tree pit designs can be modified to accept and treat storm water runoff, thereby functioning as an STP. Traditional landscaping guidance either does not allow or does not address planting trees in storm water practices (Figures 17 and 18). Despite the fact that tree planting is rare in STPs, there are many potential benefits to doing so. Research on rainfall interception, evapotranspiration, and pollutant uptake of trees indicate that trees in STPs could significantly increase the efficiency of the traditional practice designs (see Box 2 on page 4 for hydrologic and water quality benefits of trees). Median pollutant removal efficiencies for standard STPs are presented in Table 9.

Table 9. Pollutant Removal (Median %) by Standard Storm Water Treatment Practices

Storm Water Treatment Practice	Total Suspended Solids	Total Phosphorus	Soluble Phosphorus	Total Nitrogen	Nitrate + Nitrite
Storm Water Wetland	76	49	36	30	67
Bioretention Facility	N/A	65	N/A	49	16
Dry Swale	93	83	70	92	90
Filter Strip (150 foot width)	84	40	N/A	N/A	20

N/A = not available
Sources: Winer (2000), Yu and others (1993)

Figure 17. Storm water ponds with trees incorporated offer benefits over a conventional storm water pond with no trees (left).

Figure 18. Swales with trees offer greater benefits than a swale with no trees (left).

The SFP designs presented in this chapter were developed during a series of design workshops attended by storm water engineers, foresters, arborists, and landscape architects. The goal of the workshops was to identify potential limitations to planting trees in STPs, both from an engineering perspective and from the standpoint of tree survival and health. The resulting SFP designs were intended to address these limitations through design modifications, species selection, or other methods.

To identify which species of trees and shrubs would be best suited to each STP, it was necessary to first identify the conditions within each practice. In addition to the typical urban planting constraints, STPs have other planting constraints that may limit tree growth (Table 10).

Table 10. Characteristics of Storm Water Treatment Practices that May Limit Tree Growth

Characteristic	Storm Water Treatment Practice			
	Storm Water Wetland	Bioretention, Bioinfiltration	Swale (dry)	Filter Strip
Extremely compacted soils (limited soil volume)	X		X	
Exposure to high winds and high temperatures	X			
Exposure to inundation (frequency, duration and depth varies)	X	X	X	X
Loose, unconsolidated soils, high in organic matter, possibly anaerobic	X	X		
Ice damage and scour	X			
Potential for damage from mowers	X		X	X
Competition from invasive species	X			
High chloride levels		X	X	X
Exposure to high flows during storms (2-6 cubic feet per second)			X	X
Exposure to drought during dry periods	X	X	X	
May be used for snow storage		X	X	X
Exposure to moderate to high levels of urban storm water pollutants (e.g., metals)	X	X	X	X
High sand content of soils (filter medium)		X	X	

Perhaps the most common planting constraint in STPs is periodic inundation or saturation of soils by storm water runoff. Table 11 provides details on the frequency, duration, and depth of inundation that trees and shrubs might be exposed to within each of the four groups of STPs. Figure 19 illustrates the four planting zones in storm water ponds and wetlands.

Many of the tree planting constraints within STPs listed in Table 10 can be addressed by selecting species that are tolerant of less than optimal conditions. In addition, species planted in STPs should be able to reduce storm water runoff (through rainfall interception and evapotranspiration) and mitigate pollutants commonly found in this runoff. Metro (2002) defined a list of characteristics of trees that best perform these functions. Based on this list and on the characteristics presented in Table 10, several desirable characteristics of trees to plant in STPs were defined (Box 9). Trees used in STPs should

Table 11. Inundation in Selected Storm Water Treatment Practices

Inundation Characteristics[1]		Storm Water Treatment Practice						
		Storm Water Pond and Wetland Planting Zones[2]				Bioretention, Bioinfiltration	Swale (dry)	Filter Strip
		Zone I	Zone II	Zone III	Zone IV			
Frequency	Continuous	N/A	X					
	Frequent			X		X	X	X
	Infrequent				X			
Duration	Continuous		X					
	Extended			X	X			
	Brief					X	X	X
Depth	< 6 inches							X
	6-12 inches		X			X		
	Depends on planting elevation			X	X		X	

[1]Frequent inundation = 10-50 times per year or more
Infrequent inundation = a few times per year to once every 100 years
Extended inundation = 2-3 days or more
Brief inundation = a few to several hours
[2]See Figure 19 for an illustration of planting zones.

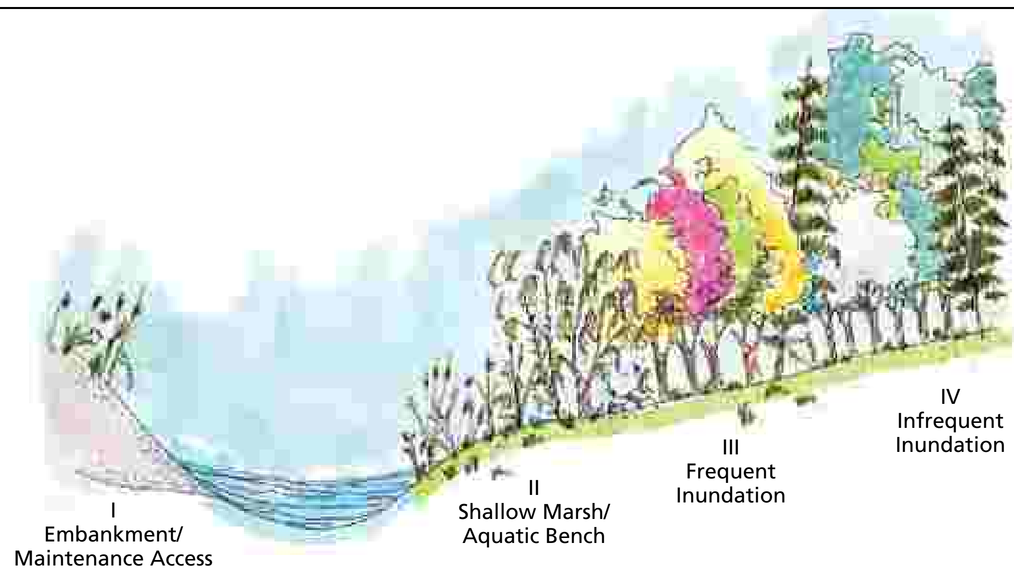


Figure 19. A storm water pond or wetland contains four planting zones.

have several of these characteristics. Additional detail on which tree characteristics are appropriate for specific SFPs is provided later in this chapter. Part 3 of this manual series provides further guidance on species selection.

Table 12 presents the potential engineering conflicts associated with trees in STPs that were identified during the design workshops, and some corresponding design methods to reduce or eliminate these conflicts. These engineering design methods have been incorporated into subsequent SFP concept designs in this chapter.

BOX 9. DESIRABLE CHARACTERISTICS OF TREES FOR STORM WATER TREATMENT PRACTICES

- Persistent foliage
- Wide-spreading, dense canopies
- Long-lived
- Fast growing
- Tolerant of drought
- Tolerant of inundation or saturated soils
- Resistant to urban pollutants (air and water)
- Tolerant of poor soils
- Extensive root systems
- Rough bark
- Tomentose or dull foliage surface
- Vertical branching structure

Table 12. Potential Engineering Conflicts and Resolutions, for Planting Trees in Storm Water Treatment Practices

Potential Engineering Conflict	Resolutions
Tree litter may clog outlets and drainage pipes, increasing maintenance, and potentially drowning trees if not unclogged.	Use alternative outlet structures that do not clog. Select species that do not produce excessive litter.
It may be difficult to remove sediment from practices that require periodic sediment removal without harming or removing trees.	Modify practice design so that trees are separate from areas where sediment is deposited (e.g., use a forebay in a wetland).
Trees may shade out grass and contribute to erosion in practices with higher flows.	General consensus was that this should not be a concern. As a precaution, plant shade-tolerant ground covers where possible.
Tree roots may puncture filter fabric or underdrains.	Increasingly, designers are moving away from the use of filter fabric between the filter media and site soil, as it may create an undesirable soil-water interface. To replace the function of the filter fabric where needed, a sand or pea gravel layer may be used. Tree roots clogging or puncturing underdrains should not be a major concern. As a precaution, do not plant trees directly over underdrains.
Presence of trees in practice may reduce storage or conveyance capacity.	Modify practice design to account for trees (e.g., make it slightly larger).
Mowing around trees, where required, may be more difficult.	Cluster trees where possible to allow easier mowing. Cease mowing where it is not necessary and allow regeneration. Use meadow grasses that do not require frequent mowing (if appropriate for the region).
Overgrowth of trees in maintenance areas may limit access.	Limit trees in maintenance access areas and within 15 feet of these areas.
Trees on embankments may compromise stability.	Do not plant trees within 15 feet of embankment.
Trees with excessive fruits, nuts, and other litter may be nuisances, particularly adjacent to impervious surfaces.	Select species that do not produce excessive litter, particularly when planting near impervious surfaces.

Seven concept designs for SFPs are presented in the remainder of this chapter in fact sheet format. These designs are graphical representations only and do not include all of the items needed for final design and engineering. Each fact sheet contains the following sections:

Description – brief description of practice, where it applies and benefits of incorporating trees.

Design Modifications – modifications to the standard STP to improve planting environment or reduce tree-engineering conflicts.

Species Selection – guidance on desirable species characteristics for planting trees and shrubs in the practice. Part 3 of this manual series includes an urban tree selection guide with tree species and their characteristics.

Planting Guidance – general and specific guidance on exactly how to incorporate trees into the practice.

Maintenance – recommended maintenance for tree-planting areas.

Topics for Future Research – unresolved issues or areas for further research or discussion.

Further Resources – resources for additional information.

This guidance on incorporating trees into STPs is provided as a better alternative either to having no trees at all or to allowing uncontrolled growth of volunteer species (Figure 20), which may conflict with the function of the practice and does not necessarily provide ideal habitat conditions.

Figure 20. Overgrowth of willows in this pond limits maintenance access and essentially creates a monoculture.

Wooded Wetland

Description

A wooded wetland is a variant of a standard storm water wetland design that provides detention and water quality treatment of storm water runoff. Most traditional storm water wetlands contain few, if any, large trees. The wooded wetland design incorporates trees and shrubs into planting zones II, III and IV shown in Figure 19 (page 26).

A wooded wetland is a fairly large practice and typically treats a minimum drainage area of 10 acres or more. This size makes it an ideal practice for highway cloverleaves, large residential subdivisions, and other large open areas such as parks and schools. The wooded wetland design is shown in Figure 21.

Planting trees in a storm water wetland can increase water use through evapotranspiration and may increase pollutant removal through nutrient uptake and biological soil processing. Additional benefits include habitat for wildlife, reduced mowing costs, shading of the permanent pool, deterrent of Canada geese, and bank stabilization.

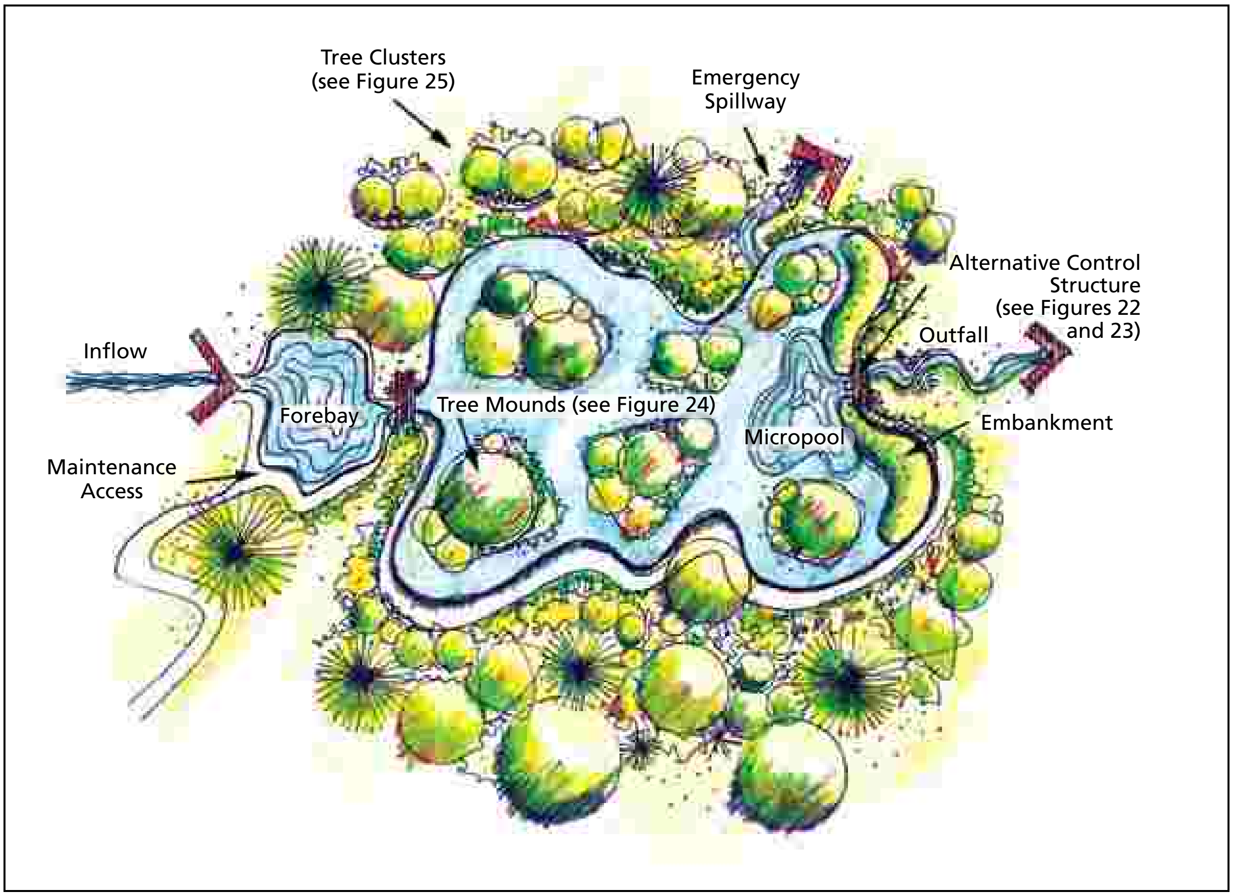


Figure 21. A wooded wetland incorporates trees into the design.

Wooded Wetland *Continued*

Design Modifications

- ☐ Use an alternative control structure such as a weir with a v- or rectangular-notch and a hood to prevent clogging by woody debris (Figure 22). This control structure should be designed to address seepage and uplift on the weir wall, for example, by providing for seepage through the structure by using weep holes or by allowing sufficient travel distance along the base of the weir wall (so it behaves as an anti-seep collar). See USACE (1989) for additional guidance on floodwall and retaining wall design.
- ☐ Include measures to keep permanent pools at relatively safe elevations even when outlets clog. This alternative, used in Montgomery County, MD, incorporates perforated underdrains surrounded by stone along the face of each dam. The underdrains connect to flow restrictors within the embankment to ensure that the required flow controls are met. The designs also include a small (secondary) riser, which the underdrains and flow restrictors tie into (Figure 23). This secondary riser allows for a small amount of ponding if the underdrains become clogged. The resulting water surface elevation increase is relatively small and still allows for unclogging of underdrain flows without much problem.
- ☐ Use a forebay to trap sediment and allow for sediment removal without removing or injuring trees.

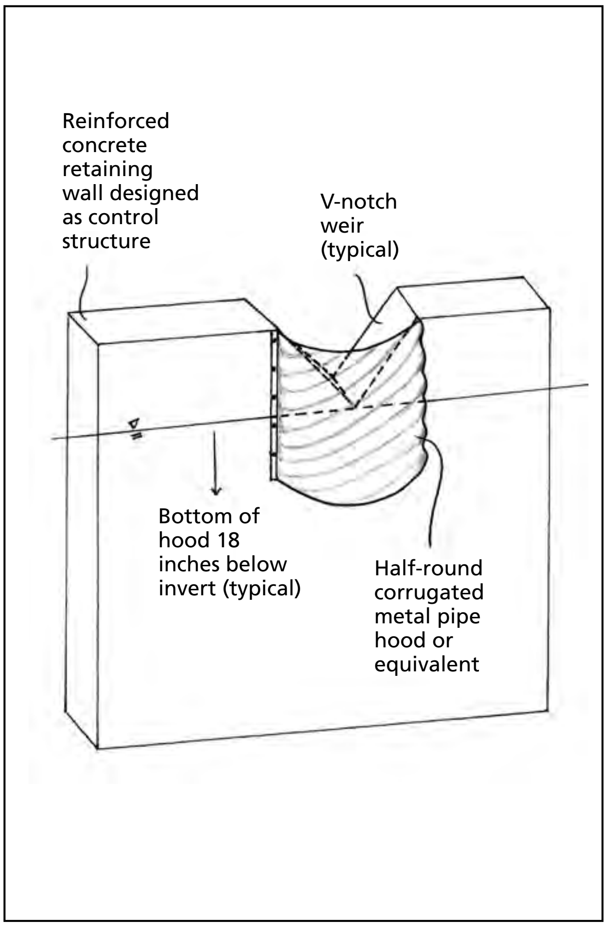


Figure 22. A weir wall with a v-notch and a hood resists clogging by woody debris.

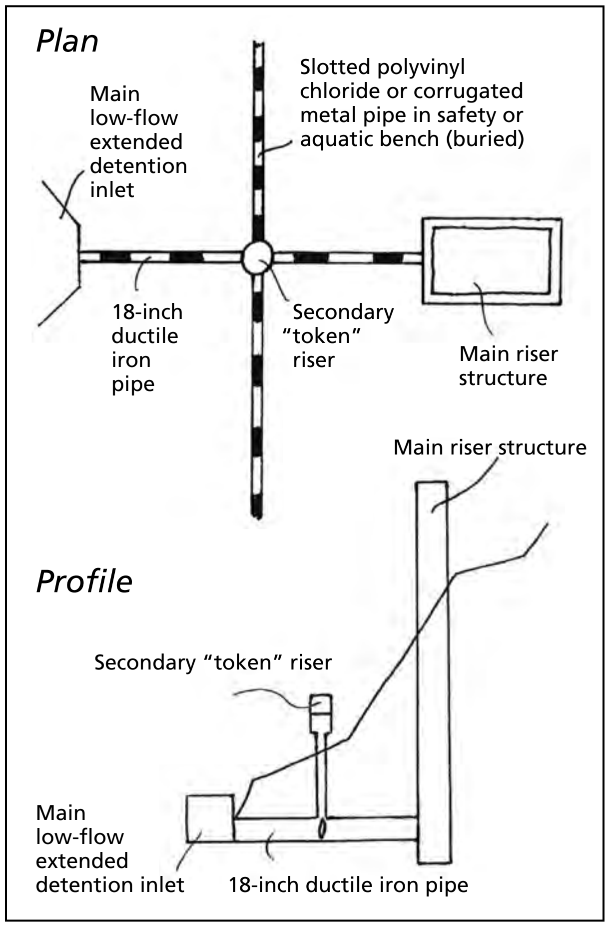


Figure 23. A secondary riser helps to keep permanent pools at safe elevations, even when outlets clog.

Species Selection

Species selection is key because most site conditions can be addressed by selecting appropriate tree species, rather than by trying to modify site conditions. Select a diverse mix of hardy, preferably native species (minimum of three), that are adapted to soils and site conditions.

Other desirable species characteristics include the following:

- ☐ Tolerant of compacted soils
- ☐ Tolerant of drought
- ☐ Tolerant of inundation
- ☐ Tolerant of urban pollutants

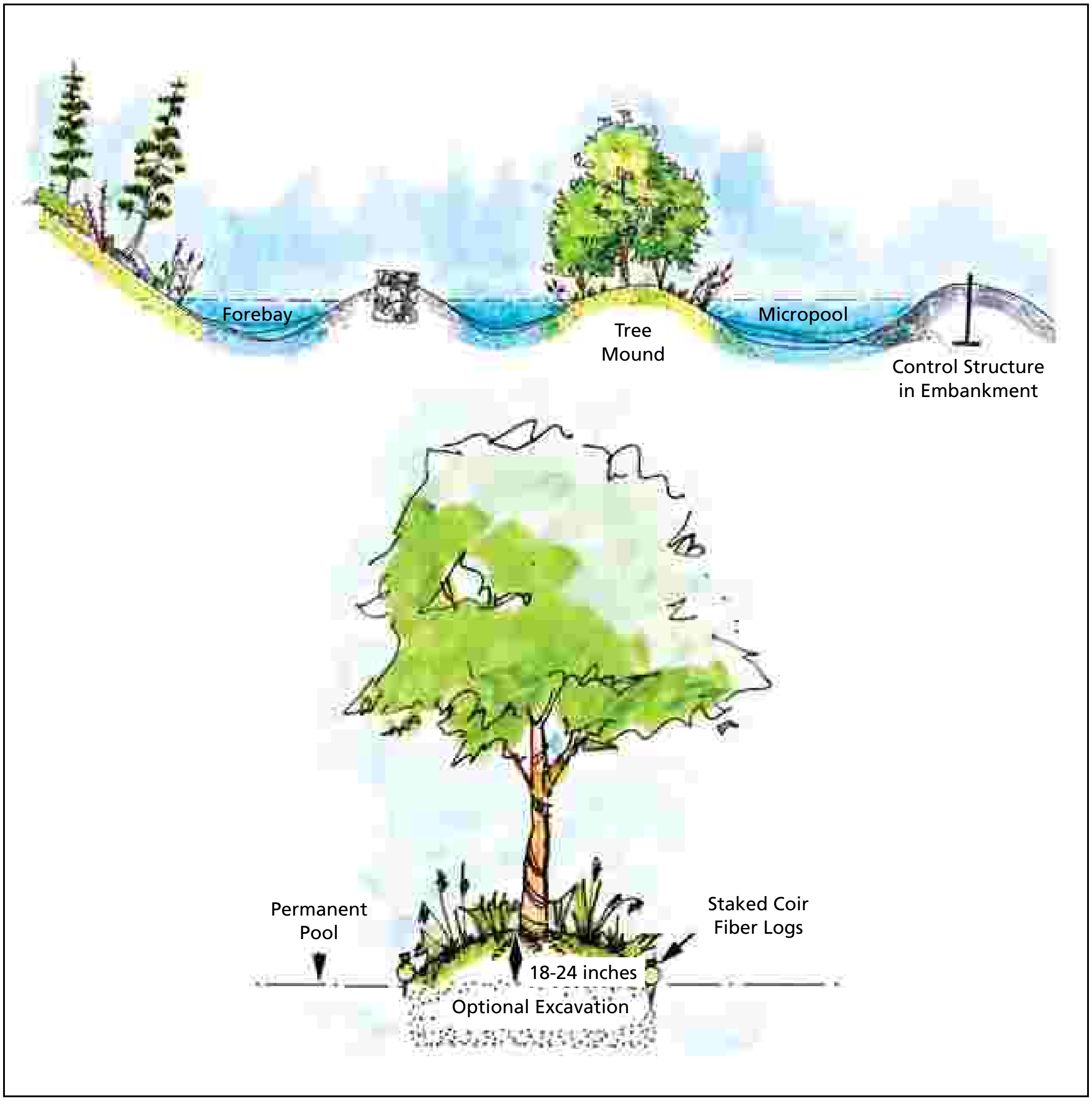


Figure 24. Tree mounds are one feature of a wooded wetland that incorporates trees.

Wooded Wetland *Continued*

General Planting Guidance

- ☐ Do not allow trees on embankment or in maintenance access area. Some small shrubs may be allowed (e.g., dogwoods or other "manageable" vegetation).
- ☐ Do not allow trees within 15 feet of embankment toe or maintenance access areas. Use a permanent pool to enforce this setback.
- ☐ Plant trees on mounds in shallow marsh area (Figure 24 on previous page).
- ☐ Plant trees in clusters on side slopes (Figure 25).

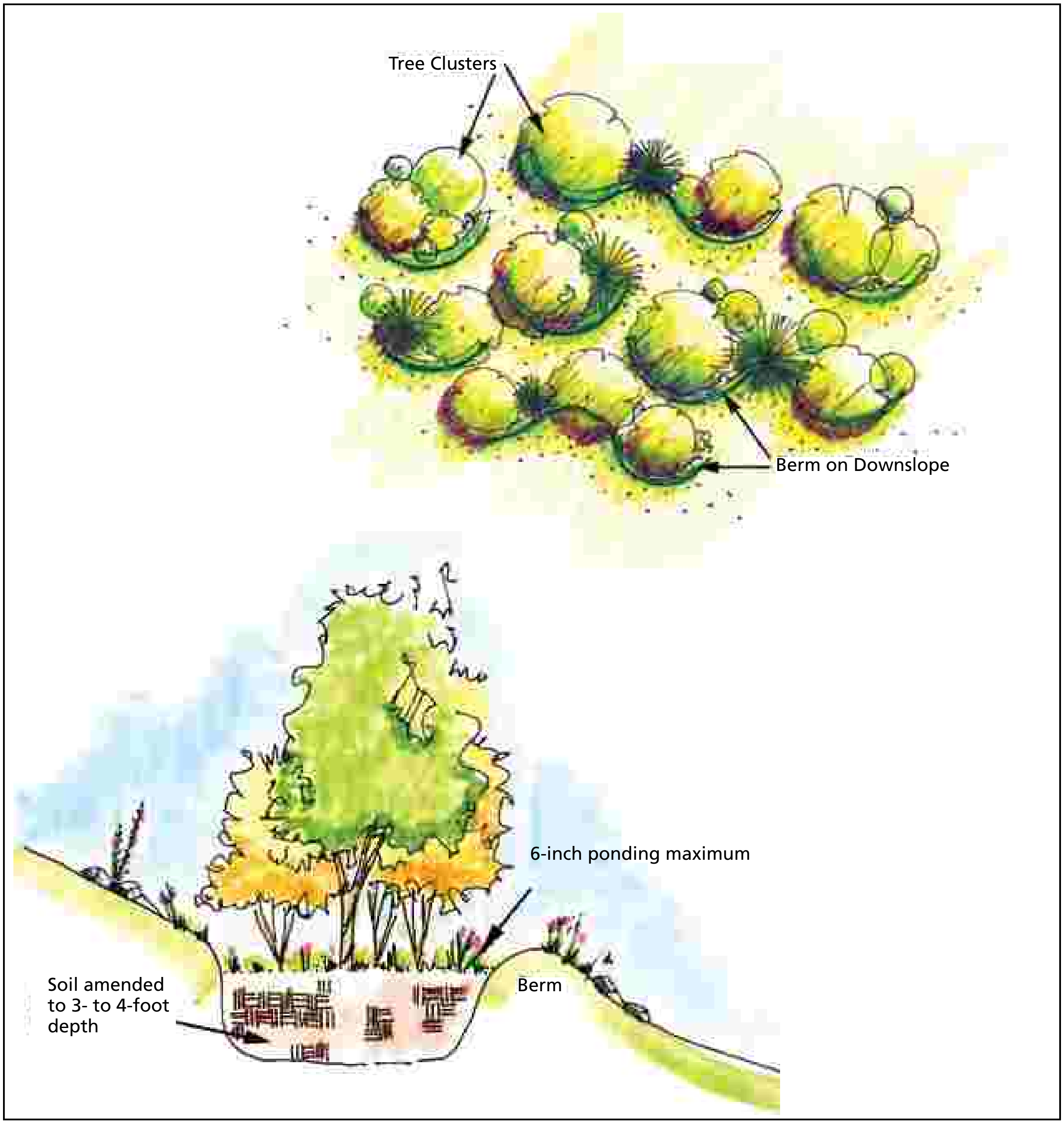


Figure 25. Tree clusters increase the soil and water volumes available for trees planted on side slopes.

Specific Planting Guidance

Tree Mounds

Tree mounds are islands located in the shallow marsh area of the wetland that are planted with trees (Figure 24). Mound placement should be such that a long internal flow path is created within the shallow marsh area. After initial wetland construction, mark boundaries of mound locations. Excavate the area of tree mounds 2 feet deep, if compacted. Stake coir fiber logs or hay bales, or use rock to form the boundaries of the mound. Backfill holes with amended soil. Mound elevation should be 12-18 inches above the permanent pool based on typical dimensions of coir fiber logs. However, the center of the mound where trees are planted may be 18-24 inches above the permanent pool, to reduce the duration of inundation.

Tree mounds should incorporate one large shade tree and several small trees or shrubs, depending on the size of the island. Seedlings may be planted, but if larger stock is used, a dedicated water source must be available, and the stock should be from a wetland. Size of islands should relate directly to the size and number of trees desired (e.g., provide sufficient soil volume for each tree—usually at least 400 cubic feet).

Tree Clusters

Tree clusters should be used on side slopes ranging from 10:1 to 3:1 to provide additional soil volume and water for trees (Figure 25). Clusters should have a minimum of three trees and contain trees that have the same tolerance for the anticipated degree of inundation. Tree clusters should be used at various elevations all the way around the slopes and arranged so that any runoff from the sides of the cluster will be directed downhill to the next cluster. Tree clusters should consist of a series of interconnected planting holes to increase available soil volume.

After constructing wetland side slopes, excavate planting holes that are 3-4 feet deep for each tree cluster. The size of the hole depends on the ultimate size of the tree but should provide adequate soil volume, and holes should be adjacent to each other so trees can share rooting space. Backfill the hole with amended soil. Use spoils to construct a berm on the downslope side of the tree cluster. Elevation of planting hole should be 6 inches below the top of the berm to allow for some ponding during storm events. Overplant with seedlings for fast establishment and to compensate for mortality.

Wooded Wetland *Continued*

Maintenance

- ☐ Plan for minimal maintenance of trees (e.g., frequent watering may not be feasible).
- ☐ Use tree shelters to protect seedlings from mowers and deer where needed.
- ☐ Use Integrated Vegetation Management (IVM) to control vegetation in embankment and maintenance access areas. IVM entails maintaining low-growing vegetation (e.g., 6 feet high) through mowing, hand removal of vegetation, or selection spraying (with herbicide approved for aquatic use) of individual trees in early growing stage (Genua, 2000).
- ☐ Do not mow wetland side slopes except for initial mowing required when native grasses are used.

Topics for Future Research

- ☐ Additional guidance is needed on weir wall design or design of an alternative outlet structure that resists clogging and addresses seepage and uplift.
- ☐ Need additional guidance on designing ponds and wetlands to preserve existing trees.
- ☐ May need alternative to coir fiber logs for mounds near a permanent pool.
- ☐ Measure changes in water quality due to trees in wetlands.

Further Resources

Genua, S. M. 2000. Converting power easements into butterfly habitats. Washington, DC: Potomac Electric Power Company (PEPCO). www.butterflybreeders.org/pages/powerease_sg.html

Schueler, T. R. 1992. Design of stormwater wetland systems: guidelines for creating diverse and effective stormwater wetlands in the mid-Atlantic Region. Washington, DC: Metropolitan Washington Council of Governments.

U.S. Army Corps of Engineers. 1989. Retaining and flood walls. Engineer Manual No. 1110-2-2502. Washington, DC: U.S. Army Corps of Engineers.

Bioretention and Bioinfiltration Facilities

Description

Bioretention and bioinfiltration facilities are shallow, landscaped depressions that contain a layer of prepared soil, a mulch layer, and vegetation. These facilities provide filtering of storm water runoff by temporarily ponding water during storms. Bioretention facilities have underdrain systems, while bioinfiltration facilities allow runoff to infiltrate into existing site soils (infiltration rates greater than 0.5 inches per hour).

The standard bioretention and bioinfiltration designs sometimes incorporate trees, but mainly as a landscaping "afterthought." The concept design presented here not only incorporates trees and shrubs, but has also been modified to improve growing conditions and decrease potential engineering conflicts (Figure 26). Planting trees and shrubs in bioretention and bioinfiltration facilities may increase nutrient uptake and evapotranspiration.

Bioretention and bioinfiltration facilities are typically small (footprints are generally 5% of the impervious area they receive drainage from, drainage areas are less than 2 acres) and can be used in many applications. Where space is available, a forested or multi-zone filter strip may be used as pretreatment for bioretention and bioinfiltration facilities.

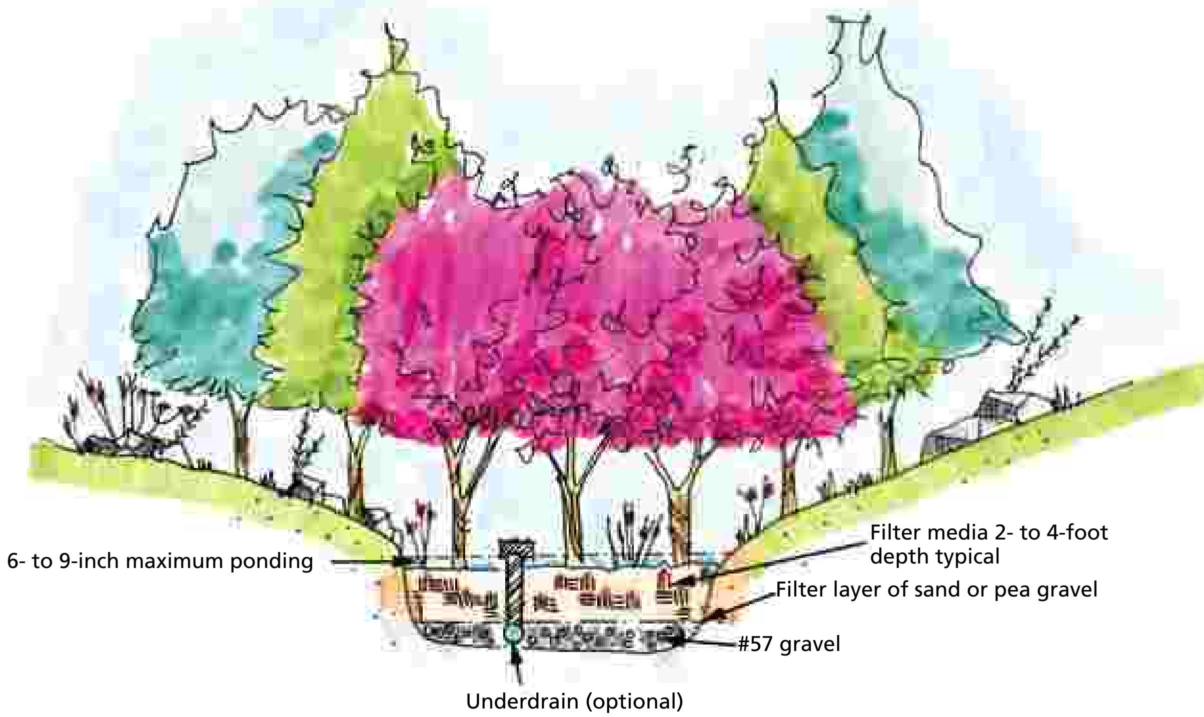


Figure 26. Bioretention and bioinfiltration facilities remove pollutants from storm water runoff using a filter medium.

Bioretention and Bioinfiltration Facilities *Continued*

Design Modifications

- ☐ Filter fabric should not be used between the filter media and the gravel jacket around the underdrain, as it creates an undesirable soil/water interface. A filter layer of sand or pea gravel may be used in lieu of filter fabric in this area to prevent the migration of fines into the gravel layer below. Ferguson (1994) provides a formula for determining the composition of this sand layer, and Prince George's County (2001) provides guidance on use of a pea gravel layer. Filter fabric may not be necessary along the sides of the excavated area unless there is concern about lateral movement of water into the adjacent soil (e.g., in applications where lateral seepage may cause upheaval of adjacent pavement).
- ☐ Use #57 (i.e., 1 ½-inch diameter) gravel instead of #2 around underdrain to provide some filtering. The underdrain may be suspended within #57 gravel to provide enhanced recharge and infiltration by increasing the stone reservoir.
- ☐ Allow for 6-9 inches of ponding during storm events.

Species Selection

Species selection is key in bioretention designs since it is more efficient than trying to change the site characteristics. Select a minimum of three hardy, native tree species that are adapted to soil and site conditions.
Other desirable species characteristics may include the following:

- ☐ Tolerant of inundation
- ☐ Tolerant of drought
- ☐ Wide spreading canopy
- ☐ Tolerant of salt

General Planting Guidance

- ☐ Have a landscape architect create a planting plan for the facility.
- ☐ Do not plant trees directly over the underdrain as a precautionary measure.
- ☐ Excavate the center only to a depth of 4 feet and backfill with filter media (infiltration rate of at least 0.5 feet per day). Use existing soil on side slopes (minimum 4:1 slopes). Use a filter medium with a lower sand ratio, or plant large trees only on side slopes to reduce potential for upheaval.
- ☐ Overplant with bare root seedlings for fast establishment and to account for mortality. Alternatively, plant larger stock when a dedicated water source is available using desired spacing intervals (35-50 feet for large and very large trees) and random spacing, or use a mix of seedlings and larger stock.
- ☐ Provide adequate soil volume for trees: in general, 2 cubic feet of useable soil for every square foot of mature canopy (Urban, 1999). Assume some shared rooting space between trees.

Maintenance	☐	Use tree shelters to protect seedlings where deer predation is a concern.
	☐	Use mulch to retain moisture.
Topics for Future Research	☐	Quantify increased pollutant removal due to trees in facility.

Further Resources

Center for Watershed Protection. 1996. Design of stormwater filtering systems. Ellicott City, MD.

Ferguson, B. K. 1994. Stormwater infiltration. Boca Raton, FL: CRC Press, Inc.

Prince George's County. 2001. Bioretention manual. Upper Marlboro, MD: Department of Environmental Resources Program and Planning Division.

Urban, J. 1999. Room to grow. Treelink 11: 1-4.

Alternating Side Slope Plantings (Swale)

Description	Alternating side slope plantings are trees planted on the side slopes of a dry swale or other open channel conveyance system in an alternating pattern. Alternating side slope plantings can be used in open channels with longitudinal slopes up to 2%, to provide shade, rainfall interception, limited slope stabilization, and esthetic value.
Design Modifications	None.
Species Selection	Species selection is key because it is more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species with the following characteristics: ☐ Tolerant of inundation ☐ Tolerant of salt ☐ Wide spreading canopy.
General Planting Guidance	☐ Trees should be planted singly or in clusters in an alternating pattern on the side slopes. As a general rule, tree or cluster spacing should be six times the channel width (Figure 27), to impose meanders on channel flow. ☐ Stock can be seedlings (overplant for fast establishment and to account for mortality) or larger stock planted at desired spacing intervals. ☐ Excavate planting hole to a depth of 2-4 feet and backfill with amended soil if existing soil is compacted. ☐ The channel bottom and side slopes may be planted with turf or with native grasses (if able to withstand the runoff velocity the swale is designed to convey). ☐ Establish a defined edge on the top slope of the channel using trees, shrubs, or spaced rock. This edge protects trees from mowers and provides a visual border to let residents know the plantings are intentional.
Maintenance	☐ Use mulch to retain moisture ☐ Mow around trees regularly if turf, or twice a year if native grasses. ☐ Use mulch, tree shelters, or rock borders to protect trees from lawn mowers.

Topics for Future Research

- ☐ Is there potential for trees to shade out grass and contribute to erosion?
- ☐ What species can be planted on channel bottom and around trees as an alternative to turf that can also withstand the runoff velocity the swale is designed to convey?

Further Resources

Center for Watershed Protection. 1996. Design of stormwater filtering systems. Ellicott City, MD.

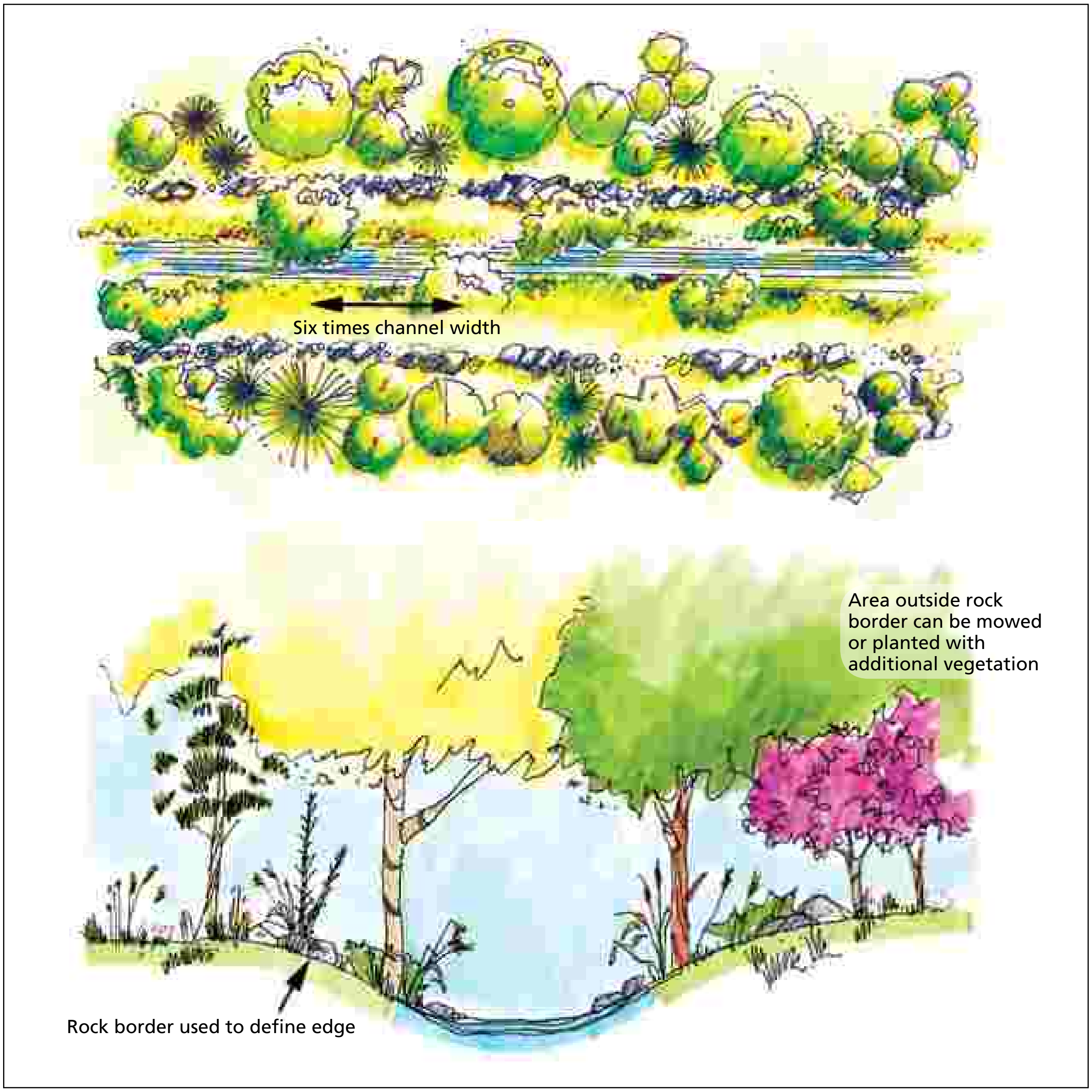


Figure 27. Alternating side-slope plantings are an attractive way to incorporate trees into swales without obstructing channel flow.

Tree Check Dams (Swale)

Description

Open channel conveyance systems such as dry swales often incorporate check dams to slow runoff and prevent erosion, when longitudinal slopes range from 2% to 6%. Traditional check dams are constructed of rock, railroad ties, or other material. Tree check dams (Figure 28) use tree mounds (Figure 24 on page 31) to dissipate velocity. Tree check dams may also increase evapotranspiration and pollutant removal in the swale soils.

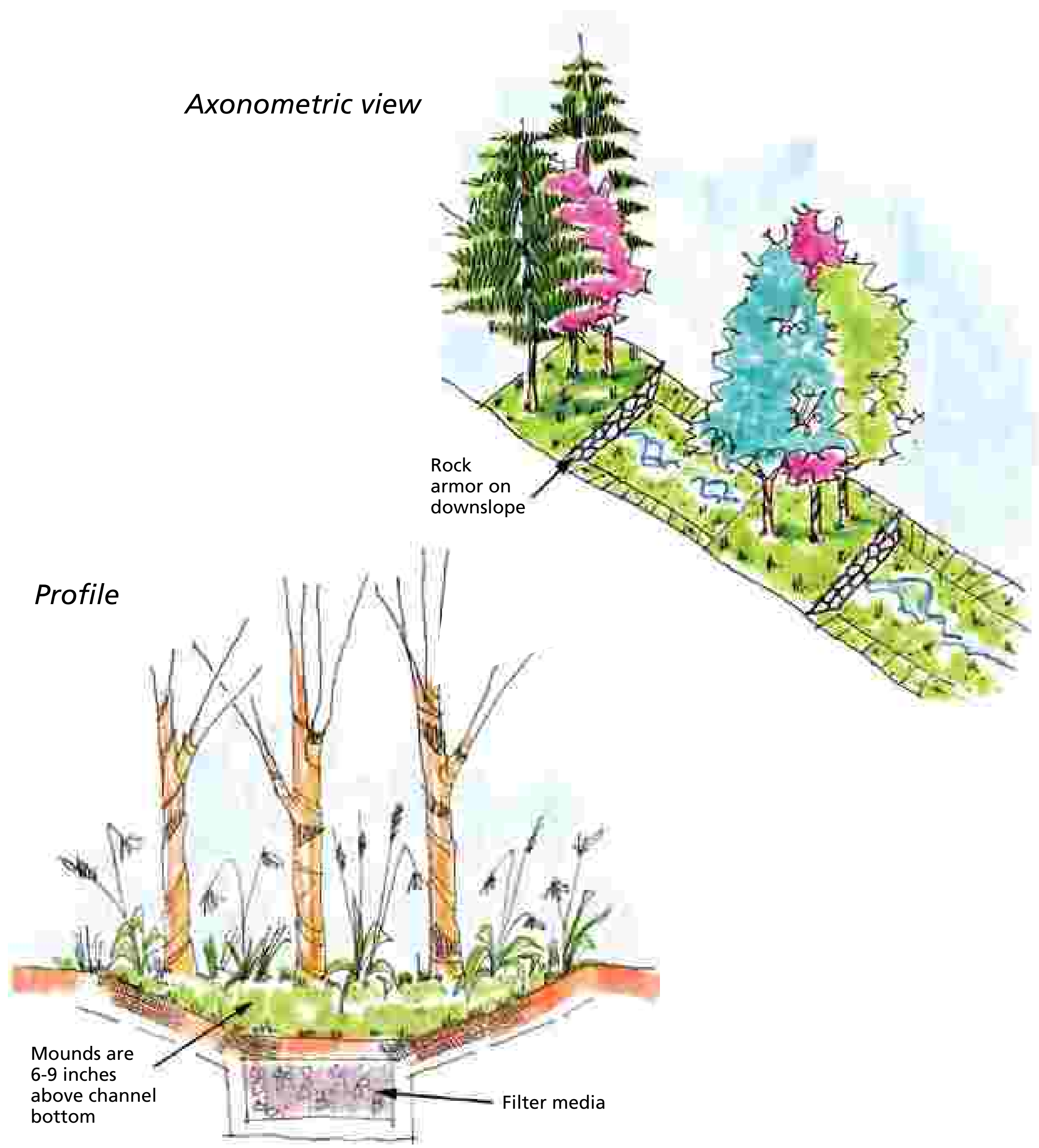


Figure 28. Tree check dams slow runoff and prevent erosion in swales with slopes of 2% to 6%.

Design Modifications	Account for increased roughness and reduced capacity by subtracting the cross-sectional area of trees from the channel cross-section when computing channel capacity.
Species Selection	Species selection is key because it is more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions. In particular, consider the size of trees at maturity in relation to channel width. Trees that are too large may block flow across the channel, so small trees and shrubs may be best for check dams. Other desirable species may have these characteristics: ☐ Tolerant of inundation ☐ Tolerant of salt
General Planting Guidance	☐ Spacing of check dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam. ☐ Check dam mounds should be no higher than 6-9 inches above the bottom (invert) of the channel. ☐ The mound should be constructed across the entire width of the channel, and have a weep hole or armored opening to allow ponded water to seep through the mound. Mounds should be armored with rock on the downslope side, particularly on steeper slopes, to protect from erosion. ☐ Excavate to a depth of 3-4 feet and backfill with amended soil if existing soil is compacted. ☐ Plant trees and shrubs on the mounds, using bare root seedlings to minimize transplant stress to roots. ☐ Plant turf grass or native grasses (if able to withstand the runoff velocity the swale is designed to convey) along the channel bottom and side slopes.
Maintenance	☐ Use mulch to retain moisture. ☐ Periodically remove debris and trash from the check dams. ☐ Use mulch, tree shelters, or rock to protect the tree from lawnmower damage. ☐ Mow turf regularly or native grasses twice a year.

Tree Check Dams (Swale) ***Continued***

Topics for Future Research	☐ Will tree mounds be stable enough to withstand high flows? ☐ Should larger stock be used to prevent seedlings from washing away? ☐ Is there potential for trees to shade out grass and contribute to erosion? ☐ What species can be planted on the channel bottom and around trees as an alternative to turf that can also withstand the runoff velocity the swale is designed to convey? ☐ Can dimensions of tree mounds be further defined?
Further Resources	Center for Watershed Protection. 1996. Design of stormwater filtering systems. Ellicott City, MD. Metro. 2002. Green streets: innovative solutions for stormwater and stream crossings. Portland, OR.

Forested Filter Strip

Description

A traditional filter strip is a grass area that is intended to treat sheet flow from adjacent impervious areas. Sheet flow is runoff that flows over land with no defined channels. Filter strips function by slowing runoff velocities, filtering out sediment and other pollutants, and providing some infiltration into underlying soils.

A forested filter strip provides a similar function but incorporates trees and a small ponding zone (optional) into the design (Figures 29 and 30). The ponding zone is a small depression with a low berm where water ponds during most storm events (e.g., around a 1-inch rainfall). The entire filter strip is planted with trees and shrubs, but since the depression is wetter than the remainder of the practice, the two zones are distinguished by referring to them as the ponding zone and the forested zone. Additional benefits provided by a forested filter strip include evapotranspiration, wildlife habitat, and infiltration promoted by macropore formation.

Forested filter strips may be used as follows:

- ☐ In linear areas such as stream buffers and transportation corridors.
- ☐ As pretreatment for a stream buffer or other storm water treatment practice.
- ☐ Where visual screening or a buffer is desired.

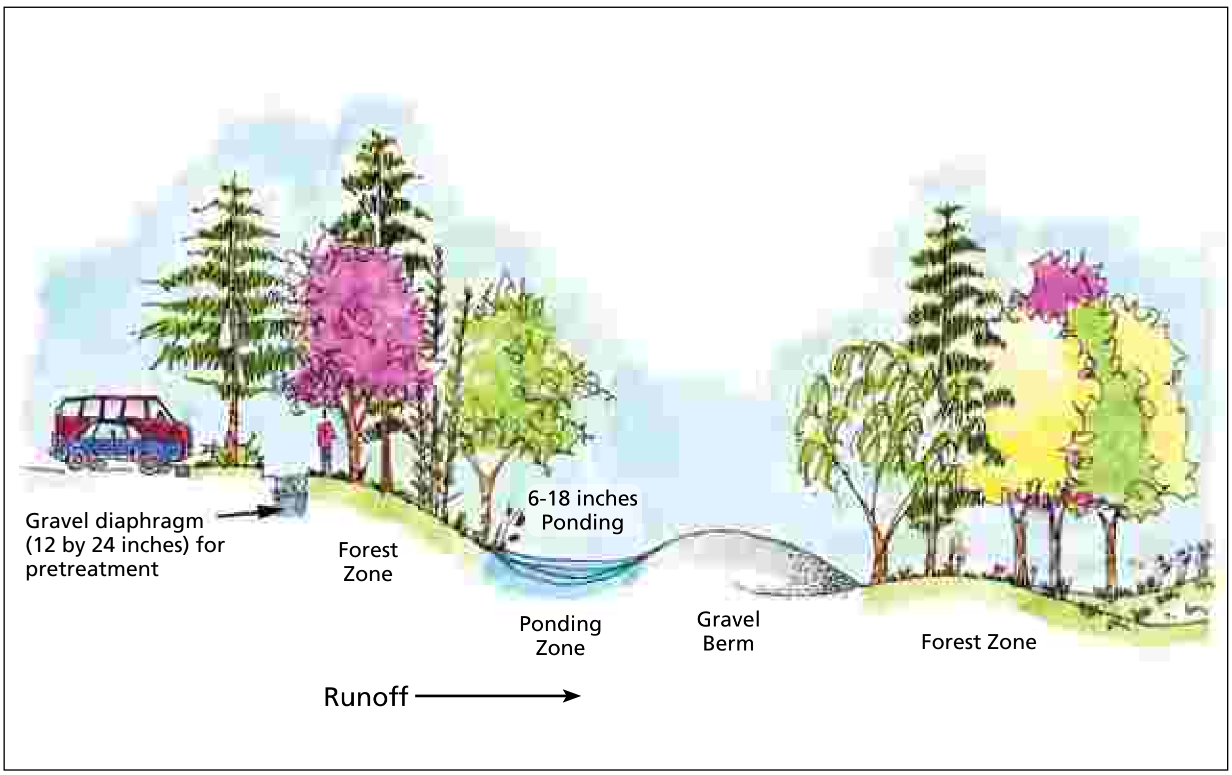


Figure 29. Forested filter strip profile shows how runoff flows through the various zones.

Forested Filter Strip *Continued*

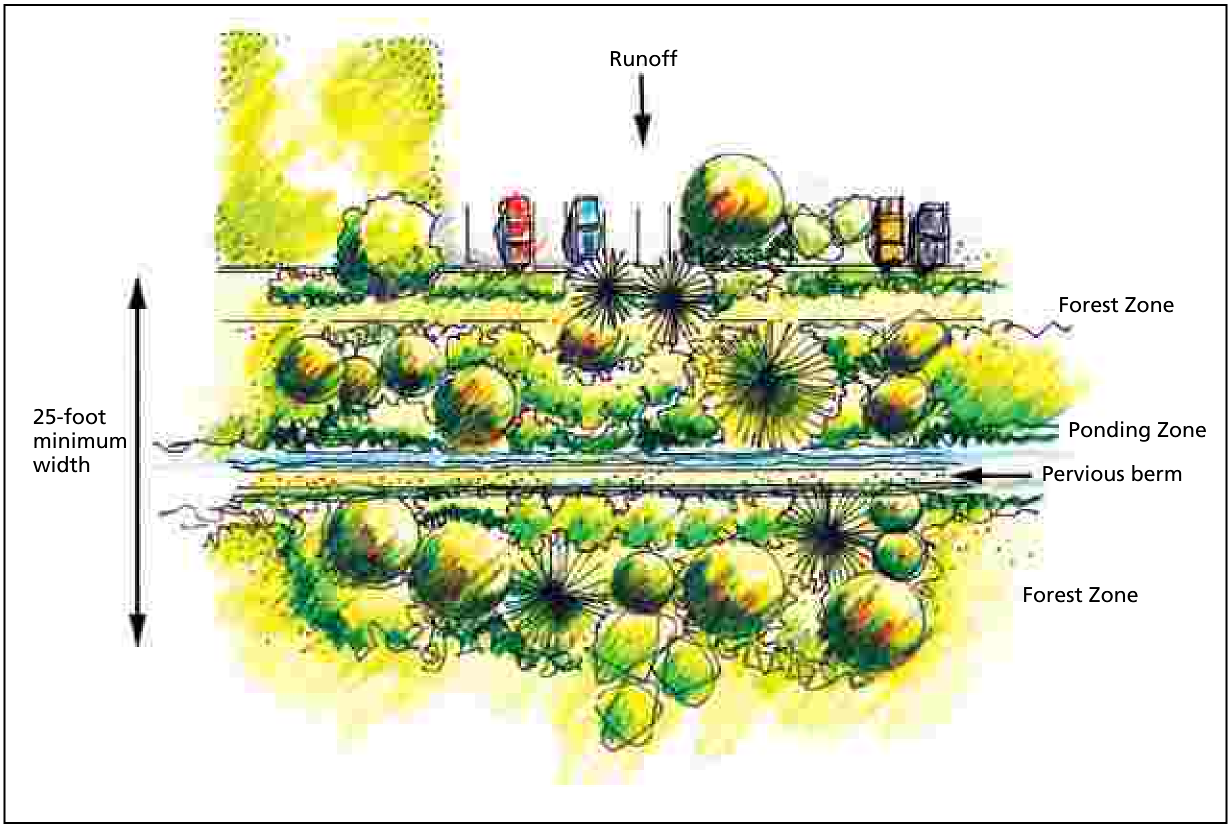


Figure 30. Forested filter strip plan shows its suitability to a linear area.

Design Modifications

- ☐ Unlike a traditional grass filter strip, the forested filter strip is not limited to accepting sheet flow runoff. If runoff is concentrated, the filter strip inlet should be armored with rock.
- ☐ Use a gravel diaphragm for pretreatment (acts as a level spreader and allows fine sediment to settle out where sheet flow is present).
- ☐ When a significant volume of storm water runoff is expected, the forested filter strip should have a small berm constructed of pervious material such as gravel, rock, or earth. If the berm is earthen, insert weep hole pipes so ponded water filters to the other side. If the berm is gravel, gabions may be used. A gabion is a wire mesh cage filled with rock and is used to prevent erosion. The height of the berm should be 6-18 inches above the bottom of the depression and at least 6 inches below the lowest inflow elevation.
- ☐ Overall dimensions should provide surface storage for the water quality volume. During larger storms, runoff will overtop the berm. Minimum width of the filter strip should be 25 feet. The slope should range from 2% to 6%.

Species Selection	Existing trees should be incorporated into the design where possible. Otherwise, select a diverse mix of native species (minimum of three) that have these characteristics: ☐ Tolerant of salt ☐ Tolerant of inundation (standing water in ponding zone, fluctuating water levels in forested zone).
General Planting Guidance	☐ Shrubs and small trees can be incorporated into the ponding zone, and larger trees can be incorporated into the forested zone. ☐ Conserve existing soil, if undisturbed, and use soil amendments if site soils are compacted. ☐ Overplant with seedlings for fast establishment and to account for mortality. Alternatively, plant larger stock at desired spacing intervals (35-50 feet for large and very large trees) using random spacing.
Maintenance	☐ Use mulch to retain moisture. ☐ Use tree shelters to protect seedlings.
Topics for Future Research	☐ Quantify increased pollutant removal due to trees in filter strip.
Further Resources	Center for Watershed Protection. 1996. Design of stormwater filtering systems. Ellicott City, MD. Maryland Department of the Environment. 2000. Maryland stormwater design manual. Baltimore, MD.

Multi-Zone Filter Strip

Description

A traditional filter strip is a grass area that is intended to treat sheet flow from adjacent impervious areas. Sheet flow is runoff that flows over land with no defined channels. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some infiltration into underlying soils.

A multi-zone filter strip provides a similar function but incorporates trees and shrubs into the design. A multi-zone filter strip features several vegetation zones that provide a gradual transition from turf to forest (Figures 31 and 32). The zones are turf, meadow, shrub, and forest. The multi-zone filter strip can be effectively designed as a transition filter zone to an existing forest area. Additional benefits provided by a multi-zone filter strip include evapotranspiration, wildlife habitat, and infiltration promoted by macropore formation.

Multi-zone filter strips may be used as follows:

- ☐ In linear areas such as stream buffers and transportation corridors.
- ☐ As pretreatment for a stream buffer or other storm water treatment practice.
- ☐ Where runoff is present as sheet flow and travels over short distances (a maximum of 75 feet of impervious area, or 150 feet of pervious area).
- ☐ Where safety and visibility are concerns (e.g., next to parking lot or public area)

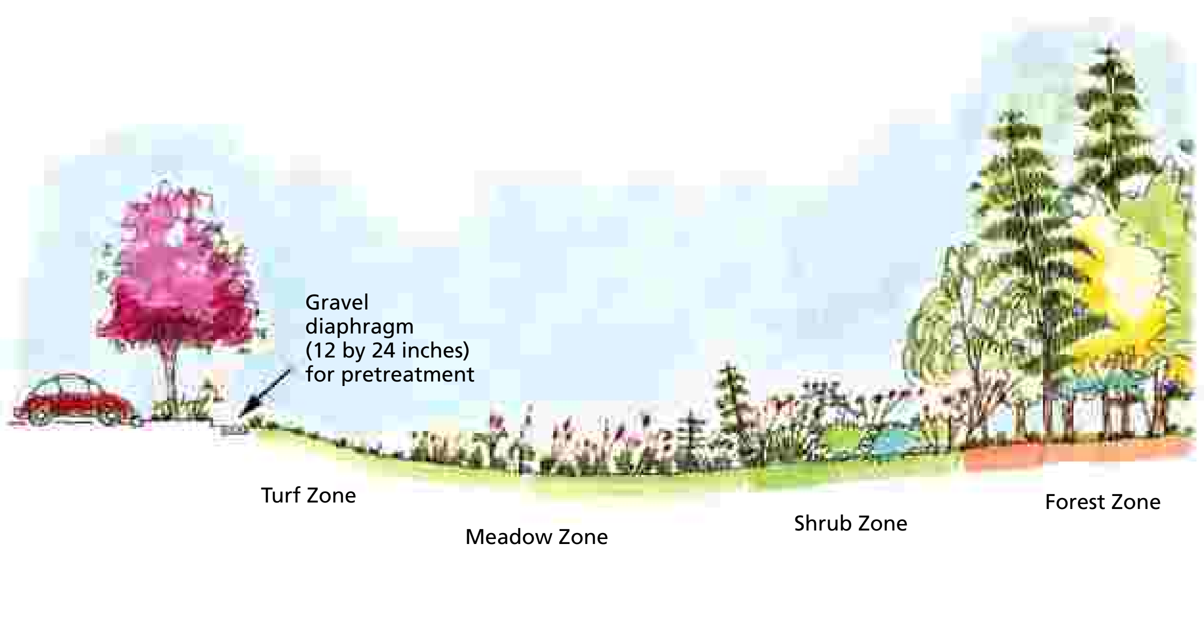


Figure 31. A multi-zone filter strip (profile) includes four successive vegetation zones.

Design Modifications	☐	Use curb stops or parking stops to keep cars from driving on the grass area, if next to a parking lot.
	☐	Use a gravel diaphragm for pretreatment.
	☐	Minimum width of filter strip should be 25 feet.
	☐	When a significant volume of stormwater runoff is expected, a small berm and ponding area may be incorporated as described in the Forested Filter Strip.
Species Selection	Existing trees should be incorporated where possible. Otherwise, select and plant a minimum of three native species with these characteristics:	
	☐	Tolerant of inundation
	☐	Tolerant of salt
General Planting Guidance	☐	Plant each zone with the desired vegetation. Widths of each vegetative zone may vary. Shrub zone may ultimately become a tree zone.
	☐	Conserve existing soil, if undisturbed, and use soil amendments if compacted.
	☐	Overplant with seedlings for fast establishment and to compensate for mortality, or plant larger stock at desired spacing intervals (35-50 feet for large and very large trees) using random spacing.
Maintenance	☐	Use mulch to retain moisture.
	☐	Use tree shelters to protect seedlings.
	☐	Mow turf zone regularly and reseed as needed.
	☐	Mow meadow zone twice a year.

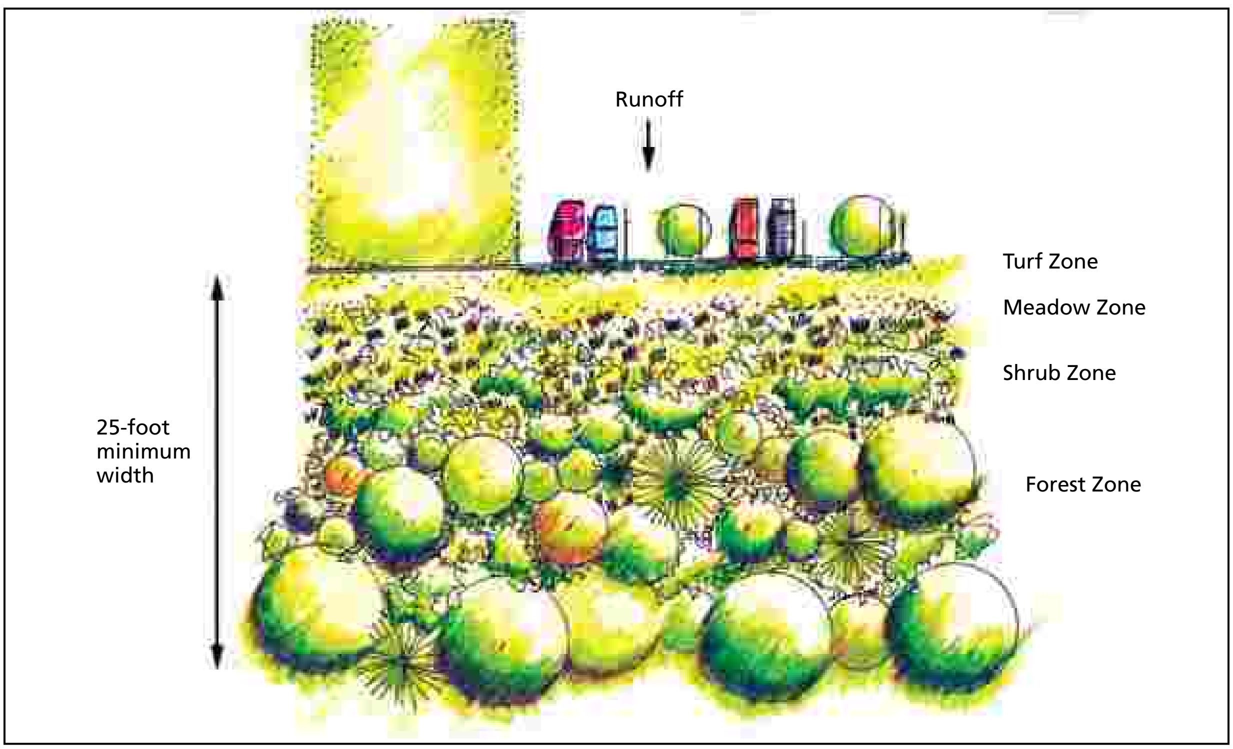


Figure 32. A multi-zone filter strip (plan) requires a minimum width of 25 feet.

Multi-zone Filter Strip *Continued*

Topics for Future Research	☐ Quantify additional pollutant removal due to trees in filter strip.
Further Resources	Center for Watershed Protection. 1996. Design of stormwater filtering systems. Ellicott City, MD. Maryland Department of the Environment. 2000. Maryland stormwater design manual. Baltimore, MD.

Linear Storm Water Tree Pit

Description

A linear storm water tree pit is similar to a traditional street tree pit design, but is modified so the pit accepts and treats storm water runoff and provides an improved planting environment for the tree. A storm water tree pit has additional soil volume, regular irrigation, and better drainage to promote tree growth. A continuous soil trench underneath the pavement connects individual tree pits (Figures 33 and 34).

Linear storm water tree pits are most useful for the following conditions:

- ☐ Where existing soils are very compacted or poor.
- ☐ Where open space for planting is limited (e.g., highly urban areas) and rooting space can be provided for trees underneath pavement.
- ☐ In street tree or other linear applications (although it can be adjusted for a different application, such as clustered plantings in a courtyard).
- ☐ New development, or as a retrofit of existing development, when done in conjunction with repair of underground utilities or a streetscaping project that requires sidewalk excavation.

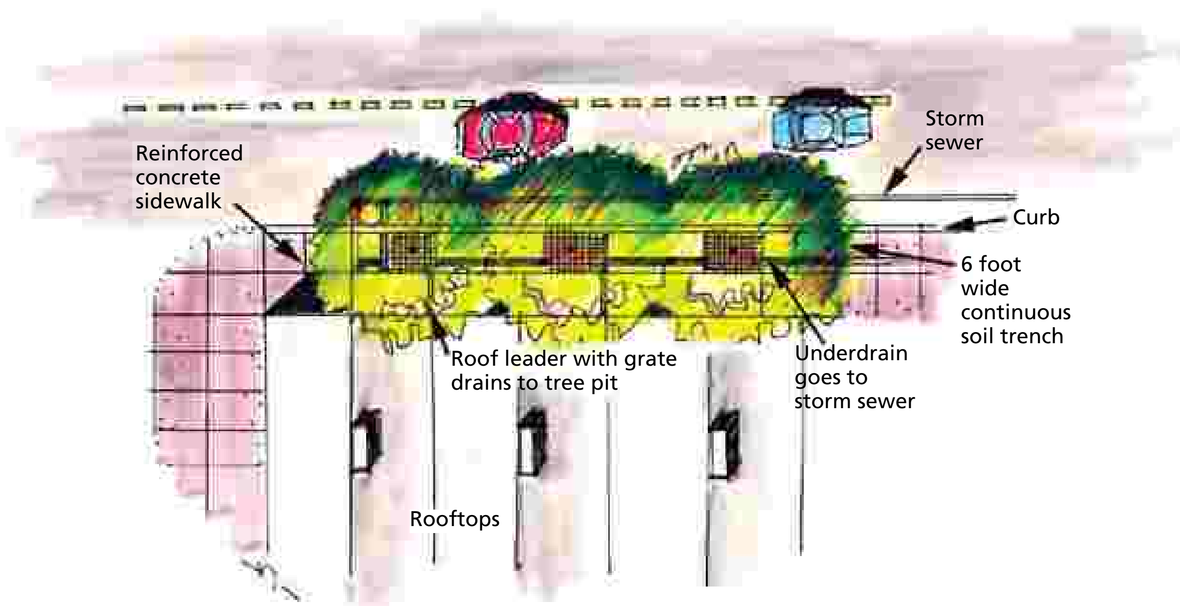


Figure 33. A linear storm water tree pit (plan view) collects and treats storm water that is directed from rooftops.

Linear Storm Water Tree Pit *Continued*

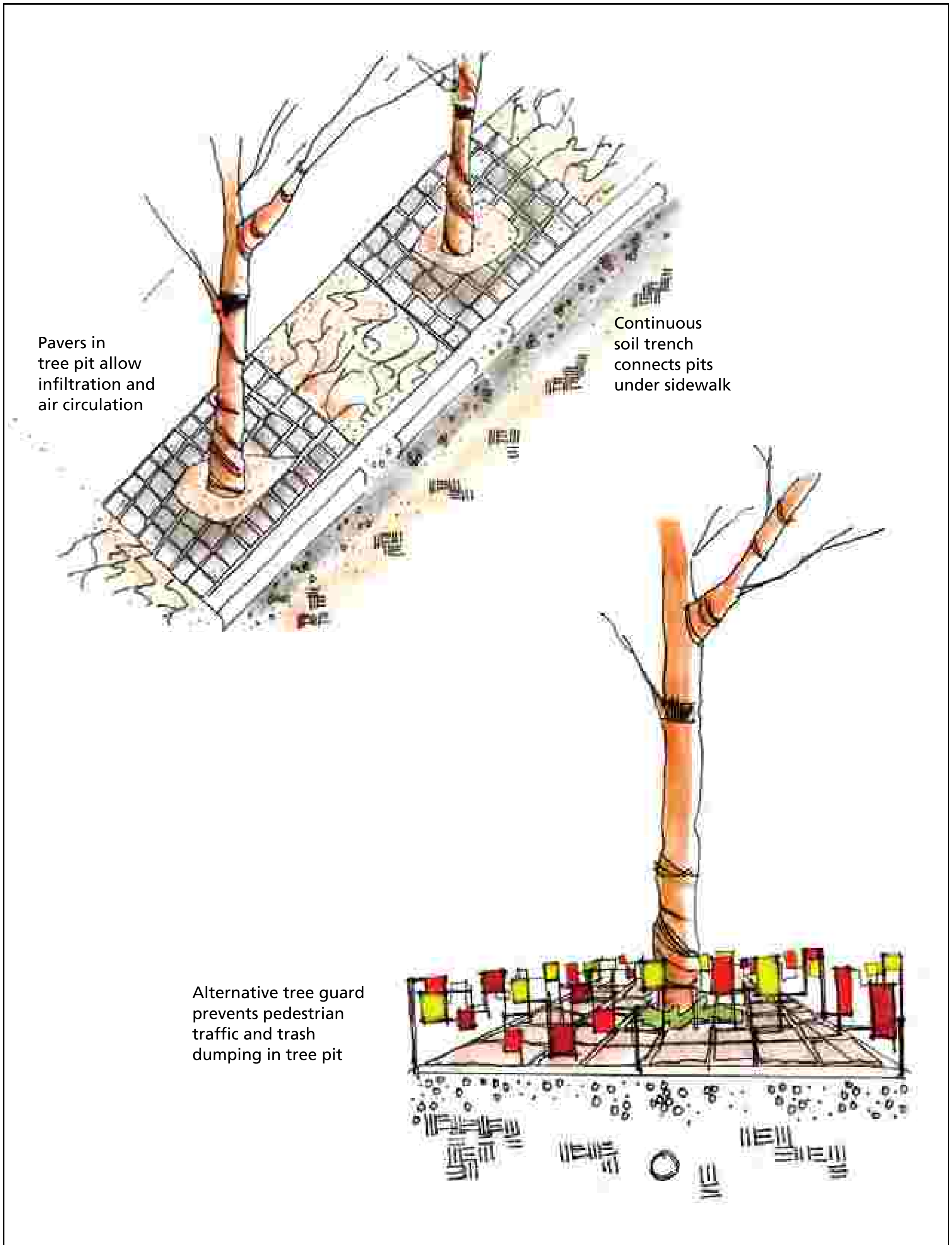


Figure 34. Tree pits are connected through a soil trench, and tree pit protection prevents damage from pedestrian traffic.

Design Modifications	☐	Storm water is directed from rooftops to tree pits using sunken roof leaders covered with grates. An alternative is to use curb cuts to direct street runoff to the pits for added water quality benefits. In this case, a filter screen or cleanout device must be provided to capture trash and litter.
	☐	An underdrain that connects either to existing storm drain inlets or to the storm sewer is installed under tree pits. The underdrain is surrounded by a layer of gravel to provide some filtering. A variation is to add a gravel base under the underdrain to allow some infiltration.
	☐	Trees are planted within a linear trench with filter medium to allow filtering of storm water and shared rooting space for trees underneath pavement.
	☐	Reinforced concrete sidewalks should have wide surface openings to accommodate the mature size of the trees (sidewalks will be cantilevered over planting holes).
	☐	Consider use of structural soils under pavement, which allows tree roots to grow in it and also meets engineering specifications (see Bassuk and others (n.d.) and Part 3 of this manual series for more information).
Species Selection	Species selection is critical in storm water tree pits because unmodified site conditions are often highly stressful to healthy tree growth. A mix of hardy species should be selected that are adapted to the following soil and site conditions:	
	☐	Tolerant of poor, compacted soils
	☐	Tolerant of salt
	☐	Tolerant of urban pollutants
	☐	Tolerant of inundation
	☐	Tolerant of drought
	☐	Wide spreading canopy
General Planting Guidance	☐	Excavate a planting trench 3-4 feet deep and a minimum of 6 feet wide. The volume for each tree should be adequate for the mature size of the tree, assuming some shared soil volume. Backfill trench with filter medium. The top of the planting trench should be slightly below grade to allow space for air circulation.
	☐	Plant at desired spacing intervals.
	☐	Install concrete posts, fencing, or other structures (see Figure 34) to prevent pedestrians from stepping in tree pit (tree grates are not recommended since they can damage the tree if they are not adjusted as it grows).

Linear Storm Water Tree Pit *Continued*

Maintenance	☐	Use mulch to retain moisture.
Topics for Future Research	☐	Need better method to prevent use of tree pits as trash cans.
	☐	Develop guidance on sizing and volume of tree pits so as not to direct too much water into pits.

Further Resources

Bassuk, N.; Grabosky, J.; Trowbridge, P.; Urban, J. [N.d.]. Structural soil: an innovative medium under pavement that improves street tree vigor. Ithaca, NY: Cornell University, Urban Horticulture Institute. www.hort.cornell.edu/department/faculty/bassuk/uhi/outreach/csc/article.html

Hammerschlag, R. S.; Sherald, J. L. 1985. Traditional and expanded tree pit concepts. In: METRIA 5: Selecting and Preparing Sites for Urban Trees. Proceedings of the Fifth Conference of the Metropolitan Tree Improvement Alliance. University Park, PA: The Pennsylvania State University.

Hoke, J. R., Jr., ed. 2000. Architectural graphic standards, 10th ed. New York, NY: John Wiley and Sons, Inc.

Urban, J. 1999. Room to grow. Treelink 11: 1-4.

Chapter 4. Planting Trees Along Streets and in Parking Lots

This chapter provides guidance on planting trees along local streets and within parking lots at new development sites. Pervious portions of a development site that make good candidates for tree planting and are often overlooked include local road rights-of-way, landscaped islands in cul-de-sacs or traffic circles, and parking lots. Many local landscaping ordinances often require developers to plant street trees or to landscape a certain percentage of every parking lot.

One of the most common features of highly desirable neighborhoods is the presence of large street trees that form a canopy over the road. Many newer developments either do not incorporate street trees or use small, ornamental trees or other types of vegetation within the planting strip (Figure 35). Street trees are traditionally planted in a linear fashion along either side of the road. Alternatives to this design include these: planting trees in clusters along the side of the road (Figure 36), planting trees within median strips (Figure 37), or planting trees in islands located in cul-de-sacs or traffic circles (Figure 38). Each planting area has specific considerations for incorporating trees to ensure adequate space is provided and to address common concerns about visibility and conflicts with overhead wires or pavement (Figure 39).

Figure 35. The environment differs drastically in a development with no street trees (top) from one with trees that matured to form a canopy over the street (bottom).

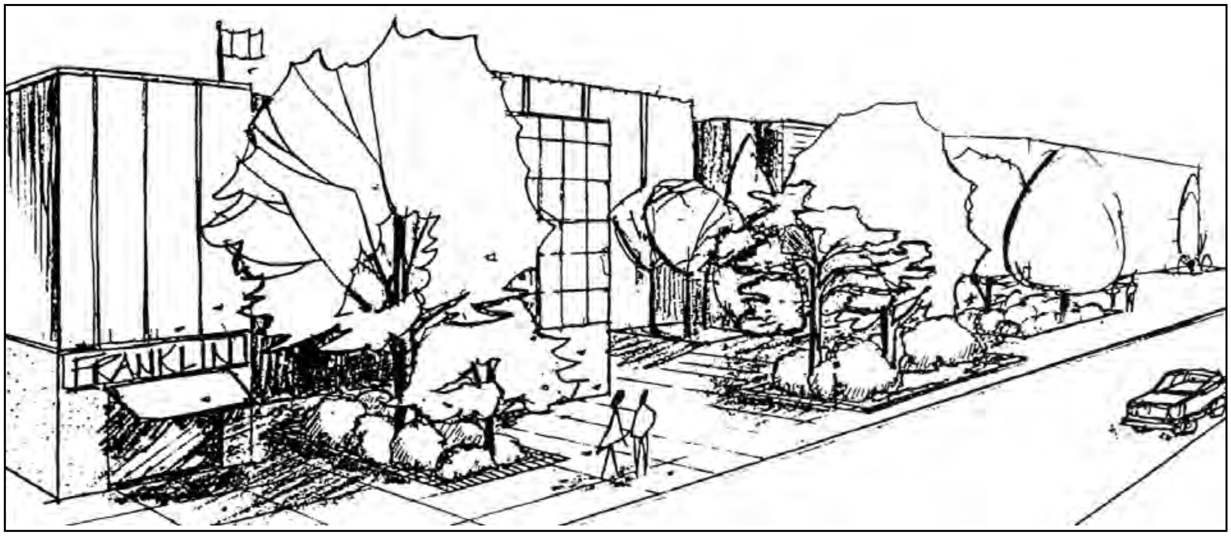


Figure 36. Non-linear street tree plantings are an alternative to linear roadside plantings. (Source: Meyer, n.d., p. 32)

Figure 37. Trees planted in a median strip provide shade, slow traffic, and make a street more attractive (left) than one with little vegetation (right).

Figure 38. A cul-de-sac (left) is typically overlooked as a place to plant trees (right) .

Figure 39. Trees planted in holes that are too small may eventually crack nearby pavement.

Trees in parking lots reduce the urban heat island effect, remove pollutants, provide shade and habitat for wildlife, and increase the esthetic value of the parking lot. Many commercial parking lots, however, use a “cookie cutter” design that does not incorporate trees (Figure 40). Because a parking lot can be a very harsh climate for a tree, several important design considerations are necessary.

Figure 40. The harsh environment of a parking lot (left) can be tempered by including an interior planting strip that allows trees to share rooting space (right).

Planting guidance for trees along streets and in parking lots is presented in the remainder of this chapter in fact sheet format. Each fact sheet contains the following sections:

Description – brief description of the planting concept.

Pre-Planting Considerations – potential conflicts with planting trees at the site or unique features that drive plant selection and planting procedures. Most of these considerations are addressed in the Species Selection, Site Preparation, Planting Guidance, or Maintenance sections.

Species Selection – desirable characteristics of species to be planted at the site. Part 3 of this manual series includes an Urban Tree Selection Guide with tree and shrub species and their characteristics.

Site Preparation – recommendations for preparing the site for planting.

Planting Guidance – recommendations for stock selection, planting zones, plant spacing and arrangements, and planting methods.

Maintenance – recommendations for tree maintenance.

Potential for Storm Water Treatment – potential for integrating trees and storm water treatment practices in that particular location.

Further Resources – resources for additional information.

Planting Trees Along Local Streets

Description

Local roads offer three areas to incorporate trees: the buffer, the median strip, and landscaped islands in cul-de-sacs or traffic circles (Figures 41 and 42). The buffer consists of the area between the edge of the road pavement and adjacent private property. The median strip is the area between opposing traffic lanes. Cul-de-sacs are large diameter bulbs that enable vehicles to turn around at the end of streets. They often involve large areas of pavement but present a good opportunity to plant trees in neighborhoods.

Trees planted along local roads can reduce air pollution and storm water runoff, provide habitat for wildlife such as birds, provide shade for pedestrians, reduce air temperatures, stabilize the soil, provide a visual screen and barrier from noise and highway fumes, and make for a visually pleasing environment for drivers and homeowners.

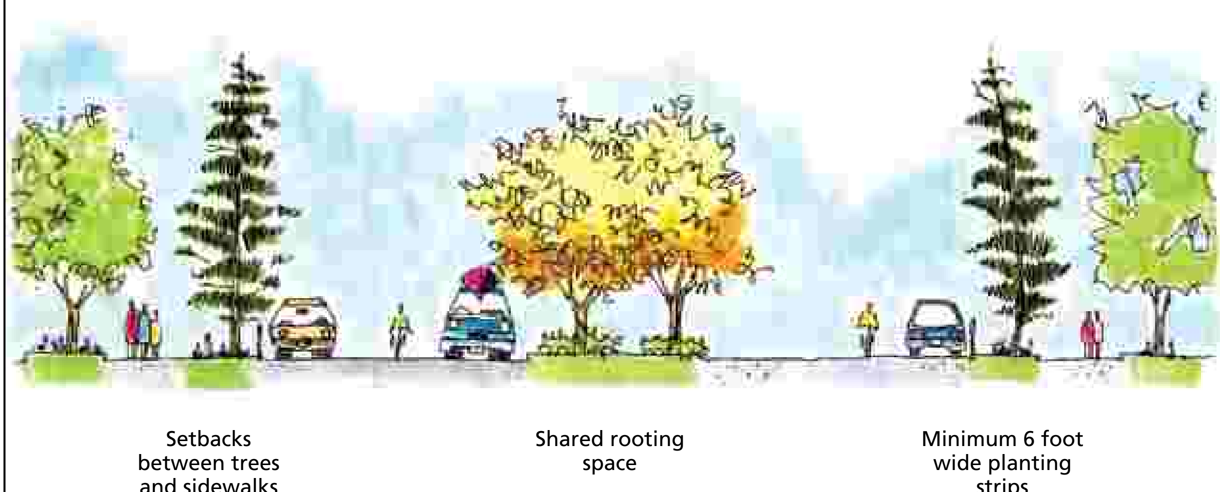


Figure 41. Trees can be incorporated into various planting areas along local roads.

Planting Trees Along Local Streets *Continued*

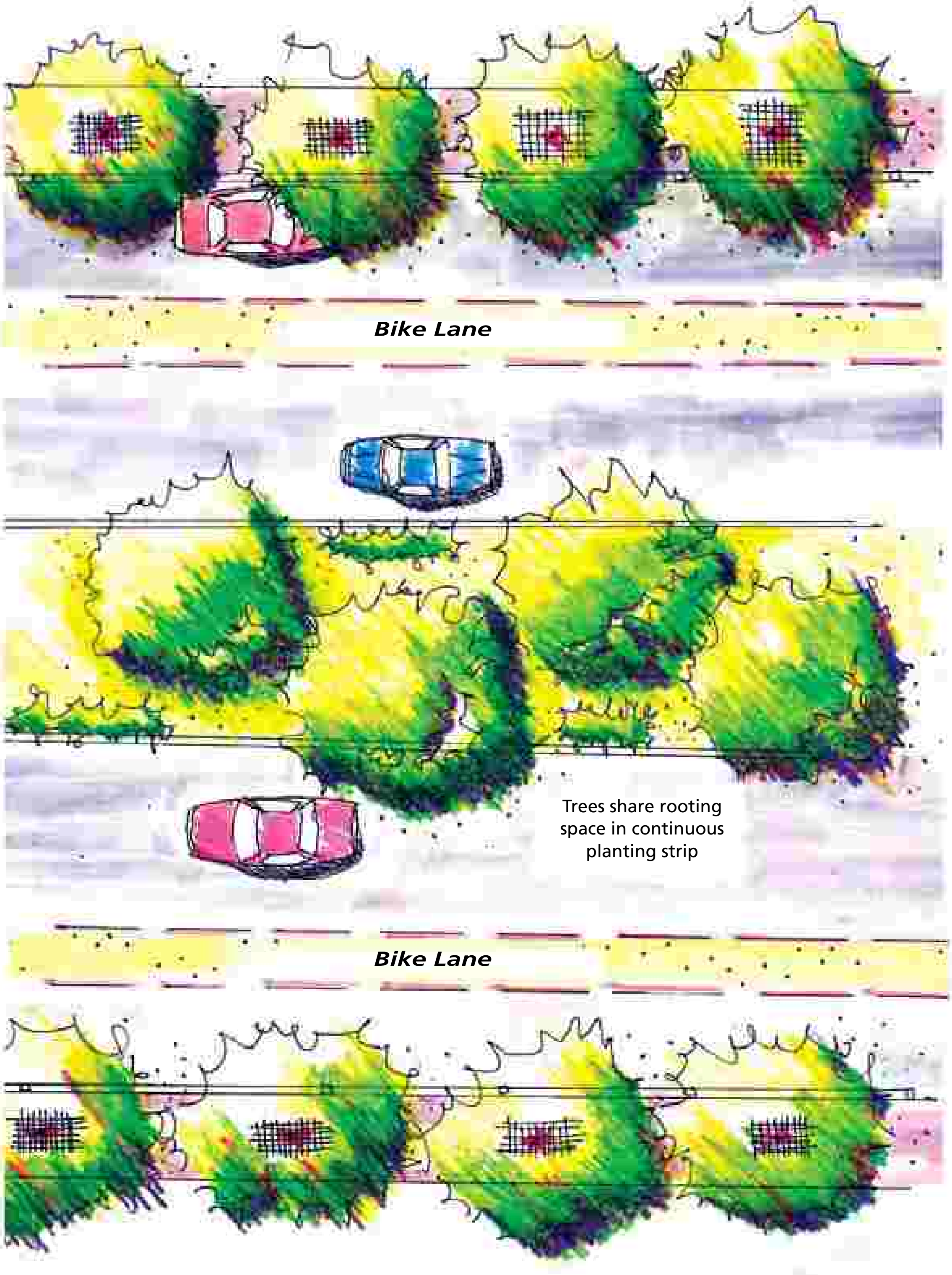


Figure 42. Tree planting along local roads (plan view) can utilize wide, linear planting areas to accommodate large, healthy trees.

Pre-Planting Considerations

Before planting trees along local roads, designers need to address some important considerations:

- ☐ How to provide clear lines of sight, safe travel surfaces, and overhead clearance for pedestrians and vehicles
- ☐ How to prevent compaction of planting area soils by construction and foot traffic
- ☐ How to resolve potential conflicts between trees and utilities, pavement, and lighting
- ☐ How to make the road corridor more attractive with plantings
- ☐ How to reduce tree exposure to auto emissions, polluted runoff, wind, and drought
- ☐ How to provide enough future soil volume for healthy tree growth
- ☐ How to prevent damage to trees from cars
- ☐ How to address concerns about increased tree maintenance, damage to cars from trees (e.g., sap, branches) and roadway snow removal and storage

Species Selection

Species selection is very important in the road corridor, because of the many potential urban stressors associated with roadway planting. A diverse mix of hardy species should be selected that are adapted to soil and site conditions and are tolerant of the following:

- ☐ Drought
- ☐ Poor or compacted soils
- ☐ Inundation (if used for storm water treatment)
- ☐ Urban pollutants (oil and grease, metals, chloride)

In addition, select tree species with these characteristics:

- ☐ Do not produce abundant fruits, nuts, or leaf litter
- ☐ Have fall color, spring flowers, or some other esthetic benefit
- ☐ Can be limbed up to 6 feet to provide pedestrian and vehicle traffic underneath.

Site Preparation

- ☐ Clean up trash.
- ☐ Improve soil drainage by tilling and adding compost.
- ☐ Remove invasive plants if present.

Planting Trees Along Local Streets ***Continued***

General Planting Guidance	☐ Provide adequate soil volume, preferably by having at least a 6-foot wide planting strip, or locating sidewalks between the buffer and street to allow more rooting space for the trees in adjacent property. ☐ Provide adequate setbacks from utilities, signs, lighting, and pavement. ☐ Use tree clusters as an alternative to linear plantings, which will provide shared rooting space. ☐ Use structural soil under pavement to provide shared rooting space. ☐ Use groupings of species that provide fall color, flowers, evergreen leaves, and varying heights to create an esthetically pleasing landscape.
Maintenance	☐ Use mulch to retain moisture. ☐ Plan for minimal maintenance of trees (watering may not be feasible). ☐ Water trees during dry periods if possible. ☐ Have trees pruned by a qualified arborist to maintain sight lines and overhead clearance. ☐ Monitor and control invasive species.
Potential for Storm water Treatment	Local road buffers and median strips are ideal locations to treat storm water runoff from roads. Trees planted in these areas can be incorporated in storm water forestry practices such as bioretention and bioinfiltration facilities, alternating side slope plantings, tree check dams, forested filter strips, multi-zone filter strips, and linear storm water tree pits. Trees planted in landscaped islands can be used to intercept rainwater and treat storm water runoff from the surrounding pavement. Bioretention and bioinfiltration facilities may be well suited to cul-de-sac islands. See Chapter 3 for more detail on storm water forestry practices.
Further Resources	Bassuk, N.; Grabosky, J.; Trowbridge, P.; Urban, J. [N.d.]. Structural soil: an innovative medium under pavement that improves street tree vigor. Ithaca, NY: Cornell University, Urban Horticulture Institute. www.hort.cornell.edu/department/faculty/bassuk/uhi/outreach/csc/article.html Costello, L. R.; Jones, K. S. 2003. Reducing infrastructure damage by tree roots: a compendium of strategies. Cohasset, CA: Western Chapter of the International Society of Arboriculture. Georgia Forestry Commission. 2002. Community tree planting and establishment guidelines. Macon, GA. www.gfc.state.ga.us/Publications/UrbanCommunityForestry/CommunityTreePlanting.pdf Gerhold, H. D.; Wandell, W. N.; Lacasse, N. L. 1993. Street tree factsheets. University Park, PA: The Pennsylvania State University College of Agricultural Sciences. Metro. 2002. Green streets: innovative solutions for stormwater and stream crossings. Portland, OR.

Planting Trees in Parking Lots

Description

Parking lots have two distinct areas where trees can be planted—the interior and the perimeter—each of which has unique planting requirements and considerations (Figure 43). The parking lot interior can be a very harsh planting environment for trees, due to higher temperatures of the pavement, little water, exposure to wind, air pollution, and potential damage from automobiles. Landscaped islands are typically used within parking lots to provide a separation between parking bays and to meet landscaping requirements. These islands may be planted with grass, trees, or other vegetation and can be designed to accept storm water. Typically, most traditional parking lot islands do not provide adequate soil volumes for trees.

Trees planted along the perimeter of a parking lot provide a screen or buffer between the lot and an adjacent land use or road. Perimeter planting areas often provide a better planting environment for trees and good opportunities for conserving existing trees during parking lot construction.

The many benefits of incorporating trees in parking lots include shade for people and cars, reduction of the urban heat island effect, interception of storm water, improved esthetics, improved air quality and an increase in or creation of habitat for birds.

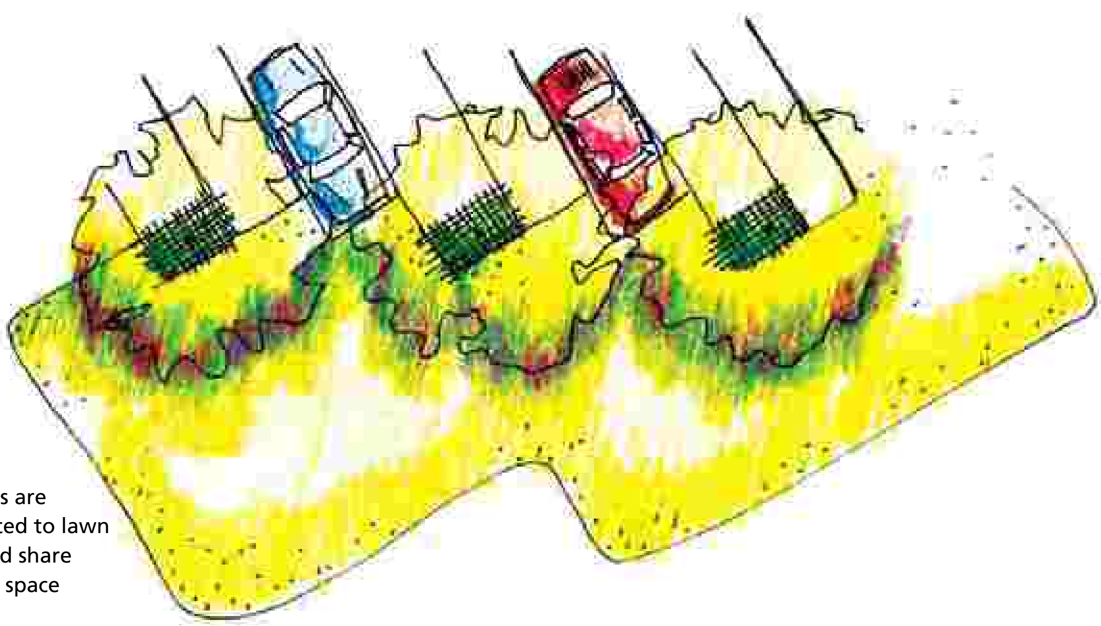


Figure 43. Parking lots can be designed to provide larger spaces to plant trees.

Planting Trees in Parking Lots *Continued*

Pre-Planting Considerations

Before planting trees in parking lots, designers need to address some important considerations:

- ☐ How to provide clear lines of sight, safe travel surfaces, and overhead clearance for movement of pedestrians and vehicles within the lot
- ☐ How to prevent compaction of planting area soils by construction and foot traffic
- ☐ How to resolve potential conflicts between trees and surrounding utilities, pavement, and lighting
- ☐ How to maximize canopy coverage and shading in the lot and make it more attractive with plantings
- ☐ How to reduce exposure of trees to auto emissions, polluted runoff, wind and drought
- ☐ How to provide adequate soil volume for trees in the confined space of a parking lot
- ☐ How to prevent damage to trees from cars
- ☐ How to address concerns about safety, increased maintenance due to tree litter, damage to cars from trees (e.g., sap, branches), and snow removal and storage
- ☐ How to maximize plantings for visual screening and buffers, at the same time offering view corridors to merchants

Species Selection

Species selection is important in urban parking lots because it is such a stressful environment. Tree species that comprise a diverse mix of hardy, native species that are adapted to soils and site conditions are needed.

The following characteristics should be sought when selecting a parking lot tree:

- ☐ Tolerant of salt
- ☐ Tolerant of drought and extreme temperatures
- ☐ Tolerant of poor, highly compacted soils
- ☐ Tolerant of urban pollutants
- ☐ Tolerant of inundation, if used for storm water treatment
- ☐ Does not produce abundant fruits, nuts, or leaf litter
- ☐ Wide-spreading canopy

Site Preparation

- ☐ Improve soil drainage by tilling soils and adding compost.

General Planting Guidance	☐ Use structural soils below pavement to allow for root growth where possible. ☐ A few great trees are better than a lot of smaller ones. ☐ Design concave planting areas to discourage pedestrian traffic. ☐ Provide adequate setbacks from utilities, signs, lighting, and pavement. ☐ Plant only species that are appropriate for parking lots. ☐ Maintain appropriate setbacks from edge of planting strip or island to allow clear sight lines and reduce heat impact on trees (generally 4 feet). ☐ Maintain an adequate setback between parking stalls and trees to prevent damage from cars. ☐ Plant large balled and burlapped stock. ☐ Have a landscape architect design the parking lot planting plan.	
Specific Planting Guidance	*Interior*	Use alternative planting clusters in parking lot islands that allow shared rooting space and provide additional soil volume for trees. Employ “better site design” techniques, which include reducing the size of parking stalls to make the parking lot more efficient and to provide more room for trees (CWP, 1998)
	Perimeter	Use trees to provide shade over pedestrian walkways. Maintain a 6- to 8-foot overhead clearance for pedestrian walkways. When planting on steep slopes, use tree clusters and create small earthen berms around the group to retain moisture. When planting along a flatter slope, use linear spacing for safety and functionality
Maintenance	☐ Use mulch to retain moisture. ☐ Plan for minimal maintenance (watering may not be feasible). ☐ Have trees pruned by a qualified arborist to maintain sight lines and overhead clearance. ☐ Monitor and control invasive species.	
Potential for Storm Water Treatment	Ordinances usually require developers to landscape a minimum percentage of parking lot interiors. When properly built, these landscaped areas can double as storm water treatment facilities, which can result in cost savings for the developer. Storm water forestry practices for parking lots include: ☐ Parking lot interiors—Bioretention and bioinfiltration facilities, alternating side slope plantings or tree check dams, linear storm water tree pits ☐ Parking lot perimeters—Bioretention and bioinfiltration facilities, forested filter strips, and multi-zone filter strips See Chapter 3 for more detail on storm water forestry practices.	

Planting Trees in Parking Lots *Continued*

Further Resources

Appleton, B.; Horsley, J.; Harris, V.; Eaton, G.; Fox, L.; Orband, J.; Hoysa, C. 2002. Trees for parking lots and paved areas. In Trees for problem landscape sites. Publication No. 430-028. Blacksburg, VA: Virginia Cooperative Extension. www.ext.vt.edu/pubs/trees/430-028/430-028.html.

Center for Urban Forest Research. 2002. Fact Sheet #3: Making parking lots more tree friendly. Davis, CA: USDA Forest Service, Pacific Southwest Research Station.
http://cufr.ucdavis.edu/products/CUFR_181_UFfactsheet3.pdf.

Center for Urban Forest Research. 2002. Where are all the cool parking lots? Davis, CA: USDA Forest Service, Pacific Southwest Research Station.
http://cufr.ucdavis.edu/products/3/cufr_151.pdf.

Center for Watershed Protection. 1998. Better site design: a handbook for changing development rules in your community. Ellicott City, MD.

City of Sacramento, CA. 2003. Parking lot tree shading design and maintenance guidelines.

Costello, L. R.; Jones, K. S. 2003. Reducing infrastructure damage by tree roots: a compendium of strategies. Cohasset, CA: Western Chapter of the International Society of Arboriculture.

Appendix A. Forest Stand Delineation

This appendix contains the following field sheets, which were created as part of Maryland's Forest Conservation Act requirements, for use in delineating forest stands before developing a site:

- Forest Conservation Worksheet
- Field Sampling Data Sheet
- Explanation of Terms
- Techniques for Forest Structure Data Collection
- Forest Structure Data Sheet
- Forest Structure Analysis
- Forest Stand Summary Sheet.

These field sheets and guidance were originally published in Darr (1991) and were redrawn and/or adapted from Appendix D in the Maryland Forest Conservation Manual (Greenfeld and others 1991). These sheets can be used outside Maryland. See the Maryland manual for further guidance on conducting a Forest Stand Delineation (FSD).

Forest Conservation Worksheet

Input Data

A. Total site area: ______________________________
B. Area within 100 year floodplain: _______________________________
C. Area of agricultural land (no change in status): __________
D. Net tract area (A – B – C): ______________________________________

E. Land use category: ____
F. Afforestation threshold: _______________________________________
G. Conservation threshold: ____

H. Current forest cover: ____
I. Forest area above afforestation threshold: ________________
J. Forest area above conservation threshold: ________________

K. Above conservation threshold to be cleared: ______________
L. Below conservation threshold to be cleared: _____________
M. Total forested area to be cleared: _________________
N. Forested area above conservation threshold to be saved: _____

Calculations

Break-Even Point:

O. Acres above conservation threshold to be retained for no required reforestation: J * 20% = _________acres

Afforestation Requirement:

P. Forested acres required: D * F = ________
Q. Acres to be afforested: P – H = ________

Reforestation Requirements:

R. Acres cleared above threshold: K * ¼ = _______
S. Acres cleared below threshold: L * 2 = _______
T. Reforestation credit: N * 1.25 = _______
U. Total reforestation requirements: R + S – T = ________ acres

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure D-1, p. D-3.

Field Sampling Data Sheet

Property Name: *Prepared by:*
Stand # *Plot #* *Date:*

Tree Species (note dominant and co-dominant species)	**Size Class of Trees Within the Sample Plot**				
	Number of Trees 2-6 in. dbh	Number of Trees 7-10 in. dbh	Number of Trees 11-17 in. dbh	Number of Trees 18-29 in. dbh	Number of Trees >30 in. dbh
Number of trees per size class					
List of understory species					
Basal area					
Number of dead trees per plot					
Comments					

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Table D-1, p. D-4.

Explanation of Terms

Forest Stand Information

Stand # – divide the vegetative cover into different stands depending on species groups, size groups, cover types, etc.

Acres – measure the acreage in each separate stand and open areas. Round off to the nearest 1/20 acre.

Species – list the four or five most common, dominant and co-dominant species tallied.

Size class – use the following size classes: 2-6 in. dbh, 7-10 in. dbh, 11-17 in. dbh, 18-29 in. dbh, and greater than 30 in. dbh.

Basal area – this is a density measurement and should be expressed on a per acre basis for each stand.

Number of Trees – count all trees 2 in. dbh or greater occurring on the plot.

Number of Tree Species – count the total number of tree species occurring on the plot.

Number of Dead Trees – count the total number of dead trees occurring on the plot.

Understory Species – record the 3 to 5 most commonly occurring understory species on the plot.

Forest Cover Type – use the Society of American Foresters classification, the Maryland Forest Association Species List, and the species tallied on site to determine this.

Forest Structure Data Sheet

Number of Understory Shrubs – count the total number of shrubs occurring on the plot.

Percent canopy closure – estimate the canopy closure using the method described.

Percent Understory Herbaceous Ground Cover – estimate the herbaceous ground cover using the method described.

Percent Down Woody Debris (greater than 2 inches in diameter) – estimate the amount of dead and down woody debris on the ground using the method described.

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Table D-2, p. D-5.

Techniques for Forest Structure Data Collection

To measure canopy coverage, herbaceous coverage, dead and downed woody debris, material present and exotic species, it will be necessary to sample in the following way:

1. Construct a sampling tube from a paper towel or toilet paper roll. Attach wires or string on one end of the tube in the configuration of a cross with four evenly spaced openings (see A below).

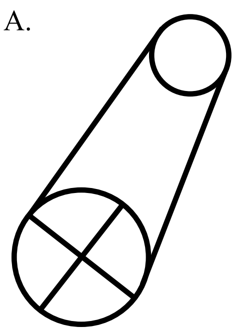
2. Select one random sampling point within each forest stand. To do this, construct a circular sampling plot of 1/10 acre. Take samples from four points around the circle and one within the circle (see B below).

3. Walk to each sample point and look through the sampling tube at each sample point.
   a. For canopy coverage, record "yes" or "no" for green seen through the tube when pointed up (tube must be held vertically; count only trees 7 in. dbh and larger).
   b. For herbaceous coverage, record "yes" or "no" for green seen through the tube when pointed down (tube must be held vertically).
   c. For dead and down woody material, record "yes" or "no" for any root wads, logs, downed limbs, or bark seen through the tube (tube must be held vertically).
   d. For exotic or invasive species, record "yes" or "no" for any of these species seen through the tube (tube must be held vertically).

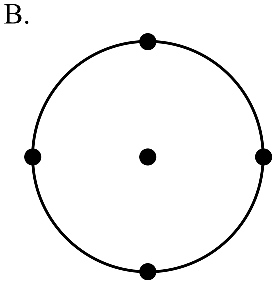
4. Calculate the percentage of sample points at each sample site which were answered by "yes." Use the above information and additional information provided in the forest stand summary sheet to calculate the forest structure value to be assigned to the site for each individual parameter.

5. Count number of shrubs found within a 1/100-acre plot. Shrubs can be most easily counted if the central stem can be identified.

A.



B.



Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure D-2, p. D-6.

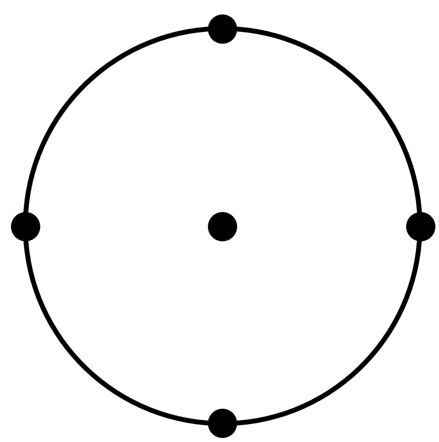
Forest Structure Data Sheet

Property: *Prepared by:*
Stand#: *Plot #:* *Date:*

Forest Structure Variable	Sample point 1	Sample point 2	Sample point 3	Sample point 4	Sample point 5	% yes
Canopy coverage						
Herbaceous ground cover						
Downed woody debris						
Invasive plant cover						
Number of shrub species (1/100 acre)						

Forest Structure Sampling Method:

1/10-acre plot,
5 sample points



Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Table D-3, p. D-7.

Forest Structure Analysis

The following parameters will be measured and evaluated at each site according to the Techniques for Forest Structure Data Collection. Each parameter at each sample site will be given a value of 3, 2, 1, or 0; 3 represents the most valuable structure and 0 the least valuable. Upon completion of the sampling, the person preparing the forest stand delineation will calculate the forest structure value for each stand. This analysis along with the other forest stand data will be used to determine the retention potential of the stand.

To determine the total habitat value use the following scale:

Range of total habitat numbers from samples taken April – October:

15-21	Priority forest structure
7-14	Good forest structure
0-6	Poor forest structure

In the winter and late fall, from November – March, only numbers 1, 3, 4, 5, 7 can be measured. During that time, the range of total habitat numbers will be:

11 – 15	Priority forest structure
6 – 10	Good forest structure
0 – 5	Poor forest structure

1. Percent Canopy Closure of trees with a dbh greater than 7 inches	
70% - 100%	3
40% - 69%	2
10% - 39%	1
0% - 9%	0

2. Number of Understory Shrubs per 1/100 acre	
6 or more	3
4 - 5	2
2 - 4	1
0 - 1	0

3. Number of Dead Trees per 1/10-acre plot	
3 or more	3
2	2
1	1
0	0

4. Percent of Dead and Downed Woody Material Present	
15% - 100%	3
5 in. – 14 in.	2
0-1	1
0	0

5. Size Class of Dominant Trees	
Greater than 20 inches	3
7 in. - 19.9 in.	2
3 in. - 6.9 in.	1
Less than 3 in.	0

6. Percent of Understory Herbaceous Coverage	
75% - 100%	3
25% - 74%	2
5% - 24%	1
0% - 4%	0

7. Number of Tree Species with a dbh greater than 7 in. per plot	
6 or more	3
4 - 5	2
2 - 4	1
0 - 1	0

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure D-3, p. D-8.

Forest Stand Summary Sheet

Property Name:

Prepared by:

Date:

Stand Variable	Stand # Acreage	Stand # Acreage
Forest Association (SAF cover type)		
Size class of dominant trees		
Number of trees/acre		
Number of tree species/plot		
Basal area		
Number of dead trees/acre		
List of common understory species		
Number of shrubs 1/100 acre plot		
Percent canopy coverage		
Percent herbaceous cover		
Percent downed woody material		
Percent exotic or invasive species		
Forest Structure Value		
Comments		

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Table D-4, p. D-9.

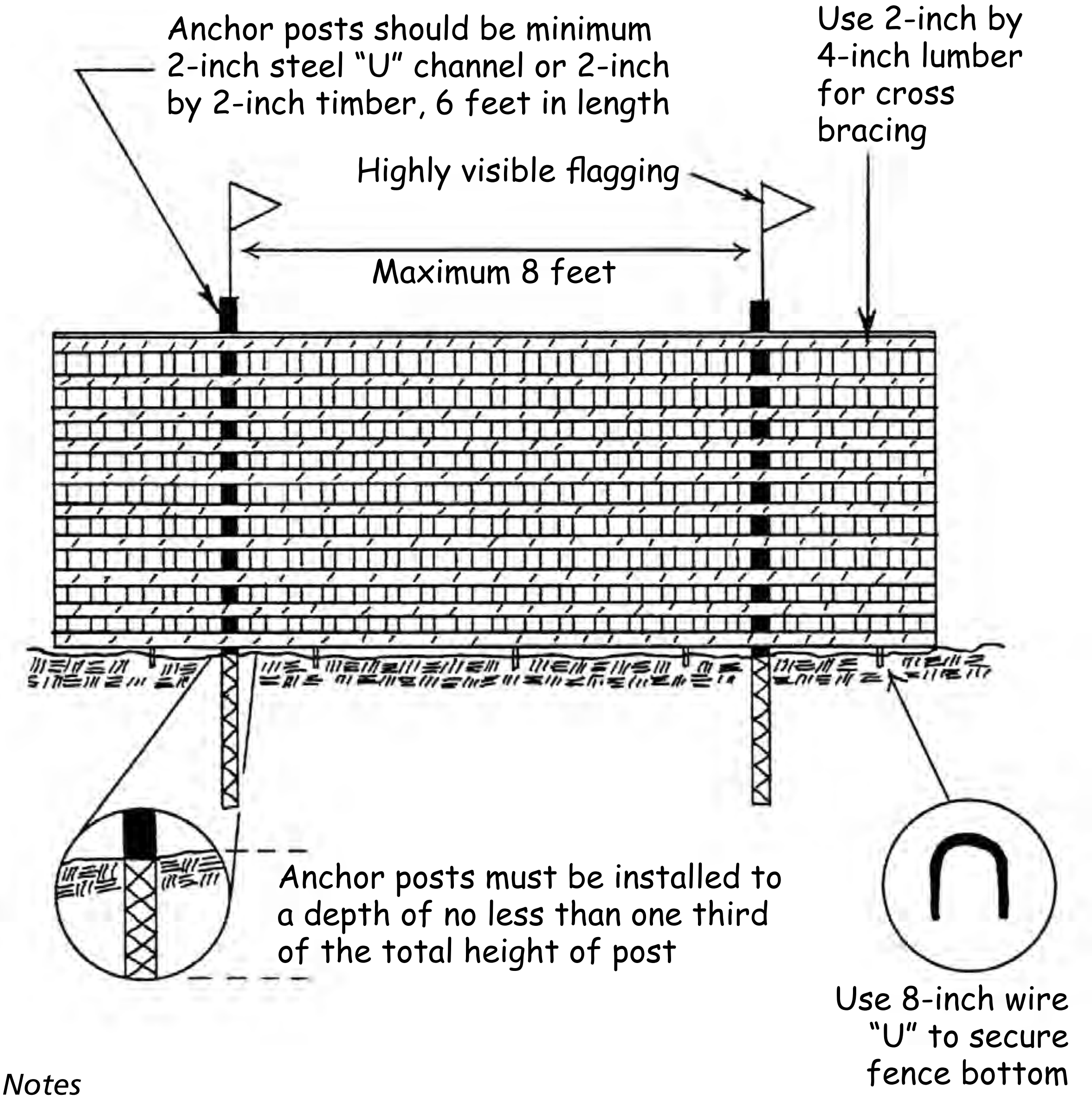
Appendix B. Tree Protection Specifications

This appendix contains specifications for the following tree protection techniques, for use during construction:

- Blaze orange plastic mesh
- Three strand barbed wire
- Snow fence
- Signage
- Filter cloth on wire mesh
- Staked straw bale dike
- Earthen dike and swale.

These specifications were originally published in Darr (1991) and were redrawn and/or adapted from Appendix J in the Maryland Forest Conservation Manual (Greenfeld and others, 1991). These techniques and specifications can be used outside Maryland. See the Maryland manual for more information on using these techniques.

Blaze Orange Plastic Mesh

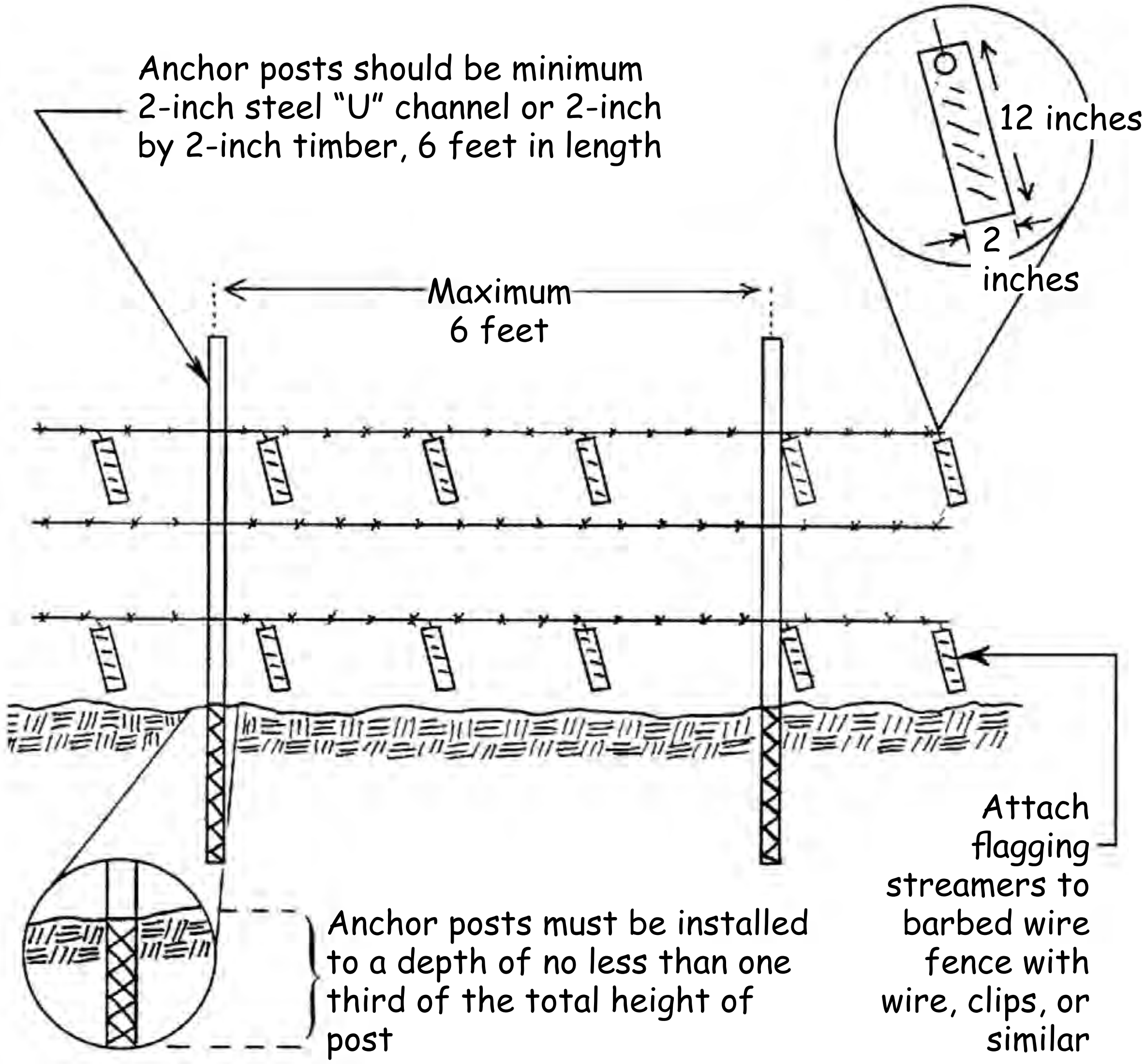


Notes

1. Forest protection device only.
2. Retention Area will be set as part of the review process.
3. Boundaries of Retention Area should be staked and flagged prior to installing device.
4. Root damage should be avoided.
5. Protective signage may also be used.
6. Device should be maintained throughout construction.

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure J-4, p. J-6.

Three Strand Barbed Wire

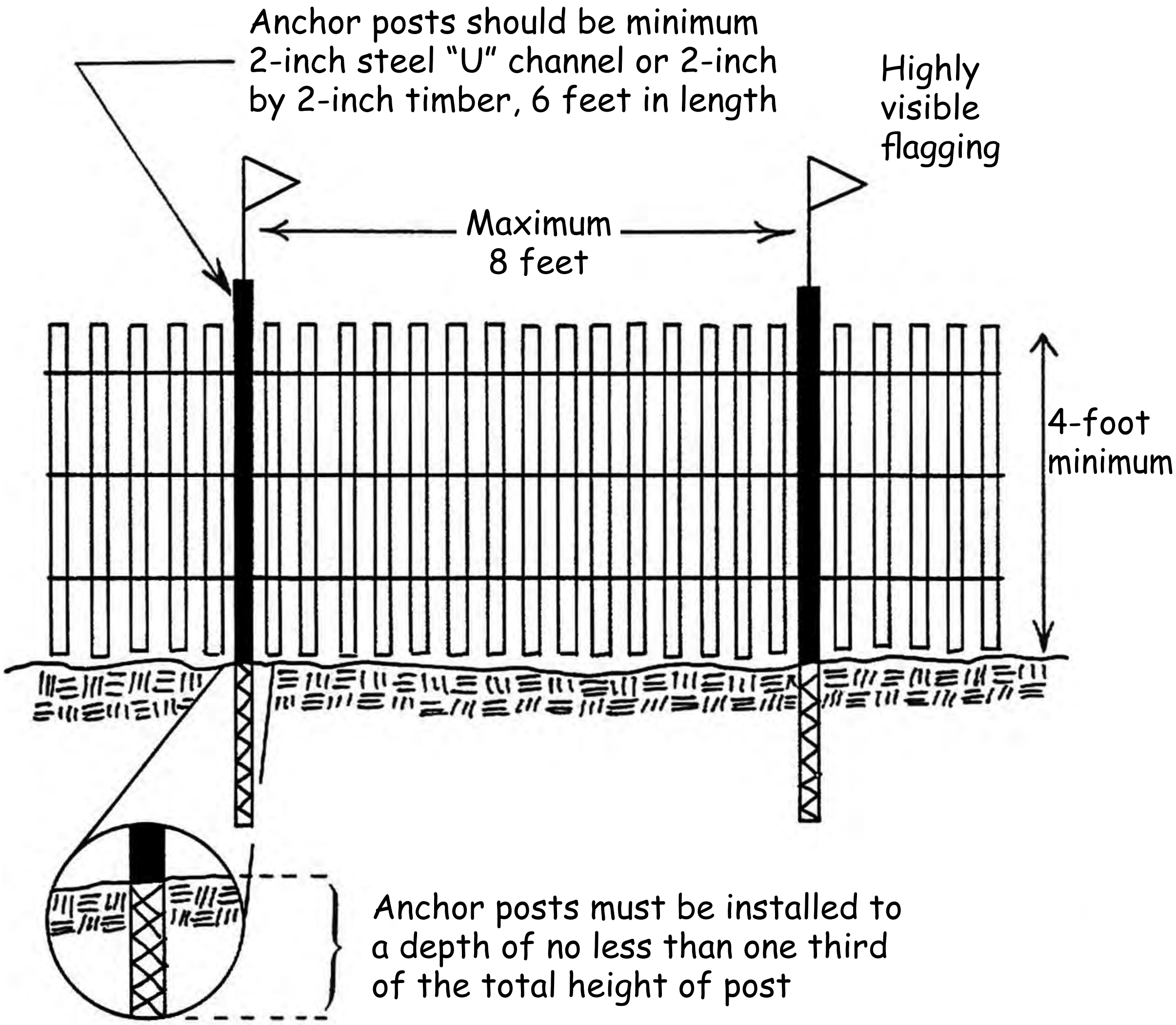


Notes

1. Forest protection device only.
2. Retention Area will be set as part of the review process.
3. Boundaries of Retention Area should be staked and flagged prior to installing device.
4. Avoid root damage when placing anchor posts.
5. Barbed wire should be securely attached to posts.
6. Device should be properly maintained during construction.
7. Protective signage is also recommended.

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure J-5, p. J-7.

Snow Fence



Notes

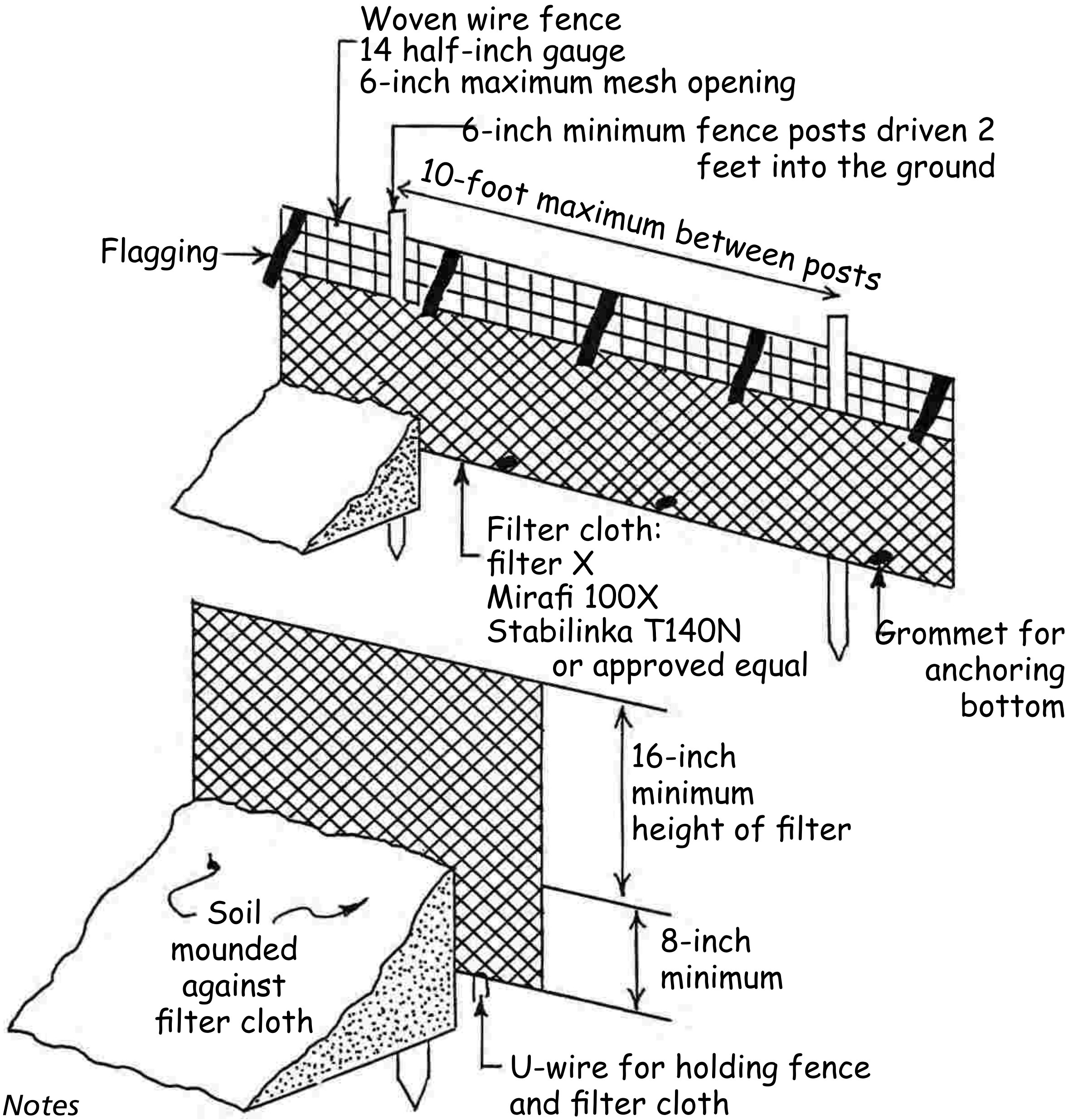
1. Forest protection device only.
2. Retention Area will be set as part of the review process.
3. Boundaries of Retention Area should be staked prior to installing protective device.
4. Avoid root damage when placing anchor posts.
5. Device should be properly maintained during construction.
6. Protective signage is also recommended.

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure J-6, p. J-8.

Signage

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure J-7, p. J-9.

Filter Cloth on Wire Mesh

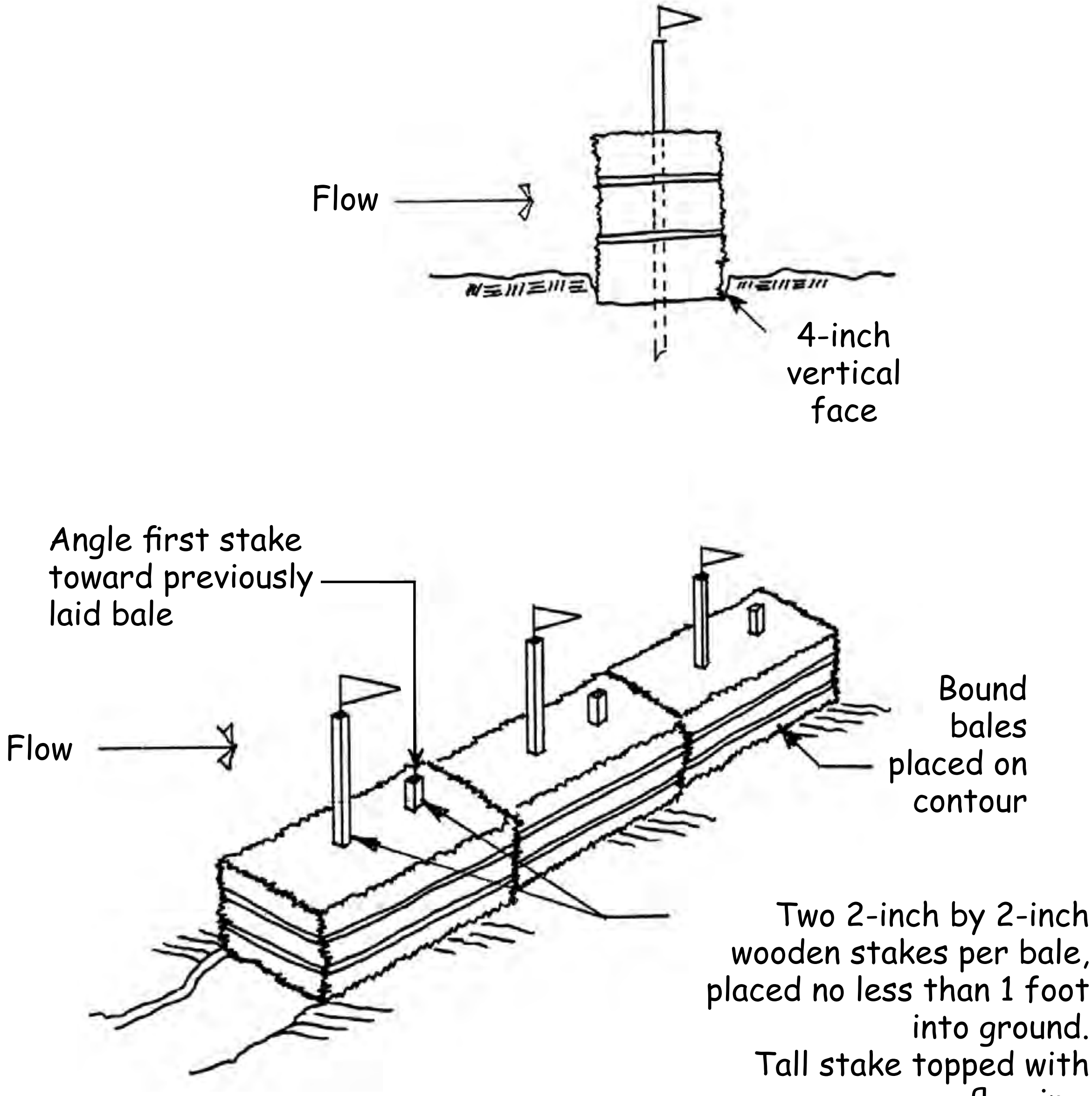


Notes

1. Combination sediment control and protective device.
2. Retention Area will be set as part of the review process.
3. Boundaries of Retention Area should be staked prior to installing protective device.
4. Root damage should be avoided.
5. Mound soil only within the limits of disturbance.
6. Protective signage is also recommended.
7. All standard maintenance for sediment control devices applies to these details.

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure J-8, p. J-10.

Staked Straw Bale Dike

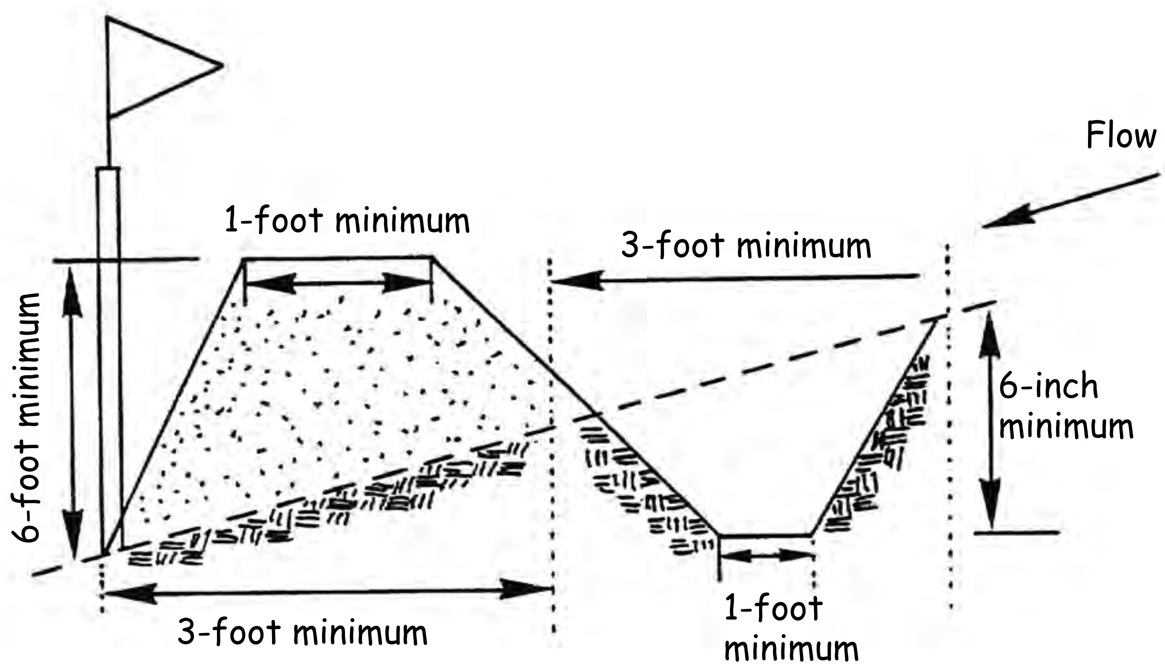


Notes

1. Combination sediment control and protective device.
2. Retention Area will be set as part of the review process.
3. Boundaries of Retention Area should be staked prior to installing protective device.
4. Root damage should be avoided.
5. This device should only be placed within the limit of disturbance.
6. Protective signage is also recommended.
7. All standard maintenance for sediment control devices applies to these details.

Source: Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest conservation manual: guidance for the conservation of Maryland's forests during land use changes, under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments. Figure J-9, p. J-11.

Earthen Dike and Swale



Notes

1. Combination sediment control and protective device.
2. Retention Area will be set as part of the review process.
3. Boundaries of Retention Area should be staked prior to installing protective device.
4. Root damage should be avoided.
5. The top or toe of slope should be within the limit of disutrbance.
6. Equipment is prohibited within critical root zone of retention area; place dike accordingly.
7. All standard maintenance for earthen dikes and swales applies to these details.
8. All standard reclamation practices for earthen dikes and swales shall apply to these details.

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Urban Watershed Forestry Manual

Part 3: Urban Tree Planting Guide

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Urban Watershed Forestry Manual

Part 3. Urban Tree Planting Guide

Third in a Three-Part Manual Series on Using Trees to Protect and Restore Urban Watersheds

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Pesticide Precautionary Statement

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers--out of reach of children and pets--and away from foodstuffs.

Apply pesticides selectively and carefully. Do not apply a pesticide when there is danger of drift to other areas. Avoid prolonged inhalation of a pesticide spray or dust. When applying a pesticide it is advisable that you be fully clothed.

After handling a pesticide, do not eat, drink, or smoke until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If the pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Dispose of empty pesticide containers by wrapping them in several layers of newspaper and placing them in your trash can.

It is difficult to remove all traces of an herbicide (weed killer) from equipment. Therefore, to prevent injury to desirable plants do not use the same equipment for insecticides and fungicides that you use for an herbicide.

NOTE: Registrations of pesticides are under constant review by the Federal Environmental Protection Agency. Use only pesticides that bear the EPA registration number and carry directions for home and garden use.

ABOUT THIS MANUAL SERIES

This is the third in a three-manual series on using trees to protect and restore urban watersheds. A brief description of each part follows.

Part 1. Methods for Increasing Forest Cover in a Watershed introduces the emerging topic of urban watershed forestry. This part also presents new methods for the watershed planner or forester, to systematically measure watershed forest cover and select the best methods for maintaining or increasing this cover by protecting, enhancing, and reforesting large parcels of primarily public land across the watershed. These methods are based on extensive review of the latest research and input from experts in a wide range of related fields.

Part 2. Conserving and Planting Trees at Development Sites presents specific ways to enable developers, engineers, or landscape architects to incorporate more trees into a development site. The proposed approach focuses on protecting existing trees, planting trees in storm water treatment practices, and planting trees in other open spaces at a development site. This part introduces conceptual designs for storm water treatment practices that utilize trees as part of the design (referred to as storm water forestry practices). These designs were developed with input from experts in storm water engineering, forestry, and a range of related fields.

Part 3. Urban Tree Planting Guide provides detailed guidance on urban tree planting that is applicable at both the development site and the watershed scales. Topics covered include site assessment, planting design, site preparation and other pre-planting considerations, and planting and maintenance techniques. An Urban Tree Selection Guide is included for use in selecting the best tree and shrub species for the planting site.

Urban watershed forestry is a new practice that draws from multiple disciplines, including forestry, hydrology, engineering, landscape architecture, mapping, planning, and soil science. Consequently, some ideas drawn from each discipline have been simplified in this manual in order to be easily understood by a diverse audience. In addition, the latest and most relevant research from each discipline has been used to support the new practice. The research summarized in this manual, however, is not intended to provide a comprehensive literature review.

This manual series draws heavily upon research and examples from the Chesapeake Bay watershed and the northeastern region of the United States. The manuals primarily apply to these regions, and may also apply in other humid regions of the country where the natural vegetative cover is predominately forest. Finally, several elements in the manuals are brand new and will require additional testing, research, and analysis. We welcome future additions to the methodology and techniques presented.

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The preparation of the manual was greatly influenced by two design workshops held in Annapolis, MD, in winter 2004. The first workshop focused on developing conceptual designs for integrating trees and storm water treatment practices, while the second workshop developed guidelines for planting trees in specific urban locations. More than 40 local, regional, and national experts participated in the workshops, including foresters, storm water engineers, landscape architects, arborists, urban soil scientists, watershed planners, and representatives from parks, and transportation and utility companies.

The Center for Watershed Protection project team included:

- Karen Cappiella
- Tom Schueler
- Jennifer Tomlinson
- Tiffany Wright

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Chapter 1. Introduction

The urban landscape can be a harsh environment for trees. A variety of pollutants, temperature extremes, hydrologic modifications, compacted soils, invasive plants, and many other factors can make it difficult to sustain healthy tree cover (Figure 1). In fact, the average life expectancy of newly planted urban trees has been reported to be 10 to 15 years, and only 7 to 10 years for urban street trees (Urban, 1999; Appleton and others, 2002). While the exact causes of urban tree mortality are difficult to pinpoint and may take years to appear, some common causes are known (Box 1). Most traditional guidance on planting trees does not adequately address these factors.

The purpose of this manual is to provide detailed guidance on how to address these urban impacts and how to improve the growing environment for trees, for anyone planning an urban tree planting project.

Figure 1. A typical urban planting site has many limiting factors.

BOX 1. COMMON CAUSES OF URBAN TREE MORTALITY

- Limited soil volume
- Poor soil quality
- Air pollution
- Construction activities
- Physical damage from mowers, vehicles, or vandals
- Damage from insects or animals
- Soil compaction from heavy foot traffic
- Soil moisture extremes
- Exposure to wind and high temperatures
- Competition from invasive plant species
- Improper planting and maintenance techniques
- Poor nursery production practices
- Conflicts with infrastructure
- Disease
- Exposure to pollutants in storm water runoff

This manual builds upon Parts 1 and 2 in this manual series (Cappiella and others 2005, 2006). Part 1 provides guidance on methods to increase forest cover in a watershed, including reforesting large areas of public turf. Many of the priority urban planting locations are subject to severe stress. Table 1 indicates some of the unique stressors that frequently affect these planting areas. Column 1 in this table indicates the corresponding page number in Part 1 or 2 of this manual series that describes planting guidelines for each location.

Table 1. Special Considerations and Site Preparation for Planting Trees in Various Urban Locations

Urban Planting Location	Special Considerations (Chapter 4, this manual)					Site Preparation (Chapter 5, this manual)		
	Inadequate Soil Volume	Storm Water Runoff	Infrastructure Conflicts	Animal Impacts	Human Impacts	Trash and Debris	Poor Soils	Invasive Species
Highway rights-of-way[1]	●	◖	●	●	◖	●	●	●
Residential lawns[1]	◖	◖	◖	◖	●	◖	◖	◖
Local streets[2]	●	●	●	◖	●	◖	●	◖
Parking lots[2]	●	●	●	◖	●	◖	●	◖
Parks[1]	◖	◖	◖	◖	●	●	◖	◖
School grounds[1]	◖	◖	◖	◖	●	●	◖	◖
Storm water dry ponds[1]	●	●	◖	◖	◖	◖	●	●
Streams and shorelines[1]	◖	◖	◖	◖	◖	●	◖	●
Utility corridors[1]	◖	◖	●	◖	◖	◖	◖	●
Vacant lots[1]	◖	◖	◖	◖	●	●	●	●

● = Very likely to be a consideration when planting trees in this location
◖ = May be a consideration, depending on location and site-specific factors
[1] See Part 1 of this manual series for more information on planting in this type of urban location.
[2] See Part 2 of this manual series for more information on planting in this type of urban location.

Guidance for conserving and planting trees in specific areas of a development site is provided in Part 2 of this manual series. Seven "storm water forestry practices" are recommended to integrate trees into the design of storm water treatment practices. As might be expected, the planting environment in these practices can be harsh. Table 2 presents the seven storm water forestry practices and indicates which of the urban planting considerations covered in this manual may apply. Other factors such as trash, invasive species, and animal impacts are likely to be more location-specific and may apply in any of these practices.

Table 2. Special Considerations for Planting Trees in Storm Water Treatment Practices		
Typical Storm Water Treatment Practice	**Special Considerations for Tree Planting**	**Related Storm Water Forestry Practices**
Storm water wetland 	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Inadequate soil volume (from compacted side slopes) • Human impacts (mowing)	Wooded wetland (Part 2, page 29)
Bioretention 	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Infrastructure conflicts (underdrain)	Bioretention and bioinfiltration facilities (Part 2, page 35)
Dry swale 	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Human impacts (mowing) • Inadequate soil volume	Alternating side slope plantings (Part 2, page 38) Tree check dams (Part 2, page 40)
Filter strip 	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Human impacts (mowing)	Forested filter strip (Part 2, page 43) Multi-zone filter strip (Part 2, page 46)
Urban tree pit 	• Inadequate soil volume • Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Infrastructure conflicts (underdrain)	Linear storm water tree pit (Part 2, page 49)

The techniques presented in this manual generally support the following design principles for urban tree planting, adapted from Urban (1999) and GFC (2001):

1. **Provide adequate soil volume to support trees at maturity.** A general guideline is to provide at least 2 cubic feet of usable soil for every 1 square foot of mature canopy (the area within the projected mature drip line of the tree). Planting areas should be designed as interconnected soil volumes so trees can share rooting space.

2. **Preserve and improve soil quality.** Limit clearing and grading to protect native soils at the site. Soil volume should be accessible to air, water, and nutrients. This is best done by separating paving from the tree's rooting area, which also allows for periodic inspection of the planting area. Soils should be amended if necessary to improve drainage and fertility.

3. **Provide adequate space for the tree to grow.** Design surrounding infrastructure to accommodate long-term growth of the tree, and space trees appropriately to allow for long-term growth and management.

4. **Select trees for diversity and site suitability.** Plant a variety of species that are tolerant of the climate and soil conditions as well as any urban impacts at the site.

5. **Protect trees from other impacts.** Develop designs that protect the tree over its entire life from pedestrian traffic, toxic runoff, browsing, high temperatures, and other urban impacts.

While this manual provides guidance on a variety of special planting and tree protection techniques, it also recognizes that each planting site is unique. It is not possible to address every possible planting scenario. Therefore, additional resources are provided for more information.

The rest of this manual is organized by the following chapters:

Chapter 2. Urban Reforestation Site Assessment – Describes how to evaluate site conditions to determine what to plant.

Chapter 3. Basic Planting Design – Outlines the basic elements of a planting plan that apply to most planting sites.

Chapter 4. Special Considerations for Urban Tree Planting – Describes additional considerations that are common to urban planting sites, for a planting plan.

Chapter 5. Site Preparation Techniques – Gives detailed methods for preparing the site for planting.

Chapter 6. Planting, Inspection, and Maintenance Techniques – Describes techniques that help ensure a healthy future for new plantings.

Chapter 2. Urban Reforestation Site Assessment

The Urban Reforestation Site Assessment (URSA) is used to collect detailed information about planting site conditions. The URSA provides a tool to help organize important data to help determine where and what to plant, and what special methods are needed to prepare the site and reduce conflicts due to existing site constraints. The purpose of an URSA is to collect data at the most promising reforestation sites in an urban watershed, in order to develop detailed planting plans. The goal is to have all the available information about an individual planting area contained in a single form.

This chapter describes the URSA in detail. For more information on methods to select, screen, and prioritize candidate planting sites across a watershed or development site, consult Part 1 (Chapter 2) and Part 2 (Chapter 2) of this manual series.

Nine major elements are evaluated at each potential reforestation site to develop an effective planting strategy:

1. *General Site Information* – information about the location, property owner, and current land use at the site.

2. *Climate* – climate data, to help select tree and shrub species

3. *Topography* – local topographic features that may present planting difficulty

4. *Vegetation* – data on current vegetative cover, to determine if removal of vegetation is necessary and to select tree and shrub species

5. *Soils* – soil characteristics, to determine if soil amendments are needed, and to select appropriate tree and shrub species

6. *Hydrology* – site drainage, to determine if the site has capacity to provide water quality treatment of storm water runoff, and to select tree and shrub species most tolerant of the prevailing soil moisture regime

7. *Potential Planting Conflicts* – available space for planting and other limiting factors, to define specific planting locations, select tree and shrub species, or identify special methods to improve the growing environment.

8. *Planting and Maintenance Logistics* – logistical factors that may influence tree survival and future maintenance needs

9. *Site Sketch* – detailed sketch of the planting site

The URSA can be customized based on the needs and interest of the field crew. Not all elements will apply to every planting scenario, and each section of the field sheet (Appendix A) may be adapted for the site.

The URSA is based on the assumption that planting potential at the candidate site is reasonably good. The URSA was developed based on several existing assessments listed in Table 3. In addition, the

URSA addresses specific urban planting conditions. One of these conditions, storm water runoff, is a factor that is frequently overlooked in urban reforestation projects.

Table 3. Resources Used in Creating the Urban Reforestation Site Assessment	
Site Assessment Resource	**Source**
Cornell Urban Horticulture Institute's Site Assessment Checklist	Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance (Bassuk and others, 2003)
Site Assessment and Species Selection Worksheet	Recommended Trees for Vermont Communities (Chapin, 2001)
Soil and Site Indicator Scorecards for Connecticut Community Gardeners	Soil Quality and Site Assessment Cards (NRCS, 2002)
Checklist 1: Site Selection	Planting Trees in Designed and Built Community Landscapes: Checklists for Success (Reynolds and Ossenbruggen, 1999)
Chapter 3: Site Assessment	Reclaiming Vacant Lots (Haefner and others, 2002)
Section 7: Site Evaluation, Planting and Establishment	Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest buffers (Palone and Todd, 1998)
Appendix H: Planting Considerations and Erosion-Control Fabric	Integrated Streambank Protection Guidelines (WSAHGP, 2002)

Some simple desktop preparation is required before going out in the field to conduct the URSA. Fields shaded in gray on the URSA field sheet should be filled out in the office, including the general site information, USDA plant hardiness zone, regional forest association, stream order (if applicable), local ordinance setbacks, and party responsible for maintenance. The soil chemistry section, which is optional, should be completed after conducting the URSA, or when soil sample results are received. Field crews may also wish to create a simple field map for locating sites if they are planning to evaluate multiple sites in one day.

Staffing requirements for the URSA typically include a two-person field crew with some local knowledge of native and invasive plant species and basic forestry training. Knowledge of storm water management, soils, and hydrologic principles are also helpful, as well as prior experience in tree planting. The URSA can be conducted by local agency staff, or by trained watershed volunteers. It takes approximately 2 hours to complete the field form for each acre of proposed planting area if simple testing methods are used. The time spent at each site will vary depending on the type and size of the site. Up to 6 hours are needed to work up a detailed planting plan for each site back in the office. The URSA should be conducted during the growing season to better observe the growing conditions and existing vegetation. Equipment needed for the URSA is listed in Box 2; most can be obtained from forestry suppliers.

BOX 2. EQUIPMENT NEEDED FOR THE URBAN REFORESTATION SITE ASSESSMENT

- Field forms
- Writing utensils
- Field maps (optional)
- Tape measure
- Local plant identification books
- Invasive species identification resources
- Camera
- Spray paint or flagging
- Jugs of water and a watch (optional)
- Screwdriver or soil penetrometer
- Piece of rebar
- Small sledge hammer
- Shovel
- pH test kit
- Soil test kits (optional)
- Tennis or table tennis balls
- Soil auger

With the exception of the general site information, all sections of the URSA Field Sheet (Appendix A) should be completed for the specific planting area, rather than for the entire property that contains the planting area. Instructions for completing each section of the field sheet are provided below.

General Site Information

In addition to completing the fields described below, field crews should photograph the planting area to record the site and anything of note as they complete the field sheet.

Location

Describe the site location, being as specific as possible, and using a consistent system for identifying planting sites. This may include noting the site address, nearest cross streets, GPS coordinates, page and grid of area map, subwatershed name, name of site, specific site identification, or all of these.

Property Owner

Note the name of the property owner. Contact the owner before conducting the field assessment, to obtain permission to access the site. Contact information may also be recorded here.

Current Land Use

Give a brief description of the general use or function of the site. Note if the site is currently under construction, and also list its intended future use, if known.

Climate

USDA Plant Hardiness Zone

Check the hardiness zone of the site using the USDA Plant Hardiness Zone Map available from the U.S. National Arboretum at www.usna.usda.gov/Hardzone/. Bassuk and others (2003) recommend regarding the site as one zone colder than listed if planting involves above-ground containers, because trees in containers are more susceptible to cold winter temperatures.

Sunlight Exposure

Evaluate the site to determine how much sun is received in the planting area during the growing season. This will determine what species can be planted there. Consider that a site has full sun if it receives more than 6 hours of direct sunlight. Partial sun means less than 6 hours of direct sun or filtered light for most of the day (as is common under a tree with fine textured leaves). A shady site receives little or no direct sunlight, or less than 6 hours of filtered light. Key elements to help determine sun exposure in the field are aspect and presence of structures that may block sunlight. For example, an east-facing planting area would receive morning sun (part sun), but if blocked by a nearby building would be considered shady.

Microclimate Features

Important microclimate factors to note include high wind exposure and excessive heat (re-reflected heat load). Signs of excessive wind include trees that are leaning or growing in the same direction, and plants with stunted growth on the wind-facing side. Sites that are commonly very windy include hilltop planting areas and urban sites where wind is funneled between tall buildings (e.g., wind tunnels). Reflected and reradiated heat loads from pavement, cars, buildings, and other urban surfaces can cause a tree to heat up and lose water at a faster-than-normal rate (Bassuk and others, 2003). These areas are typically south-facing, and on sunny days are noticeably warmer than nearby spots. If either of these microclimate factors exist in the planting area, tree species that are tolerant of drought must be chosen.

Topography

Steep Slopes

Note the presence of any steep slopes (typically defined as greater than 15%) and mark them on the site sketch. Steep slopes can make access difficult for planting and may require special planting techniques. Species planted on slopes should be more resistant to drought, as they will dry out faster. Also, special care should be taken not to disturb slopes during site preparation and planting, to prevent soil erosion.

Low-Lying Areas

Note the presence of any low-lying areas and mark them on the site sketch. Low-lying areas may be more evident during or after a rainfall since they collect water during storms. Trees can be planted in low-lying areas and used to treat storm water runoff, provided the species selected are tolerant of some standing water.

Vegetation

Regional Forest Association

Record the regional forest association, which indicates the climax or dominant species that characterize the types of plants found there. A useful source is a map of Küchler's Potential Natural Vegetation Groups, available from the USDA Forest Service at www.fs.fed.us/fire/fuelman/pnv.htm. Tree species that are dominant in a regional reference forest may be listed instead. This information is used to help select species of trees and shrubs to plant, particularly when the goal is to reforest an entire site.

Current Vegetative Cover

Note the type(s) of vegetation that are currently present in the planting area and the percent coverage, including turf, other herbaceous plants, trees, shrubs, or none. If any existing trees or shrubs are to be preserved, the species should be recorded on the field sheet. Note the presence and density (% coverage of the site) of all invasive plant species or noxious weeds present.

The current vegetative cover helps determine what type of vegetation removal or site preparation is needed before planting. Recording existing tree species at the planting area is also helpful to determine if the planting area is a good candidate for natural regeneration. Generally, any species located within 300 feet can be a seed source (Hairston-Strang, 2005). If existing trees and shrubs will be preserved, appropriate site preparation and planting techniques should be chosen to protect these trees. The type and density of invasive plant species will determine if control is necessary, and will help to select the type of control methods.

Adjacent Vegetative Cover

Note the dominant species present in any forest area adjacent to the planting area, if one exists. Also note the presence and density (percent coverage of the site) of invasive plant species or noxious weeds present adjacent to the planting area. Recording species present at an adjacent forested site gives an idea of what species might regenerate naturally over time due to the presence of a nearby seed source. Key things to look for include the presence of (1) light-seeded species (e.g., maple, sycamore, ash, pine, yellow poplar) upwind of the site (can be fairly far away), or (2) heavy-seeded species (e.g., oaks, hickories) upslope within 300 feet (Hairston-Strang, 2005). Presence of invasive plants adjacent to the planting area is usually an indicator that invasive plant control will be necessary at the planting site.

Soils

Soil characteristics, such as drainage, compaction, pH, and quality, should be evaluated at several sampling locations across the site, as characteristics of urban soils can vary greatly, even over a short distance. Record the findings for each sample location on the field form, check off the appropriate box based on the average condition, and record sample locations and results on the site sketch if results are highly variable.

Texture

Soil texture may be predominately sandy or clayey, or be a mixture of sand, silt, and clay, known as loam. Check the soil texture using the texture-by-feel technique and record the results. Sandy soils have a gritty feel and will not form a ball when moist. Clayey soils are sticky and plastic when moist, will form a strong ball resistant to breaking, and will provide a thin ribbon over 2 inches long. Identifying soil texture is important so that tree species that are tolerant of the soil texture may be chosen.

Drainage

Soil drainage can generally fall into one of three categories: poor, moderate, and excessive. To check drainage in the field, dig a hole 12 to 15 inches deep and remove a large handful of soil for examination. Soils with grey mottling or a foul odor indicate poor drainage. Other indicators of poor drainage include presence of plants that grow in poorly drained soils, and presence of low-lying areas that collect runoff.

To more accurately classify the site soil into one of the three drainage categories, dig a hole 12 inches deep and fill with water. Allow the water to drain completely, then refill the pit with water, and measure the depth of water in the pit. After 15 minutes, note the depth of water and calculate the rate of drainage in inches per hour. If water drainage is less than 1 inch per hour, the site is poorly drained. If drainage ranges from 1 to 6 inches per hour, soil drainage is considered moderate. If faster than 6 inches per hour, soil drainage is classified as excessive. Evaluating soil drainage is important so that tree species that are tolerant of the site drainage may be chosen.

Compaction

Soil compaction can be measured in one of several ways. The “screwdriver test” is the simplest and quickest method. Test the soil by inserting a screwdriver into the soil surface (this works best if done 2 days after a rainfall during the growing season). If the screwdriver goes into the soil easily, the soil has minimal or no compaction. If the screwdriver can be pushed into the soil, but requires some pressure, the soil is moderately compacted. If the screwdriver cannot be driven into the soil by hand, the soil is severely compacted.

The screwdriver test is useful in assessing surface compaction but may not detect deeper compacted layers, such as buried pavement, rubble, or compacted clay beneath the surface soil. Using a similar approach, it may be useful to test for subsurface soil compaction by using a 2- to 3-foot piece of 3/8-inch rebar and a small sledgehammer. In this way, the same qualitative evaluation can be made to a greater depth than is possible with the screwdriver test.

Another similar test is to dig a hole 2 feet deep with a shovel. The level of soil compaction is directly related to the difficulty encountered in digging the hole. For example, if the digging is easy, no compaction is present. If the digging is difficult or impossible, soils are severely compacted. A soil auger may also be used to test compaction. A dutch or Edelman auger is particularly useful for wet, clay, or heavily rooted soils.

More detailed tests of soil compaction include penetrometer readings and soil bulk density analysis. Because soil penetrometer readings are strongly related to soil moisture, penetrometer readings should be taken 24 hours after a hard rain (which may limit its utility during the URSA). At each sample site, record the average depth of penetration at which the probe measurement exceeds 300 pounds per square inch (Duiker, 2002). The most expensive but accurate test is to take soil cores and send them to a lab for analysis of bulk soil density. Evaluating soil compaction is important so that tree species that are tolerant of compaction may be chosen, soils can be amended before planting, or both.

pH

Test the soil pH at several spots in the planting area using a test kit, record the findings on the field form, and check off the appropriate box based on the average soil pH. If pH is highly variable, mark the sample locations and readings on the site sketch. Areas near buildings or pavement may test very alkaline due to building rubble so be sure to include these areas in the sampling if trees will be planted nearby. Rapid soil test kits for pH are available from county Cooperative Extension offices or home and garden centers. Evaluating soil pH is important so that tree species that are tolerant of the soil pH may be chosen.

Other Soil Features

Record any additional soil features of note, such as active or severe erosion, potential soil contamination, recent construction or soil disturbance, and debris or rubble in soil. If erosion is present, note the extent and severity of erosion, as well as the location and size of any rills, gullies, or soil slumping. Potential soil contamination may be indicated by the presence of drums containing hazardous or unidentified material; evidence of past dumping of restaurant waste, oil, construction debris or other materials; or unusual coloration of soil layers. Evidence of recent cuts or fills or recent construction activity includes buried trunk flares on existing trees, soil layers that are noticeably lighter in color than lower layers, absence of highly organic topsoil layer, and presence of newly paved surfaces or construction debris.

Presence of any of these soil features may indicate that some action is necessary to address impacts before planting. For example, erosion caused by excessive storm water runoff should be addressed by actions that eliminate the runoff source, or divert or infiltrate runoff at the site. If a site is suspected of contamination, further investigation should be conducted before proceeding with the project (e.g., research the site history, consult with landowner, conduct an environmental site assessment, pursue cleanup options). If soils are very disturbed amendments may be needed, or it may be necessary to bring in new soil.

Soil Chemistry (Optional)

The field crew may also want to test soil quality to determine specific nutrient, organic matter, and mineral deficiencies, or confirm soil contamination. Soil samples may be sent to a lab to be analyzed for organic matter content, salt content, and availability of key nutrients such as phosphorus, potassium, calcium, and magnesium. Soil quality testing need not be expensive—check with county Cooperative Extension offices to see if they provide low-cost or free soil testing. Alternatively, a visual assessment of soil quality can be made based on the condition of existing vegetation, presence of an organic topsoil layer, number of earthworms present, or other factors. Soil quality results should be recorded in the soil quality portion of the field form.

Hydrology

Site Hydrology

Note whether the planting area is an upland or riparian site. For riparian sites where planting is proposed on both stream banks, the hydrology section should be filled out separately for each bank. The blank space at the bottom of the hydrology section may be used to record data for the opposite bank.

Storm Water Runoff to Planting Site

Storm water flow to the planting site may be in a pipe or open channel, or be shallow concentrated flow or sheetflow. Note all the types of storm water runoff that flow to the planting site.

To determine if runoff bypasses the site in a pipe, look for storm sewer manholes, and follow their path (typically spaced at 200 foot to 400 intervals) to see where the runoff travels. For riparian areas, check for storm water pipe outfalls to the stream. Storm drain mapping from the local public works department may also be used to locate the storm sewers. To determine if an upslope drainage area discharges directly to a planting area, look for pipe outfalls to the site, and note the diameter of any pipe outfalls found (pipe size is related to the area drained). Walk around the entire planting area to look for open channels that direct flow around or across the planting area.

Runoff that is not contained in a pipe or open channel can either be shallow concentrated flow or sheetflow. Shallow concentrated flow typically forms when runoff travels over pervious surfaces greater than 150 feet, or impervious surfaces greater than 75 feet. Common indicators of shallow concentrated flow include rills, gullies, erosion, and sediment deposits. Sheetflow can only be maintained over about 150 feet of pervious surface or 75 feet of impervious surface before it starts to concentrate. These flow patterns are best observed at the site during a storm event.

Storm water runoff information is used to make decisions about whether and how to modify site drainage to treat storm water using trees or other methods, and to moderate the water balance at the site for trees and shrubs. The volume of storm water flow entering the planting area determines whether a site is currently at, under, or over its capacity to treat storm water runoff.

Contributing Flow Length

The contributing flow length is the longest distance over which runoff travels before it enters the planting area. For larger planting areas, it is the distance runoff travels before leaving the planting area, by entering an open channel, an inlet, or a different portion of the property. To measure the contributing flow length, walk a path from the point that is most hydraulically distant (typically the point on the farthest upgradient ridgeline) to the lowest point of entry to the planting area (or to the lowest point or outlet of larger planting areas). If conducting this assessment during a dry period, it may be helpful to use a tennis ball or a table tennis ball to determine which way runoff would flow by placing the ball on the ground at the farthest upgradient point and observing which direction it rolls. When walking the contributing flow length, note the slope and the dominant cover type. Sketch the contributing flow length on the URSA field sheet, marking any changes in land cover or slope along the way.

The contributing flow length is used to determine or verify if runoff to the planting site is sheetflow or shallow concentrated flow. If the contributing flow length is less than 75 feet over an impervious surface or less than 150 feet over a pervious surface, the runoff will likely remain as sheetflow and will not concentrate.

Floodplain Connection (Riparian Areas Only)

If the planting area is riparian, note the presence of levees or other structures that restrict flood flows onto the floodplain, and the bank height. The stream order will already have been recorded in the office but may be verified in the field. If desired, the depth to seasonal high water table can be measured using a soil auger and observing wetness, mottling, or gleying. Test pits or monitoring wells can also be used to measure depth to groundwater, if desired, but may be cost-prohibitive.

In urban areas, floodplains tend to be drier than their rural counterparts due to three factors: water table is lower due to reduced groundwater flows, floodplains are disconnected from their streams due to stream incision or construction of levees, and storm water runoff bypasses the buffer area by being piped directly to the stream. In these areas, upland species may be more suited to the hydrology of the site than floodplain species. Therefore, it is important to verify the hydrologic conditions at the site. In general, first order streams with bank height greater than 3 feet, and second order or higher streams with bank height greater than 5 feet, are likely to be disconnected from the floodplain (Schueler and Brown, 2004). Depth to groundwater is a good indicator of floodplain connection. The depth to seasonal high water table can be used as a general estimate of depth to groundwater, since groundwater elevations do not fluctuate substantially over the year (Palone and Todd, 1998).

Potential Planting Conflicts

This section is used to record the presence of potential planting conflicts at the site, in order to identify if site preparation or other special techniques are needed to reduce these conflicts and improve growing conditions for the trees.

Space Limitations

Note the presence of aboveground or belowground space limitations, such as overhead wires, pavement, structures, signs, lighting, existing trees, or underground utilities. Mark the location on the site sketch, and record the height of overhead wires, signs, and lighting. Utilities such as gas lines will often be marked (to warn people not to dig), while presence of electric and sewer lines may be less apparent. Look for manholes and sewer inlets to estimate location of sewers, consult the property owner, or estimate locations based on utility maps. Exact locations of utilities will be needed before site preparation and planting by calling the local department responsible for locating utilities (Miss Utility in the Mid-Atlantic) to mark their location at the site.

Presence of infrastructure may indicate that the use of alternative designs, materials, or maintenance practices are recommended to accommodate both trees and infrastructure without conflict. Existing infrastructure can limit the available space for planting, if setbacks are necessary to avoid future conflicts between trees and infrastructure as the trees mature. By recording the location of existing infrastructure and factoring in appropriate setbacks for trees (where applicable), a more accurate estimate of the area available for planting can be derived. Setbacks may be based on what is recommended by local utilities or required by local ordinance.

Other Limiting Factors

Record the presence of any other limiting factors such as these:

- Trash dumping and debris
- Deer, beaver, or other animal impacts
- Mowing conflicts
- Presence of wetlands
- Insects or disease
- Heavy pedestrian traffic

Record the type of trash present, its source (if known), and estimate how many truckloads are needed to remove it, to assist in planning cleanups. Note any evidence of impacts from deer, beavers, neighborhood pets, rodents, or other animals. This may include the presence of animal droppings, removal of bark on existing trees, or presence of nearby beaver dams. Impacts from deer are evidenced by sparse or nonexistent understory, a distinct browse line, or presence of nonpreferred browse species in existing or adjacent forests. Wetland indicators include the presence of wetland vegetation, poorly drained soils with grey mottling, foul odor, or standing water. If existing trees show evidence of disease or insect damage, record the type and extent of damage and the species affected. If heavy pedestrian traffic is evident, mark the location of pathways on the site sketch.

Other limiting factors will need to be addressed before planting. If trash dumping and debris is present, it will need to be removed. If animal impacts are present, methods to control populations or reduce their impact on trees should be evaluated. If the site is currently being mowed, provisions will be necessary to change the mowing practices after planting. This may include posting signs or using fencing or mulch to keep mowers far away from trees. If a wetland is suspected to be present at the site, it may be necessary to conduct a wetland delineation and obtain a permit before starting the project. This will also affect species selection for the site. In areas with heavy pedestrian traffic, the site should be designed to minimize impacts to trees, and may include use of mulch, fencing, or other protective measure.

Local Ordinance Setbacks

This section should be completed before going out in the field, to record setbacks between trees and infrastructure that are mandated by local ordinance or utility. Most setback requirements can be found in local ordinances related to site or subdivision development. Also check with local utility companies to determine their clearance requirements for different voltage wires. The purpose of this section is twofold: first, it ensures the designer complies with any required local setbacks; and, second, it allows analysis of required local setbacks to suggest changes to local ordinances to allow for better tree growth or incorporate more trees into the urban landscape.

Planting and Maintenance Logistics

Site Access

Indicate whether access to the site allows for delivery of planting materials, temporary storage of planting materials, room to maneuver heavy equipment, volunteer parking, and facilities for volunteers. This determines the methods and equipment to use in site preparation and planting. For example, if the site is not accessible by heavy equipment due to steep slopes, planting, soil amendments, and invasive plant removal will need to be done by hand. If volunteers will be used for planting, it is important to scope out facilities and parking ahead of time.

Water Source

Note the presence and type of any water sources. Sources may include rainfall, storm water runoff (indicated by shallow concentrated flow, sheetflow, or outfall to site in the Hydrology section of the field sheet), nearby hose hook-up (note distance from planting area), stream or overbank flow (in riparian areas), irrigation system, or nearby fire hydrant (work with local fire department to water trees). It is important to evaluate water sources since newly planted trees must be watered regularly the first year or two after planting. The existence of a nearby water source for irrigation makes this critical maintenance task much easier.

Party Responsible for Maintenance

The field crew should identify the land owner, local volunteer group, or homeowners association that is responsible for maintenance before going out to the site. It is important to designate up front the party responsible for maintaining the new plantings, to ensure that maintenance such as watering, mulching, weed control, removing tree shelters, and adjusting stakes will actually occur. The responsible party should be informed about proper maintenance techniques and the desired schedule.

Site Sketch

The field crew should quickly sketch the site, including the following features as a minimum:

- Property boundary, landmark features (e.g., roads, streams) and adjacent land use and cover
- Boundary and approximate dimensions of proposed planting area
- Variations in sun exposure, microclimate, and topography within planting area
- Current vegetative cover, location of trees to be preserved, and invasive species
- Location and results of soil samples (if variable)
- Flow paths to planting area and contributing flow length, location of outfalls
- Above or below ground space limitations (e.g., utilities, structures)
- Other limiting factors (e.g., trash dumping, pedestrian paths)
- Water source and access points
- Scale and north arrow

The site sketch will ultimately be the foundation for the more detailed planting plan. An example URSA sketch is provided in Figure 2. Specific information on how to use the URSA data to develop a planting plan is provided in Chapter 3.

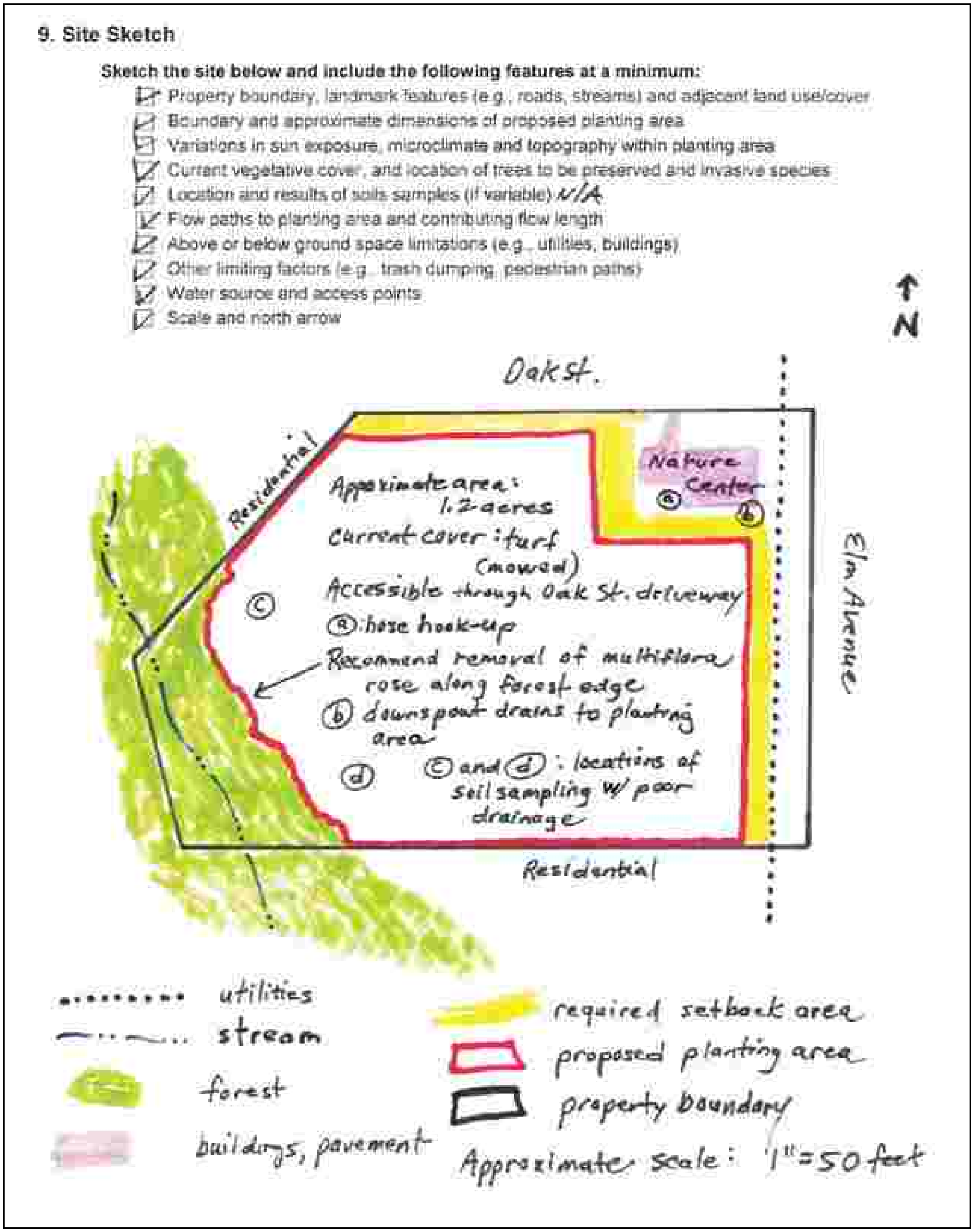

Figure 2. The site sketch for an urban reforestation site assessment becomes the foundation for a detailed planting plan.

Chapter 3. Basic Planting Design

Successful urban tree planting involves selecting appropriate species and plant materials, spacing plants appropriately, and developing a realistic planting plan, including a cost estimate. Each planting decision can be made using data gathered during the URSA (Chapter 2).

This chapter describes the factors to consider in developing the planting plan for a site.

Selecting Plant Species

The primary purpose of a planting plan is to determine what species of trees and shrubs to plant. Planting the right tree in the right place is a simple but often overlooked strategy to improve the survival of urban trees, even under difficult growing conditions, and to yield the greatest benefit from the tree. Proper species selection will ultimately save money through lower maintenance and replacement costs and higher landscaping value (Akbari and others, 1992 and ISA, 2000a). Species selection is based on site-specific information evaluated at each planting area, as well as on planting objectives. This section summarizes key factors in selecting the right species for the planting area.

Factors Influencing Species Selection

Factors influencing species selection include environmental conditions at the planting area and desired tree functions. In addition, native species are often recommended because they are better adapted to local conditions and generally require less maintenance. However, severe site conditions in urban environments may dictate the selection of well-adapted, hardy, nonnative species, provided they are not invasive. Environmental conditions and desired tree functions are described below.

Environmental conditions at the planting area are an important factor and are usually evaluated through the URSA (Chapter 2). Table 4 summarizes these environmental conditions and provides guidance on how to use them to select trees species from the Urban Tree Selection Guide in Appendix B. In general, tree species should be adapted to the local climate, as well as to the specific soil type, soil drainage, soil pH, and sun exposure present at the site. Trees should be hardy and resistant to any noted disease or pests in the area, and be able to tolerate observed urban conditions, such as compacted soil. Trees should also be appropriate for the intended use of the site and should, at maturity, fit the planting space provided, considering both above ground and below ground limitations.

Species may also be selected to promote tree characteristics that provide a certain function or benefit at the site, such as a high Leaf Area Index (LAI). The LAI of a tree represents the relative surface area of leaves and branches. The LAI is important in terms of potential for trapping small rainfall events and thus potential for reduction of storm water runoff. LAI is also an important factor in a tree's ability to yield various benefits of air pollution reduction. Values for LAI for various common tree species are currently under development. Other desirable characteristics may include these:

- Fast growth rate
- Ornamental traits – seasonal foliage color, blooming season, and characteristics of flowers
- Large size (> 50 feet in height)

- Specific form (e.g., pyramidal, upright)
- Wide-spreading canopy to provide shade
- Provides food for wildlife (fruits, nuts)

Table 4. Environmental Conditions That Affect Species Selection

Environmental Conditions from URSA (Chapter 2)	Species Selection Guidance	Corresponding Fields in Urban Tree Selection Guide (Appendix B)
USDA plant hardiness zone	Select species tolerant of planting area hardiness zone.	Hardiness zone
Sunlight exposure	Select species tolerant of sun exposure at site.	Sun exposure
Microclimate features	If high wind exposure or re-reflected heat load, select species tolerant of drought.	Drought tolerance
Topography	If low-lying areas, select species tolerant of flooding. If steep slopes, select species tolerant of drought.	Drought tolerance Flood tolerance
Regional forest association	Use species from regional forest association as preliminary target species list.	None
Soil texture	Select species tolerant of soil texture at the site.	Soil components
Soil drainage	Select species tolerant of soil drainage at the site.	Soil moisture
Soil compaction	Select species tolerant of soil compaction at the site	Soil compaction
Soil pH	Select species tolerant of soil pH at the site.	pH level
Soil chemistry	If soils have high salt content, select species tolerant of salt.	Salt tolerance
Storm water runoff to planting site	If site is under-capacity, select species tolerant of drought. If site is at-capacity or over-capacity, select species tolerant of flooding (see Chapter 4 for guidance on identifying these types of sites from URSA data).	Drought tolerance Flood tolerance
Floodplain connection	If floodplain is connected, select species tolerant of flooding.	Flood tolerance
Space limitations	If infrastructure is present, select species appropriate for the planting space (see Chapter 4 for specific guidance).	Height Canopy spread Form or habit Root structure
Other limiting factors	If other limiting factors are present, select species that are tolerant of these factors (see Chapter 4 for specific guidance).	Flood tolerance Pest or disease tolerance

The Urban Tree Selection Guide in Appendix B can be used to select tree and shrub species that are appropriate for a given site, based on their tolerance for environmental conditions and tree characteristics discussed above. The Urban Tree Selection Guide is compiled from multiple sources and is most applicable to the Northeast and Midwest regions of the United States. Site designers should always consult with local horticulturists, arborists, landscape architects, or other foresters who are familiar with the local conditions to refine the tree species selection and better assure the success of the project.

The Importance of Diversity

Maintaining a high level of species diversity in urban forests is important to prevent forest mortality due to species-specific insect or disease outbreaks (e.g., Dutch elm disease). A good rule of thumb is to plant a minimum of five species and set a minimum and maximum number of each species (NC DENR, 2004; ACB, 2000; CBF, 2001). When re-creating a local forest association, a diverse mix of 10-12 species is recommended, including understory trees and shrubs (NC DENR, 2004). As a caveat, the designer should always keep in mind the project goals, setting, and the availability of plant materials, when determining the number of species to plant. Just as too few species can be a problem, selecting too many species can complicate project implementation.

In addition to species diversity, it is also important to create a diversity of habitats to maximize wildlife benefits. In a forest, this means having vertical layers of vegetative cover, including canopy, midstory, understory, and ground cover. If desired, a shrub layer can be planted along with larger trees at the time of planting to increase diversity and create an understory. If the planting plan seeks to establish both canopy species and understory trees, a rule of thumb is to plant at least three or four understory trees for every canopy tree to provide structural diversity similar to mature forests (NC DENR, 2004; Palone and Todd, 1998).

Choosing Plant Materials

Tree and shrub materials are available for purchase in three basic nursery production forms: balled and burlapped, bare root, and container grown stock (Figure 3). Each type of plant material varies in size, cost, survival rates, planting procedures, and establishment success (Buckstrup and Bassuk, 2003; Palone and Todd, 1998; Tree Trust, 2001; WSAHGP, 2002). Some key advantages and disadvantages of the three types of plant materials are compiled in Table 5.

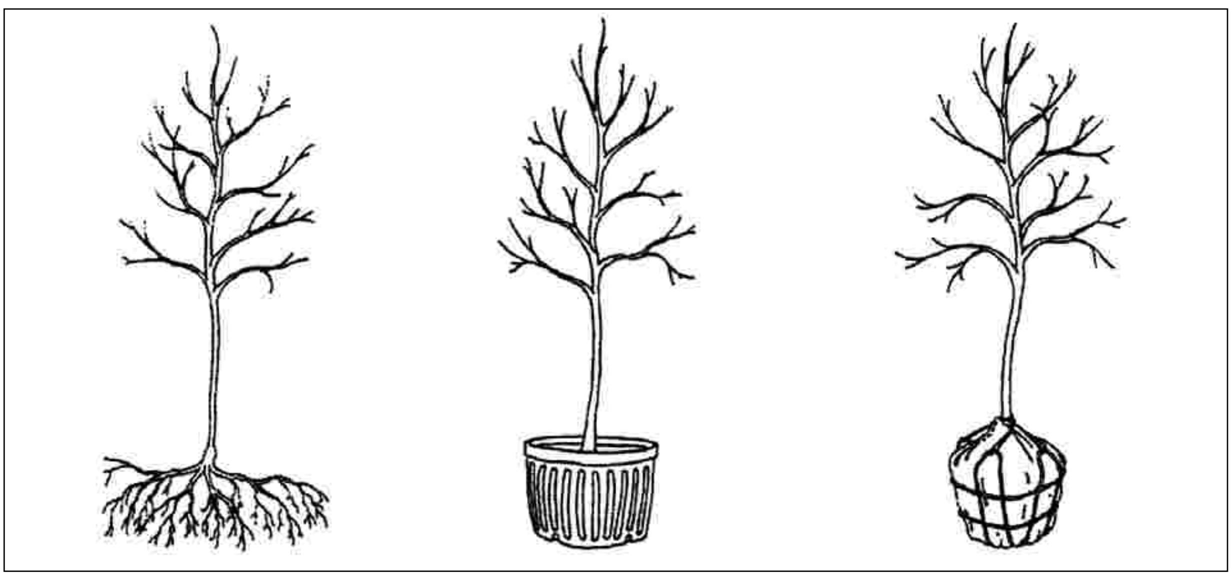

Figure 3. Three types of plant materials are available: (from left) bare root, container grown, and balled and burlapped (Illustration by Nina DiRenzo, used with permission from Nina Bassuk, Director of Cornell Urban Horticulture Institute)

Table 5. Advantages and Disadvantages of Various Plant Materials			
Type of Plant Material	**Size Range**	**Advantages**	**Disadvantages**
Bare root	Seedlings up to 2-inch caliper	• Inexpensive • Easy to plant and transport • Condition of roots is easy to evaluate • Soil interface problems are not an issue	• Limited planting window • Not appropriate for all species • Requires special storage/handling • More subject to accidental damage by mowers
Container grown	Seedlings up to 2-inch caliper	• Longer planting window • Readily available • Visible to maintenance crews	• Moderate to high cost • Roots may be pot-bound • May require more watering after planting
Balled and burlapped	1- to 4-inch caliper	• Longer planting window than bare root • Larger size makes plants more resistant to damage • Heights are generally above most competing plants	• Most expensive • Difficult to plant without machinery • Cannot see condition of roots

Source: Buckstrup and Bassuk (2003), Hairston-Strang (2005), Palone and Todd (1998), Tree Trust (2001), and WSAHGP (2002)

Bare root stock are usually small trees that are dug out in fall or early spring and stored with no soil attached to their roots. Due to their small size and manageability, bare root trees are very easy to plant. Roots must be kept moist until planting and should be planted in spring while they are dormant, to avoid drying out. **Container grown trees** are trees that have been growing in a container for several months to a year. They can range in size from seedlings in gallon pots to 4- to 5-foot trees in larger pots. Container grown trees are considered easy to plant and establish in almost any season. Balled and burlapped trees are trees that are dug, wrapped in burlap, and kept in the nursery for an additional period of time. **Balled and burlapped trees** can be very large and are difficult to plant without heavy equipment.

Tree sizes range from seedlings up to 4-inch caliper. Larger trees and shrubs are sold by the caliper inch, which is defined as the diameter of the stem measured 6 inches above the ground (or 12 inches above the ground for trees greater than 4 inches in diameter). Trees larger than 2-inch caliper are more expensive but may work best where intensive uses are anticipated, as in urban parks. Larger plant material may also attain the desired planting goals more rapidly because they mature rapidly.

Generally the most cost effective and successful type of plant material is bare root seedlings (Buckstrup and Bassuk, 2000; NC DENR, 2004), provided special techniques are used to prevent root desiccation (see Chapter 6 for information on Storing Plant Materials). Bare root material grows relatively rapidly after the root system is established, reaching canopy closure soon after similar size balled and burlapped material (Palone and Todd, 1998). One drawback is that bare root seedlings are not as visible as other plant materials, are more likely to be damaged by mowing and maintenance equipment, and generally take more effort to protect.

For urban tree plantings, a mix of bare root seedlings and larger trees may be the best approach (Doherty and others, 2003; Palone and Todd, 1998). One option can be large trees on the outer edge of a planting to mark the location, with bare root seedlings planted inside. Ultimately, planting strategies are largely determined by the extent of available funding.

Plant materials should be grown locally or ordered from a local nursery so they are adapted to regional conditions. Trees that have been properly trained and pruned in the nursery require less pruning after planting, become established more quickly, and are more resistant to damage from winds and other stressors (Mock, 2002). Reputable nurseries should adhere to landscape plant specifications set forth in the *American Standard for Nursery Stock* (ANLA, 2004). However, these numeric standards are not quality based, so individual trees should also be inspected to be sure they are of high quality. Guidance on inspecting nursery stock is provided in Chapter 6, and in ISA (2000b), and Polomski and Shaughnessy (1999).

Determining Plant Density

The layout of trees and shrubs at the planting site will vary with the ultimate goal of a planting project (e.g., street tree plantings, park, forest). For tree plantings along streets or other sites constrained by infrastructure, plant spacing is determined by proximity to infrastructure and ultimate expansion of the tree canopy. For example, spacing of 30 to 50 feet is typically recommended for a large street tree (i.e., over 50 feet high when mature).

When planting in larger spaces, such as a park, reforestation of the entire area will provide the most benefits in terms of cooling, storm water reduction, and habitat. Where this is not possible due to conflicting uses or site constraints, planting trees in clusters or groves is recommended. Planting trees in clusters improves plant health, species richness, and habitat diversity (Hobbs, 1988; Tree Trust, 2001; Sudbrock, 1996; WSAHGP, 2002). Trees that are planted in interconnected soil volumes will grow larger than if planted singly, because interconnected soil volumes result in a more even distribution of water and roots (Urban, 1999). The spacing of plants within the forest, tree cluster, or other layout is an important element of planting design, and will ultimately determine how many trees and shrubs are needed for the planting.

Plant spacing is based on the desired stem density, and should also account for survival rates of the stock and species selected. The project budget and maintenance needs can also affect plant spacing. For example, where mowing is necessary to control invasive plants, spacing should allow mowing between individual trees. In general, more dense spacing (more than 400 trees per acre) helps to achieve forest canopy closure more quickly, which in turn reduces competition from weeds (Hairston-Strang, 2005). However, higher densities (more than 500 trees per acre) should be thinned later to improve the quality of the stand by promoting larger trees (Hairston-Strang, 2005). When planting larger stock where the goal is landscaping rather than forest, spacing of 30 to 50 feet is recommended for large trees. Three potential spacing options for different plant materials are provided in Table 6.

Table 6. Example Planting Densities for Various Size Trees			
Scenario	**Tree Size**	**Spacing (feet)**	**Resulting Stem Density (trees per acre)**
1	Seedlings	8	340
2	Tree with ¾-inch d.b.h.*	14	160
3	Tree with 2 ½-inch d.b.h.*	17	150
In scenario 1, seedlings are planted at a greater density than what is ultimately desired, to allow for losses due to competition, stress, and herbivory. Using an average survival rate of 50%, plant spacing of 8 by 8 feet results in sufficient stem density upon maturity. In scenario 2, planting density is somewhat higher than the stem density desired, to account for losses due to competition, stress, and herbivory. Based on a survival rate of 75%, plant spacing of 14 by 14 feet achieves the desired stem density. The plant material in this scenario is at least several feet high and about three quarters of an inch in diameter. In scenario 3, spacing is based on the ultimate desired stem density since these larger plant materials will be most likely to survive. In this approach, the canopy, midstory, and understory may all be planted at once in their final locations. The 17- by 17-foot spacing used results in a canopy tree density that is comparable to that typically found in a mature forest.			

Source: ACB (2000)
* d.b.h. = diameter at breast height

For large planting projects that use a mix of stock, species, and plant sizes, a general rule of thumb for estimating the number of trees and shrubs needed is provided below (from ACB, 2000):

$$\text{Number of plants needed} = \frac{\text{length (feet)} \times \text{width (feet) of planting area}}{\text{50 (square feet)}}$$

This formula assumes that each randomly planted tree or shrub occupies an average space of 50 square feet and that average trunk spacing is 10 feet. Using this rule of thumb, a tree mortality rate of up to 40% can be absorbed by the growing forest system.

There are two schools of thought regarding plant layout and spacing when re-creating a forest: **uniform plant distribution** and **random plant distribution** (Palone and Todd 1998). Layout and maintenance are much simpler with uniform distribution, particularly when volunteer labor is used for installation. Mixing species randomly within the planting can enhance variability and the natural appearance of a uniform plant distribution planting. A disadvantage to uniform planting is that the reforestation project may appear “too structured and unnatural.” Over time, however, tree mortality will compensate for uniformity and leave vacant spaces between trees, as well as opportunities for germination of seed dispersed naturally from adjacent trees.

Random distribution provides the initial “natural spacing” appearance, but may create difficulties when trying to perform survivability counts, as well as maintenance activities, such as mulching (Palone and Todd, 1998). Whichever method is chosen, plant spacing should be close enough to reflect the natural forested situation observed in the local area (Palone and Todd, 1998; CBF, 2001), and provide as much canopy closure as possible in forested zones. The method should also provide enough distance for adequate plant establishment before root systems begin to compete within the limited growing space.

Planting Plan and Cost Estimate

A planting plan should be developed for each planting site based on the information collected during the URSA (Figure 4). Up to 6 hours of time may be needed to develop a planting plan for each site, depending on the size of the site. A landscape architect (LA) may use the URSA data to draw up a conceptual sketch of how the site will look when planted, and then translate this idea into a planting plan. Planting plans are essentially a blueprint of how the tree planting will be done and should contain the following minimum information (CBF, 2001; ACB, 2000):

- Map or sketch of the site with appropriately marked planting zones
- Plant species list (number, size, type of stock)
- Planting directions (spacing, layout)
- Planting instructions
- Equipment and supply list
- Site preparation instructions
- Implementation and maintenance schedule
- Cost estimate (planning-level costs for the entire project)

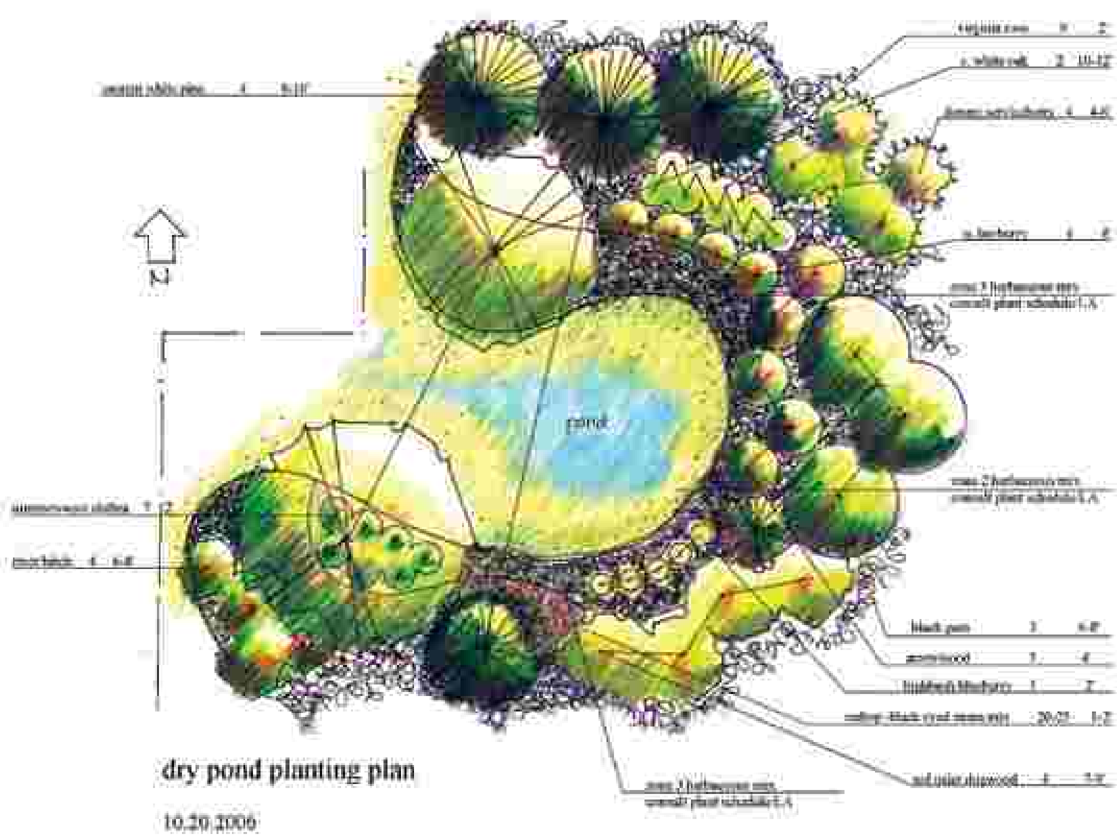

Figure 4. A planting plan for an urban reforestation site includes a map or sketch of the site showing the locations of species to be planted.

Unit costs for plant materials and supplies are provided in Table 7 to help estimate the planting project cost. The unit costs for plant materials vary depending on the size of the plant, the species, and the number purchased. Unit costs for mulch and compost depend on whether it is delivered, and the type or grade. Other cost factors include any labor, equipment, site preparation, or maintenance costs needed to ensure success. Each cost factor is discussed below, and a worksheet for estimating all project costs is provided in Appendix C.

Table 7. Estimated Unit Costs for Plant Materials and Planting Supplies

Item		Cost*
Plant Materials	Bare root trees	$0.30 --- $40.00 each
	Container grown trees	$2.50 --- $80.00 each
	Balled and burlapped trees	$35.00 -- $400.00 each
Supplies	Tree shelters (12 to 72 inches)	$1.00 ---- $4.00 each
	Tree stakes	$1.00 ---- $2.00 each
	Mulch	$6.00 -- $20.00 per cubic yard
	Compost	$11.00 -- $20.00 per cubic yard

Source: Chollak and Rosenfeld (1998), Environmental Concern, Inc. (2005), Hairston-Strang (2005), Octoraro Native Plant Nursery (2004), Palone and Todd (1998), and Tree Trust (2001).
*Cost does not include installation.

Unit costs for plant materials in Table 7 do not include installation costs. For example, the installed cost of tree shelters ranges from $4.00 to $5.00 per tree (Hairston-Strang, 2005). Installation costs for tree planting can range from low cost hand-planting to higher cost machine planting. For bare root trees, hand planting with mattocks or dibble bars is the least expensive method, but root spread may be compromised. If power augers are used to dig planting holes, installation costs should run from $0.40 to $0.50 per tree, making the installed cost $0.70 to $40.50 per tree. Installation of container grown trees will be similar to the costs associated with bare root planting. Balled and burlapped trees will generally cost the most to install, ranging from $18.00 to $50.00 per tree, depending upon method, size of plant, and source (Palone and Todd, 1998).

Installation costs will vary greatly depending on the cost of the given labor source used: agency staff, contracted labor, watershed groups, or volunteers. The cost of local agency staff is usually moderate. Staff of watershed groups have a relatively low labor cost. Volunteers are certainly the lowest cost labor type but most arrive with low skill levels and require additional training. Using volunteer labor greatly reduces the costs involved in tree planting, but is never without charge. A modest investment is needed to recruit, train, coordinate, and provide refreshments for volunteers.

Equipment costs also vary greatly depending on the size of plant material and planting area, labor type, and whether the equipment is purchased, rented, or donated. Equipment can include mechanical tree planters, power augers for digging holes, delivery trucks, or a Bush Hog for removing unwanted plants. Small equipment that may be needed for site preparation and planting include mattocks or shovels, wheelbarrows, swinging blades, work boots, gloves, measuring tapes, hammers, and flagging.

Site preparation cost estimates are provided in Chapter 5. Maintenance costs will vary by site and can include mowing, pruning, mulching, weed control, watering, or supplemental plantings.

Chapter 4. Special Considerations for Urban Tree Planting

To grow, a tree needs the right balance of sunlight, water, rooting space, and soil nutrients. The urban planting environment often lacks many of these growth factors and imposes unique stresses on trees. Conflicts between trees and infrastructure (e.g., utilities and pavement) may damage trees and infrastructure, and result in tree removal. It is important to evaluate the potential stressors and conflicts present at each planting site. Most conflicts can be addressed through appropriate species selection, soil amendments, planting layout, or other special techniques.

This chapter discusses techniques to ensure adequate soil volume, effectively treat storm water, reduce infrastructure conflicts, and protect trees from other impacts.

Calculating Soil Volume

Because space is a premium in many urban areas, urban trees are typically allotted only small planting areas, regardless of the size of the tree. In addition, poor urban soil quality may further reduce the rooting volume that can actually be used by a tree. Soil is critical to tree health because it provides structure and vital water and nutrients. Several tree functions are linked to adequate root volume (Urban, 1999; VCE, 2002). Limited soil volumes, however, confine roots, restrict growth, reduce anchorage, and supply inadequate moisture and nutrients (VCE, 2002). Most urban street tree pits average only about 50 cubic feet of soil (Figure 5), while a large tree actually requires at least 400 cubic feet of usable soil (Urban, 1999). Inadequate rooting volume appears to be a contributing factor in the low life expectancy of the average urban tree, estimated at less than 10 years after planting (VCE, 2002).

Figure 5. Typical urban tree pits provide only about 50 cubic feet of soil.

When planning an urban planting project where space is limiting, it is important to evaluate how to provide the optimal soil volume for each tree. The first step is to calculate the optimal soil volume per tree. A general rule of thumb is to measure the area within the projected mature drip line of the tree and provide 2 cubic feet of usable soil per square foot (Grabosky and others, 1999; Urban, 1999). Based on this rule of thumb, Urban (1999) correlated crown projection and tree size to identify minimum required soil volume for various size trees (Figure 6).

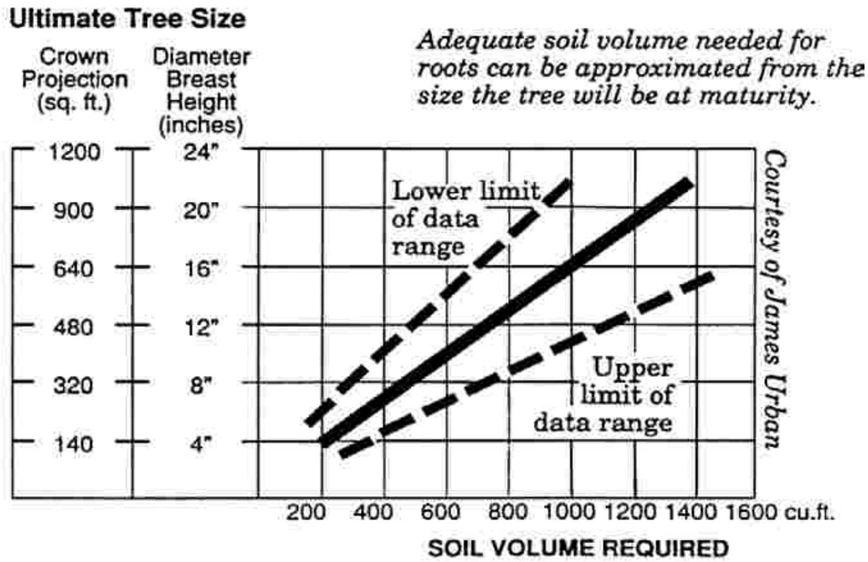

Figure 6. The soil volume required for various size trees assumes a soil depth of 3 feet. (Source: James Urban)

Trowbridge and Bassuk (2004) have developed a more detailed calculation that takes into account a tree's specific water needs, its expected water loss based on local atmospheric conditions, and its average water-holding capacity. A modified version of their soil volume equation follows.

$$\text{Soil volume} = [((3.14 \times r2) \times LAI \times ER \text{ x } 0.2) / AWHC] \times RF$$

where:

r (ft) =	radius of tree canopy at maturity.
LAI =	leaf area index, the ratio of total tree leaf surface area to crown projection. LAI can be derived from regional data where it exists (typical range is 1.5 to 3).
ER (ft/day) =	evaporation rate, the highest mean monthly evaporation rate divided by the number of days in the month. ER can be derived from pan evaporation data (data derived from measuring evaporation in pans of water, often available from local weather stations).
AWHC =	available water holding capacity, which varies by soil type but typically ranges from 10% to 20%. AWHC can be derived from testing the planting area soil.
RF (days) =	rainfall frequency; the average length of a dry period in the region, with dry period being defined as a period with less than the rainfall amount that constitutes a critical rainfall event. Rainfall data are available from the National Oceanic and Atmospheric Administration, and the average should be based on at least 10 years of data.

The soil volume equation assumes that usable soil is provided in the planting area to a depth of 3 feet. The calculation and the earlier rule of thumb are based on the assumption that the soil volume provided is usable, meaning it is uncompacted, and contains adequate organic matter and nutrients. If the existing soil is unusable, it may need to be amended or replaced, either over the entire site or around individual planting holes (see Chapter 5 for information on soil amendments).

Determining the required soil volume for a planting site helps determine if existing soil and space are adequate to plant the desired number and size of trees. To determine the available soil volume at the site, multiply the planting area (minus any portions that cannot be planted due to infrastructure or conflicting use) by a rooting depth of 3 feet. If insufficient soil volume is present, the designer should decide how to redesign the planting site to provide more area or depth for tree planting or use alternative plant materials. For example, when planting in a tree lawn, the width of the tree lawn could be increased by decreasing the road width, where feasible, to provide more soil for trees. Another option is to use an alternative tree layout that allows trees to share rooting space. If the site cannot be redesigned, the number or size of trees planted at the site, or both, should be reduced to ensure that individual trees have a decent chance of survival.

Evaluating Storm Water Runoff

Too little water or too much water can cause tree mortality at urban planting sites. Too much water is often the result of storm water runoff from nearby impervious surfaces being directed towards planting areas and overwhelming the infiltration capacity of the soil or the saturation tolerance of the tree species. Too little water reaches an urban tree when rainfall that would normally soak into the ground can infiltrate only a small area around each planting pit. The rest becomes storm water runoff that is efficiently directed into nearby storm sewers, making it unavailable to tree roots (Figure 7). Designing urban planting sites for the expected volume of storm water and rainfall helps to ensure an appropriate water balance for trees and can improve water quality, as trees remove pollutants from storm water runoff. Part 1 of this manual series summarizes the water quality benefits of trees.

Figure 7. Urban trees in raised planters receive very little water from rainfall or runoff.

This section outlines a method to evaluate the capacity of planting areas to accept and treat storm water runoff from adjacent areas. This simple evaluation of storm water runoff to the site is made during the URSA (Chapter 2), and is used to identify appropriate storm water treatment and planting strategies. Table 8 provides a summary of three possible storm water treatment capacity conditions at a planting area, and corresponding storm water and planting strategies to address them. Each storm water capacity condition is discussed in more detail below.

Table 8. Storm Water Treatment Capacity Conditions of Potential Planting Sites

Capacity Condition	Site Description	Storm Water Strategy	Planting Strategy
Under capacity	Receives no runoff; runoff bypasses site in pipes or ditches, or infiltrates before reaching the site.	Daylight the pipe or split the flow.	Choose drought-tolerant species or provide irrigation.
At capacity	Receives only sheet flow; runoff travels over a relatively short distance before reaching the site.	Install filter strip with trees or plant trees behind small berm.	Plant species that are suited to the wetness of the site.
Over capacity	Receives concentrated flow; runoff travels over longer distance before reaching the site, or is directed to the site in a storm water outfall.	Install perimeter treatment practice or pipe the flow.	Plant wet-tolerant species using large stock.

Under-Capacity Sites

Under-capacity sites receive no concentrated storm water runoff or sheet flow and, consequently, provide no storm water treatment (Figure 8). Runoff from adjacent land either infiltrates before reaching the planting area, due to high soil infiltration rates, or bypasses the planting area in a pipe or ditch. Trees at under-capacity sites may require supplemental water in order to grow.

Figure 8. This under-capacity site receives no storm water runoff.

Identifying under-capacity sites

Several factors evaluated during the URSA help to determine if a planting area is under capacity for storm water treatment. The first is an evaluation of storm water runoff to the planting site. Under-capacity sites show no evidence of upgradient drainage, and have no storm water outfalls, shallow concentrated flow, or sheetflow to the site. Also, if pipes or open channels direct runoff across or around the site, the site is under capacity.

Another factor is the "contributing flow length." This is the longest distance over which runoff travels before entering the planting area. For larger planting areas, it is the distance runoff travels before leaving the planting area. Flow length should be measured by following a path from the point that is the most hydraulically distant (typically the point on the farthest upgradient ridgeline) to the lowest point of entry to the planting area, or to the lowest point on the planting area for larger sites. If the contributing flow length is less than 75 feet and is impervious (or 150 feet and pervious), the site is usually considered under capacity. Under-capacity sites also show no signs of receiving storm water runoff.

Storm water strategies

Storm water strategies for under-capacity sites where runoff bypasses the planting area involve modifying the site drainage or splitting flows to allow for some treatment of storm water. One option is to split the flow from the pipe so that a portion of the runoff is diverted into the reforestation site and travels as sheet flow, while the remainder of the runoff continues through the pipe and into the stream (also called partial daylighting). Several variables need to be analyzed to determine whether daylighting is feasible, but a rule of thumb is that daylighting works best where the site is too small to handle all of the runoff from the pipe. For more information on pipe daylighting and flow splitting, see Schueler and Brown (2004).

Planting strategies

Where storm water strategies are not pursued, the planting strategy at under-capacity sites should account for the lack of runoff at the site. Unless an adjacent water source is found, the only water source will be rainfall, and the site may be vulnerable to drought. Therefore, the species planted should be tolerant of drought (see Appendix B, Chart 1, for species tolerant to drought). A small soil berm may also be created around the planting hole to hold water near the tree.

At-Capacity Sites

At-capacity sites receive sheet flow only from adjacent land, and the amount of flow does not overwhelm the capacity of the site to treat storm water runoff (Figure 9).

Identifying at-capacity sites

Planting sites that are at capacity show no evidence of shallow concentrated flow or of upslope drainage area outfalling to the site. Sheetflow may be observed; however, sheet flow is difficult to maintain over long distances. Therefore, under this condition, the contributing flow length will be a maximum of 75 feet for impervious surfaces and a maximum of 150 feet for pervious surfaces. As the slope of the contributing flow length increases, these maximum distances will be reduced, since increasing slope will cause runoff to concentrate more quickly.

Figure 9. This at-capacity site receives rooftop runoff from adjacent townhomes.

Storm water strategies

Areas that are at capacity are prime locations for incorporating storm water forestry practices (SFPs), such as the forested filter strip. SFPs are storm water treatment practices that have been modified to incorporate trees into the design, Therefore, if they will not conflict with the intended use of the site, trees planted can be part of a practice design. The forested filter strip incorporates a small depression and berm to temporarily pond water and allow it to enter the forested area slowly without causing erosion. Figures 10 and 11 illustrate the forested filter strip, and Part 2 of this manual series provides guidance on its design.

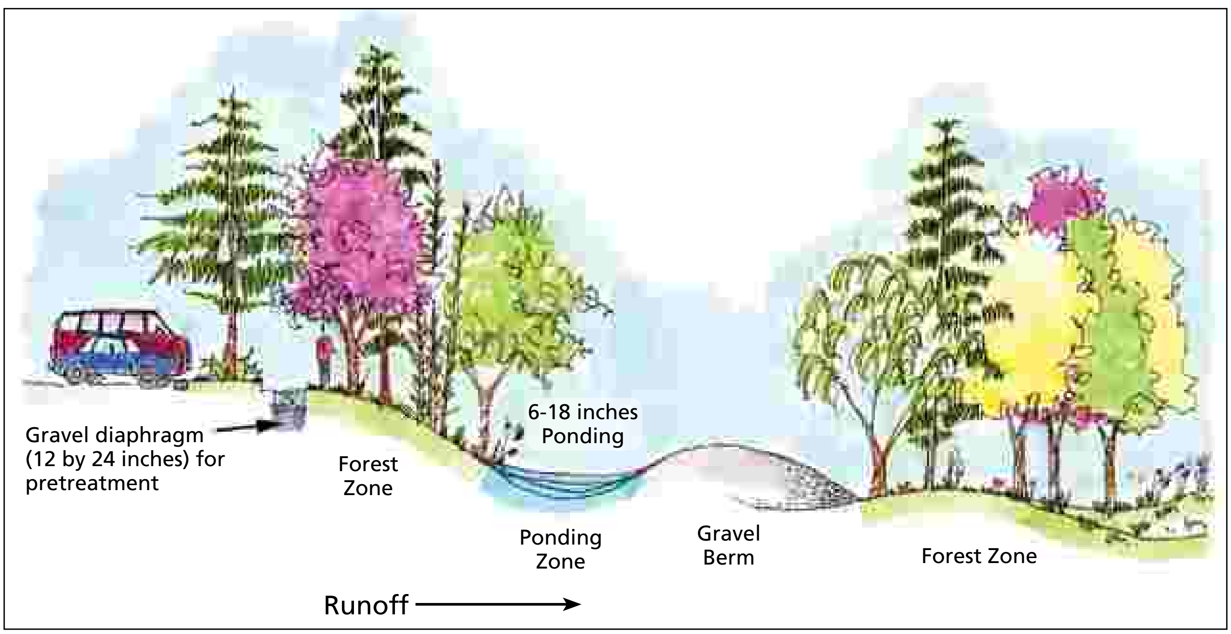

Figure 10. Forested filter strip profile shows how runoff flows through the various zones.

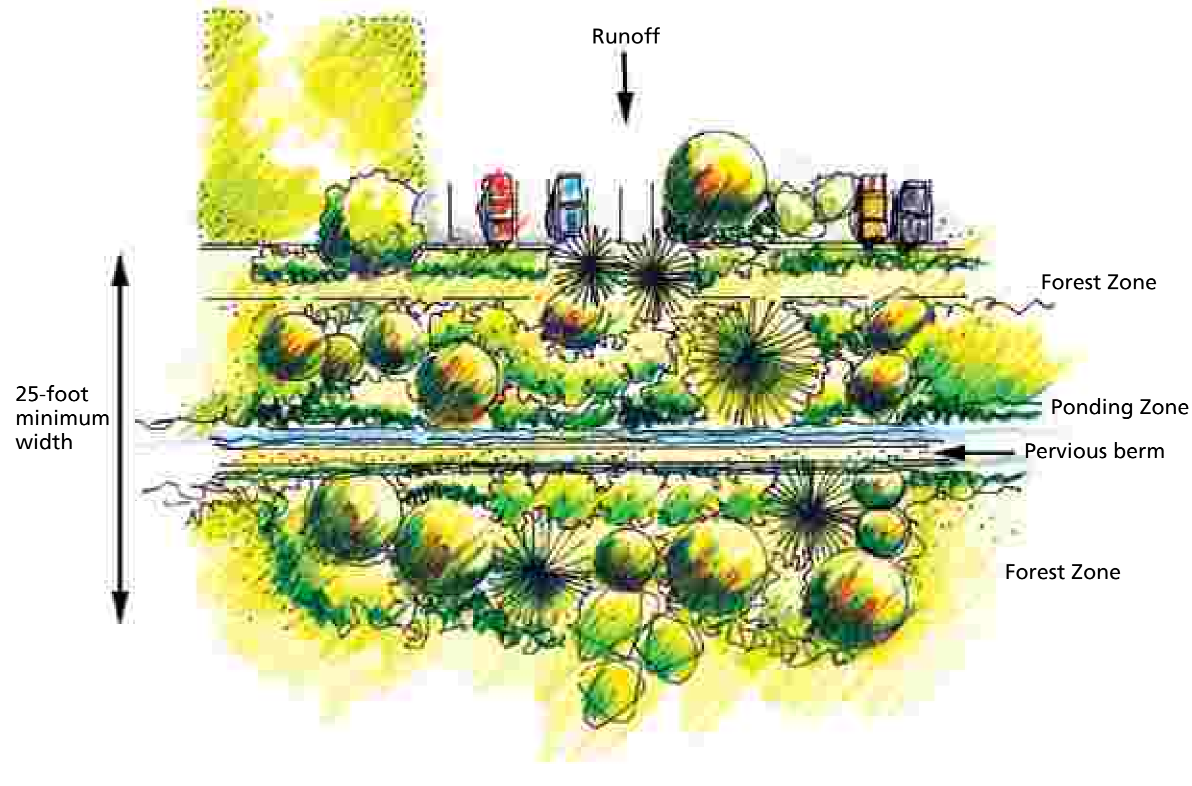

Figure 11. Forested filter strip plan view shows its suitability to a linear area.

Planting strategies

Where storm water strategies are not pursued, the planting strategy is to use trees to treat storm water runoff, taking into account the volume of storm water runoff at the site when selecting tree species. Storm water runoff provides a source of irrigation for newly planted trees and, if maintained as sheetflow, will not erode new plantings. The species planted should be tolerant of occasional inundation. See Appendix B, Chart 1, for flood tolerance of tree species. Depending on the volume of runoff and the soil drainage, planting strategies may also include providing positive surface drainage away from the tree, mounding the planting soil so that the root ball is partially above grade, or installing subsurface drain lines to remove excess water (Urban, 1992).

Over-Capacity Sites

Over-capacity sites receive shallow concentrated flow, or runoff from an upslope drainage area, or both (Figure 12). Over-capacity sites typically have some potential for treating storm water runoff at their perimeter. Runoff from adjacent land travels over impervious surfaces longer than 75 feet or over pervious surfaces longer than 150 feet, or runoff from an upstream drainage area is directed to the planting area in a storm water outfall.

Identifying over-capacity sites

Over-capacity sites typically show evidence of shallow concentrated flow. Common indicators include rills, gullies, erosion, and sediment deposition at the perimeter of or within the site. Contributing flow lengths are greater than 75 feet (impervious) or 150 feet (pervious), and there may also be an upslope drainage area that outfalls to the site.

Figure 12. Concentrated flow at this over-capacity site must be dealt with before planting.

Storm water strategies

The perimeter of an over-capacity site may be an ideal location to install a storm water treatment practice. Bioretention or filter strips are two possible options for sites where the maximum runoff velocity is 4 to 5 feet per second for a 2-year storm (Claytor and Schueler, 1996). Figure 13 illustrates a bioretention facility that incorporates trees into the design. Part 2 of this manual series, and Claytor and Schueler (1996) provide design guidance for bioretention facilities.

At sites with runoff velocity greater than 1 foot per second, concentrated flow may already have begun to erode the channel. In these cases, the channel should be stabilized using bioengineering techniques, up to the 10-year storm flow height. If channel stabilization is not sufficient, piping the flow may be the only option to eliminate gullies and erosion in the planting area. Over-capacity sites with erosion problems should be corrected before planting trees. See Schueler and Brown (2004) for more information on using bioengineering techniques.

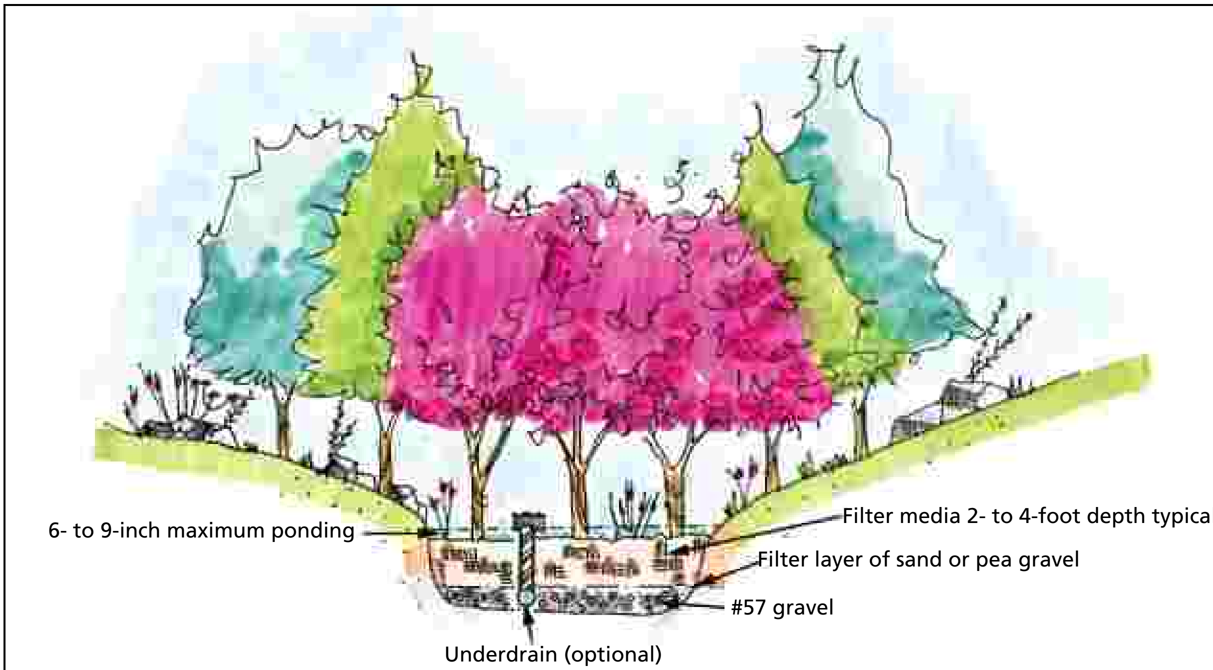

Figure 13. A bioretention facility with trees removes pollutants from storm water runoff.

Planting strategies
Since trees in over-capacity sites may be subject to high flows and erosion, larger stock that is tolerant of occasional inundation should be planted (see Appendix B, Chart 1, for flood tolerance of tree species). Depending on the volume of runoff and the soil drainage, planting strategies may also include providing positive surface drainage away from the tree, mounding the planting soil so that the root ball is partially above grade, or installing subsurface drain lines to remove excess water (Urban, 1992). Sites that have extreme runoff volumes may not be suitable for planting unless storm water is diverted to manage excess flows.

Reducing Conflicts Between Trees and Infrastructure

The built nature of the urban landscape presents unique challenges to maintaining and expanding tree cover while minimizing damage to adjacent infrastructure, such as pavement, structures, and utilities (Figure 14). The municipal costs to repair infrastructure damaged by trees can be high. The annual cost of repairing sidewalk and road damage by trees is estimated at more than $42 million in California alone (Dodge and Geiger, 2001). Where trees and infrastructure conflict, the offending trees are often removed or pruned to the point where they no longer provide their intended benefits. The unique quality of the urban forest is its coexistence with the built environment. Planting the right tree in the right place, and using specific design and construction techniques can reduce these conflicts and allow substantial tree canopy to thrive in the urban landscape. It is important to consider and, if necessary, make changes in these areas:

- Species selection
- Site design and layout
- Construction materials
- Maintenance strategies

Preplanning that incorporates these types of changes can prevent tree-infrastructure conflicts in new developments or can remedy existing conflicts when used in a retrofit. Changing the way sites are built early in the design process can reduce damage to both infrastructure and trees, and integrate trees into the urban landscape to provide maximum benefits. Part 2 of this manual series provides information on incorporating trees into development sites. Table 9 indicates which strategies apply to the five major types of infrastructure discussed in this chapter: utilities, pavement, structures, lighting and signs, and trails. Strategies for each type of infrastructure are discussed below.

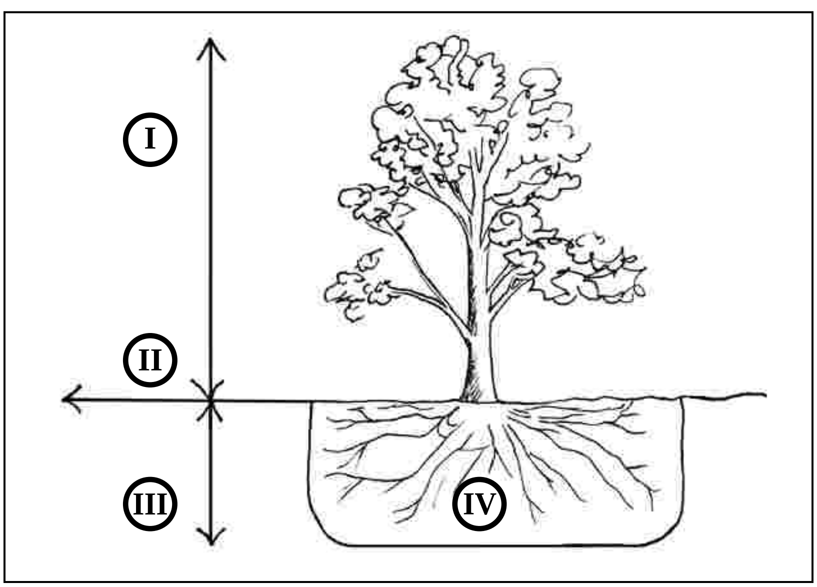

Figure 14. Trees may conflict with infrastructure (I) above ground, (II) at the surface, (III) below ground, or (IV) in the root zone.

Table 9. Methods That Reduce Conflicts Between Trees and Infrastructure				
Type of Infrastructure	**Method**			
	Tree Species Selection	**Site Design and Layout**	**Construction Materials**	**Tree or Utility Maintenance**
Utilities	X	X	X	X
Pavement	X	X	X	X
Structures	X	X	X	X
Lighting and signs	X			
Trails	X	X		

Utilities

Utilities include overhead wires and underground utilities. Overhead wires are normally confined to electric, telephone, or cable, while underground utilities can also include water, sewer, or gas lines. Methods to reduce conflicts for overhead wires and underground utilities are discussed below.

Overhead wires

Overhead wires having the most potential for conflict with trees are high voltage electric lines. When trees planted directly underneath these lines grow to maturity, they can lead to brief or sustained power outages, downed wires, or other safety hazards (PSU, 1997). Utility companies regularly prune trees growing near high voltage power lines to ensure safety and minimize service disruptions. The recommended clearance between trees and wires varies according to voltage; check with the local utility company to locate high voltage wires and identify clearance standards. High voltage wires are often those placed highest on the power pole.

The best way to avoid conflicts between trees and overhead wires is to install utilities underground. Many communities are already doing this, while others are in the process of changing their local codes to allow the placement of utilities under street rights-of-way. This method usually applies only to new developments, because of the cost involved, but could be applied in a retrofit where utility wires needed to be upgraded anyway. If utilities cannot be placed underground, they can be located on only one side of the street. Small trees can be planted underneath the wires (using appropriate species and setbacks), and large trees can be planted on the other side of the street.

When trees are planted near overhead wires, appropriate species and setbacks should be used. Some commonly recommended setbacks and maximum tree heights when planting near overhead wires are presented in Table 10. These setbacks are general guidance only and do not necessarily apply in every situation. Local utility companies can provide additional guidance on the location of high voltage wires and recommended overhead clearance between trees and these wires. Another consideration is that in space-limited urban areas, it may not be possible to adhere to these setbacks and still find room to plant trees (especially large ones). To accommodate trees, these setbacks can be reduced with the knowledge that trees planted near high voltage wires will require regular pruning and species should be selected accordingly. For example, tree species with a large, coarse, horizontal branching structure (e.g., London plane or red oak) can be pruned extensively, unlike species with a pyramidal growth form or those known to be structurally unstable, such as Bradford pear (Figure 15).

Table 10. Recommended Minimum Setbacks for Overhead Wires		
Recommended Setback	**Description**	**Source**
10-15 feet*	Height setback between top of mature tree and overhead wires	Gilman, 1997; Head and others, 2001
10 feet	Distance setback for small trees (< 30 ft)	GFC, 2002; Gilman, 1997
15 -20 feet	Distance setback for medium trees (30-50 ft)	PSU, 1997; Head and others 2001
20 to 40 feet	Distance setback for large trees (> 50 ft)	Nebraska Forest Service, 2004; Head and others 2001
20 feet	Distance setback from transmission right-of-way for all trees taller than 15 feet	Kochanoff, 2002

*Based on the typical height of overhead wires (25 to 45 feet), trees planted under utilities should be 15-30 feet tall when mature, to maintain this height setback (City of Chicago, no date; City of Seattle, no date; Kochanoff, 2002; PSU, 1997)

Figure 15. Bradford pear trees are not well suited to extensive pruning to reduce conflict with overhead wires.

Finally, maintenance strategies can be used to reduce conflict between trees and overhead wires. This includes pruning methods that minimize damage to trees. Directional pruning is the arboriculturally preferred pruning method and is now used by most utilities (PSU, 1997). With directional pruning, branches growing towards wires are removed back to the parent branch or trunk. By removing the branch at a point where it would shed naturally if the branch died from natural causes, future growth is directed away from wires.

Underground utilities

Underground utilities, such as water, sewer, electric, and gas lines generally do not cause conflicts with trees, with a few exceptions. First, for safety reasons, tree planting is not recommended near underground utilities to reduce the possibility of hitting gas or sewer lines. A 10-foot setback is recommended to create a safe buffer to underground lines (GFC, 2002; Gilman, 1997; Head and others, 2001).

Next, tree roots can cause sewer and water pipes to clog because the roots naturally seek out water and may enter the pipes through small cracks or weeping joints. It is rare for roots to cause structural failure of sewer pipes, as structural failure is most often due to inadequate construction (Randrup and others, 2001). Interference between trees and sewer systems is most likely to occur with older or deteriorating systems (Randrup and others, 2001). Use of appropriate construction materials and methods can prevent this deterioration, but little can be done for failing existing systems short of costly upgrades. A more cost-efficient approach used by homeowners is to periodically clean out the pipes using a sewer-drain cleaning service.

Conflicts may also arise when installation, repair, or maintenance of underground utilities leads to damage of nearby trees. Maintenance strategies that do the least amount of damage to nearby trees should be chosen. Tunneling is a useful alternative to other methods, such as trenching or root pruning (Costello and Jones, 2003). Tunneling uses pneumatic excavation tools or hydro-excavation techniques to remove soil under and around roots to create opening for pipes and cables (Costello and Jones, 2003). In bypassing roots, tunneling is thought to have a minimal effect on tree health and structure.

Finally, tree roots can impact perforated pipes used for drainage in storm water treatment practices and other areas. These pipes may become clogged with roots from nearby trees, since tree roots tend to grow towards a water source. Where feasible, a 15- to 25-foot setback between trees and perforated pipes is suggested to reduce this conflict (MDE, 2000; Shaw and Schmidt, 2003).

Pavement

Trees can cause damage to pavement when tree roots grow under the pavement, causing lifting and cracking (Figure 16). Damage to sidewalks is especially common along narrow planting strips between sidewalks and streets (called tree lawns). Inadequate setbacks between trees and pavement are a common cause of damage to pavement; however, other factors that contribute include the quality of the soil and the sidewalk material. Asphalt sidewalks had significantly more conflicts with roots than did concrete sidewalks (Wong and others 1988). The potential for sidewalk damage increased where planting soils were compacted, because roots tend to grow along the surface in search of water and oxygen (City of Saint Louis 2002, Day 1991). Once tree roots cause damage, reducing or correcting the damage can harm the tree; or the tree may be removed completely in order to correct the problem.

Traditional street tree plantings emphasize individual tree pits in which tree roots are confined, creating potential for damage to nearby sidewalks as roots seek out water and oxygen. To reduce conflict between trees and pavement, appropriate species selection and changes to site designs and layouts, and construction materials may be used. Most of these alternatives apply to sidewalks. Each is discussed below.

Figure 16. Tree roots cause adjacent pavement to crack.

Species selection should be a consideration when planting trees near pavement. Tree species with large trunk flare or root buttress characteristics are not good choices to plant in small tree lawns (Costello and Jones, 2003). Appropriate species for these spaces should be chosen based on the trunk diameter at ground level (DGL), which accounts for the trunk flare, root buttress, and trunk diameter. To avoid conflict, the DGL of species to be planted should be significantly less than the size of the planting space (Costello and Jones, 2003). Costello and Jones (2003) provide guidance on determining DGL values for local species.

Alternative site designs ensure that trees have an adequate volume of good soil, water, and oxygen available so that roots are discouraged from growing near the surface. Redesign is generally feasible only for new developments but could be applied as a retrofit where sidewalk renovation is planned in conjunction with relocation or repair of underground utilities. Box 3 presents some examples of alternative sidewalk design methods for reducing tree conflicts. Figure 17 illustrates one of these methods, a curving sidewalk. The goal of alternative sidewalk designs is to provide enough soil rooting volume through larger planting space or shared rooting volume so that tree roots do not need to grow underneath the sidewalk.

BOX 3. ALTERNATIVE SIDEWALK DESIGN METHODS

- Larger planting space
- Curving sidewalk
- Pop-outs
- Nonstandard slab sizes
- Monolithic sidewalks
- Increased right-of-way
- Tree islands
- Narrower streets
- Bridging
- Lower planting sites
- Modified gravel layer
- Sidewalk elimination

Source: Costello and Jones (2003)


Figure 17. A curving sidewalk allows space for street trees.

Another element of site design that can be changed to reduce tree-sidewalk conflicts is to increase setbacks between trees and pavement. Most forestry guidance on the subject recommends a minimum setback of 10 to 15 feet (GFC, 2002; Francis and others, 1996; City of Saint Louis, 2002). This is supported by a study that found damage to sidewalk was most likely to occur when setbacks were less than 10 feet (Randrup and others, 2001). While these setbacks can greatly reduce potential for damage to sidewalks, if they are strictly adhered to in urban areas, there may not be adequate space for planting large trees. If use of these setbacks would eliminate trees entirely, designers should pursue alternative site layouts and construction materials to ensure that trees are integrated into urban areas, where their benefits are most needed.

Construction materials that can be used to reduce tree-sidewalk conflicts can be grouped into alternative sidewalk construction materials and materials used in the tree root zone (Box 4).

Alternative sidewalk materials include strategies to strengthen concrete or concrete alternatives. Concrete is strengthened by reinforcing with rebar, mesh, fiber, or an alternative fiberglass-reinforced plastic rebar. Alternatives to concrete include asphalt, which may not reduce damage but is more easily replaced than concrete; permeable concrete or brick pavers, which will lift individually rather than as an entire slab of concrete; and rubber sidewalks, which are flexible and can expand with the tree roots. One limitation of flexible pavements is they do not work well with compacted soils. The goal of alternative sidewalk materials is to allow tree roots to grow underneath the sidewalk while preventing sidewalk damage. Costello and Jones (2003) provide additional information on alternative sidewalk materials.

BOX 4. ALTERNATIVE CONSTRUCTION MATERIALS TO REDUCE TREE-SIDEWALK CONFLICTS

Alternative Sidewalk Materials

- Reinforced slab
- Thicker slab
- Expansion joints
- Pervious concrete
- Asphalt
- Decomposed granite and compacted gravel
- Permeable pavers
- Recycled rubber
- Mulch
- Grind edge
- Ramps or wedges
- Mudjacking

Materials Used in Root Zone

- Root barriers
- Continuous trenches
- Root paths
- Structural soil
- Root channels
- Foam underlay
- Steel plates

Source: Costello and Jones (2003)

Materials used in the tree root zone to reduce tree-sidewalk conflicts include root guidance systems and structural soils. Root guidance systems are designed to direct root growth away from infrastructure. Methods used range from barriers or plates that restrict root growth either laterally or radially, to underground trenches, paths, and channels, through which roots are directed to appropriate areas. The success of root guidance systems has been variable. They apparently are most effective in situations where tree-infrastructure conflicts are not a major concern, for example, on sites with uncompacted soils or sufficient planting area (Gilman, 1997; Harris and others, 2004). Experts caution against using root guidance systems to force the tree to stay within a confined planting space; roots will generally find their way around these barriers if needed. Most root guidance systems must be installed at the time of planting or sidewalk construction and are not suited for a retrofit. Consult Costello and Jones (2003) for a detailed review of root guidance systems.

Structural soils are engineered soils that provide a suitable medium for plant growth while also meeting hardscape engineering requirements. Structural soils are used to replace existing site soils that are not suitable for planting, and they increase rooting space and reduce infrastructure damage at sites where alternative sidewalk designs are not feasible. Structural soils are sold under various brand names, including CU Soil, developed by Cornell University's Urban Horticulture Institute, Carolina Stalite, and Amsterdam Tree Soil, which has been successfully used in tree pits in the city of Amsterdam in the Netherlands. Costello and Jones (2003), Grabosky and others (1999), and Couenburg (1994) provide some additional information about these specific types of structural soils.

The most common application of structural soils is for street tree plantings, as they can be used under pavements that bear light loads, such as sidewalks. Structural soil allows root growth to occur underneath pavement so that roots can grow outside of the tree pit. As a result, tree roots have access to a continuous soil trench that runs underneath the sidewalk and connects to the planting pits. Figure 18 illustrates a typical application of structural soils within a linear street tree design.

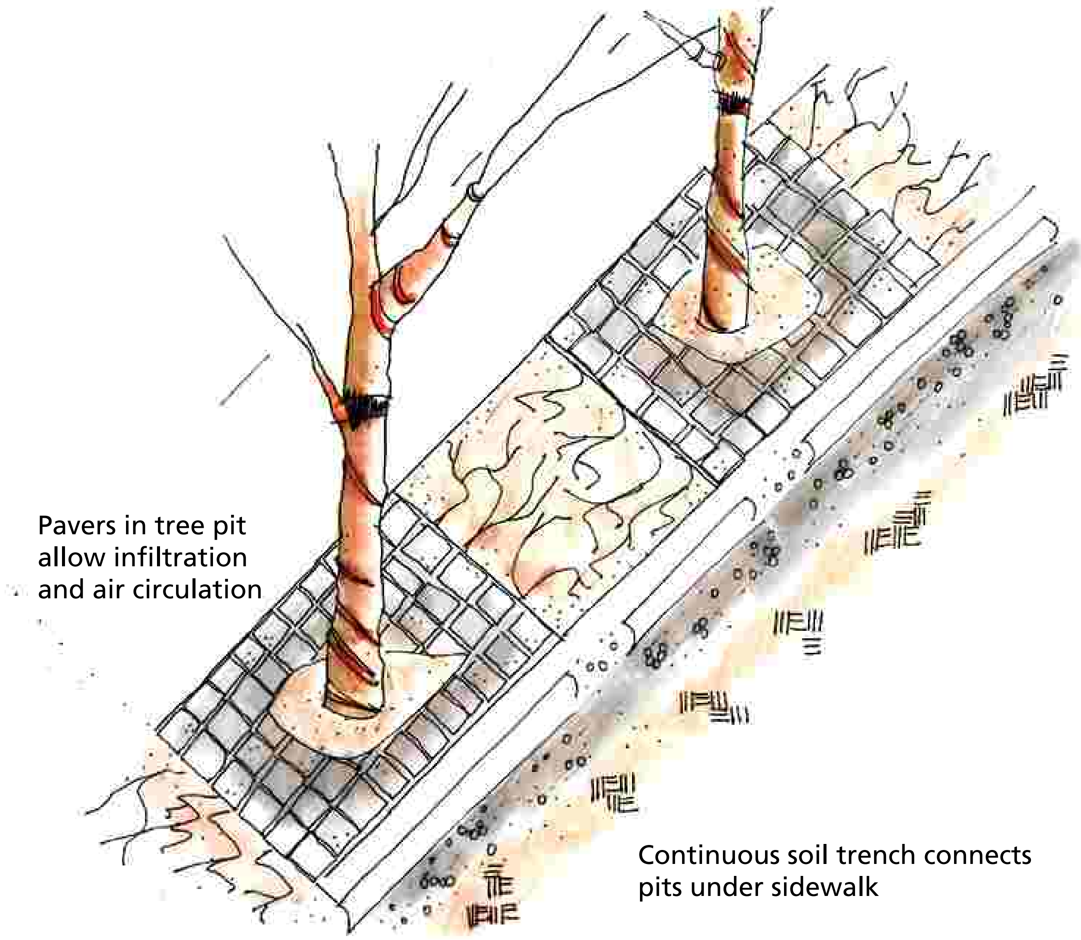

Figure 18. Structural soils used in a street tree application increase rooting space.

Structures

Trees planted next to structures may not have enough room for proper root development and are subject to increased heat load reflected off building surfaces. If trees have aggressive roots, they have the potential to undermine the building foundation. Additional damage to the building may be caused by falling branches or the tree toppling over due to one-sided root growth. Because of these potential conflicts, recommended setbacks between trees and structures range from 15 feet for small trees (trees under 30 feet high when mature) and 20-25 feet for large trees (trees over 50 feet high when mature) (GFC, 2002; Nebraska Forest Service, 2004). In arid regions or other areas where fire is a concern, a larger setback is often required to provide a firebreak. For example, clearing of vegetation is often required within 100 feet of homes in California (Cochran, 1997).

These setbacks are guidelines only and can be reduced to allow planting of trees that shade buildings and intercept rainfall, provided adequate soil volume is present (Figure 19). If this method is pursued, the tree's lower branches must be pruned to allow the trees to grow over the structure. A rule of thumb regarding pruning is to maintain two-thirds of the tree height as crown.

Figure 19. Trees planted in a narrow strip between structures may not get enough light or soil.

Lighting and Signs

To prevent trees from blocking lights and signs in urban areas, appropriate setbacks and species selection are important. Trowbridge and Bassuk (2004) recommend allowing a distance setback of 10 feet between trees and lighting, and increasing this distance for large trees (over 50 feet high at maturity). Species should be selected that are the appropriate size for planting near lighting and signs. Tall trees work best near lights; the mature tree height should be such that the canopy will grow above the light and will not prevent light from reaching the ground (Gilman, 1997). For signs, choose small trees near tall signs and near lower signs, plant large stock with high branches.

Trails

Urban greenways and trails provide an opportunity for recreation, and trees can enhance this experience. However, safety can be a concern when trees are planted near trails and reduce visibility. To ensure safety near trails, a setback should be provided between trails and trees or shrubs. Flink and Searns (1993) recommend a setback of 10 feet between the centerline of the trail and trees or shrubs, and advise planting only low-growing herbaceous vegetation within this setback. Additionally, they suggest limiting the use of evergreens and trees with drooping limbs near trails and trail approaches, seating areas, and intersections. Palone and Todd (1998) recommend regular pruning and vegetation maintenance in these same areas to maintain visibility; for example, prune existing trees so limbs do not extend below 8 feet from the ground.

Protecting Trees from Animal and Human Impacts

Potential human and animal impacts should be considered when developing a planting plan to protect trees from impacts. The URSA helps determine if any protection measures are needed. Animals such as deer and beavers can impact newly planted trees through browsing and gnawing. These animal impacts are often compounded in suburban areas, since few natural predators exist, hunting is restricted, and remaining habitat is limited. Human impacts can include damage to trees from heavy pedestrian traffic, automobiles, lawnmowers, and vandals, to name a few. Methods to protect trees from beavers, deer, and human impacts are described below. In addition, installing signs, fencing, flagging, or a combination of these, can be useful at any planting site in letting the public know about the reforestation project, and to protect the trees from impacts.

Beavers

Beavers can cause damage to existing trees in riparian areas by flooding from beaver dams or to new trees by removal of tree bark (Kwon, 1996). Some solutions for dealing with beavers include these:

- Deer repellent, which has an unpleasant odor and will drive beavers away
- Water level control devices where a pipe is installed under the dam, and the water is drained
- Live-trapping and physical relocation of beaver
- Tree guards, which are 3-foot collars made of heavy cloth or wire mesh, installed around the base of each newly planted tree

Local regulations may restrict beaver relocation or water level control devices. Tree guards can be cost prohibitive on a large or densely planted site. For additional information on methods to protect trees from beaver damage, see CT DEP (2000), Jensen and others (1999), Kwon (1996), and LeBlanc (1997).

Deer

Excessive deer browsing damages existing shrubs, prevents regeneration of trees and shrubs, and is one of the primary ways that plants are damaged, in both residential and natural areas (Turner, 1998). Deer feed on the young leaves of understory plants, seedlings, and seeds, which may make reforestation plans and buffer establishment more difficult. Forests that are heavily impacted by deer may have a sparse understory, a distinct browse line up to a height of 5 feet, and little regeneration of new trees and shrubs. If forested sites adjacent to the planting area show indications that deer are present, appropriate precautions should be taken to protect planted trees.

Methods to reduce damage to trees from deer in urban areas include repellents, fencing, and tree shelters. Additional options include selecting and planting species that are unpalatable to deer, and planting larger stock so that the crown of the tree is above the browsing height of deer (PERT, no date). Listings of tree and shrub species that generally are not preferred by deer are provided at these Web sites:

- Maryland Department of Natural Resources. Less palatable landscape plants. www.dnr.state.md.us/wildlife/ddmtplants.asp

- Rutgers Cooperative Research and Extension. Landscape Plants Rated by Deer Resistance. www.rce.rutgers.edu/deerresistance/default.asp
- University of Minnesota Extension Service. Coping with Deer in Home Landscapes. www.extension.umn.edu/projects/yardandgarden/ygbriefs/h462deer-coping.html

Typically some combination of these methods is most effective, since deer are adaptable and may find a way around any one particular method. Deer control methods are described below.

Figure 20. Tree shelters can be installed to protect seedlings at a reforestation site.

Tree shelters are plastic tubes that enclose the lower portion of the tree and protect trees against browsing by deer and rubbing by bucks. Tree shelters also retain moisture and reduce weed competition, and are generally the most cost-effective method for protecting trees from deer. To protect seedlings from deer, shelters should be 4 feet high. Chapter 6 provides more detail on tree shelters, and Figure 20 illustrates tree shelters installed to protect seedlings at a planting site.

Deer repellent is a malodorous substance that drives deer away, and commercially available products include in-soil systemic tablets and foliar sprays. Systemic repellent tablets are most effective at moderate deer densities while foliar sprays work best for short term (8-12 weeks) protection from browsing (Hairston-Strang, 2005). Lemieux and Maynard (1999) recommend using a repellent that both tastes and smells bad to combat feeding when deer are hungry enough to tolerate the smell. See Tregoning and Kays (2003) for more information on the effectiveness of various deer repellents.

Fencing can be used to exclude deer from a planting area (Figure 21). Deer fencing should be 8- to 10-feet high and can be electric, wire, or wire and plastic (Hairston-Strang, 2005). This method can be very effective, but is also expensive and requires some maintenance to repair damage. A more cost-effective option is to plant new trees in clusters and fence them in (Hairston-Strang, 2005).

Figure 21. Deer heavily browse understory vegetation in unprotected forest (right) outside a deer exclosure.
(Photo courtesy of Will McWilliams)

Human Impacts

In urban areas, human impacts on newly planted trees can be caused by automobiles, vandals, pedestrian traffic, and mowing. Accidental damage from mowing is most common in tree plantings in former turf areas. The most common injury to curbside trees is from vehicles (Foster, 1978). Damage to trees from vehicles or mowers can open wounds that allow disease to enter. Vandalism may be more common in highly urban areas, and in some sites plants may be "relocated" for personal use. Heavy pedestrian traffic can damage seedlings or cause soils in the planting area to become compacted.

To reduce damage to trees from pedestrian traffic, concrete bollards, posts, fencing, thorny shrubs, or pathways can be installed to direct traffic away from the planting areas (Figure 22). Using mulch also reduces impacts to tree root areas. Use of mulch and tree shelters can reduce potential damage from lawnmowers. Additional information on tree shelters and mulch is provided in Chapter 6. Using appropriate setbacks between street trees and the edge of the curb in areas with on-street parking can reduce damage from cars. In addition, species planted along roadsides should not have thin bark (Gilman, 1997). At planting sites that have high potential for vandalism, installing lighting, tree cages, or benches may protect trees. Palone and Todd (1998) suggest planting large stock and using trees with thorns or inconspicuous bark to discourage vandalism.

Figure 22. Posts were placed between trees planted in a Baltimore vacant lot to discourage pedestrian traffic near trees and to prevent illegal dumping in the lot.

Chapter 5. Site Preparation Techniques

Planting trees in urban areas can greatly improve community character and provide multiple environmental benefits. However, urban sites are often highly disturbed and may need to be prepared for planting by removing trash and other debris, controlling invasive plants, and amending the soil. The Urban Reforestation Site Assessment (URSA) worksheet in Appendix A indicates what level of site preparation is needed for successful reforestation at each planting site.

This chapter describes methods for preparing urban sites for planting.

Trash and Debris Cleanup

Illegal dumping of trash, rubble, and other debris often occurs in isolated or unpoliced urban areas such as riparian corridors or parks, where dumpers dispose of trash for free instead of going through the proper channels and paying required fees (Figure 23). If present, trash and debris should be removed from the site before tree planting. Removing trash and debris not only makes the site more attractive, but it also prevents release of pollutants from the illegally dumped material into local waterways. Site cleanup and subsequent tree planting can often discourage future use of the site as a dumping area.

Figure 23. Trash and debris must be cleaned up as part of preparing a site for planting.

Evaluating the Site

Several types of information are collected during the URSA to determine cleanup needs before planting, as shown in Table 11.

Table 11. Factors to Evaluate at an Illegal Dumping Site	
Information Collected During URSA	**Use in Planning Trash Cleanup**
Location of trash	The location of trash and other illegally dumped material should be noted on the site sketch to make the cleanup efficient.
Volume of trash	Estimated volume of trash in number of pickup truck loads will determine how many staff or volunteers are needed, the number of trash bags or type of equipment needed, and can also be used to estimate cost of disposal.
Type(s) of trash	Recording the types of trash present (e.g., household garbage, appliances, medical waste, construction debris) will help to identify potential safety hazards, determine whether heavy equipment is needed, and identify disposal options (i.e., recycling, landfill, dumpster).
Source of trash	It is important to note the source of trash and debris (if known) in order to develop a plan to address source of trash (i.e., education program, fines, better lighting, dumpster management).
Site access	Identifying parking areas and facilities for volunteers, temporary storage areas for collected trash, and access for heavy equipment or trucks helps to organize the logistics of the cleanup.

Planning and Implementing the Cleanup

Depending on the volume and type of trash dumped at the site, the project can be implemented by municipal staff or by volunteers from the community led by a local watershed group and supported by municipal agencies. Trash cleanup projects are ideal for watershed and other volunteer groups because almost anyone can participate, and they are effective means to educate volunteers and increase community awareness about watershed restoration. If volunteers are used, they should be recruited well in advance of the cleanup day. Recruitment of volunteers may include posting flyers at community locations or on Web sites, or direct recruiting through a watershed organization, school or church group, neighborhood association, or other organization. Organizers should notify local newspapers, radio, and television about the cleanup, with an emphasis on progress made, the watershed restoration effort, and recognition of volunteers.

Whether the cleanup is done using volunteers or municipal staff, safety is an essential responsibility for the cleanup organizer, and potential risks should be thoroughly evaluated. In addition, arrangements for removing trash and debris should be made in advance with the local public works department. It may be helpful to coordinate with local recycling centers on how to recycle materials collected during the cleanup (plastics, aluminum, glass). If hazardous, toxic, or medical waste is present at the site, a local hazardous materials team or emergency crew may be needed to clean up the site and determine if it is necessary to remediate the site. Typical supplies needed for a site cleanup include but are not limited to these: liability waiver forms, waders, orange safety vests, protective gloves, emergency contact numbers, first aid kits, refreshments, trash pickup tools, wheelbarrows, trash bags, heavy equipment (such as a loader) for transporting larger materials, and a pickup truck or dump truck (rental if necessary) for disposal.

Cleanups are typically done in a single day. Cleanup typically begins at the farthest point and volunteers are broken into groups to clean designated areas of the site. All trash and debris collected during this period should be organized into piles of recyclables (such as plastic, glass, aluminum, and yard waste) and nonrecyclable garbage. Municipal recycling and trash removal agencies should coordinate trash hauling. It is helpful to track the amount and type of garbage collected during the cleanup.

An important followup to removing trash and debris from a planting site is to take action to ensure that illegal dumping does not continue to be a problem at the site. Depending on the source of the problem, the following methods may be used to discourage dumping:

- Placing locks on dumpsters
- Constructing dumpster shelters
- Installing *No Dumping* signs
- Fencing vacant lots
- Limiting vehicle access to the site
- Installing better lighting
- Conducting watershed education
- Citizen monitoring (particularly if the site is part of a stream reach)

Costs of Trash and Debris Cleanup

The overall cost of a stream cleanup is highly dependent on the amount of donated supplies and services. Trash and debris hauling and landfill disposal fees can be significant—costs range from $76 to $225 per ton, depending on the type of trash and responsible party (PEL, 1995). Donation of services, corporate sponsors, waiving of fees, and the use of publicly owned equipment can reduce some of the cleanup costs. Most cleanups use volunteer labor, but organizers must supply equipment, such as hand tools, waders, and safety equipment (e.g., gloves, goggles). Efforts should be made to obtain these materials as donations or at a reduced cost. Additional costs include volunteer appreciation materials, refreshments for volunteers, promotional materials, and educational materials.

Invasive Plant Control

Invasive plant species are generally defined as plants that out-compete and replace more desirable native species due to their aggressive growth patterns. Although both native and nonnative plants can be invasive, the majority of invasive plants are nonnative species. Invasive plants are commonly found in disturbed landscapes such as urban areas, agricultural areas, stream corridors, and roadsides, and are often unintended escapees from nearby landscaped areas. Invasive plants are able to become dominant because they typically have many of the following characteristics (Haber, 1997):

- Grow rapidly
- Grow under a wide range of climate and soil conditions

- Produce abundant seeds
- Have adaptations that promote easy dispersal
- Have seeds that stay viable for many years in soil
- Have adaptations, such as bad taste or odor, that reduce herbivory by larger animals
- Lack insect pests or pathogens to keep them under control in a new ecosystem

Evaluating the Site

Invasive plants that will limit the survival of newly planted trees should be removed before planting, and must be monitored and controlled after planting to encourage the establishment of new trees. The density and extent of invasive plant species present at a planting site are recorded during the URSA. If desired, a more detailed survey of invasive plants can be completed for the planting site, as described in Galli and others (2003).

Identification of invasive plants requires local knowledge of invasive plant species and identification skills. Some examples of invasive plants commonly found in the northeastern United States include oriental bittersweet, purple loosestrife, Japanese knotweed, porcelainberry, Canada thistle, multiflora rose, kudzu, mile-a-minute weed, garlic mustard, phragmites, tree-of-heaven, Japanese honeysuckle, and English ivy (Figure 24). State native plant societies, regional exotic pest plant councils, and state invasive species councils are good sources of information on invasive plant species, as are Huebner and others (2004) for the northeast United States, Miller (2003) for the southern United States, USDA NRCS (2006), and National Invasive Species Council (2003).

Figure 24. Tree-of-heaven (left) and English ivy (right) are common invasive plants in many urban areas of the United States.

Table 12 presents an indexing system developed by the Metropolitan Washington Council of Governments to rank the level of invasive species infestation based on the percent coverage of invasive plants at a particular site.

Table 12. Invasive Plant Indexing System

Invasive Plant Coverage (Percent per acre)	Ranking
0 – 10	None – Very Light
10 – 25	Light
25 – 50	Moderate
> 50	High

Source: Galli and others (2003)

Galli and others (2003) recommend control of invasive plants if the ranking is light to high. However, complete eradication of invasive species may not be practical if coverage is high, populations are well-established, adjacent properties are overrun, or invasive species are deep-rooted (May, 2001; National Invasive Species Council, 2003). A more realistic goal at these sites may be to manage the unwanted vegetation each year to keep its growth in check. It may also be too expensive and difficult to control each of the many nonnative and invasive species present at some urban sites. A more reasonable approach is to identify which plants will limit the success of new plantings and focus efforts on control of those species. Adequate control methods may not available for all invasive plant species, and it can take up to 5 years to successfully eradicate invasive species from a site (May, 2001).

Selecting and Implementing Control Methods

Methods to control invasive plants fall into four major categories: physical, chemical, cultural, and biological controls. **Physical methods** of plant control methods include manual removal, mechanical removal, heavy equipment removal, solarization, girdling, and prescribed burning. **Chemical methods** include the use of selective herbicides to kill unwanted vegetation. **Cultural control** involves the modification of human behavior both within and around the natural area. **Biological control** uses a plant's natural enemies to control the species population. Methods to remove and control invasive species are generally selected based on the species characteristics (e.g., perennial or annual, method of propagation), level of infestation, site characteristics, and budget and time constraints (Haber, 1997; May 2001; PERT, no date). Table 13 provides a comparison of each method, followed by additional detail on implementation. Generally, the most applicable methods for urban areas are manual, mechanical, chemical, and cultural methods.

Table 13. Comparison of Invasive Plant Control Methods				
Method		**Advantages**	**Disadvantages**	**Applicability**
Physical	Manual	• Inexpensive • Has little ecological impact	• Labor intensive	• Works for annuals or taprooted plants • Best used on small areas
	Mechanical – Mowing	• Simple to add to regular maintenance program	• Requires repeated applications	• Works for annuals • May be combined with other methods • Requires adequate space for mowing between plants
	Mechanical – Heavy Equipment	• Removes roots effectively	• Creates land disturbance • More expensive than chemical methods	• Best used on densely infested sites with no native vegetation or sensitive resources to protect • Best used for initial removal only
	Solarization	• Inexpensive • Low labor • Has little ecological impact	• Cannot re-plant for up to 2 years • May leave site susceptible to further invasions	• Works for winter annual weeds that germinate under cool conditions • Best used in summer • Best used for initial removal only
	Girdling	• Has little ecological impact • Remaining tree • provides habitat • Inexpensive	• Limited species applicability • Requires at least 1 year to be effective • Creates safety hazard	• Applies to trees only • Works on pines, some oaks and some maples (typically not invasive)
	Burning	• Kills plant roots and stems, may kill seeds • Fire is a natural and desirable process in many ecosystems	• May release weeds • Can be hazardous • Requires permit or is restricted in urban areas	• May be used in combination with herbicides • Applicable in less populated areas
Chemical		• Does not create land disturbance • Less costly than mechanical controls • Kills plant roots and stems	• May have toxic effects if not used properly • Can be labor intensive • Repeat application may be required	• Should be used in concert with mechanical controls such as mowing • Works on most annuals and perennials
Cultural		• Several methods provide additional benefits (e.g., crops, shade, habitat) • Has little ecological impact	• Can be labor-intensive	• Mainly used for long-term control or spread prevention
Biological		• Has little ecological impact • Cost-efficient	• Does not eradicate species but provides some control	• Applicable at regional scale • Only works for species with specialized natural enemies

Manual methods

Manual plant control includes using a shovel, machete, or loppers to carefully remove plants by hand. As much of the root as possible should be removed and care should be taken not to cause erosion or compact the soil.

Mechanical methods

Mechanical plant removal includes using a mower, chain saw, or weed whip to remove plants (Figure 25). Mowing is most commonly used and reduces seed production and restricts weed growth (Tu and others, 2001). The mower blade should be set high enough to cut the weeds but not the desired vegetation (May, 2001). Cut fragments should be collected if species are capable of re-sprouting from stem or root fragments (Tu and others, 2001).

Figure 25. A weed whip may be helpful in removing invasive species.

Heavy equipment

Mechanical plant removal with heavy equipment includes using a bulldozer, backhoe, or loader to remove plants in areas where invasive plant density is high, native species are absent, and impacts to sensitive natural resources are negligible (RNSP, 2002). This method should be followed immediately by tree planting, and requires proper erosion and sediment control practices.

Solarization

Solarization (also called smothering) involves covering the soil with a sheet of black or clear plastic (polyethelyne film) to increase soil temperature and block sunlight to kill plants (Tu and others, 2001). Solarization is used for weeds whose seeds are sensitive to temperature changes. This method may cause significant biological, physical, or chemical soil changes that will prevent new plant growth for up to 2 years (Tu and others, 2001).

Girdling

Girdling involves use of a knife, axe, or saw to cut away a strip of bark several centimeters wide around a tree trunk, which kills the tree. The cut should be deep enough to remove the inner bark, which is needed for transport of food through the plant, but not so deep as to topple the tree (Tu and others, 2001). The remaining dead tree can provide habitat for nesting birds if it does not pose a safety hazard. This technique is used only on species that do not resprout in response to girdling (Tu and others, 2001).

Prescribed burning

Fire consumes above-ground vegetation and may kill seeds or break the dormancy of seeds, allowing later removal of plants (RNSP, 2002). Fire affects the composition of native plants and may support its natural resistance to invasives (RNSP, 2002). Prescribed burns may include large-scale burns or spot-burning; however, both require a permit. The weather, topography, and available fuel will determine the temperature and intensity of the prescribed burn, and the burn is most effective if done just before flowering or seed set, or at the young seedling or sapling stage (Tu, and others, 2001).

Chemical

With chemical methods, herbicides are applied manually to the offending plants with a weed wick or wiper, or with a sprayer if no desirable vegetation exists at the site (May, 2001). Use of herbicides in riparian areas should be limited to those formulated for aquatic use, such as those containing glyphosate (Palone and Todd, 1998). A buffer should be provided between the application area and any surface waters, and application should be staged to limit any potential toxic effects (Tu and others, 2001). Herbicides should only be used if mechanical, cultural, and biological means are not acceptable or feasible. Herbicides should be applied only during the growing season by a trained, certified pesticide applicator, in accordance with Integrated Pest Management (IPM) guidelines (RNSP, 2002).

Cultural

Cultural methods are generally used to prevent or minimize the spread of invasives rather than to remove them. Techniques include revegetation, restoring soil conditions that favor native vegetation, cultivation, grazing, crop rotation, mulching, use of tree shelters, and proper disposal and maintenance techniques. Examples of proper disposal and maintenance techniques include cleaning boots, tools, tires, and machinery before leaving the site, to avoid tracking seeds of invasives off-site, and using plant disposal methods that do not contribute further to the spread of the invasive plant (RSNP, 2002).

Biological

Biological controls can include the introduction of an invasive plant's natural enemies, such as insects, fungus, or bacteria, which target the invasive plant and limit growth or reproduction. This method is best used on large established populations, but it does not completely eradicate invasive species. Biological controls typically take about 3 to 8 years to show results, but they have little ecological impact (May, 2001). Biological controls of invasive plants are primarily applied on a regional basis. Additional information about biological control of invasive plants in the eastern United States can be found in Van Driesche and others (2002).

Integrated Vegetation Management

No one method of controlling invasive plants is ideal; rather, a combination of biological, physical, chemical, and cultural methods should be used. This approach is often referred to as Integrated Vegetation Management (IVM). It entails taking a comprehensive look at the available methods, considering their effect on the surrounding environment, and addressing both initial removal and long-term control. A successful invasive species control program also seeks to understand the life cycle of the species involved as well as the effectiveness of each control measure (Palone and Todd, 1998). A long-term plan for the management of invasive plants is also necessary, especially in areas where infestations are severe, and will be most intensive as new native plants establish. Additional guidance on IVM and implementation of specific invasive plant control methods is provided in Tu and others (2001) and MD SHA (no date).

Costs of Invasive Plant Control

The costs of controlling invasive plants can range widely, due to the variety of methods available for control. Examples of costs for commonly used methods are $12 per acre for mowing and $54 per acre for herbicide application (Palone and Todd, 1998). Costs for specific invasive plant removal projects in New York and Rhode Island ranged from $50 to $1,000 per acre (PFWP, 2001a; PFWP, 2001b).

Soil Amendments

Most urban planting sites are highly disturbed and do not provide ideal conditions for tree growth (Figure 26). Progressive cycles of development and redevelopment involve wholesale earthmoving; erosion or removal of topsoil; compaction of subsoils; and the filling of depressions, wetlands, and natural rainfall storage areas. Consequently, urban soils are typically very compacted, which physically impedes root development and suffocates the tree by limiting available oxygen (Coder, 2000; VCE, 2002). Most urban soils have a surface bulk density greater than 1.5 grams/cm^2, while bulk densities around 1.4 to 1.6 grams/cm^2 or greater have been identified as limiting to root growth (Craul, no date; CWP, 2000a; USDA Forest Service, 2005). The quality of most urban soils is also poor and is usually not ideal for plant growth, because most of the soil organic matter is removed along with the topsoil during construction. In addition, the soil pH in urban areas is often elevated from excessive building rubble, which contains calcium.

Figure 26. Soils at urban planting sites are often highly compacted and full of rubble, trash, and other pollutants.

Due to the unique properties of urban soils, most need to be amended before planting, to improve growing conditions and increase tree survival. Soils may be amended across the entire planting site or at individual planting holes if the site is large. Compost has been highly successful for improving urban soils, as it increases organic matter, improves drainage, and adds vital nutrients. Other amendments that can improve soil quality include gypsum, limestone, peat, and sulfur. These amendments are described below.

- *Compost* – Compost is decomposed organic material and has long been used in agricultural applications. Compost has recently become more common in urban and suburban settings and is applied to decrease bulk density, improve water- and nutrient-holding capacity, and increase nutrient levels (CWP, 2000a).

- *Gypsum* – Gypsum is hydrated calcium sulfate and is used to decrease soil salinity by combining with sodium to become a soluble salt. Gypsum also increases calcium and sulfur without affecting pH and enhances the structure of clay soils (Chollak and Rosenfeld, 1998).

- *Limestone* – Limestone decreases soil acidity and comes in two forms: calcareous (adds calcium) or dolomitic (adds magnesium) to the soil (DOD, 1996).

- *Peat* – Peat is undecomposed organic matter that increases organic matter, acidity, and water- and nutrient-holding capacity of the soil without increasing nutrient content (DOD, 1996).

- *Sulfur* – Sulfur comes in two forms: agricultural sulfur or aluminum sulfate and is used to increase soil acidity (DOD, 1996).

Evaluating Urban Soils

Soil compaction, pH, and drainage are evaluated at the planting site during the URSA to determine what, if any, soil amendments are needed. Typically, soils that are moderately to severely compacted, are very alkaline or acidic, or are poorly drained will need to be amended. When a penetrometer is used to evaluate soil compaction, soil amendments are necessary if more than half of the samples from the top 15 inches of soil have readings that exceed 300 pounds per square inch (Duiker, 2002). When soil bulk density is analyzed, bulk density greater than 1.5 grams per cubic centimeter should be amended (CWP, 2000a; Kays, 1985). If desired, more detailed soil quality data can be collected during the USRA, such as organic matter content, nutrient availability and salt content. The addition of compost can improve many of these conditions and is recommended for most urban planting areas.

Table 14 provides guidance on corrective measures based on specific soil characteristic thresholds (Palone and Todd, 1998; Craul, 1993; DOD, 1996; Chollak and Rosenfeld, 1998). Soil improvement is recommended if the moderately impacted threshold is exceeded for a given soil parameter, and is required if soils are severely impacted. Specific thresholds for soil properties may vary with soil types and regions.

Table 14. Recommended Corrective Measures for Urban Soils			
Soil Characteristic	**Moderately Impacted Threshold**	**Severely Impacted Threshold**	**Corrective Measure**
Percent sand	>75	>90	Add compost or peat
Percent kaolinitic clay	>50	>65	Add compost or peat
Percent expandable clay	any	>10	Add gypsum
Percent clay and silt	>50	>75	Add compost or peat
Bulk density of clay (mg/m^3)	<1.4	>1.5	Add compost or peat
Bulk density of loam (mg/m^3)	>1.5	>1.7	Add compost or peat
Aeration porosity (percent large pore volume)	<2	<1	Add compost or peat
Infiltration, percolation, and permeability rates (in/hr)	<0.25	<0.20	Add compost or peat
Depth to bedrock (ft)	<4	<2	Add topsoil
Impermeable layers (ft)	<6	<4	Mix soils
Acidic soils (pH)	<6	<4	Add lime
Alkaline soils (pH)	>7.5	>8.5	Add compost or peat, add sulfur
Cation exchange capacity (meq/100g)	>5	<3	Add compost and/or peat
Potassium (lbs/acre)	<124		Add compost
Phosphorus (lbs/acre)	<44		Add compost
Magnesium	Variable		Add dolomitic limestone or compost if deficient
Calcium	Variable		Add calcareous limestone, gypsum, or compost if deficient
Percent organic matter	<1		Add compost or peat
Soluble salt (ppm)	600	1,000	Add gypsum or sulfur, add compost or peat

Planning and Implementing Soil Amendments

Ideally, application rates for soil amendments should be determined by the current soil properties, the desired soil properties, and the properties of the soil amendment itself. For example, compost from one source may have a much higher nutrient or salt content than another source, so the compost should be tested before application. If soil testing is not possible, a general rule of thumb for compost application is to use a 2:1 ratio of loose soil to compost (Chollak and Rosenfeld, 1998; CWP, 2000b). This rule of thumb is based on a target soil organic matter content of 8 to 13 percent, as well as the typical organic matter content of both compost and urban soils (Chollak and Rosenfeld, 1998; Stenn, 2005).

Application rates for lime, gypsum, and sulfur vary and should be determined by soil test results for pH and macronutrients such as nitrogen, sulfur, potassium, magnesium, and calcium. Unterschuertz (1997) and Muntean (1997) promote adding 50 to 100 pounds of gypsum per 1,000 square feet, at the same time as compost incorporation, to improve the structure of heavy clay soils. Lime applications typically range from 50 to 100 pounds per 1,000 square feet to improve unsuitable alkalinity and nutritional deficiencies (Chollak and Rosenfeld, 1998). Sulfur is required as elemental sulfur, and requirements range from 2 to 5 pounds per 1,000 square feet annually (Stahnke, 2004; Muntean, 1997).

Soil should be amended at individual planting holes to a depth of 2 to 3 feet (Figure 27). Soils deeper than 3 feet are generally not very useful to trees (Urban, 1999). In most cases, it will be cost prohibitive to amend soils across the entire planting area, but this may be feasible at smaller sites. At each planting hole, the soil is excavated and placed on a tarp. Next, the soils and compost are mixed in a large bucket at the appropriate ratio and used to fill in the hole. Since each tree will be planted in a hole that is two to three times the width of the root ball or root mass, it is important to amend the entire width of the planting hole. An equally important step is to hand mix the amended soil into the existing site soil along the sides of the planting hole. The purpose of this step is to prevent an interface between the amended soil and the existing site soil that limits water movement in either direction, due to significant differences in soil properties (Hammerschlag and Sherald, 1985).

Figure 27. Amending soil at a planting hole with compost decreases bulk density, improves water- and nutrient-holding capacity, and increases nutrient levels.

After incorporating soil amendments, each planting hole should be marked with flagging so it can be easily found at planting time. Trees should be planted as soon as possible after amending the soil in order to prevent erosion, so a temporary cover crop such as clover may be necessary to stabilize the soil until the planting project is completed.

The planting plan for the reforestation project should include a site sketch indicating the boundaries of the areas to be amended or the location of planting holes, an equipment list, and an implementation schedule for soil amendments. Existing vegetation such as turf or weeds may need to be removed from the site before implementation. A sod cutter, brush mower, or ripper may be used to remove turf, weeds, shrubs, or other vegetation. An alternative is to incorporate the vegetation into the existing soil during subsoiling or tilling, provided the plants are nonwoody and noninvasive. Incorporating the vegetation into the soil will require approximately 8 weeks before replanting the site because of the time required for the incorporated material to decompose (Chollak and Rosenfeld, 1998). Equipment needed for soil amendments is listed in Table 15.

Table 15. Equipment for Urban Soil Amendment Projects

Equipment	Use
Sod cutter or Bush Hog	Removing vegetation
Various soil amendments	Improving soil quality
Measuring tape	Measuring planting area, quantifying amendment application rates
Wheelbarrow	Removing rocks, rubble, vegetation, excess soil
Gloves	Handling soil amendments
Pickup truck	Disposing of trash, vegetation, and excess soil from the site, and delivering amendments
Tarp	Storing soil from planting hole
Large bucket	Mixing soil amendments
Shovel, spade, or auger	Digging planting holes

Costs of Soil Amendments

The cost of soil amendments will vary depending on the methods used, the type of labor, and the source of compost. If free compost is available through public works or other local department, project costs will be greatly reduced. For example, estimated costs of delivered compost per cubic yard range from $11 to $20 (Chollak and Rosenfeld, 1998). Based on these estimates, the cost of compost amendments per planting hole would range from $0.66 to $1.20 per tree, for a tree with a 6-inch diameter root ball, assuming soils are amended to a depth of 2½ feet.

Chapter 6. Planting, Inspection, and Maintenance Techniques

Key elements of tree planting include obtaining and storing plant materials, planting the trees, post-planting tree protection, and maintenance and inspection of newly planted trees. This chapter describes each of the planting and maintenance elements essential to ensure a healthy future for new trees and shrubs.

Obtaining and Storing Plant Materials

This section describes methods for obtaining and storing plant materials before the planting day.

Obtaining Plant Materials

One potentially frustrating aspect of tree planting is spending a lot of time evaluating the site and selecting just the right tree species, only to find that some of the species are not available for purchase. Designers should devote some effort to researching and determining the best places to purchase their plant materials and planning ahead for ordering and purchase. Availability is usually related to the type of plant material and the species.

In general, there are three types of sources for obtaining plant materials: private nurseries, government nurseries, and nonprofit organizations. Table 16 provides a description of each source. Web resources for obtaining plant materials are provided below:

- American Forests Historic Tree Nursery Store
  www.historictrees.org/store.htm

- National Arbor Day Foundation Tree Store
  www.arborday.org/shopping/trees/trees.cfm

- Natural Resources Conservation Service Plant Materials Program Sources of Seed and Plants
  http://plant-materials.nrcs.usda.gov/technical/biorip/sources.html

- North American Native Plant Society Plant Sources
  www.nanps.org/sources/frame.shtml

- Plant Native's Native Plant Nursery Directory
  www.plantnative.org

- Reforestation, Nurseries, and Genetics Resources Plant Materials Directory
  www.rngr.net/Applications/directory

Table 16. Sources of Plant Materials	
Plant Material Source	**Description**
Private nurseries	Wide range of local private nurseries, some sell wholesale, and some specialize in natives. Typically have the widest selection of species and stock. Some may not have a wide selection of natives.
Government nurseries	Includes state nurseries and other government nurseries, such as Natural Resources Conservation Service Plant Materials Centers. Typically have native tree seedlings available for purchase in large quantities for community reforestation projects. May be limited to seedlings or small stock.
Nonprofit organizations	Wide range of local nonprofit organizations or national nonprofits, such as American Forests and National Arbor Day Foundation. Typically have native tree seedlings available for purchase at low cost for reforestation projects.

In general, it is best to order from a nursery that grows their plants locally, since the trees will already be adapted to the local climate. It is also good to check with references who have used the nursery before. Place orders early (e.g., before early spring) to ensure the best selection, and consider ordering 10 to 15 percent more trees than are actually needed for replacements. In most cases, plants should not be paid for until delivery so the plants can be inspected to ensure they are in good condition. Quality of nursery stock is very important; for example, a healthy rootball is critical to a tree's ultimate survival. When inspecting nursery stock, look for the following indicators of potential defects in the root ball (Polomski and Shaughnessy, 1999):

- Trunk moves or appears to be loose in the root ball when pushed (tree may not be stable)
- Top layer of roots are more than 1-2 inches below the surface of the soil (tree planted too deeply)
- Large roots escaping from bottom of container (when pruned, may cause tree decline)
- Container does not slide easily off root ball (tree may be pot-bound)
- Many circling roots on outside of root ball (tree may be pot-bound)
- Black roots on surface of root ball (indicates damage from extreme temperatures or overwatering)

Polomski and Shaughnessy (1999) provide additional guidance on inspecting nursery-grown trees for problems in the root ball, branches, and overall health, while ISA (2005) provides additional guidance on determining if nursery stock has been planted too deeply. If trees are being picked up from the nursery rather than delivered, protect them with a cover during transportation, to avoid overheating and desiccation and damage to leaves if leafed out. If trees will not be planted immediately, a temporary storage location must be identified.

Storing Plant Materials

Proper storage and preparation of plant materials *before* planting is essential to ensure that new trees and shrubs will establish and thrive. After receiving plant material, it should be kept covered, shaded, and moist or watered until placed in the ground. The root balls of balled and burlapped stock and the packing of bare root stock should be thoroughly watered and kept moist with a covering of peat moss, straw or saw dust until planted (Palone and Todd, 1998). Container material is least susceptible to moisture stress and will store well if properly watered. Bare root trees are the most susceptible to desiccation and should be stored in a cool place until planting. If possible, bare roots should be dipped in hydrogel or muddy water, then stored immediately in large plastic bags until planting. Hydrogel is a synthetic water-absorbing polymer available in many brands. A sample method for dipping trees in hydrogel can be found in Buckstrup and Bassuk (2000). If hydrogel is not used, the tree roots should be soaked in water for 12-24 hours before planting (Buckstrup and Bassuk, 2003).

Planting Techniques

This section describes planting techniques for various plant materials, planting on steep slopes, and methods to encourage natural regeneration.

Planting Techniques for Various Plant Materials

Planting techniques and optimal planting seasons vary for different plant materials, and are presented in Table 17. General planting guidance that is appropriate for all plant materials includes digging a hole that is no deeper than the root ball or mass but two to three times wider than the spread of the root ball or mass because the majority of the roots on a newly planted tree will develop in the top 12 inches of soil and spread out laterally. Thus, the wider the area of soil that is prepared (amended or broken up) before planting, the more successful the planting (Trowbridge and Bassuk, 2004). Make sure the bottom of the hole is undisturbed or compacted and level to prevent sinking and shifting of the tree after planting.

Table 17. Tree Planting Techniques

Plant Material	Planting Technique	Planting Season
Bare root	Hand plant with shovel, dibble bars, or mattocks (Can be machine planted at large sites with compatible soils if cost-efficient)	Fall,* early spring
Container grown	Hand plant or use mechanical planting tools (e.g., auger)	Spring or fall, summer if irrigated
Balled and burlapped	Use backhoe (or other specialized equipment) or hand plant.	Spring or fall

Source: Palone and Todd (1998), WSAHGP (2002), NJDEP (2004)

*One Cornell University study showed that bare-root trees planted in fall grow better during the first growing season than those planted in spring (Trowbridge and Bassuk, 2004).

One of the most important planting guidelines is too make sure the tree is not planted too deeply. The root collar, the lowest few inches of trunk just above its junction with the roots (often indicated by a flare), should be exposed (Flott, 2004). Trees planted too deeply have buried root collars, and are weakened, stressed, and predisposed to pests and disease (Flott, 2004). Trees planted too deeply can also form adventitious roots near the soil surface in an attempt to compensate for the lack of oxygen available to buried roots. Adventitious roots are not usually large enough to provide support for a large tree and may eventually lead to collapse (Flott, 2004). ISA (2005) provides additional guidance on how to avoid planting too deeply. It is generally better to plant the tree a little high, that is, with the base of the trunk flare 2 to 3 inches above the soil, rather than at or below the original growing level (ISA, 2003b).

Proper handling during planting is essential to avoid prolonged transplant shock and ensure a healthy future for new trees and shrubs. Trees should always be handled by the root ball or container, never by the trunk. Specific instructions for planting a tree are presented in Box 5, including variations for specific plant materials. Specifications for planting a tree are illustrated in Figure 28.

BOX 5. INSTRUCTIONS FOR PLANTING A TREE

1. Dig a hole that is two to three times as wide as the root spread, container diameter, or balled and burlapped root ball. The hole should be no deeper than the root ball height or depth of soil in the container. The hole should be shallow enough that the root collar of the tree will be exposed when planted.

2. Break up any compacted soil on the sides of the planting space and make sure the bottom of the hole is firm to prevent settling.

3. Remove all string or wiring from bare root and container grown trees. Remove the container from container grown trees and shake off any excess soil.

4. Prune any dead, diseased, broken, or circled roots on bare root or container grown trees.

5. Place the tree upright in the hole (mechanical equipment may be needed for large trees). Make sure roots of bare root trees are relatively straight and spread out. Straighten the tree in the hole and check that the root collar is visible at soil level.

6. Cut burlap, rope, and wire basket away from root ball on balled and burlapped trees. Remove entirely if possible.

7. Gently pack backfill soil around base of root ball. Allow rest of backfill to settle naturally, use water to settle, or tamp lightly. Continue to fill the planting hole with soil up to the tree base.

8. Install tree shelters or stakes if needed. If staking is necessary, use one or two stakes with separate flexible ties and remove after 1 year. Stakes should be extended into undisturbed soil.

9. Apply a 2- to 4-inch layer of mulch over the entire rooting area, leaving a 3-inch circle of bare soil around the trunk.

10. Water the tree thoroughly.

Sources: Buckstrup and Bassuk (2003), DOD (1996), Flott (2004), Greenfeld and others (1991), Haefner and others (2002), NVRC (1997), Palone and Todd (1998), Trowbridge and Bassuk (2004), WSAHGP (2002)

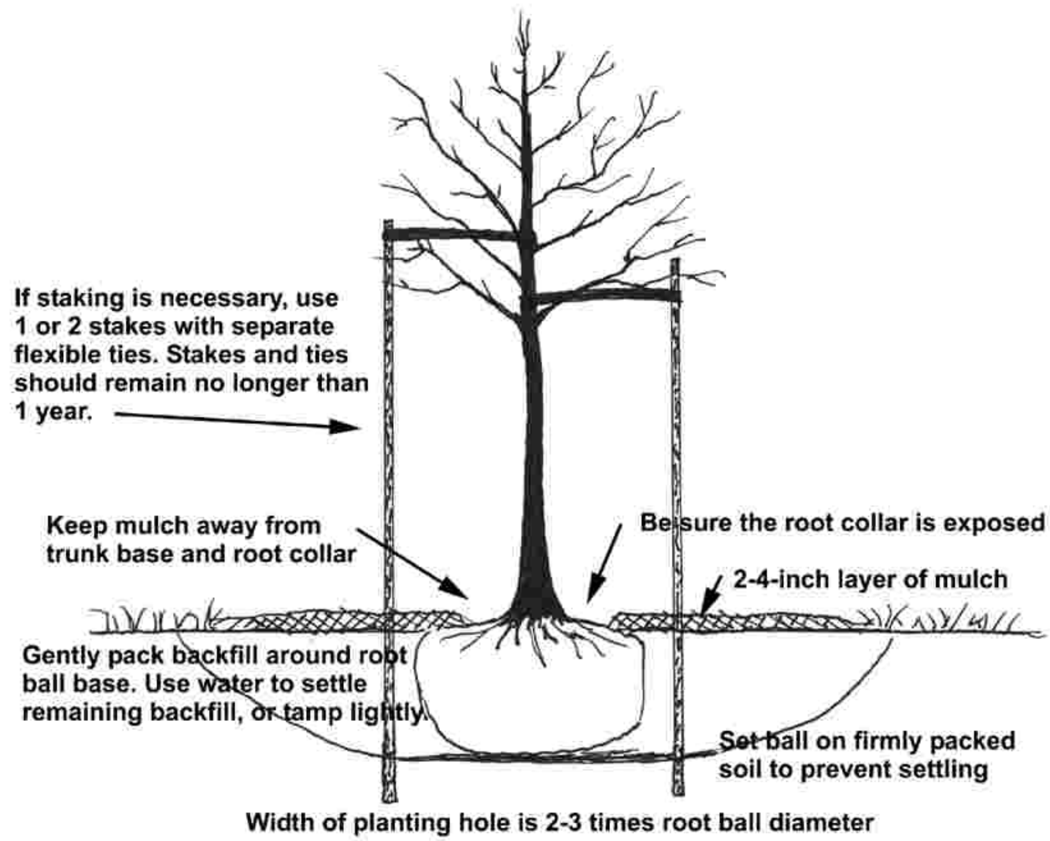

Figure 28. Following approved tree planting specifications improves chances of tree survival. (Adapted from Flott, 2004 and ISA, 2003b)

Planting on Steep Slopes

Steep slopes will require additional measures to ensure planting success and reduce erosion, especially if the slope receives storm water runoff from upland land uses. Depending on the steepness of the slope and the runoff volume, rill or gully erosion may occur on these slopes, requiring a twofold approach: controlling the storm water and stabilizing the slope. Chapter 4 provides some guidance on controlling storm water runoff at a planting site.

Erosion control blankets are recommended to temporarily stabilize soil on slopes until vegetation is established (Caraco, 2000; Morrow and others, 2002). Erosion control fabrics come in a variety of weights and types, and should be combined with vegetation establishment such as seeding. Other options for stabilizing slopes include applying compost or bark mulch, plastic sheeting, or sodding (Caraco, 2000). For more information on erosion control blankets, see Schueler and Brown (2004).

Trees will add stability to slopes because of their deep roots, provided they are not planted by digging rows of pits across a slope (Morrow and others, 2002). Trees and shrubs should be phased in gradually after grass is established or planted simultaneously provided low, slow-growing grasses are used to avoid competition (Morrow, and others, 2002). Required maintenance will include mowing (if slopes are not too steep), and repairing bare or eroded areas.

Planting methods for slopes steeper than 3:1 (1 foot vertical change for every 3 horizontal feet) involve creating a level planting space on the slope (see Figure 29). A terrace can be dug into the slope in the shape of a step. The existing slope can be cut and the excavated soil can be used as fill. A low soil berm (or rock berm) can be formed at the front edge of each step or terrace to slow the flow of water. Trees can also be planted in clusters on slopes (using the above method) to limit potential for desiccation. Staggering tree placement and mulching will prevent water from running straight downhill. Figure 30 illustrates a tree cluster, which uses trees to treat storm water runoff.

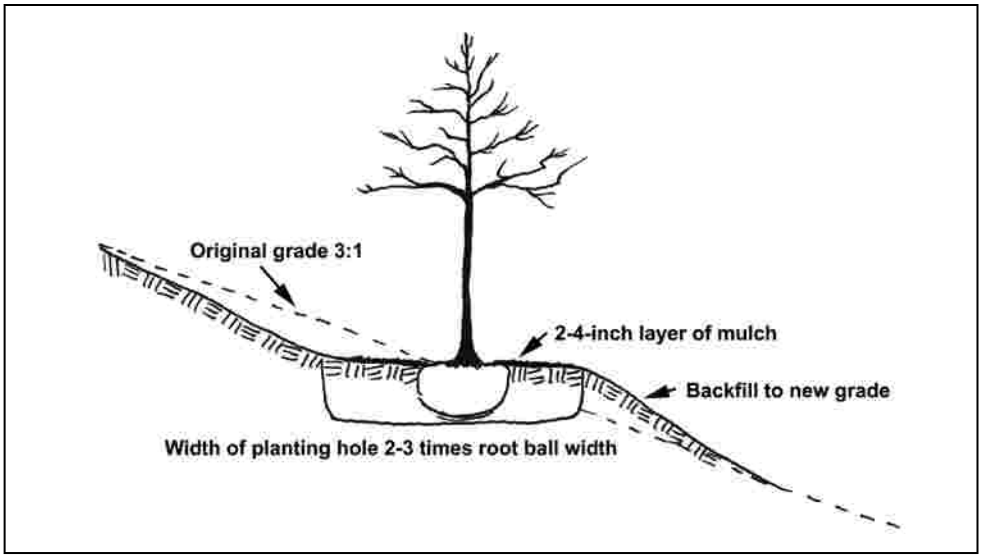

Figure 29. The specifications for planting on a steep slope create a level planting space.

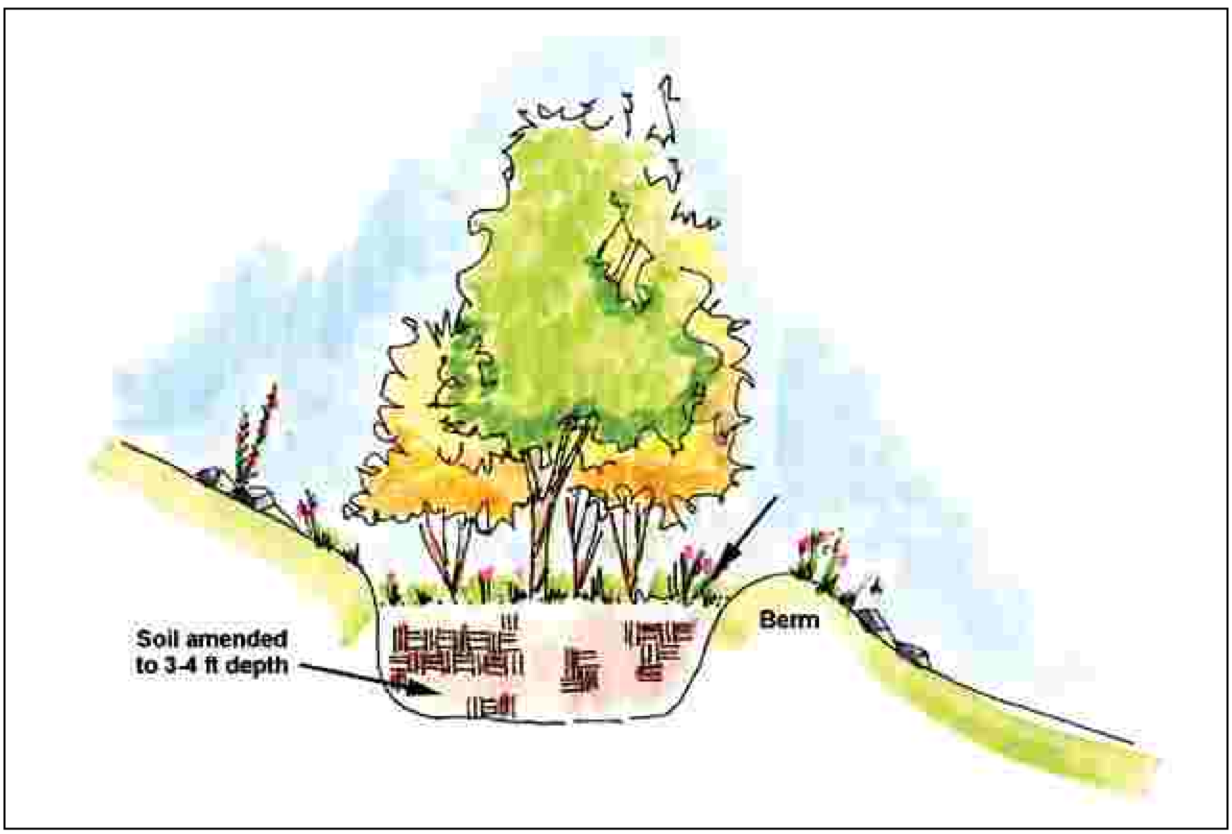

Figure 30. A tree cluster planted on the side slope of a storm water pond helps to treat storm water runoff.

Encouraging Natural Regeneration

Natural regeneration is the process by which trees and forests establish from seeds produced and germinated on site. Most of the eastern United States gets enough rain that trees will eventually regenerate in sites where they are not kept out by mowing, cultivation, browsing, chemicals, or land development. Natural regeneration is the least expensive option for establishing forest cover on a site, and should be considered as an option when evaluating planting sites. One major disadvantage of this technique in urban areas is the high potential for regeneration of invasive or nonnative species with cessation of mowing. Table 18 summarizes the advantages and disadvantages of natural regeneration.

Table 18. Advantages and Disadvantages of Natural Regeneration

Advantages	Disadvantages
• Lower establishment costs • Less labor and equipment required • New seedlings have good early root development • Less soil disturbance and soil erosion • Trees are adapted to the area • Creates diverse stands of varying ages • Enhances native wildlife • Avoids transplant shock • Excess seedlings from dense stands can readily be transplanted to new areas	• Regeneration of canopy may take longer • Less control over species, spacing, and density • Trees may not grow where most advantageous for multiple uses or maintenance • Requires viable seed bank • Delays in regeneration can occur due to environmental conditions or inadequate seed fall • Selective regeneration of particular species may occur due to deer, lack of seed dispersal, or lack of regeneration trigger (such as fire)

Source: Featherstone (2000), Willistin and others (1998)

Natural regeneration in urban areas may be limited due to loss of seed bank, poor seedbed conditions, high pedestrian traffic, soil compaction, and competition from invasive species. A thorough assessment of the site (see Chapter 2) will help determine if regeneration is a feasible method of restoration and identify ways to encourage regeneration. In general, sites that are good candidates for natural regeneration have these characteristics (Hairston-Strang, 2005):

- Desirable tree seed sources nearby (Figure 31)
- Adequate seed dispersal methods,
- Bare mineral soils with good seed-to-soil contact,
- Low compaction,
- Controlled deer population,
- Limited invasive species, and
- Current vegetative cover that does not consist of thick sod-forming grass, such as fescue.

Adequate seed sources include light-seed species (e.g., maple, sycamore, ash, pine, yellow poplar) located upwind of the site (can be fairly far away), heavy-seeded species (e.g., oaks, hickories) within 300 feet upslope, or existing tree species on the site that produce root sprouts (e.g., aspen, black locust, persimmon) (Hairston-Strang, 2005). If perches for birds are present, the potential for seed dispersal is greater due to droppings.

Figure 31. This natural regeneration site has some existing trees that provide a seed source.

Sites that are probably not good candidates for natural regeneration include those with severe soil problems (e.g., very compacted or shallow soils), high density of invasive species, uncontrolled deer populations, existing vegetation in poor condition, or high pollution input (Sheahan, 1998; Hairston-Strang, 2005). Sites that are not ideal candidates can be helped along using several techniques, including these: improving soil conditions; controlling invasive plants; installing fencing or other methods to control deer; discing (mixing) or herbicide application, or both, to release the seed bank and allow trees to seed in sod-forming grasses; and installing perches to encourage seed spread by birds. To encourage natural regeneration as a way to fill in gaps in canopy of urban forest remnants, forest litter should be left on the ground. This encourages natural regeneration by providing biomass material for regrowth and habitat for insects and animals (Willistin and others, 1998).

Maintenance for natural regeneration sites is similar to that for reforestation sites: watering, weeding, and mulching. Signage should be installed to restrict mowing and inform the public of the purpose of the project. Monitoring should be performed regularly to assess plant growth and survival as well as species composition. Supplemental plantings may be necessary if invasive species are dominant or for species that have difficulty regenerating to provide diversity on the site.

Post-Planting Tree Protection

Mulch, stakes, tree shelters, and signage are commonly used to protect newly planted trees from damage by wind, pedestrian traffic, deer, vandalism, and other potential impacts. Each is described below.

Mulch

Once the tree has been properly planted, 2 to 4 inches of organic mulch should be spread over the soil surface out to the drip line of the tree (other weed control options, such as weed mats, are discussed in the following section). If planting a cluster of trees, mulch the entire planting area. Slow-decomposing organic mulches, such as shredded bark, compost, leaf mulch, or wood chips provide many added benefits for trees. Mulch that contains a combination of chips, leaves, bark, and twigs is ideal for reforestation sites. (ACB, 2000; ISA, 2003a). Grass clippings and sawdust are not recommended as mulches because they decompose rapidly and require frequent application, resulting in reduced benefits. Mulch has many benefits, including these (CBF, 2001; ISA, 2003a):

- Retains soil moisture by preventing evaporation and promoting infiltration
- Moderates soil temperature extremes

- Reduces competition from grass and weeds
- Prevents erosion
- Prevents damage to the trunks of trees by lawn equipment
- Enriches the soil by adding organic matter and nutrients as it decomposes
- Prevents soil compaction

For well-drained sites up to 4 inches of mulch may be applied, and for poorly drained sites a thinner layer of mulch should be applied. Mulch should never be more than 4 inches deep or applied right next to the tree trunk; however, a common sight in many landscaped areas is the "mulch volcano" (Figure 32). This over-mulching technique can cause oxygen and moisture-level problems, and decay of the living bark at the base of the tree. A mulch-free area, 2- to 3-inches wide at the base of the tree, is sufficient to avoid moist bark conditions and prevent decay (ISA, 2003a).

Figure 32. A mulch volcano (left) can cause the trunk to rot; a properly mulched tree (right) has space around the trunk.

Stakes

Studies have shown that trees will establish more quickly and develop stronger trunk and root systems if they are **not** staked at the time of planting (ISA, 2003b). Staking for support may be necessary only for top-heavy trees or at sites where vandalism or windy exposure are a concern (Buckstrup and Bassuk, 2003; Doherty and others, 2003; ISA, 2003b).

If staking is necessary for support, two stakes used in conjunction with a wide flexible tie material will hold the tree upright, provide flexibility, and minimize injury to the trunk. Figure 28 on page 63 provides a schematic for staking a tree. To prevent damage to the root ball, stakes should be placed in undisturbed soil beyond the outer edges of the root ball. Perhaps the most important part of staking is its removal. Over time, guy wires (or other tie material) can cut into the growing trunk bark and interfere with the movement of water and nutrients within the tree. Staking material should be removed within 1 year of planting (Doherty and others, 2003).

Tree Shelters

Tree shelters are 2- to 5-foot tall plastic tubes that enclose seedlings to protect them from lawnmowers, weeds, wind, animals, drought, and trampling (Figure 20 on page 43). Tree shelters also create a greenhouse effect around seedlings that significantly improve growth rates and establishment success for many species (Sweeney, 1993). This can be especially crucial for tree survival on difficult or dry upland sites (Meyer, 1993; Palone and Todd, 1998; Sweeney, 1993). Tree shelters do not work as well in shaded conditions and are recommended for deciduous trees only (Sweeney, 1993).

Tree shelters should be removed 2 to 3 years after installation (Sweeney, 1993; Palone and Todd, 1998). They must be maintained to ensure that they are stable, and kept free of shading weeds in summer and dead grasses in winter (Sweeney, 1993). Tree shelters also require wooden stakes for support, and a plastic mesh cap to keep birds and wasps from nesting in them (Meyer, 1993; Palone and Todd, 1998; Sweeney, 1993). See Palone and Todd (1998) for sources of tree shelters and Hairston-Strang (2005) for installation instructions.

Signage

In most urban areas, the best protection for any reforestation project is installing signs to increase its visibility. Signage can help prevent un-intentional trampling or mowing, and educates the public about the purpose of the project (Figure 33).

Figure 33. Signage is used to prevent mowing and to inform the public of a reforestation project.

Tree Inspection and Maintenance

Every urban tree planting site requires regular inspection and maintenance such as watering, weed control, pruning, and pest management. Fertilization is usually not needed for newly planted trees, but may be beneficial later, depending on soil and growing conditions. The Tree Care Industry Association (2004) provides guidance on tree fertilization. Inspection, replacement, and removal of tree shelters and stakes should also be part of a maintenance plan. Planting sites should be regularly inspected to assess plant growth, survival, and species composition. Based on inspection results, supplemental plantings may be needed to replace trees that did not survive.

An inspection and maintenance schedule should be created for each reforestation site, should include immediate post-planting inspection and maintenance, and should extend at least 3 to 5 years from initial planting. Most inspection and maintenance tasks will take place during the growing season; however, it may be necessary to conduct certain tasks during the dormant season (e.g., removal of certain invasive species). Trained volunteers (e.g., homeowners' association, local civic group) or public works staff typically will be responsible for tree maintenance, while tree inspectors are usually trained foresters, arborists, or other professionals who can diagnose tree health. A sample inspection schedule is provided in Table19, and each activity is explained in further detail in the next section.

Table19. Example Inspection and Maintenance Schedule*

Inspection and Maintenance Activity	Year 1	Year 2	Year 3	Year 4	Year 5
Regularly inspect tree health and survival	X	X	X	X	X
Water trees	X	X	X		
Remove tree shelters			X	X	X
Remove stakes and wires		X			
Implement invasive species and noxious weed control methods as needed	X	X	X	X	X
Prune damaged, dead, or diseased branches		X	X	X	X
Implement Integrated Pest Management methods as needed	X	X	X	X	X
Install supplemental plantings if desired		X	X	X	X

*Adapted from Hairston-Strang (2005) and Palone and Todd (1998)

Inspection

Initial planting inspection

Each tree should be inspected for proper planting and post-planting protection immediately after initial planting. Any problems should be corrected immediately. A specific checklist for initial planting inspection may include the questions in Box 6.

BOX 6. SAMPLE CHECKLIST FOR INITIAL INSPECTION OF A PLANTING SITE

- ☐ Is the tree planted at the correct height?
- ☐ Has a tree shelter been installed properly?
- ☐ Are stakes installed properly (if needed)?
- ☐ Has mulch been properly applied around trees?
- ☐ Has the tree been well watered?
- ☐ Has flagging been installed to help locate the tree?

Long-term inspection

For newly planted trees, transplant shock is common and causes a great deal of stress on a new tree. For this reason, newly planted trees must be inspected more frequently than established trees. The time it takes for a tree to become established varies with the size at planting, species, stock, and site conditions, but generally, trees should be inspected every few months during the first 3 years after planting, to identify problems and implement repairs or modify maintenance strategies (WSAHGP, 2002).

After the first 3 years, annual inspections should be sufficient to check for problems. Trees may also be inspected after major storm events for any damage that may have occurred. The inspection should take only a few minutes per tree, but prompt action on any problems encountered results in healthier, stronger trees. Aside from correcting problems and ensuring survival, inspection data can help to refine and improve the success of future plantings.

A checklist for long-term inspection of urban tree planting sites is given in Box 7.

BOX 7. CHECKLIST FOR LONG-TERM INSPECTION OF A PLANTING SITE

- ☐ Assess tree vigor and overall health (see Greenfield and others, 1991 for guidance).
- ☐ Count the number of living trees and record species to determine survival rates.
- ☐ Evaluate cause of mortality for dead trees and recommend supplemental plantings if deemed appropriate.
- ☐ Determine if pruning is need for damaged, dead, or diseased branches.
- ☐ Inspect trees for signs of insect damage and disease.
- ☐ Determine if stakes need to be adjusted or removed.
- ☐ Determine if tree shelters need to be adjusted, replaced, or cleared of wasps.
- ☐ Evaluate if additional weed control is needed.
- ☐ Determine if natural regeneration is occurring and record species.

Repairs should be completed as soon as possible. If a significant number of trees are dead or damaged, supplemental plantings may be done after evaluating and addressing the cause of mortality or damage. It may not be economically desirable to replace trees if the cause of damage is unknown or is uncontrollable. Hairston-Strang (2005) provides guidance on determining the cause of tree mortality.

Watering

Proper water management is perhaps the most crucial maintenance activity to ensure survival of newly planted trees. If plans are not made to water new trees, they may die during periods of drought. Over watering can also be fatal to young trees and will cause leaves to turn yellow or fall off in older trees. Although watering can be costly and time-consuming, it is well worth the effort. Watering options include regular or soaker hoses, sprinklers, buckets, drip irrigation, or installation of larger capacity watering tanks or irrigation systems. Buckets or jugs with very small holes can be used to create a crude drip system (Sedbrook, 2005). The local fire department or public works can also provide help in watering. Techniques that may help increase plant survival when it is too costly to irrigate include these (Palone and Todd, 1998):

- Monitor the rainfall and groundwater at the site during the site assessment to evaluate whether it is suitable for planting with no supplemental irrigation.
- Plant during the rainy season.
- Choose species that are tolerant of both dry and wet conditions.
- Mulch regularly.
- Dip plant roots in water before planting.
- Use storm water runoff at the site as a source of irrigation water where feasible (see Chapter 4 for information on evaluating storm water runoff).

Some rules of thumb for watering include these:

- Water newly planted trees regularly (at least once a week) during the first growing season. Water less frequently (about once a month) for the next two growing seasons. After three growing seasons, water only during drought. The exact watering frequency will vary for each tree and site.
- A general horticultural rule of thumb is that trees need 1 inch of rainfall per week during the growing season (Petit and others, 1995). Monitoring soil moisture, using watering systems with timers and shutoff valves, and monitoring rainfall at the site are all helpful in ensuring the tree gets the right amount of water.

Figure 34. A soaker hose is an efficient way to water newly planted trees.

- Water trees deeply and slowly near the roots. Light, frequent watering of the entire plant can actually encourage roots to grow at the surface. Soaker hoses (Figure 34) and drip irrigation work best for deep watering of trees and shrubs.
- Continue watering until mid-fall, tapering off during lower temperatures. Watering can continue one to two times per month through the winter, but only when the ground is not frozen.

Pruning

Pruning is usually not needed for newly planted trees but may be beneficial for tree structure. If necessary, prune only dead, diseased, broken or crossing branches at planting (Doherty and others, 2003; Trowbridge and Bassuk, 2004). As the tree grows, lower branches may be pruned to provide clearance above the ground, or to remove dead or damaged limbs that sprout from the trunk. Refer to ANSI A300 Standards (Part 1 Pruning) for Tree Care Operations for pruning guidance for mature trees or make sure that a certified arborist does the pruning (TCIA, 2004).

Weed Control

Controlling weeds is a cost-effective method to accelerate the growth of tree seedlings. For trees larger than seedlings, only a few years of weed control may be needed, as trees will soon be tall enough to compete with the herbaceous layer. Mowing and mulching are two common methods of weed control. Additional control methods are discussed in Chapter 5.

Mowing is an option for weed control where sufficient space exists between plantings for mower access. Drawbacks of mowing are that it can inhibit natural regeneration between plantings, and mulch or tree shelters are necessary to protect tree trunks from mower strikes (Palone and Todd, 1998). If mowing is used, mow twice a year during the first three growing seasons to a height of 6 inches, but do not let weeds get higher than 12-14 inches before mowing (ACB, 2000; WSAHGP, 2002). Mowing immediately around newly planted trees is not recommended as this may actually increase nutrient uptake in the herbaceous layer, and retard seedling growth (Palone and Todd, 1998).

For mulched areas, weeding should be a regular part of the maintenance schedule. Mulch twice a year—in late spring and during leaf fall. A well-aged hardwood mulch has good moisture retention and weed control benefits. Check the depth of mulch regularly to maintain a 2- to 4-inch depth. Do not add mulch if there is a sufficient layer in place. Rake the old mulch to break up any matted layers and to refresh the appearance. If mulch is piled against the stems or tree trunks, pull it back several inches so that the base of the trunk and the root crown are exposed (ISA, 2003a).

Mulch or any other weed control method will never guarantee complete eradication of weeds at a site. Most likely, a combination of several methods will be necessary, and some form of weed control will be necessary over the long term. Several products that are frequently used in combination with mulch include weed mats, landscape fabric, and shredded newspaper; all are effective in reducing weed rooting within organic mulch beds.

Integrated Pest Management

No one method of controlling pests is ideal; rather, a combination of biological, physical, chemical, and cultural methods should be used. This approach is often referred to as Integrated Pest Management (IPM), and entails taking a comprehensive look at the available methods, considering their effect on the surrounding environment, and addressing both initial removal and long-term control. IPM typically includes biological control methods, where beneficial insects are used to control populations of insect pests. Pesticides and herbicides are used only as a last resort, and the least toxic alternative is preferred. For more information on Integrated Pest Management, refer to the University of Maryland Department of Entomology Web site: www.mdipm.umd.edu/.

Appendix A. Field Sheet for the Urban Reforestation Site Assessment (URSA)

Instructions for completing this URSA field sheet are in Chapter 2.

1. General Site Information

Location:

Property owner:

Current land use:

2. Climate

USDA plant hardiness zone:

Sunlight exposure:

- ☐ Full sun (6 hours or more of direct sun per day)
- ☐ Part sun or filtered light (< 6 hours per day)
- ☐ Shade (< 3 hours of direct sun per day)

Microclimate features (check if present):

- ☐ High wind exposure
- ☐ Re-reflected heat load
- ☐ Other:

3. Topography

Steep slopes

Are any slopes > 15% present in the proposed planting area? Y/N

If Yes, estimate slope:

Low-lying areas

Are any low-lying areas present in the proposed planting area? Y/N

Notes:

4. Vegetation

Regional forest association (or dominant species from reference site):

Current vegetative cover (check all that apply and note percent of planting area):

- ☐ Mowed turf: _____%
- ☐ Other herbaceous: _____%
- ☐ None: _____%
- ☐ Trees or shrubs: _____%

Note species to be preserved:

Are invasive plants or noxious weeds present? Y/N

If Yes, note species and percent coverage at site.

Adjacent vegetative cover:

Is forest present? Y/N

If Yes, note dominant species:

Are invasive plants or noxious weeds present? Y/N

If Yes, note species and percent coverage at site.

5. Soils

Texture:

- ☐ Clay
- ☐ Loam
- ☐ Sand

Drainage:

- ☐ Poor (< 1" per hour)
- ☐ Moderate (1" - 6" per hour)
- ☐ Excessive (> 6" per hour)

Compaction:

- ☐ None
- ☐ Moderate
- ☐ Severe

pH:

- ☐ Acid (5.0 – 6.8)
- ☐ Neutral (6.8 – 7.2)
- ☐ Alkaline (7.2 – 8.0)

Other soil features (check if present and describe:

- ☐ Active or severe soil erosion
- ☐ Potential soil contamination
- ☐ Debris and rubble in soil
- ☐ Recent construction or other soil disturbance
- ☐ Other:

Soil Chemistry (Optional)

List results of soil tests if applicable (e.g., levels of phosphorus, salt, or organic matter in the soil).
Describe any visual indicators of soil quality.

6. Hydrology

Site hydrology:

- ☐ Upland
- ☐ Riparian

Note: For riparian planting sites where planting is proposed on both stream banks, fill out this section for each bank separately

Stormwater runoff to planting site (check all that apply):

- ☐ Bypasses site in pipe
- ☐ Upslope drainage area outfalls to site
  Note diameter of pipe outfall: ______
- ☐ Open channel directs flow across or around the site
- ☐ Shallow concentrated flow (e.g., evidence includes rills, gullies, sediment deposits)
- ☐ Sheetflow
- ☐ Unknown

Contributing flow length:

Slope: ______%
Length: _______ft
Dominant cover type:

- ☐ Impervious
- ☐ Pervious

Floodplain connection (riparian areas only):

Are levees present? Y/N
Bank height: _____ft
Depth to water table (optional): _____ft

Stream order: _______

Contributing Flow Length Sketch:

7. Potential Planting Conflicts

Space limitations (check if present, and note height of overhead wires, signs and lighting):

- ☐ Overhead wires: _____ft
- ☐ Pavement
- ☐ Structures
- ☐ Signs: _____ft
- ☐ Lighting: _____ft
- ☐ Underground utilities
  Note type:
- ☐ Other:

Other limiting factors (check if present and describe below):

- ☐ Trash dumping/debris
  Note type of trash, volume (estimated pickup truck loads), and source if known:
- ☐ Deer, beaver or other animal impacts
- ☐ Mowing conflict (e.g., site is mowed regularly)
- ☐ Wetland present
- ☐ Insect infestation or disease
- ☐ Heavy pedestrian traffic
- ☐ Other:

Notes:

Local Ordinance Setbacks

Check local ordinances or utility requirements and note any required setbacks from these features.

8. Planting and Maintenance Logistics

Site access (check if present):

- ☐ Delivery access for planting materials
- ☐ Temporary storage areas for soils, mulch, etc.
- ☐ Heavy equipment access
- ☐ Volunteer parking
- ☐ Nearby facilities for volunteers

Party responsible for maintenance (if known):

Water source (check all that apply):

- ☐ Rainfall only
- ☐ Storm water runoff
- ☐ Hose hook-up nearby
  Note distance from hook-up to planting area (ft):
- ☐ Irrigation system in place
- ☐ Overbank flow from river or stream
- ☐ Fire hydrant nearby
- ☐ Other:

9. Site Sketch

Sketch the site below and include the following features at a minimum:

- ☐ Property boundary, landmark features (e.g., roads, streams) and adjacent land use/cover
- ☐ Boundary and approximate dimensions of proposed planting area
- ☐ Variations in sun exposure, microclimate, and topography within planting area
- ☐ Current vegetative cover, location of trees to be preserved, and invasive species
- ☐ Location and results of soil samples (if variable)
- ☐ Flow paths to planting area and contributing flow length
- ☐ Above or below ground space limitations (e.g., utilities, structures)
- ☐ Other limiting factors (e.g., trash dumping, pedestrian paths)
- ☐ Water source and access points
- ☐ Scale and north arrow

Appendix B. Urban Tree Selection Guide

Once planting sites have been selected and the Urban Reforestation Site Assessment has been conducted, the tree selection guide in this appendix can be used to narrow the field of possible choices for planting in the urban environment. Tree species can be selected based either on their tolerance to environmental conditions at the site (Chart 1) or on desired tree characteristics, such as small size for use near overhead wires (Chart 2).

When using the charts in this appendix, keep in mind that a given tolerance for one variable may be influenced by another variable. For example, sun exposure may influence a species' ability to manage a prolonged drought, or a species which grows to its fullest in sandy textured, well-drained soils may not persevere when planted in a windy (thus drying) setting. With this in mind, these charts should be used as a "first-cut" guide to tree selection for a given set of circumstances. To refine the species selection and to ensure success of the planting, consult local horticulturists, arborists, landscape architects, or other natural resource professionals who are familiar with the geography and site specifics of the planting area.

Tree species in this appendix were selected on the basis of two characteristics: the overlap of their hardiness capability with the climate of the Mid-Atlantic and Northeast, and Midwest U.S. regions; and their ability to tolerate one or more variables typically associated with urban environments (e.g., salt tolerance, compaction). The information about each species was derived from a variety of primary sources, which are listed below. When data elements were not fully available from these sources or elements were in conflict, the other resources, also listed below, were used to validate information.

Primary Sources

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Definitions Used in Chart 1

Hardiness Zone – This is the acceptable Hardiness Zone that the tree is capable of growing in. Hardiness Zones are determined by the average minimum temperature of a given location. A higher Hardiness Zone means a warmer climate is needed to sustain a healthy specimen. Data are based on the USDA Plant Hardiness Zone Map.

Soil Moisture – Four subheadings indicate the amount of moisture that is required for a plant to survive. Many plants have the ability to survive in many different levels of soil moisture. Note that it is critical to give newly transplanted trees several years of supplemental watering to hasten their establishment before expecting them to possess wider soil moisture level tolerance.

Sun Exposure – **Full sun** plants require more than 6 hours of direct sunlight a day, **partial shad**e plants tolerate direct sun for less than 6 hours a day or filtered light for most of the day, and **full shade** plants tolerate little or no direct sunlight or less than 6 hours of filtered sunlight a day.

Soil Components – Each soil type has a certain proportion of sand, loam, and clay. Soils with a high proportion of sand generally hold little water due to sand's large particle size around which water passes. Soils with a high proportion of clay are relatively impermeable. The tolerance ratings in this section provide general characteristics of the soil needed by a particular tree species.

Drought Tolerance – This is the plant's ability to survive a single period of very little rainfall. Some plants are able to do this despite having unusually moist soil requirements.

Flood Tolerance – Tolerant trees can survive when flooded for 30 to 40 percent of the growing season, medium trees can survive when flooded for 10 to 30 percent of the growing season, and intolerant trees will not survive if flooded for more than 10 percent of the growing season.

Pest/Disease Tolerance – This field notes the relative susceptibility of tree species to pest/disease problems.

Soil Compaction – Compacted soil inhibits root growth. Some trees are able to grow in compacted soils, nonetheless, which would prove beneficial when planting trees on degraded sites.

Salt Tolerance – This refers to soil salinity, not aerosol salt. Soil tolerance is a consideration in those areas where road salt is used to de-ice the roads during the winter months.

pH level – Trees that require acid soil are listed as 5.0 – 6.8. Trees that require neutral soil are listed as 6.8 – 7.2. Trees that require alkaline soil are listed as 7.2 – 8.0.

Parts of Chart 1 are marked with shaded boxes according to the following legend:

T	= tolerant
M	= moderately tolerant
I	= intolerant
	= unknown

Chart 1. Tree Tolerance to Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture			
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought
American basswood	*Tilia americana*	3 to 8	M	T	T	I
American beech	*Fagus grandifolia*	3 to 8	I	T	T	M
American elder	*Sambucus canadensis*	4 to 10	M	T	M	I
American elm (hybrids)	*Ulmus* hybrids	4 to 6	T	T	T	T
American hazelnut	*Corylus americana*	4 to 9	I	T	M	I
American holly	*Ilex opaca*	5 to 6	M	T	M	I
American hophornbeam	*Ostrya virginiana*	3b to 9	I	T	M	I
American hornbeam	*Carpinus caroliniana*	3 to 9	M	T	M	I
American sycamore	*Platanus occidentalis*	3 to 9	T	T	M	I
Amur maackia	*Maackia amurensis*	3 to 7	I	T	T	M
Bald cypress	*Taxodium distichum*	5 to 10	T	T	T	I
Black cherry	*Prunus serotina*	3 to 9	I	T	M	I
Black tupelo	*Nyssa sylvatica*	4 to 9	T	T	T	M
Black walnut	*Juglans nigra*	5 to 8	I	T	T	T
Black willow	*Salix nigra*	3 to 5	T	T	I	I
Blackhaw	*Viburnum prunifolium*	3b	I	M	T	T
Boxelder	*Acer negundo*	3 to 9	T	T	T	I
Bur oak	*Quercus macrocarpa*	3 to 8	T	T	T	T
Butternut hickory	*Carya cordiformis*	4 to 9	T	T	T	I
Buttonbush	*Cephalanthus occidentalis*	5 to 9	T	T	M	I
Canada hemlock	*Tsuga canadensis*	3b to 7	I	T	M	I
Chestnut oak	*Quercus prinus*	4 to 8	I	T	T	I
Chinese fringetree	*Chionanthus retusus*	5 to 9	I	T	T	T
Common chokeberry	*Prunus virginiana*	2 to 6	I	T	T	M

Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/ Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
T	M	I	T	T	T	I	I	M	I	I	7.2 - 8.0
T	T	M	T	T	T	T	I	T	I	I	5.0 - 6.8
T	T	I	T	T	T	M	T	T	I	I	5.0 - 6.8
T	I	I	T	T	T	T	M	T	M	M	7.2 - 8.0
T	M	I	T	I	T	M	I	T	I	I	5.0 - 6.8
T	T	T	T	T	T	T	M	T	T	T	5.0 - 6.8
T	M	I	T	M	T	I	I	T	T	I	5.0 - 6.8
T	T	M	T	M	T	M	T	T	I	I	6.8 - 7.2
T	I	I	M	M	T	T	T	M	T	I	5.0 - 6.8
T	M	I	T	M	T	M	I	T	I	M	5.0 - 6.8
T	I	I	T	T	T	M	T	T	T	M	6.8 - 7.2
T	I	I	T	M	T	M	I	M	I	T	6.8 - 7.2
T	I	I	M	M	T	M	M	T	I	M	5.0 - 6.8
T	T	I	T	I	T	T	M	I	M	T	6.8 - 7.2
T	I	I	M	T	T	I	T	I	T	M	6.8 - 7.2
T	M	I	M	I	M	T	I	M	I	I	7.2 - 8.0
T	I	I	T	T	T	T	T	I	T	I	5.0 - 6.8
T	I	I	T	T	T	T	M	I	I	T	7.2 - 8.0
T	T	I	T	M	T	I	M	I	M	I	6.8 - 7.2
T	T	M	T	M	T	M	T	M		M	6.8 - 7.2
M	T	T	T	I	T	I	I	I	I	I	6.8 - 7.2
T	M	I	M	I	T	M	T	M			6.8 - 7.2
T	T	M	T	M	T	T	I	T	I		6.8 - 7.2
T	M	I	T	I	T	M	I	I	I	T	6.8 - 7.2

Chart 1. Tree Tolerance to Environmental Conditions - *continued*

Common Name	Scientific Name	Hardiness Zone	Soil Moisture			
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought
Common hackberry	*Celtis occidentalis*	3 to 9	I	T	T	I
Common spicebush	*Lindera benzoin*	4 to 9	I	T	M	I
Crabapple	*Malus* spp.	3 to 8	I	T	M	M
Crimeon linden	*Tilia euchlora*	3 to 7	I	T	T	I
Douglas fir	*Pseudotsuga menziesii*	4 to 6	I	T	T	I
Eastern cottonwood	*Populus deltoides*	3 to 9	T	T	T	T
Eastern hemlock	*Tsuga canadensis*	3b to 7	I	T	T	I
Eastern hophornbeam	*Ostrya virginiana*	3b to 9	I	T	T	I
Eastern larch	*Larix laricina*	2 to 4	M	T	T	M
Eastern redbud	*Cercis canadensis*	4 to 9	I	T	T	I
Eastern redcedar	*Juniperus virginiana*	3b to 9	I	T	T	T
Eastern white pine	*Pinus strobus*	3 to 7	M	T	T	I
Elderberry	*Sambucus canadensis*	4 to 9	M	T	M	I
English oak	*Quercus robur*	4 to 8	I	T	T	T
European beech	*Fagus sylvatica*	4 to 7	I	T	T	I
European hornbeam	*Carpinus betulus*	5 to 7	M	T	T	I
Flowering dogwood	*Cornus florida*	5	I	T	T	I
Fringetree	*Chionanthus virginicus*	4 to 9	I	T	T	I
Ginkgo	*Ginkgo biloba* (male only)	4 to 8	I	T	T	T
Golden rain tree	*Koelreuteria paniculata*	5	M	T	T	T
Gray birch	*Betula populifolia*	3 to 6	M	T	T	I
Green ash	*Fraxinus pennsylvanica*	4 to 9	M	T	T	I
Hawthorn	*Crataegus viridis*	4 to 7	M	T	T	T
Hazel alder	*Alnus serrulata*	5 to 9	T	T	M	I

Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/ Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
T	M	I	T	I	T	I	M	I	M	T	7.2 - 8.0
T	T	I	T	M	T	I	T	T			7.2 - 8.0
T	M	I	T	M	T	M	M	I		M	6.8 - 7.2
T	I	I	T	I	T	M		M		I	7.2 - 8.0
T	M	I	M	M	T	I	M	I		I	6.8 - 7.2
T	M	I	T	T	T	T	T	I	T	T	6.8 - 7.2
M	T	T	T	M	T	I	I	I	I	I	5.0 - 6.8
T	M	I	T	I	T	I	I	T	I	I	7.2 - 8.0
T	M	I	M	M	T	T	M	I	T	T	5.0 - 6.8
T	M	M	T	I	T	I	M	T	M	M	6.8 - 7.2
T	M	I	T	M	T	T	I	M	I	T	7.2 - 8.0
T	M	I	T	M	M	M	I	I	I	I	5.0 - 6.8
T	T	I	M	M	T	I	T	I			6.8 - 7.2
T	I	I	T	I	T	T	I	I		M	7.2 - 8.0
T	M	I	T	I	T	M	I	M	I	I	5.0 - 6.8
T	M	I	M	M	T	M		T	I	I	7.2 - 8.0
M	T	T	T	I	T	M	T	I		I	6.8 - 7.2
T	T	M	T	M	T	I	I	T	I	I	5.0 - 6.8
T	M	I	T	I	T	M	T	T		T	6.8 - 7.2
T	M	I	T	M	T	T		T		T	7.2 - 8.0
T	I	I	T	T	T	M	T	I	M	T	6.8 - 7.2
T	M	I	T	M	T	M	T	I	T	M	6.8 - 7.2
T	I	I	T	M	T	T	M	I	T	M	7.2 - 8.0
T	I	I	T	T	T	I	T	T	T	I	6.8 - 7.2

Chart 1. Tree Tolerance to Environmental Conditions - *continued*

Common Name	Scientific Name	Hardiness Zone	Soil Moisture			
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought
Hedge maple	*Acer campestre*	5 to 8	I	T	T	T
Highbush cranberry	*Viburnum trilobum*	2 to 7	I	T	M	I
Honeylocust	*Gleditsia triacanthos inermis*	4 to 9	I	T	T	T
Horsechestnut	*Aesculus × carnea*	5a	I	T	T	I
Hybrid elm	*Ulmus* hybrids	3 to 5	M	T	T	T
Japanese tree lilac	*Syringa reticulata*	3 to 7	I	T	T	T
Japanese zelkova	*Zelkova serrata*	5 to 8	I	T	T	I
Katsura tree	*Cercidiphyllum japonicum*	4 to 8	M	T	I	I
Laurel oak	*Quercus laurifolia*	6 to 9	T	T	T	I
Littleleaf linden	*Tilia cordata*	3b to 7	I	T	T	I
Loblolly pine	*Pinus taeda*	6 to 9	M	T	T	I
London planetree	*Platanus × acerifolia*	5 to 8	T	T	T	T
Mountain ash	*Sorbus* cultivars	4 to 6	I	T	T	I
Mountain-laurel	*Kalmia latifolia*	4 to 9	I	T	M	I
Mugo pine	*Pinus mugo*	3 to 7	I	T	M	I
Northern red oak	*Quercus rubra*	3b to 7	I	T	T	M
Nuttall oak	*Quercus nuttallii*	5 to 9	M	T	T	M
Overcup oak	*Quercus lyrata*	5 to 9	T	T	T	M
Paperbark birch	*Betula papyrifera*	2 to 6	M	T	T	I
Pawpaw	*Asimina triloba*	5 to 8	I	T	M	I
Persimmon	*Diospyros virginiana*	4 to 9	I	T	T	M
Pin oak	*Quercus palustris*	6 to 9	T	T	T	M
Pond cypress	*Taxodium ascendens*	5 to 9	T	T	T	M
Red (slippery) elm	*Ulmus rubra*	3 to 9	M	T	T	M
Red maple	*Acer rubrum*	3b to 9	T	T	T	I

Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/ Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
T	T	I	T	M	T	T		T	T	M	7.2 - 8.0
T	T	I	M	M	T	M	T	M	T	M	5.0 - 6.8
T	M	I	M	M	T	T	M	I	T	T	7.2 - 8.0
T	M	I		M	T	M		I	M	M	7.2 - 8.0
T	T	I	M	M	T	T	T	M	T	T	7.2 - 8.0
T	M	I	T	M	T	T	I	M		M	7.2 - 8.0
T	M	I	T	M	T	I		M	T	M	7.2 - 8.0
T	M	I	M	M	T	I		T	I	M	7.2 - 8.0
T	T	I	T	M	T	M		T	T	I	6.8 - 7.2
T	M	I	T	I	T	M	T	I	M	I	7.2 - 8.0
T	I	I	T	M	T	M	M	M	T	I	5.0 - 6.8
T	T	M	T	M	T	T	M	I	T	M	7.2 - 8.0
T	I	I	T	I	T	I	M	I	M		5.0 - 6.8
M	T	M	T	M	T	I	I	I			5.0 - 6.8
T	T	I	M	M	T	M	T	I	T	T	7.2 - 8.0
T	M	I	T	I	T	M	T	I	T	T	7.2 - 8.0
T	M	I	M	M	T	M	T	T	T	M	5.0 - 6.8
T	T	I	T	T	T	T	T	T	T		5.0 - 6.8
T	M	I	T	M	T	I	I	M	I	T	5.0 - 6.8
T	T	M	T	I	T	I	I	T	I	M	6.8 - 7.2
T	T	M	T	I	M	T	M	M	M	M	5.0 - 6.8
T	I	I	T	T	T	M		M	T	M	5.0 - 6.8
T	T	T	T	T	T	M	T	M		M	5.0 - 6.8
T	T	T	T	M	T	M	T	T	T		6.8 - 7.2
T	T	M	T	T	T	I	T	I	T	I	5.0 - 6.8

Chart 1. Tree Tolerance to Environmental Conditions - *continued*

Common Name	Scientific Name	Hardiness Zone	Soil Moisture			
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought
Red-osier dogwood	*Cornus sericea*	2 to 7	T	T	M	I
River birch	*Betula nigra*	3b to 9	T	T	T	I
Sassafras	*Sassafras albidum*	4 to 9	I	T	T	T
Scarlet oak	*Quercus coccinea*	4 to 9	I	T	T	T
Serviceberry	*Amelanchier arborea*	4 to 9	I	T	T	I
Shagbark hickory	*Carya ovata*	4 to 8	M	T	T	T
Shingle oak	*Quercus imbricaria*	4 to 8	I	T	T	M
Shumard oak	*Quercus shumardii*	5 to 9	M	T	T	M
Silky dogwood	*Cornus amomum*	4 to 8	T	T	T	M
Silver linden	*Tilia tomentosa*	4 to 7	I	T	T	I
Silver maple	*Acer saccharinum*	3 to 9	T	T	T	I
Smooth sumac	*Rhus glabra*	3 to 9	I	M	T	T
Sourwood	*Oxydendrum arboreum*	5	I	T	T	I
Sugar maple	*Acer saccharum*	4 to 8	I	T	T	I
Sugarberry	*Celtis laevigata*	5 to 9	M	T	T	I
Swamp chestnut oak	*Quercus michauxii*	5 to 8	M	T	M	I
Swamp white oak	*Quercus bicolor*	4 to 8	M	T	T	I
Sweet-bay magnolia	*Magnolia virginiana*	5 to 9	T	T	M	I
Sweetgum	*Liquidambar styraciflua*	5 to 9	M	T	T	I
Trident maple	*Acer buergeranium*	5 to 8	I	T	T	M
Tulip tree	*Liriodendron tulipifera*	4 to 9	M	T	T	I
Water hickory	*Carya aquatica*	5 to 9	T	T	T	I
White ash	*Fraxinus americana*	4 to 9	M	T	T	I
White oak	*Quercus alba*	3b to 9	I	T	T	I
Willow oak	*Quercus phellos*	5 to 9	M	T	T	T
Winterberry	*Illex verticillata*	3 to 5	T	T	T	I
Witch hazel	*Hammamelis virginiana*	3b to 8	I	T	T	I

Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/ Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
T	T	I	M	T	T	M	T	M	T	I	6.8 - 7.2
T	M	I	T	T	T	I	M	M	T	I	5.0 - 6.8
T	T	I	T	I	T	T	I	T	T	M	5.0 - 6.8
T	M	I	T	I	M	T	I	T	I	M	5.0 - 6.8
T	T	M	T	I	T	I	I	T	I	I	6.8 - 7.2
T	T	M	T	M	T	T	I	T	M	I	5.0 - 6.8
T	M	I	T	M	T	M	M	T	M	M	5.0 - 6.8
T	M	I	T	I	T	M		T	T	M	7.2 - 8.0
M	T	M	T	I	T	M	T	T	T	I	5.0 - 6.8
T	M	I	T	I	T		T		M	M	7.2 - 8.0
T	M	I	T	T	T	I	T	I	T	M	5.0 - 6.8
T	M	I	T	M	T	T	T	T	I	T	6.8 - 7.2
T	T	M	T	I	T	M	I	T	I	M	6.8 - 7.2
T	T	M	T	I	T	I	I	I	I	I	6.8 - 7.2
T	M	I	T	M	T	M	T	M	T	T	6.8 - 7.2
T	M	M	M	M	T	I	M	M	T		5.0 - 6.8
T	T		M	T	T	I	M	T	T		6.8 - 7.2
T	T	M	T	T	T	I	T	T	T		5.0 - 6.8
T	M	I	T	T	T	I	T	T	T	M	6.8 - 7.2
T	I	I	T	I	T	M		T	M	M	5.0 - 6.8
T	T	M	T	M	T	I	I	T	I	I	5.0 - 6.8
T	T	I	T	M	T	M	T	T	T	I	6.8 - 7.2
T	T	M	T	M	T	I	M	I	M	M	6.8 - 7.2
T	T	M	T	T	T	M	I	I	I	T	5.0 - 6.8
T	T	M	T	T	T	T	M	I	T	I	6.8 - 7.2
T	T	M	T	T	T	M	I	M	T	I	5.0 - 6.8
I	M	T	M	M	T	I	I	T	I	I	5.0 - 6.8

Definitions Used in Chart 2

Height – Tree height is measured in feet from the base of the tree to the tip of the canopy.

Canopy Spread – The width is measured as the diameter of the canopy in feet.

Growth Rate – Slow growth is defined as having an annual leader increment of 12 inches or less. Medium growth is defined as having an annual leader increment between 12 to 24 inches. Fast growth is defined as having the potential to produce 24 or more inches of annual leader increment.

Form/Habit – A description of the tree's overall shape or outline and its structure, when mature.

Root Structure – Shallow lateral roots form a fibrous mat up to 4 feet deep and from 1½ to 3 times the reach of the canopy. Deep lateral roots are extensive underground systems that grow more than 4 feet underground, with the same reach as shallow lateral roots; they are not recommended for use near perforated drainage pipes and irrigation systems. The taproot is the single thick root that grows straight into the soil to a depth of 15 feet or more. Plants with a sizeable taproot are considerably more tolerant to drought because the taproot penetrates to a depth where water is available.

Native – In the context of this chart, native species are those that are indigenous to the Mid-Atlantic or Northeastern Region of the United States. The native species in the chart have evolved in these geographic regions and thus are adapted to the historic range of climatic, physical, and biological factors associated with these regions. A few of the trees in the chart, while native, are not native to the geographic region of interest and are so noted (e.g., native to western or southeastern United States). Lastly, there are species that are not native or are cultivars. Non-native species were introduced to the United States from other parts of the world, while cultivars are a by-product of breeding species for certain desired characteristics.

Fruit – Describes the type of fruit and, in some cases, also lists fruit color or size. Fruit types are generically presented. Appeal to wildlife (e.g., acorns of oak species, berries) and significance of limb, bark, or fruit litter should also be considered (see the list of Sources for this appendix for more information).

Seasonal Foliage Cover – Describes the plants leaf color during the growing season and notes any color changes for autumn.

Flower – Information about when plants bloom and flower color. There are also subjective notes to document if the flower is visually appealing ("showy") or visually insignificant ("not showy").

Chart 2. Tree Characteristics

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
American basswood	*Tilia americana*	50 to 80	35 to 50	medium	youth: pyramidal, mature: oval & rounded
American beech	*Fagus grandifolia*	50 to 75	40 to 60	slow	oval, pyramidal, symmetrical
American elder	*Sambucus canadensis*	8 to 12	6 to 10	fast	upright vase canopy, multiple stems
American elm (hybrids)	*Ulmus* hybrids	50 to 70	40 to 60	fast	varies with cultivar
American hazelnut	*Corylus americana*	8 to 15	6 to 10	medium	straight, spreading, ascending branches
American holly	*Ilex opaca*	40 to 50	15 to 25	slow	pyramidal, symmetrical
American hophornbeam	*Ostrya virginiana*	30 to 50	20 to 30	slow	oval to rounded, horizontal drooping branches
American hornbeam	*Carpinus caroliniana*	30 to 50	20 to 35	slow	horizontal, pyramidal to vase, symmetrical
American sycamore	*Platanus occidentalis*	75 to 90	50 to70	fast	rounded, spreading, pyramidal
Amur maackia	*Maackia amurensis*	20 to 35	15 to 25	slow	rounded, vase shape, symmetrical
Bald cypress	*Taxodium distichum*	50 to 70	20 to 40	medium	pyramidal, buttressed trunk at base
Black cherry	*Prunus serotina*	60 to 90	35 to 50	fast	oval
Black tupelo	*Nyssa sylvatica*	30 to 60	20 to 40	medium	pyramidal or irregular-round, dense branching
Black walnut	*Juglans nigra*	70 to 90	60 to100	medium	open, rounded
Black willow	*Salix nigra*	60 to 100	20 to 35	fast	straight trunk, upright branches, narrow
Blackhaw	*Viburnum prunifolium*	15 to 20	10	medium	small tree or shrub, short trunk, rounded
Boxelder	*Acer negundo*	30 to 50	40 to 60	fast	rounded, multi-stemmed branching
Bur oak	*Quercus macrocarpa*	60 to 80	60 to 90	slow	large trunk, broadly rounded, open

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	Fall	Blooming Season	Characteristics
deep lateral	native	nutlet	green	yellow	summer	light yellow, fragrant, not showy
shallow lateral	native	nut	green	copper	spring	yellow, not showy
shallow lateral	native	berry, purple-black	green	yellow	summer	white, showy
shallow & deep lateral	native	samara, disc-shaped	green	yellow	spring	green, not showy
shallow lateral	native	nut	green	brown	spring	white on long stalks, showy
shallow lateral	native	berry, red	green	green	spring	white, not showy
deep lateral & taproot	native	pods, small, greenish-white inflated in hanging clusters	dark green	yellow	spring (female), winter (male)	dioecious, male flower is showy
deep lateral	native	**nutlet**	**green**	**orange, red, yellow**	**spring**	**orange, yellow, not showy**
shallow lateral	native	syncarp, round, bristly	green	yellow, not showy	spring	red, not showy
shallow lateral	not native	pod	green	green, not showy	summer	white, showy
shallow lateral	native	cone, small	green	orange-brown	spring	brown, not showy
deep lateral, taproot	native	cherry, small, dark red, nearly black, produces fruit litter	dark green	yellow-red	spring	white, showy
taproot	native	berry, bluish, small, produces fruit litter	green	orange-red, variable	spring with leaves	green-white, not showy
taproot	native	seed housed in green or brown 1-2" husk, produces fruit litter	green	yellow	spring	green, not showy
shallow lateral	native	capsule, small, with cottony seeds	green	yellow-brown	spring	yellow, not showy
deep lateral	native	berry, blue-black	green	red, shiny	spring	white, showy, small
deep lateral	native	samara, profuse, produces fruit litter	light green	yellow-green to brown	spring	yellow-green, not showy
taproot	native	acorn, fringed cap, produces fruit litter	dark green	dull yellow-green	spring, with leaves	yellow, not showy

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Butternut hickory	*Carya cordiformis*	60 to 80	30 to 40	slow	tall trunk, broad, rounded
Buttonbush	*Cephalanthus occidentalis*	6 to 12	6 to 10	slow	shrub, rounded, loosely branched
Canada hemlock	*Tsuga canadensis*	40 to 70	25 to 35	medium	pyramidal, branches pendulous
Chestnut oak	*Quercus prinus*	60 to 70	30 to 50	medium	rounded and relatively dense branching
Chinese fringetree	*Chionanthus retusus*	15 to 25	10 to 25	slow	small tree, rounded, multi-stemmed
Common chokeberry	*Prunus virginiana*	20 to 30	18 to 25	fast	oval to upright small tree, spreading
Common hackberry	*Celtis occidentalis*	40 to 60	60 to 70	medium	rounded with pendulous branches
Common spicebush	*Lindera benzoin*	6 to 12	6 to 10	slow	rounded shrub
Crabapple	*Malus* spp.	16 to 30	8 to 35	medium	rounded, upright to weeping, varies
Crimeon linden	*Tilia euchlora*	40 to 60	20 to 30	medium	pyramidal to rounded, densely branched
Douglas fir	*Pseudotsuga menziesii*	40 to 80	12 to 20	medium	pyramidal crown, densely branched
Eastern cottonwood	*Populus deltoides*	75 to 100	50 to 75	fast	vase-shaped, spreading branches
Eastern hemlock	*Tsuga canadensis*	40 to 70	25 to 35	medium	pyramidal, branches pendulous
Eastern hophornbeam	*Ostrya virginiana*	30 to 50	20 to 30	slow	rounded, horizontal, drooping branches
Eastern larch	*Larix laricina*	40 to 80	15 to 30	medium	pyramidal, open, drooping branches
Eastern redbud	*Cercis canadensis*	20 to 30	25 to 35	medium	spreading, open branching
Eastern redcedar	*Juniperus virginiana*	40 to 50	8 to 20	slow	densely pyramidal

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
taproot	native	nut, produces fruit litter	yellow-green	yellow-gold	spring, with leaves	green, not showy
lateral	native	nutlets	dark green	evergreen	summer	white, showy
shallow lateral	native	cone	dark green	evergreen	summer	yellow-green, not showy
lateral	native	acorn, produces fruit litter	yellow-green	orange-yellow to yellow brown	spring	yellow-green, not showy
lateral	not native	berry, blue	green, leathery	yellow	spring	white, showy, fragrant
shallow lateral	native	berry, red to dark purple	dark green	yellow	spring	white, showy
deep lateral	native	berry, orange-red	green	yellow, yellow-green	spring, with leaves	not showy
lateral	native	berry, scarlett	light green, fragrant	yellow to gold	spring, before leaves	dioecious, yellow-green, small, somewhat showy in early spring
lateral	varies	berry, red, small, produces fruit litter	varies	varies	spring	white to pink, showy, fragrant
lateral	not native	nutlets, small	dark green	green to yellow-green	summer	yellow fragrant, showy
lateral	not native to Mid-Atlantic or North-east	cone, pendulous	green	evergreen	summer	not showy
shallow lateral	native	capsule, opens with cottony seeds	medium green	yellow	spring, before leaves	greenish catkins, not showy
shallow lateral	native	cone, small	dark green	evergreen	summer	not showy
deep lateral, taproot	native	pods, greenish-white in tight clusters	dark green	yellow	spring/ winter	not showy
shallow lateral	native	cone	blue-green	yellow	spring	not showy
shallow lateral	native	pods	early leaves purplish then green	yellow to golden	spring, before leaves	purple-pink, showy
taproot	native	cones, greenish blue, glaucous	sage green	evergreen	winter to spring	not showy, dioecious

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Eastern white pine	*Pinus strobus*	50 to 80	20 to 40	medium	broadly pyramidal, horizontal branches
Elderberry	*Sambucus canadensis*	5 to 12	4 to 6	fast	shrub, multiple stemmed, spreading branches
English oak	*Quercus robur*	40 to 60	40 to 60	slow	massive tree with short trunk, broadly round
European beech	*Fagus sylvatica*	50 to 60	35 to 45	slow	pyramidal to rounded, low branches
European hornbeam	*Carpinus betulus*	40 to 60	30 to 40	slow	rounded
Flowering dogwood	*Cornus florida*	20 to 30	20 to 30	medium	rounded, low branching
Fringetree	*Chionanthus virginicus*	12 to 15	10 to 15	slow	shrub, large,open spreading habit
Ginkgo	*Ginkgo biloba* (male only)	50 to 60	30 to 40	slow	pyramidal, open, wide-spreading branches
Golden rain tree	*Koelreuteria paniculata*	30 to 40	30 to 40	medium	irregular rounded, open
Gray birch	*Betula populifolia*	40 to 50	30 to 40	medium	pyramidal
Green ash	*Fraxinus pennsylvanica*	40 to 60	30 to 50	fast	rounded
Hawthorn	*Crataegus viridis*	20 to 25	12 to 35	slow	rounded to vase-shaped
Hazel alder	*Alnus serrulata*	6 to 20	4 to 15	fast	small tree, multi-stemmed
Hedge maple	*Acer campestre*	25 to 35	25 to 35	slow	rounded, low branching
Highbush cranberry	*Viburnum trilobum*	8 to 12	8 to 12	medium	large shrub, upright spreading, multi-stemmed
Honeylocust	*Gleditsia triacanthos inermis*	40 to 80	30 to 70	fast	rounded, spreading
Horsechestnut (red)	*Aesculus* × *carnea*	35 to 50	30 to 45	slow	rounded, dense branching
Hybrid elm	*Ulmus* hybrids	50 to 70	40 to 60	varies with cultivar	varies with cultivar
Japanese tree lilac	*Syringa reticulata*	20 to 25	15 to 20	slow	oval, spreading, densely branched

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	Fall	Blooming Season	Characteristics
deep lateral	native	cones, pendant	bluish green,	evergreen	summer	not showy
lateral	native	berry, blue in clusters	dark green	yellow-green	summer	white to cream, showy
lateral	not native	acorn	dark green	brown	spring with leaves	not showy
shallow lateral	not native	husk, small, covered with bristles	dark green	red to gold	spring with leaves	not showy
lateral	not native	nutlets in pendulous cluster	dark green	yellow to yellow-green	spring	not showy
shallow	native	berry, red cluster	dark green	red to red-purple	spring	white, showy
deep lateral	native	berry, blue	green	yellow-brown to golden	spring	white, showy, fragrant
lateral	not native	not applicable to male trees	green	yellow	spring	not showy, dioecious
deep lateral	not native	capsule, green to brown	green to blue-green	yellow	summer	yellow clusters, showy
shallow lateral	native	nutlet, small	dark green	yellow	spring	catkins, not showy
shallow lateral	native	samara-like	green	yellow	spring with leaves	not showy, dioecious, flower litter problem
shallow lateral	native	berry, red	green	scarlet to purple	spring	white clusters, showy
shallow lateral	native	cone-like, small	green	yellow-brown	winter to early spring	yellow-brown catkins, in late winter
shallow lateral	not native	samara	dark green	yellow	spring	green, not showy
shallow lateral	native, upper North-east	berry, red	dark green	yellow to red-purple	spring	white, showy
shallow lateral, taproot	natural-ized	pod, long brown, produces fruit litter	light green	yellow-brown	summer	not showy
shallow lateral	not native	nut, glossy, somewhat prickly	dark green	yellow-brown	spring	pink to red clusters, showy
shallow lateral	not native	samara, small	green	yellow	late winter to spring	greenish-red, not showy
lateral	not native	capsule	dark green	yellow-brown	summer	cream, showy, fragrant

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Japanese zelkova	*Zelkova serrata*	50 to 80	50 to 75	medium	vase-shaped, spreading branches
Katsura tree	*Cercidiphyllum japonicum*	40 to 60	25 to 60	fast	rounded
Laurel oak	*Quercus laurifolia*	60 to 70	35 to 45	fast	oval, densely branched
Littleleaf linden	*Tilia cordata*	50 to 70	30 to 50	medium	oval to rounded, densely branched
Loblolly pine	*Pinus taeda*	60 to 90	30	fast	oval to rounded, branches horizontal
London planetree	*Platanus × acerifolia*	70 to 100	65 to 80	medium	open and spreading
Mountain ash	*Sorbus* cultivars	15 to 25	15 to 25	medium	varies with cultivar
Mountain-laurel	*Kalmia latifolia*	3 to 15	3 to 15	slow	large shrub, symmetrical
Mugo pine	*Pinus mugo*	15 to 20	20 to 25	slow	prostrate or pyramidal
Northern red oak	*Quercus rubra*	40 to 60	40 to 60	medium	rounded, open
Nuttall oak	*Quercus nuttallii*	60 to 80	40 to 50	fast	oval, open
Overcup oak	*Quercus lyrata*	40 to 60	35 to 60	medium	rounded
Paperbark birch	*Betula papyrifera*	50 to 70	25 to 50	medium	rounded, low branching
Pawpaw	*Asimina triloba*	15 to 20	15 to 20	medium	shrub/small tree, rounded crown
Persimmon	*Diospyros virginiana*	30 to 60	20 to 35	slow	rounded crown
Pin oak	*Quercus palustris*	50 to 70	40 to 50	medium	oval-pyramidal
Pond cypress	*Taxodium ascendens*	70 to 80	15 to 20	slow	conical
Red (slippery) elm	*Ulmus rubra*	50 to 80	40 to 60	medium	vase-shaped
Red maple	*Acer rubrum*	35 to 60	30 to 70	medium	varies with cultivar

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	Fall	Blooming Season	Characteristics
lateral	not native	berry, small	green	yellow-orange to red	spring	not showy
shallow lateral	not native	pods, small in clusters	bluish-green	yellow to orange	spring before leaves	not showy
lateral	native	acorn	green	yellow	spring	not showy
deep lateral	not native	nutlet	dark green	yellow green to yellow	summer	yellow pendant clusters, fragrant, showy
shallow taproot, lateral	native	cone	green	evergreen	summer	not showy
shallow	not native	syncarp, bristly, rounded, produces fruit litter	green	yellow-brown	spring	not showy
lateral	not native	berry, orange-red	green	varies	spring	white clusters, showy
lateral	native	capsule	dark green	evergreen	spring	white to deep rose, showy
deep lateral	not native	cone	yellow-green	evergreen	summer	not showy
lateral, short taproot	native	acorn, produces fruit litter	green to blue-green	brown	spring with leaves	not showy
shallow lateral	native to central US	acorn, produces slight fruit litter	green	red	spring	not showy
lateral	native	acorn, produces fruit litter	dark green	yellow-brown	spring with leaves	not showy
lateral	native	nutlet	dark green	yellow	spring before leaves	not showy
deep lateral	native	berry, yellow turning brown/ black, produces fruit litter	green	yellow to yellow-green	spring with leaves	purple, not showy
taproot	native	berry, yellow to pale orange	dark green	yellow-green to red-purple	spring	white, fragrant, somewhat showy
shallow lateral	native	acorn, produces fruit litter	dark green	bronze to red	spring	not showy
taproot	native to South-east	cone	green	orange-brown	spring	not showy
lateral	native	samara	dark green	yellow	spring before leaves	not showy
shallow lateral	native	samara	green	yellow, orange, red	spring before leaves	red, showy

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Red-osier dogwood	*Cornus sericea*	7 to 9	7 to 10	fast	broad-spreading shrub
River birch	*Betula nigra*	40 to 50	30 to 40	fast	pyramidal to oval, multi-stemmed
Sassafras	*Sassafras albidum*	30 to 60	25 to 40	medium	rounded
Scarlet oak	*Quercus coccinea*	70 to 75	40 to 50	medium	rounded
Serviceberry	*Amelanchier arborea*	20 to 30	15 to 25	medium	oval, multi-stemmed
Shagbark hickory	*Carya ovata*	60 to 80	25 to 35	slow	oblong
Shingle oak	*Quercus imbricaria*	60 to 70	40 to 50	slow	rounded, open
Shumard oak	*Quercus shumardii*	60 to 80	45 to 65	medium	rounded
Silky dogwood	*Cornus amomum*	6 to 10	6 to 10	medium	shrub, rounded, multistemmed
Silver linden	*Tilia tomentosa*	50 to 70	35 to 55	medium	pyramidal, densely branched
Silver maple	*Acer saccharinum*	50 to 70	30 to 50	fast	rounded, spreading
Smooth sumac	*Rhus glabra*	10 to 15	10 to 15	fast	shrub/small tree, spreading
Sourwood	*Oxydendrum arboreum*	40 to 60	30 to 35	slow	varies
Sugar maple	*Acer saccharum*	45 to 50	35 to 40	slow	rounded
Sugarberry	*Celtis laevigata*	60 to 80	60 to 80	medium	rounded, spreading branches
Swamp chestnut oak	*Quercus michauxii*	60 to 70	30 to 50	medium	rounded
Swamp white oak	*Quercus bicolor*	50 to 60	50 to 60	slow	broad, open

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
shallow lateral	native	berry, white	green	purple to red	spring	white, showy
shallow lateral	native	nutlet	green	yellow	spring before leaves	not showy
taproot	native	berry, dark blue	green	yellow to orange to red	spring	yellow, showy
taproot	native	acorn, produces some fruit litter	dark green	scarlet	spring	not showy
shallow lateral	native	samara	green	varies	spring	greenish-yellow, showy
taproot	native	nuts encased in hard-shelled husk, produces fruit litter	yellow-green	yellow to golden brown	spring with leaves	not showy
taproot	native	acorn, produces fruit litter	dark green	red to scarlet	spring with leaves	not showy
taproot	native	acorn, produces some fruit litter	dark green	yellow to red	spring with leaves	not showy
shallow lateral	native	berry, blue	dark green	green to reddish purple	spring	yellowish-white, showy
shallow lateral	not native	nutlet	dark green	green-yellow to yellow	summer	yellow, clusters, fragrant, showy
shallow lateral	native to South-east	samara	green, silvery	yellow-brown	spring	greenish, yellow to red, some showy
shallow lateral	native	berry, deep red, cluster	dark green	yellow to orange-red	summer	green-yellow, not showy
deep lateral	native	capsule, brown	dark green	yellow, red to purple	summer	white, fragrant, showy
shallow lateral	native	samara	green	yellow, orange to red	spring before leaves	yellow clusters, somewhat showy
shallow lateral	native	berry, orange-red to blue-black, produces short-term fruit litter	green	yellow	spring	not showy
lateral	native	acorn, produces fruit litter	green	brown to dark red	spring	not showy
shallow lateral	native	acorn, produces some fruit litter	dark green	yellow, red-purple	spring	not showy

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Sweet-bay magnolia	*Magnolia virginiana*	10 to 20	10 to 20	medium	shrub/small tree, loose, open
Sweetgum	*Liquidambar styraciflua*	50 to 75	40 to 65	medium	rounded
Trident maple	*Acer buergeranium*	20 to 25	20 to 25	slow	rounded, low branching, bonsai potential
Tulip tree	*Liriodendron tulipifera*	70 to 90	35 to 50	fast	oval crown
Water hickory	*Carya aquatica*	50 to 65	30 to 40	fast	oval
White ash	*Fraxinus americana*	50 to 70	40 to 60	medium	rounded
White oak	*Quercus alba*	60 to 100	50 to 90	slow	broad rounded, spreading
Willow oak	*Quercus phellos*	40 to 60	30 to 60	medium	rounded
Winterberry	*Illex verticillata*	6 to 10	6 to 10	slow	shrub, rounded, densely branched
Witch hazel	*Hammamelis virginiana*	10 to 12	12 to 18	medium	shrub, irregular, spreading branches

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
shallow lateral	native	aggregate of red berry-like fruits	dark green	yellow to yellow-brown, semi-evergreen	spring, ongoing	creamy white, fragrant, showy
lateral, taproot	native	aggregate of stiff capsules, produces fruit litter	green	yellow, orange, red, purple	spring with leaves	not showy
lateral	not native	samara	dark green	yello, orange, red	spring	not showy
shallow and deep lateral	native	cluster of woody samaras	green	yellow	spring	pale green with orange, showy
taproot	native to South-east	seeds in a thin husk, produces fruit litter	dark green	yellow to golden brown	spring before leaves	not showy
shallow lateral	native	samara	dark green	yellow to purple	spring	not showy
taproot	native	acorn, produces some fruit litter	gray green	red to scarlet	spring	not showy
shallow lateral	native	acorn, produces some fruit litter	dark green	yellow, brown, red	spring with leaves	not showy
shallow lateral	native	berry, red	green	yellow	spring	white clusters, showy
deep lateral	native	capsule	green	yellow	summer into fall	yellow, somewhat showy

Appendix C. Urban Tree Planting Budget Worksheet

1. General Site Information
Planting Site ID: _________
Planting Site Location:
Owner Name and Contact Information:
Proposed Planting Date: ________
Worksheet Completed by: _______

2. Site Preparation
Trash cleanup, invasive plant removal, or soil amendments

Type	*Number of units*	*Unit cost*	*Total cost*
		$	$
		$	$
		$	$
		Subtotal $_______________	

3. Plant Materials
Species, type, size and number

Materials	*Number*	*Unit cost*	*Total cost*
		$	$
		$	$
		$	$
		$	$
		$	$
		$	$
		$	$
		Subtotal $_______________	

4. Equipment and Supplies *Heavy equipment rental or purchase, supplies (e.g., shovels, gloves, stakes, tree shelters)*			
Type	*Number*	*Unit cost*	*Total cost*
		$ $ $ $	$ $ $ $
			Subtotal $______________

5. Maintenance *Units costs (non-labor) related to maintenance (e.g., mulch)*			
Type	*Number of units*	*Unit cost*	*Total cost*
		$ $ $ $	$ $ $ $
			Subtotal $______________

6. Labor *Includes labor for all stages of the planting project (site preparation, planting, and maintenance)*			
Type	*Number hours*	*Rate*	*Total cost*
		$ $ $ $	$ $ $ $
			Subtotal $______________
7. Total Cost			$____________________

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