



TREE SPACE DESIGN

GROWING THE TREE

OUT OF THE BOX

Casey Trees®
WASHINGTON DC

Project Summary:

From 2006 to 2008, Casey Trees convened an advisory group of arborists, urban foresters, landscape architects and horticulturists to create design standards that will enable trees in urban environments to survive and thrive, while maintaining sufficient space for pedestrian circulation. Although urban trees face numerous challenges to growth and development, the advisory group focused on providing trees with adequate soil volume for root growth and preventing soil compaction.

This report addresses these key issues by presenting (1) a matrix of recommended soil volumes based on sidewalk width and (2) design options to achieve those soil volumes. Soil volume recommendations range from 400 cubic feet to more than 1000 cubic feet based on the sidewalk width. Design methods include open soil areas, covered soil areas and root paths. Although this report addresses the design conditions in Washington, DC, the recommendations are applicable for any urban area with similar characteristics.

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Tree Space Design: Growing the Tree out of the Box

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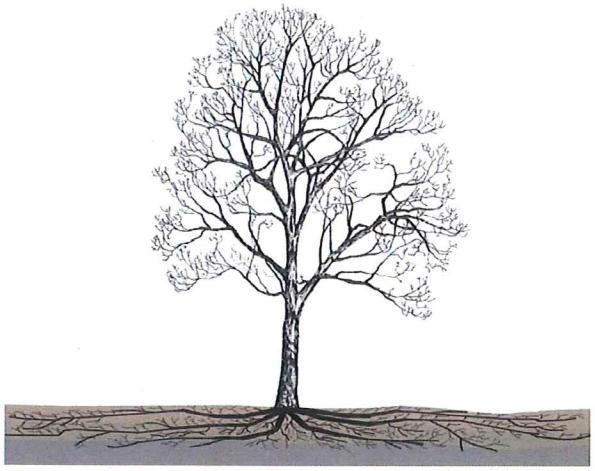
About Casey Trees:

Casey Trees is a nonprofit organization founded in 2001 to restore, enhance and protect the tree canopy of the Nation's Capital. The Planning & Design program within Casey Trees engages and collaborates with government, developers, designers and advocates to ensure that policies, plans and construction techniques protect existing trees and forests and create spaces capable of supporting large, healthy trees. For more information, visit: www.caseytrees.org/programs/planning-design.

Soil Volume: Why is it Important?

A tree's ability to grow and stay healthy is largely dependent on available rooting space. This is particularly evident in highly urbanized areas where many trees exist in small planting spaces with little available soil. Trees in this situation tend to be short-lived, and most never function as vibrant components of a city's infrastructure.

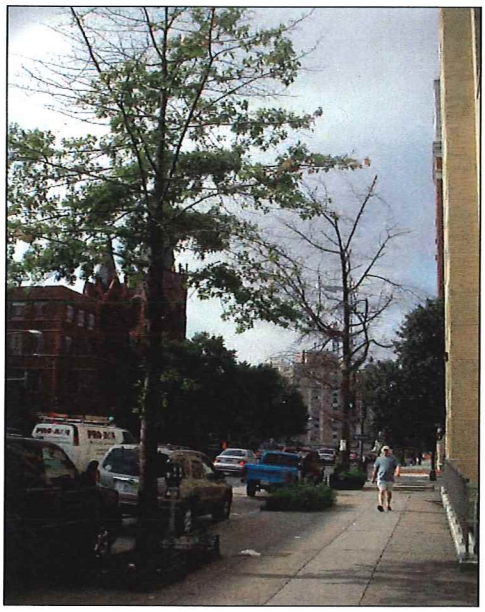


Tree roots grow far beyond the tree canopy when given the space to grow.

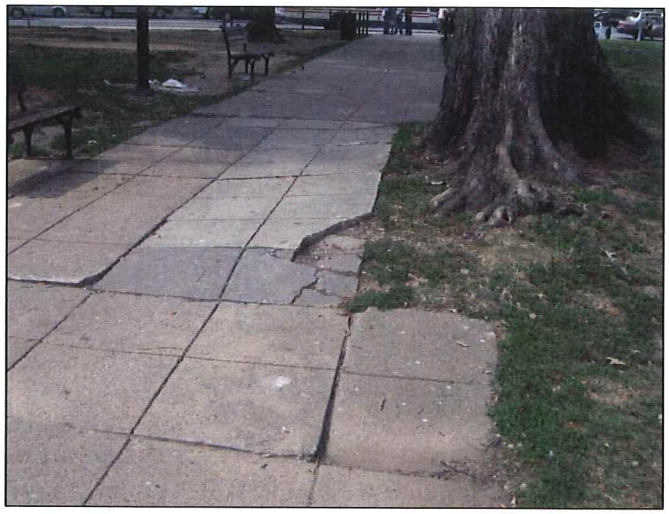
A growing tree will send roots far into the surrounding soil. In uncompacted soil, the roots of a mature tree can spread to more than twice the width of the tree's canopy. Trees get nutrients from soil, but roots also need the air and water that occupy voids between soil particles. In uncompacted soil, these voids are abundant.

In dense urban areas where soils are often compacted and covered by pavement, the soil has few voids. Tree roots cannot penetrate highly compacted soil and will not grow in soil that lacks air and water. Roots of street trees frequently grow in the space between the compacted soil and overlying pavement, where air and water are present. As these roots grow, they lift the pavement and cause sidewalk heaving.

Trees growing in typical urban "tree boxes" are usually surrounded by compacted soil. If the tree roots cannot expand into the surrounding soil, they will continue to grow in the tree box until they have filled up the available space. When the needs of the tree exceed the capacity of the soil, the health of the tree will begin to decline and it will eventually die. Trees in typical urban tree boxes rarely reach their full growth potential and cannot provide the wide range of benefits that mature, healthy trees offer.



Street trees decline after growing in confined soil areas until the roots have exceeded the capacity of the space.

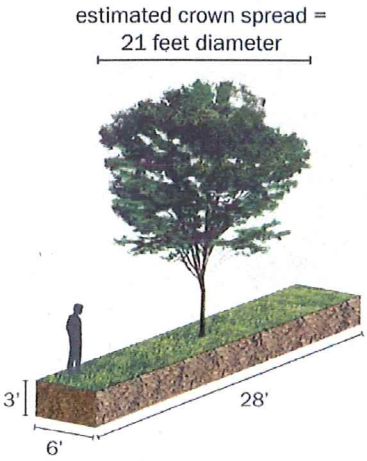


In compacted soil, tree roots often grow in the small void space just beneath the pavement, causing sidewalk heaving.

Published research suggests that trees need 1 to 2 cubic feet of soil volume for every square foot of crown area spread. A tree in a typical 4-foot by 10-foot street tree space has 120 cubic feet of available soil. When the roots cannot grow out of the box, the tree is expected to grow to a canopy spread of 10 feet before declining, as illustrated below. Tree spaces with 500 cubic feet of soil will enable trees to grow a canopy of more than 20 feet, and even larger soil volumes will yield larger trees.

This report focuses on increased soil volumes as one of the best ways to enable larger and healthier trees in cities. Soil volume recommendations range from a minimum of 400 cubic feet to more than 1000 cubic feet based on the sidewalk width.

Soil Volume = 120 cubic feet



Soil Volume = 500 cubic feet

Soil Volume = 1000 cubic feet

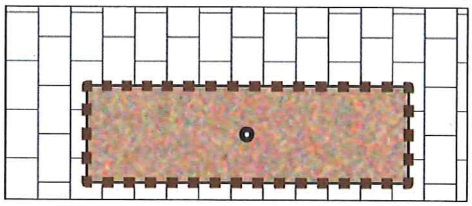
Trees on Pennsylvania Avenue NW, in Washington, DC have grown to different sizes several years after planting (left, image courtesy of Urban Horticulture Institute, Cornell University). Trees along the street have about 300 cubic feet of available soil under the pavement, while trees to the right of the sidewalk are planted in a large green space. The same trees show significant difference in trunk growth and canopy density nearly 30 years later (right).

Design Methods: How to Achieve Soil Volume

Several design methods can be used to achieve adequate soil volumes. Soil areas can be open or covered, and root paths can be used to connect soil spaces where needed.

Open Soil Area

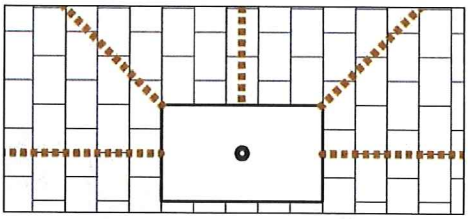
An unpaved area of soil surrounding a tree, which contains existing, new or amended soil. An open soil area may be planted or covered with mulch. Open soil areas reduce impervious surface and stormwater runoff.

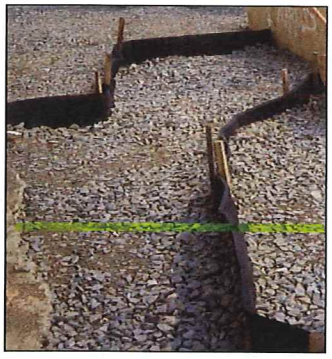


Open soil areas can be continuous or separated by pavement. Open soil areas can be planted with groundcover, ornamental plants or grass or covered with mulch as shown in the images above.

Root Paths

Constructed paths that use aeration or drainage strips to give roots a way to grow out of the tree space and under pavement in order to access better planting soils. Root paths can connect tree spaces and adjacent green spaces.

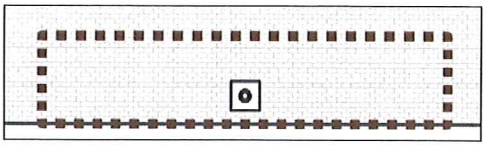




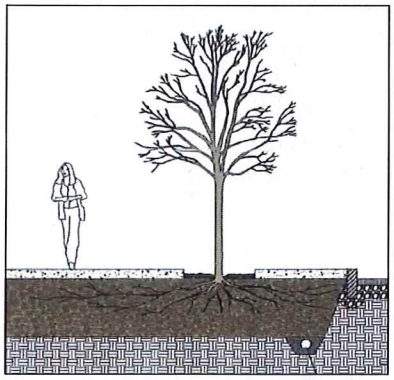
Root paths under construction, shown in ground trench (above left) and extending out from a tree space (middle, photos courtesy of James Urban). Root paths run under the pavement to connect tree spaces to landscape areas (above right).

Covered Soil Area

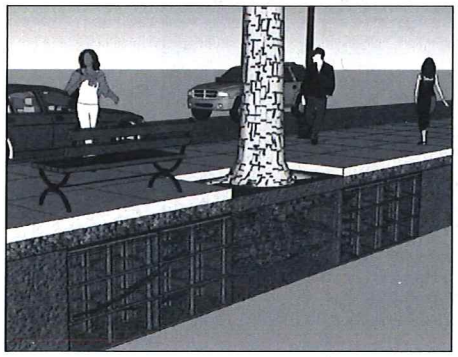
An area of soil that is under pavement and specially designed to accomodate tree root growth. Design methods include structural soil, sidewalk support and soil cells.



A variety of **pavements**, both solid and permeable, can be used to create a covered tree space. Pavers, such as granite cobbles and permeable paver blocks (shown above left and middle), placed with gaps between the stones allow water to flow to the soil below. Grates can be used as a soil covering when they are not immediately adjacent to the tree.



Structural soil, a mix of stone and soil (left), was developed to support pavement, pedestrian and vehicle loads while maintaining the void space required for tree root growth. It is placed in the area to be covered and compacted during the construction process. Tree roots grow through voids between the stones (far left, image courtesy of Urban Horticulture Institute, Cornell University).

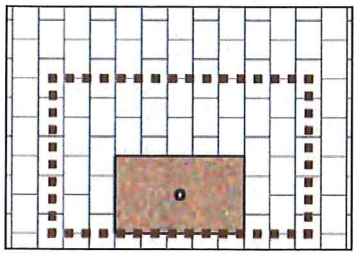


Soil cells are plastic structures designed to be filled with soil and covered with pavement. Tree roots grow in the uncompacted soil between the structural supports (left, image courtesy of Deep Root Partners, LP).

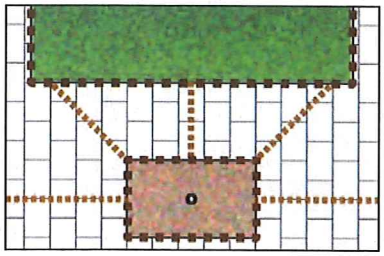
Combinations of Design Methods

Design methods can be combined in several ways to achieve greater soil volumes. Open soil areas can be used in combination with covered soil areas, and root paths can connect soil areas to green spaces. Creatively combining design methods is a way to work around utilities and other streetscape elements.

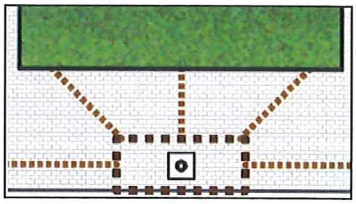
Open & Covered Soil Area



Open Soil Area Connected to Green Space



Covered Soil Area Connected to Green Space



Soil areas under suspended pavement and root paths connect trees to landscape areas on K St., NW.

Structural soil and root paths connect trees on 15th St., NW to the green space next to the building.

Trees on 8th St., SE are growing in structural soil with permeable pavers covering portions of the tree space.

Structural soil under the sidewalk expands growing space for trees on Pennsylvania Ave., NW.

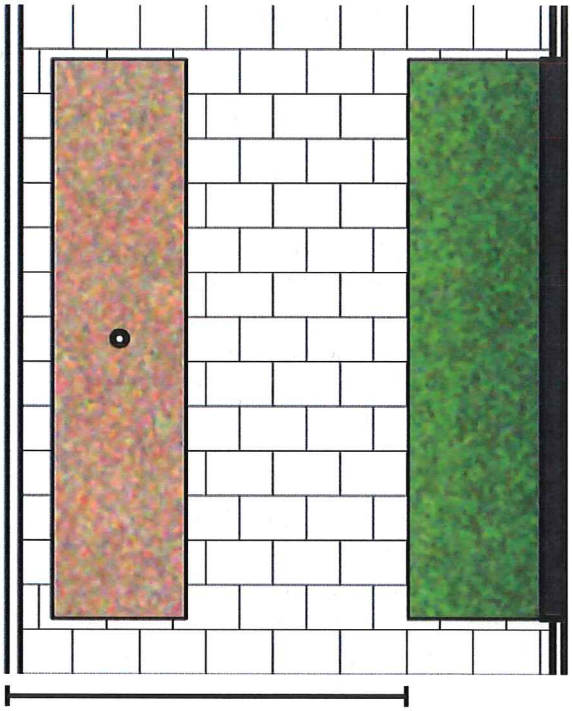
Tree Space: Defining the Terms

Curb Walk
A paved area between the curb face and the tree space that allows motorists to exit vehicles and step onto a paved area. Typical curb walk width is around 2 feet.

Tree Space
The dedicated area for planting and growing a street tree. This area may be open or covered.

Walking Space
The area of the sidewalk for pedestrian circulation. The Americans with Disabilities Act (ADA) requires a minimum 42-inch walking space width. Typical widths range from 4 feet on narrow sidewalks to 10 feet in areas with high pedestrian traffic.

Sidewalk Width =
Curb Walk + Tree Space + Walking Space
The distance from the curb face to the far edge of the walking space (usually the edge of the green space). In Washington, DC, this distance is defined in the District Department of Transportation (DDOT) Street Distribution Card.



Sidewalk Width =
Curb Walk + Tree Space + Walking Space

Green Space
A planted area between the walking space and the building line. This area can be used as additional rooting space when the tree space is connected to it. In Washington, DC, green space located in the public right-of-way is also called the "public parking" area and the width is defined in the DDOT Street Distribution Card.

Building Line
The face of the building on the street.

Design Matrix Parameters

The Tree Space Design Matrix gives recommendations for soil volume, tree space width, minimum open soil area and curb walk use. These parameters are based on sidewalk width. The matrix fields are defined below.

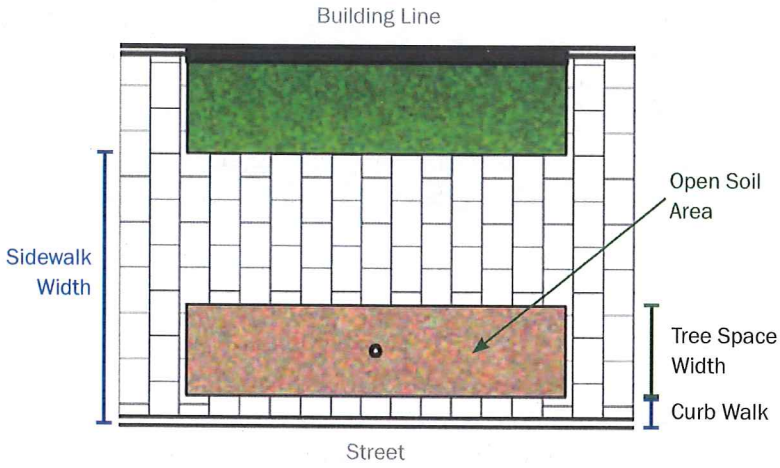
Sidewalk Width
Distance from the curb face to the far edge of the walking space (not including the green space). Includes the curb walk, tree space and walking space.

Tree Space Soil Volume
Sum total of soil volumes from each design method used for a tree. A soil depth of 3 feet is assumed in all examples in this report. Soil depths of 4 feet are encouraged where possible.

Minimum Tree Space Width
Minimum dimension for soil space within the sidewalk width.

Minimum Open Soil Area
Minimum area of the tree space that should be open and not covered by paving. Open soil areas should be planted and/or covered with mulch.

Curb Walk?
Should a curb walk be included in the tree space design? Curb walks can be easily accomodated for sidewalk widths greater than 16 feet. For sidewalk widths between 12 and 15 feet, curb walks are recommended if space allows. For sidewalk widths 11 feet and less, curb walks will likely not fit, but a covered soil area may act as a curb walk.



Tree Space Soil Volume (cubic feet) =

Open soil area (length x width x depth) (feet) +

Covered soil area (length x width x depth) (feet) +

Root path length (feet) x 0.25 +

Green space area (length x width x depth) (feet)

Include only applicable soil areas and design methods for each tree.

Tree Space Design Matrix

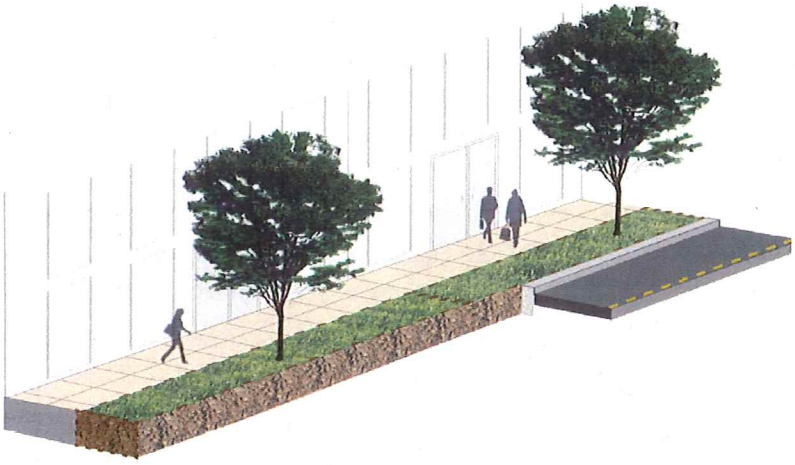
The recommended tree space soil volume is determined by the sidewalk width. Design methods, such as open soil areas, covered soil areas and root paths may be combined to meet the recommended soil volume. Examples on the following pages show the use of different design methods to achieve a variety of soil volumes for several different sidewalk widths.

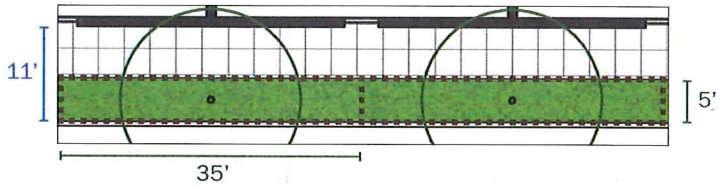
Sidewalk Width (feet)	Tree Space Soil Volume (cubic feet)	Minimum Tree Space Width* (feet)	Minimum Open Soil Area* (square feet)	Curb Walk?
8	400	4	cover ok	no
9	400	4	cover ok	no
10	500	4	cover ok	no
11	500	4	cover ok	no
12	600	4	cover ok	recommended
13	600	4	cover ok	recommended
14	700	4	70	recommended
15	700	5	75	recommended
16	800	5	80	yes
17	800	6	85	yes
18	900	6	90	yes
19	900	7	100	yes
20	1000	8	110	yes
21	1000	8	120	yes
22	1100	8	130	yes
23 and greater	= sidewalk width x 50	8	= sidewalk width x 7	yes

*For sidewalk widths less than 14 feet in areas with high pedestrian traffic, the soil area may be almost completely covered. Where the tree space is covered, a minimum tree opening of 2 feet by 2 feet is recommended for flexible paving that can be removed (e.g. pavers set on sand or soil). A minimum tree opening of 4 feet by 4 feet is recommended for rigid paving (e.g. concrete). Tree grates are not recommended due to the widespread occurance of trees growing into grates from lack of grate maintenance.

Design Method Examples: All Open Soil Area

Sidewalk width: **11** feet
Soil volume: **500** cubic feet
Tree space width: **5** feet
Open soil area: **175** square feet
Walking space: **6** feet

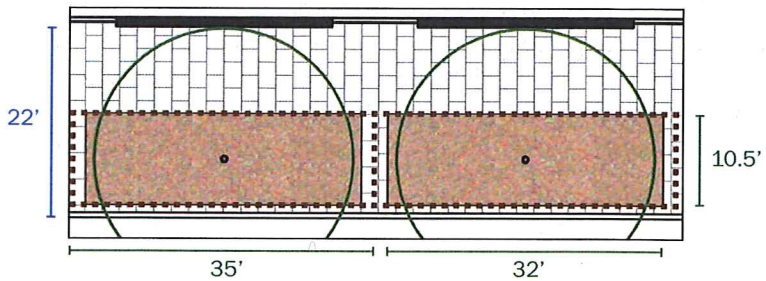




Soil volume =
Open soil area (35' x 5' x 3')

Design Method Example: Open & Covered Soil Areas

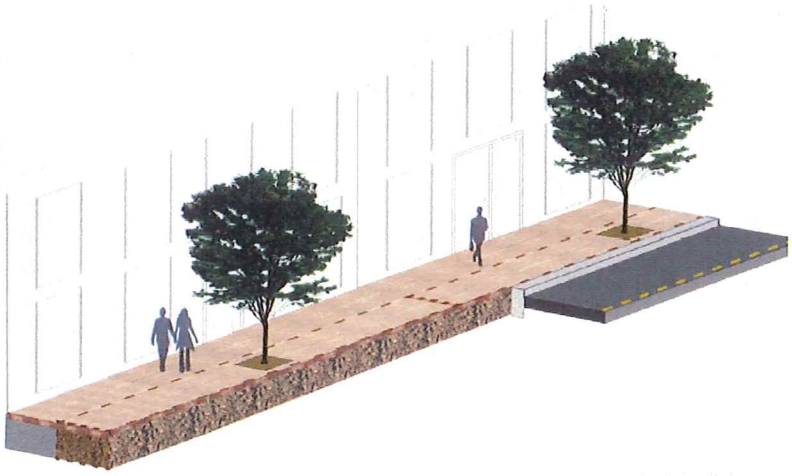
Sidewalk width: **22** feet
Soil volume: **1100** cubic feet
Tree space width: **10 ½** feet
Open soil area: **336** square feet
Walking space: **10** feet
Curb walk: **1½** feet

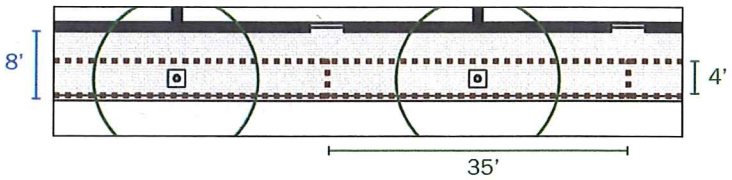


Soil volume =
Open soil area (32' x 10.5' x 3') +
Covered soil area (3' x 10.5' x 3')

Design Method Examples: All Covered Soil Area

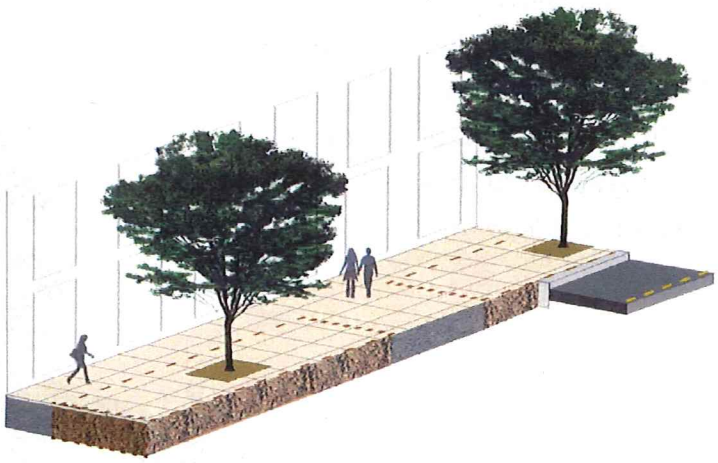
Sidewalk width: **8** feet
Soil volume: **400** cubic feet
Tree space width: **4** feet (covered)
Walking space: **4 ½ - 8** feet

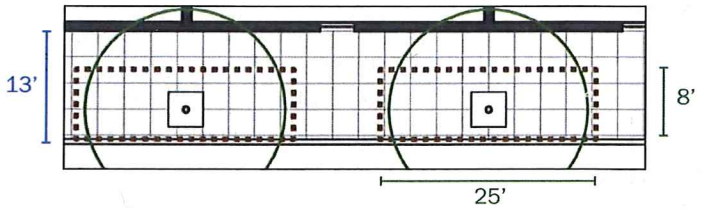




Soil volume =
Covered soil area (35' x 4' x 3')

Sidewalk width: **13** feet
Soil volume: **600** cubic feet
Tree space width: **8** feet (covered)
Walking space: **7 - 13** feet

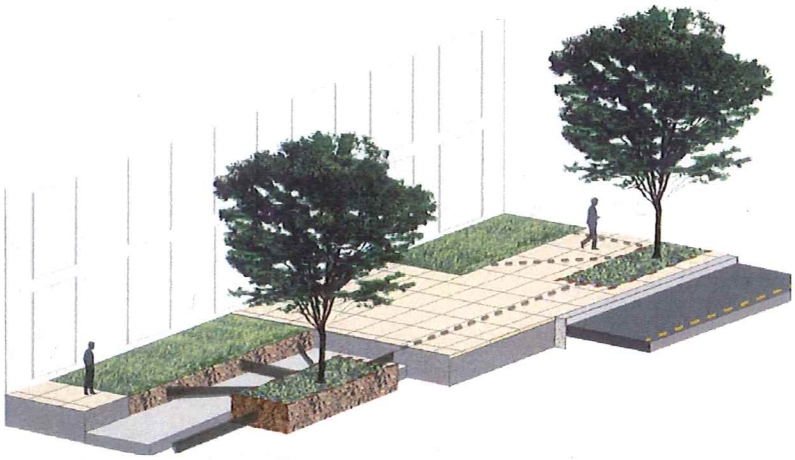


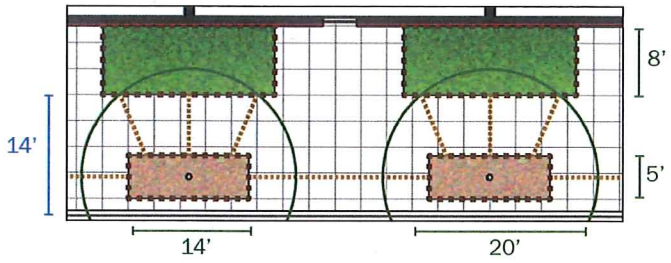


Soil volume =
Covered soil area (25' x 8' x 3')

Design Method Examples: Open Soil Area Connected to Green Space

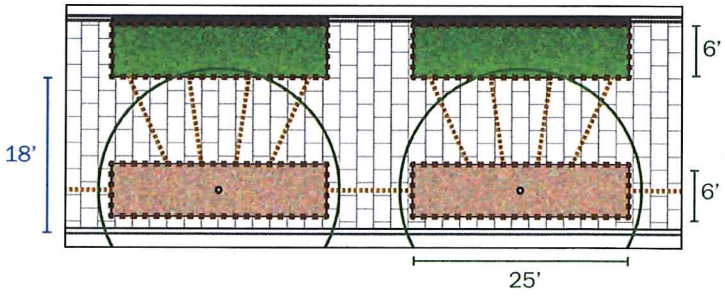
Sidewalk width: **14** feet
Soil volume: **700** cubic feet
Tree space width: **5** feet
Open soil area: **70** square feet
Walking space: **7** feet
Curb walk: **2** feet





Soil volume =
Open soil area (14' x 5' x 3') +
Root paths (43' x .25') +
Green space (20' x 8' x 3')

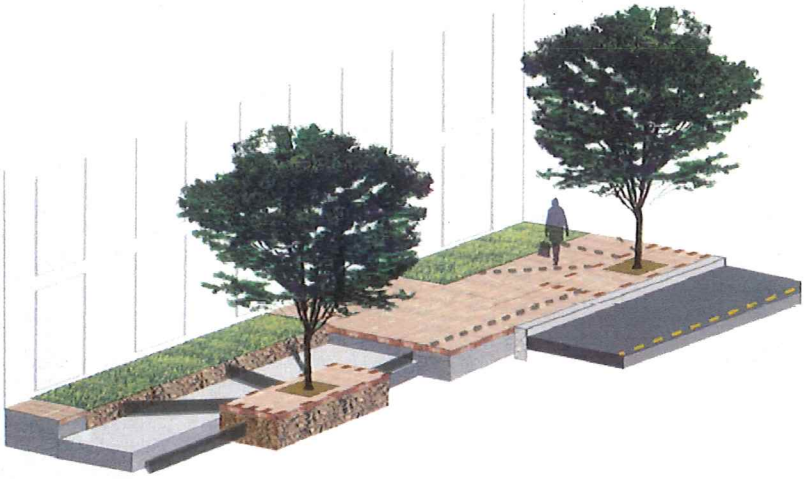
Sidewalk width: **18** feet
Soil volume: **900** cubic feet
Tree space width: **6** feet
Open soil area: **150** square feet
Walking space: **10** feet
Curb walk: **2** feet

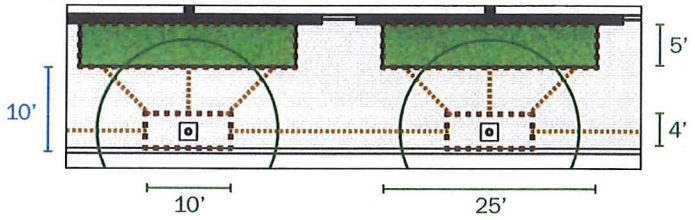


Soil volume =
Open soil area (25' x 6' x 3') +
Root paths (52' x .25') +
Green space (25' x 6' x 3')

Design Method Example: Covered Soil Area Connected to Green Space

Sidewalk width: **10** feet
Soil volume: **500** cubic feet
Tree space width: **4** feet
Walking space: **6 ½ - 10** feet

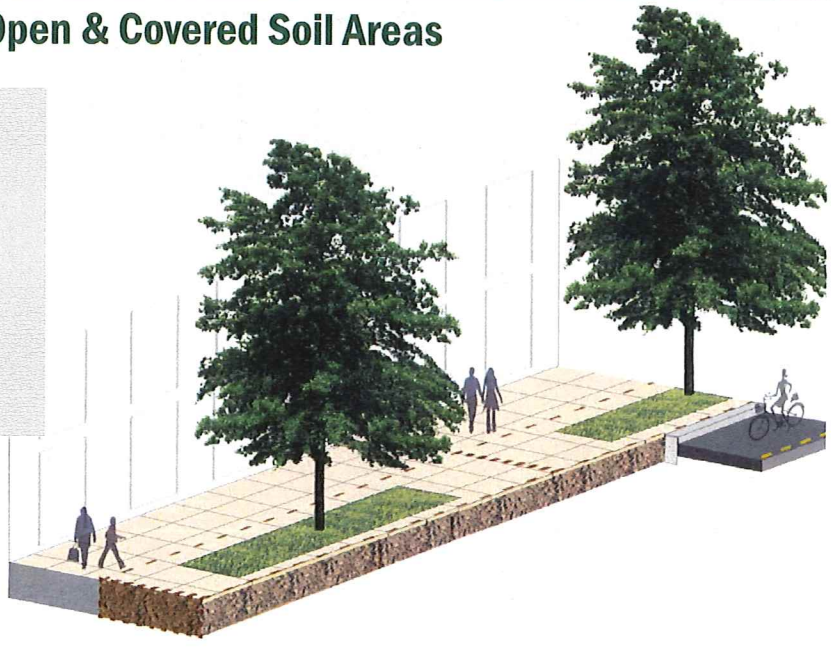


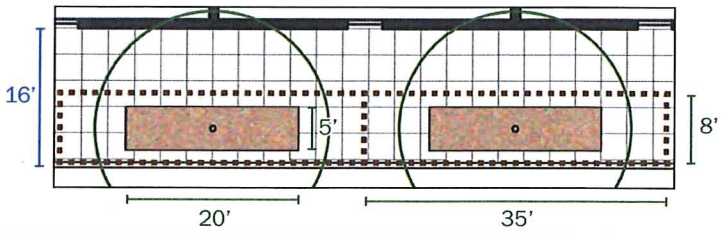


Soil volume =
Covered soil area (10' x 4' x 3') +
Root paths (45' x .25') +
Green space (25' x 5' x 3')

Design Method Example: Open & Covered Soil Areas

Sidewalk width: **16** feet
Soil volume: **800** cubic feet
Tree space width: **5** feet (open)
8 feet (total)
Open soil area: **100** square feet
Walking space: **9** feet
Curb walk: **2** feet

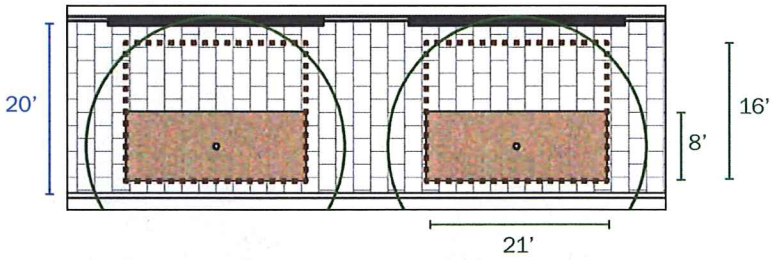




Soil Volume =
Total Soil Area (35' x 8' x 3')

Design Method Example: Open & Covered Soil Areas

Sidewalk: **20** feet
Soil volume: **1000** cubic feet
Tree Space Width: **8** feet (open)
16 feet (total)
Open Soil Area: **168** square feet
Walking Space: **10** feet
Curb Walk: **2** feet



Soil Volume =
Total Soil Area (21' x 16' x 3')

Conclusion

Trees can be a vibrant part of the urban environment, providing numerous environmental, economic and social benefits. Yet the ability of trees to grow and thrive in developed areas is limited by the availability and condition of rooting space. The widespread application of the soil volume recommendations and root-friendly design methods in this report will yield healthier, longer-lived urban trees.

The Tree Space Design Matrix is intended for inclusion in design standards. Casey Trees also recommends use of the matrix and design methods for individual projects. Creating spaces that provide trees with adequate soil volume will not only ensure better tree health, but will minimize damage to, and extend the life of, paved surfaces.

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Tree space standards in the Mt. Vernon Triangle area have led to larger open tree areas and the use of curb walks.


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