SMITHSONIAN GARDENS
SOILS MANAGEMENT PLAN

Summary of Approach

Smithsonian Gardens is a living museum and vital public garden within the Smithsonian Institution, the world's largest museum, education, and research complex. The collective health of its plants is vital to the success of the gardens. Currently, these plants are at risk due to challenges from high public use pressures, regular construction, high maintenance soil design practices and the present climate crisis, which are exacting upon long-term sustained plant health. The most critical variable to protect plants from these risks and enable resilient plant growth is proper care for the soil. Healthy soil = healthy plants.

Taking soil samples from over 50 locations within Smithsonian Gardens, along with historical research of topography changes and construction, there is a clear narrative of imported soil of various soil texture types through the first 175 years of development with different levels of success. The locally imported and naturally occurring loam soils in the first 100 years of Smithsonian Institution's development have provided stability for optimal plant growth and resilience to adverse impacts. More recent imported soils, many responding to the landscape industry-driven trend towards an artificially mixed 'universal' planting soil, have been more irregular in their resiliency and success. Some of these high sand content mixes have lead to nutrient leaching, low moisture retention, and plant stress only a few years after installation.

In addition to the plant health concerns, the complexity of maintaining a patchwork of various textured planting soils demands excessive maintenance resources beyond what can be successfully managed.

The Soil Management Plan, therefore, provides a clear framework for managing existing soils, identifying and remediating poorly functioning soils, and defining requirements for consistent, contextually appropriate soil types and installation methods on all future projects. All of which are predicated on the foundational recommendation for returning to the more successful naturally-occurring, unscreened soils - defined as Clay Loam, Loam, Sandy Clay Loam, and Sandy Loam - with defined ranges for percent sand, silt, and clay appropriate to the region. The following four points outline the scope of this Plan:

- How to assess soil health and concerns;
- Prioritization and phasing of planting soil remediation;
- Managing, protecting, and rebuilding soils for long-term resilience;
- Specifications and best practice details for soil installation on future projects

The development of this Plan is the result of a historical evaluation of soils along the National Mall, in-depth field observations, soil testing, and regular consultation with Smithsonian Gardens landscape architects, arborists, and horticulturalists. In the end the goal is to achieve consistent and healthy soils, those that contain a balanced physical, chemical and biological condition to give life to healthy plants for future generations of visitors at Smithsonian Gardens to enjoy.

Smithsonian Gardens

gardens.si.edu

SMITHSONIAN GARDENS
SOILS MANAGEMENT PLAN

Client Team

SMITHSONIAN GARDENS

Marisa Scalera, Landscape Architect
Jake Hendee, Arborist
Sarah Hedean, Manager - Living Collections
Joy Columbus, Director
Jeff Schneider, Deputy Director and Grounds Manager
Eric Calhoun, Supervisory Horticulturalist
James Gagliardi, Supervisory Horticulturalist
Melinda Whicher, Supervisory Horticulturalist

Design Team

WOLF JOSEY LANDSCAPE ARCHITECTS

Paul Josey, Principal, PLA
Mary Wolf, Principal, PLA
Dustin Smith, Associate, PLA

OLSSON

Ted Hartsig, Soil Scientist

Soils Management Plan

September 3, 2021

Final Draft

This project received Federal support from the Smithsonian ***Collections Care Initiative (CCI)****, administered by the National Collections Program*

Cover Photo
© Smithsonian Gardens

CONTENTS


© Wolf Josey

INTRODUCTION

"The soil is the great connector of lives, the source and destination of all. It is the healer and restorer and resurrector, by which disease passes into health, age into youth, death into life. Without proper care for it we can have no community, because without proper care for it we can have no life." **-Wendell Berry, *The Unsettling of America: Culture and Agriculture***

Project Purpose

Smithsonian Gardens is a living museum and vital public garden within the Smithsonian Institution, the world's largest museum, education, and research complex. Its gardens surround the Smithsonian museums, and the soils that support them reflect the natural heritage of the United States and the regional area. The influence of national firms in the design of landscapes for the Smithsonian Institution over the course of more than 150 years, and because each respective firm or era has often held a different attitude towards soil design, led to garden evolution with less regionally-specific soil approaches and a lack of soil type consistency. The complexity of maintaining various engineered and non-native planting soils has tasked Smithsonian Gardens' institutional knowledge and resources beyond what can be successfully managed.

The benefits of resilient, regionally native planting soils have been neglected by a landscape industry-driven submission to a 'universal' planting soil, commonly referred to as sand-based soil. The perceived one-soil-fits-all notion is quickly cast in doubt when the perceived benefit of these sand-based soils - resistance to compaction - is eclipsed by the excessive inputs (irrigation and fertilization) required to support healthy plant growth. Given the inability to hold nutrients and moisture, coupled with increasingly severe weather such as long droughts and high temperatures, sand-based soils are not sustainable nor healthy, and they will require increased maintenance and monetary support in the attempt to maintain the vegetation planted on them, especially as potential climatic trends become more severe.

Regional loam-based soils, those native to the Piedmont region in D.C. and Virginia, and once common in planting design before the advent of the National Mall as we know it today, are best suited for creating healthy, biologically dynamic soils. They have better nutrient and water holding capacity and rely less on irrigation and fertilization. They also support critical soil microbial communities that are essential for healthy plant growth and sustainability. The analysis of soil and plant health presented in this document has revealed the loam-based soils from the first 100 years, between the early Smithsonian Pleasure Grounds and the 1930's grading of today's Mall, have provided long-term stability for optimal plant growth and resilience to adverse impact.

This Plan recommends the use of unscreened naturally formed loam soils sourced from the Piedmont region in Virginia and local parts of Maryland. These soils typically have characteristics (soil clay content, structural stability, and native organic matter content) that favor stable aggregate structure formation, drainage, and compaction resistance. The work that follows revolves around this foundational declaration.

Scope of Work and Methodologies

The Smithsonian Gardens Soils Management Plan provides a strategic framework for managing existing soils, identifying and remediating poorly functioning soils, and defines the contextually appropriate requirements for new-project soil types and installation. The following four points outline the scope of this Plan:

1. How to assess and determine soil condition and needs;

2. Prioritization and phasing of remedial soil work and best practice techniques;

3. Managing, preserving, and rebuilding soils for long-term resilience;

4. Specifications and best practice details for soil installation for new construction projects (**Appendix F**).

The development of this Plan is the result of in-depth field observations, soil testing, and regular input from Smithsonian Gardens staff and horticulturalists. The recommendations outlined herein are project-proven. They have been implemented, tested, and amended on real world projects throughout Virginia and Washington D.C. that have demonstrated success.

Study Boundaries

The study area comprises all landscapes and gardens associated with the eleven Smithsonian Institution museums along the National Mall in Washington D.C., plus the Donald W. Reynolds Center located at F Street and 7th Street. The land area of these twelve landscapes totals approximately sixty acres, of which twenty-one acres is lawn or planted garden space managed by Smithsonian Gardens.

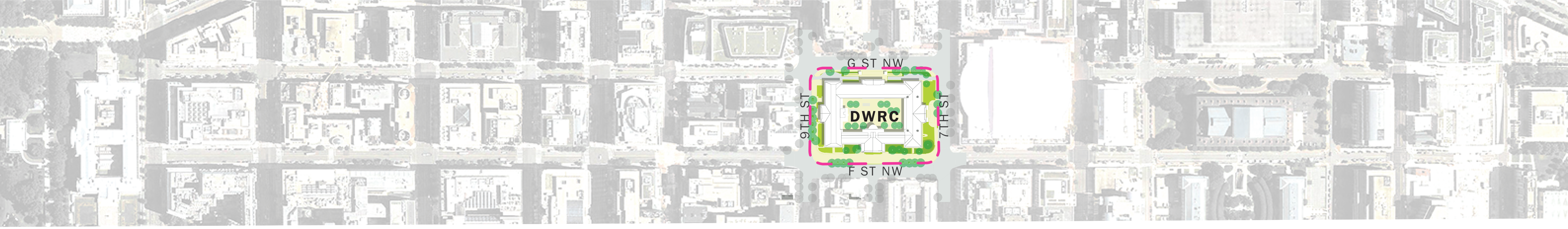
Process and Consultation

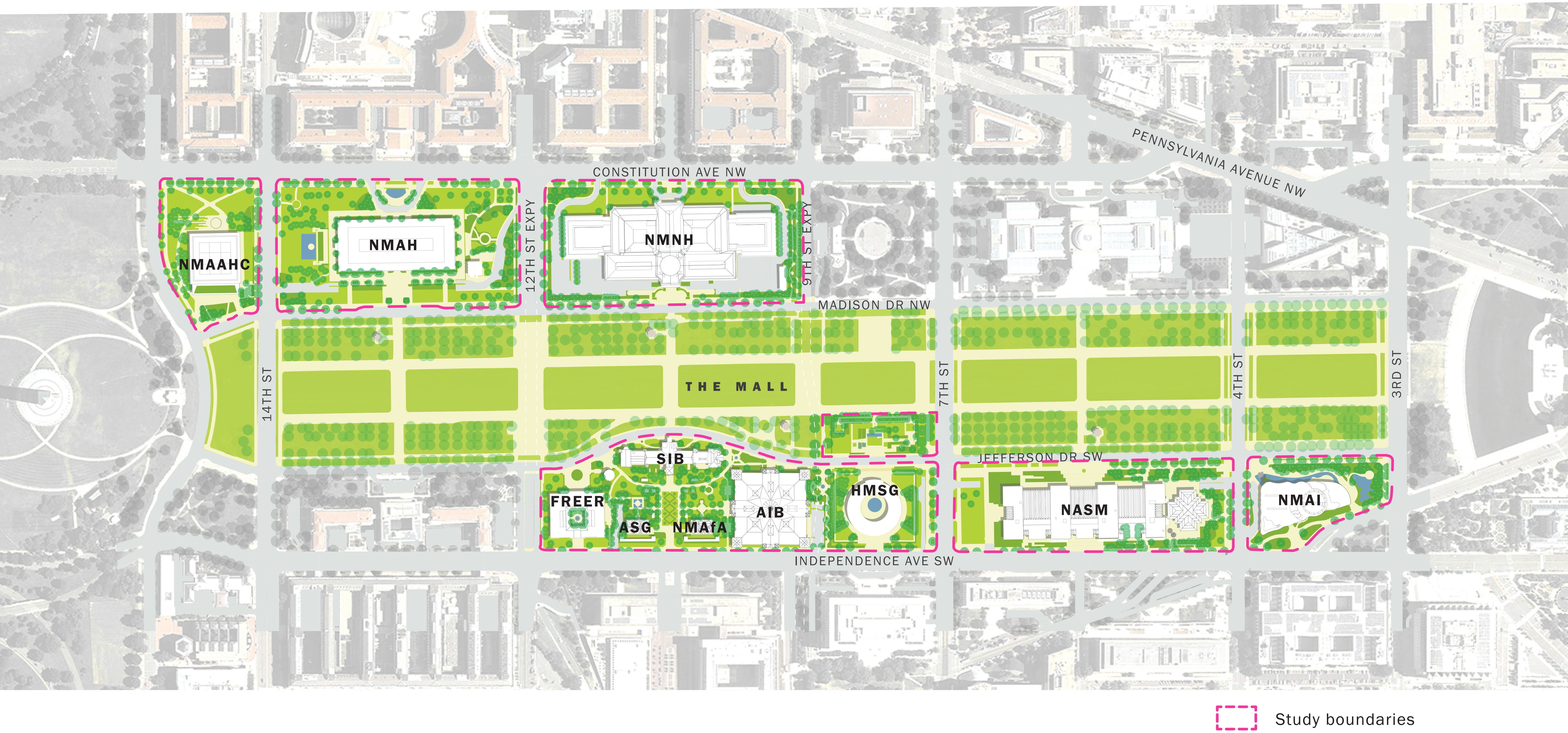
The consultant team completed an in-depth analysis of the study area's existing soils and plant health. Multiple days of soil sampling, compaction testing, and laboratory testing was completed to achieve an understanding of current planting soil types, their health and productivity, and impacts from regular and high-use pedestrian circulation and construction projects. Smithsonain Gardens staff provided invaluable knowledge on the history of museum sites, visitation, events, and most importantly, the processes and inputs required to keep the gardens beautiful and functioning everyday, year-around.

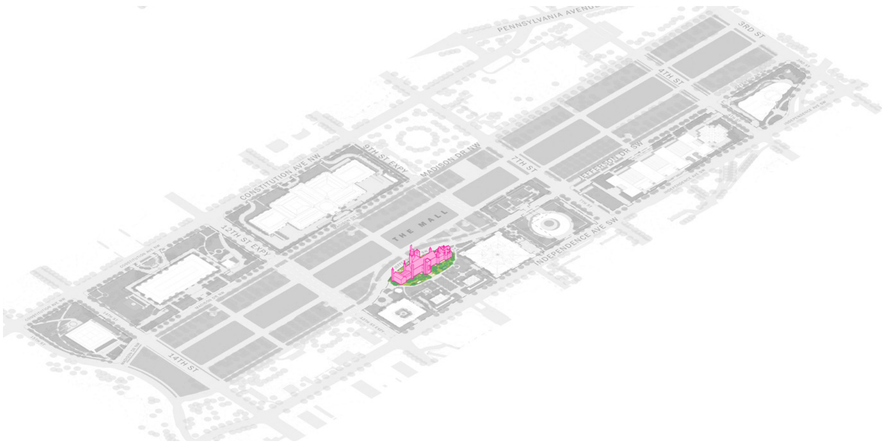
Museum Acronyms

NMAAHC
National Museum of African American History and Culture
NMAH
National Museum of American History
NMNH
National Museum of Natural History
FREER
Freer Gallery of Art
SIB
Smithsonian Institution Building - "the Castle"
ASG
Arthur M. Sackler Gallery
NMAfA
National Museum of African Art
AIB
Arts and Industries Building
HMSG
Hirshhorn Museum and Sculpture Garden
NASM
National Air and Space Museum
NMAI
National Museum of the American Indian
DWRC
Donald W. Reynolds Center

GARDENS
Victory Garden at **NMAH**
Urban Bird Habitat at **NMNH**
Pollinator Garden at **NMNH**
Kogod Garden at **DWRC**
Enid A. Haupt Garden
Mary Livingston Ripley Garden
Folger Rose Garden

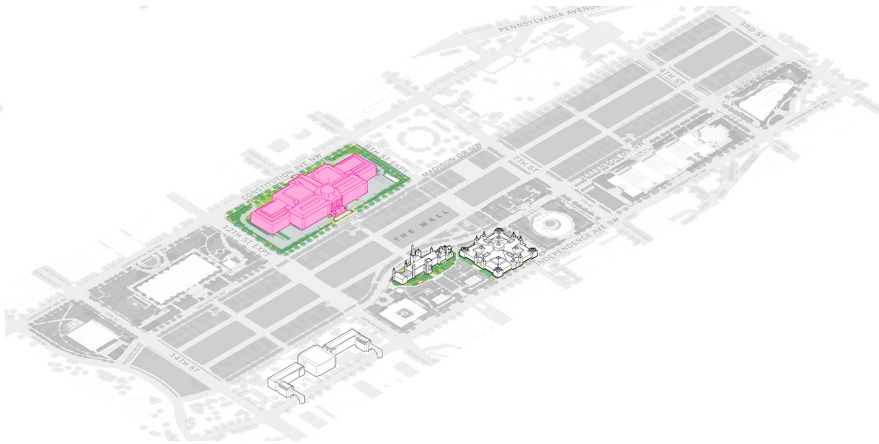

G ST NW
9TH ST
7TH ST
DWRC
F ST NW
0'
200'
400'
800


PENNSYLVANIA AVENUE NW
CONSTITUTION AVE NW
NMAAHC
NMAH
12TH ST EXPY
NMNH
9TH ST EXPY
MADISON DR NW
14TH ST
THE MALL
7TH ST
4TH ST
3RD ST
JEFFERSON DR SW
SIB
FREER
ASG
NMAfA
AIB
HMSG
NASM
NMAI
INDEPENDENCE AVE SW
Study boundaries



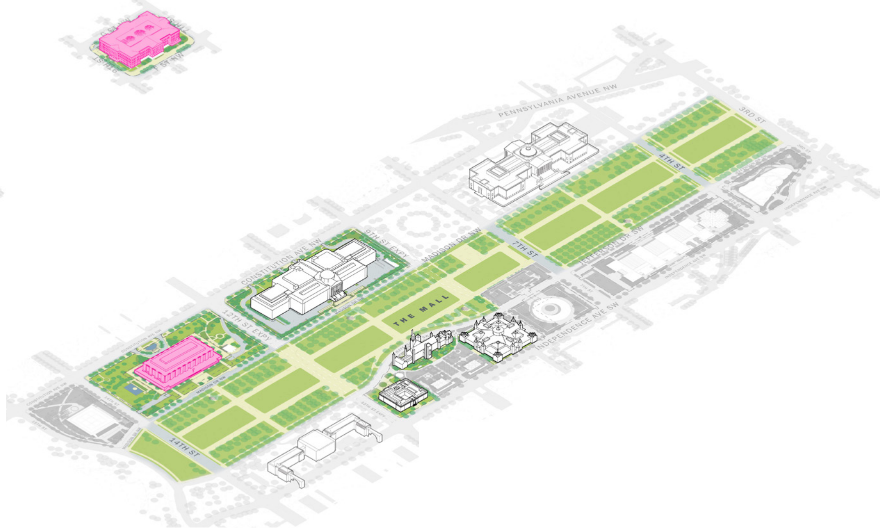
1855 | Smithsonian Institution Building (the Castle)

1881 | Arts and Industries Building

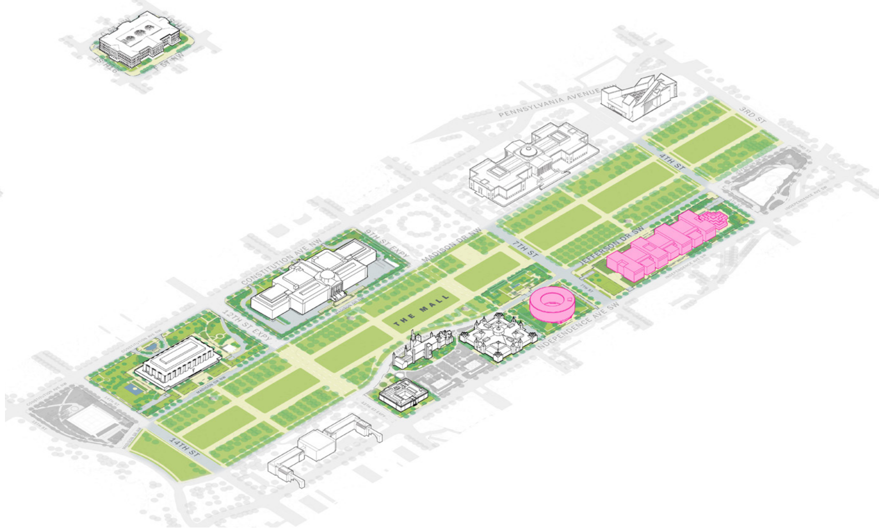


1910 | National Museum of Natural History

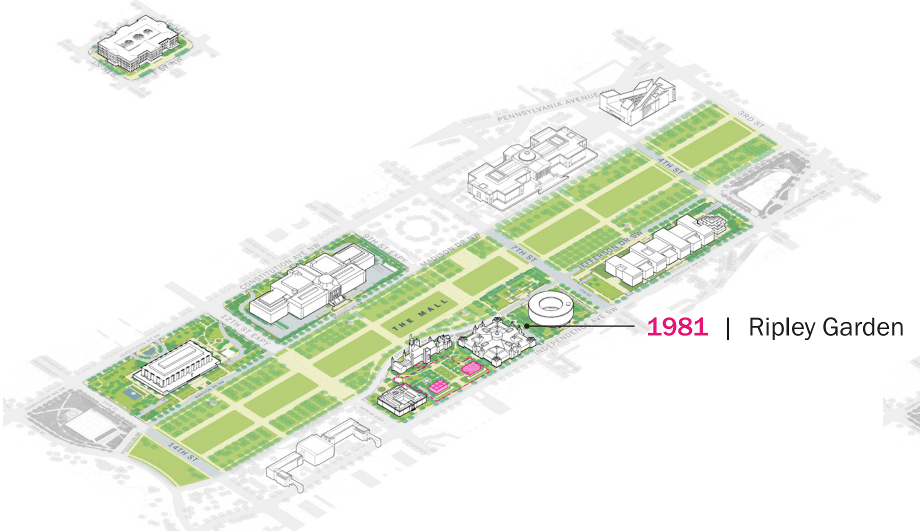
1923 | Freer Gallery of Art



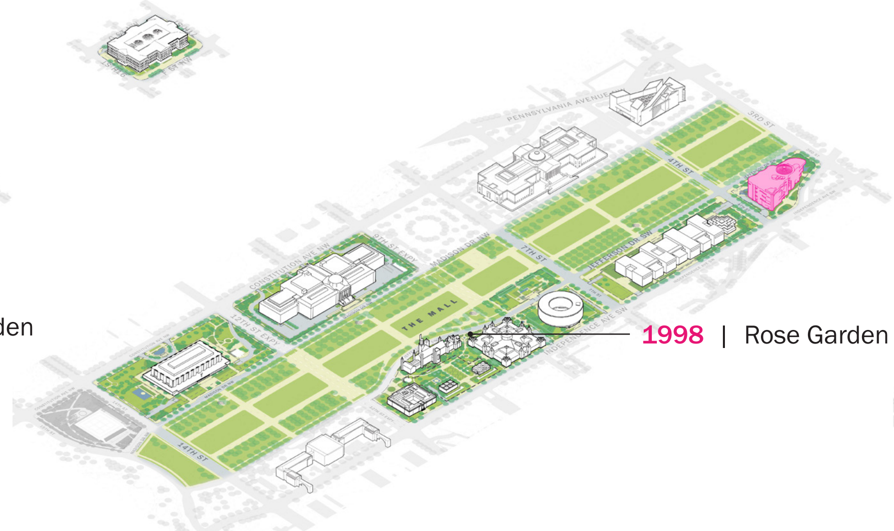
1958 | Donald W. Reynolds Center (transferred to SI)
1963 | National Museum of American History



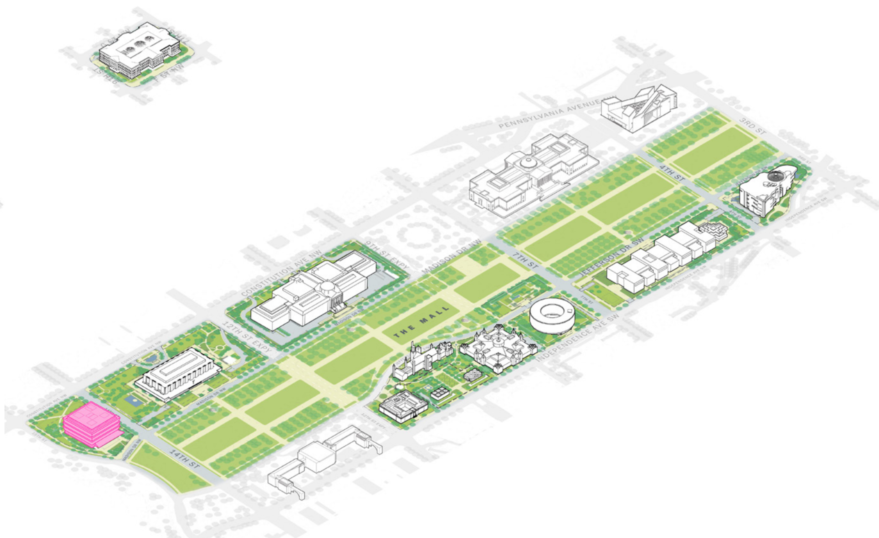
1974 | Hirshhorn Museum and Sculpture Garden
1976 | National Air and Space Museum



1984 - 1987 | Quadrangle Complex
Enid A. Haupt Garden
Arthur M. Sackler Gallery
National Musuem of African Art



2004 | National Museum of the American Indian



2016 | National Museum of African American History and Culture

A Note on Garden Development

Established in 1972 by Secretary S. Dillon Ripley, the Smithsonian Gardens (then recognized as the Office of Horticulture) institutionalized the role of horticultural education and research as part of the larger visitor experience. Its creation aligned with a decade of rapid museum construction along the National Mall, beginning with the Hirshhorn Museum and Sculpture Garden in 1974. Smithsonian Gardens' input in the design of museum landscapes, and their role as caretakers and stewards following construction projects, has increased exponentially. The challenge, and impetus for this Plan, has been keeping up with and adapting to current research and best practices in landscape planting design, particularly soils.

Left

Timeline of Smithsonian museum construction.

Overview of Final Deliverables

The following documents have been created for the use of Smithsonian Gardens:

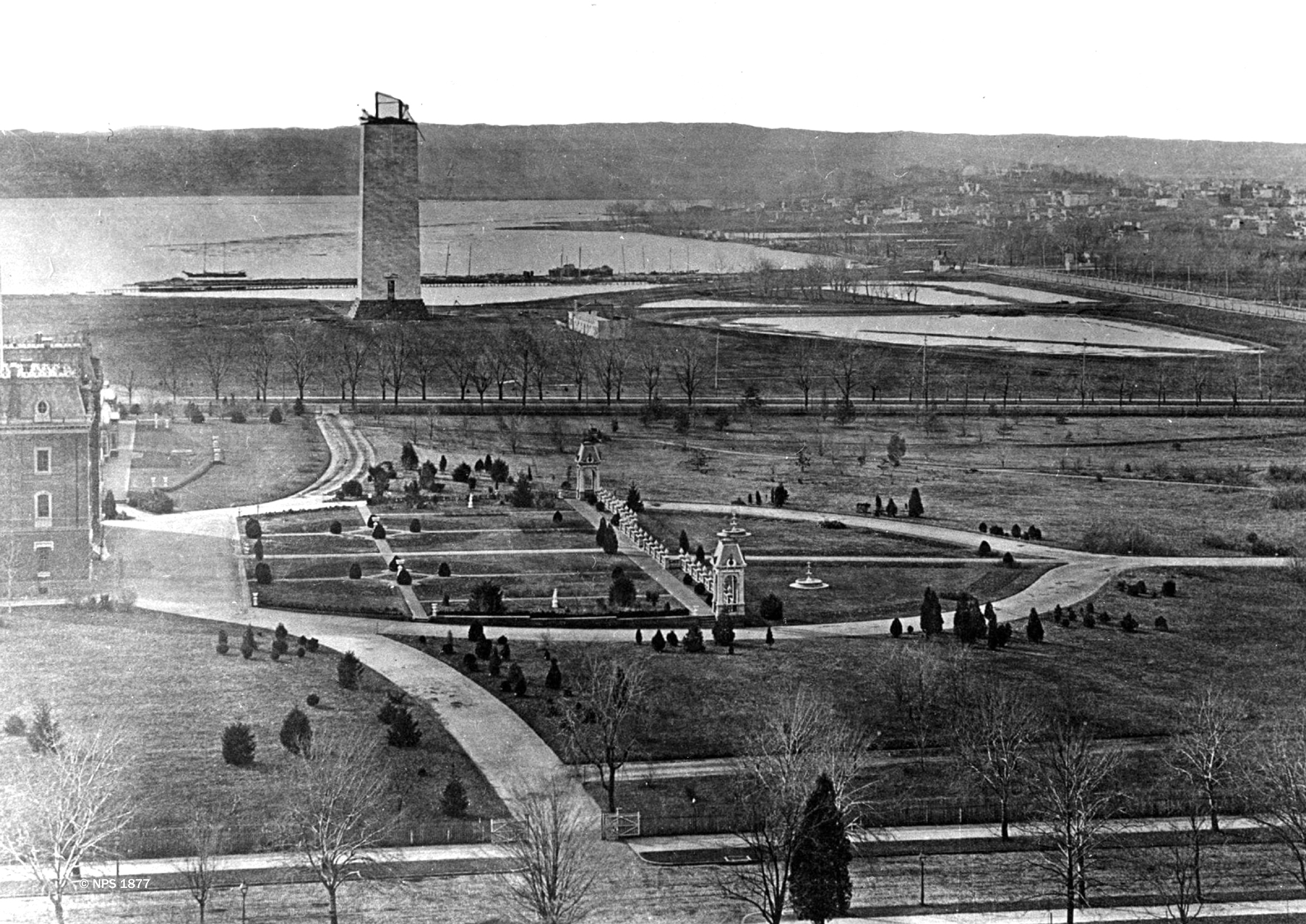
1. **Soils Management Plan Book;**
   a. History and Evolution of SG Soils
   b. Soils Management Plan
   c. Appendices
      i. Smithsonian Gardens overview
      ii. Maintenance health analysis maintenance evaluation
      iii. Soil sampling testing data
      iv. Existing soil conditions

2. **Soil Resources: Amendments and Tools**

3. **New Project Specifications and Details**
   a. Planting Soil Spec - Short
   b. Planting and Lawn Soil Spec - Full
   c. Soil installation details
   e. New projects staff FAQ sheet

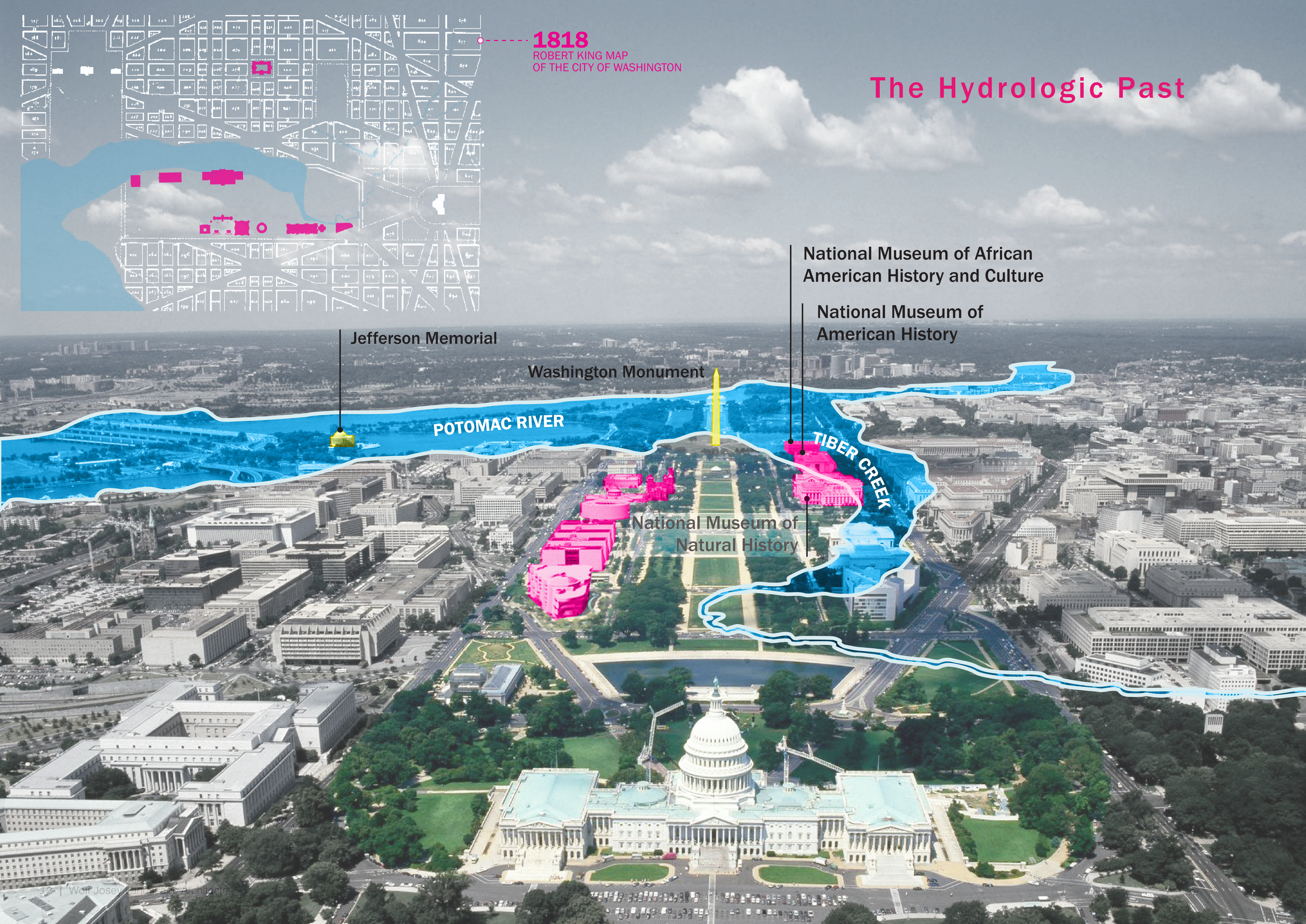
4. **Small Projects Narrative for Soil Installation and Restoration (>500 sf)**
   a. Soil remediation details

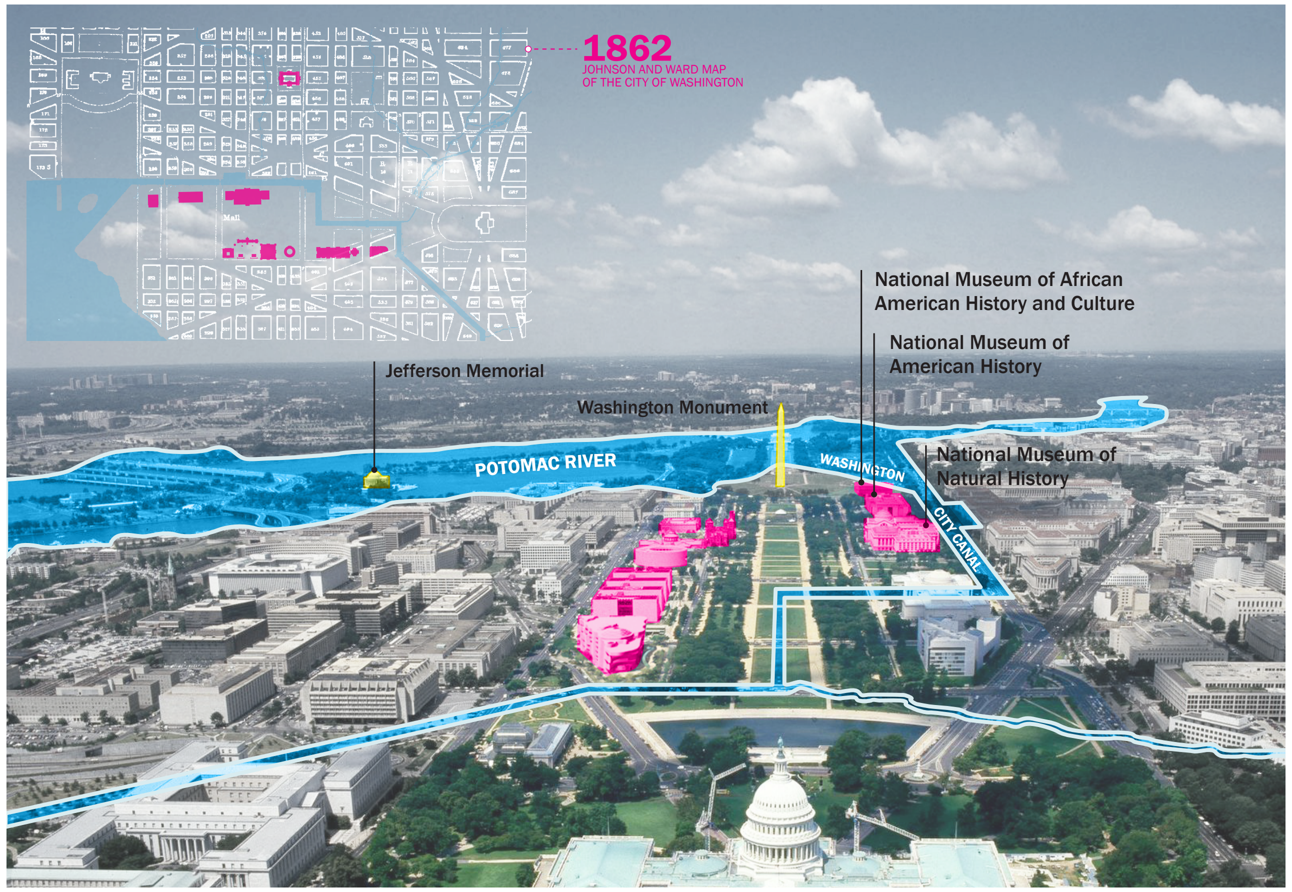
5. **Site Protection Specification Updates and Details**
   a. Tree CRZ and SRP Identification


© NPS 1877

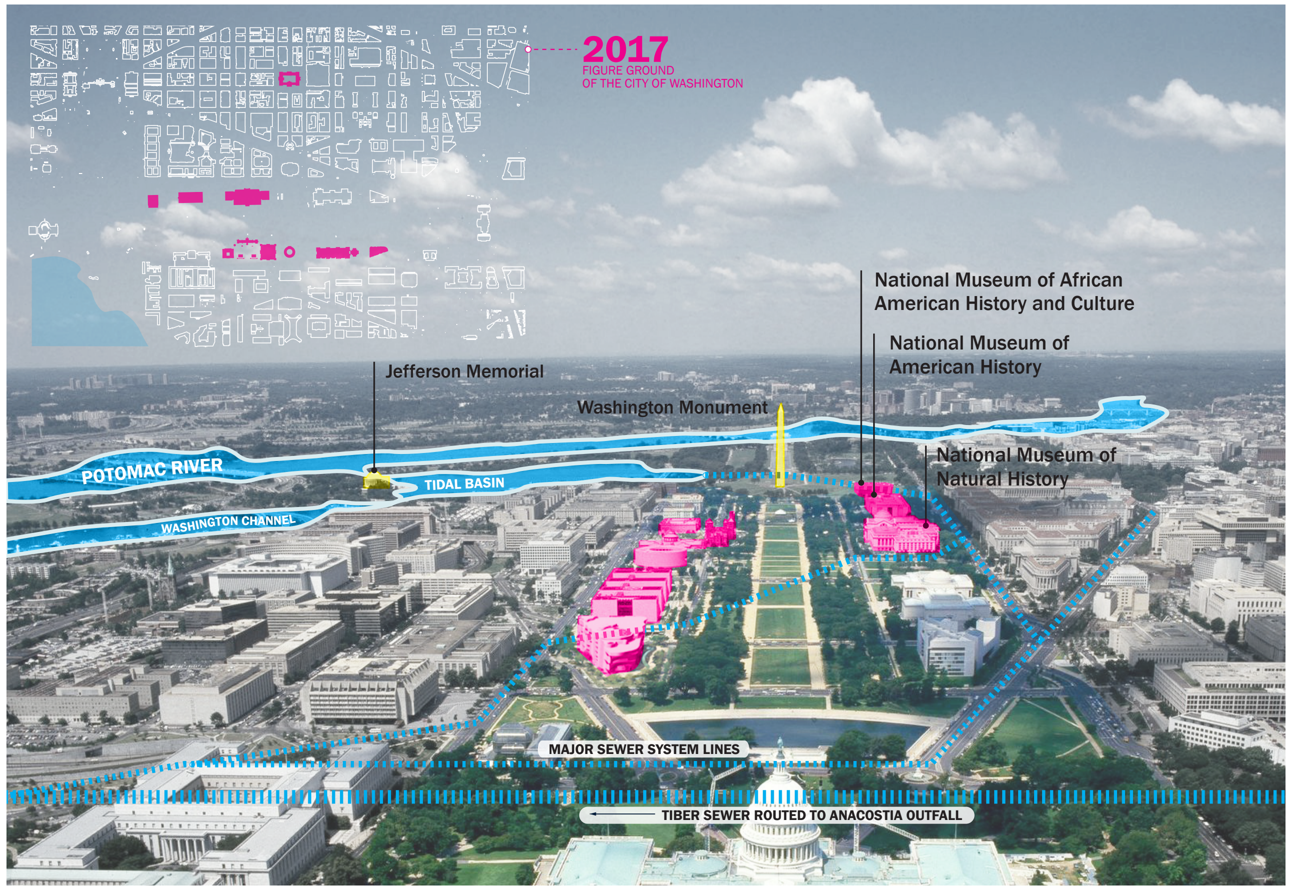
01

HISTORY AND EVOLUTION OF SMITHSONIAN GARDEN SOILS


The Hydrologic Past
1818
ROBERT KING MAP
OF THE CITY OF WASHINGTON
Jefferson Memorial
Washington Monument
National Museum of African American History and Culture
National Museum of American History
National Museum of Natural History
POTOMAC RIVER
TIBER CREEK



WASHINGTON CITY CANAL | Construction completed 1815; subsequently abandoned and filled in 1872.



MAJOR SEWER LINES | Tiber Creek now flow through a DC Water maintained tunnel

The Borrowed Soils of the Smithsonian

Hydrology Then and Now

Before Pierre Charles L'Enfant and the advent of Washington D.C. as the Capital city, the Tiber Creek once defined the northern edge of the modern-day Mall and had collected almost half of the District's overland drainage at that time. The bucolic scene of the Tiber's abundant plants and wildlife is historically depicted in Peter Waddell's painting *Tiber Creek: The Bathers*.

L'Enfant's 1791 plan was quick to transform the Tiber into a canal system that linked the Potomac and Anacostia Rivers through the city - primarily for stormwater management and the transportation of goods. The immense earthwork project, completed in sections between 1810 and 1815, became known as the Washington City Canal. Tidal flow from both the Potomac and Anacostia caused heavy sedimentation and the canal system was abandoned and filled in by 1872. Today's Tiber Creek now flows through a series of large trunk sewers maintained by DC Water.

Once reaching 700 to 800 feet at its mouth, its unsurprising that the former grounds of the Tiber - including the high water table - present soil drainage and flooding concerns for the National Museum of Natural History, the National Museum of American History, and the National Museum of African American History and Culture, which are sited directly atop its south banks.

Left

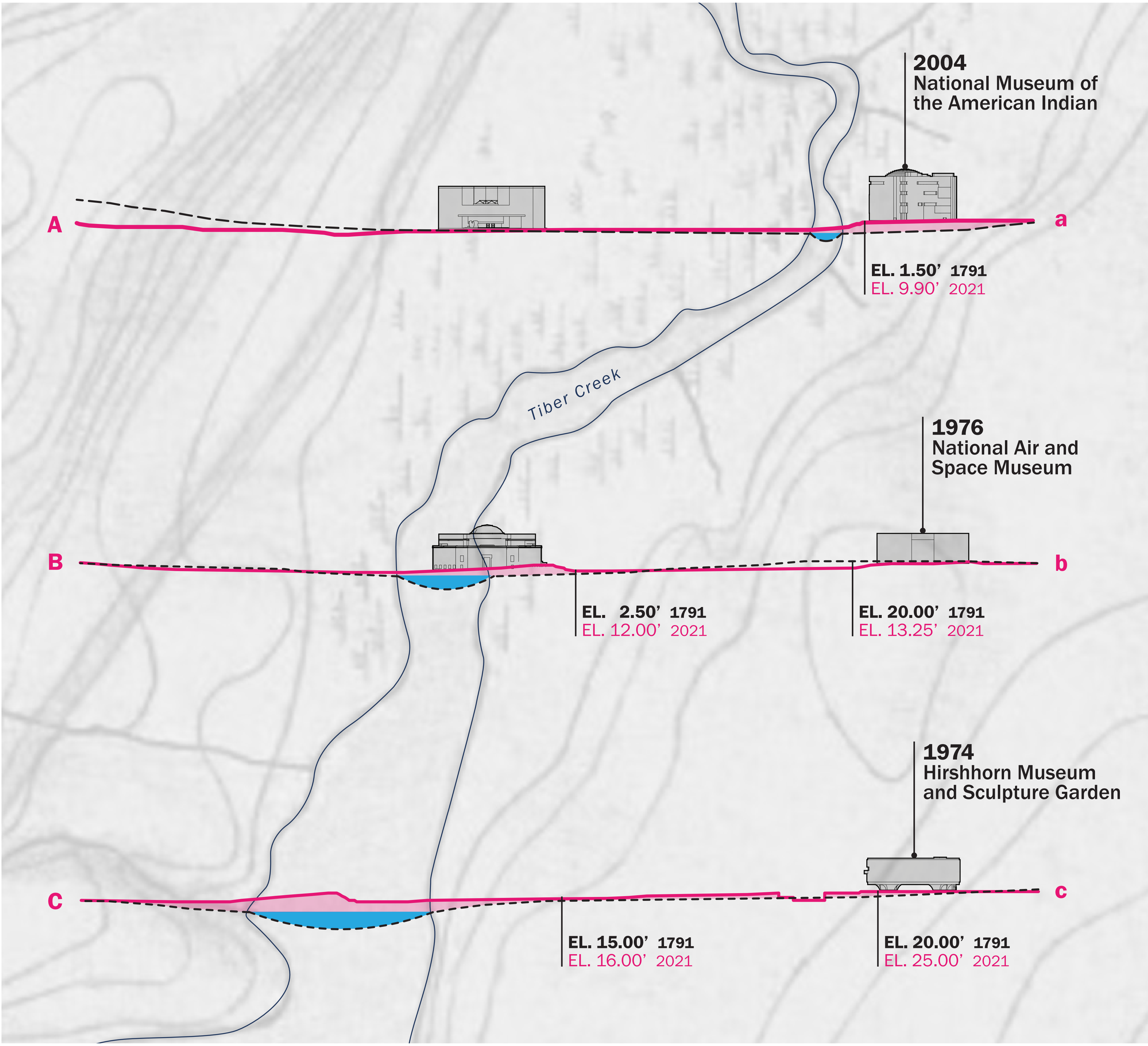
FORMER TIBER CREEK | Circa 1791, overlaid on today's DC aerial.

Topography Then and Now

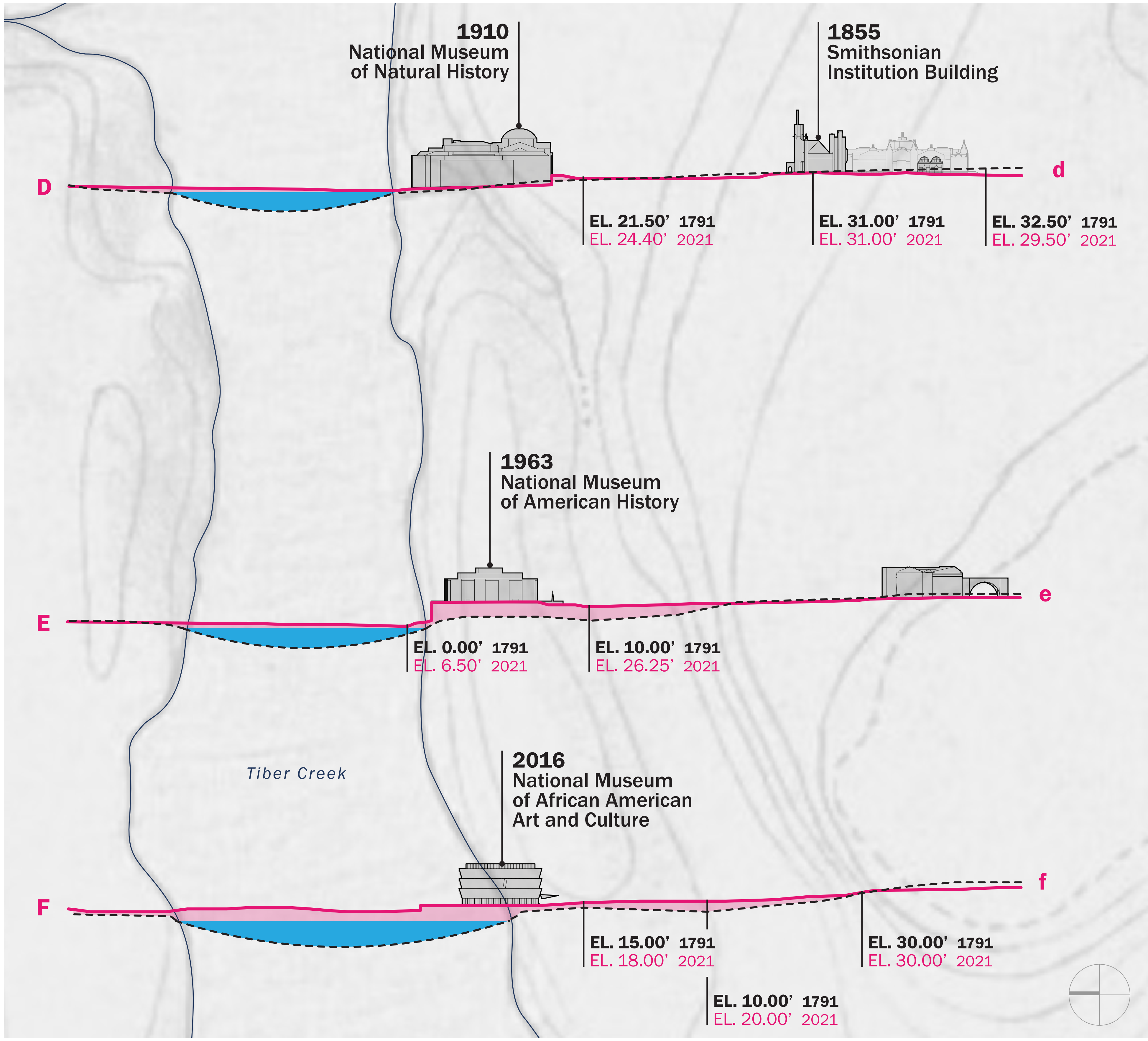
Even in 1841, years after parts of the L'Enfant plan for Washington D.C. began to be realized, the landscape was very much pastoral - this was the setting that James Smithson identified for the development of a new National Institution. The plans of Robert Mills and then Andrew Jackson Downing carved sinuous paths and created tree-framed views to the Potomac in their botanic garden-centric plans for the Smithsonian Grounds.

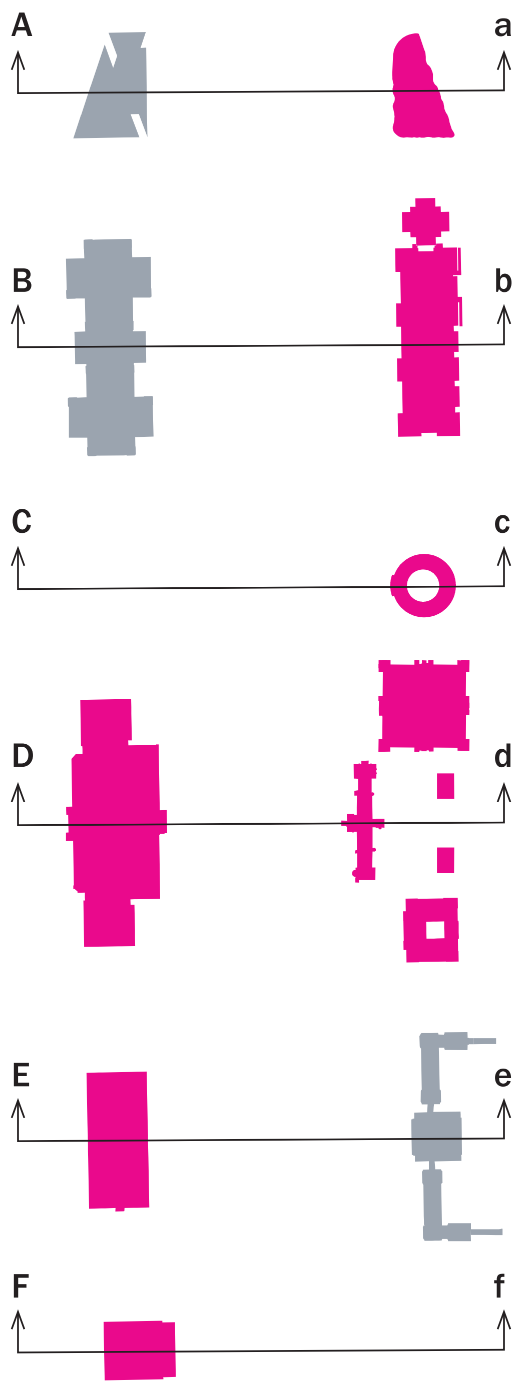
The gentle rolling landforms and landscape garden aesthetic that made up the Smithsonian Pleasure Grounds gave way to the formal, bold-gestured plan that Burnham, Olmsted and McKim developed for a National Mall in 1902 during the City Beautiful Movement. The McMillan Commission Plan, or 'Senate Park Plan' as it was informally referred to, was realized in part, beginning with wholesale regrading of the Mall in 1931. This brought level lawns, parallel roads and crossing streets, axial alignments, long defined views, and the majestic elm allees.

The fill was borrowed, imported, and some was taken from Potomac River dredgings, all of which amassed to elevations 1-foot to 16-feet above the pre-DC landform. The only remaining native soils are likely found at the base of the Smithsonian Institution Building and some parts of the National Museum of Natural History.

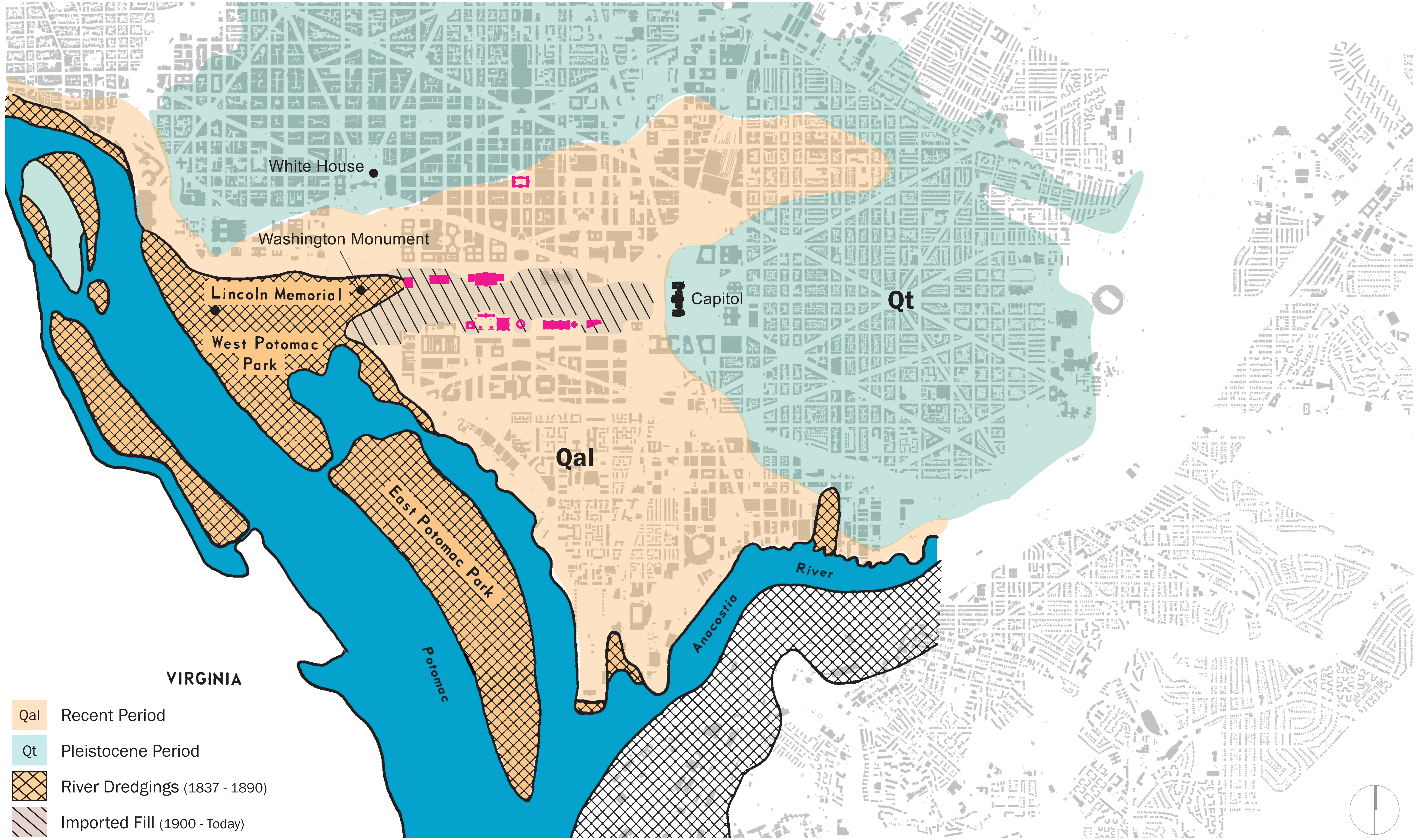


1791 TOPOGRAPHY OVERLAY | Section diagrams convey topography pre-founding of Washintgon DC (1791) with today's elevations; fill areas shown in pale pink.


1910
National Museum
of Natural History
1855
Smithsonian
Institution Building
D
d
EL. 21.50' 1791
EL. 24.40' 2021
EL. 31.00' 1791
EL. 31.00' 2021
EL. 32.50' 1791
EL. 29.50' 2021
1963
National Museum
of American History
E
e
EL. 0.00' 1791
EL. 6.50' 2021
EL. 10.00' 1791
EL. 26.25' 2021
Tiber Creek
2016
National Museum
of African American
Art and Culture
F
f
EL. 15.00' 1791
EL. 18.00' 2021
EL. 30.00' 1791
EL. 30.00' 2021
EL. 10.00' 1791
EL. 20.00' 2021


A
a
B
b
C
c
D
d
E
e
F
f

Soils and Surficial Geology



Underlying Geology

The Smithsonian Institution museums are located south of the fall line that runs parallel along the eastern edge of Rock Creek and Rock Creek Park. The fall line ends at its intersection with the Potomac River in Georgetown - a mere 2 miles from the National Mall. To the north and west of the fall line the geological condition is Piedmont crystalline rocks with saprolite cover. To the east and south of the fall line (inclusive of the study boundaries), the natural condition was formed by Coastal Plain sediments.

Much of the area surrounding the National Mall and the study boundaries is man-made. These soils have largely been created with river dredgings, which have been in place for approximately 120 years and have taken on the characteristics of naturally occurring alluvial soils. However, the Mall itself has been created with myriad forms of fill across decades of construction activity and filling operations to manage or maintain elevation objectives. This soil has been subjected to many different uses and consistent compaction, both at surface and subsurface levels, leading to stunted tree development and poor physical conditions for successful long-term planting.

RECENT PERIOD (Qal)
Alluvium and artificial fill - thickness from a few inches to 25 feet or more.

Gravel, sand, silt, and clay of lowest stream terraces and bottoms.

PLEISTOCENE PERIOD (Qt)
River terrace deposits - average thickness of 30 feet.

Gravel, sand, and loam; basal part is generally unsorted boulders, pebbles, and sand; locally contains plant fossils and peat beds.

Today's Soil Classification

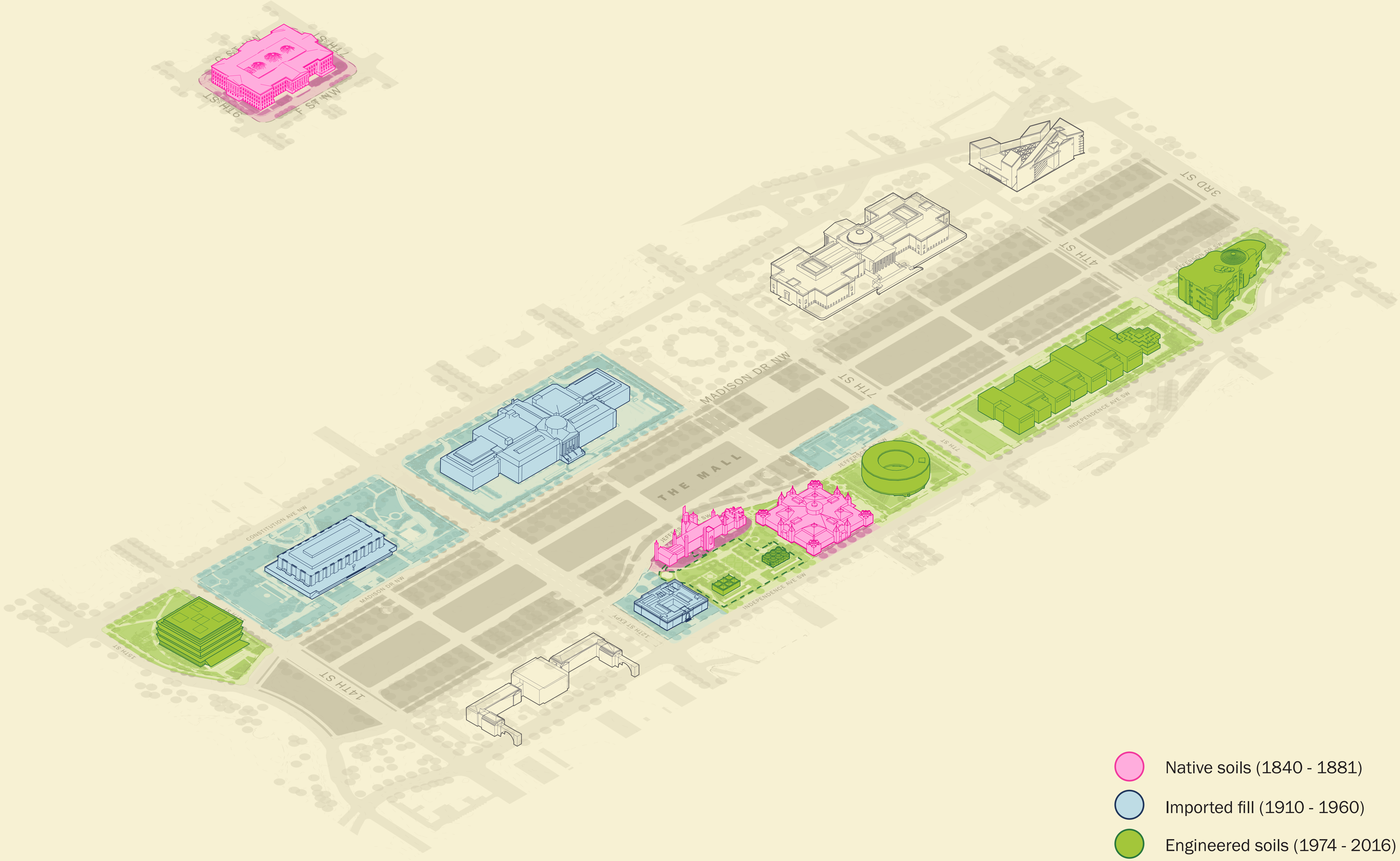
The largest soil class area throughout the study boundaries, encompassing the Mall and museum sites, is Udorthents. These soils are strongly influenced by the processes of man - cut, fill, and otherwise disturbed soils from land manipulation activities. These soils are known to be quite variable in texture and quickly succumb to the forces of compaction. The USDA soil surveys recognize these areas for their poor potential for vegetation and passive garden recreation spaces due to the largely unknown hazards of poor soil structure and chemistry.

The only other soil classification within the study boundaries is Urban Land Association. These highly modified soils are the outcome of urbanization and are too variable to assess for potential planting and garden uses without intensive on-site investigation.

Both being broad soil classifications, this document provides further review and understanding of the true characteristics of these soils through field observations, sampling, and laboratory testing.

Left
SOIL SURVEY | 1976
USDA Soil Conservation Service geology map

Soil by Time Period



The Nature of Existing Garden Soils

Soil Design Trends

Soils of the Smithsonian Gardens landscapes are a reflection of the eras when the museum buildings were constructed. The early landscape of the Smithsonian - “the Castle”, the Arts and Industries Building and the Donald W. Reynolds Center - was constructed and maintained in the native loam soils that remain present to some degree to this day. The landscapes of the National Musuem of American History, the National Museum of Natural History, and the Freer were also constructed on native loam soils, however, some areas received imported loam soils to achieve final desired elevations. Alterations to these landscapes over time introduced pockets of sandy loam soils that has resulted in some variability across these museum gardens.

The addition of new museums in the 1970’s through approximately 2004 - including the Hirshhorn Museum and Sculpture Garden, the National Air and Space Museum, and the National Museum of the American Indian, saw the movement toward mixed and manufactured soils - notably sandy loam. These soils are often used in high-use landscape applications because they drain well but generally retain sufficient water and nutrients for sustaining vegetation.

The movement toward sand-based soils continued with the Hirshhorn plaza’s re-design in 1989, which saw an increase in sand content, in some cases reaching the physical composition of loamy sand. The soils at the National Museum of African American History and Culture consist dominantly of gravelly sandy loam, gravelly loamy sand, and sand. The mixture of these soils with lightweight aggregate was intended to meet allowable bearing capacity atop the subgrade garage, but most importantly, to be well-drained and provide resistance to compaction during high-use events.

Soil Variability

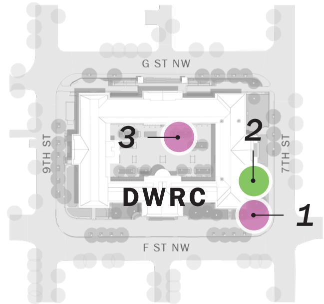
Soil conditions throughout the Smithsonian Gardens are variable and this is the result of many factors - historical alluvial deposition, placement of loamy fill during the creation of today’s National Mall, and the changes in soil theory and design beginning in the mid-1970’s and throughout the early 2000’s. Loam soil still dominates the oldest museum sites, while sandy loam is prevalent at NASM and NMAI, and highly manufactured sandy soils support the landscapes of the Hirshhorn and NMAAHC. Even within each soil texture, there is variation in soil chemical characteristics and biological activity, occuring both naturally due to plant selection and with the help of differing horticultural practices and care in each garden or landscape.

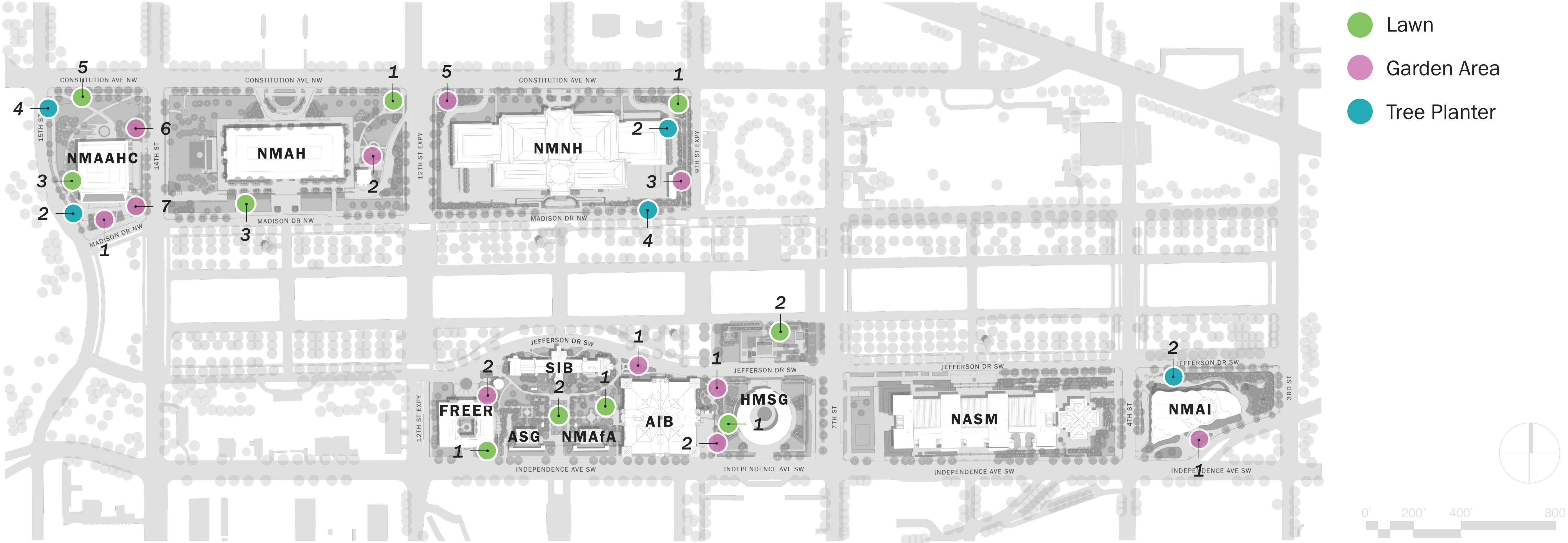
Soil Chemistry

The soil analytical results from samples collected are generally quite variable. Some parameters such as soil pH, electrical conductivity, cation exchange capacity, and calcium and magnesium, are generally consistent between all gardens and landscapes. There is strong variability in other soil parameters including, soil organic matter content, phosphorous and potassium. Low concentrations of phosphorous, potassium, sulfur, and even sodium may require attention in some locations. Overall, the soil chemical conditions are manageable and not concerning.

Soil Sampling Observations

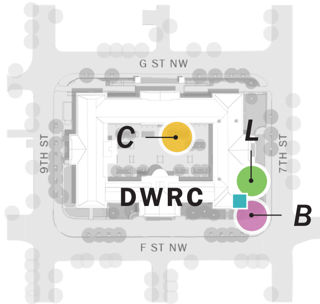
Smithsonian Gardens soils were surveyed in October 2020, at twenty-nine locations, to assess soil conditions such as structure, compaction and density, texture variability, and conditions affecting plant health.

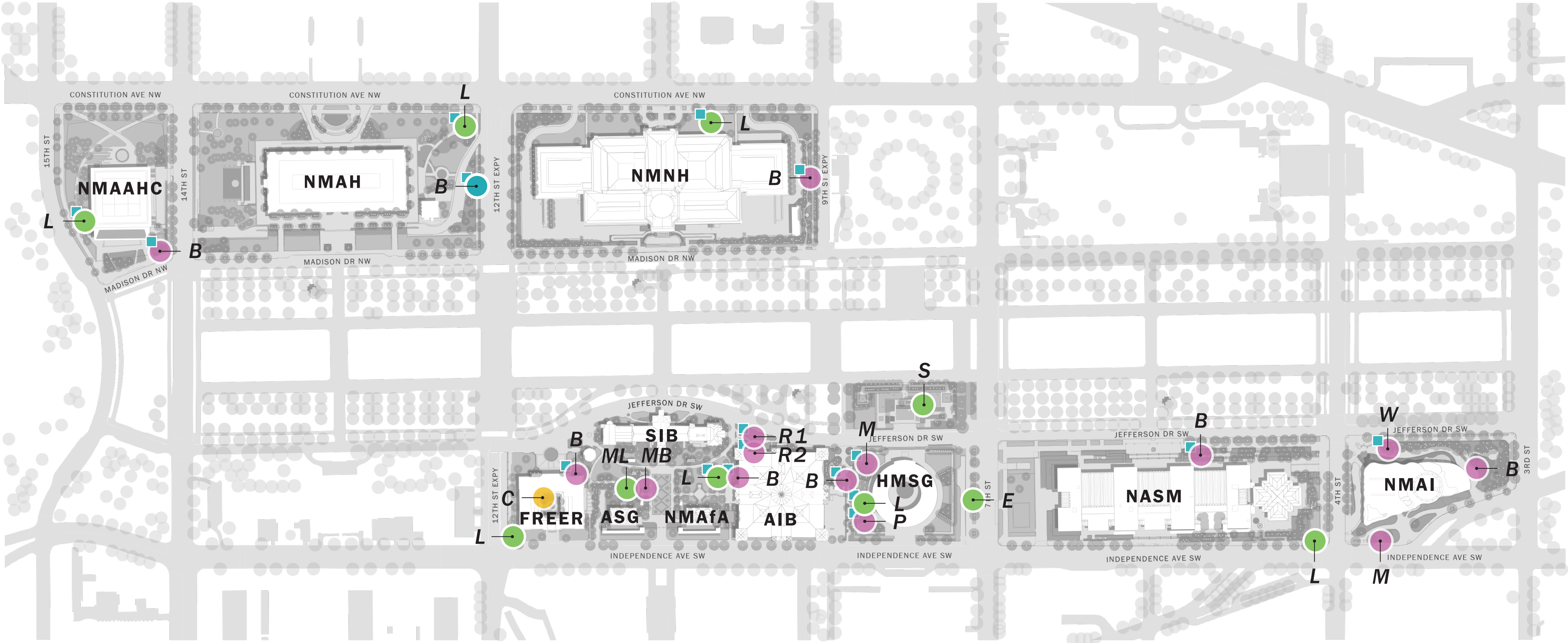




Soil Sampling Lab Testing

Additional samples were taken in February 2021 that best represented the types of soils within each garden. These were subjected to testing by outside laboratories for soil nutrient values, texture, pH, soil organic matter, and in some cases, soil biology.





Lawn*

Garden Area*

Tree Planter*

Rooftop*

Additional Testing

Mycorrhizal colonization & fungal spore counts

*Base Testing

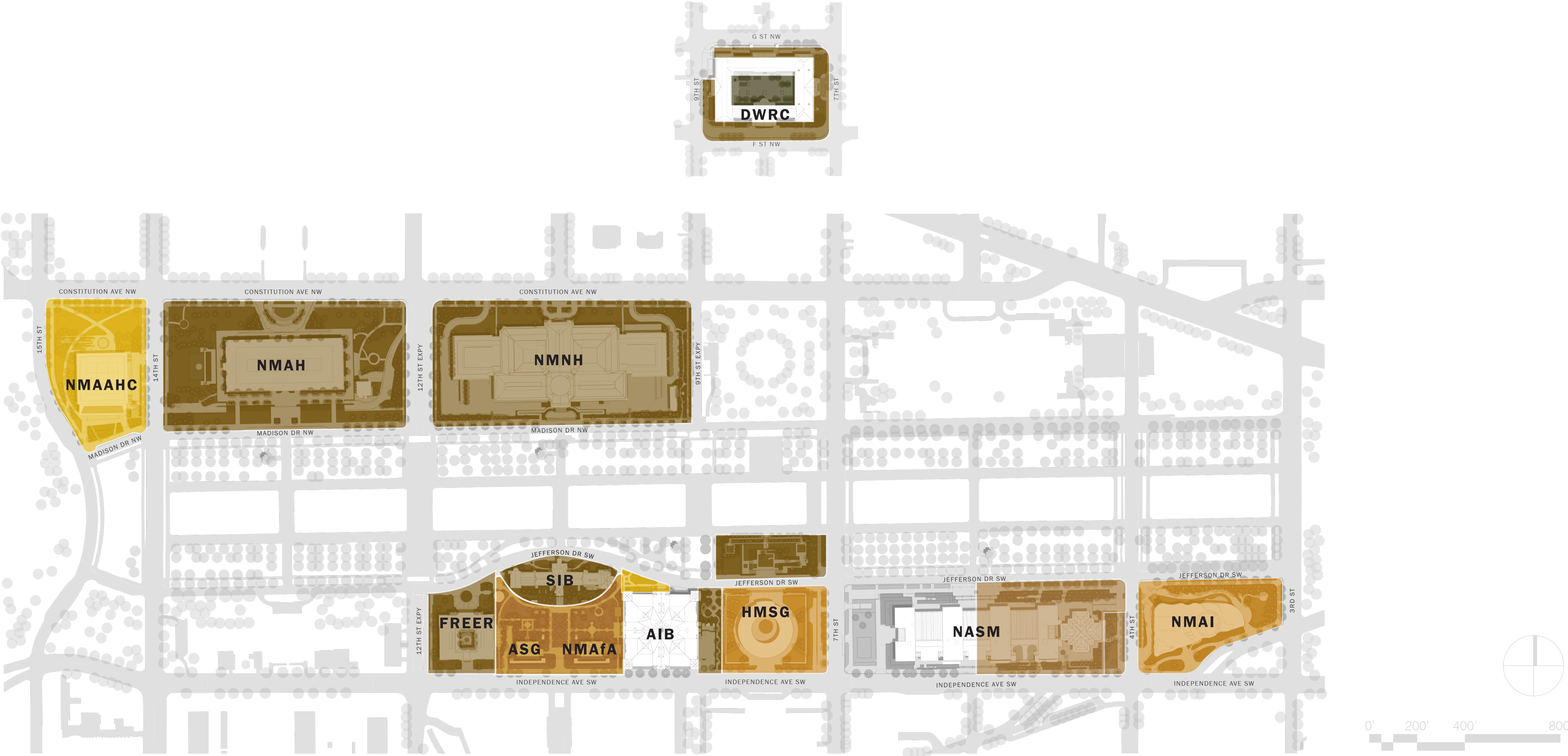
OM, P, K, Ca, Mg, pH, Buffer pH, Soluble Salts, Texture, Sieve Analysis

** Collected February 2021

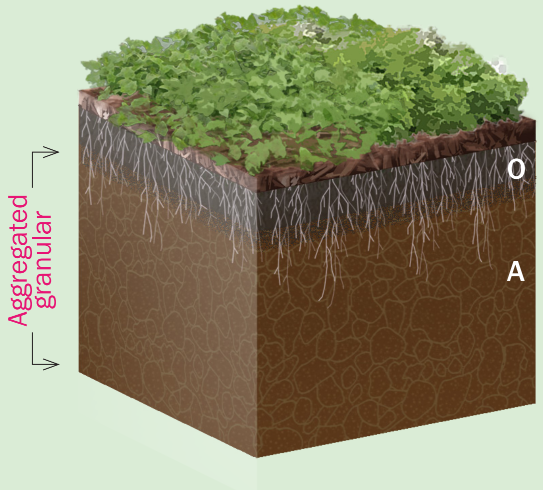





Soils at Smithsonian Gardens



1855	SIB	**Loam** native
1881	AIB	**Loam** native
1910	NMNH	**Loam** native / fill
1923	FREER	**Loam** native / fill
1960	NMAH	**Loam** imported / fill
1974	HMSG	**Loam** imported / fill
1976	NASM	**Sandy loam** 'Triple Mix'
1987	HAUPT	**Sandy loam + dredge spoils**
1989	HIRSHHORN	**Sandy loam**
2004	NMAI	**Sandy loam**
2016	NMAAHC	**Gravelly loamy sand**

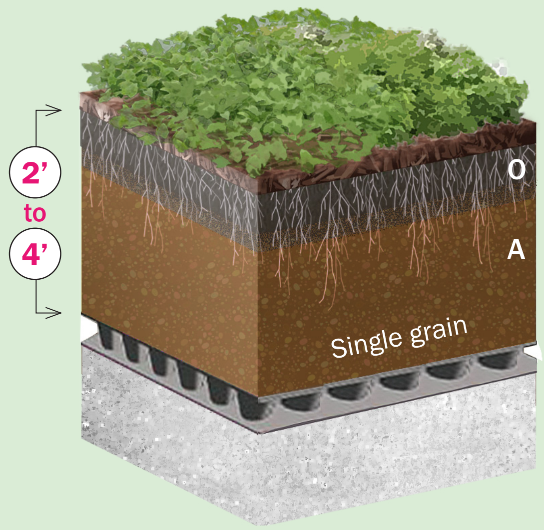


Planting On-grade

SIB - MB

Loam

OM	11.7	**Est. N Release**	150 lbs/ac
CEC	12.6	**Sol. Salts**	0.09 ppm
pH	5.2	**Mycorrhizal %**	N/A
Buffer pH	6.5	**Fungal Spores**	N/A
P	41		
K	118	**Sample Notes:**	
Ca	1270	Moist soil in surrounding area	
Mg	187		



Planting Over Structure

NMAAHC - B

Gravelly Loamy Sand

OM	8.4	**Est. N Release**	150 lbs/ac
CEC	13.4	**Sol. Salts**	0.1 ppm
pH	6	**Mycorrhizal %**	Excellent
Buffer pH	6.72	**Fungal Spores**	1 per gram
P	158		
K	87	**Sample Notes:**	
Ca	1746	Recently composted	
Mg	271		

Planting On-grade

HMSG - P

Sandy Loam

OM	8.7	**Est. N Release**	150 lbs/ac
CEC	13.7	**Sol. Salts**	0.42 ppm
pH	6.6	**Mycorrhizal %**	Good
Buffer pH	6.85	**Fungal Spores**	12 per gram
P	91		
K	60	**Sample Notes:**	
Ca	2170	Compacted; rooting through top 4" of profile; amended surface layer	
Mg	215		

Soil Texture and Structure

Soil texture describes the amount of sand, silt, and clay in a soil. Soil structure is a very important characteristic that describes the 'architecture' of soil particles' relationship to each other. Structure can be described by the stability and formations of granules, peds (small soil clumps), angular blocks, and plates. Soils without any one of these structure types is either formless or massive. Soils examined at the Smithsonian Gardens include:

NMAH, NMNH, SIB, FREER, DWRC, HMSG Sculpture Garden, Haupt Garden, Ripley Garden- Loam soil dominates the landscapes of these museums. The loam soil typically has firm, friable, and granular to sub-angular structure. In many locations, primarily the lawns, the loam soils have massive structure in which roots struggle to grow, infiltration and percolation is slow, and the exchange of oxygen is reduced.

NASM, NMAI- These landscapes are supported by sandy loam soil with somewhat loose, friable, and granular structure. These soils are typically rich in organic matter and are well drained, but also hold sufficient water and nutrients to support vegetation.

Hirshhorn Museum, NMAAHC, Rose Garden- These landscapes were intentionally designed with sandy- to gravelly-sandy loam meant to drain very well and resist compaction.

Refer to **Appendix D** for the full physical texture analysis results.

Soil Biota Diversity

Soil biological activity is a relatively 'new' and under-researched field in soil science, only becoming more influential in the last 20 - 30 years. It's often misundertood that high microbial colonization equates to healthy soil. Sunlight, plant diversity, nutrient deficiences, soil texture, and wind and rain patterns can influence soil microbial activity. Generally agreed upon is the role soil mycorrhizae can have in providing plants with necessary nutrients, water, and disease and pest resistence. A lack of soil mycorrhizae does not necessarily indicate a poor soil, however, some vegetation (such as annual plants) prefer soils that have higher bacterial populations.

Ironically, soil mycorrhizae are not always present in what may otherwise appear to be a healthy soil with healthy vegetation. Rather, mycorrhizae may have their strongest presence in soils that are relatively dry and low in nutrient and organic matter content, as observed within the sandy soils of the Hirshhorn. Their high populations in these soils suggests an effort to sustain stressed vegetation.

Select soil samples were analyzed for mycorrhizal colonization in plant roots and for mycorrhizal spores. It was observed that a soil can have both excellent to good mycorrhizal colonization of roots as well as abundant spores (example, the Hirshhorn), which may be an indicator of plant stress. A soil can also have good mycorrhizal colonization of roots but a relatively low presence of spores, suggesting good soil health and plant growth. Similarly, soil can have poor mycorrhizal colonization of roots but high spore counts (example, Pollinator Garden at NMNH). This may be the result of seasonal fluctuations in plant growth. Finally, some soils - DWRC and SIB had low to poor mycorrhizal colonization and spore counts, indicative of low fungal activity or over fertilization.

Sunlight and plant diversity played a surprising role in mycorrhizal colonization. Soils on the north sides of buildings in full shade, such as parts of the Rose Garden, were observed to have low mycorrhizae and fungal spores, whereas areas only twenty-feet away in full sun - with greater plant diversity - had higher colonization rates and more spores present.

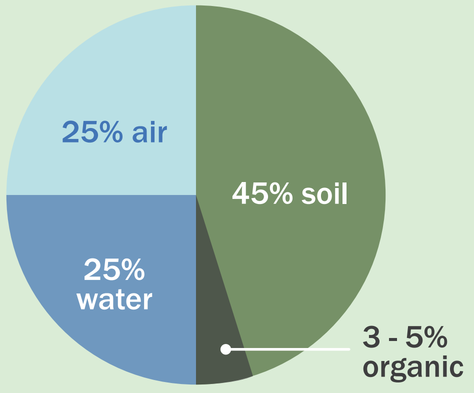
Refer to **Appendix D** for the full soil chemistry and biological analysis results.

*Given its less firmly researched relationship with plants, we have not made recommendations based on the presence of tested soil microbiology but have listed observations for future investigation.

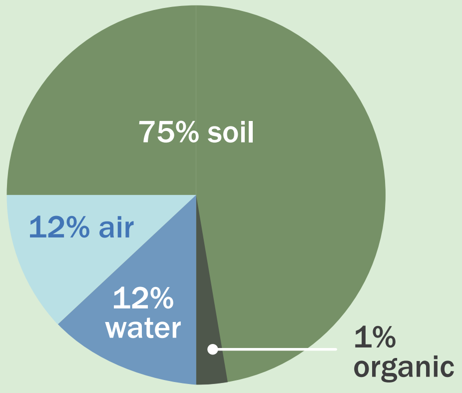
Understanding Compaction by Soil Type

Soil compaction is one of the most common and often serious soil problems affecting landscapes, especially those at Smithsonian Gardens. All is not always at it seems though, due to their smaller particle size and elongated shape, clay particles are the least susceptible to damage from compressive forces. The rounded shapes of silt and sand are the most susceptible to distributing compaction deeper into the soil profile.

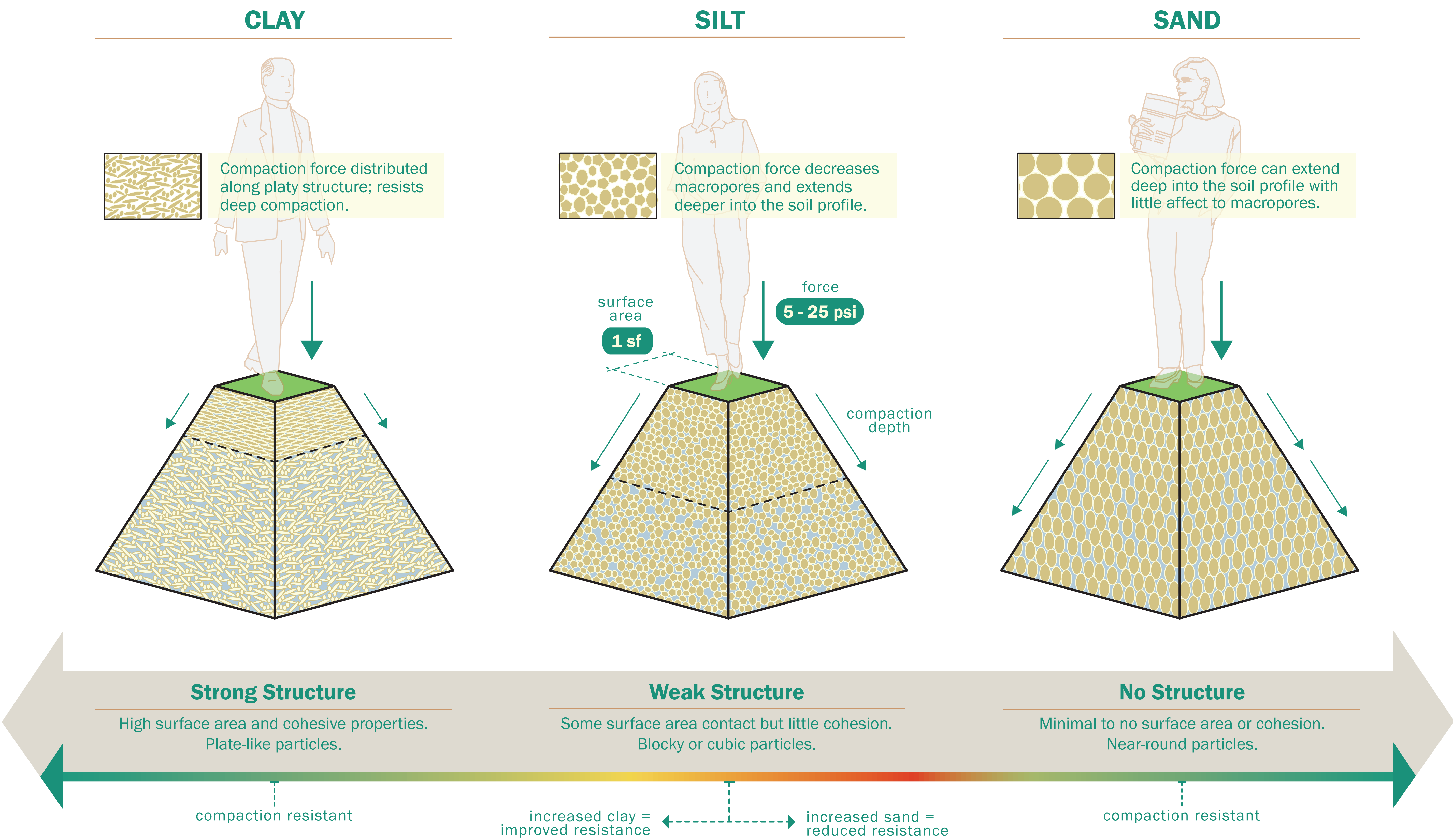
Soil compaction is not always a result of vertical forces, however. It also occurs when soils are continually wet and settlement between particles occurs to a point when the overall structure becomes very dense. Soils most resilient to the forces of compaction have high naturally occurring organic matter and deep, healthy plant roots. Organic matter acts like a flexible layer that can compress and then recover. Organic matter is often expected to be higher in clay and silt-based soils.



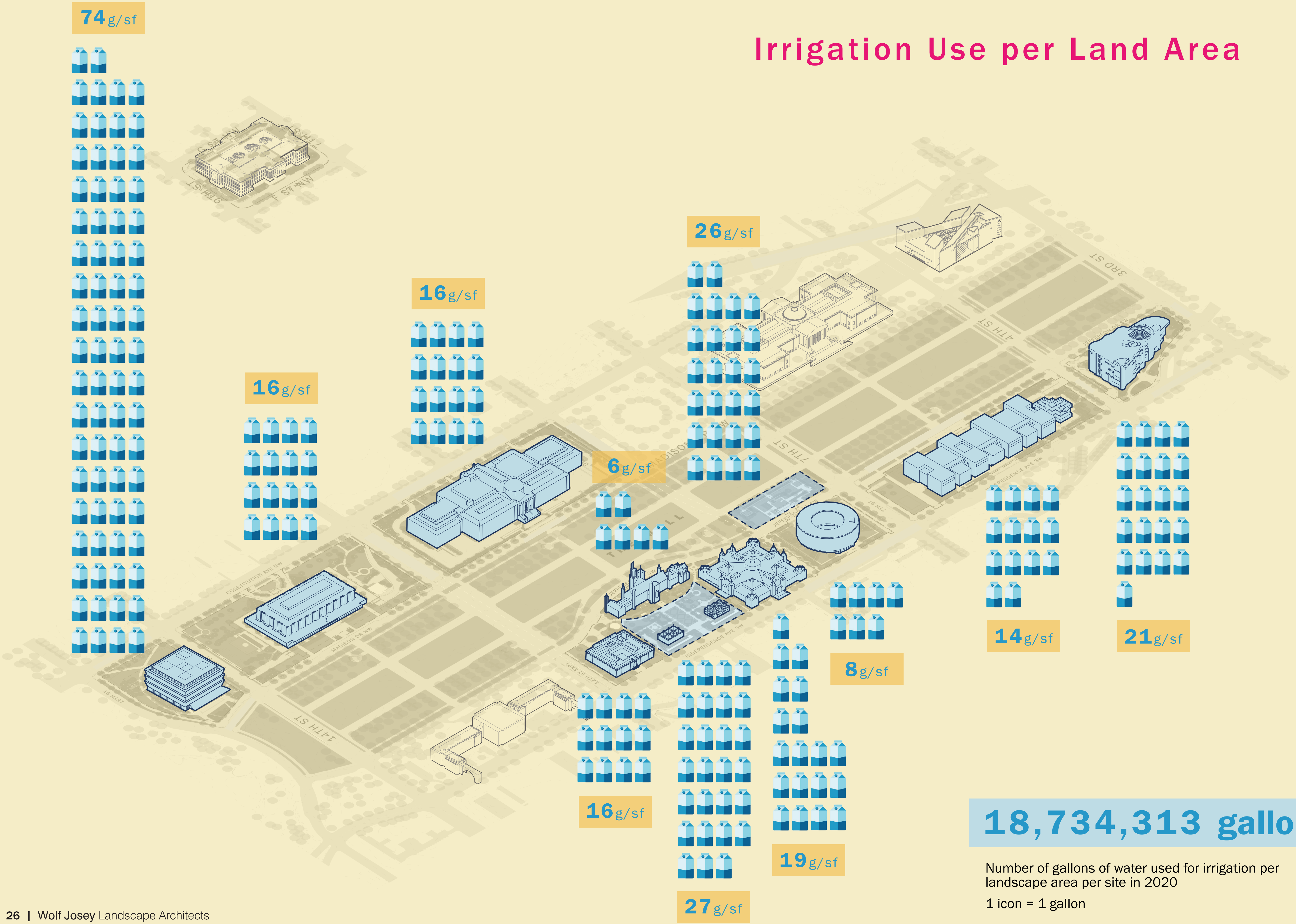
Ideal soil



Compacted soil


CLAY
SILT
SAND
Compaction force distributed along platy structure; resists deep compaction.
Compaction force decreases macropores and extends deeper into the soil profile.
Compaction force can extend deep into the soil profile with little affect to macropores.
surface area
1 sf
force
5 - 25 psi
compaction depth
Strong Structure
High surface area and cohesive properties.
Plate-like particles.
Weak Structure
Some surface area contact but little cohesion.
Blocky or cubic particles.
No Structure
Minimal to no surface area or cohesion.
Near-round particles.
compaction resistant
increased clay = improved resistance
increased sand = reduced resistance
compaction resistant

Irrigation Use per Land Area



18,734,313 gallons

Number of gallons of water used for irrigation per landscape area per site in 2020

1 icon = 1 gallon

Soil Type and Irrigation Use

Soil type has a profound affect on the amount of water that must be used to sustain vegetation during the growing season, especially during the months when peak temperatures are experienced. When describing soil type, soil texture must be considered with soil structure, as they both work together to drain excess water while also storing the necessary water for plant uptake.

In addition to soil type, the position of the soil area in context of the natural or built topography must also be considered. Soils positioned lower in a landscape will receive more water and require less irrigation. Soil on slopes (even short slopes) will shed water and may need more irrigation. Also important, are soils that are surrounded by structures such as walls, roads, subgrade garages, and other heat reflecting or absorbing materials. Soils in these areas will tend to be warmer, dry quicker, and require more irrigation.

The coarse, sandy soil, and in many cases - the gravelly sandy loam - that are present at NMAAHC are excessively drained. And as water moves rapidly through the coarse textures it simualtaneously removes what few nutrients may be present. This process also depletes the soil of many highly beneficial bacterial microflora and mycorrhizal spores. The result is a soil requiring high amounts of irrigation, fertilizers, and often pesticides or fungicides to sustain vegetation. The irrigation use of NMAAHC is nearly three times greater per land area than any other museum.

Medium- to fine-textured sands like those common at the Hirshhorn Museum will hold some water with consistent irrigation, but this water is rapidly used and depleted by plants. Although minimal use of irrigation occurred in the years of data provided to the consultant team (most likely due to an irrigation system issue), the evaluation of trees and shrubs indicated elevated levels of stress. Of interest, the soil samples analyzed for mycorrhizae showed high colonization rates and a considerable amount of fine rooting, an indication that soil microflora and the plants themselves are doing everything possible to survive. However, due to the soil's insufficient nutrient and water holding capacity, the plants will remain stressed until the inputs (water, nutrients) outweight what is being lost.

Soil Density

Soil density is often confused with soil compaction when the soil is hard, stiff, and as described before, massive in structure. High soil density (measured as a unit mass per volume, such as grams per cubic centimeter (gm/cc) or pounds per cubic foot (pcf)) is the close packing of soil particles next to each other with dominantly small micropores. High soil density can also be associated with sand, which has a greater portion of its volume filled with solid material than does silt or clay.

Well-aggregated soils - those that form strong peds that are held together by organic substances, cations, or sometimes strong attractive forces - will have good pore diversity and distribution of macropores (to allow water to drain and oxygen to enter) and micropores (to hold water and nutrients). Because of the porosity of these soils (often air-filled), the density of the soil will be lower - hence, ideal for supporting vegetation.

Productive soils typically have a density between 1.2 to 1.4 gm/cc, or 75 to 87 pcf. Sandy soils will often have densities above 1.55 gm/cc or 98 pcf. Soil density greater than these values will limit water infiltration, oxygen exchange, and root growth. The soil densities found at the Smithsonian Gardens was found to vary significantly between sample locations.

Impacts of Soil on Plant Health

Tree and plant health is possibly one of the best indicators of soil conditions, seen through shoot growth, size, leaf color, and branch dieback or decline. Where species comparisons were identified across sites, we've added notes to capture plant health associated to soil type.

In heavily compacted soil and along streetscape planting strips, stunted growth was frequently observed in trees at ~6" to 8" dbh due limited rooting volumes in confined planter areas.

Where soils and subsoils were heavily compacted, such as along 15th St at NMAAHC, excessive surface roots of new trees, leaf discoloration, slow shoot growth and poor irrigation infiltration rates were observed resulting from the soil compaction.

Trees develop more extensive root systems when planted in mulched areas than in turf areas. Dense turf roots compete for nutrients and develop a biological community unique from those that trees develop in. Where planting strips were converted from turf to perennial beds such as along 12th St and within the Pollinator Garden at NMNH, trees displayed more vigorous and healthy growth than those planted in turf areas.

Care needs to be taken within critical root zones when amending soils for plant beds beneath trees. Recent plant bed restoration and irrigation installation within the critical root zone of the Chinese Hackberry at the Reynolds Center was observed, likely damaging the fine root layer and accelerating branch dieback.

Where soils were sand based and free draining, such as NMAAHC, certain species that are adapted to more loam based soil systems displayed leaf dieback and stunted growth. Further observations are available within the **Appendix E**.

Finally, unrelated to soil health, various trees exhibited girdling roots resulting from containerized plant stock at installation. These root conditions limit mature tree growth and can lead to complete tree failure if left to develop. This was observed most notably at NMAI. Other instances of girdling roots of small, more recently planted trees were observed along the Reynolds Center streetscape.

NMNH | Healthy tree and perennial development within the 12th St beds

NMNH | Trees and plants thriving in mulched areas at the Pollinator Garden

NMAH | Declining red oak; root impacts from security wall enhancements lead to branch decline, bacterial leaf scorch

NMAAHC | Katsura tree with observed branch tip dieback and leaf loss

Analysis and Evaluation

Summary of Soils Assessment

Resulting from incremental development over 150 years, there is a patchwork of different soil types throughout Smithsonian Gardens. A loam texture was consistently found before the 1970's, at which point soil mixes with higher sand content were developed to better control compaction, drainage, and soil source variability.

These two dominant soil types, Loam-based and Sand-based have large implications on long term plant health and maintenance needs. Sand-based soils can resist compaction better, allowing for easier root growth, although they can dry out rapidly, requiring more irrigation and regular additives such as compost to help the soil retain nutrients and water.

Organic soil amendments, such as compost, decompose and evaporate from soils over time, requiring annual application in the case of sand-based soil mixes. When not regularly reapplied, the soil has a lower nutrient holding capacity, drys out quickly, and leads to plant stress - as was observed in the sand-based soil mixes of the Hirshhorn after 20 years in the ground.

Loam-based soils with high silt ratios were observed to be heavily compacted at the surface level due to high usage and poor soil structure. Larger macropores and improved soil structure was observed deeper into the soil profiles for better tree root development.

Soil chemistry, including pH, macro and micronutrient levels and soil organic matter, was observed to be generally consistent within appropriate ranges for plants throughout the gardens and not of concern for remediation.

Summary of Soil Care

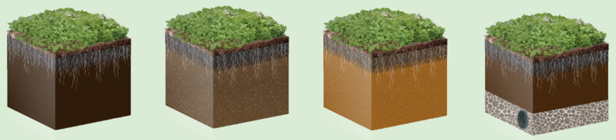
Horticulturalists at Smithsonian Gardens provided extensive insight into their care and management of plants and soils. Each museum has its own set of issues, and as such, the horticulturalists' responses are commendably site specific, but there are variations in remediation techniques, soil amendments, and allocated resources that contribute to shortcomings for achieving a consistent and comprehensive soil care and management approach (see **Appendix E** for more detail).

There were some over-arching sentiments made among all staff, however, including:

- Fill soils from previous construction projects present on-going problems
- Lack of availability of a consistent stocked supply of soil, compost, and mulch contributes to selection and procurement of materials on a case-by-case basis
- Girdling roots are most prevalent plant issue; due to poor root stock and former planting methods
- Larger scale soil profile rebuilding, generally agreed as necessary, is seen as very difficult to achieve due to access, disturbance, and cost
- Irrigation system varies in age from garden to garden. Many irrigation layouts were designed for turf, at a time before Smithsonian Gardens added planting beds. Irrigation head layout and types of heads are adjusted as the programmatic needs of gardens evolve. In some gardens these need to be adapted to current garden conditions.

1 Soil Variability

There is a patchwork of different soil types and conditions due to the regular usage of imported fill soils and the myriad construction projects since the 1850s.

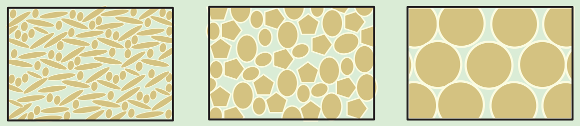


2 Soil Trends

Since the mid 1970s, there has been an increase in the use of sand-based soil mixes, which has lead to decreased nutrient and water holding capacity in soils of newer projects.

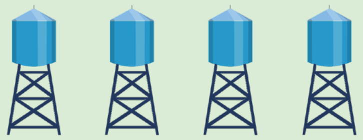
3 Soil Structure

Soil compaction has been a result of high use, regular vehicle and foot traffic, building maintenance, utility work, and common construction practices.



4 Irrigation Use

Despite having been established for 4 years, the sand-based soils at NMAAHC require ~4.25 times the amount of water per square foot of planting area than the average of all museum landscapes.

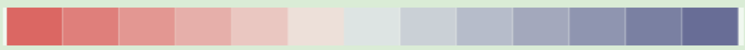


5 Plant Health

Generally good with exception of pockets of manufactured sand-based soil, areas lacking rooting volume, and stem-girdling roots.

6 Soil Chemistry

Despite the variability of soil nutrient and chemical conditions, the majority of soils have an acceptable chemical composition for growing healthy plants.




© Wolf Josey

02

SOILS MANAGEMENT PLAN

Principles for Managing Soils for Sustainability and Resilience

The present crisis associated with a changing climate creates long term challenges for sustained plant health and development at Smithsonian Gardens. The most critical approach to plant resilience is reducing plant stress through sustainable soil health in both new and existing gardens.

The most sustainable and resilient soils at Smithsonian Gardens over time have typically been those native to the region in which they formed. These naturally occurring loam-based soils have developed over thousands of years to successfully support plant growth. The process of breaking down aggregates, plant detritus, and microbial matter has created a unique and sustainable medium specifically adapted to support plant development. It is incredibly difficult to artificially replicate this dynamic soil structure and composition.

Due to their stability over time, nutrient and water holding capacity, reduced maintenance and improvements to long term plant health, unscreened, regional loam based soils are to be the foundation of future imported planting soils at Smithsonian Gardens.

Principles for healthy, sustainable soils include:

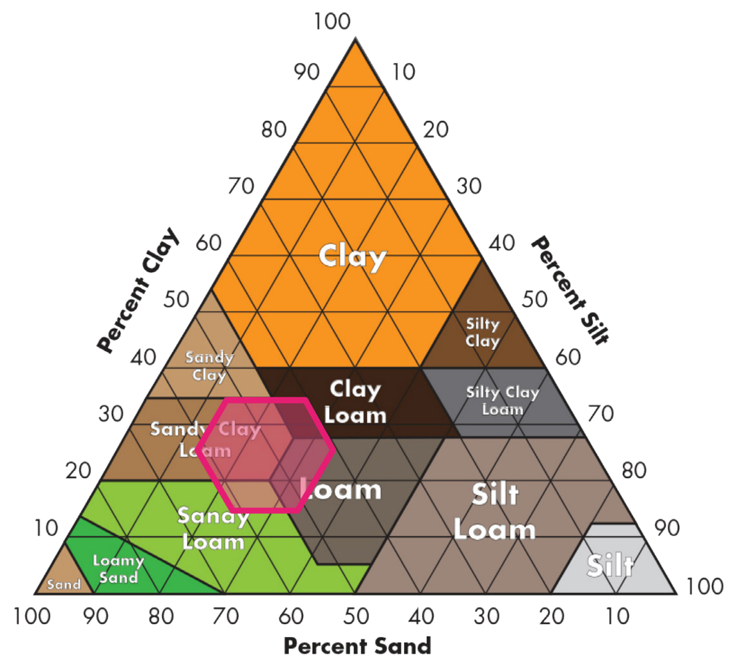
- Soils that balance drainage and soil aeration with good water holding capacity to support the growth of deep roots and rich soil organic matter.

- Soils with strong soil structure, a balanced chemical profile, and healthy soil biology to help hold colloids (fine clay and organic matter particles) together, opening pores for water and air exchange.

- Soils with rich organic matter and strong structure that are very resilient to compaction, cushioning the affect of compacting forces and foot traffic.

- Soils with rich organic matter with very good water- and nutrient-holding capacity to promote plant growth through the year and sustain plants through periods of stress.

- Soils with high(er) cation exchange capacity with the ability to hold nutrients necessary for plant growth while also buffering the affects of chemical or nutrient imbalance in the soil.



Imported loam based soil texture range for new construction projects

Specialized Soil Conditions

While naturally occurring loam-based soils offer long term flexibility and resilience for the majority of Smithsonian Gardens sites, there may be conditions where plant specific soil requirements are required. These may include soils for interior planters or be more targeted for a specific plant, such as roses. These soil types will need to be determined on a case by case basis. Specialized soils should also be contained in a way that wouldn't cause variability in drainage or lead to unintentional mixing of soils across larger garden areas.

The magenta polygon above indicates the acceptable range of percentages for sand, silt, and clay that this Plan defines as loam-based soils.

Environmental Sustainability of Locally-Sourced Native Soils

With limited storage space, it may not always be possible to re-use or restore existing soils at Smithsonian Gardens. The need for procuring healthy, locally-sourced soils is often necessary for new projects or where existing soils cannot be remediated effectively.

The goal of importing soils is not to purposefully remove healthy soils from productive, ecologically sound environments. Due to a thriving land development industry in the region (and mining to some extent), for better and worse, these healthy soils are regularly disposed of and sold as a byproduct. While these industries may not be environmentally sustainable in-and-of themselves, the native topsoils that are stripped would otherwise go to waste or spoil and deteriorate as they're stockpiled for future earthwork. These highly productive soils are better recycled and imported for use at Smithsonian Gardens.

To do this, Smithsonian Gardens will coordinate with soil providers (identified in the Specifications in **Appendix F**) to vet soil sources, borrow sites and stockpiles for their suitability. The soil providers identified for use at Smithsonian Gardens do not strip land for the sole purpose of obtaining healthy topsoils for resale.

The following actions can be addressed with the soil provider to ensure environmentally sensitive sourcing of native soils occurs:

- Select unscreened, non-blended soils (**as outlined in the Specifications in Appendix F**) which require no post-processing or other manufactured and mined inputs like sand.

- Soil sources should be selected from providers that harvest and segregate soil from the effective rooting zone (top 4 feet) and that minimize stockpile periods (i.e. soil is only harvested from the source when needed). Soil providers that practice good soil and vegetation stewardship are recommended both for their practices and for obtaining suitable quality soils.

SIB | Gingkos showing healthy year-after-year branch growth in loam soil.

The Action Plan

This Action Plan provides a strategic framework - and should be utilized as an educational resource - for managing existing soils, identifying and remediating poorly functioning soils, and protecting sensitive soils. The following five points outline the scope of this Plan.

1 Soil Problems and Assessment

A guide on examining soil for specific soil characteristics to assess its suitability for remediation, restoration, or replacement. Examination focuses on compaction, structure, and drainage.

2 Soil Remediation Strategies

Soils management requires careful consideration of site context. Critically assessing existing soil and plant conditions lead to the selection of remediation opportunity areas context-sensitive techniques.

3 Maintenance of Existing Soils

An explanation of healthy soil, why it's important, and how to maintain it through management practices and techniques.

4 Restoration of Damaged Soils

A guide on how to plan for, rebuild, and restore soils that have been historically poor or recently disturbed by construction, ex, and other impactful activities.

5 Preservation of Sensitive Soils

The best defense is offense. Proper management techniques and educational resources on maintenance practices can lead to successful, long-term plant and soil health.

1 Soil Problems and Assessment

The existing soils at Smithsonian Gardens offer a wide range of different conditions and the primary observations of poor soil health were associated with compaction, limited soil volume, low water and nutrient retention and the lack of stable soil organic matter.

Soil Compaction

Due to high pedestrian, equipment and event use, soil compaction was observed in the majority of soils at Smithsonian Gardens. Over compacted soils compress the open void space in soils, limiting room for air, water and root growth. This inhibits large tree growth, limits soil water storage/drainage and shortens average lifespans of trees significantly. This leads to higher maintenance and replacement costs as well as a less stable landscape over time.

Compacted soil beneath paving is the most problematic area observed that has limited tree growth and available soil volume. Roots forced to grow into the aggregate sub base beneath paving have led to hazardous heaving sidewalks and curbs. Trees have struggled to develop roots beyond designated planter areas, stunting their development and increasing plant stresses.

In loam based soils beneath lawns with higher clay content, compaction was more typically observed to be at the surface, with pockets of looser soil observed beneath. Tree growth was less inhibited in these areas although the surface compaction limited water from quickly draining into the soil.

Limited Soil Volume

Associated with compaction, street trees in particular are heavily impacted throughout Smithsonian Gardens with limited soil volume. The majority of street trees are stunted as a result, with reduced canopy sizes, higher signs of plant stress and shortened lifespans.

Stable Organic Matter

While possible to add compost into artificial soil mixes to increase the tested soil organic matter levels, it is a temporary increase of soil organic matter due to a high percentage of the compost evaporating as carbon dioxide over time. If the soil has a high sand content, there is an increased decline of organic matter over time due to high aeration and oxidation rates, with occasional loss through leaching via rainwater. These soil mixes become a high maintenance task, requiring annual applications of additional compost to maintain healthy soil organic matter levels.

Typical healthy loam based soils have a stable organic matter percentage between 2.5-5%. Installed sand based soil mixes were observed to have varying levels of organic matter. Recently installed soils at NMAAHC were as high as 9% while older sand based soil mixes at HMSG, once heavily mixed with compost 30 years ago, were as low at 1.7%. Without regular reapplication of compost, evaporation of compost and leaching from these mixes is consistent with expected decline of soil organic matter in sand based soil mixes.

Water & Nutrient Retention

Sand based mixes were observed to be drying out on hot days thirty minutes after irrigation leading to higher irrigation rates that have exacerbated nutrient leaching and led to increased turf diseases and plant stress.

This is due to larger sand particles being poor at nutrient and water holding compared to the finer particle sizes of clay and fine organic matter. Groundcover types and sun exposure also impacted water and nutrient retention.

Older irrigation systems have been more prone to failure leading to increased maintenance costs and risks to the plants. At HMSG, a failed 30 year old irrigation system within a depleted sand based soil mix likely stressed honeylocusts to the point of death.

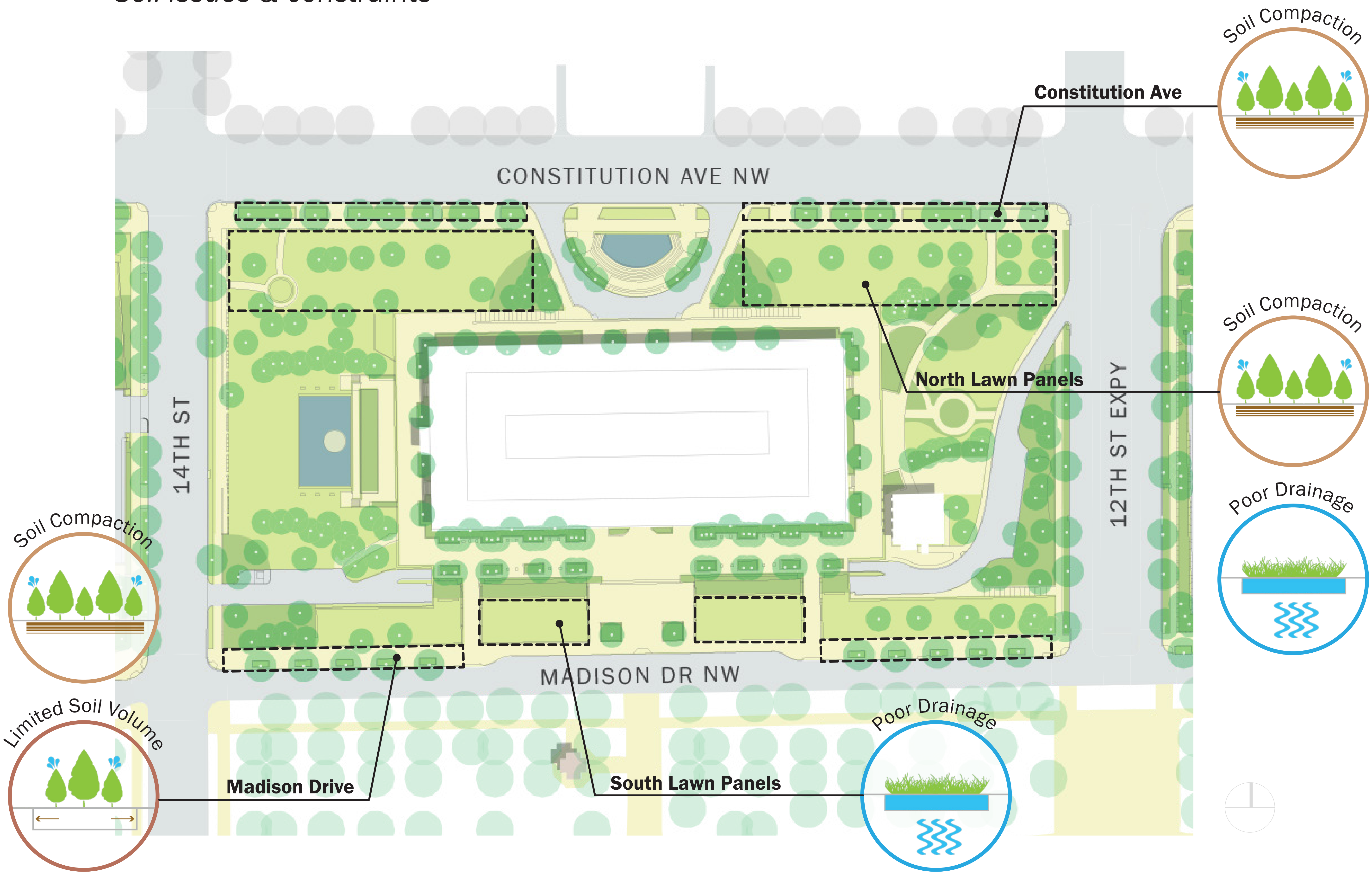
With increased periods of drought and rain resulting from the climate crisis, the ability for soils to retain water and nutrients is critical for success in the gardens.

National Museum of African American History and Culture (NMAAHC)

Soil issues & constraints

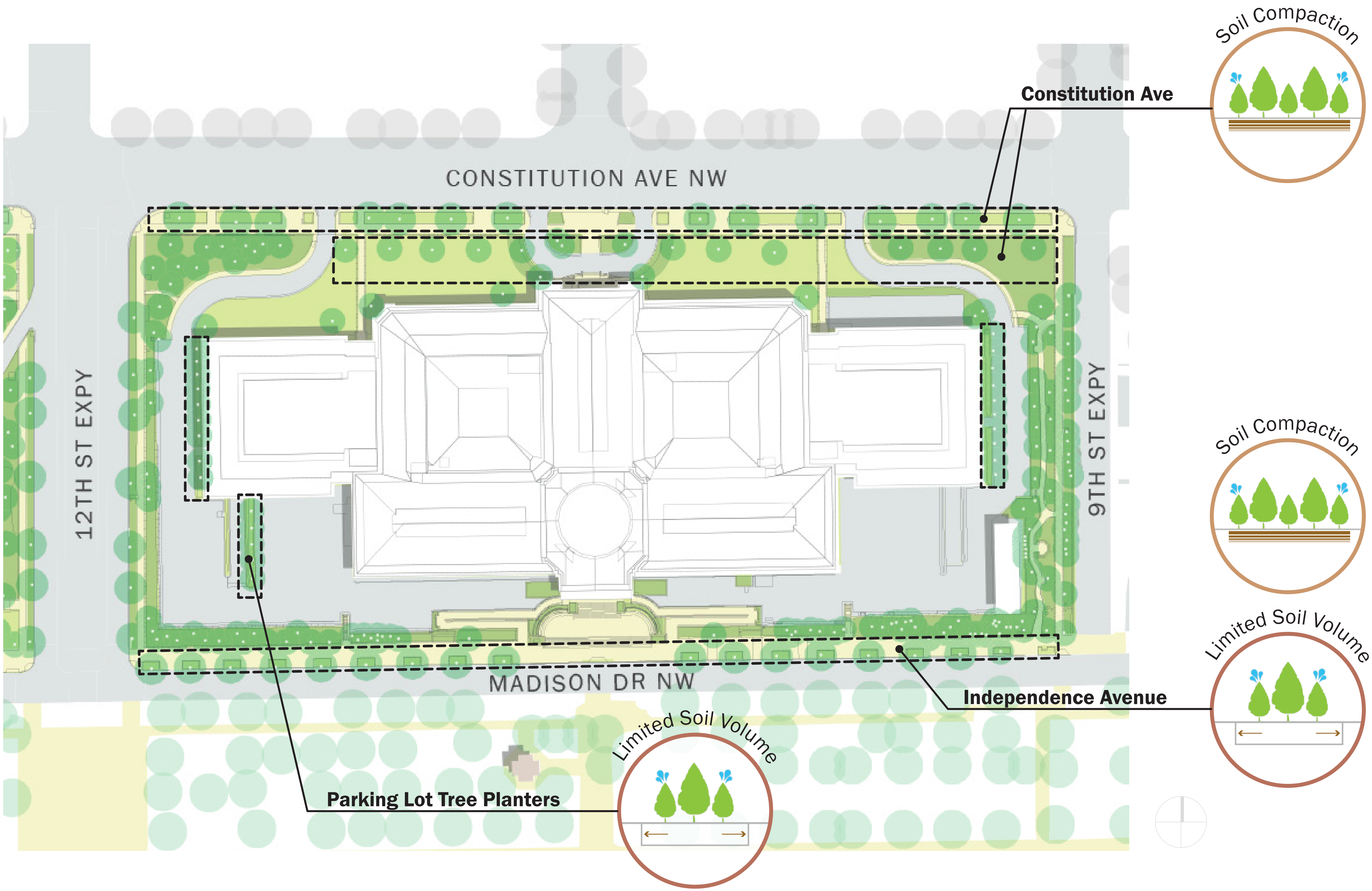
National Museum of American History (NMAH)

Soil issues & constraints



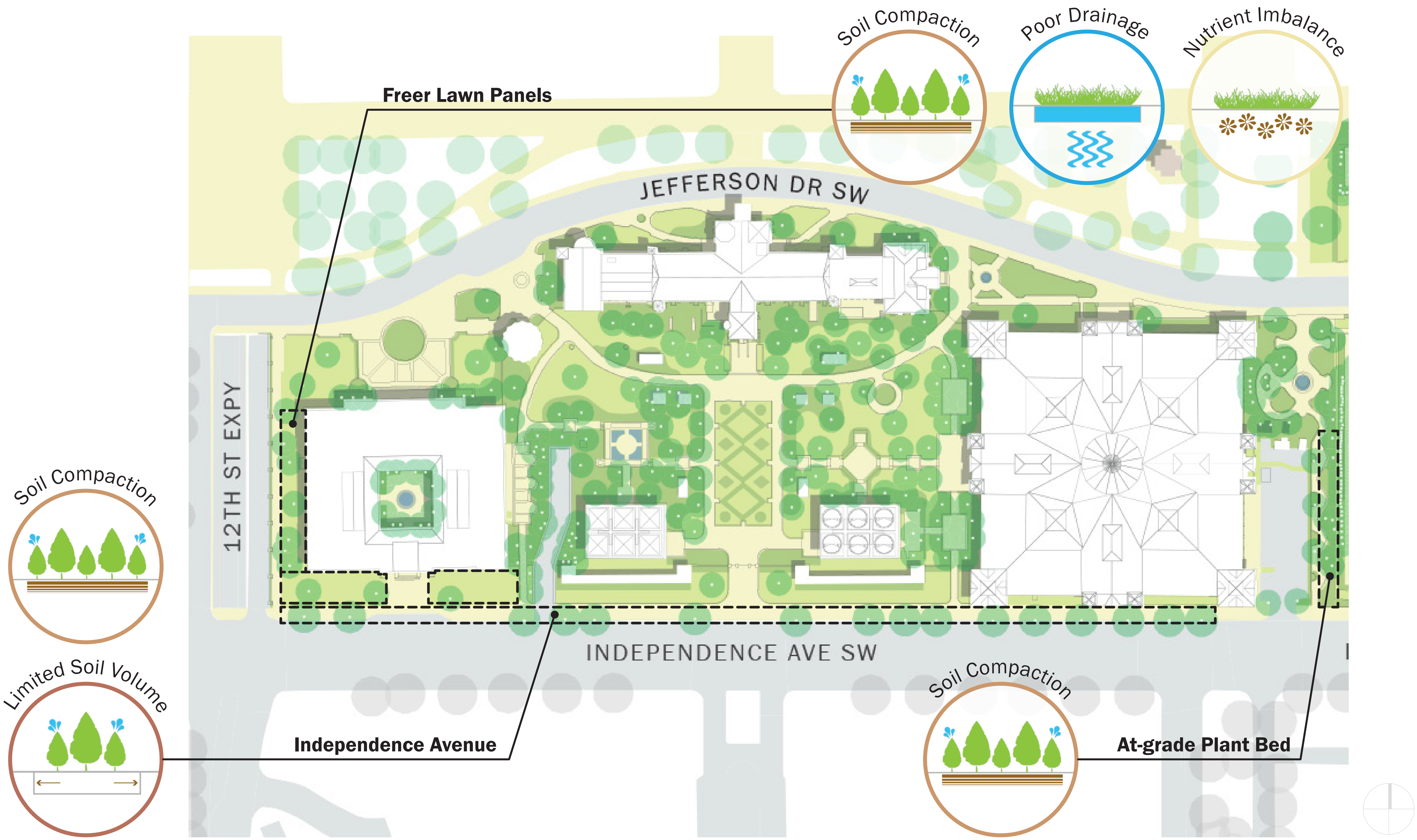
National Museum of Natural History (NMNH)

Soil issues & constraints



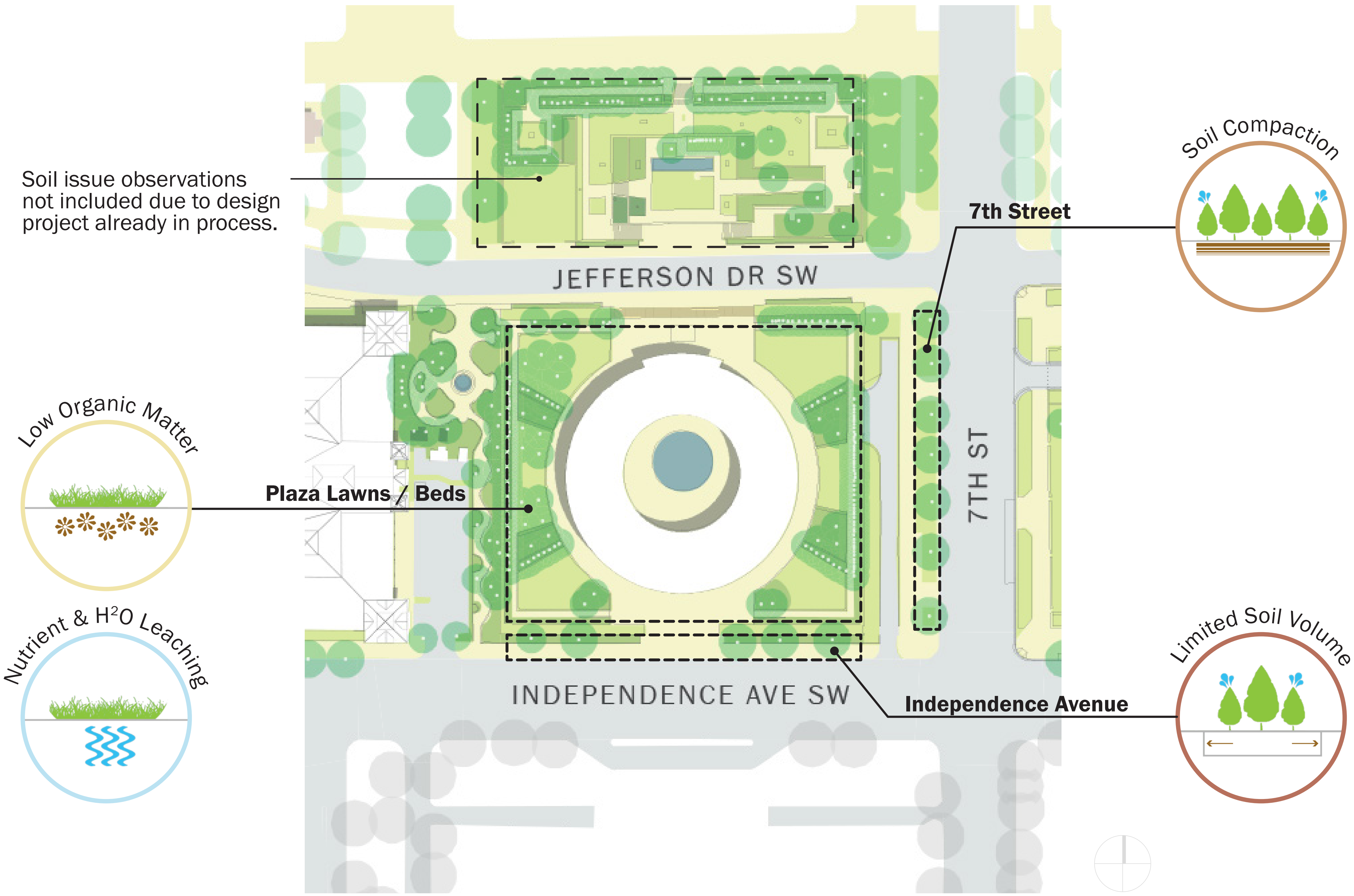
South Mall Campus (SIB, AIB, Freer, Haupt, Rose, Ripley)

Soil issues & constraints



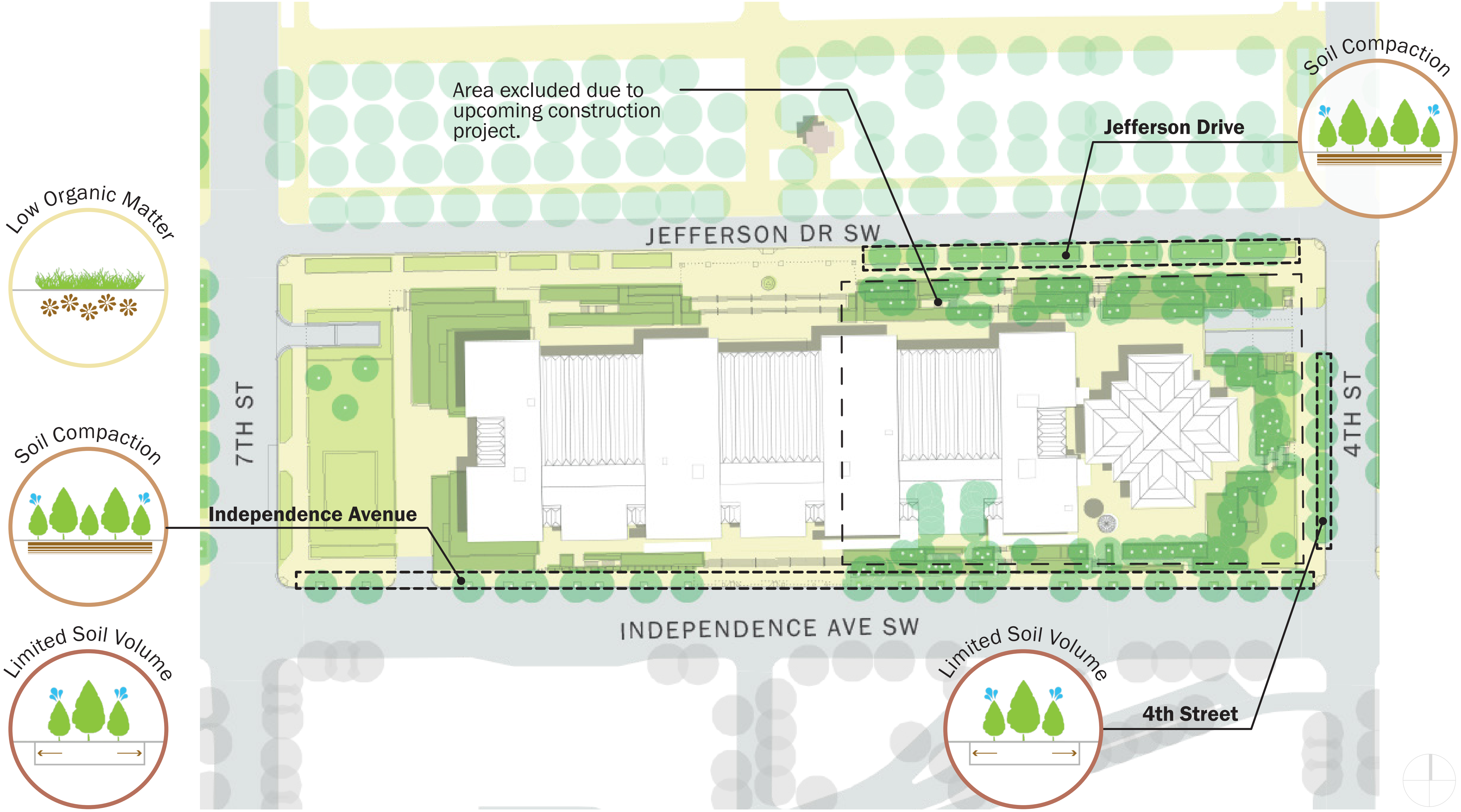
Hirshhorn Museum and Sculpture Garden (HMSG)

Soil issues & constraints



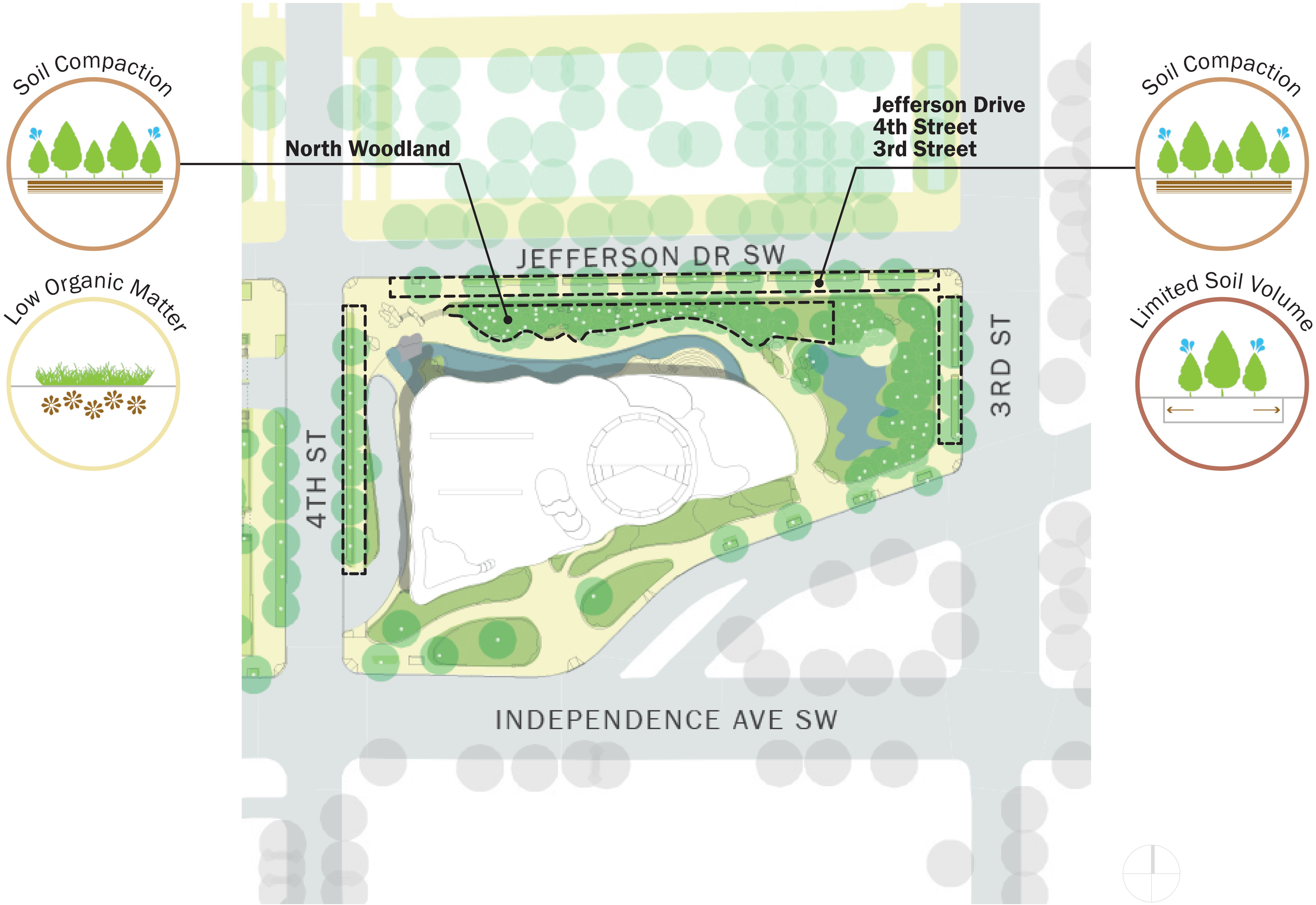
National Air and Space Museum (NASM)

Soil issues & constraints



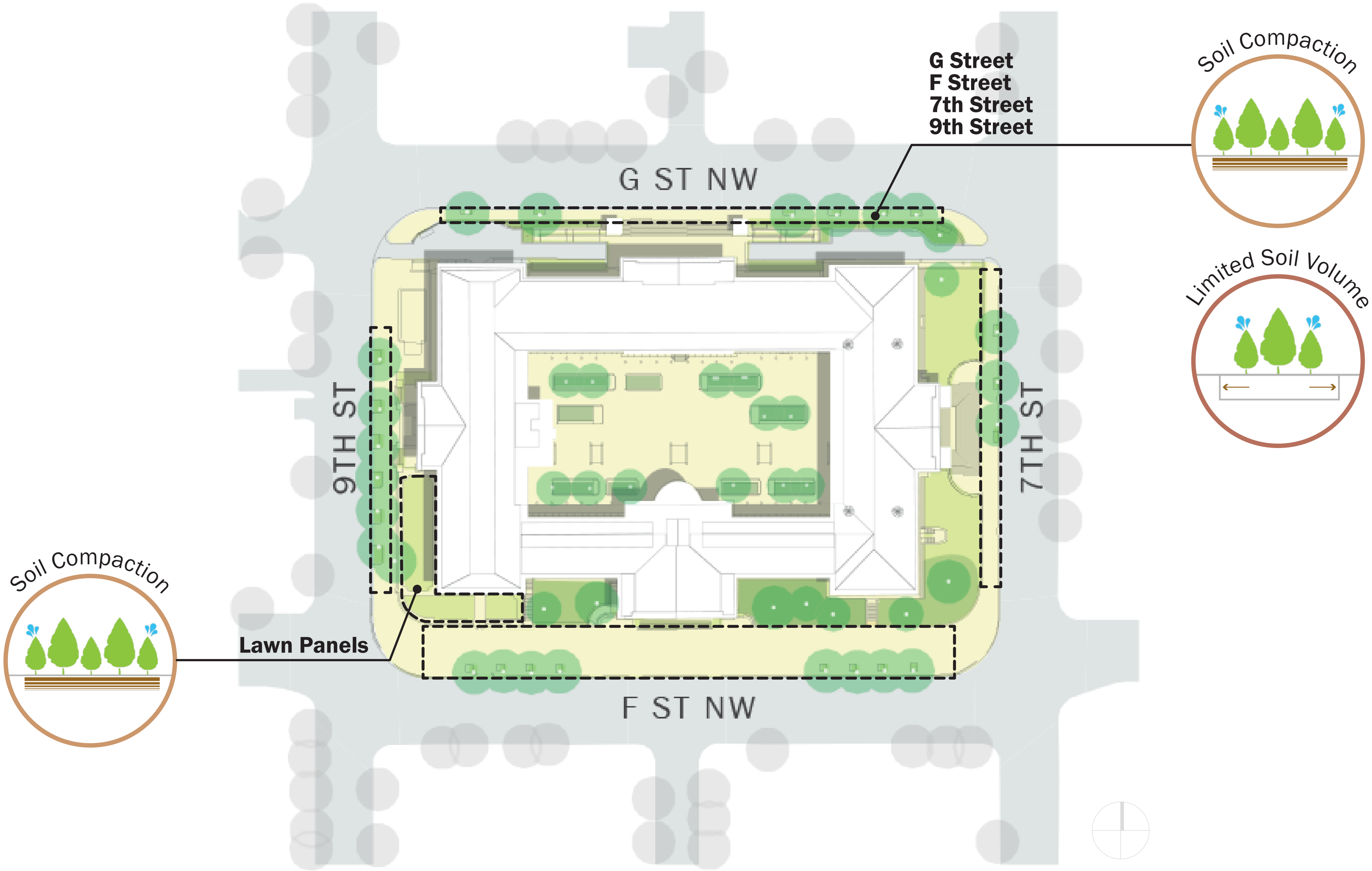
National Museum of the American Indian (NMAI)

Soil issues & constraints



Donald W. Reynolds Center (DWRC)

Soil issues & constraints



2 Soil Remediation Strategies & Approach

Renewed Approach to Loam Based Soil

For new projects with imported soil, utilizing a regional, naturally occurring loam-based soil, those native to the Piedmont region in Washington D.C. and Virginia, is required to create characteristics best suited for more consistent, healthy, and biologically diverse planting soils. Their improved nutrient and water holding capacity, strong aggregated structure that resists compaction and reduced reliance on irrigation provides reduced maintenance costs and a more sustainable medium for future plants.

These soils have developed, over thousands of years, a process of breaking down aggreagates, plant detritus and microbial matter to create a unique and stable medium specifically adapted to plant succession. In addition to strong soil structure and healthy microbial populations, this evolution sustains a more stable form of organic matter avoiding the limitations of evaporating or leaching compost for long term plant health.

Inclusion of more consistent soil types on new projects is addressed within updated construction specifications (Appendix F).

Remediation of Existing Soils

Broken into two categories to avoid damaging existing tree roots, there are eight proposed approaches to mitigate compaction, improve drainage and open soil porosity. In areas ***without*** roots, remediation ranges from simple surface treatment with mulch and compost to decompacting at increasing soil depths to improve soil porosity (deeper decompaction improves soil while raising machinery size and costs). In area ***with*** tree roots, mulch as a surface amendment is a base approach while pneumatic air tools are recommended for compaction remediation in various conditions.

Without Tree Roots

A0 Soil Surface Amendment
Leaf litter, mulch, and compost applications to improve soil quality

A1 Amending Existing Soil - 6”
General plant bed surface tilling and converting lawn area to planting area

A2 Soil Profile Rebuilding - 12”
Where soil surface compaction and structure needs remediation; using using rotary plow

A3 Soil Profile Rebuilding - 24”-30”
Where deep soil compaction, drainage, and soil structure needs remediation; using backhoe

With Tree Roots (in CRZs)

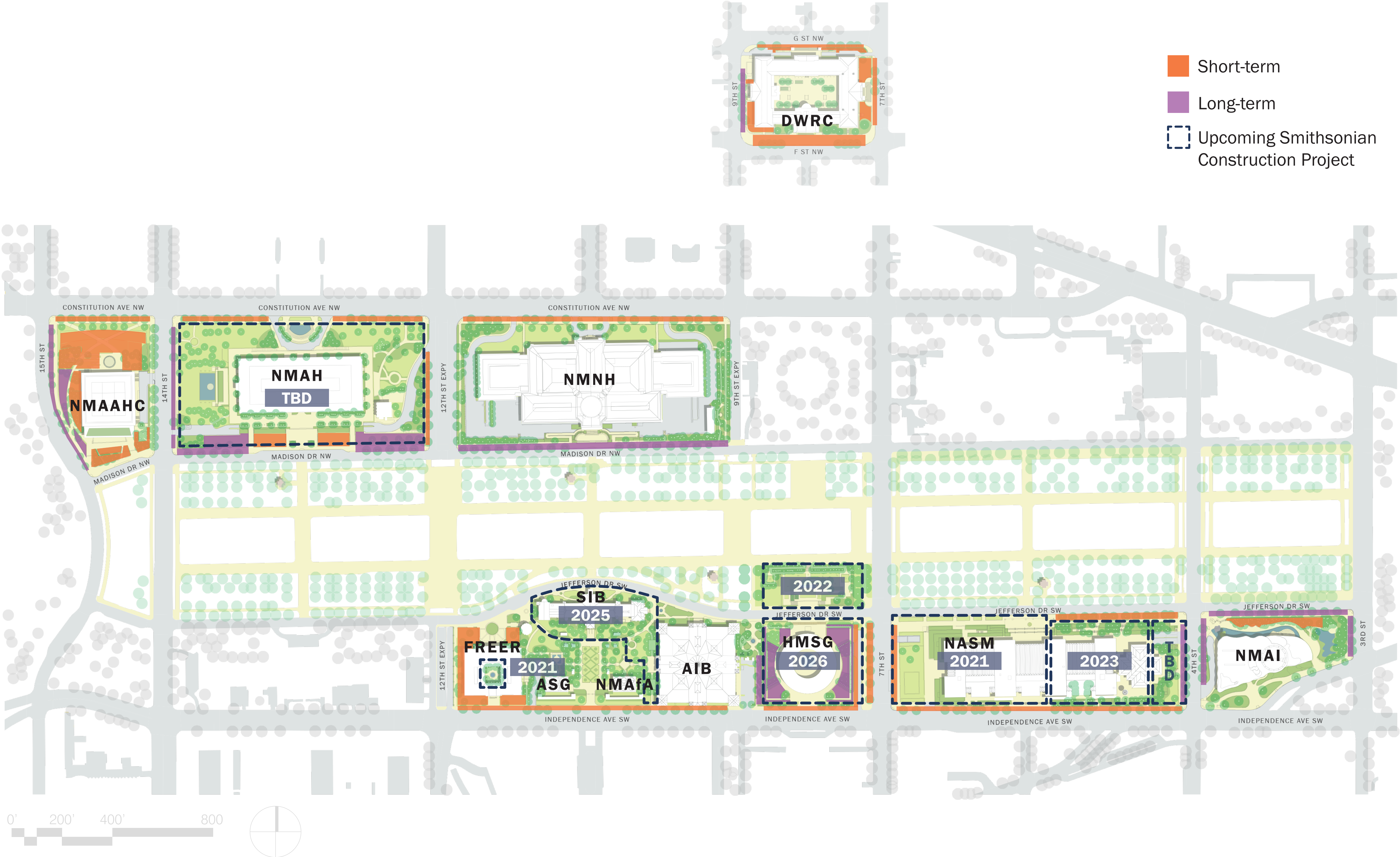
B0 Soil Surface Amendment
Mulch applications to protect bare soil and promote root growth

B1 Soil Surface Remediation (6”-8”)
Lawn and planting area remediation in CRZs; using an air spade

B2 Radial Trenching - Open Space
Improving tree root access to air, water, nutrients in decompacted soil with no adjacent constraints

B3 Radial Trenching - Streetscape
Improving tree root access to air, water, nutrients in decompacted soil where adjacent hardscape constraints are present

Soil Remediation Opportunity Areas



Short-term Remediation Opportunities

Criteria and Considerations

Short-term projects are those defined as ‘shovel-ready’. Remediation work can begin immediately as funding is available. Short-term projects were identified in collaboration with Smithsonian Gardens, and are subject to prioritization based on alignment with SG’s Strategic Plan, museum master plans, and identified needs by SG staff.

The matrix represents an assessment of remediation need, judged upon six criteria. The higher the overall score, the greater potential need for soil remediation. Soil Physical Condition and Visibility, are weighted to reflect the importance of these variables above other criteria.

Criteria including **Visibility** and **Maintenance Inputs** were graded on a sliding scale:

High — Low
4 3 2 1

Criteria including **Soil Physical Condition, Sensitivity to Impact, Plant Health and Habitat** and **Threat Resilience** were graded on a sliding scale:

Poor — Excellent
4 3 2 1

Museum	Zone / Area	Soil Physical Condition *(x1.5)*	Visibility *(x1.25)*	Maintenance Inputs	Sensitivity to Impact	Plant Health and Habitat	Threat Resilience	OVERALL	Cost	Disturbance	Proposed Remediation Strategy
NMAAHC	Hope Reading Grove	6	3.7	4	3	3	3	23	M	M	B1 - Soil Surface Remediation
NMAAHC	Spirituality Reading Grove	6	3.7	4	3	3	3	23	M	M	B1 - Soil Surface Remediation
NMAAHC	Resiliency Reading Grove	6	3.7	4	3	3	3	23	M	M	B1 - Soil Surface Remediation
NMAAHC	North Welcome Bed	6	5	4	3	3	3	24	M	M	A2 - Soil Profile Rebuilding (12”)
NMAAHC	Constitution Avenue	4.5	5	2	3	2	2	19	L	M	B1 - Soil Surface Remediation
NMAAHC	South Planting Beds	4.5	5	4	3	3	3	23	L	L	B0 - Soil Surface Amendments
NMAAHC	South Perennial Beds	4.5	3.7	4	3	2	3	21	L	L	A0 - Soil Surface Amendments
NMAAHC	South Entrance Lawn	6	3.7	3	3	3	3	22	H	H	High-Use Lawn Soil Installation
NMAAHC	North Lawn(s)	6	5	4	3	3	3	24	H	H	High-Use Lawn Soil Installation
NMAH	Constitution Avenue	6	5	2	3	3	2	21	L	M	B1 - Soil Surface Remediation
NMAH	12th Street	3	3.7	2	2	3	2	16	L	M	B1 - Soil Surface Remediation
NMNH	Constitution Avenue	6	5	2	3	3	2	21	L	M	B1 - Soil Surface Remediation
FREER	North Lawn Panels	3	5	1	2	2	2	15	L	L	B1 - Soil Surface Remediation
FREER	West Lawn Panel	4.5	5	1	2	3	2	18	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
FREER	South Lawn Panels	3	3.7	1	2	3	2	15	L	L	B1 - Soil Surface Remediation
HAUPT	Independence Avenue	4.5	5	2	4	4	2	22	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
HMSG	East perimeter lawn	3	5	1	2	4	2	17	M	M	A2 - Soil Profile Rebuilding (12”)
HMSG	7th Street	6	5	2	2	3	2	20	H	H	B3 - Radial Trenching (Streetscape)
HMSG	Independence Avenue	4.5	5	2	4	3	2	21	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
NASM	Jefferson Drive	6	5	2	4	3	2	22	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
NASM	7th Street	4.5	3.7	2	2	4	3	20	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
NASM	Independence Avenue	4.5	5	2	4	3	3	22	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
NMAI	North Woodland	3	5	2	2	3	3	18	L	L	B0 and B1 - Soil Surface Amending / Remediation
DWRC	F Street	6	2.5	1	3	4	2	19	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
DWRC	SW Corner Lawn Panels	3	1.2	1	2	3	2	12	L	L	A1 - Amending Existing Soil
DWRC	Metro Bed	6	2.5	1	4	4	3	21	L	M	A1 - Amending Existing Soil
DWRC	G Street	6	3.7	1	3	4	2	20	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
DWRC	North Entrance Beds	3	3.7	1	2	2	2	14	M	M	A2 - Soil Profile Rebuilding (12”)
DWRC	7th Street	6	2.5	1	3	4	2	19	H	H	A3 - Soil Profile Rebuilding (24” - 30”)
DWRC	East Lawn Panels	3	2.5	1	2	2	2	13	L	M	A1 - Amending Existing Soil

L Low **M** Medium **H** High

Long-term Remediation Opportunities

Criteria and Considerations

Long-term projects are those defined as having impediments to beginning work sooner, such as healthy, mature trees, or the remediation would otherwise be best completed at the time when an adjacent Capital project is impacting the proposed remediation area. Long-term projects are subject to prioritization based on alignment with SG's Strategic Plan, museum master plans or Captial improvement projects, and identified needs by SG staff.

The matrix represents an assessment of remediation need, judged upon three criteria. The higher the overall score, the greater need for soil remediation.

Criteria including **Visibility** was graded on a sliding scale:

High 4 3 2 1 Low

Criteria including **Soil Physical Condition** and **Plant Health and Habitat** were graded on a sliding scale:

Poor 4 3 2 1 Excellent

Museum	Zone / Area	Visibility	Soil Physical Condition	Plant Health and Habitat		OVERALL		Cost	Disturbance	Proposed Remediation Strategy
NMAAHC	West Lawn Planters	4	4	4		12		M	M	A2 - Soil Profile Rebuilding (12")
NMAAHC	West Tree Planters	4	4	4		12		L	M	B1 - Soil Surface Remediation
NMAAHC	15th Street	4	3	2		9		H	H	A3 - Soil Profile Rebuilding (24" - 30")
NMAAHC	15th Street	4	3	2		9		M	M	B3 - Radial Trenching (Streetscape)
NMAH	North Tree Lawn Panels	4	3	2		9		M	H	B2 - Radial Trenching (Open Space)
NMAH	14th Street	3	3	3		9		L	L	B1 - Soil Surface Remediation
NMAH	14th Street	3	3	2		8		L	L	A1 - Amending Existing Soil
NMAH	South Lawn Panels	4	2	2		8		H	H	High-Use Lawn Soil Installation
NMAH	South Tree Lawn Panels	4	2	2		8		L	L	B1 - Soil Surface Remediation
NMAH	Madison Drive	4	4	3		11		H	H	A3 - Soil Profile Rebuilding (24" - 30")
NMNH	North Tree Lawn Panels	4	2	2		8		M	H	B2 - Radial Trenching (Open Space)
NMNH	Madison Drive	4	4	3		11		H	H	A3 - Soil Profile Rebuilding (24" - 30")
HMSG	Interior Plant Beds	4	3	2		9		H	H	A3 - Soil Profile Rebuilding (24" - 30")
HMSG	Interior Lawn Panels	4	3	3		10		H	H	A3 - Soil Profile Rebuilding (24" - 30")
RIPLEY	At-grade garden below Elms	1	3	3		7		L	H	B1 - Soil Surface Remediation
NASM	4th Street	2	2	2		6		H	H	A3 - Soil Profile Rebuilding (24" - 30")
NMAI	4th Street	2	3	2		7		H	H	A3 - Soil Profile Rebuilding (24" - 30")
NMAI	Jefferson Drive	4	3	2		9		H	H	A3 - Soil Profile Rebuilding (24" - 30")
NMAI	3rd Street	4	2	2		8		H	H	A3 - Soil Profile Rebuilding (24" - 30")
DWRC	9th Street	2	4	2		8		H	H	A3 - Soil Profile Rebuilding (24" - 30")

L Low **M** Medium **H** High

A0 Soil Surface Amendment

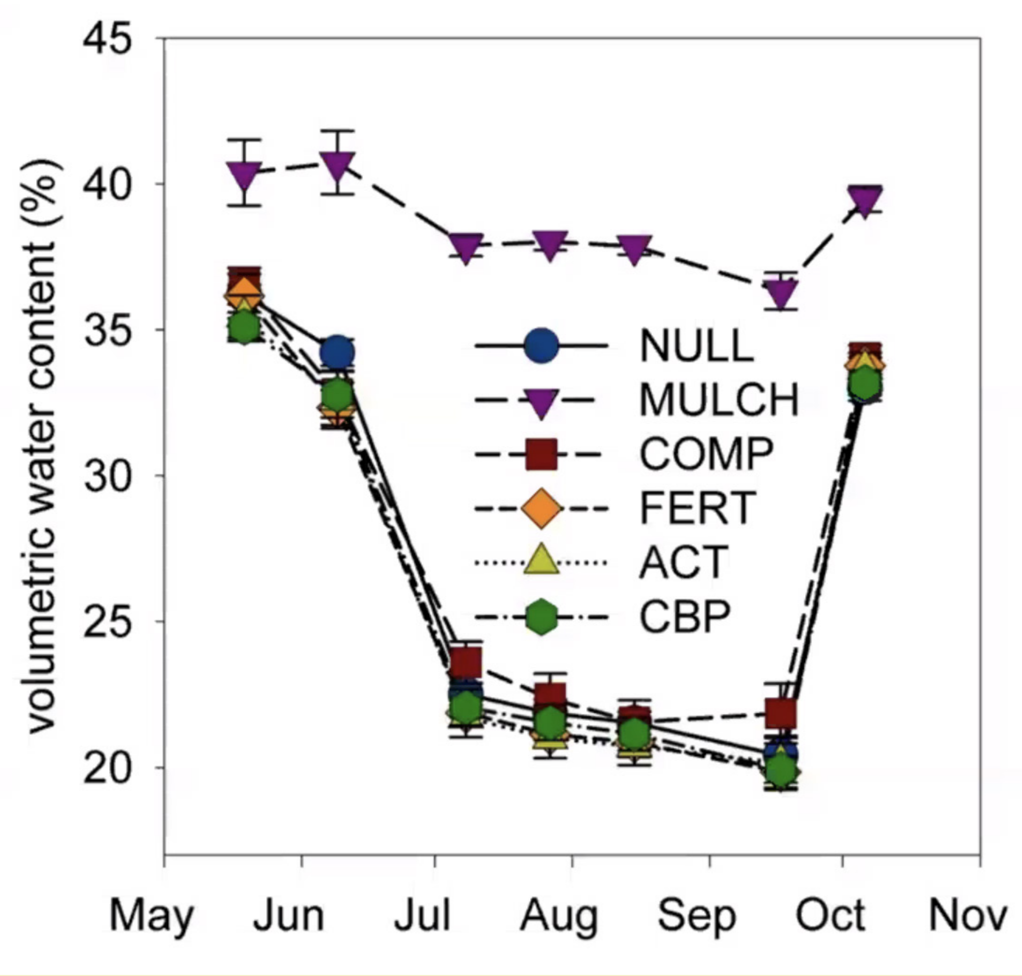
The most practical soil amendments are natural organic materials - namely mulch and compost. Good quality compost – that is compost that has been fully processed and meets the requirements of the U.S. Composting Council - is derived from plant-based materials such as leaves, grasses, and woody stems. Compost derived from animal manure or food feedstocks are typically high in salt content and should be avoided (or used with caution). Compost derived solely from bark, especially pine bark, will typically have very low pH (high acidity) and minimal nutrient content and should be avoided as a soil amendment.

Compost as a topdressing material will reduce evaporation of soil moisture and protect the soil from compaction. It is important to note that good quality compost is comprised of approximately 1.1 percent nitrogen, or about 4- to 7 pounds of nitrogen per cubic yard. This is the equivalent of about 1 pound of nitrogen per 50 square feet of area at roughly 1" depth. Compost also provides many other nutrients in slow-release form such as phosphorus, potassium, sulfur, calcium and magnesium, and many micronutrients.

As compost decomposes, it also releases humic- and fulvic acids into the soil that contribute to the build-up and establishment of more stable organic matter with increased microbial activity. The humic- and fulvic acids improve nutrient availability for plants while also contributing to soil ped development and stability, improving soil porosity.

Other soil amendments that passively improve soil conditions include calcium sulfate (gypsum) and/or calcium carbonate to improve soil structure. The calcium in these compounds enable clay colloids to bind together to form more stable soil peds that improve soil structure. Also possibly effective are microbial inoculants that typically contain a minimum of 8 mycorrhizal fungal strains and/or more than 300 bacterial strains. While reseach is not conclusive on the benefits of inoculants, if used, they should contain more than 50 fungal spores per gram of inoculant.

☑ Areas *without* Trees
$ Cost
N/A Disturbance



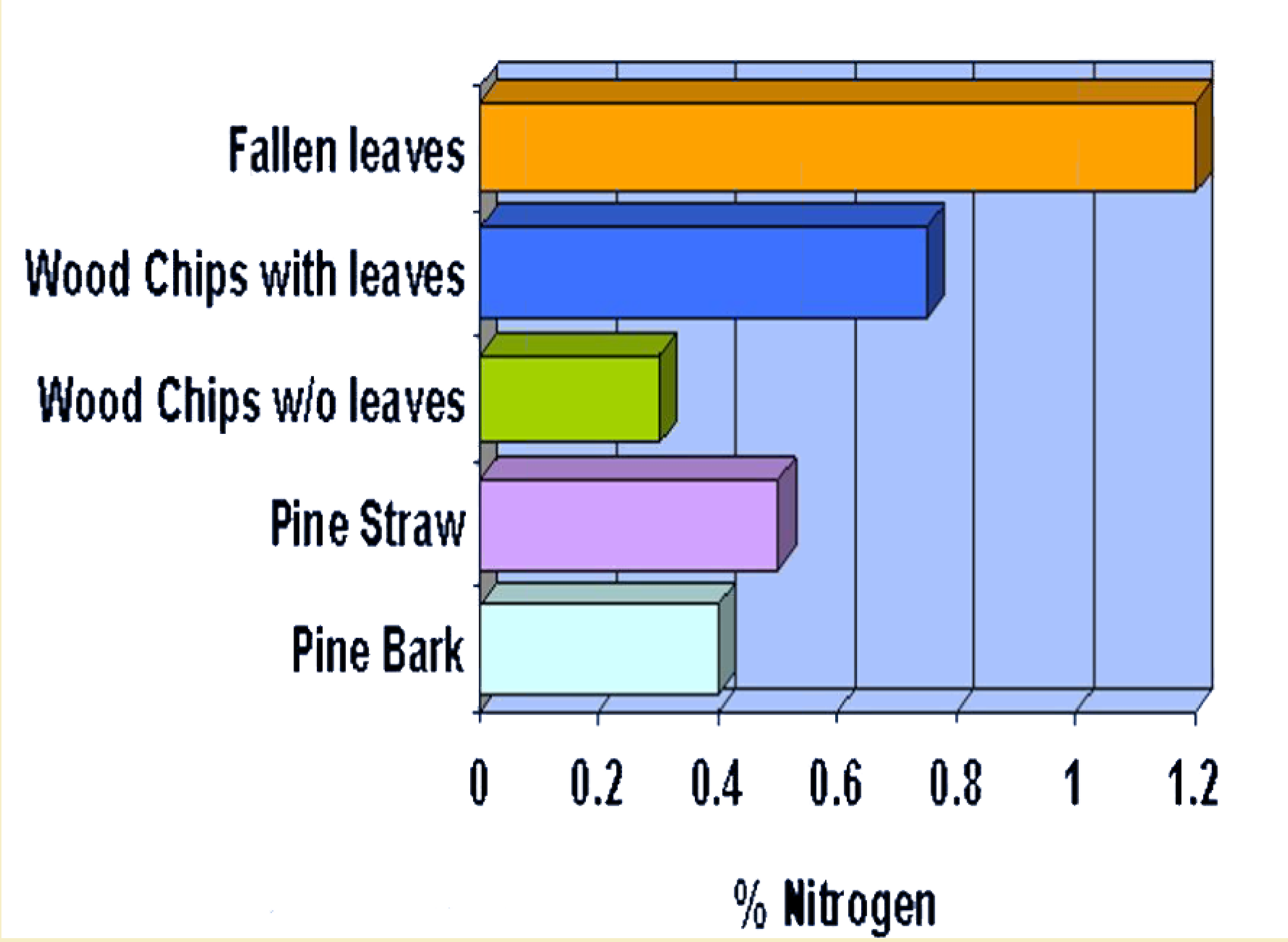
* Courtesy Bryant Scharenbroch, *Arboriculture and Urban Forestry*

B0

Soil Surface Amendment

☑	Areas *with* Trees
$	Cost
N/A	Disturbance

The best way to encourage tree root growth and protect soil from compaction and drying out, is by covering bare soil with mulch and minimizing turf. Doing so improves water holding capacity and soil structure, thereby leading to improved microbial activity and nutrient availability, thereby leading to deeper, healthier root growth. Mulch, including double shredded hardwood, straight leaf litter, and wood chips with ground leaves incorporated are among the best choices. Where visual aesthetic allows, any ground leaf litter incorporated with shredded bark mulch will improve tilth, fertility, and loosen compacted soil. Simply covering the soil with any of these options can improve root growth density by three to fives times, as compared with turf, over a period of 3-5 years.

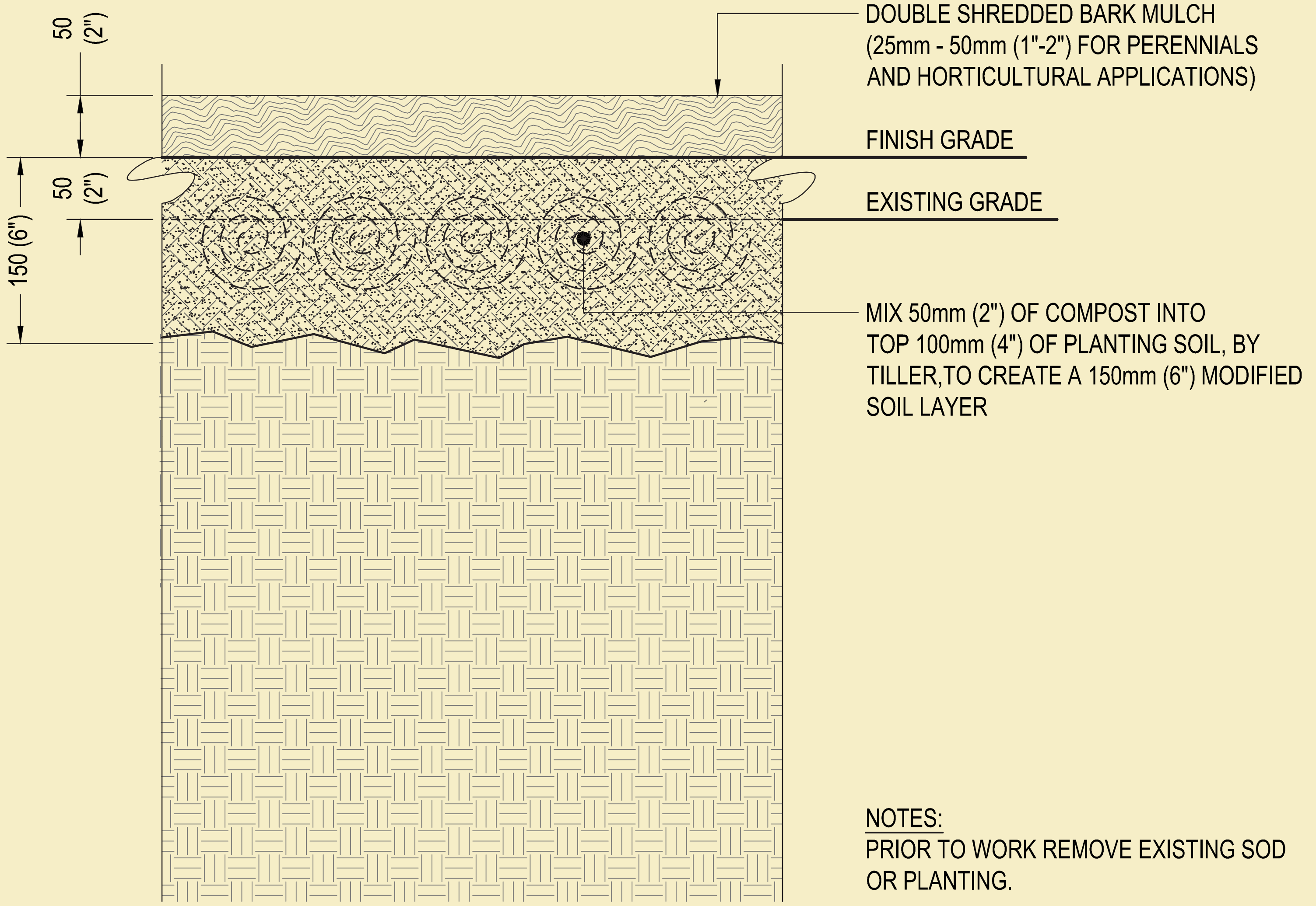


* Courtesy Gary Watson, Morton Aboretum, Chicago

A1 Amending Existing Soil (6”)

In areas with poorly draining soil and/or shallow compaction (typically hard, dense soil, often with platy structure, and less than 150mm [6”] deep), tilling and amending the existing soil with the addition of compost may be sufficient to improve soil conditions and plant growth.

☑ Areas *without* Trees
$$ Cost
Low Disturbance

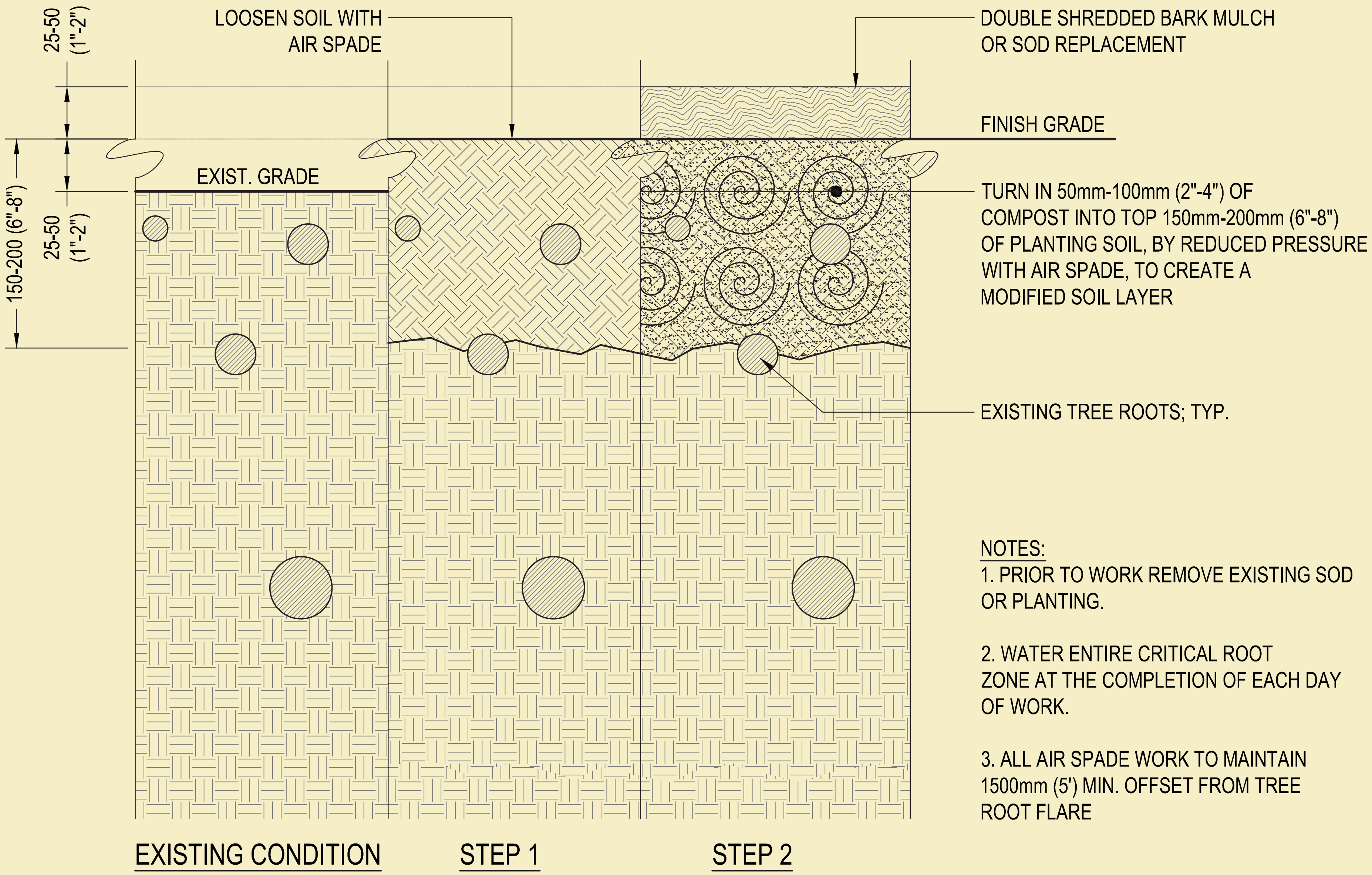


NOTES:
PRIOR TO WORK REMOVE EXISTING SOD OR PLANTING.

B1 Soil Surface Remediation (6” - 8”)

Soil decompaction and remediation within critical root zones (CRZ), or lawn areas being converted to planting areas within CRZs, should utilize pneumatic air tools (i.e. air spades) to excavate soil without physically damaging roots. Use reduced air pressure to turn in compost with the soil to create the amended soil layer.

☑ Areas *with* Trees
$$ Cost
Low Disturbance



NOTES:

1. PRIOR TO WORK REMOVE EXISTING SOD OR PLANTING.

2. WATER ENTIRE CRITICAL ROOT ZONE AT THE COMPLETION OF EACH DAY OF WORK.

3. ALL AIR SPADE WORK TO MAINTAIN 1500mm (5') MIN. OFFSET FROM TREE ROOT FLARE

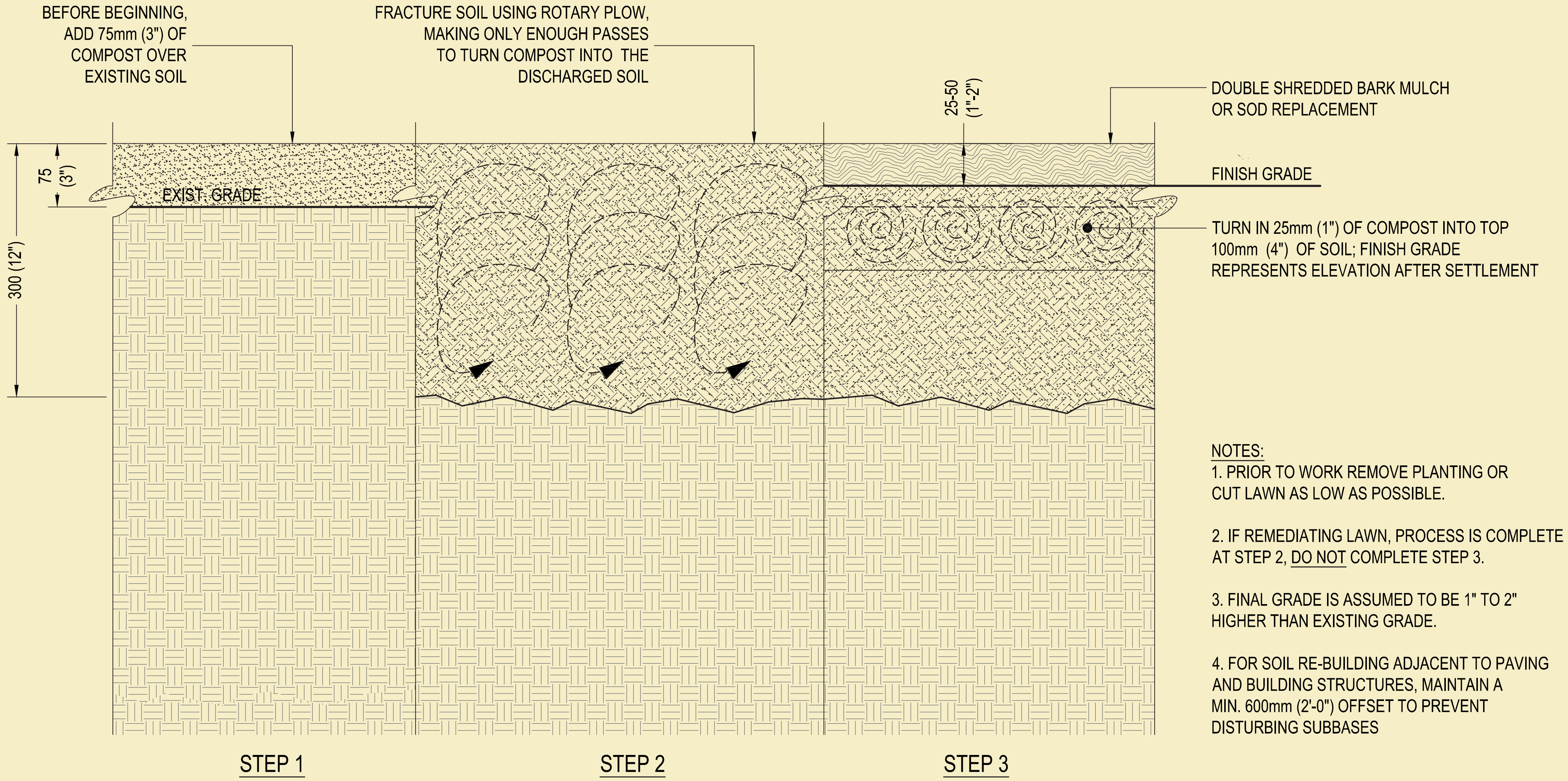
A2 Soil Profile Rebuilding (12”)

Primarily in lawn areas with poor draining soil and/or deep compaction (typically hard, dense soil greater than 150-200mm [6-8”] deep), fracturing the soil to depths of 300mm (12”) and simultaneously turning in compost will improve soil aeration, infiltration, and help rebuild soil structure.

☑ Areas *without* Trees

$$$ Cost

Med. Disturbance



NOTES:

1. PRIOR TO WORK REMOVE PLANTING OR CUT LAWN AS LOW AS POSSIBLE.

2. IF REMEDIATING LAWN, PROCESS IS COMPLETE AT STEP 2, DO NOT COMPLETE STEP 3.

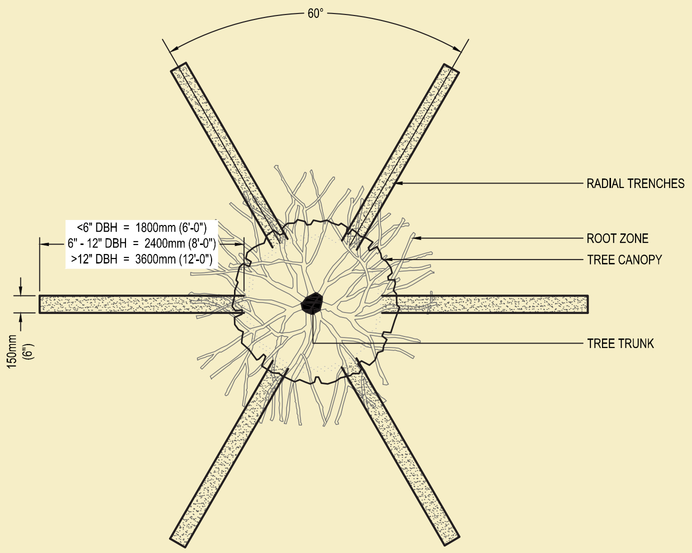
3. FINAL GRADE IS ASSUMED TO BE 1" TO 2" HIGHER THAN EXISTING GRADE.

4. FOR SOIL RE-BUILDING ADJACENT TO PAVING AND BUILDING STRUCTURES, MAINTAIN A MIN. 600mm (2'-0") OFFSET TO PREVENT DISTURBING SUBBASES

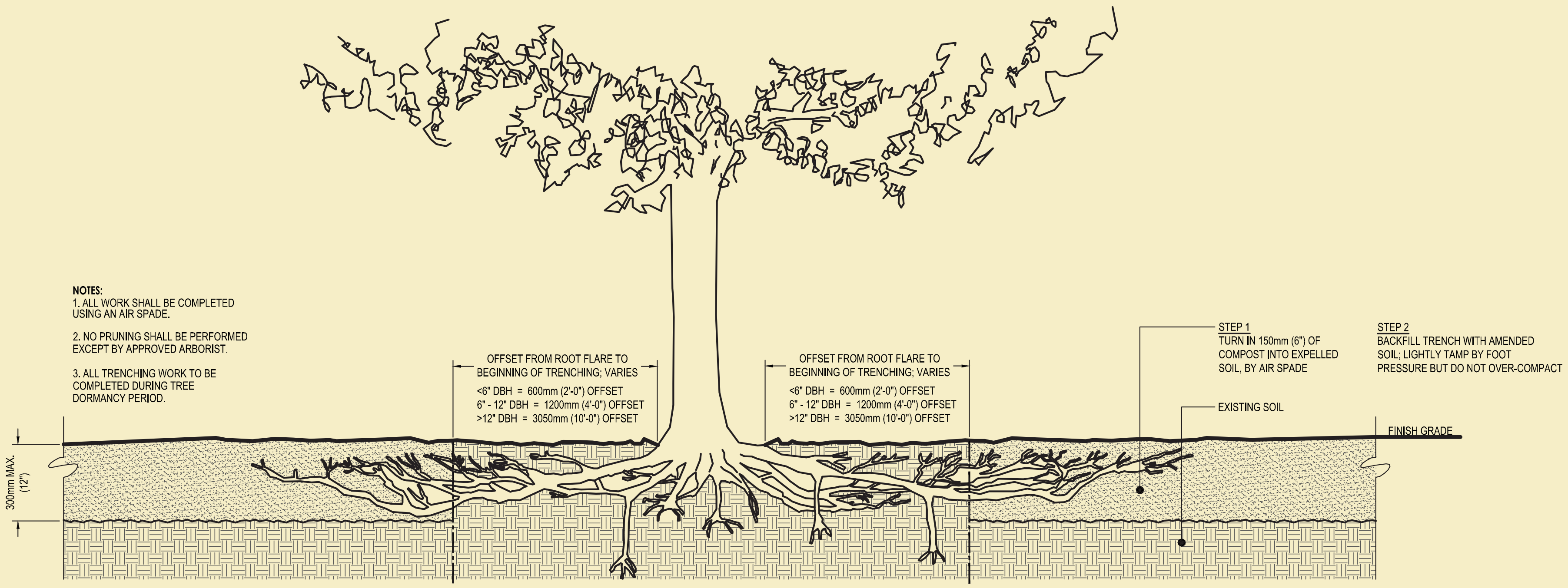
B2 Radial Trenching: Open Space

Radial trenching involves the excavation of narrow trenches, arrayed around the tree trunk at equal intervals to open compacted soil, thereby improving soil aeration and drainage. The trench shall be filled with a mixture of compost and expelled soil - allowing a deeper exchange of oxygen and water around tree roots.

☑ Areas *with* Trees
$$$ Cost
Med. Disturbance



PLAN VIEW: NTS

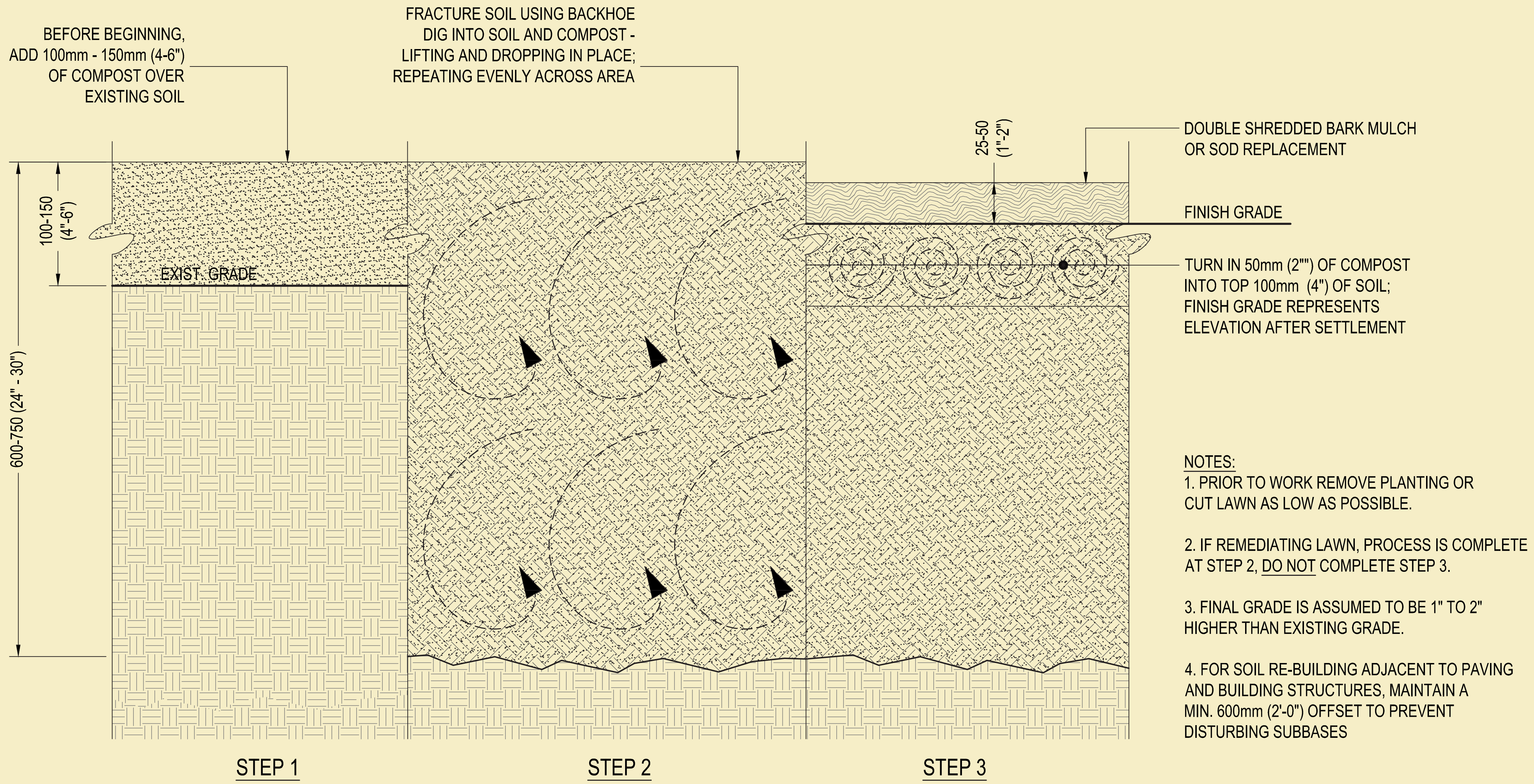


SECTION VIEW

A3 Soil Profile Rebuilding (24” - 30”)

In cases where soil compaction is excessively deep (typically in streetscape zones), and where soils have been damaged due to construction or where contractor-replacement soil has been incorrectly installed, full depth soil rebuilding will be necessary to effectively remediate the issues and prevent continual plant stress.

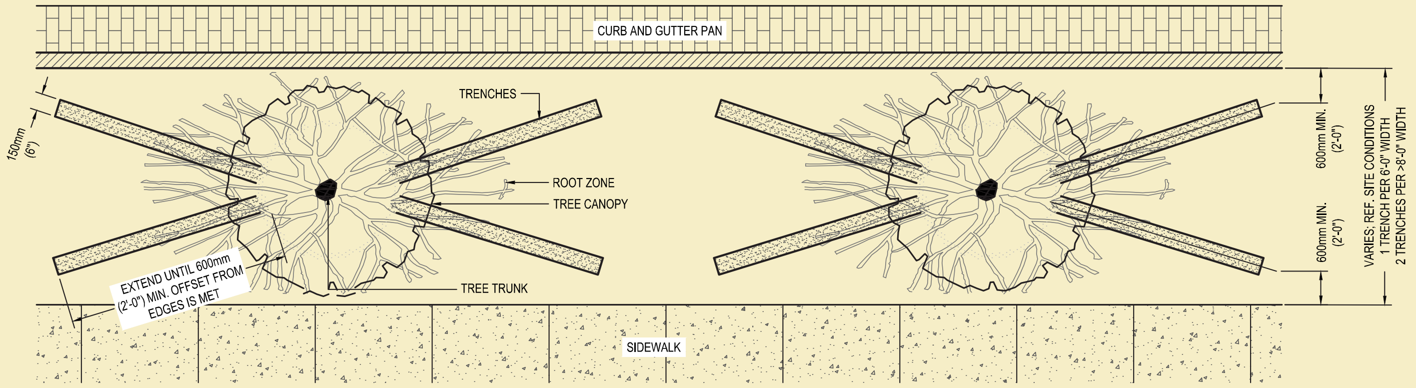
☑ Areas *without* Trees
$$$$ Cost
High Disturbance



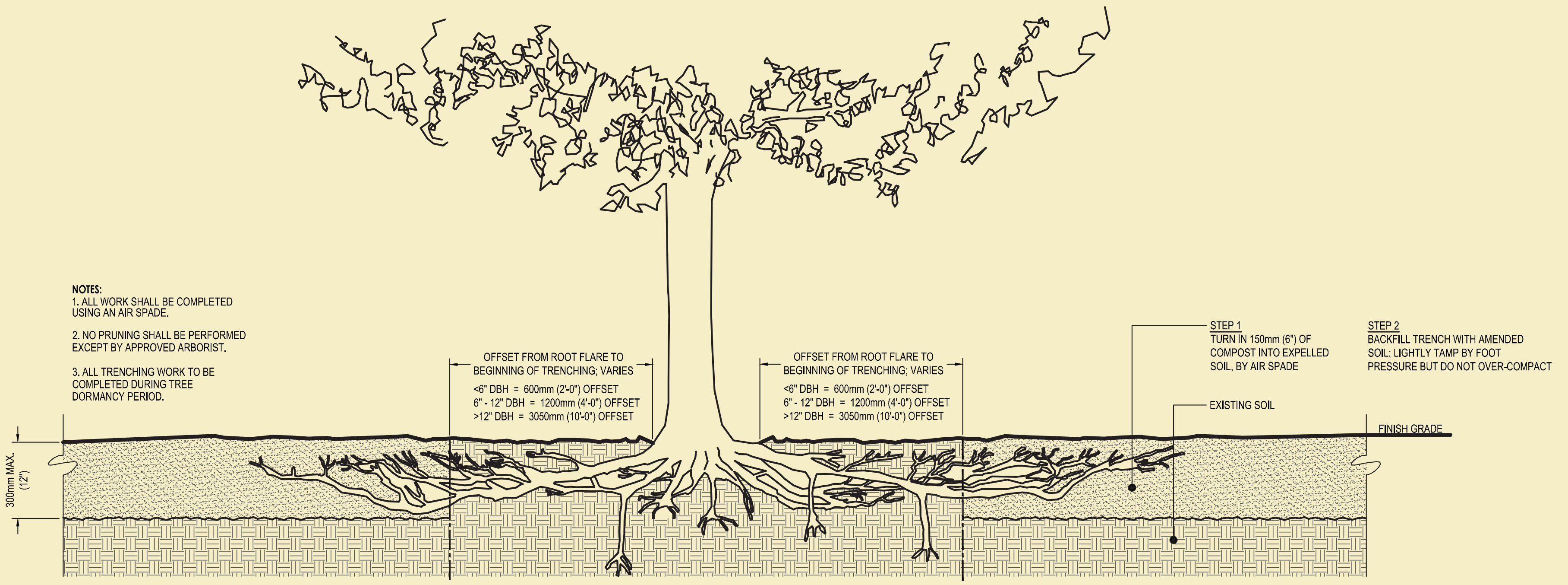
B3 Radial Trenching: Streetscape

Radial trenching involves the excavation of narrow trenches, arrayed around the tree trunk at equal intervals to open compacted soil, thereby improving soil aeration and drainage. The trench shall be filled with a mixture of compost and expelled soil - allowing a deeper exchange of oxygen and water around tree roots.

☑ Areas *with* Trees
$$$$ Cost
High Disturbance



PLAN VIEW: NTS



LONGITUDINAL SECTION VIEW

National Museum of African American History and Culture (NMAAHC)

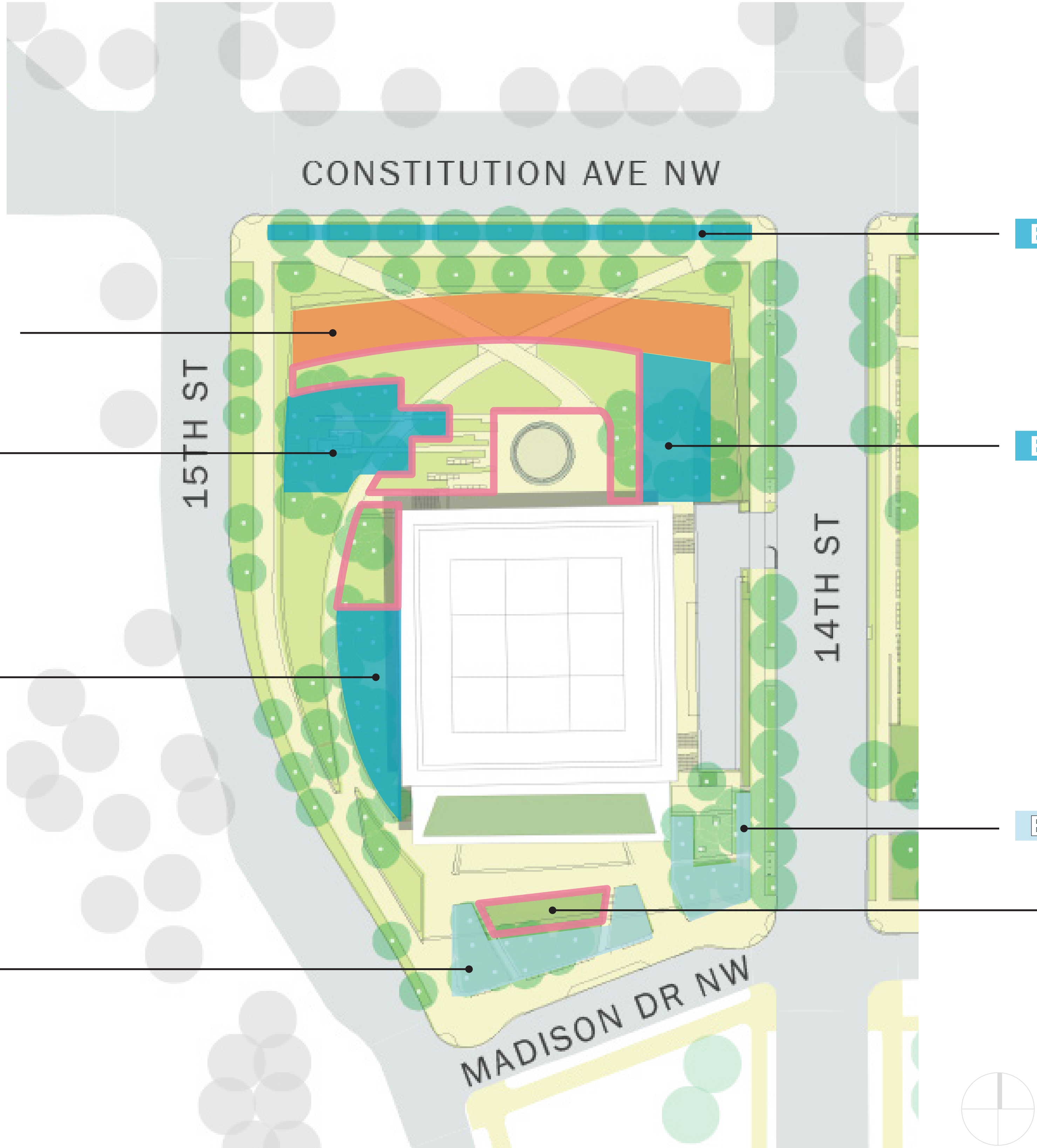
Short-term

A2 **Soil Profile Rebuilding (12")**
and conversion of lawn area
to planting area

B1 **Soil Surface Remediation**
and conversion of lawn area
to planting area

B1 **Soil Surface Remediation**
and conversion of lawn area
to planting area

B0 **Soil Surface Amendments**



B1 **Soil Surface Remediation**
and conversion of lawn area
to perennial planting area with
street tree fencing

B1 **Soil Surface Remediation**
and conversion of lawn area
to planting area

B0 **Soil Surface Amendments**

High-Use Lawn Soil
remove existing 12" deep
soil profile and replace

National Museum of African American History and Culture (NMAAHC)

Long-term

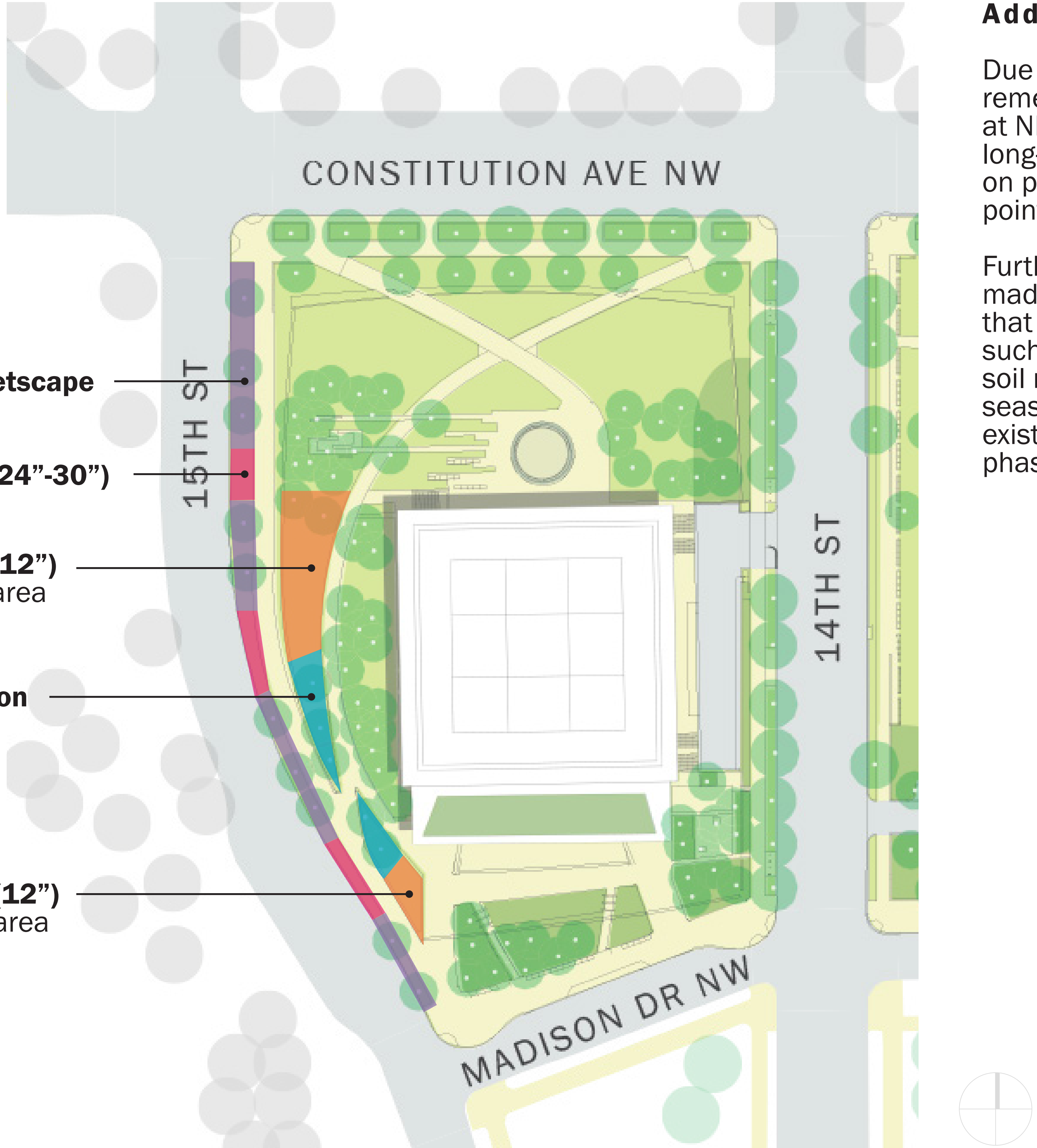
B3 **Radial Trenching - Streetscape**

A3 **Soil Profile Rebuilding (24”-30”)**

A2 **Soil Profile Rebuilding (12”)** and conversion of lawn area to planting area

B1 **Soil Surface Remediation**

A2 **Soil Profile Rebuilding (12”)** and conversion of lawn area to planting area



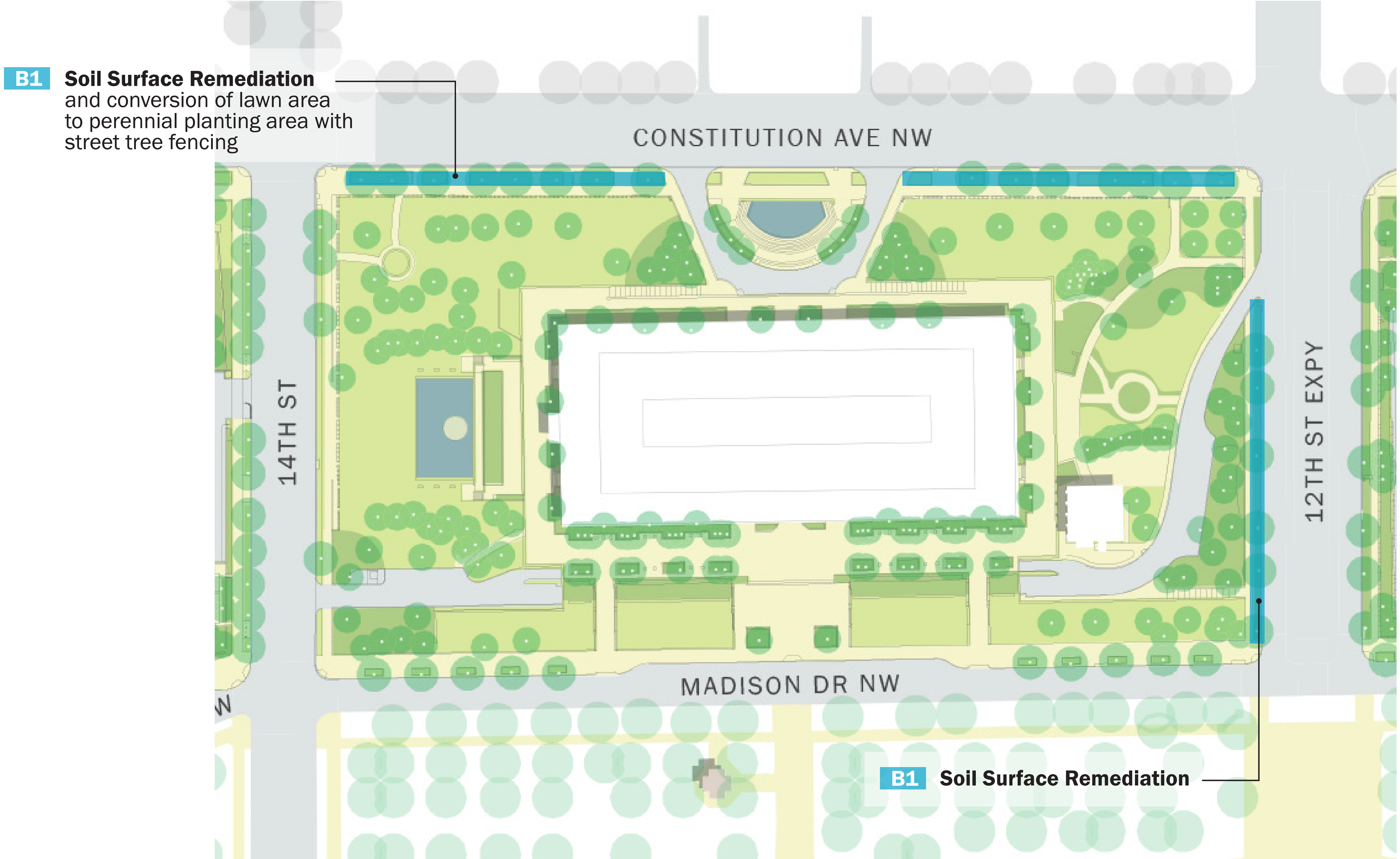
Additional Notes:

Due to various alternatives to soil remediation of sand based soils at NMAAHC, the short-term and long-term soil approaches shown on pages 58 and 59 are a starting point for remediation.

Further considerations should be made on a project-by-project basis that consider contributing factors such as project budgets, extent of soil replacement or remediation, season of impact, preservation of existing plants, and construction phasing.

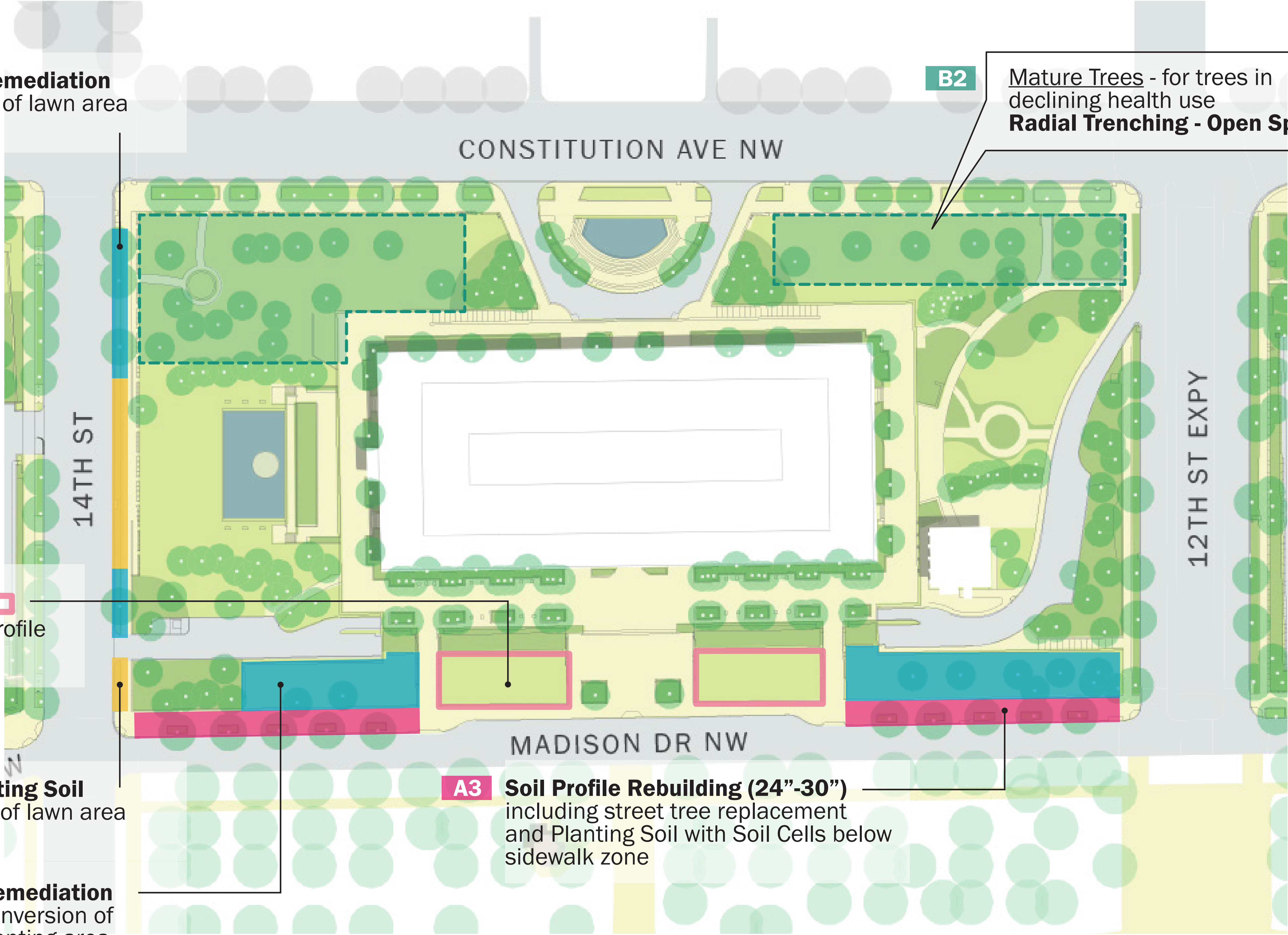
National Museum of American History (NMAH)

Short-term



National Museum of American History (NMAH)

Long-term



B1 **Soil Surface Remediation** and conversion of lawn area to planting area

B2 Mature Trees - for trees in declining health use **Radial Trenching - Open Space**

High-Use Lawn Soil remove existing soil profile and install new soil

A1 **Amending Existing Soil** and conversion of lawn area to planting area

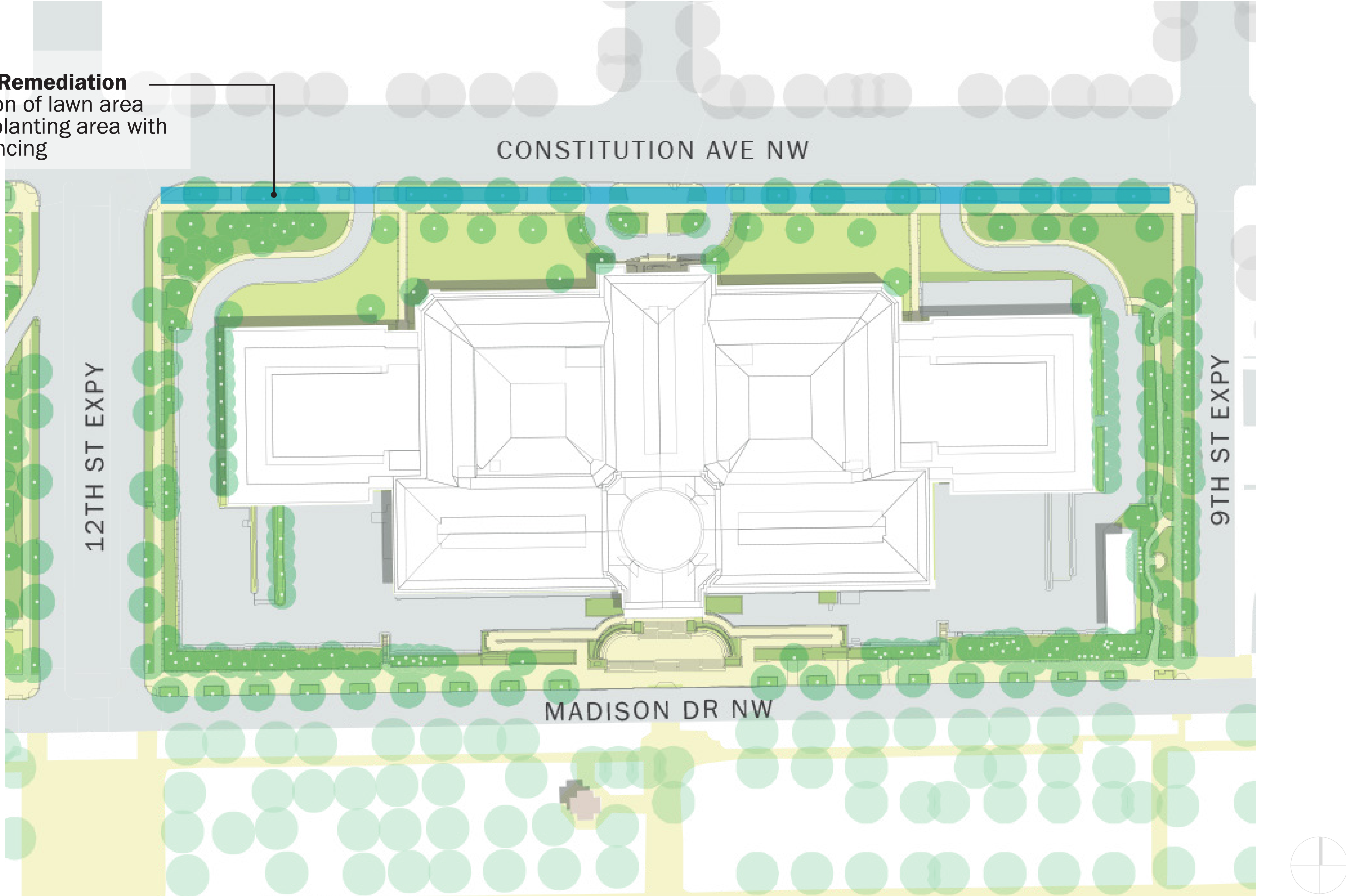
A3 **Soil Profile Rebuilding (24”-30”)** including street tree replacement and Planting Soil with Soil Cells below sidewalk zone

B1 **Soil Surface Remediation** and optional conversion of lawn area to planting area

National Museum of Natural History (NMNH)

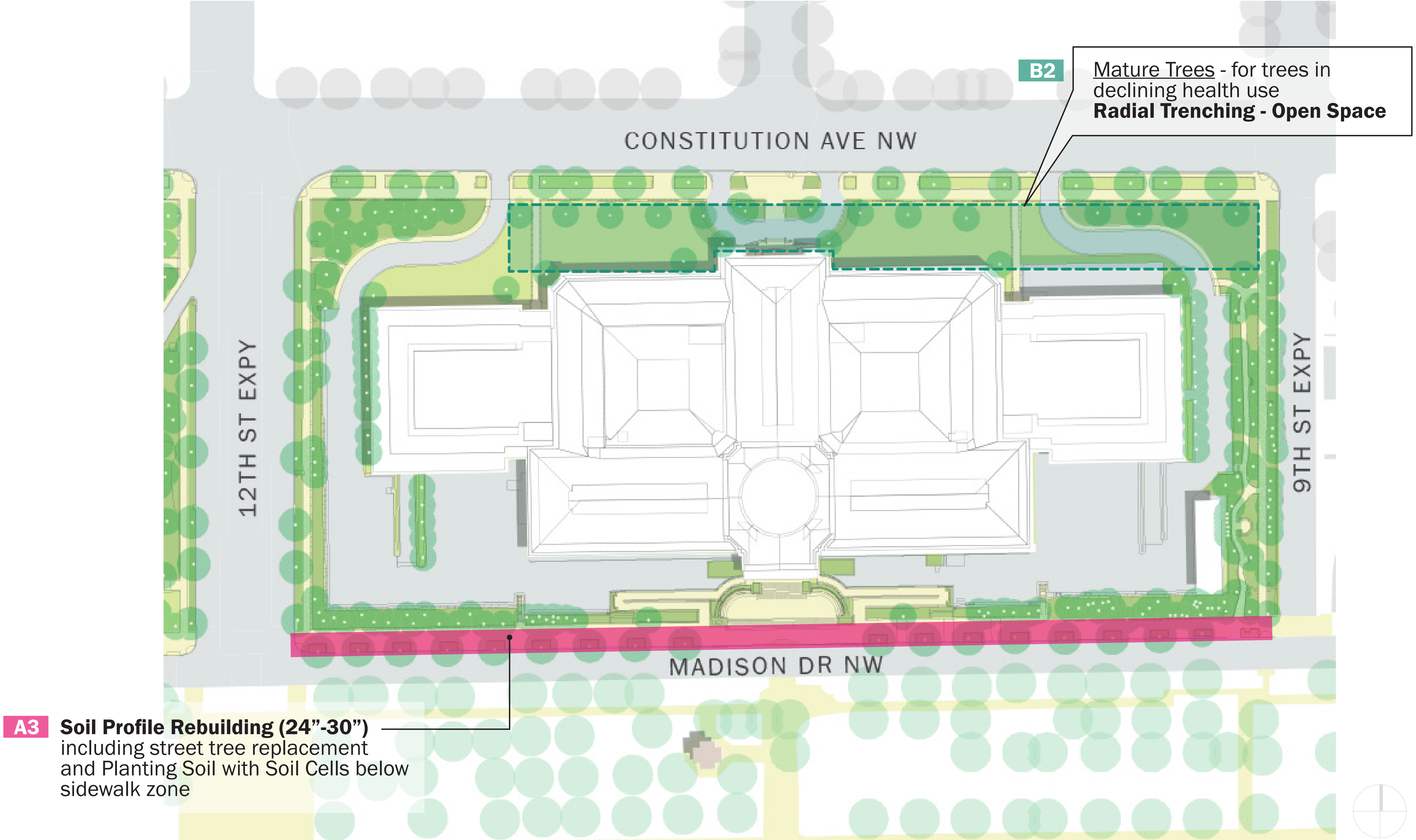
Short-term

B1 **Soil Surface Remediation** and conversion of lawn area to perennial planting area with street tree fencing



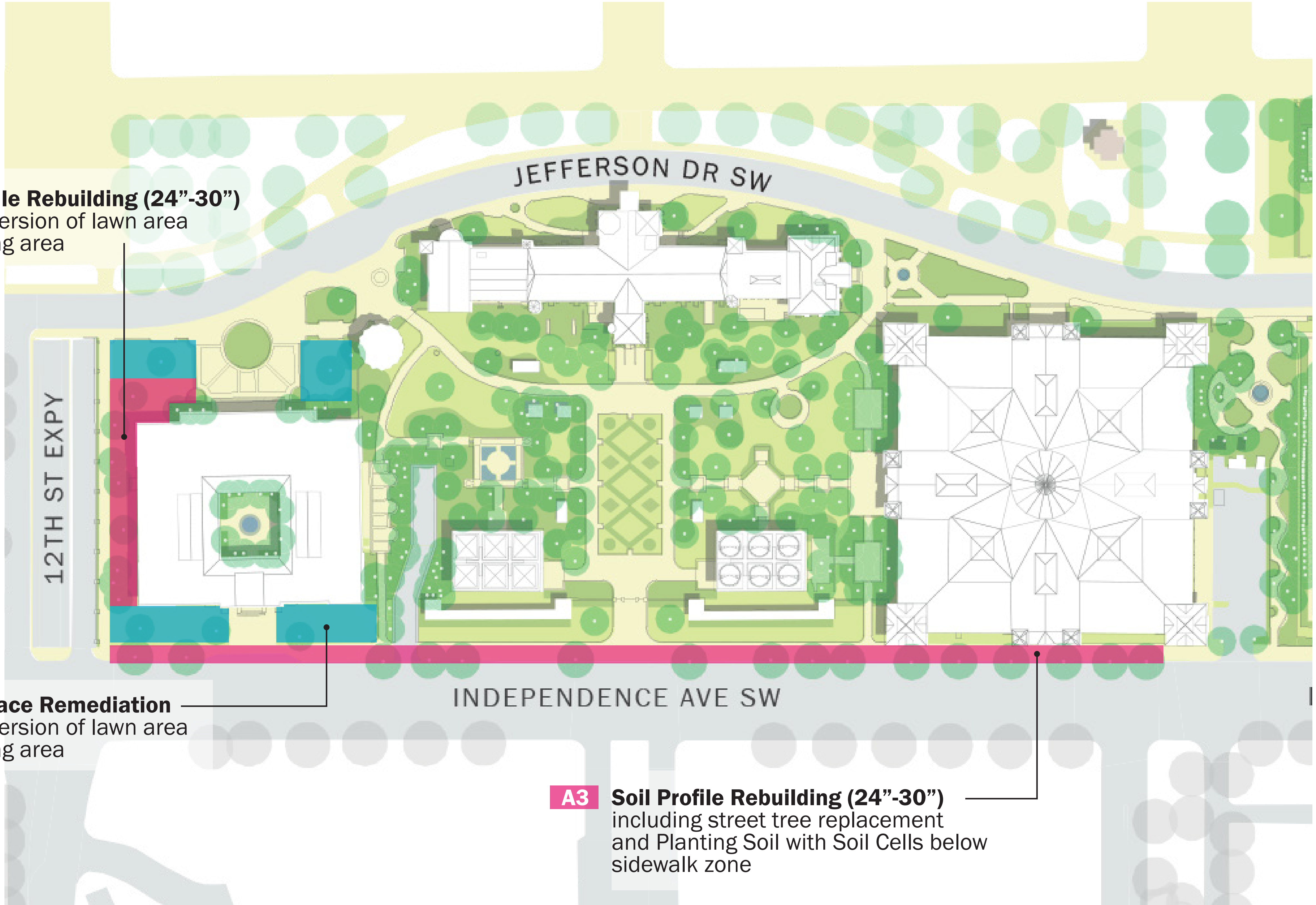
National Museum of Natural History (NMNH)

Long-term



South Mall Campus (SIB, AIB, Freer, Haupt, Rose, Ripley)

Short-term



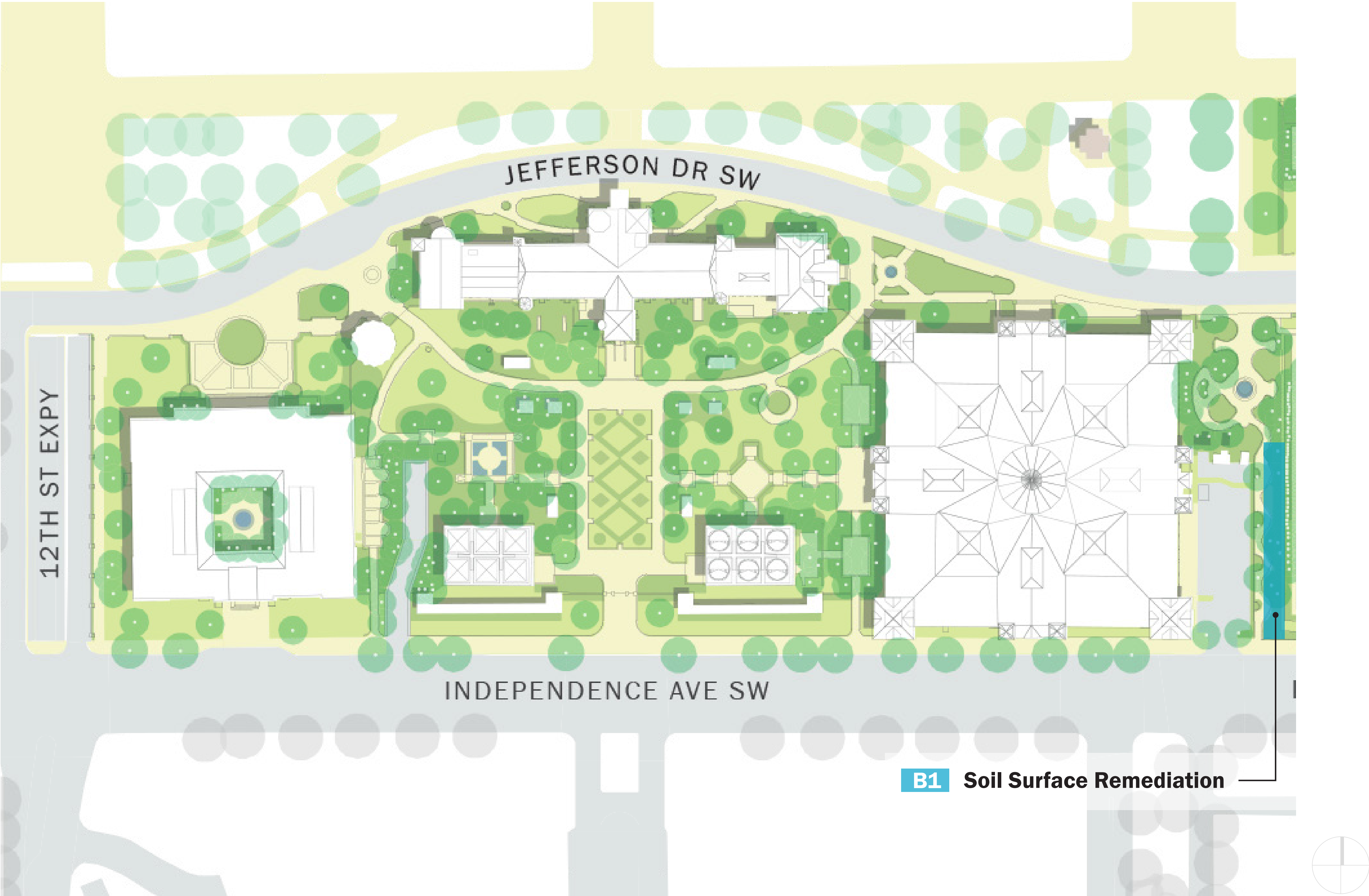
A3 **Soil Profile Rebuilding (24"-30")** and conversion of lawn area to planting area

B1 **Soil Surface Remediation** and conversion of lawn area to planting area

A3 **Soil Profile Rebuilding (24"-30")** including street tree replacement and Planting Soil with Soil Cells below sidewalk zone

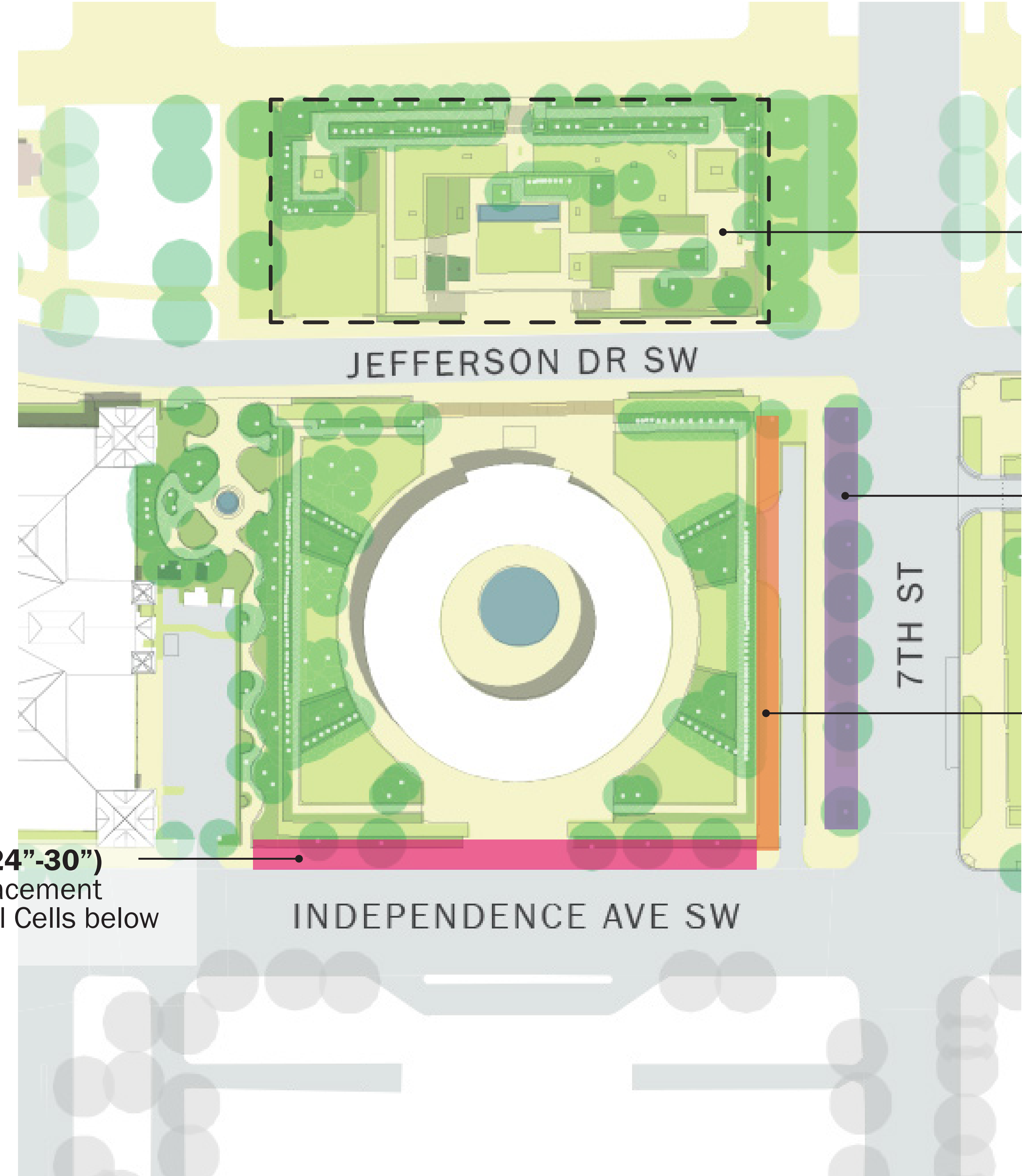
South Mall Campus (SIB, AIB, Freer, Haupt, Rose, Ripley)

Long-term



Hirshhorn Museum and Sculpture Garden (HMSG)

Short-term



Remediation observations not included due to design project already in process.

B3 Radial Trenching - Streetscape and conversion of lawn area to planting area

A2 Soil Profile Rebuilding (12") and conversion of lawn area to planting area

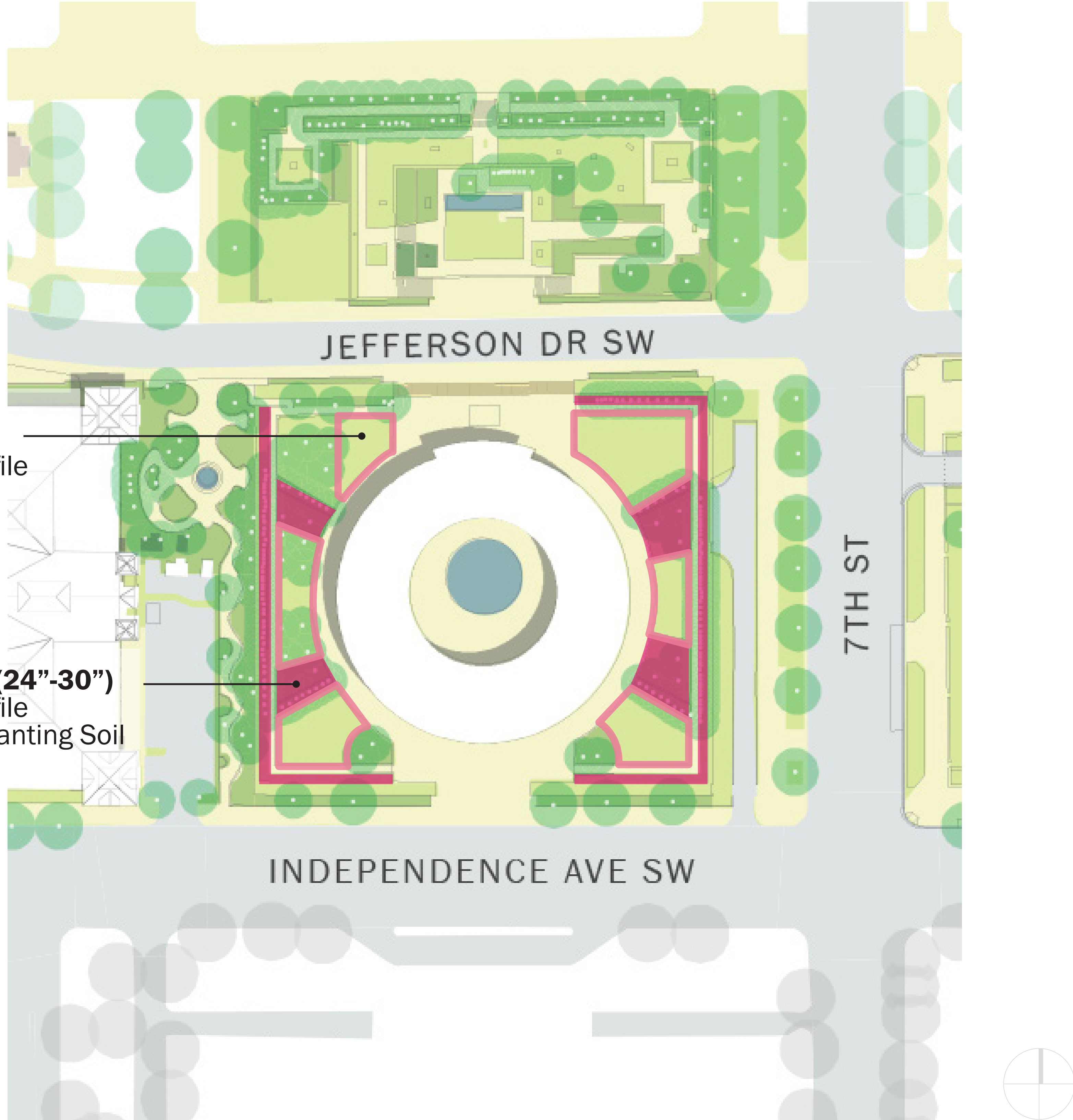
A3 Soil Profile Rebuilding (24"-30") including street tree replacement and Planting Soil with Soil Cells below sidewalk zone

Hirshhorn Museum and Sculpture Garden (HMSG)

Long-term

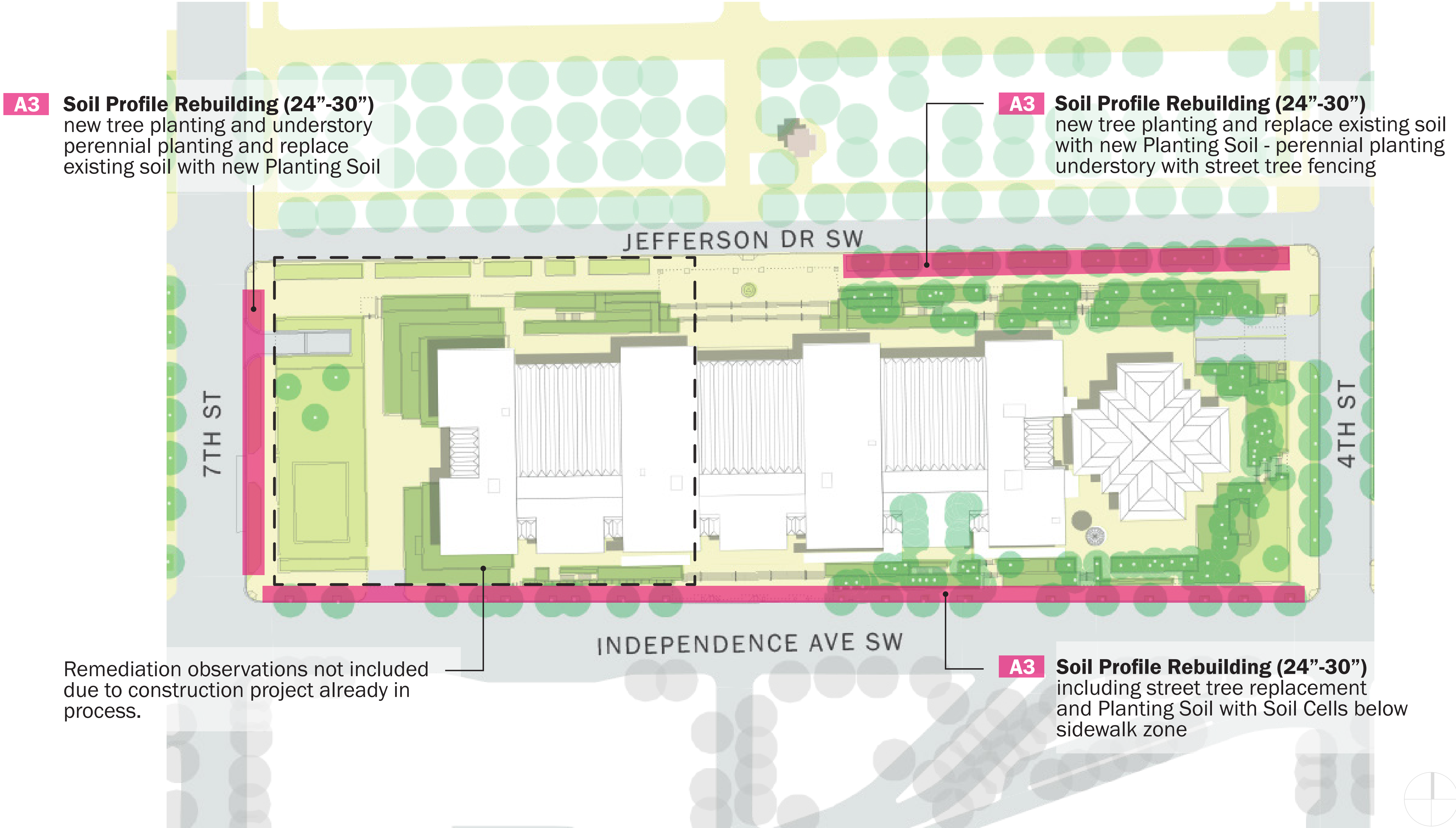
High-Use Lawn Soil
remove existing soil profile
and install new soil

A3 **Soil Profile Rebuilding (24”-30”)**
remove existing soil profile
and replace with new Planting Soil



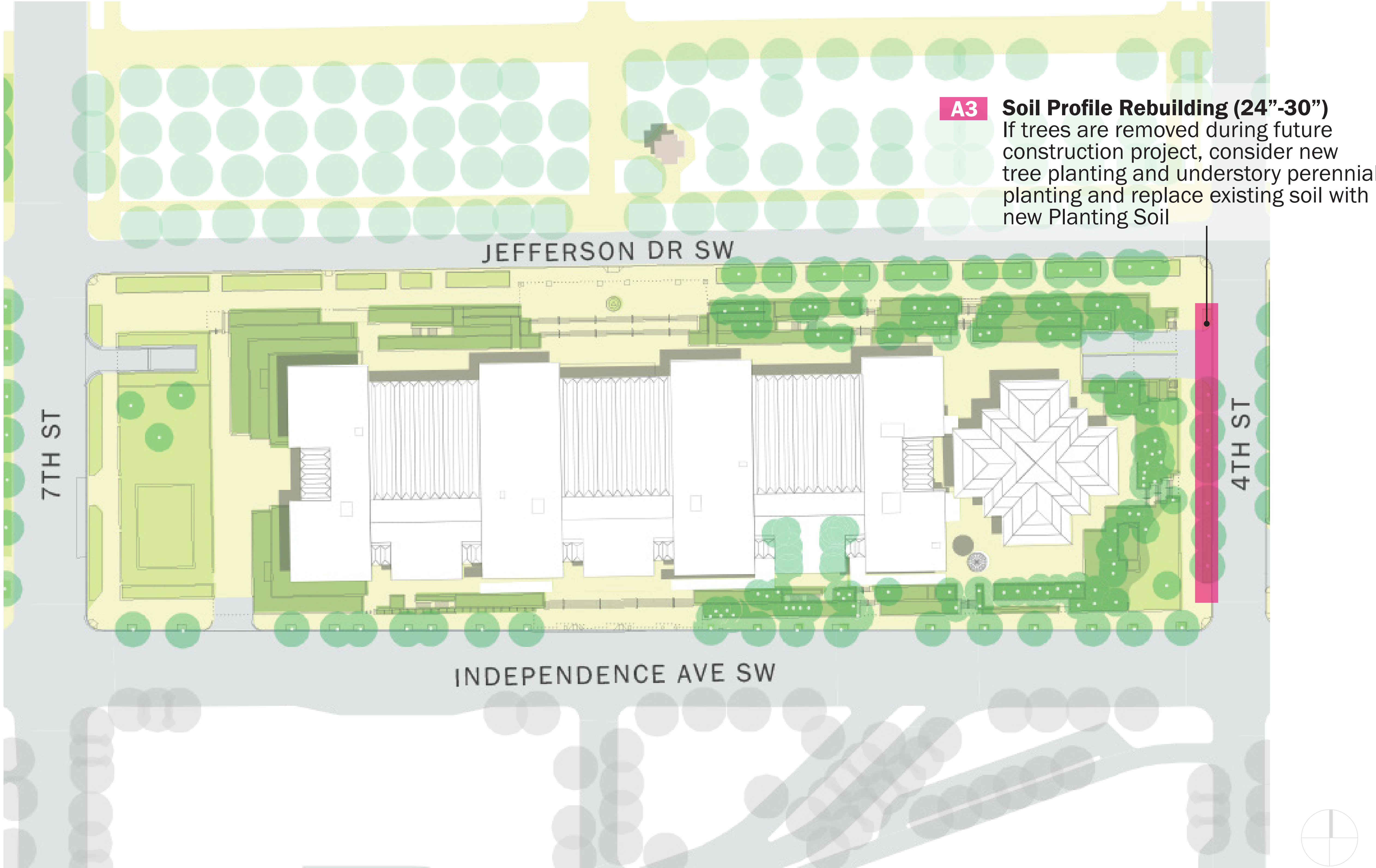
National Air and Space Museum (NASM)

Short-term



National Air and Space Museum (NASM)

Long-term



National Museum of the American Indian (NMAI)

Short-term

B0 **Soil Surface Amendments**

+

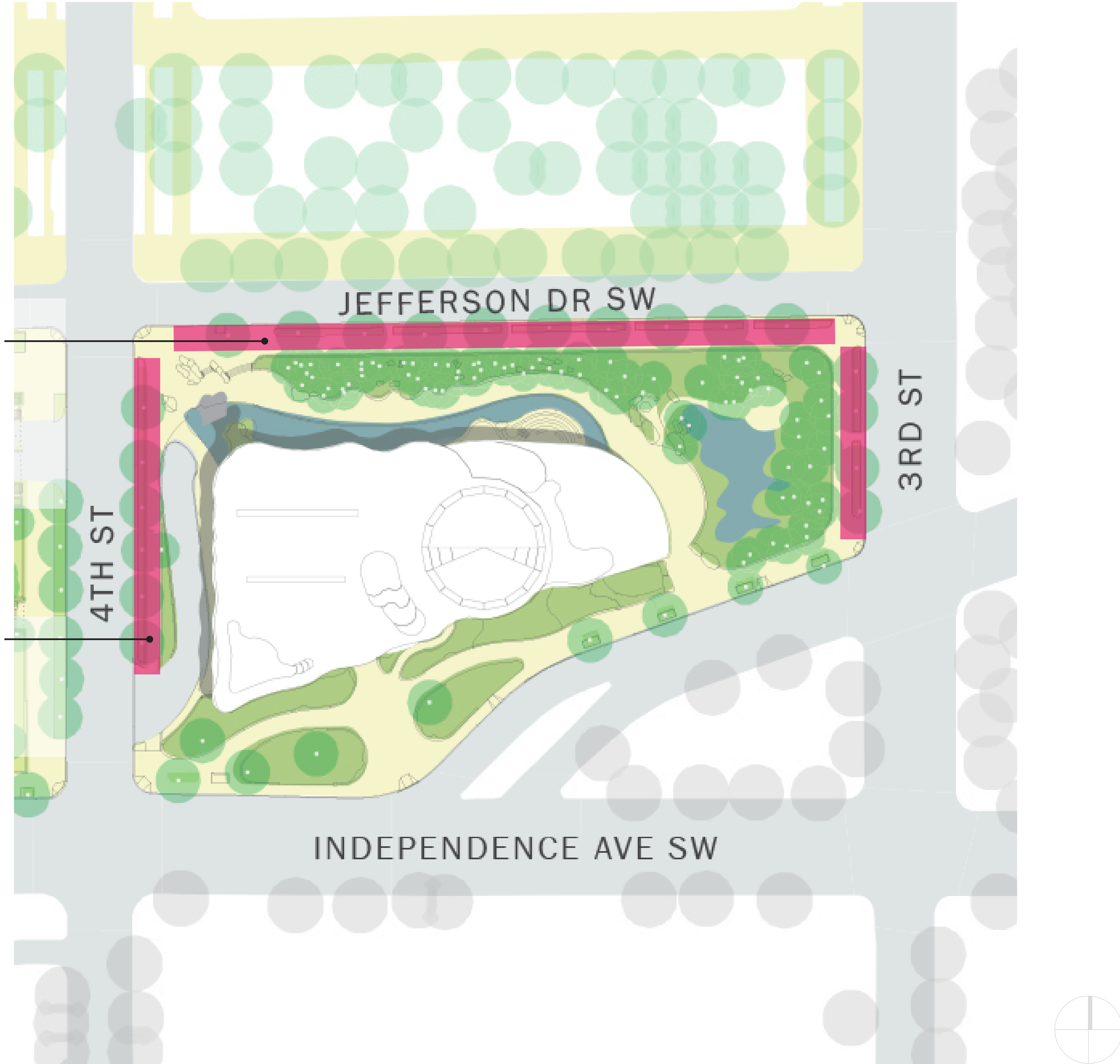
B1 **Soil Surface Remediation** including perennial plantings as ground cover

National Museum of the American Indian (NMAI)

Long-term

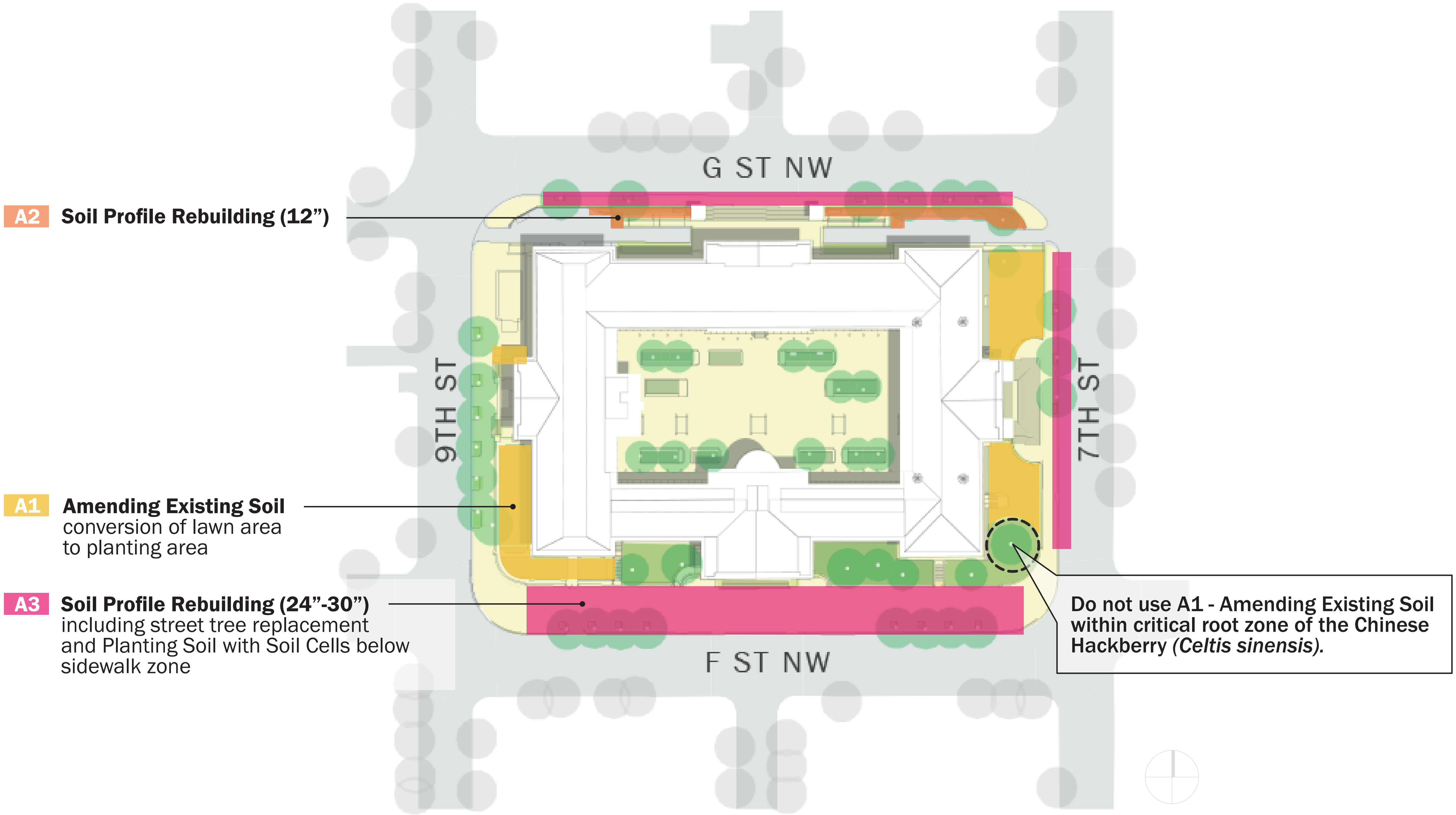
A3 **Soil Profile Rebuilding (24"-30")** including street tree replacement and Planting Soil with Soil Cells below sidewalk zone; consider perennial planting understory with street tree fencing

A3 **Soil Profile Rebuilding (24"-30")** including street tree replacement and Planting Soil with Soil Cells below sidewalk zone (3rd and 4th Streets)



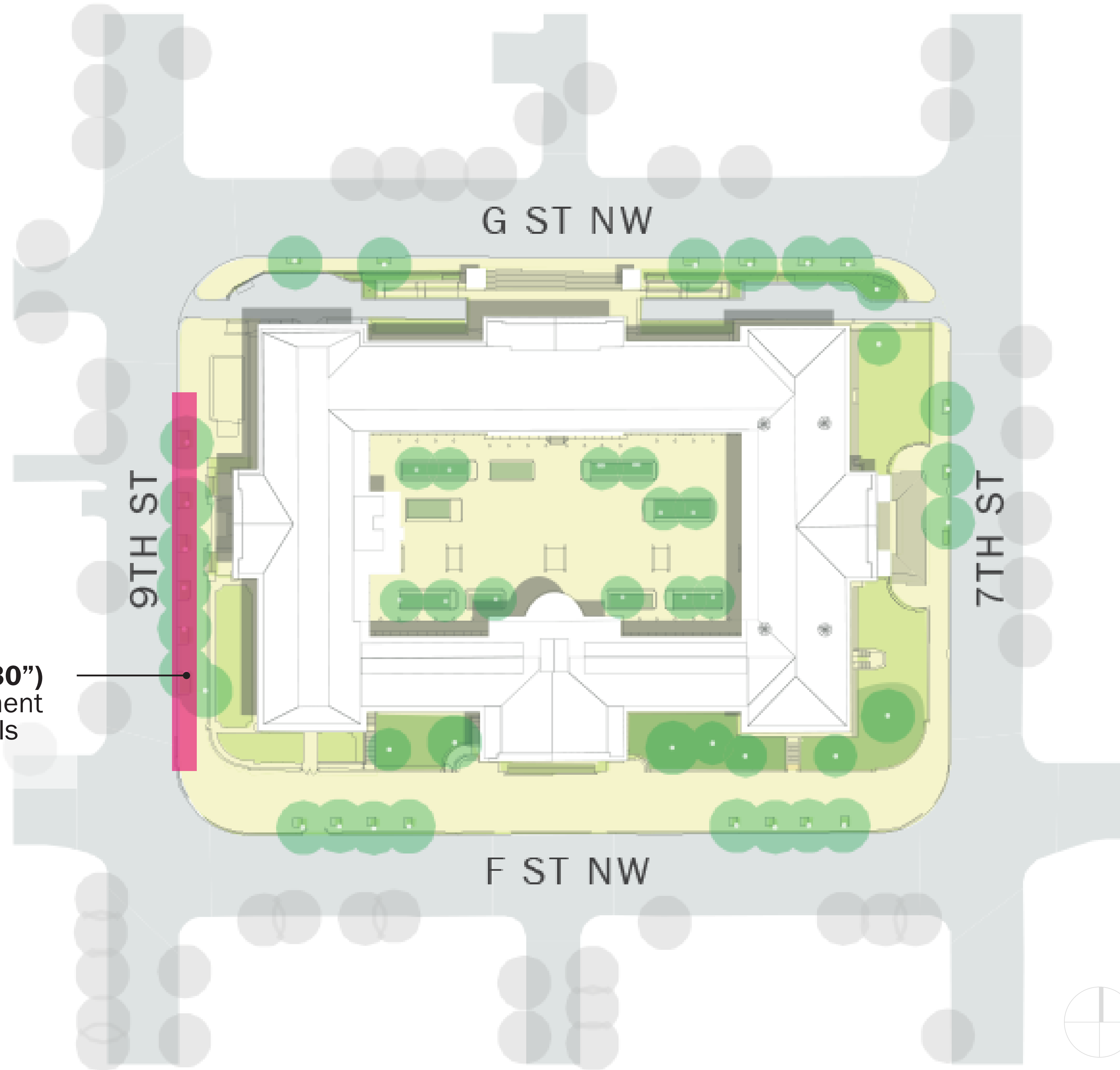
Donald W. Reynolds Center (DWRC)

Short-term



Donald W. Reynolds Center (DWRC)

Long-term



A3 **Soil Profile Rebuilding (24"-30")** including street tree replacement and Planting Soil with Soil Cells below sidewalk zone

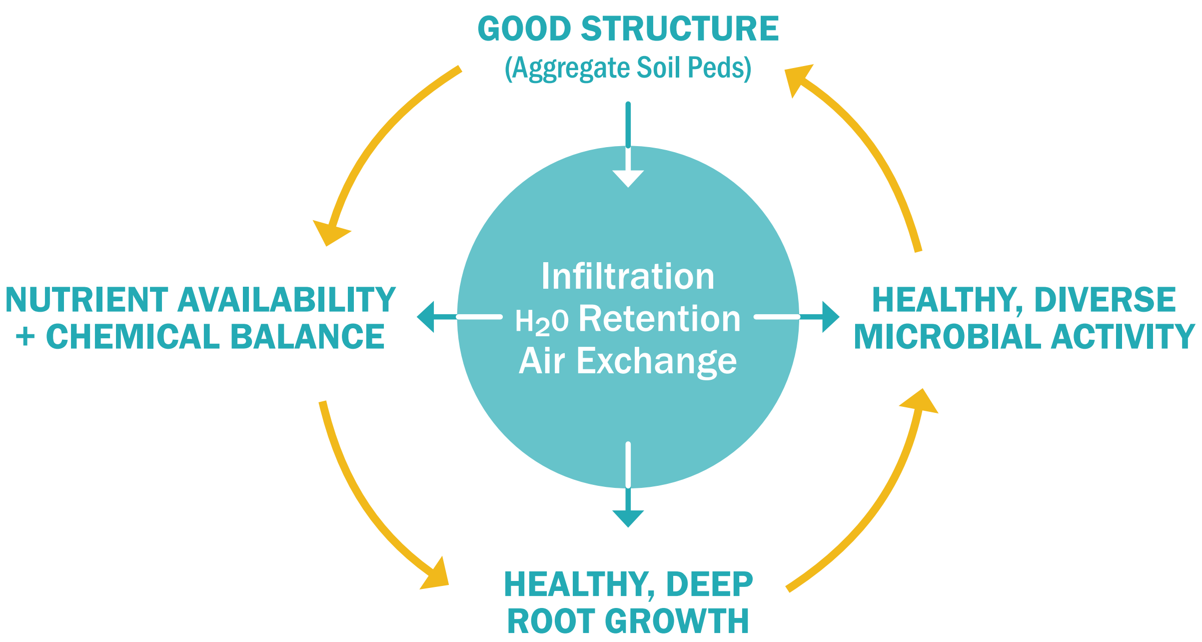
3 Maintenance of Existing Soils

Stewarding Healthy Soil

Building and maintaining healthy soil can be difficult for Smithsonian Gardens because of changing exhibits, construction disturbances, public use pressures, and the changing climate. Soil health, however, is the means for landscape resiliency in response to these challenges.

Soil is an integral component of the living landscape that must be managed and maintained to sustain healthy vegetation. Healthy soils are those that have balanced soil physical condition (soil structure), soil chemistry (nutrients, salts, and pH), and diverse, abundant biological communities that require nominal inputs.

The process of achieving healthy soil is a cycle in which each soil attribute – structure, balanced chemistry, healthy and diverse microbial communities, and plant growth – support effective soil health and function as shown in the following simple model.



Building Strong Soil Structure

The majority of landscape areas of Smithsonian Gardens consist of loam soil, with some areas having finer-textured clay loam soils. The benefits of loam soil (particularly with a higher clay content) are many, including good water-holding capacity, average to good drainage and typically good nutrient holding capacity. The existing loam soils tend to have reasonable organic matter content that contributes to these attributes. Good organic matter is often associated with good soil structure, but that may not always be the case.

Good soil structure is that which has strong aggregation of soil particles (sand, silt, and clay) into peds that resist dissolving into smaller, formless structure when subjected to the action of water. Good soil structure is often seen as “sub-angular blocky” or “granular”. The peds, or small clumps, are also often associated with organic matter but also with active soil microbial activity and balanced water content. Loam soils with higher clay content, due to cohesive properties and smaller particles/ higher surface area, have a stronger soil aggregation.

The benefits of good soil structure include improved soil drainage, enhanced oxygen exchange in the soil, deeper plant root growth, and increased resistance to compaction.

Techniques for Improving Soil Structure

1. In compacted soils, break massive or platy soil structure to open soil pores.
2. Add compost to soils. Compost by itself doesn’t necessarily improve soil structure, but it will open soil pores for a limited time, improving drainage, increasing oxygen exchange, and providing nutrients. These factors will increase microbial activity and enable plant roots to grow deeper.
3. Plant vegetation that has deep roots. Deep-rooted plants foster increased microbial populations deeper in the soil that in-turn increase soil organic matter and start to build soil structure. Create a diverse vegetative community that enhances microbial diversity and symbiotic associations.
4. Avoid over irrigation and over fertilization of the landscape. Too many nutrients will inhibit microbial growth. Too much irrigation will break down organic bonds that hold soil peds together while also reducing the amount of oxygen in the soil, decreasing microbial activity.
5. Keep soil covered, either with vegetation or with mulch. Covered soil is protected from heat, soil crusting, and cushions traffic that might compress the soil.

Minimizing Compaction

Soil compaction is the increased density of soils and in medium- to fine textured soils, the maximization of micropores and minimization of macropores. Repair of compacted soils is addressed in this soil management plan. There are practices that can be used to minimize soil compaction. The unfortunate reality is, however, that compacted soils will occur where regular activity – primarily foot traffic – occurs with little recovery of vegetation allowed.

Compaction is not always a result of heavy use of a landscape area, as it can also occur naturally where vegetation and associated soil microbial communities are stressed and die. Such stresses occur in very wet soils in which oxygen is limiting and plant roots and soil microbiology cannot flourish. The movement of water into or over the soil can move fine soil particles close together, forming dense layers through which drainage and root growth is difficult.

Soil compaction also occurs when deep disturbance of soil occurs, typically by the use of heavy equipment that exerts concentrated weight upon the soil, often forming deep ruts that destroy good soil structure.

The best resistance to compaction is a healthy root system and good soil organic matter. Deep, dense roots act as shock absorbers in the soil, allowing the soil to spring back after frequent use. If the soil roots and microbiology die away, the shock absorber system degrades, allowing soil particles to move closer together and bind together as hard, often impermeable layers.

Soil compaction actually begins when above ground portions of plants are damaged. The damaged plants can't support root growth or microbial activity, and the organic matter content of soil begins to diminish. Frequent or regular use of a landscape area may continue to damage plant structure and ultimately the lack of healthy biology in the soil will give way to compaction of soil particles.

Surface soil compaction can be prevented by a layer of mulch or leaf litter over soil to help reduce surface compaction, maintain soil moisture, and encourage root growth and microbial activity.

Practices to help Reduce Compacted Soils

1. If possible, allow landscape areas that are often used for recreation or special events to rest and recover as vegetation begins to be damaged or worn. Rotating event areas through a season is a good method of maintaining vegetation in high use areas.

2. Maintain ground cover such as mulch over areas where vegetation cannot be maintained.

3. Implement structural specialty soils where intense use of landscapes will occur. Such soils do not have to be purely sand-based, but should feature good drainage and sandier soil near the surface that will drain and resist compaction.

4. Core aeration and verti-slicing soils to reduce soil density, improve oxygen flow into deeper soil, and to break early surface compacted layers. Concurrent application of a relatively thin (about one- to two-inch) layer of good quality compost will help improve soil microbial activity and soil structure.

5. Only low ground pressure equipment (typically tracked equipment) is permitted to be used in landscaped areas. If possible, no wheel-driven equipment (exception being lawn mowers).Minimize the times that vehicles can enter an area, and to not allow pivoting or rapid turning of equipment.

6. Minimize activities on wet soils. Optimal compaction occurs when soil is moist. Monitoring of soil moisture and managing landscapes to minimize soil compaction is appropriate.

Maintaining and Improving Drainage

Poorly draining soils will result in damage to vegetation by limiting oxygen exchange into soils, reducing nutrient uptake by plants, and potentially altering the physical structure and chemistry of soils. Typically, poor soil drainage occurs because of the following:

1. Compaction, particularly with fine textured soils.

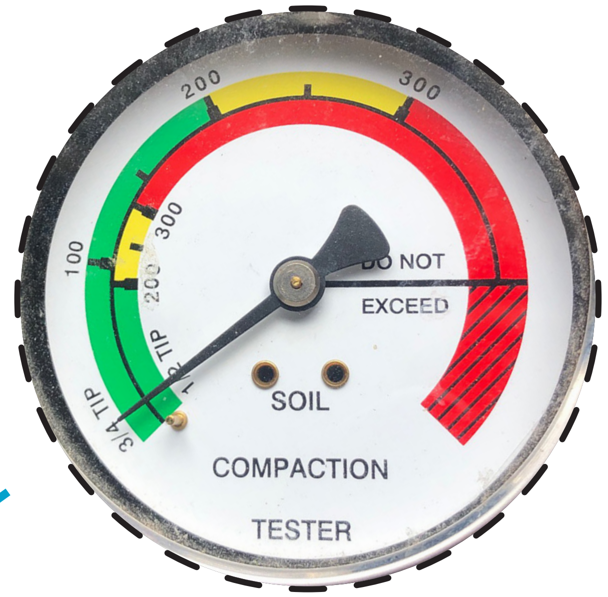
2. Self-sealing conditions, such as sediment deposition on the surface of a soil, or when soil structure degrades (relocation of fine soil particles to create clay pans or dense soil layers).

3. Excess water collection. There will be a limit to how much water can be collected in an area that can percolate into the soil.

Soils become self-sealing when fine soil particles clog soil pores and fill void spaces in the soil profile. The soil effectively becomes sealed and infiltration and percolation of water into and through the soil becomes limited. The fine soil particles move as a result of excess water movement into specific locations, and the sediment load that can be carried with that water.

Ultimately, most drainage problems occur when more water flows to a limited area than the soil has the potential to absorb.

Compaction Testing | Reference **Appendix C** for full soil compaction analyses.

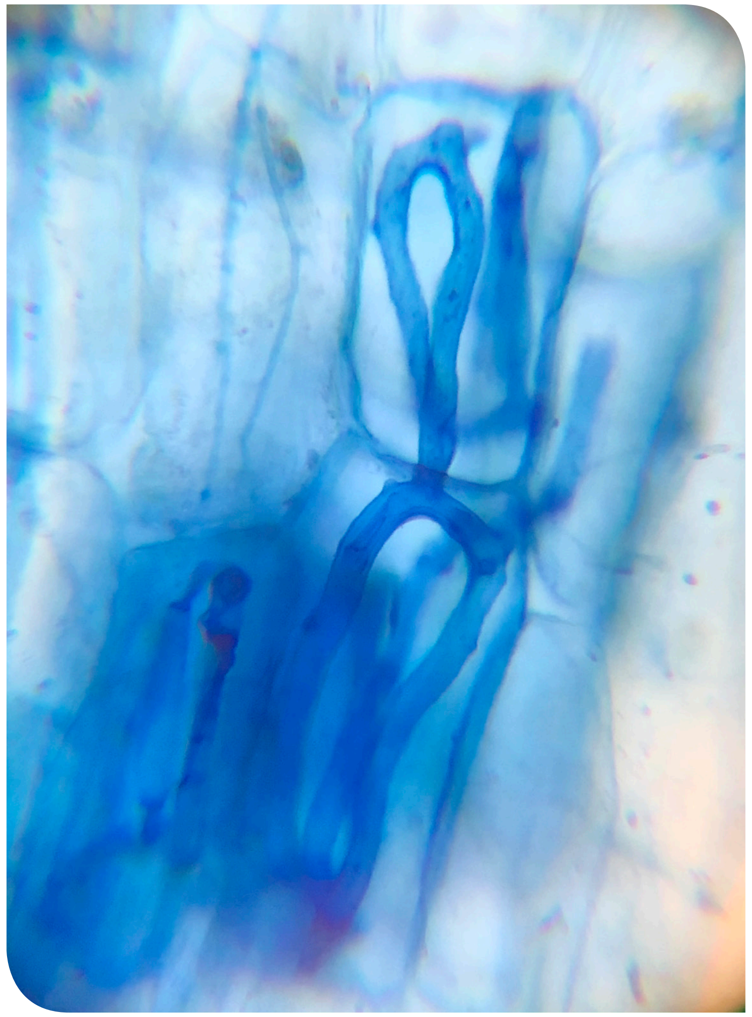


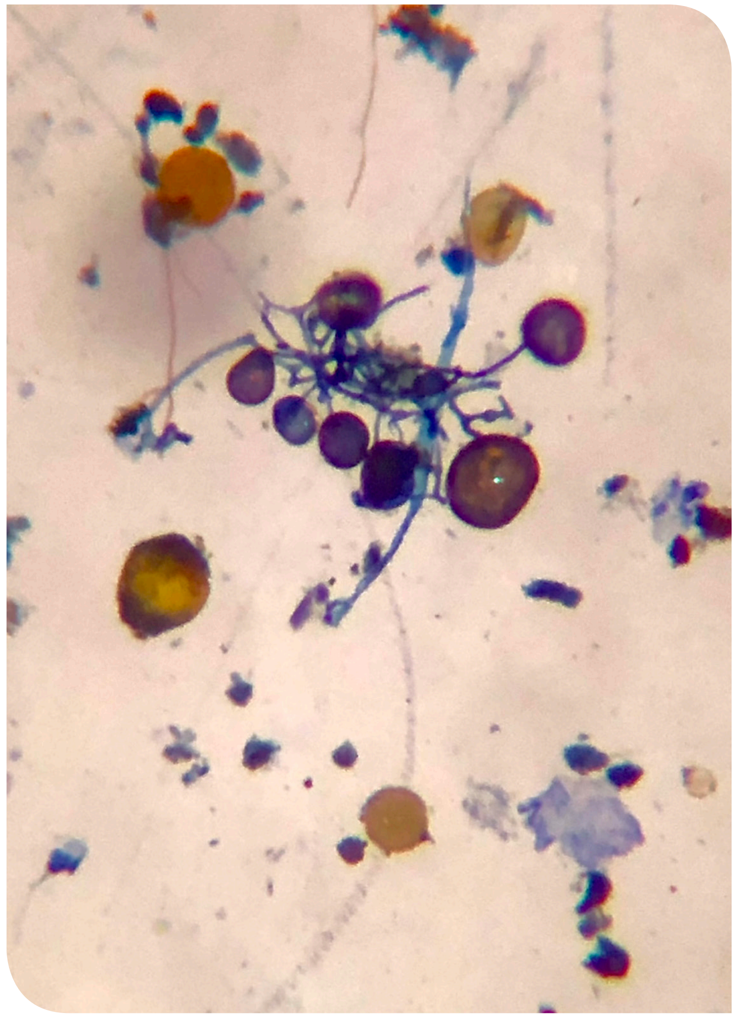
Compaction Readings

Top 6”
Penetrometer reading with 3/4” cone at surface

12” to 24”
Penetrometer reading with 3/4” cone in subgrade

- (green) <200 psi
- (yellow) 225 - 275 psi *(root limiting)*
- (red) >300 psi *(root restrictive)*





From left to right:

Mycorrhizae in root cells; exfoliated root cells in soil; and fungal spores (50-100 microns)

Soil Organic Matter - Keys to Success

Soil organic matter is essential for healthy soils. Consider the following:

- Soil organic matter substantially increases nutrient holding capacity. The cation exchange of organic matter is as much as 10 times that of clay in soils.

- Soil organic matter increases water-holding capacity. For medium-textured soils, such as those found as most of the Smithsonian Gardens landscapes, a one-percent increase in soil organic matter increases water holding capacity by about 1.03% or approximately 3,400 gallons in the top 12” of a soil profile (University of Nebraska, 2020). That can equal about 90 gallons of water per 1,000 square feet of area. Nearly all of that water is plant-available water.

- Soil organic matter provides a cushion layer between soil colloids that acts like a sponge and reduces the potential for compaction. In fact, soils with increased soil organic matter and strong structure are very difficult to compress.

- Soil organic matter serves as a home for microorganisms that transform nutrients to plant-available form.

- Much of the carbon assimilated from photosynthesis is stored below ground and in soil organic matter. More than 20 percent of photosynthetic carbon from trees is stored in roots and in the soil (this does not include that which would assimilate from fallen leaves), while as much as 70 percent of photosynthetic carbon is stored in roots and soil of grasses and groundcover plants.

How to Increase Soil Organic Matter

1. Do not over fertilize soils. Excess nutrient content will suppress diverse microbial activity that is the primary builder of soil organic matter.
2. If possible, plant diversity will help in building diverse microbial activity that builds organic matter.
3. Compost by itself will not build stable soil organic matter, but it will improve soil conditions that will hasten soil organic matter formation. Mix compost into the soil.
4. Cover soils to protect the soil surface from crusting and to aid in oxygen exchange.
5. Minimize tillage or disturbances to the soil. Tillage will break mycorrhizal hyphae and promote rapid oxidation of soil bacteria.

Desired Soil Fertility Levels

The nutrient needs of plants vary substantially. Most soils of Smithsonian Gardens were found to have adequate levels of most nutrients although, not of high concern, phosphorus (P) and potassium (K) were found in low concentrations at some locations. Consistent with test results (Appendix C), the need for fertilizers is only required at landscapes where nutrients are prone to rapid loss, such as locations with sandy soils.

The cycling of natural materials such as compost or fallen leaves, or non-woody plants that have died and can be returned to the soil will supply sufficient nutrients for trees, shrubs, and native forbs and grasses. Lawns will likely need supplemental fertilizer needs on an annual basis. Because fallen leaves are often removed from the base of trees, periodic fertilization – particularly with nitrogen – may be necessary.

Nutrient levels in soils should be kept at a relatively low maintenance level. Lower levels of nutrients, especially P and K, promotes more active soil microbial activity that not promotes natural nutrient use by vegetation, but enables soil bacterial to provide plant-growth promoting compounds back to vegetation that helps suppress diseases and stresses from insects, droughts, and other pathogens.

If and when fertilizers are needed, nearly all vegetation responds most significantly to additions of nitrogen. Caution should be applied when selecting the types and amounts of fertilizer to apply. During interviews with Smithsonian Gardens staff it was learned that high-quality organic fertilizers are most often used to support individual landscapes. Organic fertilizers typically supply the amounts of nutrients needed for plants at the right rates as they are slowly released by microbial degradation. Fertilizers should only be needed once to two times per year, or if necessary to stimulate plant growth under stressful conditions.

Soil sampling and nutrient analyses (including soil parameters for pH and total salts) need to be conducted on a regular basis. Sampling and analyses of soils once every three years is appropriate and can be accomplished on rotating scale between museum landscapes. Routine soil analyses of nutrients will identify potential problem areas, needed responses and modifications to fertilizer application schedules as needed.

4 Restoration of Damaged Soils

Many landscapes have soil areas – typically relatively small – that have historically underperformed or are afflicted with on-going issues. Problems include compaction, poor structure, excess salts (electrical conductivity), excessive drainage, poor drainage, or inconsistent physical and chemial characterists with surrounding soils, hence they perform differently. Correcting these soils can be accomplished through the following steps:

1 Assess the Area

Obtain information about activities in the area of the poor soil condition and for how long its been a problem. Information needed may include:

a. What is the public use of the poor soil condition?

b. What is the condition of surrounding soils? Are the poorly-performing soils similar in texture (and overall condition) to the surrounding soils?

c. Have attempts to establish vegetation on the problem soil failed due to unseen or indeterminate reasons?

d. Is stormwater runoff concentrated to the poorly performing area?

e. Is the soil compacted, and how deep? Are clay pans present below the surface that stops drainage and root growth?

f. Does the soil have dense massive or platy structure?

g. Can the soil be tested for agronomic/horticultural chemical parameters, including nutrients, salt content (including sodium)/electrical conductivity, organic matter, and CEC?

h. Are there subsurface objects that could be preventing drainage, root growth, and plant establishment?

i. Has there been recent construction activity in the area that may have contributed to current soil or plant conditions?

2 Map the Extents

When adequate information gathering of the poor soil area has been obtained, determine the areal extent of these conditions and the depth if possible.

3 Determine Restoration Approach

Based on the information obtained and reviewed, as well as any soil analytical data, determine if it is possible to correct the poorly-performing soil in place, or if the soil must be replaced. Restoration of soils include:

A. _Drainage_ - if soils are failing due to excess stormwater runoff, perform the following steps:

• Redirect stormwater drainage to an active inlet or drainage basin

• Remove sediment accumulation on the poorly-performing soil.

• Break compacted soil layers using hand tools (if a small area) or rototiller or rotating spade if a larger area. Blend the compacted soils with compost to increase soil porosity and friability. Regrade the soil even with the surrounding area. If necessary, add similar-textured topsoil to build positive drainage from the area.

• Grade the repaired area smooth and even with surrounding grades and prepare a firm, friable seedbed for establishing new vegetation.

B. _Chemical Imbalance_ - this can be attributed to factors such as nutrient deficiencies, soil pH, electrical conductivity and soluble salts, or high concentrations of some metals. Assessing soil chemistry for potential imbalances include:

1. Soil chemistry is rarely something that can be readily seen in a bare soil, but it can be observed by the growth of certain plants, or by discoloration or wilting of plants. Check for the following signs:

• Chlorotic leaves - this is the most common sign of nutrient deficiencies, including nitrogen, iron, magnesium, manganese, and calcium deficiency. Some deficiencies occur mostly in younger leaves, such as calcium and iron deficiencies, or in older leaves, including magnesium and manganese. Nitrogen deficiencies are seen as chlorosis in both old and newer leaves.

• Burning of leaf edges or inter-veinal margins is often an indication of potassium deficiency.

• Purpling or purple-bronze coloration on leaves is often an indication of phosphorus deficiencies.

• All of these indications can occur when soil pH is out of balance, as the acidity or alkalinity (often called the soil reaction) affects the availability of many plant nutrients.

• The effect of high soluble salts content, often measured as electrical conductivity, is often observed as wilting of plant leaves and stems and is often mistaken for the need for more water. High salts can also be observed during hot periods when evaporation of water deposits salt on the surface of the soil, often seen as a white, powdery deposition.

2. To determine if soil chemistry is causing poor soil performance some field measurements can be collected, or it may be more practical to collect a soil sample for laboratory analyses.

• Field measurement of chemical parameters can be accomplished by using a calibrated field pH meter or an electrical conductivity meter.

• There are several field test kits for major nutrients. Some, such as those purchased at most common garden centers, are easy to use but not highly accurate. Other field test kits, such as a Hach soil fertility test kit or LaMotte soil test kit, provide more accurate soil parameter results, but at higher cost.

• Collection of a soil sample for testing at an analytical laboratory is advised as this provides the most accurate and cost-effective information. Typically, a test for all appropriate soil chemical parameters from which to assess a soil cost less than $50 per sample.

3. Correcting soil chemical imbalances ranges from the addition of specific fertilizer (organic fertilizers are recommended) to improve nutrient content, to the adjustment of soil pH using lime or acidifying compounds for highly alkaline soils (ammonium sulfate or ammonium phosphate fertilizers for example). Lime (calcium carbonate) will often adjust soil pH that can mitigate chemical problems related to metals. If salt content of soils is too high, the addition of compost can help to lessen the affect of high salts. Leaching of soils with large amounts of irrigation will move salts deeper into the soil. If salt content is very high (electrical conductivity greater than 6 mS cm-1), then it may be necessary to replace the soil.

C. *Compaction* - Compaction can take several forms, ranging from shallow, surficial compaction to buried compacted layers, to hard, dense soil. Implement the following measures:

1. When compaction is limited to the top 25 to 100mm (1- to 4 inches) of soil:

• Break the compacted soil using hand tools if in a small and/or contained area, or a rototiller if a larger area is affected.

• Blend compost into the soil by spreading 25- to 50mm of compost over the tilled area surface and blending the compost into the soil to a depth of 100mm inches deep. This will break soil clumps or clods and open pore space for drainage and root growth.

• Rake the repaired area smooth with the surrounding area and prepare a firm, friable seedbed.

2. Compaction extends from the surface to more than 100mm (4-inch) deep:

• If the compacted soil has platy structure, remove the soil to replace it with imported soil with similar texture as the surrounding soil and strong aggregate structure.

• If the compacted soil has dense, hard, massive structure, break the soil into small clods less than 5mm in size and blend with compost to open soil pores and structure. If soil cannot be broken, replace it with imported soil.

• Scarify the remaining soil below the removed compacted layers to a depth of a minimum of 50mm.

• Place imported soil over the scarified soil and grade smooth and even with the surrounding soil. Compact the new surface (planting) soil using a 350 lb roller.

• Rake the soil even with the surrounding soils, addition additional imported soil if necessary to bring the graded even with the surrounding soils.

• Prepare a firm, friable seedbed for establishing new vegetation.

3. Compacted layers or clay pans exist below the surface soil:

a. Determine the depth to the clay pan. This can be accomplished using a static cone penetrometer (see soil management tools). When penetration resistance of the cone penetrometer rapidly increases there is evidence that a clay pan or compacted layer below the soil is present. If multiple probing with the static cone penetrometer, the extent of a compacted layer can be determined.

b. When the extent and depth of a buried compacted layer has been determined, the following steps can be taken to break it:

- If the compacted layer or clay layer is less 25mm thick and less than about 75mm below the surface, deep core aeration or deep knifing of the soil can be completed to break the pan and blend it with surrounding soil. Other methods of soil tillage, such as using a disk implement, rototiller, or rotating shovel can be used to break the compacted layer.

- If the compacted layer is less than 20mm thick and less than 100mm below the soil surface, deep tillage using a rototiller, rotating shovel, or disk implement can be used to break the pan and mix it with surrounding soil.

- If the compacted layer is more than 100mm below the soil surface, deep ripping or tillage can be used to break the compacted layer.

- After all measures are taken to break compacted layers, it is now appropriate to grade the disturbed soil surface smooth and even with the surrounding soil and prepare a firm, friable seedbed for new vegetation.

4. Long term strategies for breaking buried compacted layers include the use of deep rooting plants such as legumes or tillage radishes that can extend roots through compacted layers to break them. The process may take several seasons of action.

5 Preservation of Sensitive Soils

Soils in some locations at Smithsonian Gardens may be considered as sensitive soils – at least sensitive related to soil stability and horticultural productivity. Sensitive soils for the purpose of this Soil Management Plan are those that can be [adversely] impacted by moderate natural forces as well as impacts from landscape management.

Natural forces are those such as rain and heat, particularly as related to climate change. Landscape management impacts are those that are primarily attributed to often accepted tasks such as lawn mowing, irrigation, fertilization, or construction activities.

Soil impacts related to public use are not included, as pressure from museum visitors is constant and affects all soils and landscapes.

Sensitive soils are typically easily compacted, eroded, or exposure to chemicals. Sensitive soils are typically relatively fine-grained, high-silt soils that may also include soils high in fine and very fine sand. Impacts occur as described below.

Compaction

Sensitive soils are easily compacted not just by external pressures from foot or vehicle traffic, but from natural settling of unprotected soils during which the actions of wetting and drying can settle soil into higher density, less porous soils. Water may not infiltrate deep into these soils, so when they dry and evaporation occurs, salts may accumulate near the soil surface, creating saline conditions that affect plant growth and can further cement soil particles into hard blocks of soil that are difficult to break or for roots to grow into and through.

Erosion

Sensitive soils are rapidly degraded by lateral flow of water across the surface that does not easily infiltrate into the ground. Because silt and fine sands are not cohesive, they can easily be moved with the flow of water. Unprotected sensitive soils can also be affected by the energy of heavy rainfall, with raindrops dislodging fine soil particles and creating soil crusts that do not allow water infiltration or oxygen exchange.

Chemical Exposure

Sensitive soils that are high in silt and/or fine sand are not buffered against the impacts of added salts or other chemicals. Winter de-icing salts can quickly cause soils to seal, reducing effective infiltration of water. Metals such as lead and aluminum from nearby road traffic can settle into and accumulate in the sensitive soils and affect plant growth.

Landscape Management

Landscape management tasks can have adverse effects on sensitive soils. Simple tasks such as lawn mowing when the ground is too wet to over irrigation of landscapes that leach nutrients from the soil and reduce oxygen content for plants can reduce plant productivity.

Strategies to Protect and Preserve Sensitive Soils

1 **Build soil biology.** Recent research is showing the best means of protecting soils and building resiliency is to increase root growth depth and density, and to promote the development of natural organic matter. The growing biological systems build soil structure that stabilizes soil peds by “gluing” them together through organic substances such as glomalin, creates a flexible matrix of organic ligands that resist compaction, and enhances both water- and nutrient holding capacity all the while facilitating effective drainage and oxygen movement within the soil.

2 **Maintain cover over the soil.** If the soil cannot be covered by plants, it should be covered by mulch (ideally organic mulches) to provide protection from compaction, erosion, and evapotranspiration.

3 **Rest areas with sensitive soil.** Resting soil and landscapes allows the soil and plant biology to recover after heavy use or when damaged by natural forces like rain and heat. Resting landscape areas for a few weeks between high-impact events provides great support for rebuilding soil properties.

4 **Protect against salt intrusion.** The buildup of soil organic matter will help to buffer the impacts of salts and metals in soils, including changes in soil pH by taking minimizing the movement of salts (such as sodium) from being able to move into the soil. Use de-icing salts sparingly. If possible, change salt types from sodium chloride to potassium chloride or other de-icing compounds that do not cause sealing of the soil as well as impairments to plant growth.

5 **Reduce landscape maintenance during wet periods.** Though difficult to achieve, if landscape maintenance can be accomplished when soil moisture is less than approximately 20 percent of soil moisture content by volume, this will prevent compaction and rutting of soils that often requires repairs. Minimize construction projects during and shortly after rainfall events so that soils are allowed to dry.

6 **Reduce irrigation.** If possible, reduce the frequency of irrigation. Irrigation can be more effective if completed with greater volume of irrigation that is allowed to infiltrate deeper into the soil; with a longer period of time between irrigation events. The deeper irrigation causes roots to grow deep into the soil after the top of the soil begins to dry and available water is found deeper in the ground.

7 **When soils are damaged, repair them as soon as possible.** The sooner that damaged soils are repaired, the less damage will be done to the soil and plants will respond sooner with greater health.

Conclusion

Through development and re-imagining, **Change** has been and will remain a regular occurrence at Smithsonian Gardens. Maintenance, protection, and the selection of appropriate planting soils associated with new development and public use patterns will have long lasting positive effects on plant health.

Smithsonian Gardens has the benefit of a team of experienced horticulturists, arborists, and gardeners who know their respective gardens very well. It is evident that care for the soil is at the forefront, and the goal for each garden team is to maximize health and productivity through thorough research, maintenance, and plant selection. This is the best foundation an institution can have for long-term soil and plant success.

The Smithsonian Gardens Soils Management Plan builds upon this foundation by providing an in-depth inventory and assessment of current soil conditions, it identifies a consistent range of remediation opportunities, describes healthy soil qualities, and provides guidance on preserving, managing, and rebuilding soils. Utimately, the Plan describes the health standards for both existing and future planting soils.

In the urban, heavily visited environment that is Smithsonian Gardens, the soils are highly capable of achieving the healthy qualities this Plan outlines. And as **Change** continues, success will be determined by consistency of care, protection of highly productive soils, and through the selection of unscreened loam-based planting soils native to the region. While soil inputs may need to vary across the respective gardens and landscapes, including the use of amendments and irrigation, the application of care (soil types, products, techniques) should remain the same. This is the vision and roadmap for the next generation of soil and plant sustainability at Smithsonian Gardens.

NMAI | Healthy meadow planting in rich sandy loam, below mature Elm.


© Wolf Josey

03

APPENDICES

A Smithsonian Gardens Overview

B Plant Health Observations and Maintenance Evaluation

C Soil Sampling Testing Data

D Existing Soil Conditions

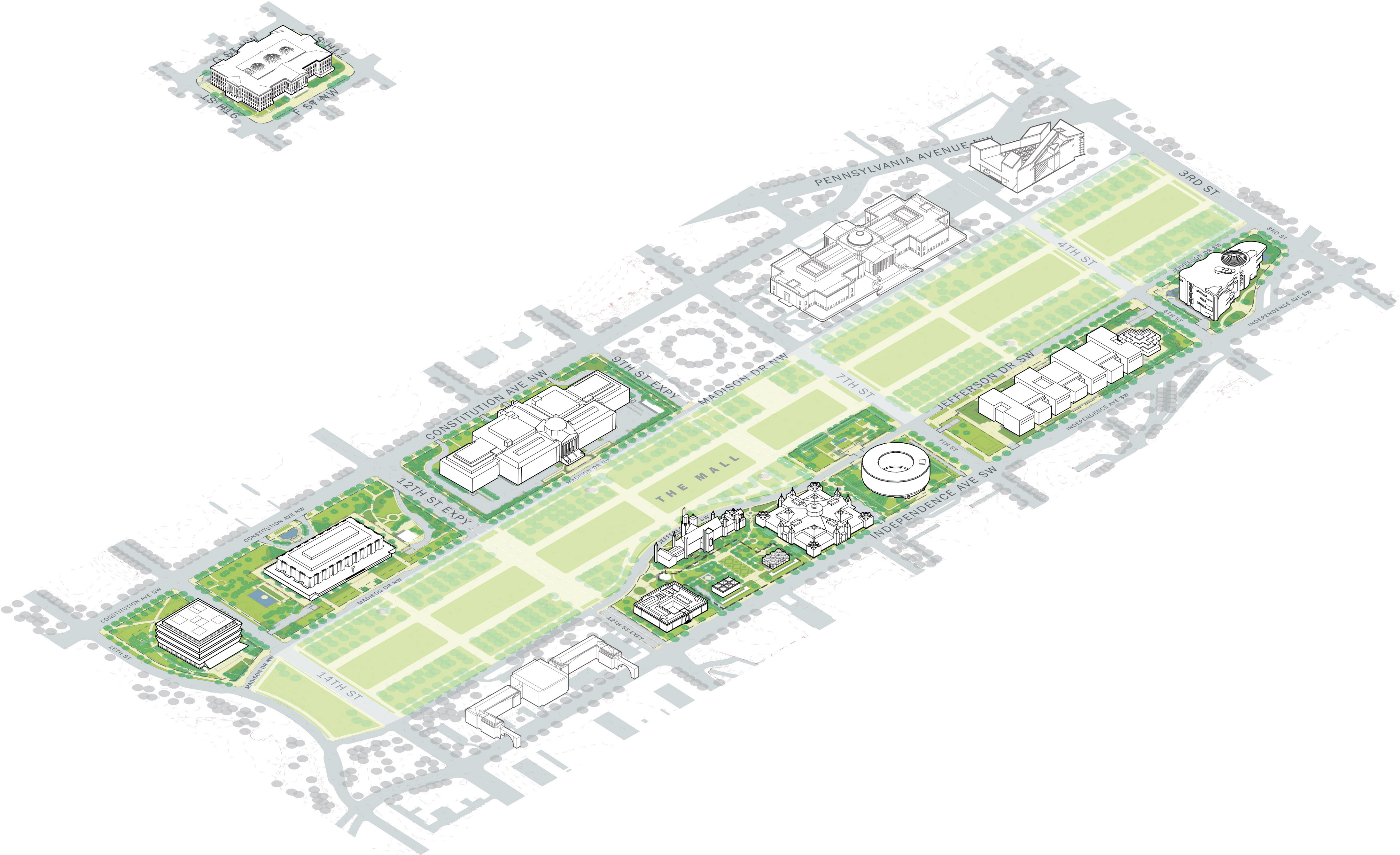
E Soil Remediation Details

F New Project Specifications and Details

G Small Projects Narrative for Soil Installation and Restoration

H Site Protection Specification Updates and Details

I Soil Resources



Smithsonian Gardens

gardens.si.edu

SMITHSONIAN GARDENS
SOILS MANAGEMENT PLAN

Soils Management Plan

September 3, 2021

Appendices A - D

Client Team

SMITHSONIAN GARDENS

Marisa Scalera, Landscape Architect
Jake Hendee, Arborist
Sarah Hedean, Manager - Living Collections
Joy Columbus, Director
Jeff Schneider, Deputy Director and Grounds Manager
Eric Calhoun, Supervisory Horticulturalist
James Gagliardi, Supervisory Horticulturalist
Melinda Whicher, Supervisory Horticulturalist

Design Team

WOLF JOSEY LANDSCAPE ARCHITECTS

Paul Josey, Principal, PLA
Mary Wolf, Principal, PLA
Dustin Smith, Associate, PLA

OLSSON

Ted Hartsig, Soil Scientist

*This project received Federal support from the Smithsonian **Collections Care Initiative (CCI)**, administered by the National Collections Program*

APPENDICES

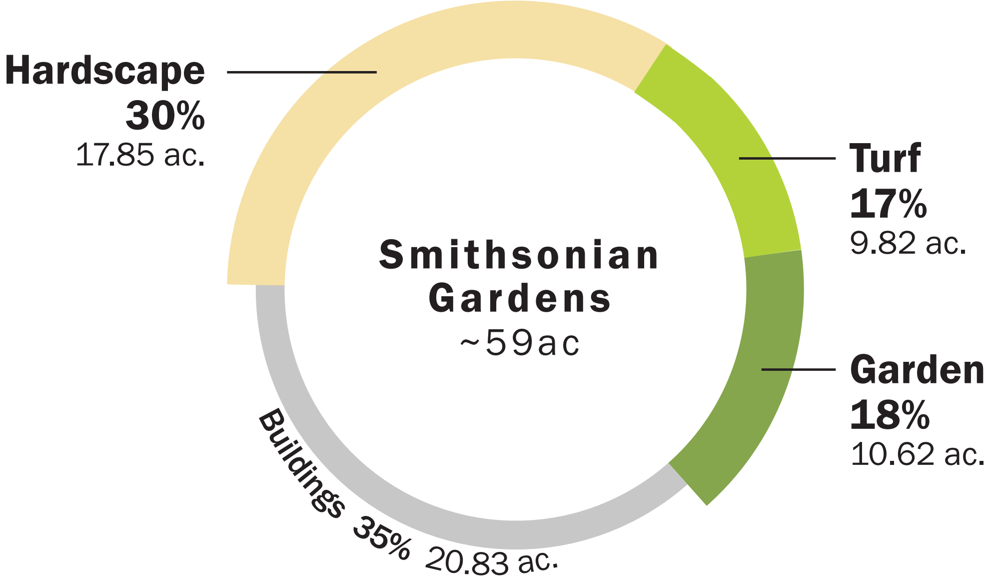
Cover Photo

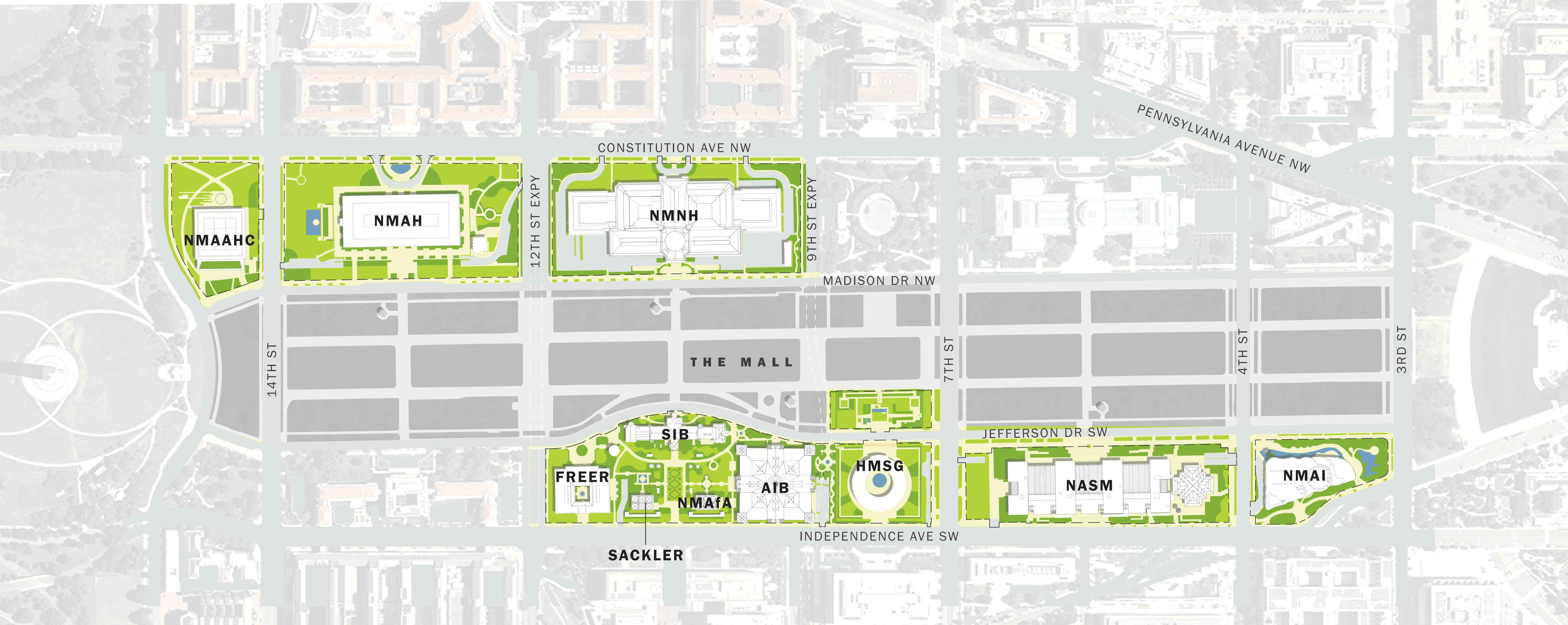
APPENDIX A

Smithsonian Gardens Overview

Landscape Area

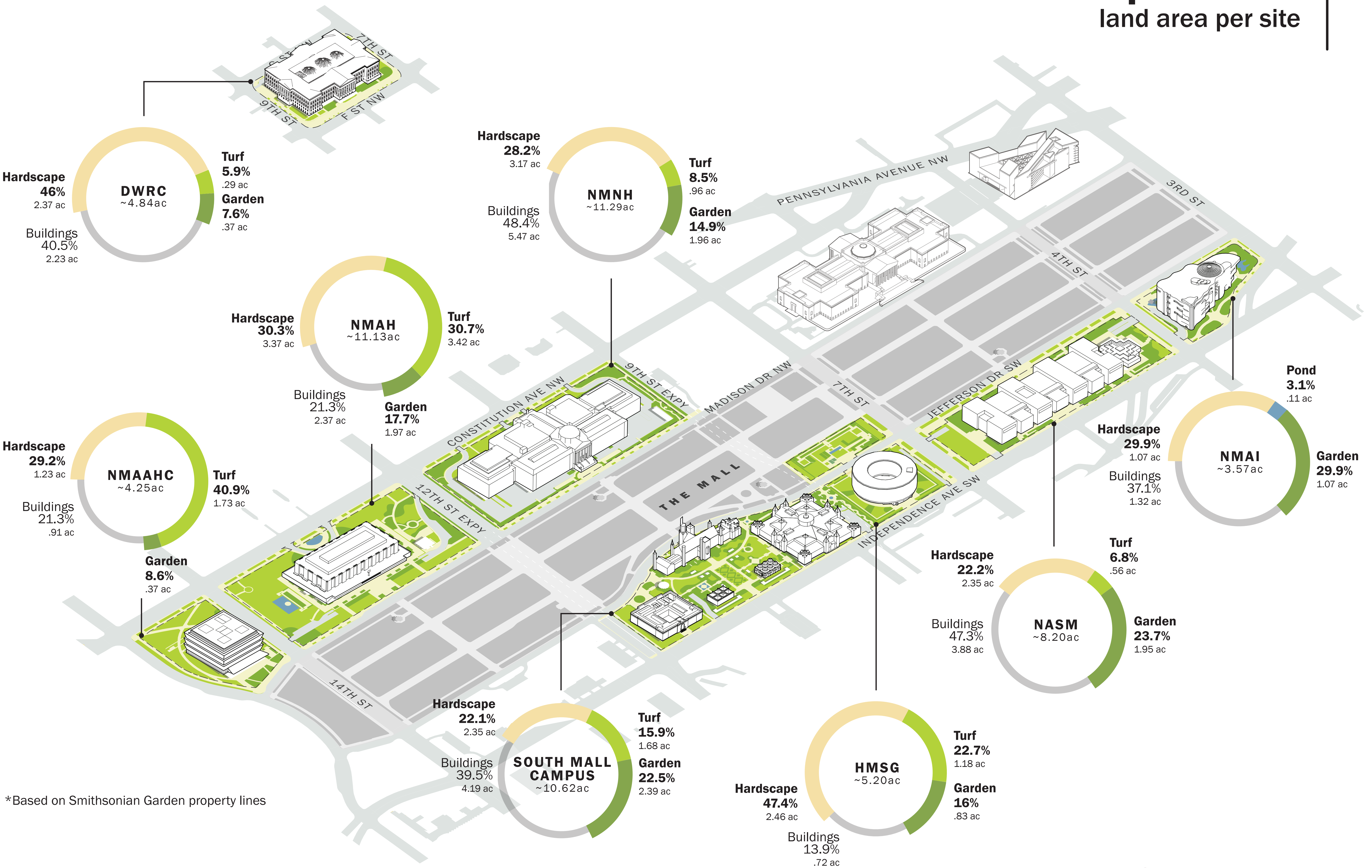
landscape land area



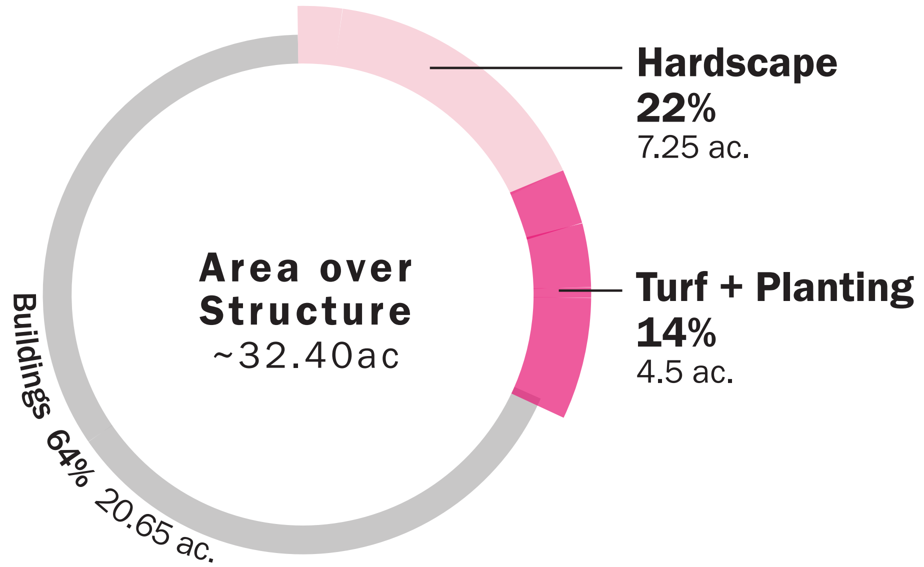


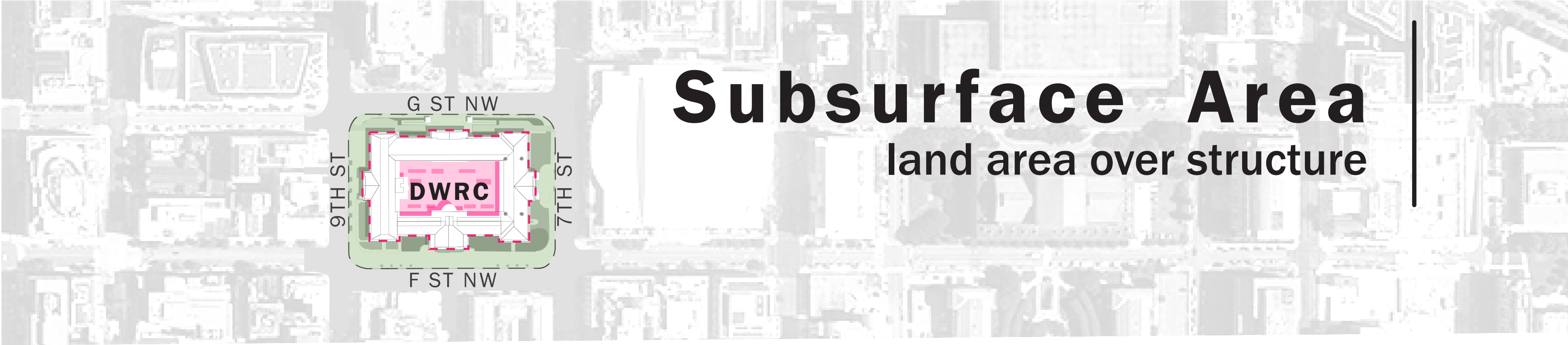
Landscape Area

land area per site



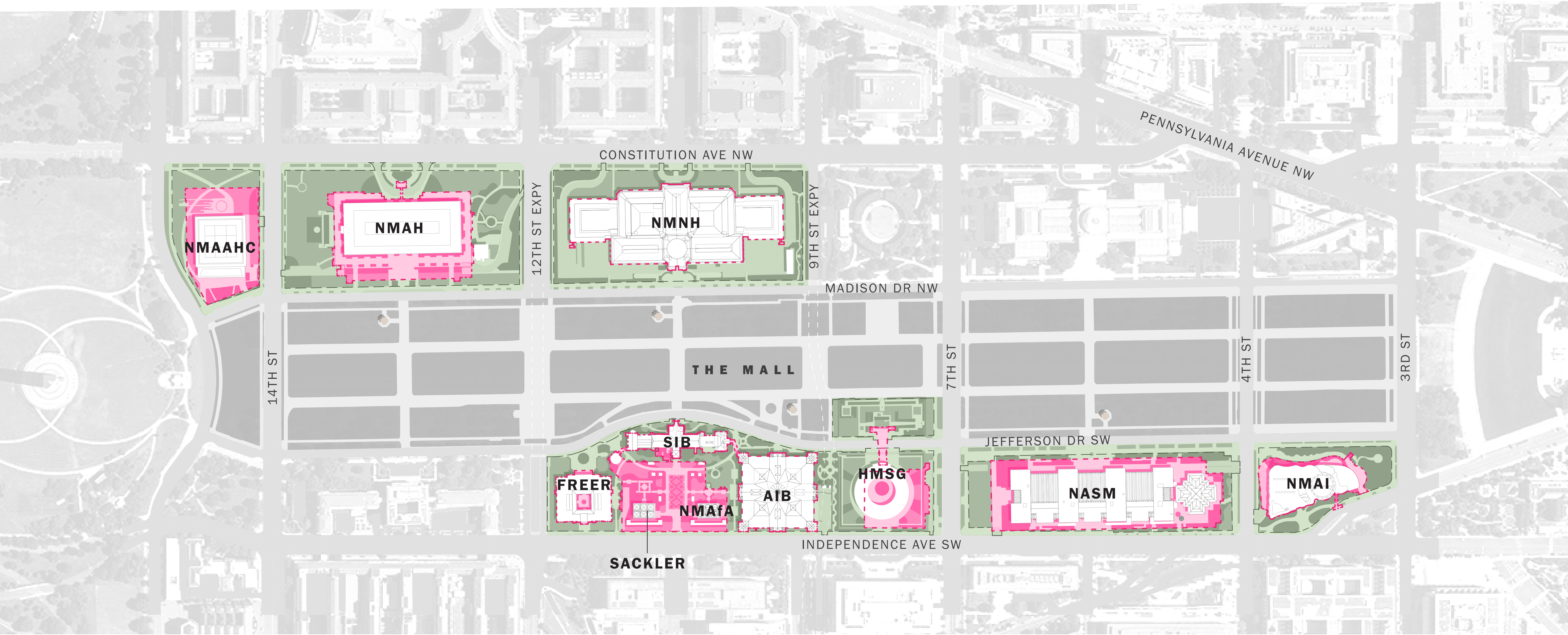
*Based on Smithsonian Garden property lines





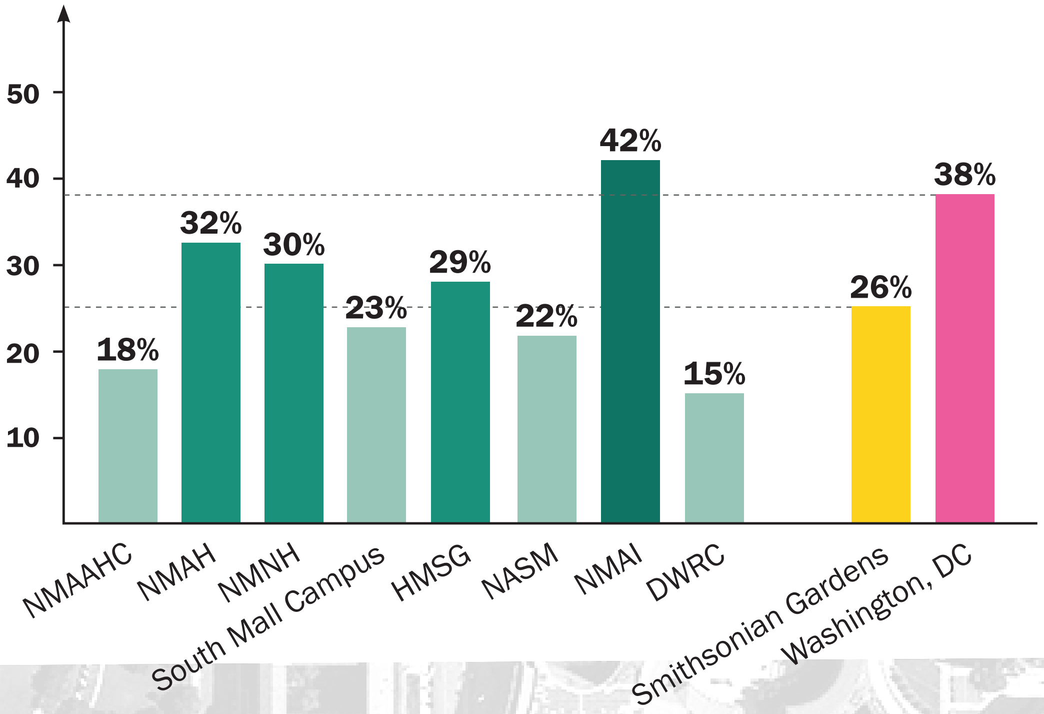
Subsurface Area

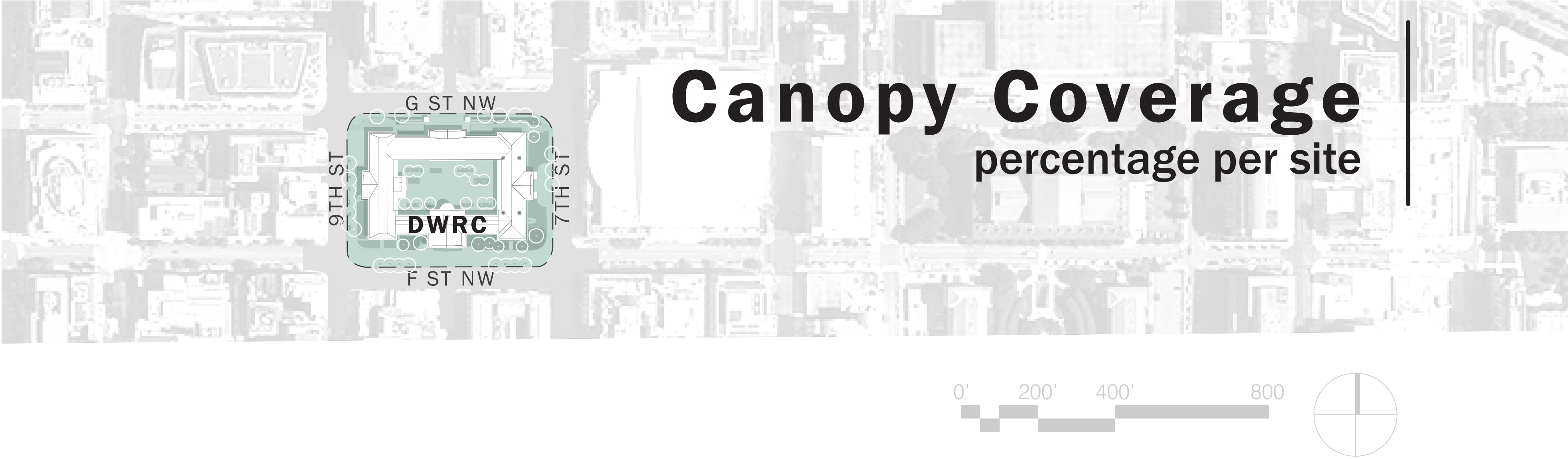
land area over structure

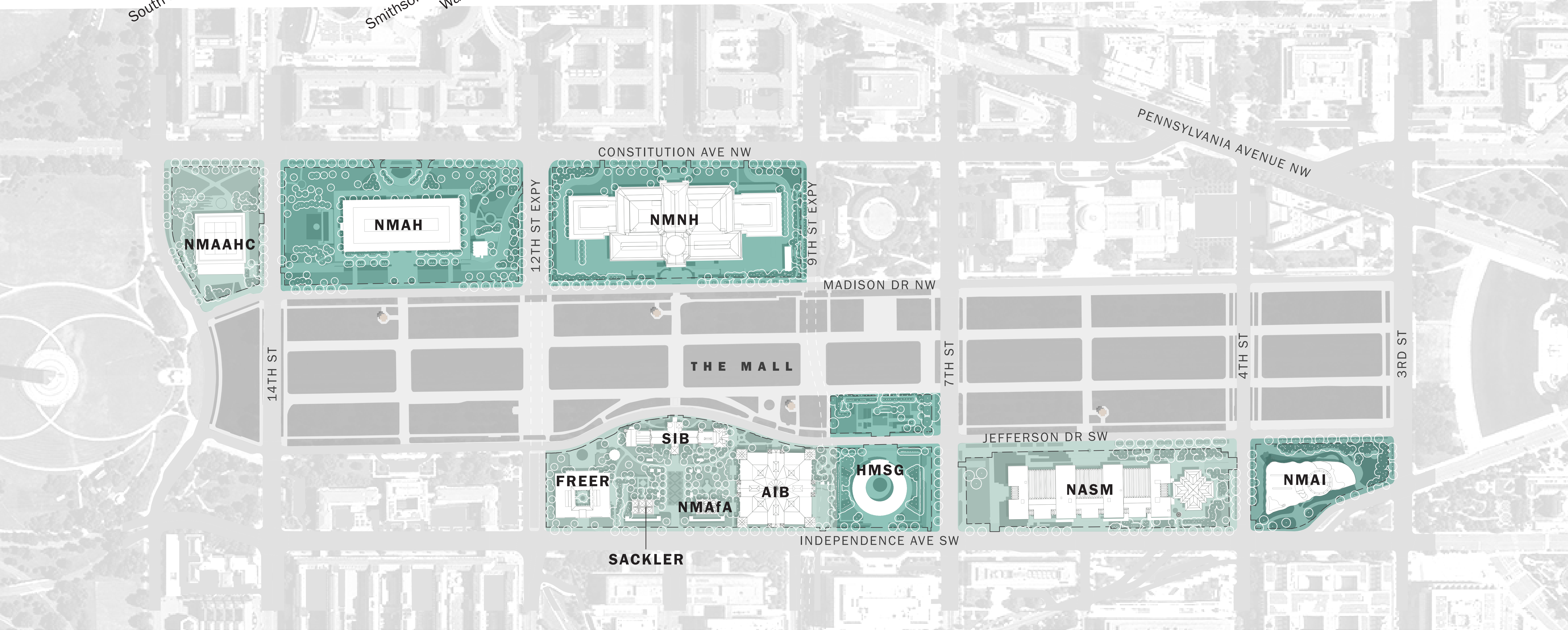


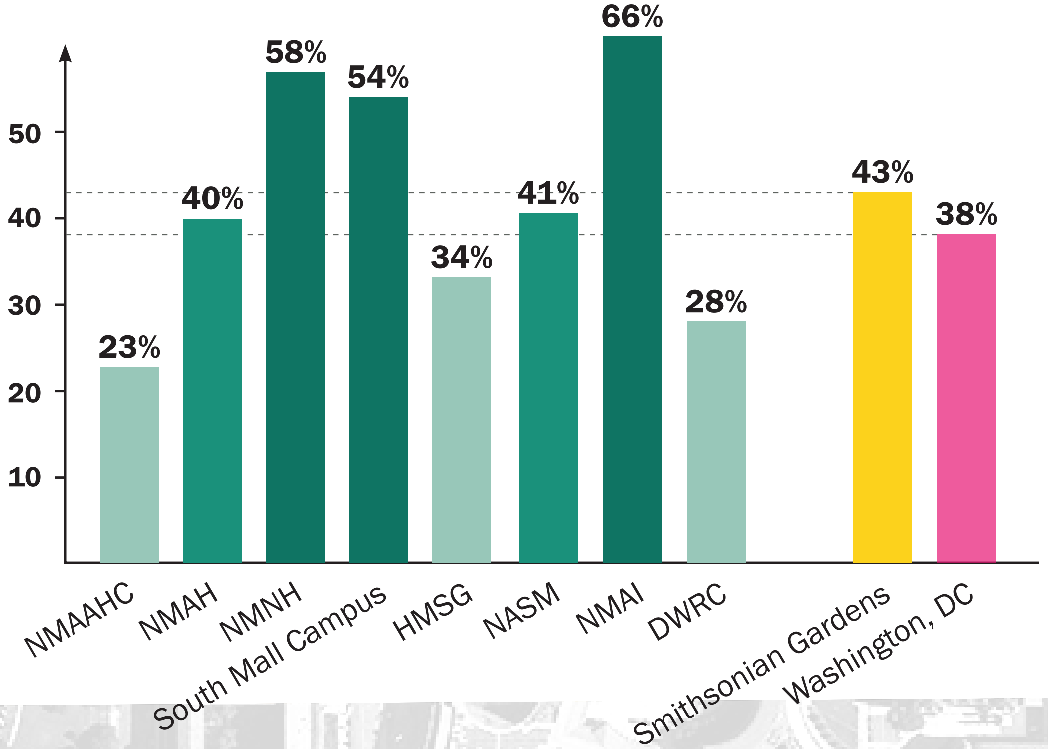
This page left blank intentionally.

Canopy Coverage
percentage per site



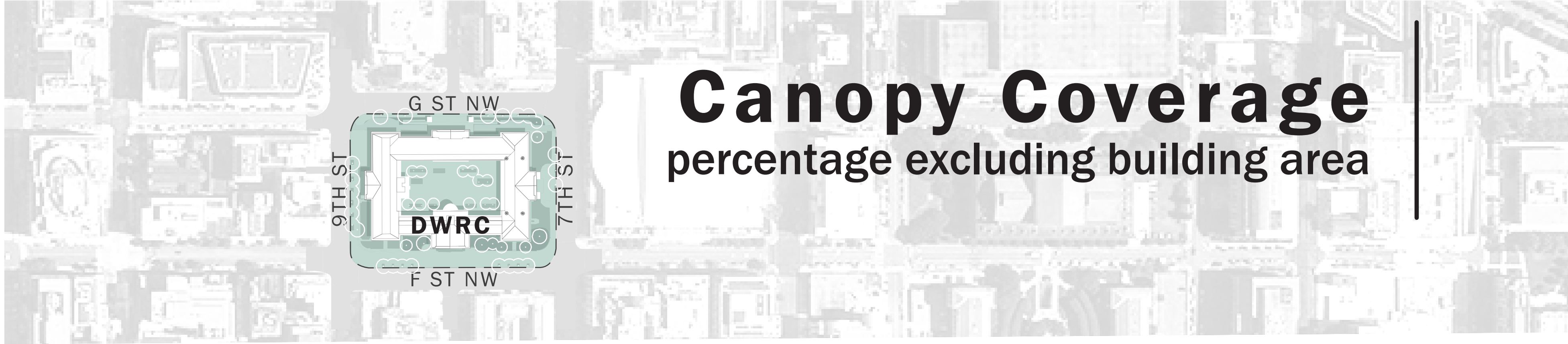


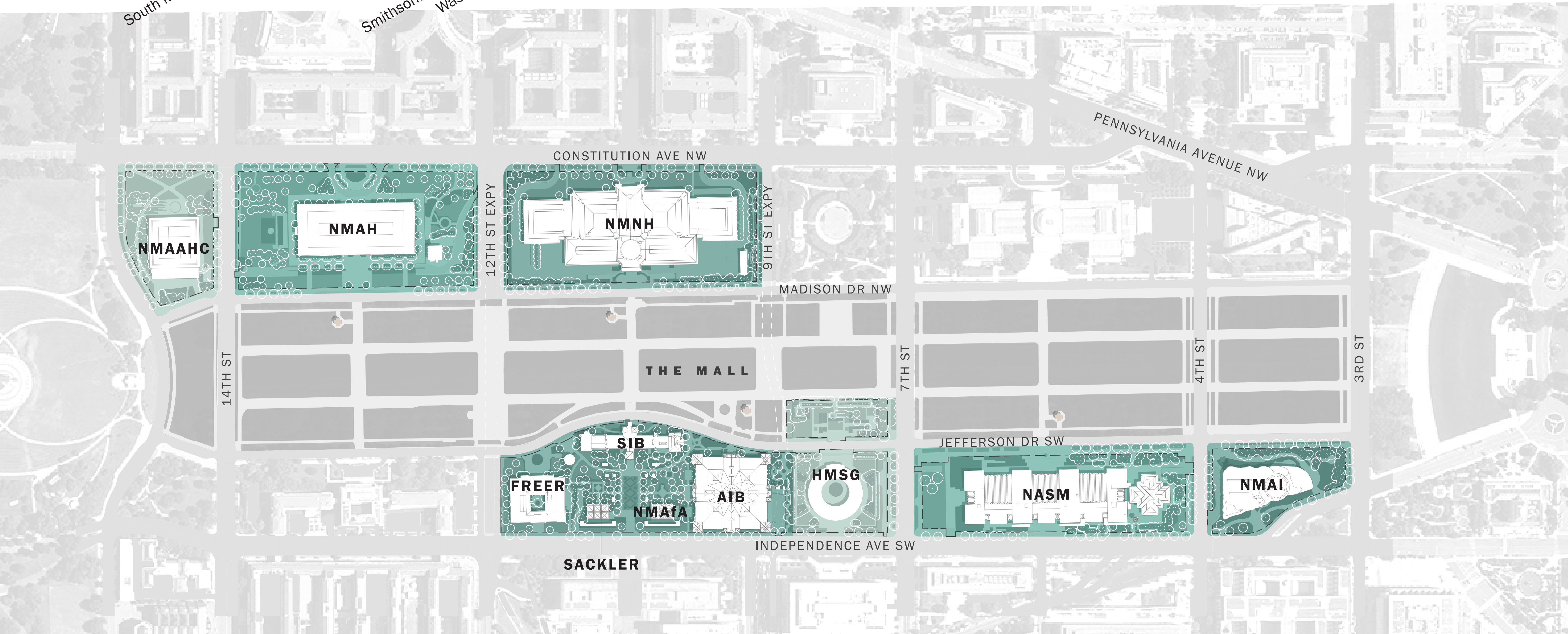




Canopy Coverage

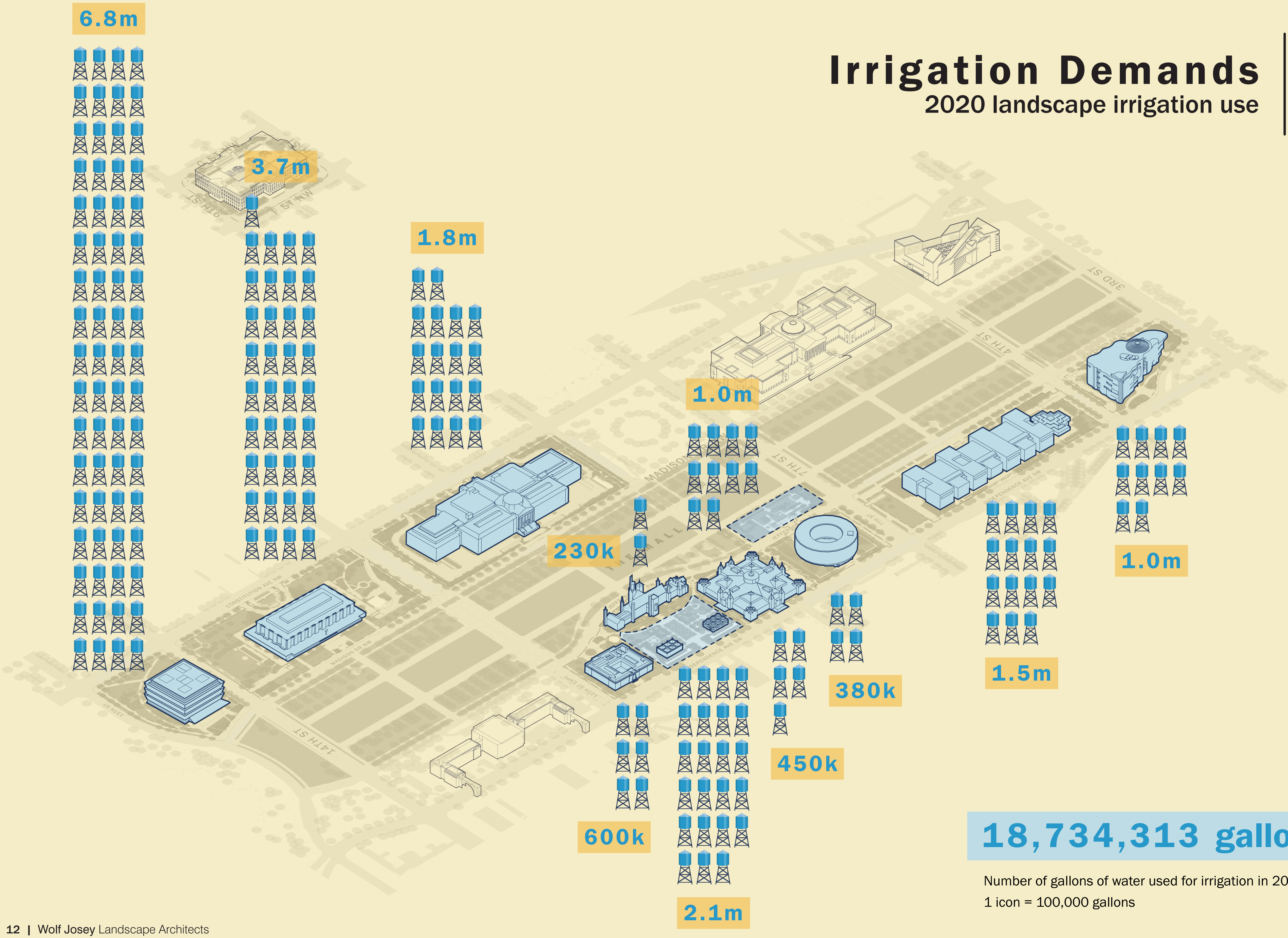
percentage excluding building area





Irrigation Demands

2020 landscape irrigation use



18,734,313 gallons

Number of gallons of water used for irrigation in 2020

1 icon = 100,000 gallons

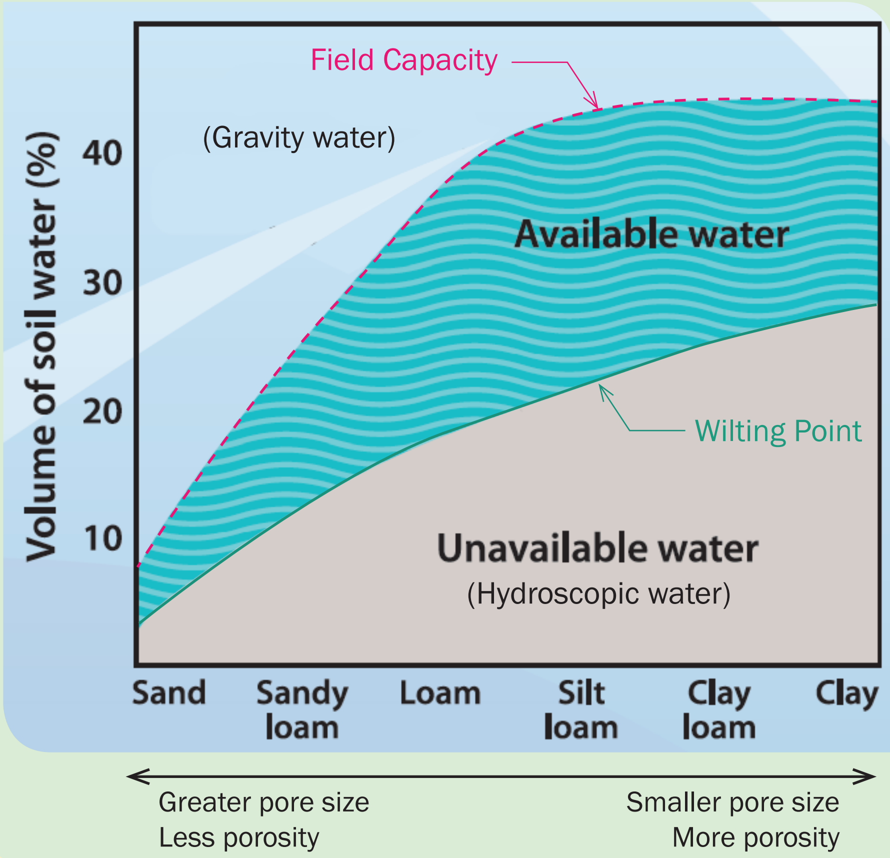
Irrigation Summary
impacts of soil type on water use

1 Sand-based Soils Pt. 1
High volumes of irrigation are necessary to support these soil types, which are generally easily drained and quick to heat up, especially over structure.

2 Sand-based Soils Pt. 2
Increased irrigation leads to readily leached nutrients, organic matter, and beneficial microbes within plant root zones.

3 Escalating Inputs
Leached nutrients and all things beneficial to healthy soils inflates the need for fertilizers, pesticides, and fungicides. The cycle is unsustainable.

4 Soil Available Water
There are soil types that inherently sustain plant communities longer between rain (and/or irrigation) events by offering greater availability of water.



APPENDIX B

Plant Health Observations and Maintenance Evaluation

National Museum of African American History and Culture

NMAAHC is the most challenging to manage due to the primarily sand based soil type

The museum requires more inputs than any other site (water, compost, fertilizer)

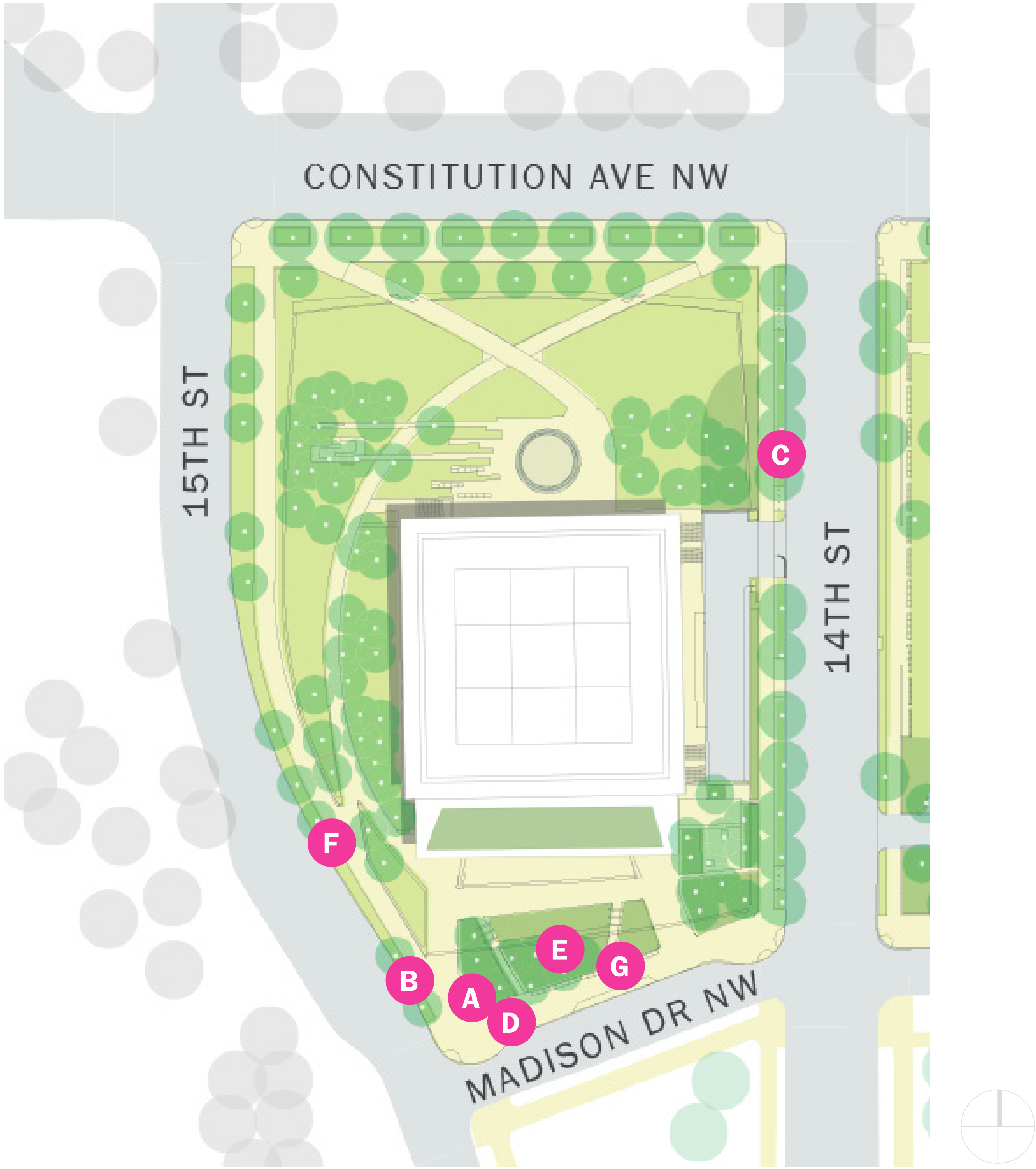
NMAAHC uses more irrigation than NMAH and NMNH combined

On a hot day the soil can go from fully saturated to dry in thirty minutes

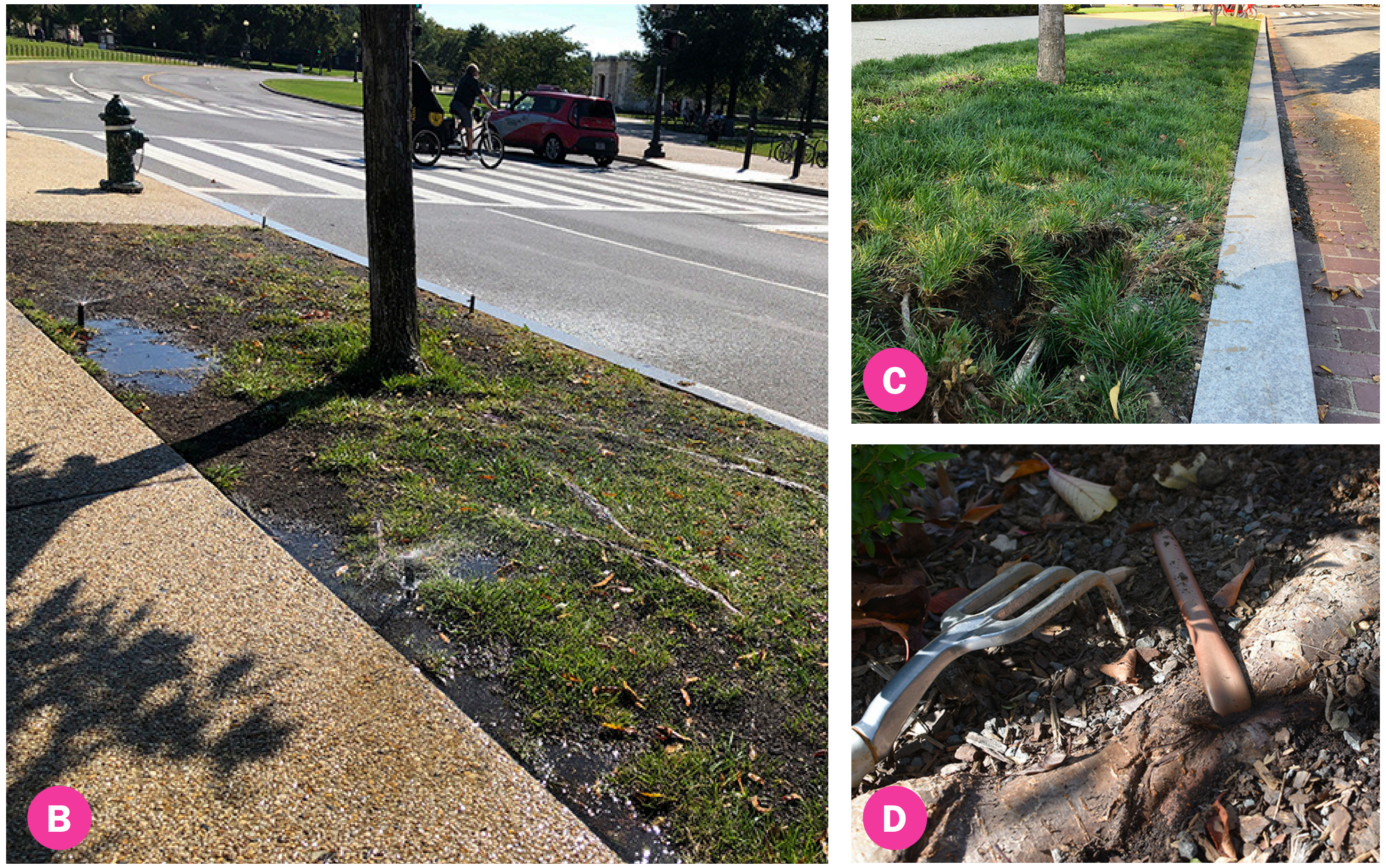
The sterile environment in the soil increases the risk for disease

Kousa dogwood, katsura, and ginkgo doing poorly; live oak trees are healthy

High pH of soil and irrigation water leads to nutrient deficiencies



Strangling Rootball Anchors



Irrigation Issues

Tree Stress + Decline

National Museum of American History

North and south lawn panels remain wet; generally unable to drain

Irrigation is completely turned off in spring and summer months

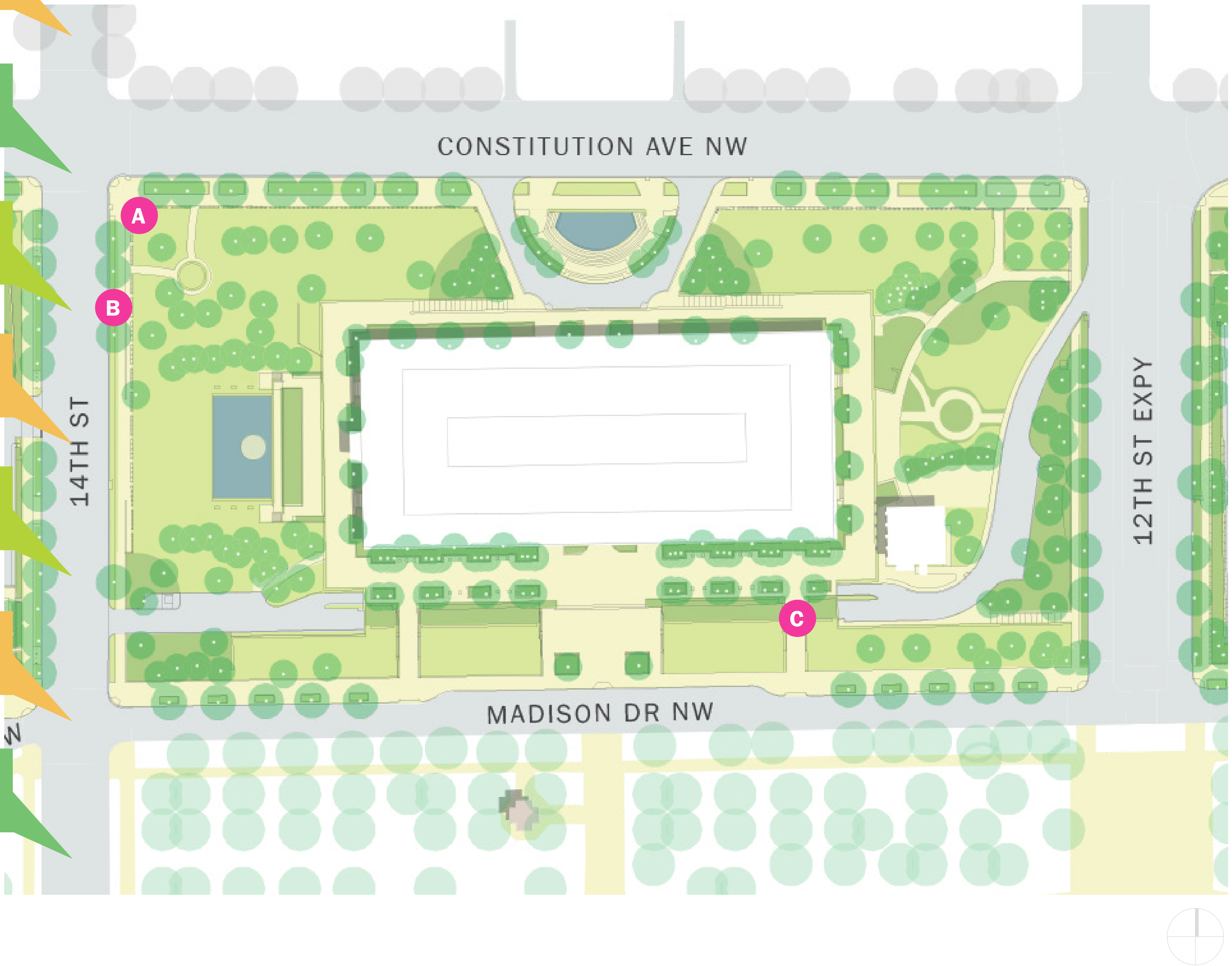
Rooting from mature oaks and elms create tough conditions for amending soils

Raised planters suffer from southern exposure and soils quick to dry out

Q. rubra suffering from bacterial leaf scorch, compaction, security wall impacts

Leftover 'construction clay' from projects creates pockets of poor soil

Site susceptible to flooding and ground subsidence (Tiber & WMATA tunnel)



Tree Decline

Healthy, Mature Planting

National Museum of Natural History

Urban Bird Habitat is very productive; limiting factor will be soil volume

Constitution Ave tree boxes heavily compacted and elms are in decline

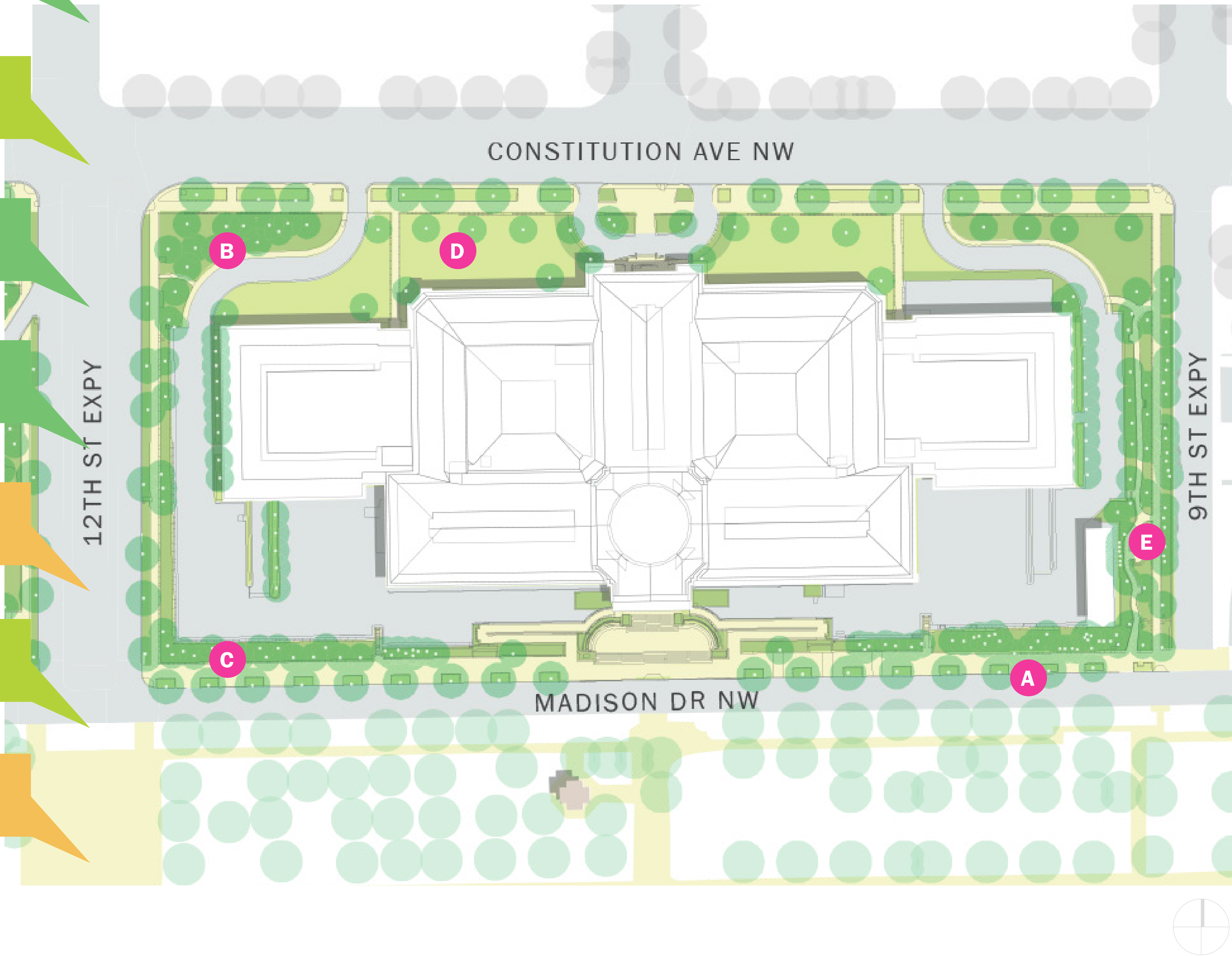
Pollinator Garden is very productive; trees have adapted to urban conditions

Perennial beds along 9th & 12th Streets have been incredibly successful

Newly installed soils at south-entrance ramp project are noticeably sandier

Older trees are in decline due to stem-girdling roots and outdated BMPs

Localized compaction and re-grading common after museum maintenance



Limited Rooting Volumes

Generally Good Tree Health

Successful Native Plant Collection

South Mall Campus

SIB, Freer, Sackler, Haupt, NMAfA, Rose, AIB, Ripley

SIB and Freer soils generally have sufficient drainage and good structure

Plant beds have been the best protectors against soil compaction

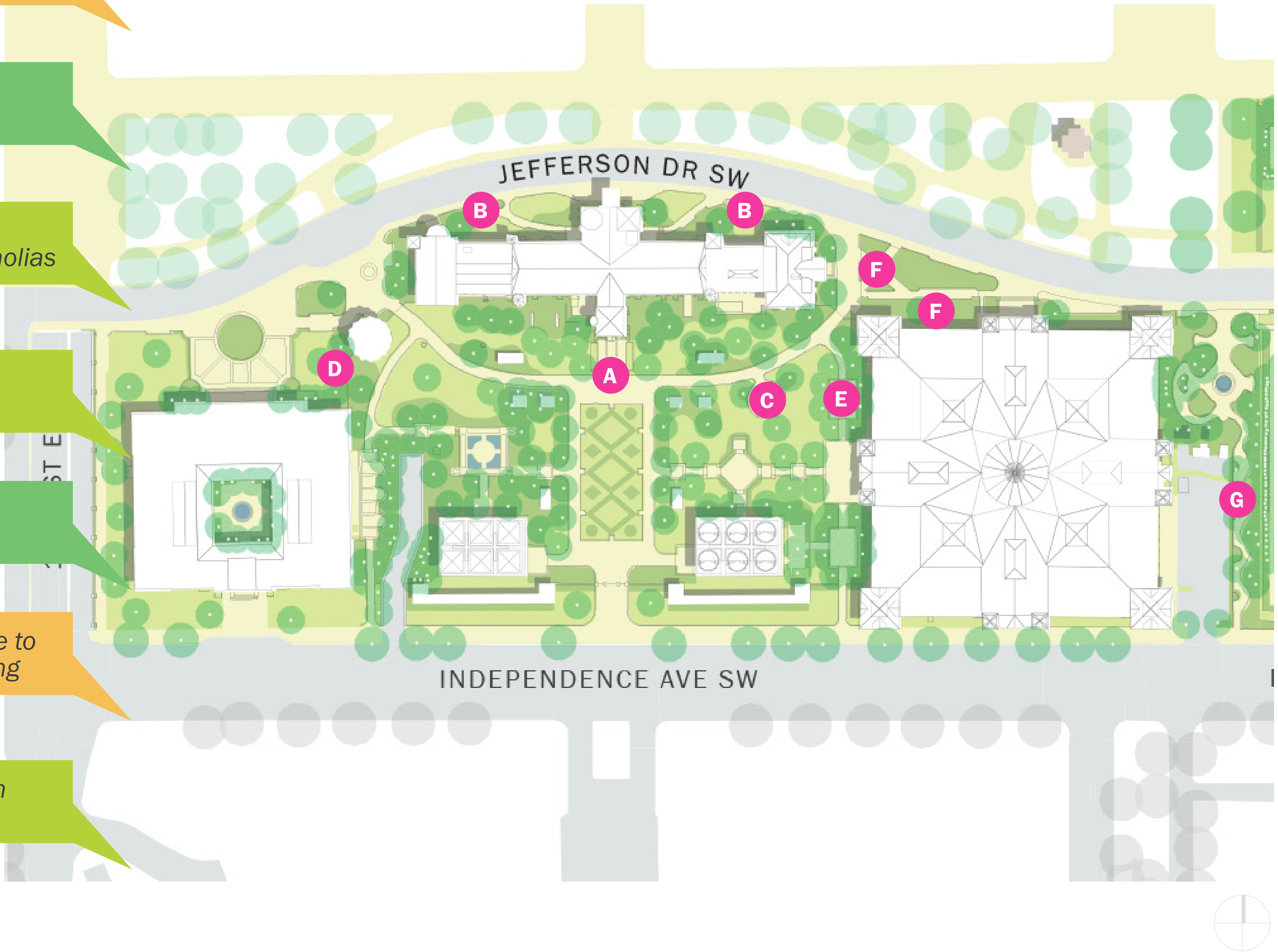
Health issues in Haupt Garden for mountain silverbells and saucer magnolias

Southern blight and access to sun impacting portions of Rose Garden

Haupt Parterre has been continually amended for +/- 25 years

Freer soils degraded at SW corner due to construction impacts, ginkgos suffering

Ripley Garden elms suck up so much water that irrigation can't keep up



Strong Annual Growth in Loam Soils

Potential Construction Impacts

Girdling Roots and Reduced Annual Growth

Healthy Plant Beds - Away from Pedestrians

Adventitious and Stem Girdling Roots

Health Variations of Sun and Shade

Healthy Elm Trees - Compacted Soils

Hirshhorn Museum and Sculpture Garden

Mature landscape is timeworn, declining, and managed to preserve existing plants

Plaza tree and turf areas are sand-based soils that are consistently underwatered

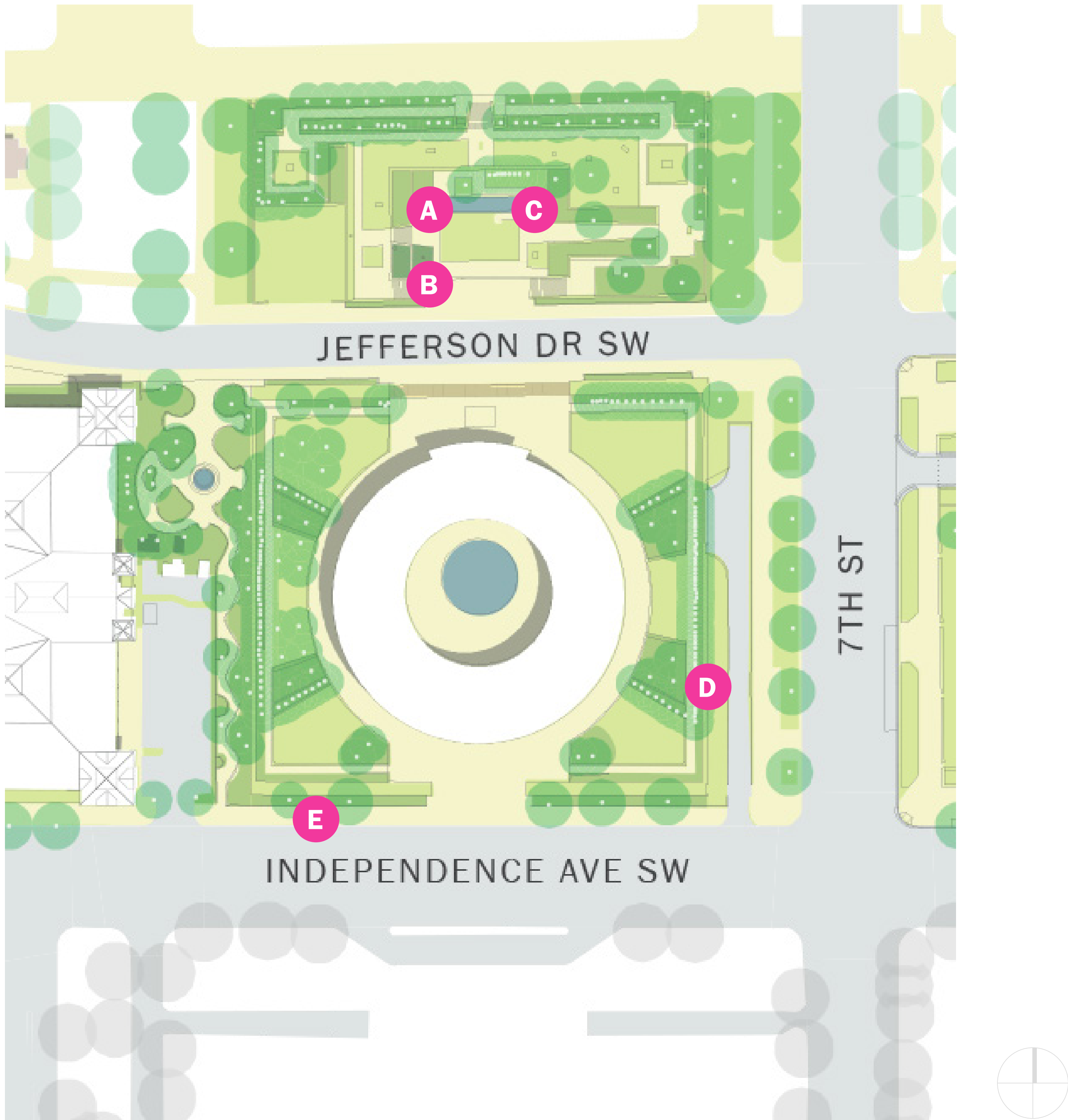
Consistent failure of honeylocusts at 12 - 14" dbh

Generally lower levels of foot traffic and compaction; pedestrians keep to paths

Sculpture Garden soils are good loamy texture with limited compaction

Lower Sculpture Garden is essentially one large 'pot bound' planter

SG tree decline due to plant selection and outdated planting and mulching practices



Generally Good Tree Health

Potential Signs of Tree Stress

Mature Elm Street Trees

National Air and Space Museum

Most trees in elevated planters are very successful, despite limited soil volume

Raised planters have led to minimal compaction issues

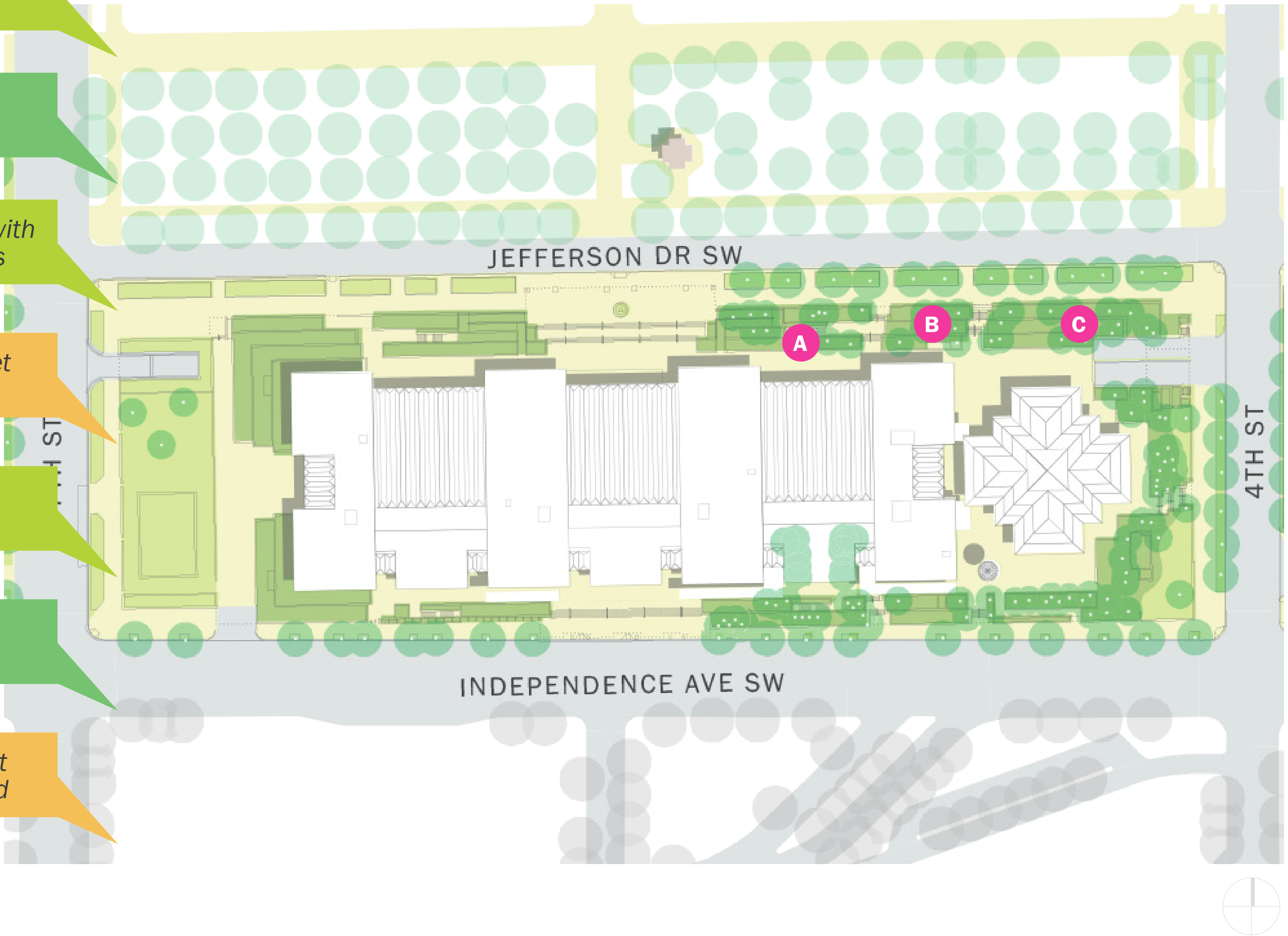
River birch zones are completely filled with roots; trees are out-living soil limitations

East-side and north planters remain wet until late spring and into early summer

Lack of sun on north-side of building leads to soil fungus and disease

Mulching occurs irregularly due to the difficulty of accessing the planters

Meadow gardens stay consistently wet and nutrient deficiencies are observed



Trees Exceeding Soil Limitations

Soil Settlement & Compaction

National Museum of the American Indian

Site consists of eight types of engineered gravelly sandy loam mixes

There is substantial subsidence in crop areas where soil has had to be added

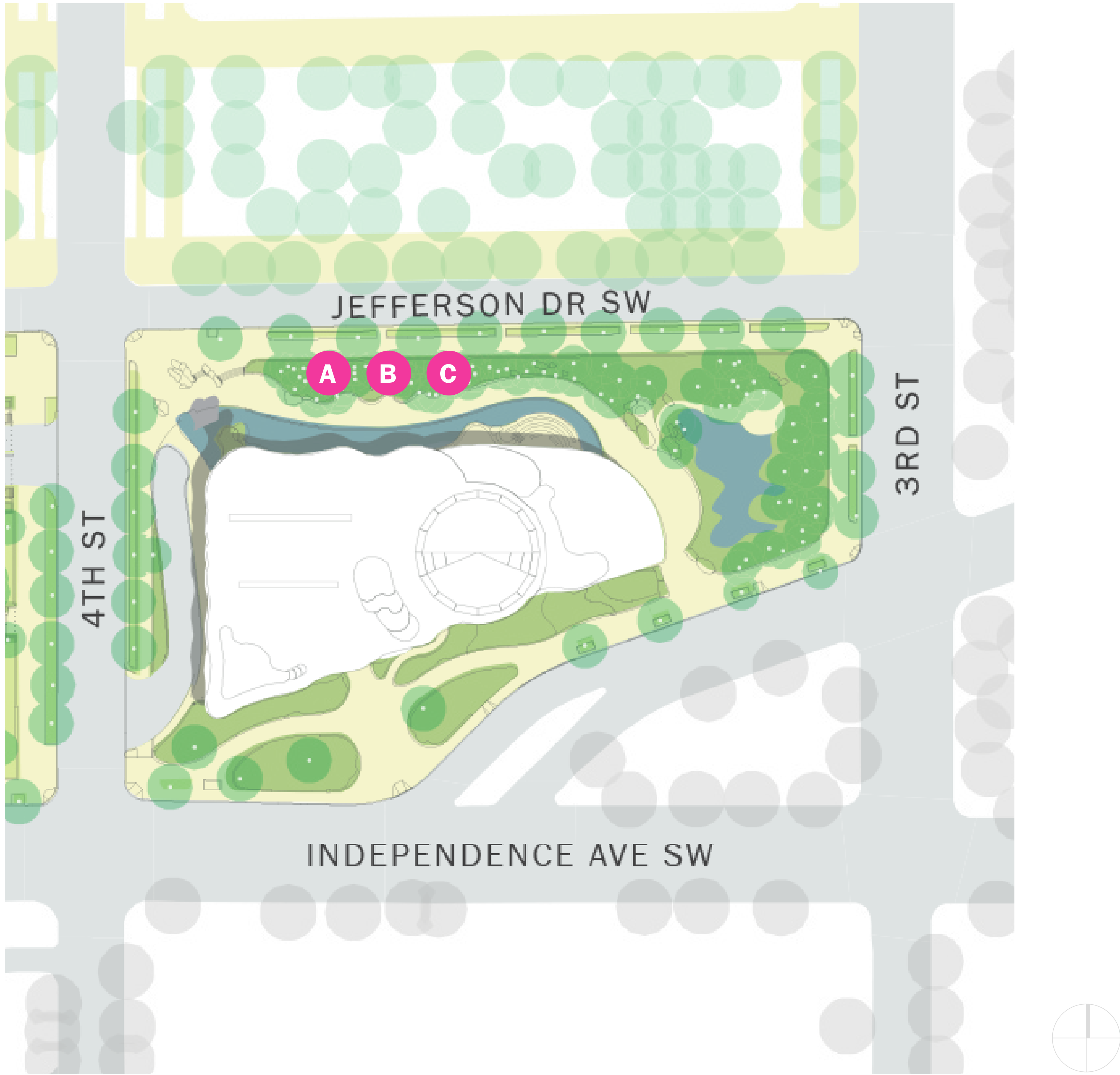
Tree boxes are heavily compacted from pedestrian circulation and events

North-side woodland landscape is well established, but heavily compacted

Trees soak up so much water that understory shrubs and perennials suffer

Leaf debris removed; detritis keeps areas too wet and humid (mosquito problems)

It's common to delay irrigation use and only run it every second or third day



Stem Girdling Roots

Donald W. Reynolds Center and Kogod Courtyard

Chinese hackberry is considered oldest in North America

South-side meadow planting has deep, organic soils

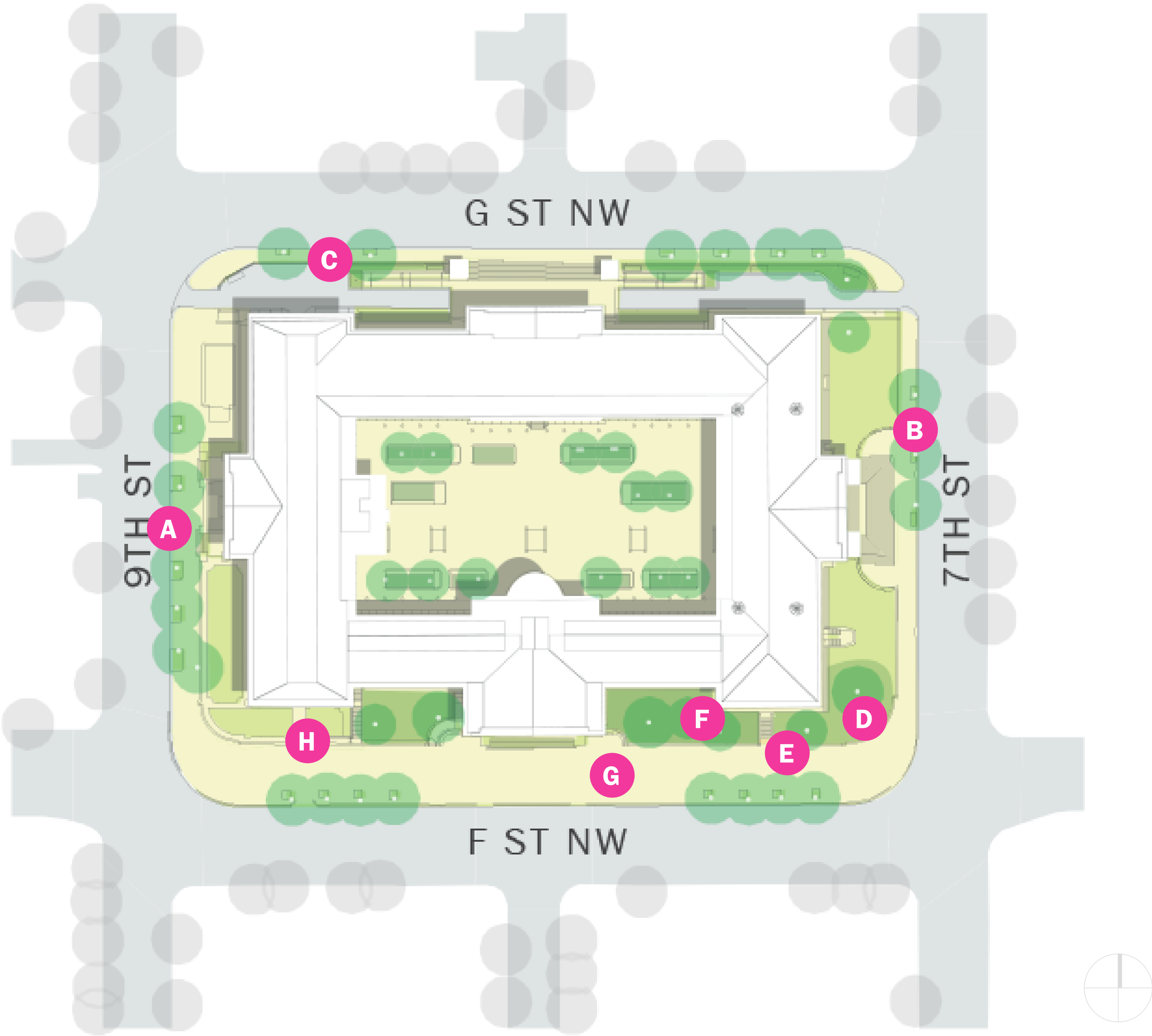
Mulch is only applied every few years

Lawn is irrigated and controlled for weeds, but generally little maintenance occurs

Courtyard soil is highly free draining, dries quickly, and is susceptible to compaction

Each courtyard planter receives new soil twice yearly

Trees and large shrubs remain year-round, perennial planting changed seasonally

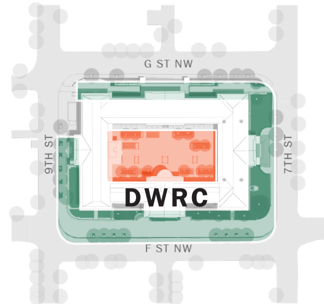


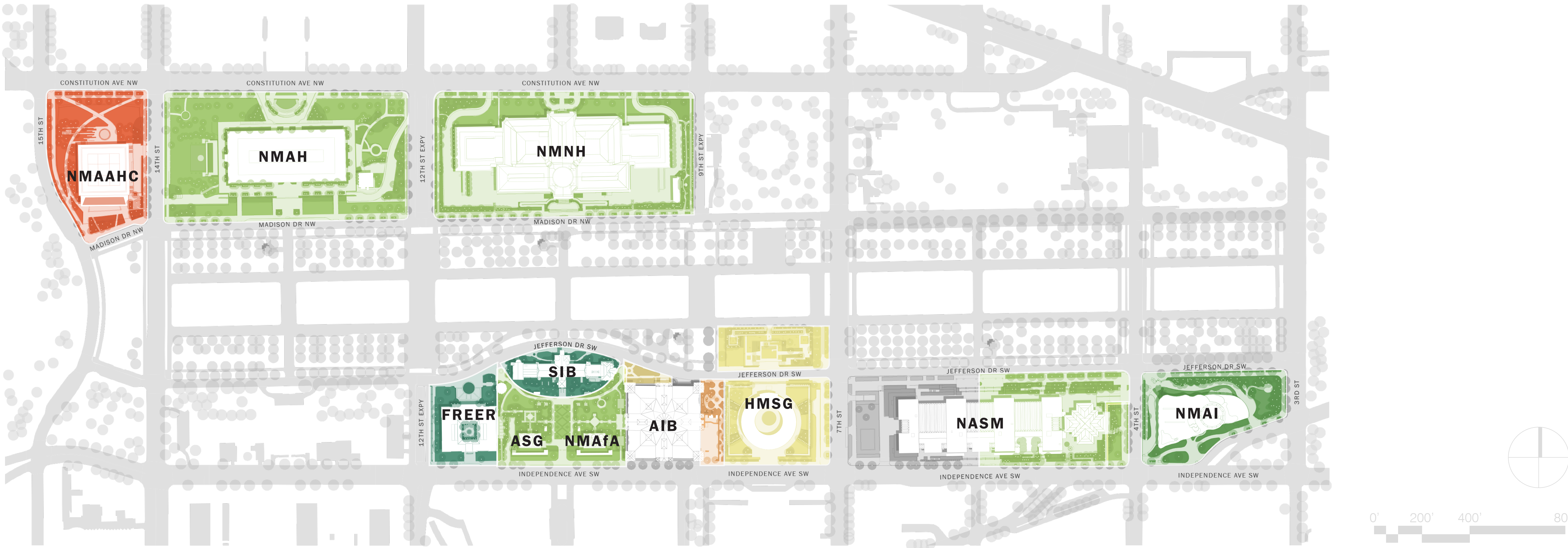
Girdling Root Stock

Successfull Perimeter Planting

Underutilized Perimeter Space

Maintenance Evaluation





Low
soil + plant maintenance

High
soil + plant maintenance

FREER
periodic care;
healthy plants

NMAI
productive soils;
healthy plants

NASM
hard to access;
mature plants

HAUPT
continually amended;
tree health concerns

ROSE
recent soil rebuilding;
blight issues

KOGOD
regular care required;
seasonal plant changes

DWRC
minimal attention;
controlled for weeds

SIB
native soils;
healthy plants

NMAH
regular care;
mature tree decline

NMNH
regular care;
successful gardens

HMSG
timeworn landscape;
declining plants

RIPLEY
above average care;
healthy plants

NMAAHC
persistent care required;
struggling plants

This page left blank intentionally.

APPENDIX C

Soil Sampling Testing Data

Textural Analysis

Testing Methodology

Smithsonian Gardens soils were physically surveyed by the consultant team in October 2020, at twenty-nine locations, to assess soil conditions such as structure, compaction and density, texture variability, and conditions affecting plant health.

Additional samples were taken again by the consultant team in February 2021 that best represented the types of soils within each garden. These were subjected to testing by outside laboratories for soil nutrient values, texture, pH, soil organic matter, and in some cases, soil biology.

Select soil samples were analyzed for mycorrhizal colonization in plant roots and for mycorrhizal spores. Given its less firmly researched relationship with plants, we have only listed observations for future investigation.

Turf & Soil Diagnostics **report # 46615 - 46633**
3/8/2021

Lab #	**Sample Id**	**Location**	**% Sand**	**% Silt**	**% Clay**	**USDA Classification**
46633-1	AIB-R1	Rose Garden - Sun	41.7	42.2	16.1	Very Gravelly Loam
46633-2	AIB-R2	Rose Garden - Shade	41.6	40.2	18.2	Loam
46633-3	DWRC-B	Bed: under *Celtis sinensis*	36.6	46.2	17.1	Loam
46633-4	DWRC-L	Lawn: near *Celtis sinensis*	59.4	26.8	13.7	Gravelly Sandy Loam
46633-5	FREE-B	Bed: *M. grandiflora*	51.9	29.1	19.1	Gravelly Loam
46633-6	FREE-L	Lawn: *G. biloba*	42.6	38.3	19.1	Loam
46633-7	**HMSG-EB**	17th St: *U. americana*	80.6	14.7	4.7	Gravelly Loamy Sand
46633-8	HMSG-E (7th)	**17th St bed: *U. americana***	48.9	33.4	17.7	Loam
46633-9	HMSG-L	Lawn: *G. triacanthos*	78	15.7	6.4	Loamy Sand
46633-10	HMSG-M	Bed: *M. grandifolia*	72.8	17.3	9.9	Gravelly Sandy Loam
46633-11	HMSG-P	Bed: *Pachysandra*	80	14.9	5.1	Gravelly Loamy Sand
46633-12	HMSG-S	Lawn: *A. saccharum*	44.8	40.3	15	Loam
46633-13	**NASM-B**	**Bed: Betula / perennials**	51	33	16	Gravelly Loam
46633-14	NASM-L	Lawn: *Q. phellos*	83.4	6.4	10.2	Loamy Sand
46633-15	NMAA-B	Bed: perennials	78.8	13	8.2	Very Gravelly Loamy Sand
46633-16	NMAA-L	Lawn: *Q. virginiana*	84.7	10.8	4.5	Very Gravelly Loamy Sand
46633-17	**NMAA-LG**	**Lawn on grade**	94.2	3.7	2.1	Sand
46633-18	NMAH-B	Bed: 12th St perennials	53.3	29.3	17.4	Gravelly Sandy Loam
46633-19	NMAH-L	Lawn: *Q. rubra*	44.5	42	13.5	Loam
46615-1	NMAI-B	Bed @ memorial	43.5	36.5	20	Gravelly Loam
46615-2	NMAI-M	Bed: meadow	55.6	25.9	18.5	Sandy Loam
46615-3	NMAI-W	Bed: *Carya / Quercus*	63.9	16.1	20	Gravelly Sandy Clay Loam
46615-4	NMNH-B	Bed: *Betula / perennials*	44.7	35.5	19.8	Loam
46615-5	NMNH-BT	Streetscape: *perennials*	55	27.1	17.9	Gravelly Sandy Loam
46615-6	NMNH-L	Lawn: *U. americana*	43.4	38	18.6	Loam
46633-20	RIPL-B	Bed: *Ulmus - perennials*	40.1	40.3	19.7	Loam
46615-9	SIB-B	Bed: *Halesia*	57.5	24.2	18.3	Gravelly Sandy Loam
46615-8	SIB-L	Lawn: *Halesia*	52.4	30.2	17.5	Gravelly Sandy Loam
46615-7	SIB-BL	Bed: *M. x soulangeana*	41.3	38	20.7	Loam
46615-10	SIB-ML	Lawn: *M. x soulangeana*	51.3	30.1	18.6	Loam

Chemical Analysis

Waypoint Analytical **report # 21-008-1320**
1/20/2021

Lab #	Sample Id		OM	CEC	Est. N Release		pH	Buffer pH	Sol. Salts		P	K	Ca	Mg	S	Na	Zinc	Mn	Fe	Cu	Bo
14402	AIB-R1	Rose Garden - Sun	3.3	9.1	103	lbs/ac	6.5	6.9	0.1	ppm	98	59	1357	174	4	14	23	33	390	5.9	0.9
14403	AIB-R2	Rose Garden - Shade	5.3	11.1	140	lbs/ac	6.6	6.9	0.1	ppm	107	100	1675	203	5	15	19	26	388	5.1	1
14414	DWRC-B	Bed: under *Celtis sinensis*	6.9	15.1	150	lbs/ac	6.9	6.9	0.2	ppm	30	102	2460	269	5	14	6.5	81	218	3.2	1.1
14413	DWRC-L	Lawn: near *Celtis sinensis*	2.8	8.1	94	lbs/ac	6.4	6.9	0.2	ppm	79	174	1067	185	13	12	6.8	25	185	2.1	0.7
14415	DWRC-C	Bed: Kogod planter	6.9	20	150	lbs/ac	6.4	6.8	0.2	ppm	136	150	2806	440	3	23	7.8	10	462	3	1.1
14396	FREE-B	Bed: *M. grandiflora*	5	10.9	134	lbs/ac	6.7	6.9	0.2	ppm	32	83	1576	261	12	27	6.1	32	183	7.9	0.7
14395	FREE-L	Lawn: *G. biloba*	20.4	21	`	lbs/ac	6.1	6.6	0.2	ppm	40	383	2154	707	60	106	5.9	16	88	2.7	4.7
14416	FREE-C	Bed: interior courtyard	5.1	14	132	lbs/ac	6.8	6.9	0.2	ppm	47	92	2312	205	9	26	15	65	211	5.5	1
14390	HMSG-E	17th St: *U. americana*	3.4	11.3	102	lbs/ac	7.2	6.9	0.3	ppm	16	63	1766	274	8	11	6.5	56	167	3.3	0.8
2712	**HMSG-EB**	**17th St bed: *U. americana***	1.7	4.6	77	lbs/ac	6.7	*n/a*	0.1	ppm	64	37	705	92	8	11	4.9	175	172	3.6	0.2
14386	HMSG-L	Lawn: *G. triacanthos*	1.6	6.5	73	lbs/ac	7	6.9	0.2	ppm	114	51	957	180	18	21	8.4	39	243	4.7	0.6
14389	HMSG-M	Bed: *M. grandifolia*	5.2	12.4	136	lbs/ac	5.8	6.7	0.1	ppm	25	109	1417	304	15	24	6.6	29	256	3.5	0.7
14388	HMSG-P	Bed: *Pachysandra*	8.7	13.7	150	lbs/ac	6.6	6.9	0.4	ppm	91	60	2170	215	10	13	13	52	199	7.8	0.7
14405	HMSG-S	Lawn: *A. saccharum*	6.2	11.8	150	lbs/ac	6.1	6.8	0.4	ppm	22	92	1617	215	9	10	4.7	106	293	2.6	0.7
2714	**NASM-B**	**Bed: Betula / perennials**	4.3	12	57	lbs/ac	7.2	*n/a*	0.1	ppm	53	90	2019	190	9	19	5.5	28	315	3.7	0.9
14391	NASM-L	Lawn: *Q. phellos*	4.3	12.3	118	lbs/ac	6.1	6.8	0.4	ppm	16	125	1567	276	18	23	16	55	190	7.1	0.9
14407	NMAA-B	Bed: perennials	8.4	13.4	150	lbs/ac	6	6.7	0.1	ppm	158	87	1746	271	13	19	16	20	435	5.8	0.9
14406	NMAA-L	Lawn: *Q. virginiana*	9.2	20.2	150	lbs/ac	6.1	6.7	0.2	ppm	89	120	2861	292	21	82	14	48	196	5.4	1.7
2715	**NMAA-LG**	**Lawn on grade**	0.5	2.3	57	lbs/ac	7.4	*n/a*	0.1	ppm	26	36	305	78	5	7	1	14	59	0.7	0.1
14410	NMAH-B	Bed: 12th St perennials	2.8	6.5	97	lbs/ac	6.9	6.9	0.2	ppm	40	64	1076	101	10	7	5.4	127	135	3.1	0.7
14408	NMAH-L	Lawn: *Q. rubra*	1.9	5.1	81	lbs/ac	6.8	6.9	0.2	ppm	19	41	748	127	8	11	3.4	62	123	2	0.4
14392	NMAI-B	Bed @ memorial	5.4	15.6	136	lbs/ac	6.9	6.9	0.1	ppm	43	137	2530	277	12	18	14	50	262	6.9	1.3
14394	NMAI-M	Bed: meadow	4	10.9	114	lbs/ac	6.7	6.9	0.7	ppm	82	66	1808	137	6	12	25	46	191	9.6	0.9
14393	NMAI-W	Bed: *Carya / Quercus*	2.4	6.8	88	lbs/ac	6.9	6.9	0.1	ppm	47	40	1091	127	6	14	12	71	132	21.4	0.6
14412	NMNH-B	Bed: *Betula / perennials*	4.2	10.6	119	lbs/ac	6	6.8	0.3	ppm	14	175	1250	268	1	10	11	25	229	3	0.7
14411	NMNH-L	Lawn: *U. americana*	4.5	12.3	122	lbs/ac	6.8	6.9	0.2	ppm	65	81	2001	198	3	20	12	61	242	6.1	1.2
14404	RIPL-B	Bed: *Ulmus - perennials*	5.1	10.8	137	lbs/ac	6.6	6.9	0.1	ppm	33	76	1542	269	14	13	5.3	144	226	2.8	0.7
14399	SIB-B	Bed: *Halesia*	9.8	14	150	lbs/ac	6.1	6.7	0.1	ppm	95	45	1981	239	7	17	21	47	309	7.1	0.9
14397	SIB-L	Lawn: *Halesia*	2.8	9.8	92	lbs/ac	6.8	6.9	0.1	ppm	46	112	1387	264	9	17	4.3	77	246	3.4	0.7
14401	SIB-MB	Bed: *M. x soulangeana*	11.7	12.6	150	lbs/ac	5.2	6.5	0.1	ppm	41	118	1270	187	4	14	12	46	347	2.6	0.8
14400	SIB-ML	Lawn: *M. x soulangeana*	3.1	9	99	lbs/ac	6.7	6.9	0.1	ppm	45	61	1423	149	11	18	15	48	357	4.9	0.9

Chemical Analysis
pH and soluble salts

pH

Healthy: 5 - 7

Soluble Salts

Healthy: < 0.8 ppm
Low Saline: 0.8 - 1.6
Saline: 1.6 - 2.4
High: 2.4 - 5.0
Very High: > 5.0

Waypoint Analytical
1/20/2021

Lab #	Sample Id		pH	Buffer pH	Sol. Salts	
14402	AIB-R1	Rose Garden - Sun	6.5	6.9	0.1	ppm
14403	AIB-R2	Rose Garden - Shade	6.6	6.9	0.1	ppm
14414	DWRC-B	Bed: under *Celtis sinensis*	6.9	6.9	0.2	ppm
14413	DWRC-L	Lawn: near *Celtis sinensis*	6.4	6.9	0.2	ppm
14415	DWRC-C	Bed: Kogod planter	6.4	6.8	0.2	ppm
14396	FREE-B	Bed: *M. grandiflora*	6.7	6.9	0.2	ppm
14395	FREE-L	Lawn: *G. biloba*	6.1	6.6	0.2	ppm
14416	FREE-C	Bed: interior courtyard	6.8	6.9	0.2	ppm
14390	HMSG-E	17th St: *U. americana*	7.2	6.9	0.3	ppm
14386	HMSG-L	Lawn: *G. triacanthos*	7	6.9	0.2	ppm
14389	HMSG-M	Bed: *M. grandifolia*	5.8	6.7	0.1	ppm
14388	HMSG-P	Bed: *Pachysandra*	6.6	6.9	0.4	ppm
14405	HMSG-S	Lawn: *A. saccharum*	6.1	6.8	0.4	ppm
14391	NASM-L	Lawn: *Q. phellos*	6.1	6.8	0.4	ppm
14407	NMAA-B	Bed: perennials	6	6.7	0.1	ppm
14406	NMAA-L	Lawn: *Q. virginiana*	6.1	6.7	0.2	ppm
14410	NMAH-B	Bed: 12th St perennials	6.9	6.9	0.2	ppm
14408	NMAH-L	Lawn: *Q. rubra*	6.8	6.9	0.2	ppm
14392	NMAI-B	Bed @ memorial	6.9	6.9	0.1	ppm
14394	NMAI-M	Bed: meadow	6.7	6.9	0.7	ppm
14393	NMAI-W	Bed: *Carya / Quercus*	6.9	6.9	0.1	ppm
14412	NMNH-B	Bed: *Betula / perennials*	6	6.8	0.3	ppm
14411	NMNH-L	Lawn: *U. americana*	6.8	6.9	0.2	ppm
14404	RIPL-B	Bed: *Ulmus - perennials*	6.6	6.9	0.1	ppm
14399	SIB-B	Bed: *Halesia*	6.1	6.7	0.1	ppm
14397	SIB-L	Lawn: *Halesia*	6.8	6.9	0.1	ppm
14401	SIB-MB	Bed: *M. x soulangeana*	5.2	6.5	0.1	ppm
14400	SIB-ML	Lawn: *M. x soulangeana*	6.7	6.9	0.1	ppm

Organic Matter (OM)

Low:	**0 - 2%**
Healthy:	**2 - 5%**
High:	**5 - 7%**
Very High:	**> 7%**

Cation Exchange Capacity (CEC)

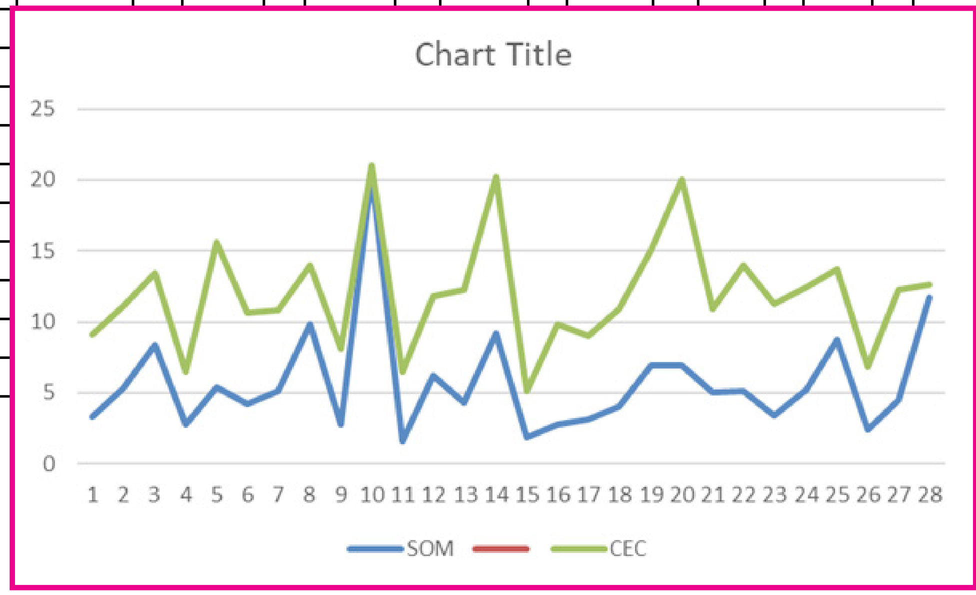
Healthy: **> 10 meq/100g**

Chemical Analysis

organic matter (OM) and CEC

Waypoint Analytical **report # 21-008-1320**
1/20/2021

Lab #	Sample Id		OM		CEC	Est. N Release		pH	Buffer pH	Sol. Salts			P		K		Ca		Mg		S	Sul	Na	So	Zinc	Zin	Mn	Mar	Fe	Iror	Cu	Cop	Bo	Bor
14402	AIB-R1	Rose Garden - Sun	3.3	M	9.1	103	lbs/ac	6.5	6.9	0.1	ppm	VL	98	H	59	L	1357	H	174	H	4	VL	14	VL	23	VH	33	H	390	VH	5.9	VH	0.9	M
14403	AIB-R2	Rose Garden - Shade	5.3	H	11.1	140	lbs/ac	6.6	6.9	0.1	ppm	VL	107	H	100	L	1675	H	203	H	5	VL	15	VL	19	VH	26	H	388	VH	5.1	VH	1	M
14414	DWRC-B	Bed: under *Celtis sinensis*	6.9	H	15.1	150	lbs/ac	6.9	6.9	0.2	ppm	VL	30	L	102	L	2460	H	269	M	5	VL	14	VL	6.5	H	81	VH	218	VH	3.2	H	1.1	M
14413	DWRC-L	Lawn: near *Celtis sinensis*	2.8	M	8.1	94	lbs/ac	6.4	6.9	0.2	ppm	VL	79	H	174	O	1067	M	185	H	13	L	12	VL	6.8	H	25	H	185	VH	2.1	H	0.7	M
14415	DWRC-C	Bed: Kogod planter	6.9	H	20	150	lbs/ac	6.4	6.8	0.2	ppm	VL	136	VH	150	M	2806	H	440	H	3	VL	23	VL	7.8	H	10	M	462	VH	3	H	1.1	M
14396	FREE-B	Bed: *M. grandiflora*	5	H	10.9	134	lbs/ac	6.7	6.9	0.2	ppm	VL	32	M	83	L	1576	H	261	H	12	L	27	VL	6.1	H	32	H	183	VH	7.9	VH	0.7	M
14395	FREE-L	Lawn: *G. biloba*	20.4	VH	21	`	lbs/ac	6.1	6.6	0.2	ppm	VL	40	M	383	VH	2154	M	707	H	60	VH	106	L	5.9	H	16	M	88	VH	2.7	H	4.7	VH
14416	FREE-C	Bed: interior courtyard	5.1	H	14	132	lbs/ac	6.8	6.9	0.2	ppm	VL	47	M	92	L	2312	H	205	M	9	VL	26	VL	15	VH	65	VH	211	VH	5.5	VH	1	M
14390	HMSG-E	17th St: *U. americana*	3.4	M	11.3	102	lbs/ac	7.2	6.9	0.3	ppm	VL	16	L	63	VL	1766	H	274	H	8	VL	11	VL	6.5	H	56	H	167	VH	3.3	H	0.8	M
14386	HMSG-L	Lawn: *G. triacanthos*	1.6	L	6.5	73	lbs/ac	7	6.9	0.2	ppm	VL	114	H	51	VL	957	H	180	H	18	M	21	VL	8.4	H	39	H	243	VH	4.7	VH	0.6	M
14389	HMSG-M	Bed: *M. grandifolia*	5.2	H	12.4	136	lbs/ac	5.8	6.7	0.1	ppm	VL	25	L	109	M	1417	M	304	H	15	L	24	VL	6.6	H	29	H	256	VH	3.5	H	0.7	M
14388	HMSG-P	Bed: *Pachysandra*	8.7	VH	13.7	150	lbs/ac	6.6	6.9	0.4	ppm	VL	91	H	60	VL	2170	H	215	M	10	L	13	VL	13	VH	52	H	199	VH	7.8	VH	0.7	M
14405	HMSG-S	Lawn: *A. saccharum*	6.2	H	11.8	150	lbs/ac	6.1	6.8	0.4	ppm	VL	22	L	92	L	1617	M	215	H	9	VL	10	VL	4.7	H	106	VH	293	VH	2.6	H	0.7	M
14391	NASM-L	Lawn: *Q. phellos*	4.3	M	12.3	118	lbs/ac	6.1	6.8	0.4	ppm	VL	16	L	125	M	1567	M	276	H	18	M	23	VL	16	VH	55	H	190	VH	7.1	VH	0.9	M
14407	NMAA-B	Bed: perennials	8.4	VH	13.4	150	lbs/ac	6	6.7	0.1	ppm	VL	158	VH	87	L	1746	M	271	H	13	L	19	VL	16	VH	20	M	435	VH	5.8	VH	0.9	M
14406	NMAA-L	Lawn: *Q. virginiana*	9.2	VH	20.2	150	lbs/ac	6.1	6.7	0.2	ppm	VL	89	O	120	L	2861	H	292	M	21	M	82	VL	14	VH	48	H	196	VH	5.4	VH	1.7	O
14410	NMAH-B	Bed: 12th St perennials	2.8	M	6.5	97	lbs/ac	6.9	6.9	0.2	ppm	VL	40	M	64	L	1076	H	101	M	10	L	7	VL	5.4	H	127	VH	135	VH	3.1	H	0.7	M
14408	NMAH-L	Lawn: *Q. rubra*	1.9	L	5.1	81	lbs/ac	6.8	6.9	0.2	ppm	VL	19	L	41	VL	748	H	127	H	8	VL	11	VL	3.4	M	62	VH	123	VH	2	H	0.4	L
14392	NMAI-B	Bed @ memorial	5.4	H	15.6	136	lbs/ac	6.9	6.9	0.1	ppm	VL															0	H	262	VH	6.9	VH	1.3	O
14394	NMAI-M	Bed: meadow	4	M	10.9	114	lbs/ac	6.7	6.9	0.7	ppm	L															6	H	191	VH	9.6	VH	0.9	M
14393	NMAI-W	Bed: *Carya / Quercus*	2.4	L	6.8	88	lbs/ac	6.9	6.9	0.1	ppm	VL															1	VH	132	VH	21.4	VH	0.6	M
14412	NMNH-B	Bed: *Betula / perennials*	4.2	M	10.6	119	lbs/ac	6	6.8	0.3	ppm	VL															5	H	229	VH	3	H	0.7	M
14411	NMNH-L	Lawn: *U. americana*	4.5	M	12.3	122	lbs/ac	6.8	6.9	0.2	ppm	VL															1	VH	242	VH	6.1	VH	1.2	M
14404	RIPL-B	Bed: *Ulmus - perennials*	5.1	H	10.8	137	lbs/ac	6.6	6.9	0.1	ppm	VL															4	VH	226	VH	2.8	H	0.7	M
14399	SIB-B	Bed: *Halesia*	9.8	VH	14	150	lbs/ac	6.1	6.7	0.1	ppm	VL															7	H	309	VH	7.1	VH	0.9	M
14397	SIB-L	Lawn: *Halesia*	2.8	M	9.8	92	lbs/ac	6.8	6.9	0.1	ppm	VL															7	VH	246	VH	3.4	H	0.7	M
14401	SIB-MB	Bed: *M. x soulangeana*	11.7	VH	12.6	150	lbs/ac	5.2	6.5	0.1	ppm	VL															6	H	347	VH	2.6	H	0.8	M
14400	SIB-ML	Lawn: *M. x soulangeana*	3.1	M	9	99	lbs/ac	6.7	6.9	0.1	ppm	VL															8	H	357	VH	4.9	VH	0.9	M



Causal relationship between soil organic matter and CEC

Chemical Analysis
organic matter (OM) and CEC

Organic Matter (OM)

Low:	**0 - 2%**
Moderate:	**2 - 5%**
High:	**5 - 7%**
Very High:	**> 7%**

Cation Exchange Capacity (CEC)

Healthy: **> 10%**

Waypoint Analytical **report # 21-008-1320**
1/20/2021

Lab #	Sample Id		OM		CEC	Age	Date
14402	AIB-R1	Rose Garden - Sun	3.3	M	9.1	5	2016
14403	AIB-R2	Rose Garden - Shade	5.3	H	11.1	5	2016
14414	DWRC-B	Bed: under *Celtis sinensis*	6.9	H	15.1	63	1958
14413	DWRC-L	Lawn: near *Celtis sinensis*	2.8	M	8.1	63	1958
14415	DWRC-C	Bed: Kogod planter	6.9	H	20	14	2007
14396	FREE-B	Bed: *M. grandiflora*	5	H	10.9	34	1987
14395	FREE-L	Lawn: *G. biloba*	20.4	VH	21	3	2018
14416	FREE-C	Bed: interior courtyard	5.1	H	14	34	1987
14390	HMSG-E	17th St: *U. americana*	3.4	M	11.3	47	1974
14386	HMSG-L	Lawn: *G. triacanthos*	1.6	L	6.5	32	1989
14389	HMSG-M	Bed: *M. grandifolia*	5.2	H	12.4	47	1974
14388	HMSG-P	Bed: *Pachysandra*	8.7	VH	13.7	32	1989
14405	HMSG-S	Lawn: *A. saccharum*	6.2	H	11.8	40	1981
14391	NASM-L	Lawn: *Q. phellos*	4.3	M	12.3	45	1976
14407	NMAA-B	Bed: perennials	8.4	VH	13.4	5	2016
14406	NMAA-L	Lawn: *Q. virginiana*	9.2	VH	20.2	5	2016
14410	NMAH-B	Bed: 12th St perennials	2.8	M	6.5	58	1963
14408	NMAH-L	Lawn: *Q. rubra*	1.9	L	5.1	58	1963
14392	NMAI-B	Bed @ memorial	5.4	H	15.6	1	2020
14394	NMAI-M	Bed: meadow	4	M	10.9	17	2004
14393	NMAI-W	Bed: *Carya / Quercus*	2.4	L	6.8	17	2004
14412	NMNH-B	Bed: *Betula / perennials*	4.2	M	10.6	111	1910
14411	NMNH-L	Lawn: *U. americana*	4.5	M	12.3	111	1910
14404	RIPL-B	Bed: *Ulmus - perennials*	5.1	H	10.8	40	1981
14399	SIB-B	Bed: *Halesia*	9.8	VH	14	6	2015
14397	SIB-L	Lawn: *Halesia*	2.8	M	9.8	166	1855
14401	SIB-MB	Bed: *M. x soulangeana*	11.7	VH	12.6	34	1987
14400	SIB-ML	Lawn: *M. x soulangeana*	3.1	M	9	34	1987

FREER - west side *G. biloba* planting

NMAAHC - east side at *Q.virginiana*

Chemical Analysis
organic matter (OM) and CEC

Organic Matter (OM)

Low: **0 - 2%**
Moderate: **2 - 5%**
High: **5 - 7%**
Very High: **> 7%**

Cation Exchange Capacity (CEC)

Healthy: **> 10%**

Waypoint Analytical
1/20/2021

report # 21-008-1320

Lab #	Sample Id		OM		CEC	Age	Date
14402	AIB-R1	Rose Garden - Sun	3.3	M	9.1	5	2016
14403	AIB-R2	Rose Garden - Shade	5.3	H	11.1	5	2016
14414	DWRC-B	Bed: under *Celtis sinensis*	6.9	H	15.1	63	1958
14413	DWRC-L	Lawn: near *Celtis sinensis*	2.8	M	8.1	63	1958
14415	DWRC-C	Bed: Kogod planter	6.9	H	20	14	2007
14396	FREE-B	Bed: *M. grandiflora*	5	H	10.9	34	1987
14395	FREE-L	Lawn: *G. biloba*	20.4	VH	21	3	2018
14416	FREE-C	Bed: interior courtyard	5.1	H	14	34	1987
14390	HMSG-E	17th St: *U. americana*	3.4	M	11.3	47	1974
14386	HMSG-L	Lawn: *G. triacanthos*	1.6	L	6.5	32	1989
14389	HMSG-M	Bed: *M. grandifolia*	5.2	H	12.4	47	1974
14388	HMSG-P	Bed: *Pachysandra*	8.7	VH	13.7	32	1989
14405	HMSG-S	Lawn: *A. saccharum*	6.2	H	11.8	40	1981
14391	NASM-L	Lawn: *Q. phellos*	4.3	M	12.3	45	1976
14407	NMAA-B	Bed: perennials	8.4	VH	13.4	5	2016
14406	NMAA-L	Lawn: *Q. virginiana*	9.2	VH	20.2	5	2016
14410	NMAH-B	Bed: 12th St perennials	2.8	M	6.5	58	1963
14408	NMAH-L	Lawn: *Q. rubra*	1.9	L	5.1	58	1963
14392	NMAI-B	Bed @ memorial	5.4	H	15.6	1	2020
14394	NMAI-M	Bed: meadow	4	M	10.9	17	2004
14393	NMAI-W	Bed: *Carya / Quercus*	2.4	L	6.8	17	2004
14412	NMNH-B	Bed: *Betula / perennials*	4.2	M	10.6	111	1910
14411	NMNH-L	Lawn: *U. americana*	4.5	M	12.3	111	1910
14404	RIPL-B	Bed: *Ulmus - perennials*	5.1	H	10.8	40	1981
14399	SIB-B	Bed: *Halesia*	9.8	VH	14	6	2015
14397	SIB-L	Lawn: *Halesia*	2.8	M	9.8	166	1855
14401	SIB-MB	Bed: *M. x soulangeana*	11.7	VH	12.6	34	1987
14400	SIB-ML	Lawn: *M. x soulangeana*	3.1	M	9	34	1987

HSMG - west side *G. triancanthos* planting

HMSG - west side at *M. grandiflora*

Chemical Analysis
pH and soluble salts

pH

Healthy: 5 - 7

Soluble Salts

Healthy: < 0.8 ppm
Low Saline: 0.8 - 1.6
Saline: 1.6 - 2.4
High: 2.4 - 5.0
Very High: > 5.0

Waypoint Analytical
1/20/2021

Lab #	Sample Id		pH	Buffer pH	Sol. Salts	
14402	AIB-R1	Rose Garden - Sun	6.5	6.9	0.1	ppm
14403	AIB-R2	Rose Garden - Shade	6.6	6.9	0.1	ppm
14414	DWRC-B	Bed: under *Celtis sinensis*	6.9	6.9	0.2	ppm
14413	DWRC-L	Lawn: near *Celtis sinensis*	6.4	6.9	0.2	ppm
14415	DWRC-C	Bed: Kogod planter	6.4	6.8	0.2	ppm
14396	FREE-B	Bed: *M. grandiflora*	6.7	6.9	0.2	ppm
14395	FREE-L	Lawn: *G. biloba*	6.1	6.6	0.2	ppm
14416	FREE-C	Bed: interior courtyard	6.8	6.9	0.2	ppm
14390	HMSG-E	17th St: *U. americana*	7.2	6.9	0.3	ppm
14386	HMSG-L	Lawn: *G. triacanthos*	7	6.9	0.2	ppm
14389	HMSG-M	Bed: *M. grandifolia*	5.8	6.7	0.1	ppm
14388	HMSG-P	Bed: *Pachysandra*	6.6	6.9	0.4	ppm
14405	HMSG-S	Lawn: *A. saccharum*	6.1	6.8	0.4	ppm
14391	NASM-L	Lawn: *Q. phellos*	6.1	6.8	0.4	ppm
14407	NMAA-B	Bed: perennials	6	6.7	0.1	ppm
14406	NMAA-L	Lawn: *Q. virginiana*	6.1	6.7	0.2	ppm
14410	NMAH-B	Bed: 12th St perennials	6.9	6.9	0.2	ppm
14408	NMAH-L	Lawn: *Q. rubra*	6.8	6.9	0.2	ppm
14392	NMAI-B	Bed @ memorial	6.9	6.9	0.1	ppm
14394	NMAI-M	Bed: meadow	6.7	6.9	0.7	ppm
14393	NMAI-W	Bed: *Carya / Quercus*	6.9	6.9	0.1	ppm
14412	NMNH-B	Bed: *Betula / perennials*	6	6.8	0.3	ppm
14411	NMNH-L	Lawn: *U. americana*	6.8	6.9	0.2	ppm
14404	RIPL-B	Bed: *Ulmus - perennials*	6.6	6.9	0.1	ppm
14399	SIB-B	Bed: *Halesia*	6.1	6.7	0.1	ppm
14397	SIB-L	Lawn: *Halesia*	6.8	6.9	0.1	ppm
14401	SIB-MB	Bed: *M. x soulangeana*	5.2	6.5	0.1	ppm
14400	SIB-ML	Lawn: *M. x soulangeana*	6.7	6.9	0.1	ppm

High Phosphorous **Fertilizer use**

High Sulfur / Sodium / Boron **Manure use**

Chemical Analysis
nutrient results

Waypoint Analytical **report # 21-008-1320**
1/20/2021

Lab #	Sample Id		OM	P		K		Ca		Mg		S	Sul	Na	So	Zinc	Zin	Mn	Mar	Fe	Iror	Cu	Cop	Bo	Bor
14402	AIB-R1	Rose Garden - Sun	3.3	98	H	59	L	1357	H	174	H	4	VL	14	VL	23	VH	33	H	390	VH	5.9	VH	0.9	M
14403	AIB-R2	Rose Garden - Shade	5.3	107	H	100	L	1675	H	203	H	5	VL	15	VL	19	VH	26	H	388	VH	5.1	VH	1	M
14414	DWRC-B	Bed: under *Celtis sinensis*	6.9	30	L	102	L	2460	H	269	M	5	VL	14	VL	6.5	H	81	VH	218	VH	3.2	H	1.1	M
14413	DWRC-L	Lawn: near *Celtis sinensis*	2.8	79	H	174	O	1067	M	185	H	13	L	12	VL	6.8	H	25	H	185	VH	2.1	H	0.7	M
14415	DWRC-C	Bed: Kogod planter	6.9	136	VH	150	M	2806	H	440	H	3	VL	23	VL	7.8	H	10	M	462	VH	3	H	1.1	M
14396	FREE-B	Bed: *M. grandiflora*	5	32	M	83	L	1576	H	261	H	12	L	27	VL	6.1	H	32	H	183	VH	7.9	VH	0.7	M
14395	FREE-L	Lawn: *G. biloba*	20.4	40	M	383	VH	2154	M	707	H	60	VH	106	L	5.9	H	16	M	88	VH	2.7	H	4.7	VH
14416	FREE-C	Bed: interior courtyard	5.1	47	M	92	L	2312	H	205	M	9	VL	26	VL	15	VH	65	VH	211	VH	5.5	VH	1	M
14390	HMSG-E	17th St: *U. americana*	3.4	16	L	63	VL	1766	H	274	H	8	VL	11	VL	6.5	H	56	H	167	VH	3.3	H	0.8	M
14386	HMSG-L	Lawn: *G. triacanthos*	1.6	114	H	51	VL	957	H	180	H	18	M	21	VL	8.4	H	39	H	243	VH	4.7	VH	0.6	M
14389	HMSG-M	Bed: *M. grandifolia*	5.2	25	L	109	M	1417	M	304	H	15	L	24	VL	6.6	H	29	H	256	VH	3.5	H	0.7	M
14388	HMSG-P	Bed: *Pachysandra*	8.7	91	H	60	VL	2170	H	215	M	10	L	13	VL	13	VH	52	H	199	VH	7.8	VH	0.7	M
14405	HMSG-S	Lawn: *A. saccharum*	6.2	22	L	92	L	1617	M	215	H	9	VL	10	VL	4.7	H	106	VH	293	VH	2.6	H	0.7	M
14391	NASM-L	Lawn: *Q. phellos*	4.3	16	L	125	M	1567	M	276	H	18	M	23	VL	16	VH	55	H	190	VH	7.1	VH	0.9	M
14407	NMAA-B	Bed: perennials	8.4	158	VH	87	L	1746	M	271	H	13	L	19	VL	16	VH	20	M	435	VH	5.8	VH	0.9	M
14406	NMAA-L	Lawn: *Q. virginiana*	9.2	89	O	120	L	2861	H	292	M	21	M	82	VL	14	VH	48	H	196	VH	5.4	VH	1.7	O
14410	NMAH-B	Bed: 12th St perennials	2.8	40	M	64	L	1076	H	101	M	10	L	7	VL	5.4	H	127	VH	135	VH	3.1	H	0.7	M
14408	NMAH-L	Lawn: *Q. rubra*	1.9	19	L	41	VL	748	H	127	H	8	VL	11	VL	3.4	M	62	VH	123	VH	2	H	0.4	L
14392	NMAI-B	Bed @ memorial	5.4	43	M	137	M	2530	H	277	M	12	L	18	VL	14	VH	50	H	262	VH	6.9	VH	1.3	O
14394	NMAI-M	Bed: meadow	4	82	O	66	L	1808	H	137	M	6	VL	12	VL	25	VH	46	H	191	VH	9.6	VH	0.9	M
14393	NMAI-W	Bed: *Carya / Quercus*	2.4	47	M	40	VL	1091	H	127	H	6	VL	14	VL	12	VH	71	VH	132	VH	21.4	VH	0.6	M
14412	NMNH-B	Bed: *Betula / perennials*	4.2	14	L	175	O	1250	M	268	H	1	VL	10	VL	11	VH	25	H	229	VH	3	H	0.7	M
14411	NMNH-L	Lawn: *U. americana*	4.5	65	O	81	L	2001	H	198	M	3	VL	20	VL	12	VH	61	VH	242	VH	6.1	VH	1.2	M
14404	RIPL-B	Bed: *Ulmus - perennials*	5.1	33	M	76	L	1542	H	269	H	14	L	13	VL	5.3	H	144	VH	226	VH	2.8	H	0.7	M
14399	SIB-B	Bed: *Halesia*	9.8	95	O	45	VL	1981	H	239	M	7	VL	17	VL	21	VH	47	H	309	VH	7.1	VH	0.9	M
14397	SIB-L	Lawn: *Halesia*	2.8	46	M	112	M	1387	H	264	H	9	VL	17	VL	4.3	H	77	VH	246	VH	3.4	H	0.7	M
14401	SIB-MB	Bed: *M. x soulangeana*	11.7	41	M	118	M	1270	M	187	M	4	VL	14	VL	12	VH	46	H	347	VH	2.6	H	0.8	M
14400	SIB-ML	Lawn: *M. x soulangeana*	3.1	45	M	61	L	1423	H	149	M	11	L	18	VL	15	VH	48	H	357	VH	4.9	VH	0.9	M

Mg %

Healthy: **10 - 18%**

Ca:Mg Ratio

Healthy: **> 6:1 ratio**
Acceptable 3 - 10

Waypoint Analytical **report # 21-008-1320**
1/20/2021

Lab #	Sample Id		OM		Percent Base Saturation %K	%Mg	%Ca	%Na	%H	Nutrient Ratios Ca:Mg	Ca:K
14402	AIB-R1	Rose Garden - Sun	3.3	M	1.7	15.9	74.6	0.7	7.7	5	44
14403	AIB-R2	Rose Garden - Shade	5.3	H	2.3	15.2	75.5	0.6	6.3	5	33
14414	DWRC-B	Bed: under *Celtis sinensis*	6.9	H	1.7	14.8	81.5	0.4	1.3	6	48
14413	DWRC-L	Lawn: near *Celtis sinensis*	2.8	M	5.5	19	65.9	0.6	8.6	3	12
14415	DWRC-C	Bed: Kogod planter	6.9	H	1.9	18.3	70.2	0.5	9	4	37
14396	FREE-B	Bed: *M. grandiflora*	5	H	2	20	72.3	1.1	4.6	4	36
14395	FREE-L	Lawn: G. biloba	20.4	VH	4.7	28.1	51.3	2.2	13.8	2	11
14416	FREE-C	Bed: interior courtyard	5.1	H	1.7	12.2	82.6	0.8	2.9	7	49
14390	HMSG-E	17th St: *U. americana*	3.4	M	1.4	20.2	78.1	0.4	0	4	56
14386	HMSG-L	Lawn: G. triacanthos	1.6	L	2	23.1	73.6	1.4	0	3	37
14389	HMSG-M	Bed: *M. grandifolia*	5.2	H	2.3	20.4	57.1	0.8	19.4	3	25
14388	HMSG-P	Bed: *Pachysandra*	8.7	VH	1.1	13.1	79.2	0.4	5.8	6	72
14405	HMSG-S	Lawn: *A. saccharum*	6.2	H	2	15.2	68.5	0.4	13.6	5	34
14391	NASM-L	Lawn: *Q. phellos*	4.3	M	2.6	18.7	63.7	0.8	13.8	3	25
14407	NMAA-B	Bed: perennials	8.4	VH	1.7	16.9	65.1	0.6	15.7	4	38
14406	NMAA-L	Lawn: *Q. virginiana*	9.2	VH	1.5	12	70.8	1.8	13.9	6	47
14410	NMAH-B	Bed: 12th St perennials	2.8	M	2.5	12.9	82.8	0.5	1.5	6	33
14408	NMAH-L	Lawn: *Q. rubra*	1.9	L	2.1	20.8	73.3	0.9	2	4	35
14392	NMAI-B	Bed @ memorial	5.4	H	2.3	14.8	81.1	0.5	1.3	5	35
14394	NMAI-M	Bed: meadow	4	M	1.6	10.5	82.9	0.5	4.6	8	52
14393	NMAI-W	Bed: *Carya / Quercus*	2.4	L	1.5	15.6	80.2	0.9	1.5	5	53
14412	NMNH-B	Bed: *Betula / perennials*	4.2	M	4.2	21.1	59	0.4	15.1	3	14
14411	NMNH-L	Lawn: *U. americana*	4.5	M	1.7	13.4	81.3	0.7	3.3	6	48
14404	RIPL-B	Bed: *Ulmus - perennials*	5.1	H	1.8	20.8	71.4	0.5	5.6	3	40
14399	SIB-B	Bed: *Halesia*	9.8	VH	0.8	14.2	70.8	0.5	13.6	5	89
14397	SIB-L	Lawn: Halesia	2.8	M	2.9	22.4	70.8	0.8	3.1	3	24
14401	SIB-MB	Bed: *M. x soulangeana*	11.7	VH	2.4	12.4	50.4	0.5	34.1	4	21
14400	SIB-ML	Lawn: *M. x soulangeana*	3.1	M	1.7	13.8	79.1	0.9	4.4	6	47
						typ. 12-18%				goal >6:1	goal >9:1

Biological Analysis

Sample Location	Arbuscular Mycorrhizal Colonization				AM Fungal Spores		
	Root length (cm)	Mycorrhiza colonization (cm)	Mycorrhizae %	Quality	In 10 gr	In 1 gr.	% Ecto.
NMAA-L – Lawn Area	No roots in sample	NA	NA		48	5	NA
NMAA-B – Perennial Bed	85	65	76	Excellent	10	1	NA
NMAH-L – Lawn Area	90	5	6	Low	22	2	NA
NMAH-B – Tree Planter Bed	165	75	45	Excellent	89	9	NA
NMNH-L – Lawn Area	140	42	30	Excellent	422	42	NA
NMNH-B – Native Perennial Bed	105	0	0	Poor	364	36	63
DWRC-B - Celtis Sinensis Bed	33	0	0	Poor	15	2	NA
NMAI-W – Carya Woodland	65	0	0	Poor	5	1	0
NASM-B – Betula Nigra Planter	120	0	0	Poor	8	1	60
HMSG-L – Lawn Area	110	42	38	Excellent	935	94	NA
HMSG-P - Pachysandra Bed	65	15	23	Good	121	12	NA
HMSG-M – Below Magnolia	22	15	68	Excellent	79	8	NA
RIPL-B – Raised Plant Bed	70	8	11	Low	17	2	NA
FREE-B – Plant Bed	25	5	20	Good	8	1	NA
SIB-L – Lawn Area	40	1	3	Low	6	1	NA
SIB-B – Planter Bed	300	0	0	Poor	10	1	NA
AIB-R1 – Rose Garden - Sun	35	22	63	Excellent	39	4	NA
AIB-R2 – Rose Garden - Shade	16	0	0	Poor	8	1	NA

Biological Analysis

mycorrhizae colonization

Full Sun	**Part Shade**
Excellent colonization	**Poor colonization**
3.3 OM	**5.3 OM**
high plant diversity	**low plant diversity**

MycoRoots Arbuscular Mycorrhizal Fungal Assessment
1/12/2021

	Arbuscular Mycorrhizal Colonization						
Sample Location	**Root length (cm)**	**Mycorrhiza colonization (cm)**	**Mycorrhizae %**	**Quality**			
AIB-R1 – Rose Garden - Sun	35	22	63	Excellent	39	4	NA
AIB-R2 – Rose Garden - Shade	16	0	0	Poor	8	1	NA
DWRC-B - Celtis Sinensis Bed	33	0	0	Poor	15	2	NA
FREE-B – Plant Bed	25	5	20	Good	8	1	NA
HMSG-L – Lawn Area	110	42	38	Excellent	935	94	NA
HMSG-P - Pachysandra Bed	65	15	23	Good	121	12	NA
HMSG-M – Below Magnolia	22	15	68	Excellent	79	8	NA
NASM-B – Betula Nigra Planter	120	0	0	Poor	8	1	
NMAA-L – Lawn Area	0	NA	NA	NA	48	5	NA
NMAA-B – Perennial Bed	85	65	76	Excellent	10	1	NA
NMAH-L – Lawn Area	90	5	6	Low	22	2	NA
NMAH-B – Tree Planter Bed	165	75	45	Excellent	89	9	NA
NMNH-L – Lawn Area	140	42	30	Excellent	422	42	NA
NMNH-B – Native Perennial Bed	105	0	0	Poor	364	36	
NMAI-W – Carya Woodland	65	0	0	Poor	5	1	
RIPL-B – Raised Plant Bed	70	8	11	Low	17	2	NA
SIB-L – Lawn Area	40	1	3	Low	6	1	NA
SIB-B – Planter Bed	300	0	0	Poor	10	1	NA

AIB - north side (shaded) rose garden

AIB - north side (sunny) rose garden

Biological Analysis
mycorrhizae colonization

Sandy Loam / Sunny

Excellent colonization
1.6 OM
low plant diversity
30-45 yrs in place

Silt Loam / Full Shade

Excellent colonization
5 OM
low plant diversity
30-45 yrs in place

MycoRoots Arbuscular Mycorrhizal Fungal Assessment
1/12/2021

Sample Location	Arbuscular Mycorrhizal Colonization				AM Fungal Spores		
	Root length (cm)	Mycorrhiza colonization (cm)	Mycorrhizae %	Quality	In 10 gr	In 1 gr.	
AIB-R1 – Rose Garden - Sun	35	22	63	Excellent	39	4	NA
AIB-R2 – Rose Garden - Shade	16	0	0	Poor	8	1	NA
DWRC-B - Celtis Sinensis Bed	33	0	0	Poor	15	2	NA
FREE-B – Plant Bed	25	5	20	Good	8	1	NA
HMSG-L – Lawn Area	110	42	38	Excellent	935	94	NA
HMSG-P - Pachysandra Bed	65	15	23	Good	121	12	NA
HMSG-M – Below Magnolia	22	15	68	Excellent	79	8	NA
NASM-B – Betula Nigra Planter	120	0	0	Poor	8	1	
NMAA-L – Lawn Area	0	NA	NA	NA	48	5	NA
NMAA-B – Perennial Bed	85	65	76	Excellent	10	1	NA
NMAH-L – Lawn Area	90	5	6	Low	22	2	NA
NMAH-B – Tree Planter Bed	165	75	45	Excellent	89	9	NA
NMNH-L – Lawn Area	140	42	30	Excellent	422	42	NA
NMNH-B – Native Perennial Bed	105	0	0	Poor	364	36	
NMAI-W – Carya Woodland	65	0	0	Poor	5	1	
RIPL-B – Raised Plant Bed	70	8	11	Low	17	2	NA
SIB-L – Lawn Area	40	1	3	Low	6	1	NA
SIB-B – Planter Bed	300	0	0	Poor	10	1	NA

HMSG - west side *G. triancanthos* planting

HMSG - west side at *M. grandiflora*

Biological Analysis
fungal spore counts

Ectomycorrhizae on Betula nigra roots

External root fungi / Hartig net interface
Excellent fungal spore count in native plants garden
Lower fungal spore count on shaded north side of NASM

MycoRoots Arbuscular Mycorrhizal Fungal Assessment
1/12/2021

	AM Fungal Spores		
Sample Location	**In 10 gr**	**In 1 gr.**	**% Ecto.**
AIB-R1 – Rose Garden - Sun	39	4	NA
AIB-R2 – Rose Garden - Shade	8	1	NA
DWRC-B - Celtis Sinensis Bed	15	2	NA
FREE-B – Plant Bed	8	1	NA
HMSG-L – Lawn Area	935	94	NA
HMSG-P - Pachysandra Bed	121	12	NA
HMSG-M – Below Magnolia	79	8	NA
NASM-B – Betula Nigra Planter	8	1	**60**
NMAA-L – Lawn Area	48	5	NA
NMAA-B – Perennial Bed	10	1	NA
NMAH-L – Lawn Area	22	2	NA
NMAH-B – Tree Planter Bed	89	9	NA
NMNH-L – Lawn Area	422	42	NA
NMNH-B – Native Perennial Bed	364	36	**63**
NMAI-W – Carya Woodland	5	1	**0**
RIPL-B – Raised Plant Bed	17	2	NA
SIB-L – Lawn Area	6	1	NA
SIB-B – Planter Bed	10	1	NA

NASM - north side *B. nigra* planter

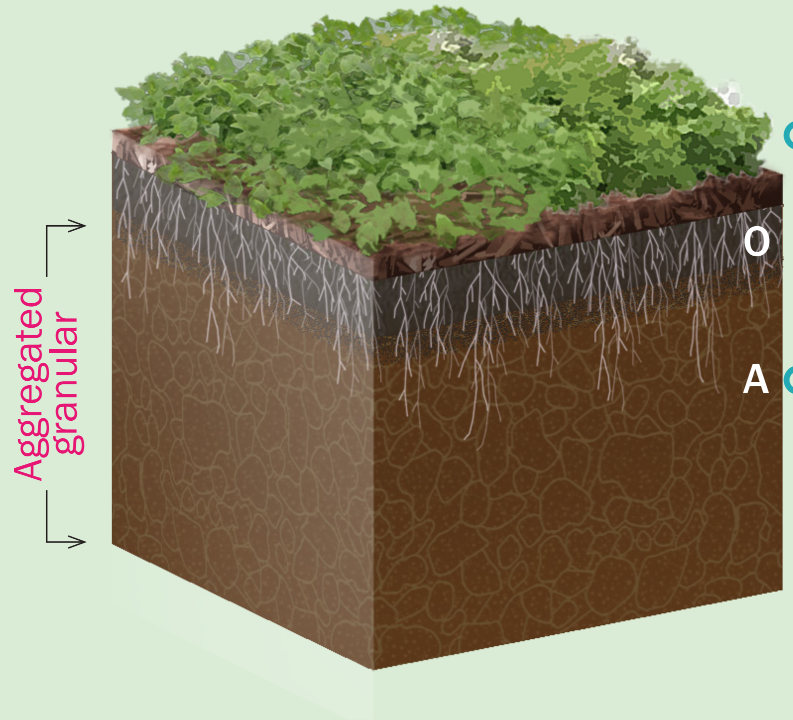
NMNH - east side native perennial bed

This page left blank intentionally.

APPENDIX D

Existing Soil Conditions

Soil Assessment
overview of information



Groundcover or vegetation type

Soil structure condition or known soil depth

Soil horizon descriptors

Condition at test location — **Planting On-grade**

Soil sample identifier — **NMNH - B**

Soil texture — Silt Loam

OM	4.2	**Est. N Release**	119 lbs/ac
CEC	10.6	**Sol. Salts**	0.27 ppm
pH	6	**Mycorrhizal %**	Poor
Buffer pH	6.77	**Ecto. %**	63
P	14	**Fungal Spores**	36 per gram
K	175		
Ca	1250		
Mg	268		

Chemical analysis data (OM, CEC, pH, Buffer pH, P, K, Ca, Mg)

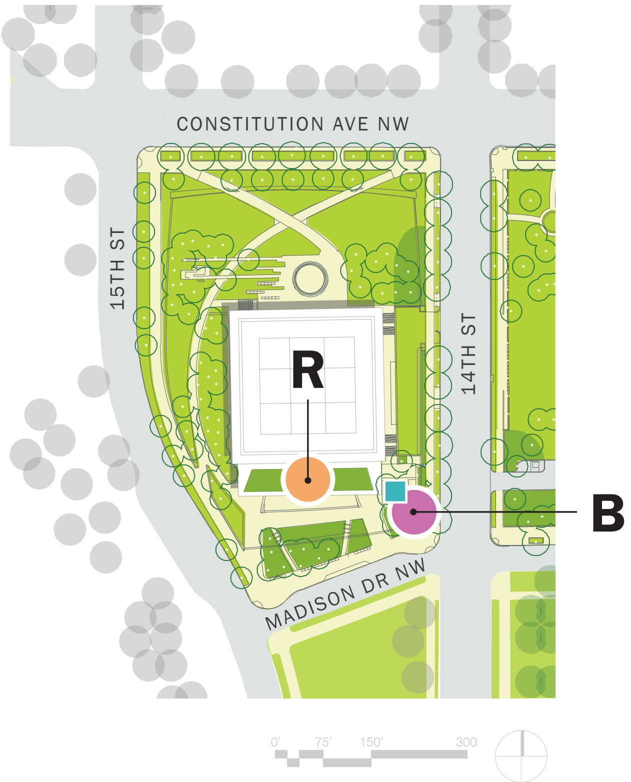
Chemical analysis data (Est. N Release, Sol. Salts)

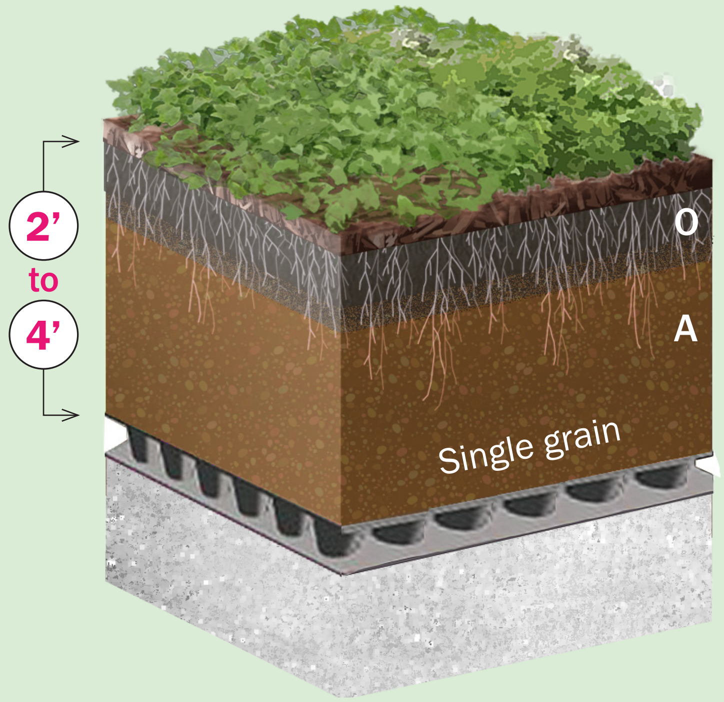
Biological analysis data (Mycorrhizal %, Ecto. %, Fungal Spores)

Sample Notes:
Amended; organic at surface; some aggregate low in profile

General sample notes

National Museum of African American History and Culture





Planting Over Structure

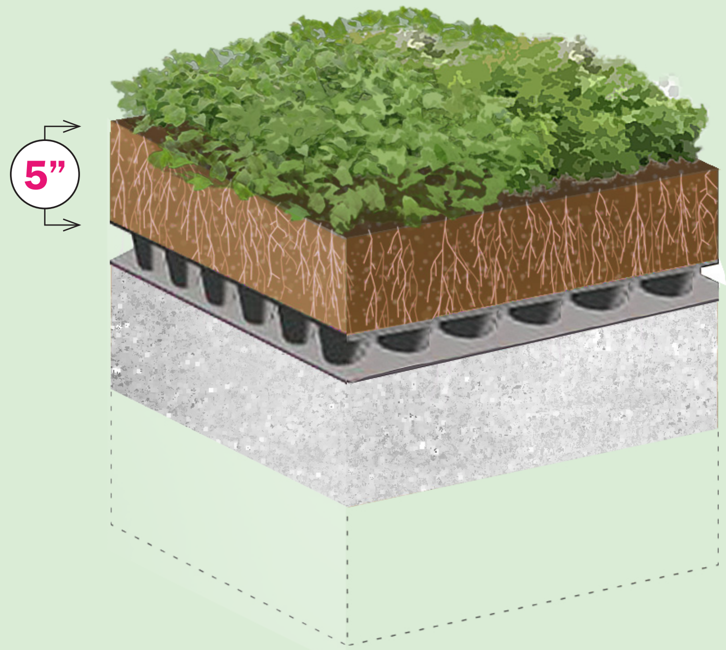
NMAAHC - B

Gravelly Loamy Sand

OM	8.4
CEC	13.4
pH	6
Buffer pH	6.72
P	158
K	87
Ca	1746
Mg	271

Est. N Release	150 lbs/ac
Sol. Salts	0.1 ppm
Mycorrhizal %	Excellent
Fungal Spores	1 per gram

Sample Notes:
Recently composted



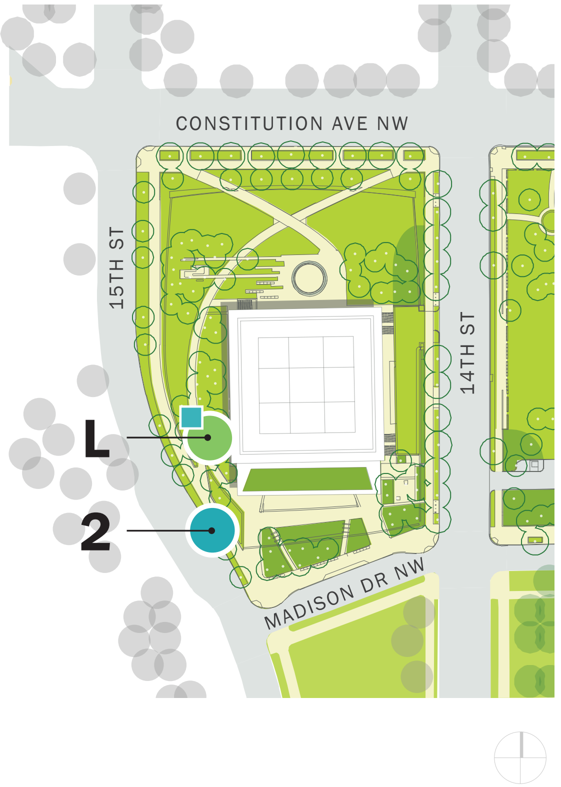
Planting On Rooftop

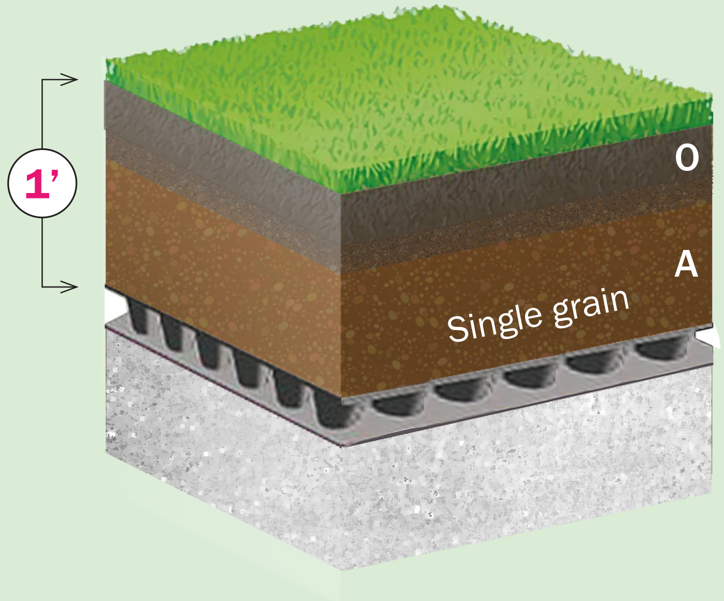
NMAAHC - R

Gravelly Loamy Sand

Sample Notes:
Not sampled

National Museum of African American History and Culture



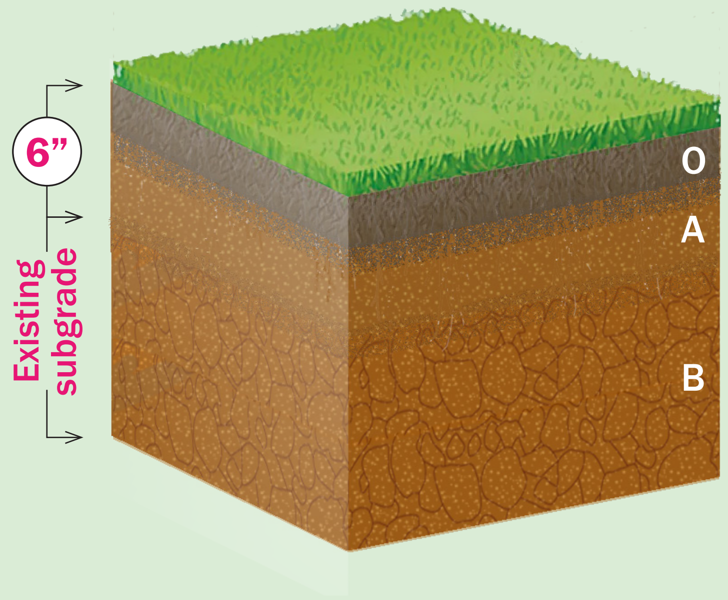


Lawn Over Structure

NMAAHC - L

Gravelly Loamy Sand

OM	9.2	**Est. N Release**	150 lbs/ac
CEC	20.2	**Sol. Salts**	0.19 ppm
pH	6.1	**Mycorrhizal %**	N/A
Buffer pH	6.65	**Fungal Spores**	N/A
P	89		
K	120	**Sample Notes:**	
Ca	2861	Compacted	
Mg	292		



Tree Planter

NMAAHC - 2

Sandy Loam

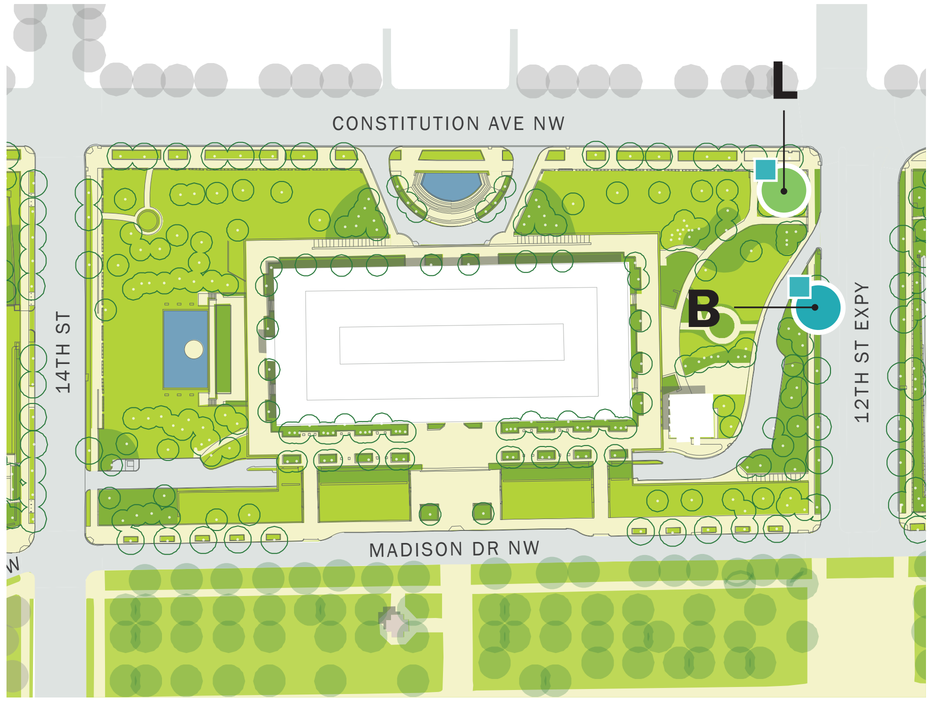
Sample Notes:
No chemical or biological analysis completed

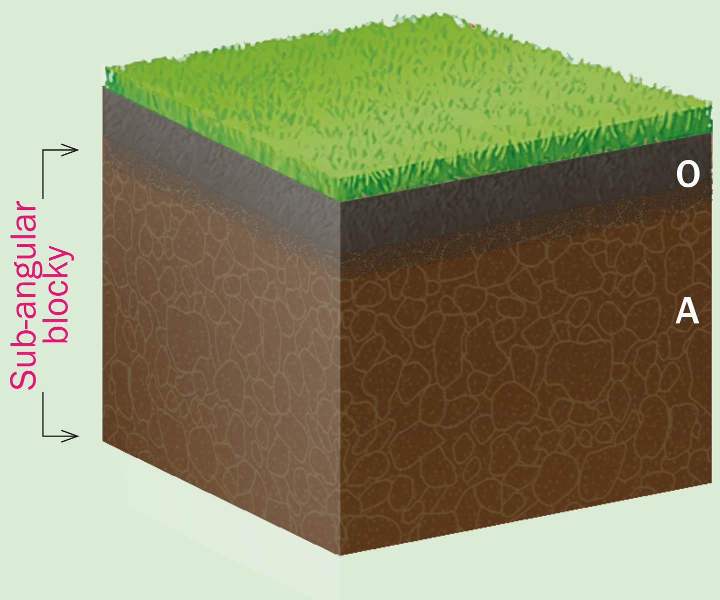
Heavily compacted

6" imported topsoil on existing subgrade or fill

Compaction Analysis
NMAAHC

National Museum of American History



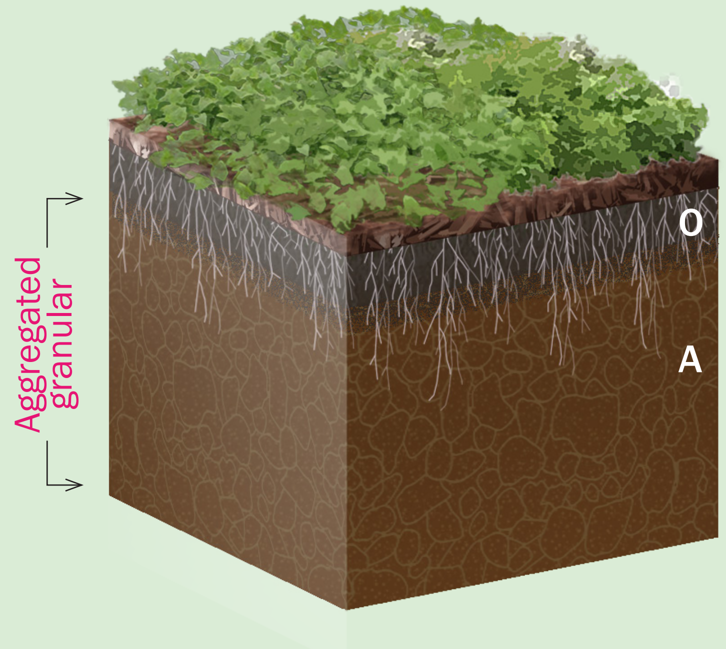


Lawn On-grade

NMAH - L

Loam

OM	1.9	**Est. N Release**	81 lbs/ac
CEC	5.1	**Sol. Salts**	0.17 ppm
pH	6.8	**Mycorrhizal %**	Low
Buffer pH	6.92	**Fungal Spores**	2 per gram
P	19		
K	41	**Sample Notes:**	
Ca	748	Compacted; some blocky structure present	
Mg	127		



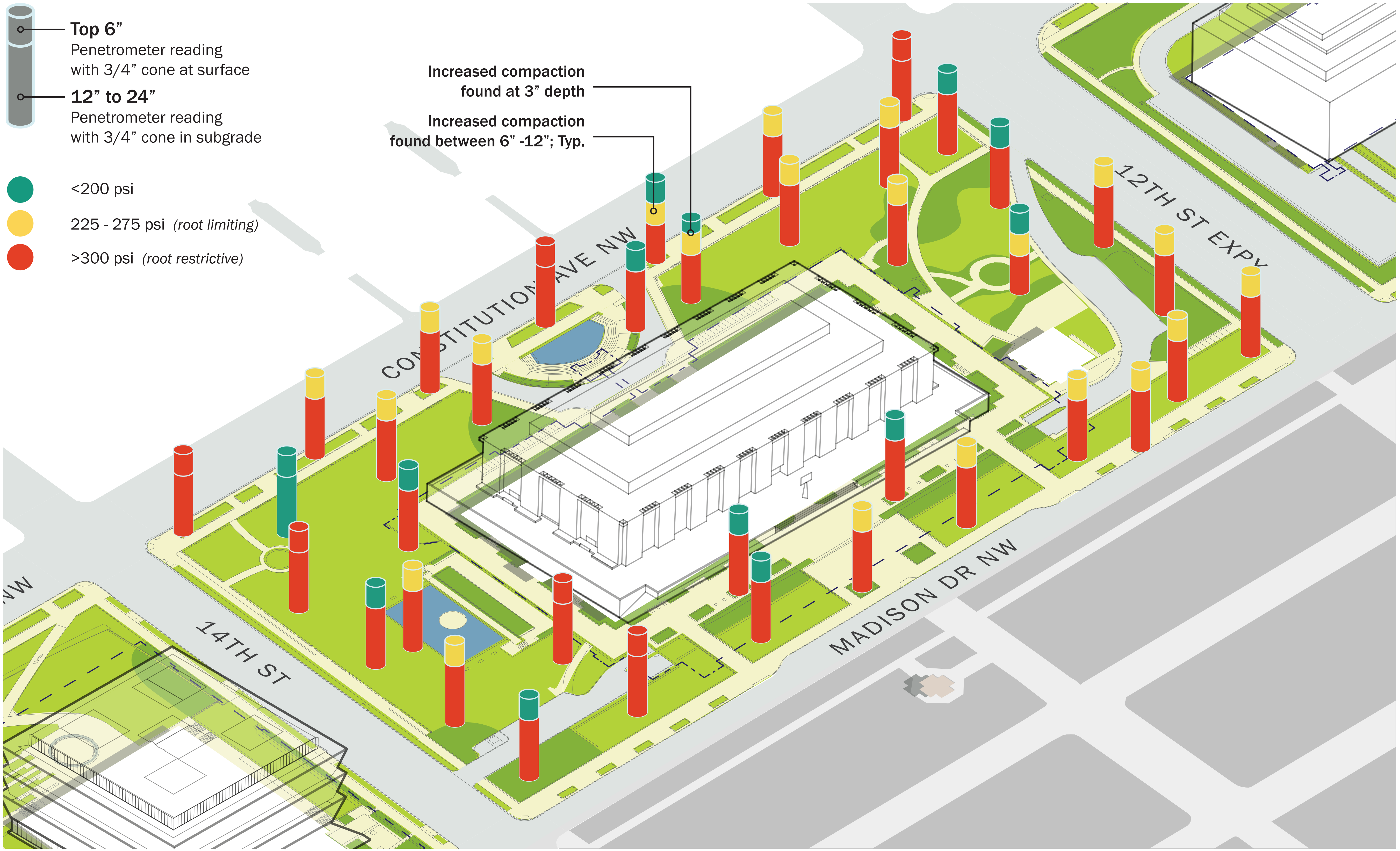
Tree Planter

NMAH - B

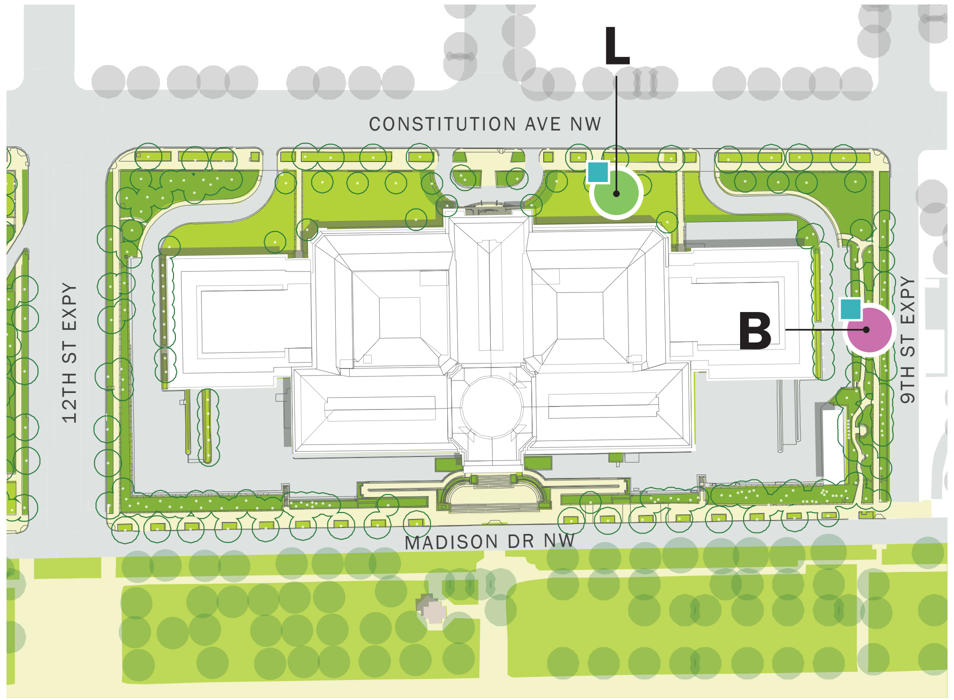
Sandy Loam

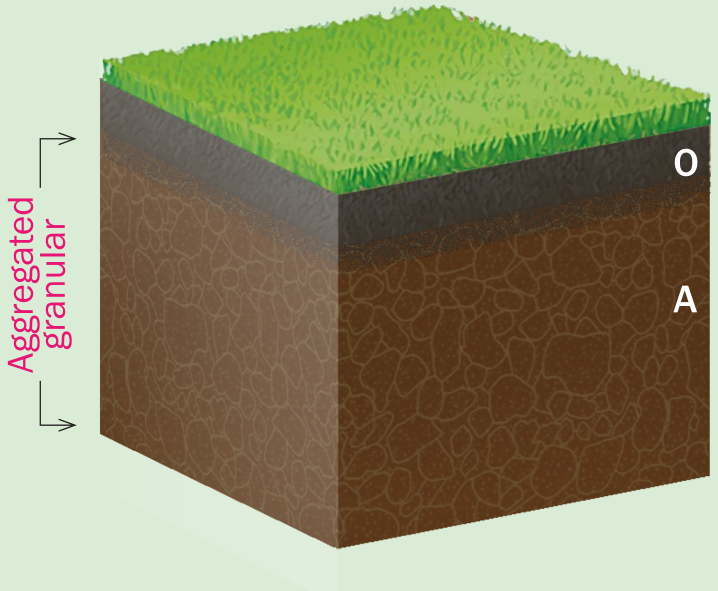
OM	2.8	**Est. N Release**	97 lbs/ac
CEC	6.5	**Sol. Salts**	0.16 ppm
pH	6.9	**Mycorrhizal %**	Excellent
Buffer pH	6.92	**Fungal Spores**	9 per gram
P	40		
K	64	**Sample Notes:**	
Ca	1076	Amended; high organic content at surface	
Mg	101		

Compaction Analysis
NMAH



National Museum of Natural History





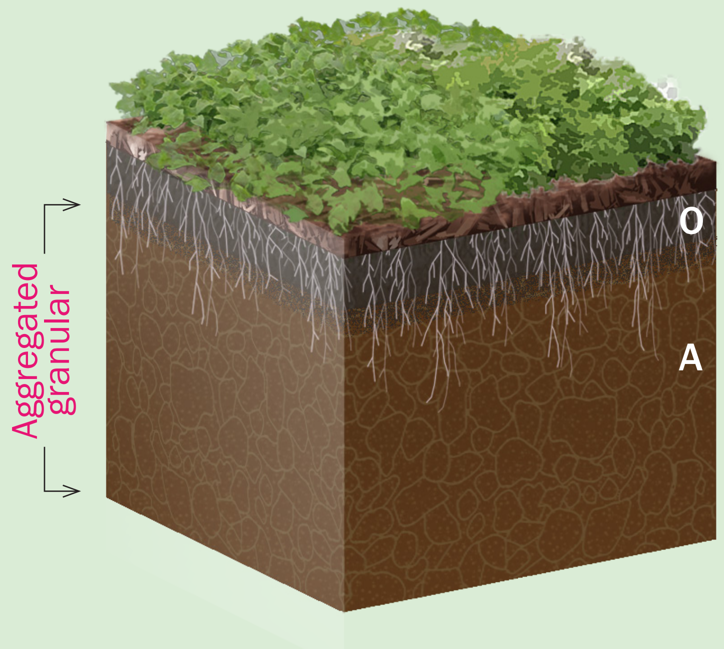
Lawn On-grade

NMNH - L

Loam

OM	4.5	**Est. N Release**	122 lbs/ac
CEC	12.3	**Sol. Salts**	0.21 ppm
pH	6.8	**Mycorrhizal %**	Excellent
Buffer pH	6.89	**Fungal Spores**	42 per gram
P	65		
K	81		
Ca	2001		
Mg	198		

Sample Notes:
Compacted; some blocky structure present



Planting On-grade

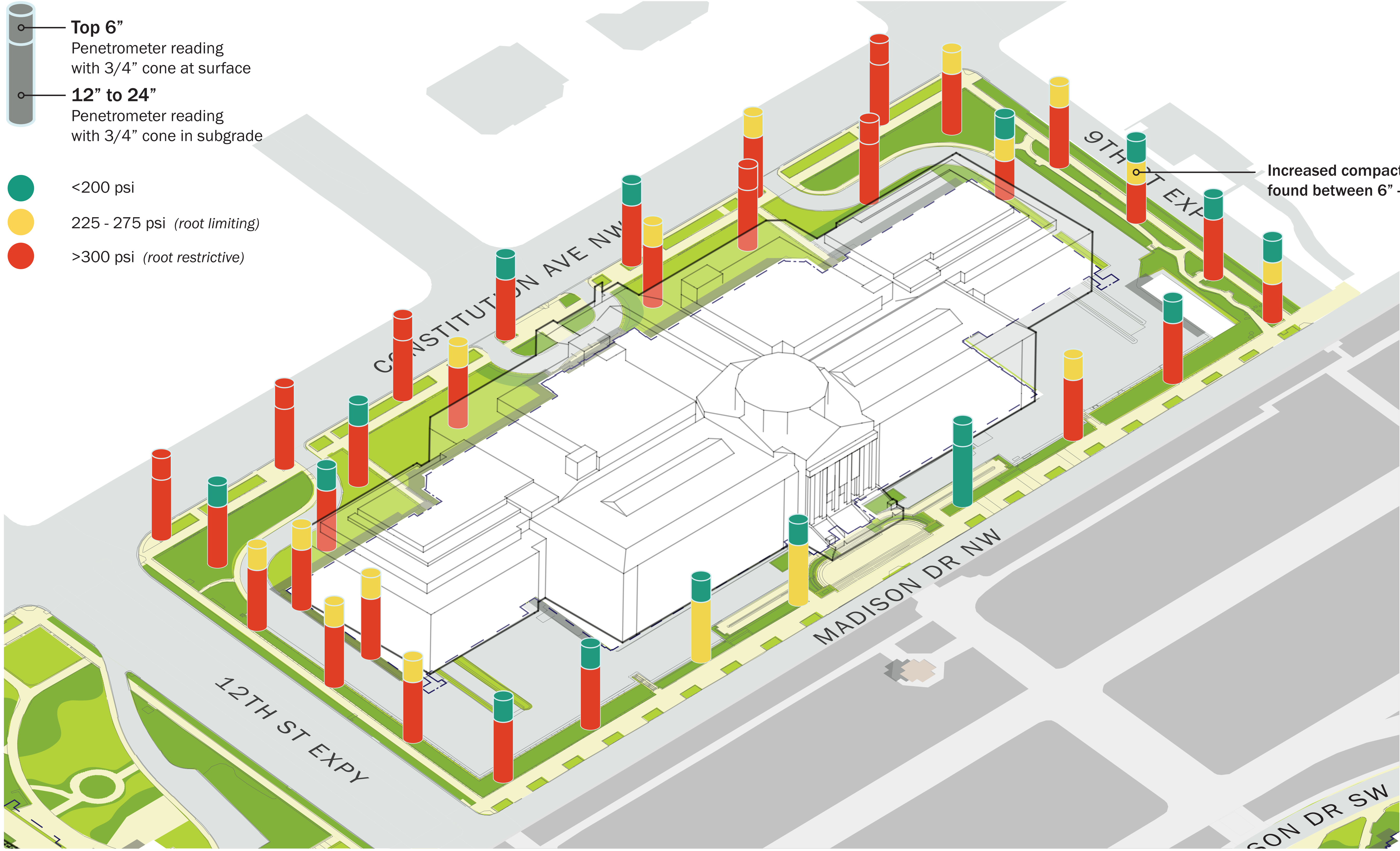
NMNH - B

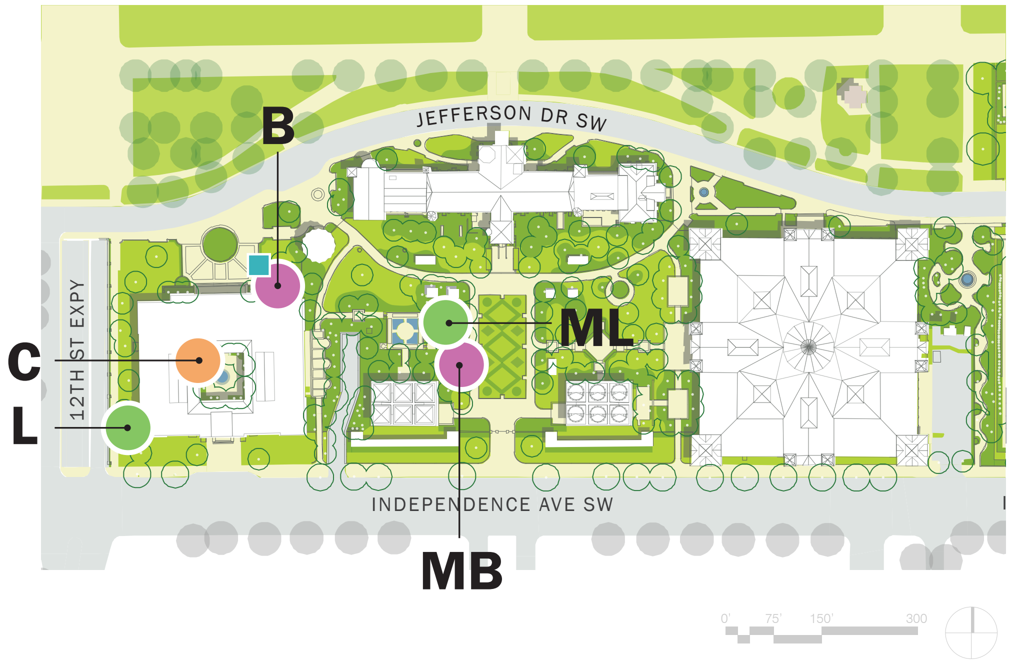
Loam

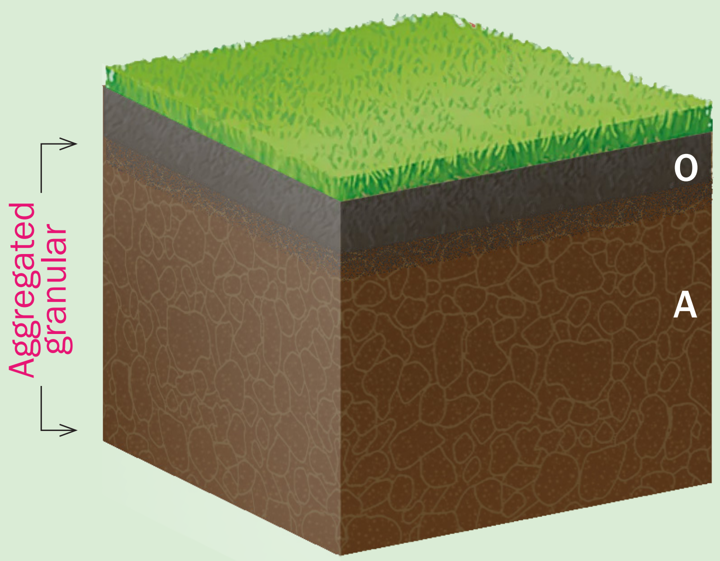
OM	4.2	**Est. N Release**	119 lbs/ac
CEC	10.6	**Sol. Salts**	0.27 ppm
pH	6	**Mycorrhizal %**	Poor
Buffer pH	6.77	**Ecto. %**	63
P	14	**Fungal Spores**	36 per gram
K	175		
Ca	1250		
Mg	268		

Sample Notes:
Amended; organic at surface; some aggregate low in profile

Compaction Analysis
NMNH







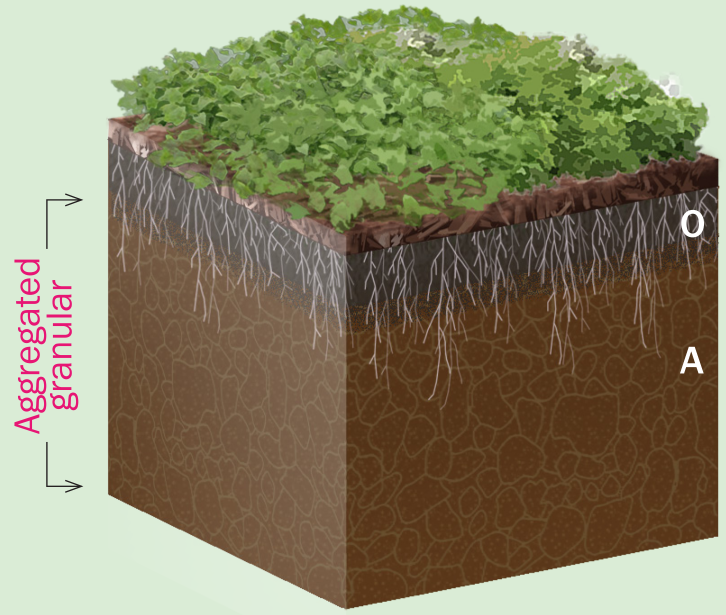
Lawn Over Structure

SIB - ML

Loam

OM	3.1	**Est. N Release**	99 lbs/ac
CEC	9	**Sol. Salts**	0.13 ppm
pH	6.7	**Mycorrhizal %**	N/A
Buffer pH	6.9	**Fungal Spores**	N/A
P	45		
K	61		
Ca	1423		
Mg	149		

Sample Notes:
Sticky feeling; high organic content at surface with some clay content in sub-base



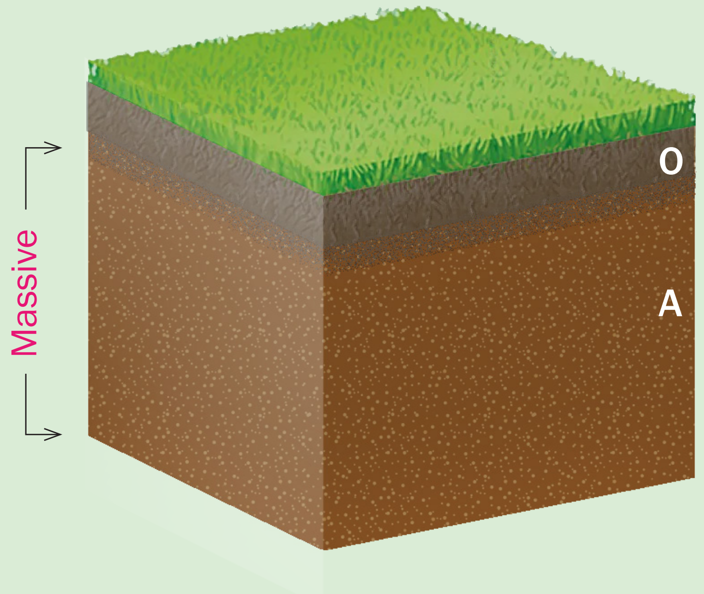
Planting Over Structure

SIB - MB

Loam

OM	11.7	**Est. N Release**	150 lbs/ac
CEC	12.6	**Sol. Salts**	0.09 ppm
pH	5.2	**Mycorrhizal %**	N/A
Buffer pH	6.5	**Fungal Spores**	N/A
P	41		
K	118		
Ca	1270		
Mg	187		

Sample Notes:
Moist soil in surrounding area

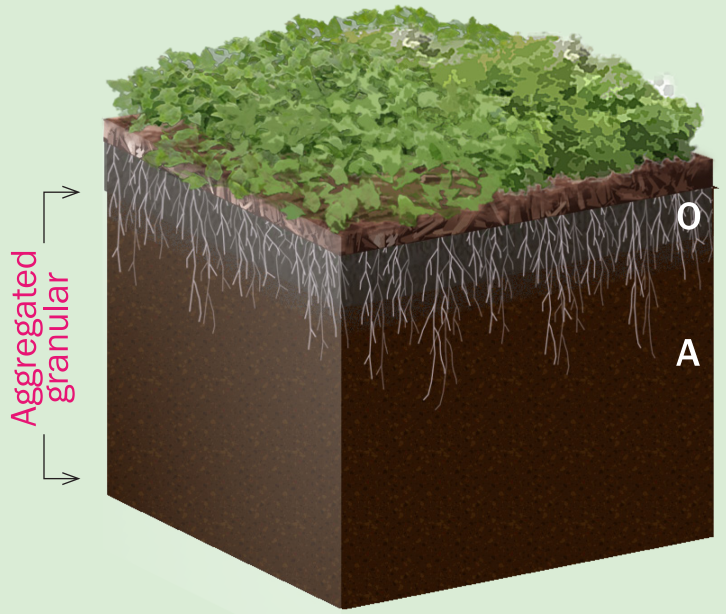


Freer Lawn On-grade

FREE - L

Loam

OM	20.4	**Est. N Release**	N/A
CEC	21	**Sol. Salts**	0.15 ppm
pH	6.1	**Mycorrhizal %**	N/A
Buffer pH	6.6	**Fungal Spores**	N/A
P	40		
K	383	**Sample Notes:**	
Ca	2154	Compacted surface layer;	
Mg	707	macropores below ~8"	



Freer Planting On-grade

FREE - B

Gravelly Loam

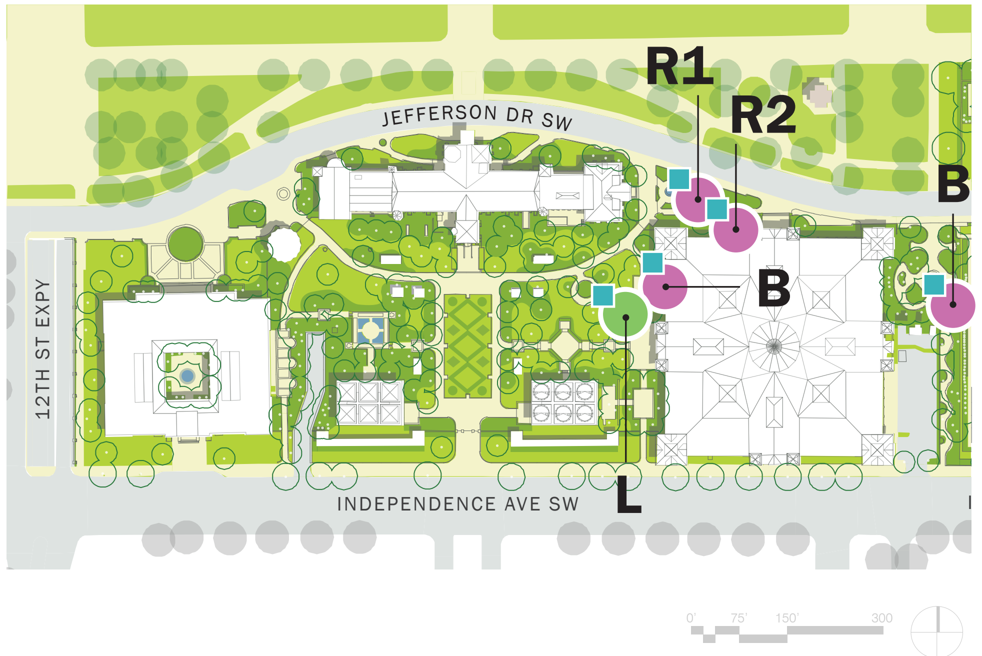
OM	5	**Est. N Release**	134 lbs/ac
CEC	10.9	**Sol. Salts**	0.19 ppm
pH	6.7	**Mycorrhizal %**	Good
Buffer pH	6.9	**Fungal Spores**	1 per gram
P	32		
K	83	**Sample Notes:**	
Ca	1576	Amended; high organic content;	
Mg	261	rooting throughout profile	

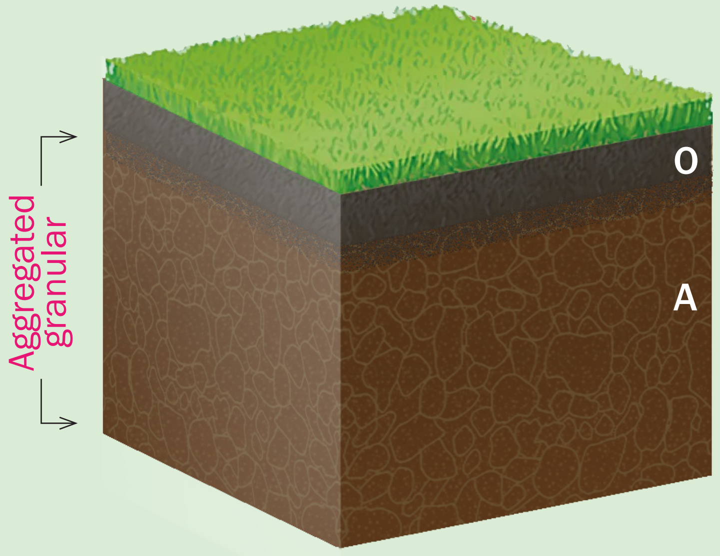
Freer Courtyard Planter

FREE - C

Silt Loam

OM	5.1	**Est. N Release**	132 lbs/ac
CEC	14	**Sol. Salts**	0.24 ppm
pH	6.8	**Mycorrhizal %**	N/A
Buffer pH	6.9	**Fungal Spores**	N/A
P	47		
K	92	**Sample Notes:**	
Ca	2312	Dense rooting expected in	
Mg	205	profile depth of only 12"	





Lawn On-grade

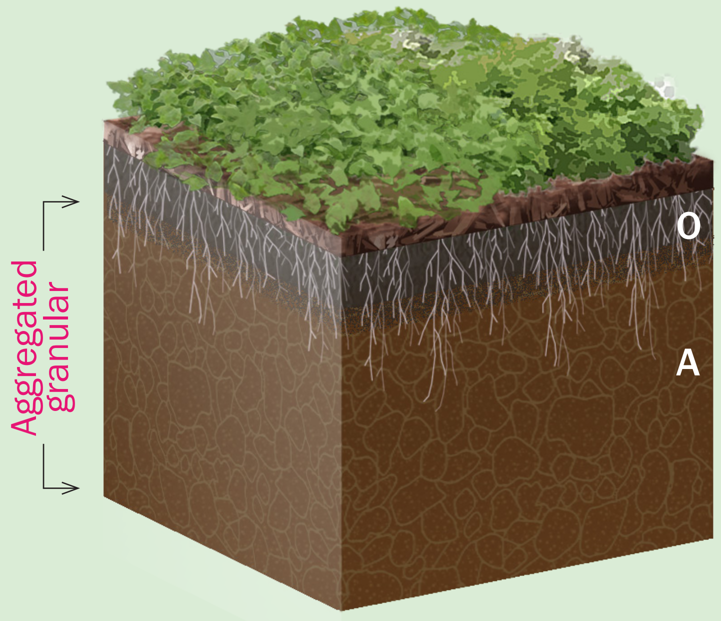
SIB - L

Sandy Loam

OM	2.8
CEC	9.8
pH	6.8
Buffer pH	6.9
P	46
K	112
Ca	1387
Mg	264

Est. N Release	92 lbs/ac
Sol. Salts	0.12 ppm
Mycorrhizal %	Low
Fungal Spores	1 per gram

Sample Notes:
Sticky feeling; high organic content at surface with some clay content in sub-base



Planting On-grade

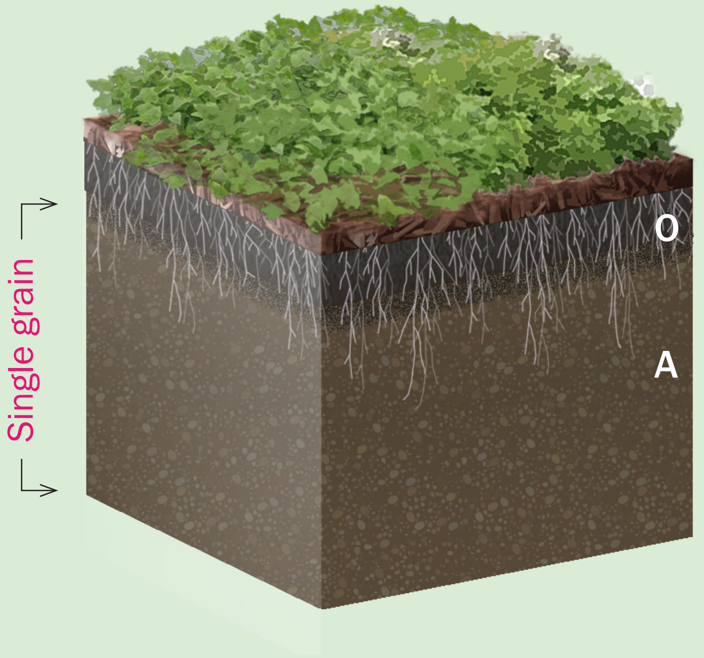
SIB - B

Sandy Loam

OM	9.8
CEC	14
pH	6.1
Buffer pH	6.7
P	95
K	45
Ca	1981
Mg	239

Est. N Release	150 lbs/ac
Sol. Salts	0.13 ppm
Mycorrhizal %	Poor
Fungal Spores	1 per gram

Sample Notes:
Moist soil in surrounding area



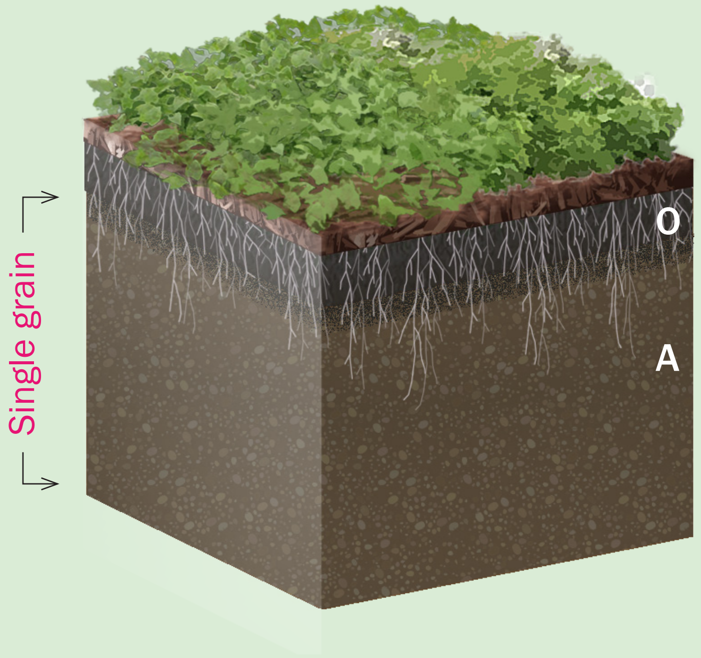
Rose Garden Planting

AIB - R1 (Sun)

Gravelly Loam

OM	3.3	**Est. N Release**	103 lbs/ac
CEC	9.1	**Sol. Salts**	0.10 ppm
pH	6.5	**Mycorrhizal %**	Excellent
Buffer pH	6.9	**Fungal Spores**	4 per gram
P	98		
K	59		
Ca	1357		
Mg	174		

Sample Notes:
Easily discernable porous rose-garden mix



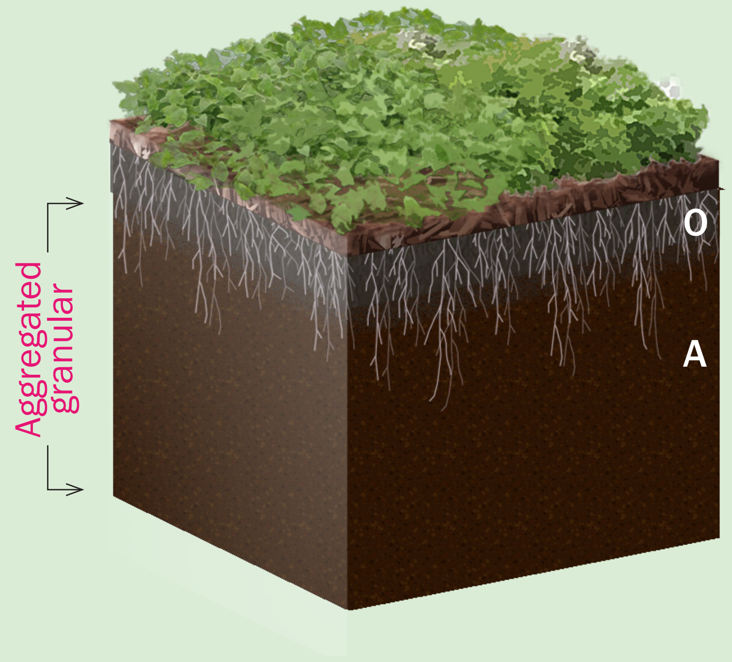
Rose Garden Planting

AIB - R2 (Shade)

Loam

OM	5.3	**Est. N Release**	140 lbs/ac
CEC	11.1	**Sol. Salts**	0.11 ppm
pH	6.6	**Mycorrhizal %**	Poor
Buffer pH	6.9	**Fungal Spores**	1 per gram
P	107		
K	100		
Ca	1675		
Mg	203		

Sample Notes:
Easily discernable porous rose-garden mix



Ripley Planter

RIPL - B

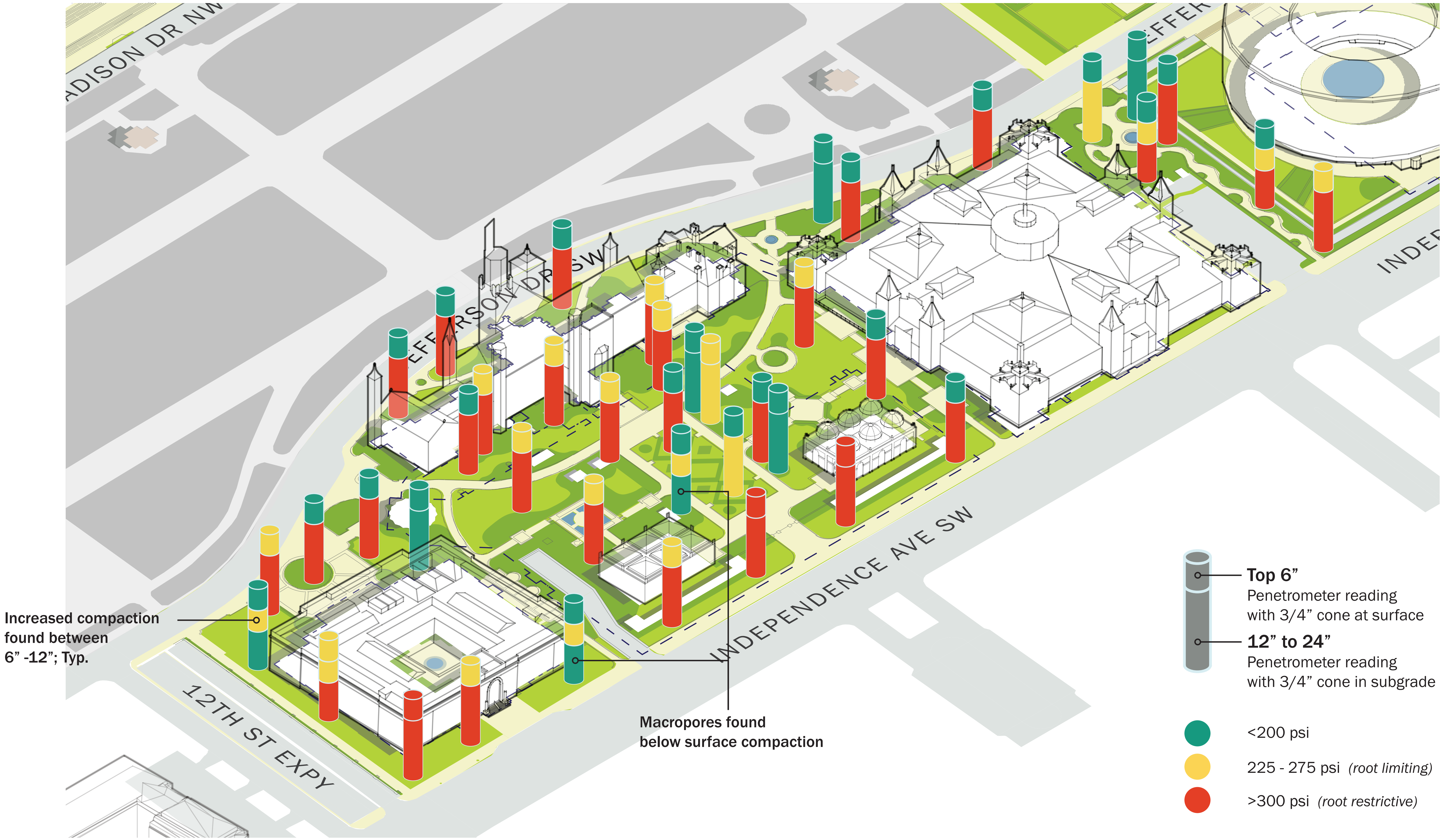
Loam

OM	5.1	**Est. N Release**	137 lbs/ac
CEC	10.8	**Sol. Salts**	0.09 ppm
pH	6.6	**Mycorrhizal %**	N/A
Buffer pH	6.9	**Fungal Spores**	N/A
P	33		
K	76		
Ca	1542		
Mg	269		

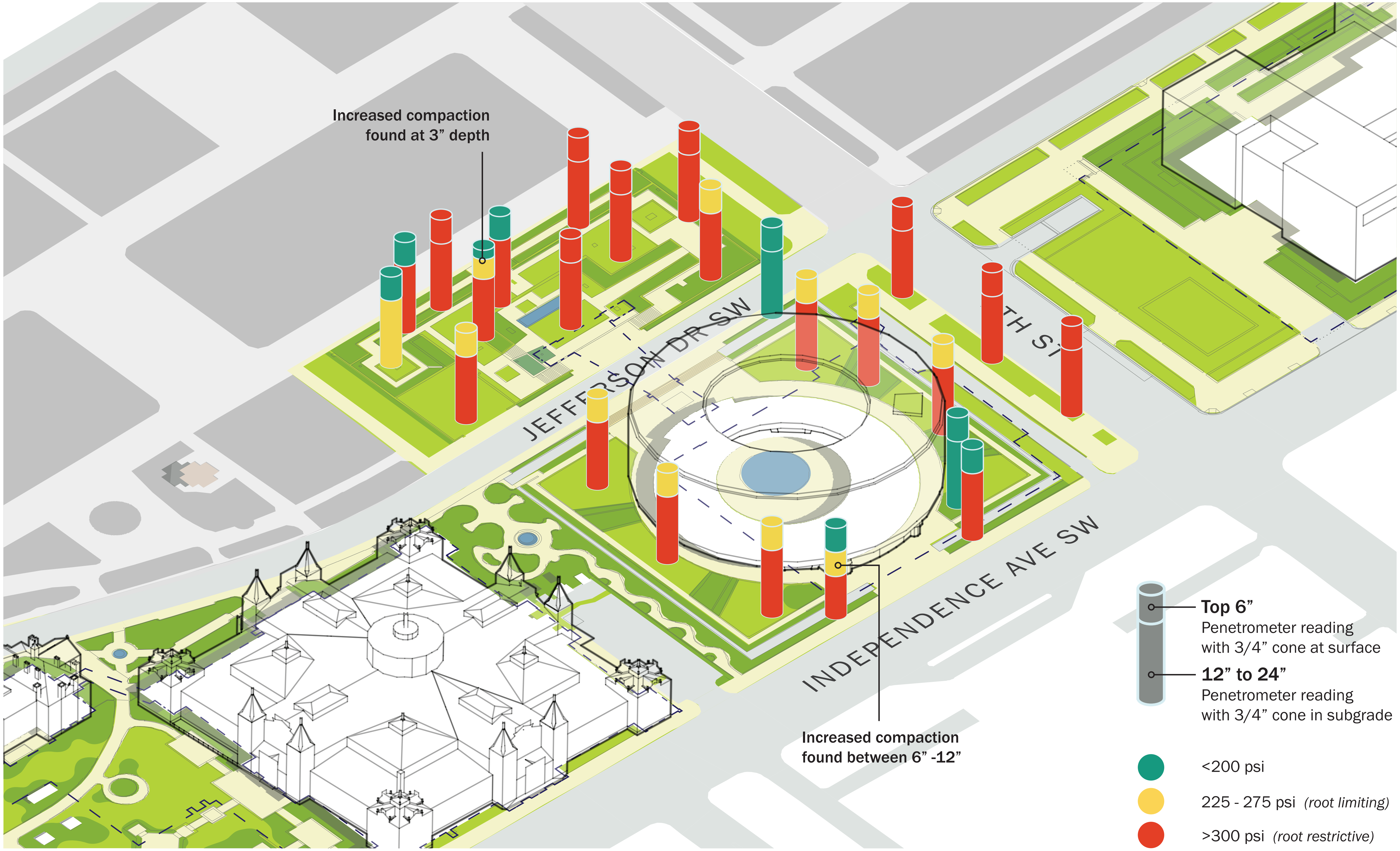
Sample Notes:
Heavily amended with organic biologic product; clayey sub-base

Compaction Analysis

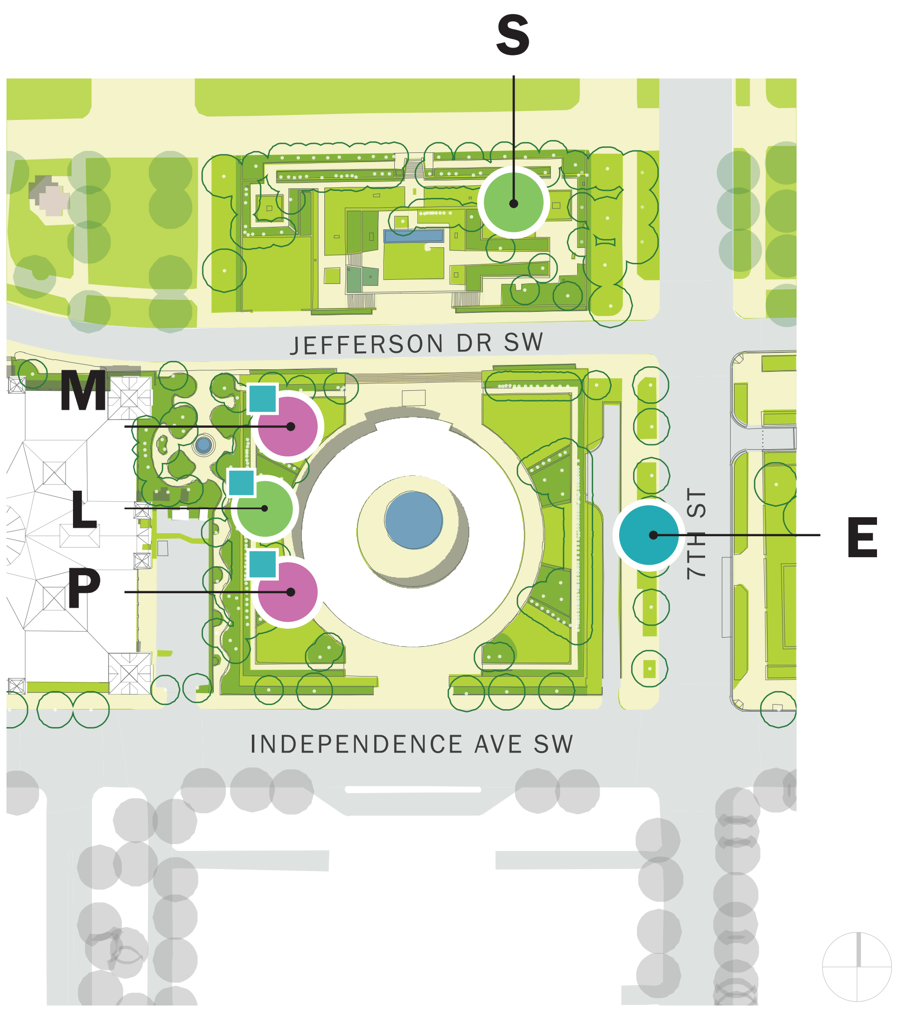
South Mall Campus



Compaction Analysis
HMSG



Hirshhorn Museum and Sculpture Garden



Planting On-grade

HMSG - P

Loamy Sand

OM	8.7
CEC	13.7
pH	6.6
Buffer pH	6.85
P	91
K	60
Ca	2170
Mg	215

Est. N Release	150 lbs/ac
Sol. Salts	0.42 ppm
Mycorrhizal %	Good
Fungal Spores	12 per gram

Sample Notes:
Compacted; rooting through top 4” of profile; amended surface layer

Planting On-grade

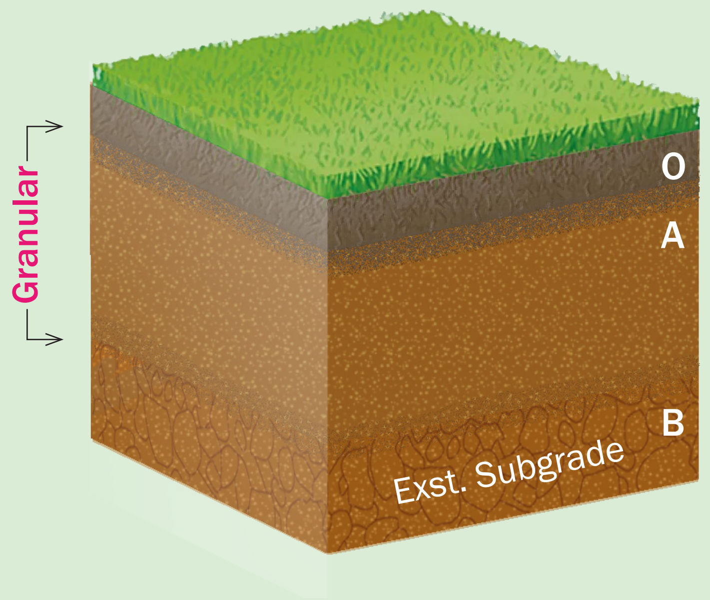
HMSG - M

Sandy Loam

OM	5.2
CEC	12.4
pH	5.8
Buffer pH	6.69
P	25
K	109
Ca	1417
Mg	304

Est. N Release	136 lbs/ac
Sol. Salts	0.14 ppm
Mycorrhizal %	Excellent
Fungal Spores	8 per gram

Sample Notes:
Below Magnolia at northwest corner of site



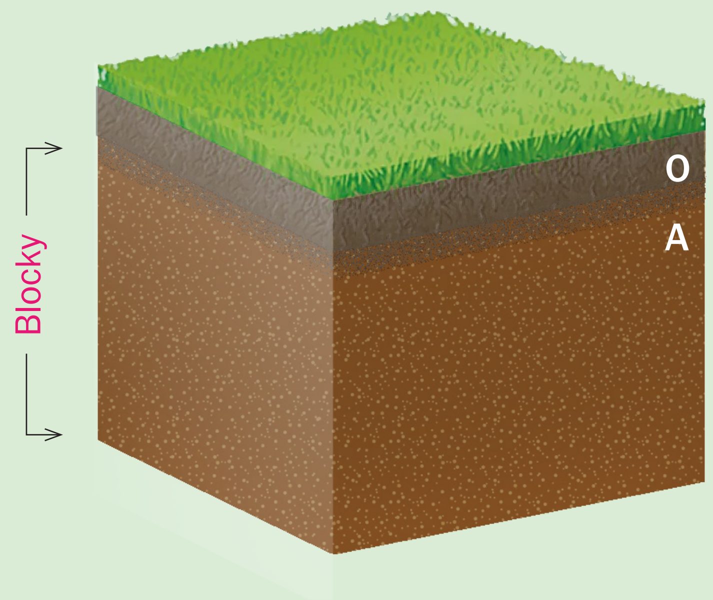
Lawn On-grade

HMSG - L

Loamy Sand

OM	1.6	**Est. N Release**	73 lbs/ac
CEC	6.5	**Sol. Salts**	0.18 ppm
pH	7	**Mycorrhizal %**	Excellent
Buffer pH	6.93	**Fungal Spores**	94
P	114		
K	51		
Ca	957		
Mg	180		

Sample Notes:
Compacted; fine rooting through top 4” of profile



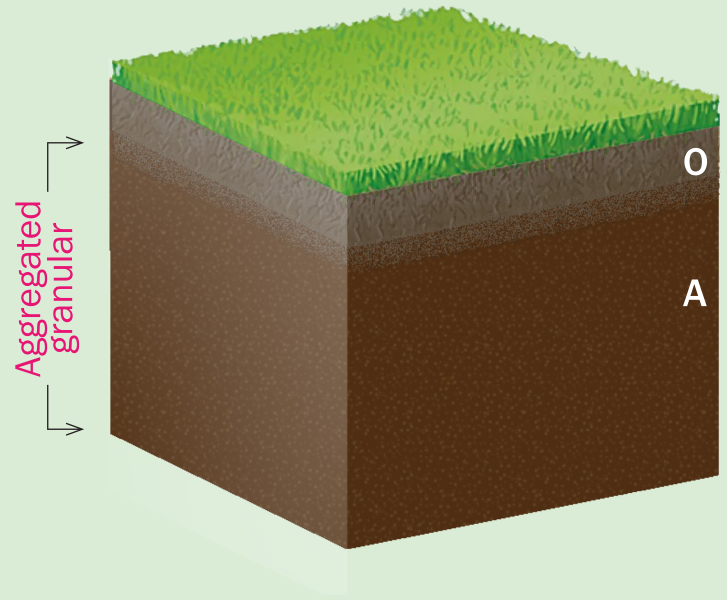
Tree Planter

HMSG - E

Loam

OM	3.4	**Est. N Release**	102 lbs/ac
CEC	11.3	**Sol. Salts**	0.32 ppm
pH	7.2	**Mycorrhizal %**	N/A
Buffer pH	6.93	**Fungal Spores**	N/A
P	16		
K	63		
Ca	1766		
Mg	274		

Sample Notes:
Heavily compacted



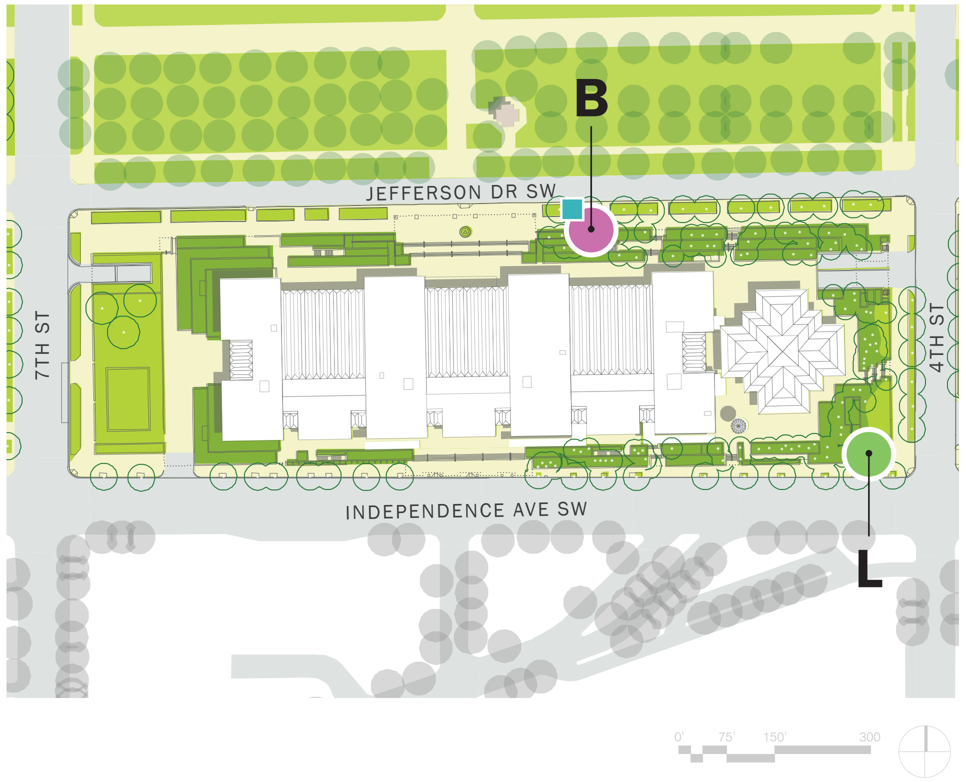
Sculpture Garden Lawn

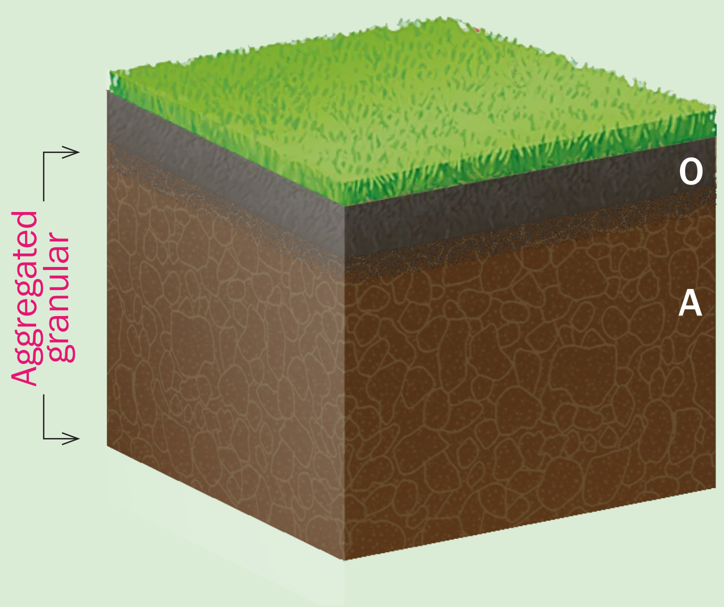
HMSG - S

Loam

OM	6.2	**Est. N Release**	150 lbs/ac
CEC	11.8	**Sol. Salts**	0.44 ppm
pH	6.1	**Mycorrhizal %**	N/A
Buffer pH	6.77	**Fungal Spores**	N/A
P	22		
K	92		
Ca	1617		
Mg	215		

Sample Notes:
Moist soil in surrounding area; clay loam sub-base below ~12”





Lawn On-grade

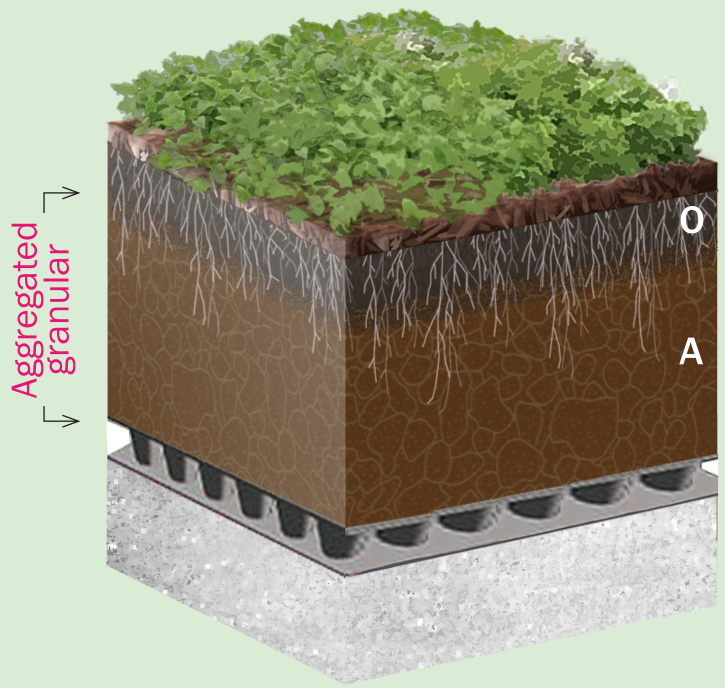
NASM - L

Loamy Sand

OM	4.3
CEC	12.3
pH	6.1
Buffer pH	6.76
P	16
K	125
Ca	1567
Mg	276

Est. N Release	118 lbs/ac
Sol. Salts	0.39 ppm
Mycorrhizal %	N/A
Fungal Spores	N/A

Sample Notes:
Moist soil in surrounding area



Planter On-Structure

NASM - B

Gravelly Loam

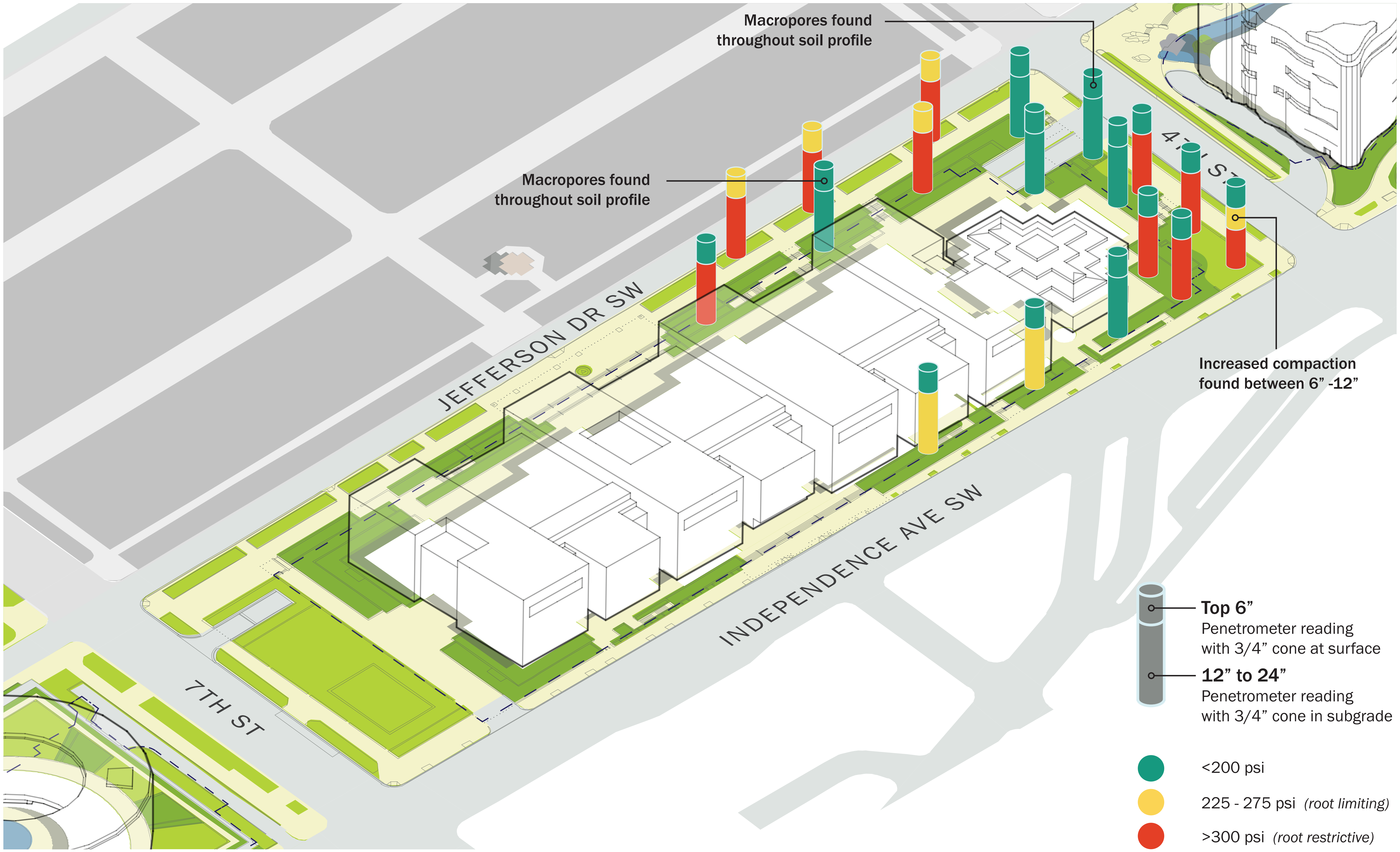
Sample Notes:
Sample data missing from testing facility

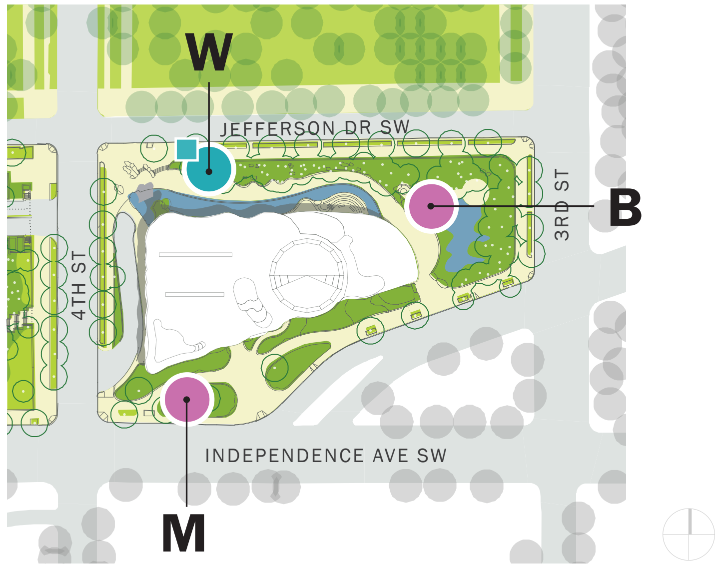
Dense rooting area and noticeable settlement

Mycorrhizal %	Poor
Ecto. %	60
Fungal Spores	1 per gram

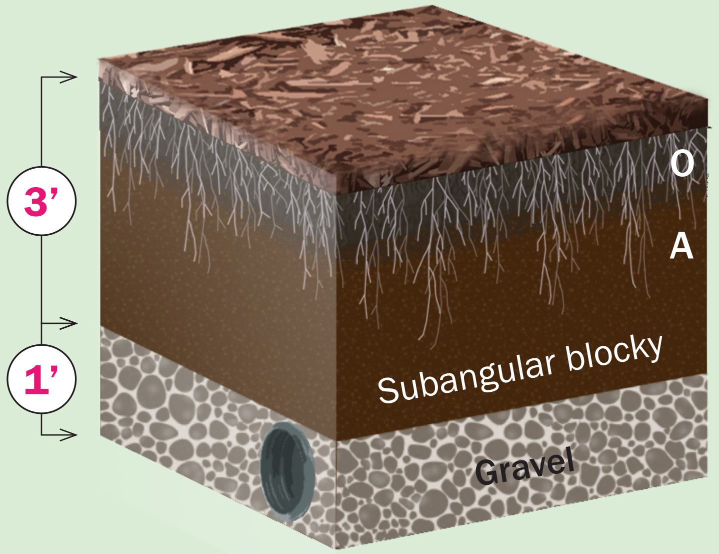
Compaction Analysis

NASM





National Museum of the American Indian



Woodland Planting

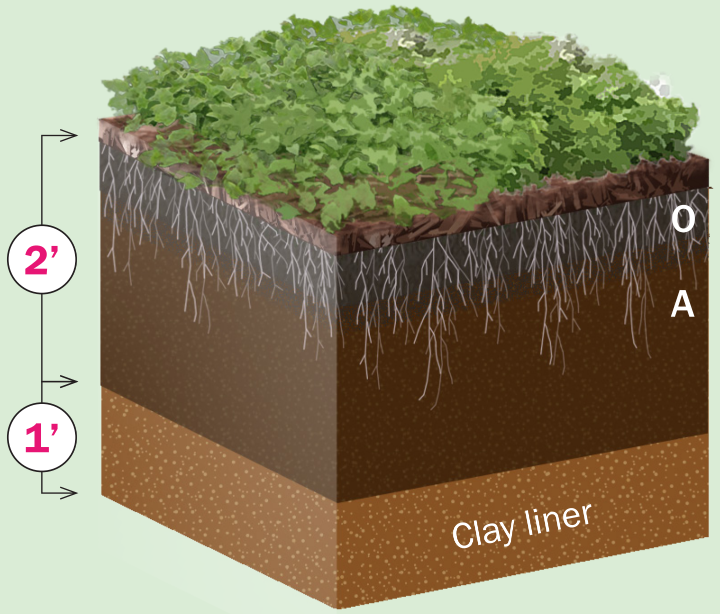
NMAI - W

Sandy Clay Loam

OM	2.4
CEC	6.8
pH	6.9
Buffer pH	6.92
P	47
K	40
Ca	1091
Mg	127

Est. N Release	88 lbs/ac
Sol. Salts	0.11 ppm
Mycorrhizal %	Poor
Ecto. %	0
Fungal Spores	1 per gram

Sample Notes:
No clay content; poor, sub-angular blocky structure



Pond Planting

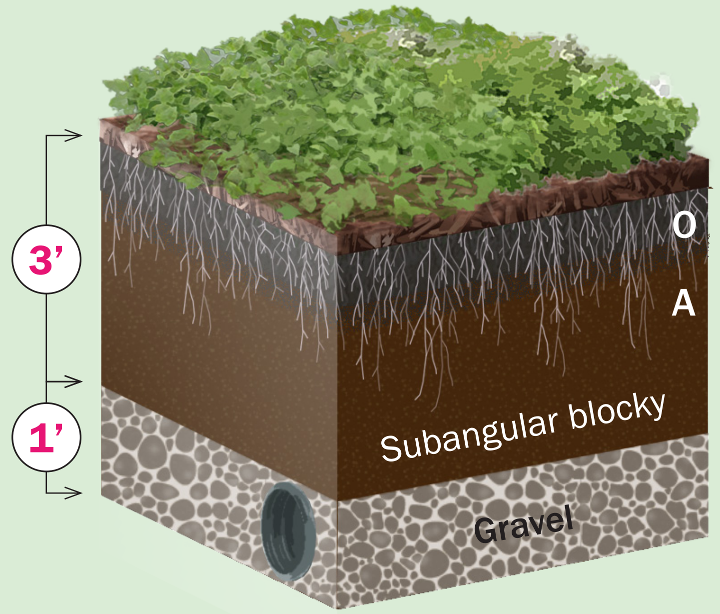
NMAI - B

Gravelly Loam

OM	5.4
CEC	15.6
pH	6.9
Buffer pH	6.91
P	43
K	137
Ca	2530
Mg	277

Est. N Release	136 lbs/ac
Sol. Salts	0.13 ppm
Mycorrhizal %	N/A
Fungal Spores	N/A

Sample Notes:
Recently renovated soil area around Memorial; clay liner sub-base



Meadow Planting

NMAI - M

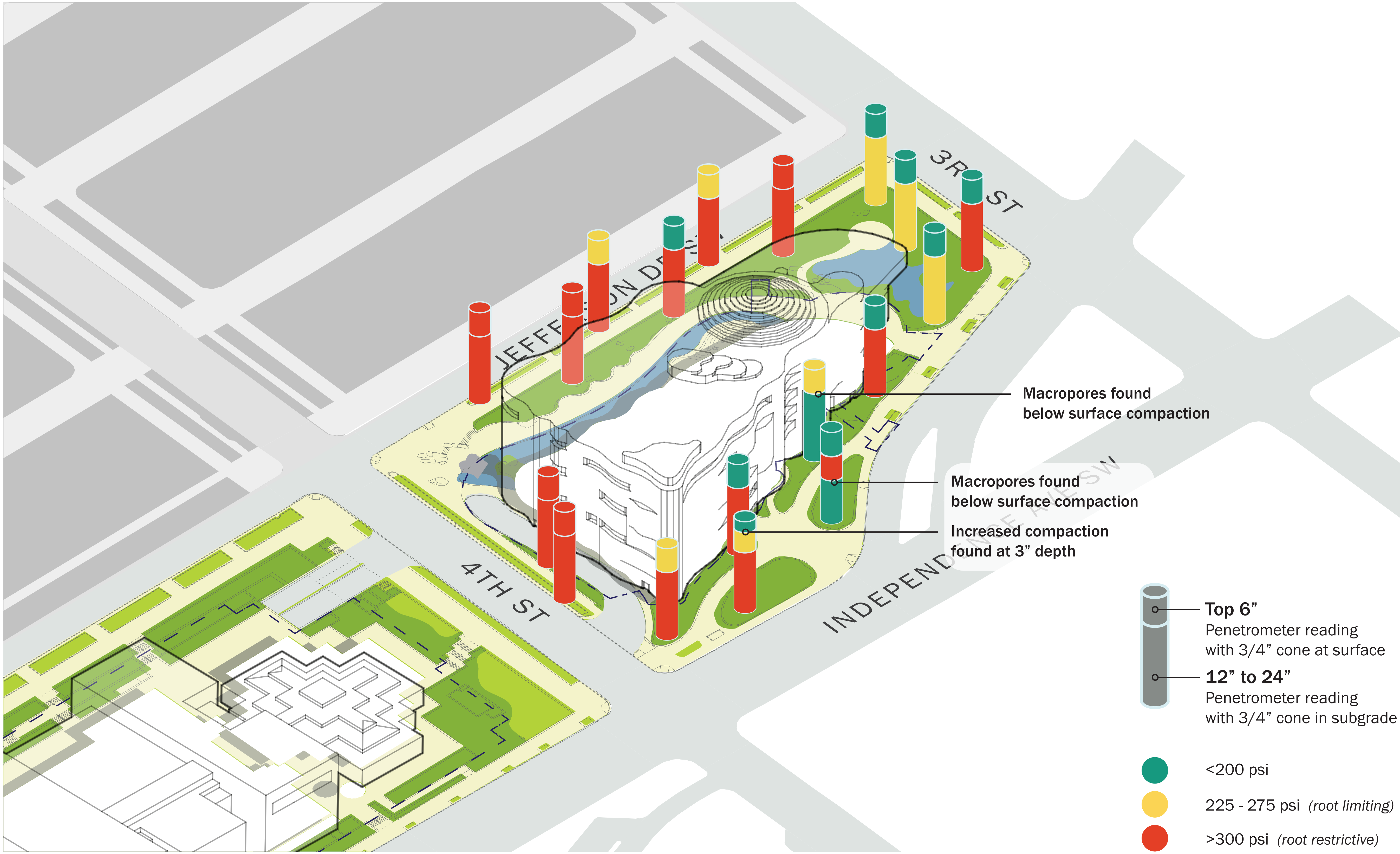
Sandy Loam

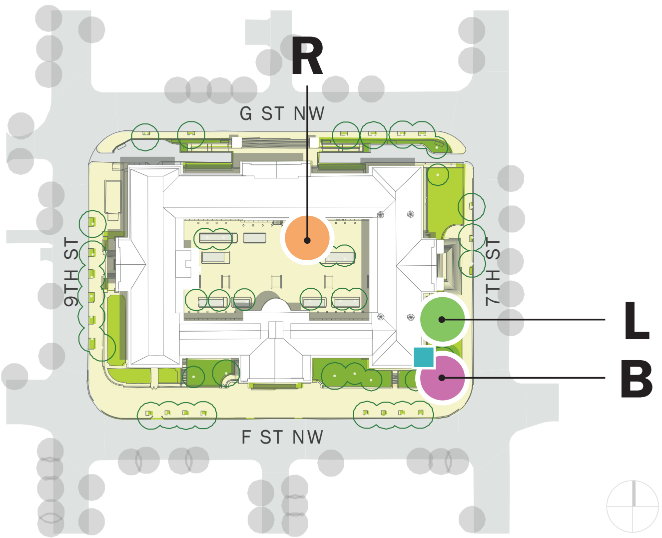
OM	4
CEC	10.9
pH	6.7
Buffer pH	6.88
P	82
K	66
Ca	1808
Mg	137

Est. N Release	114 lbs/ac
Sol. Salts	0.65 ppm
Mycorrhizal %	N/A
Fungal Spores	N/A

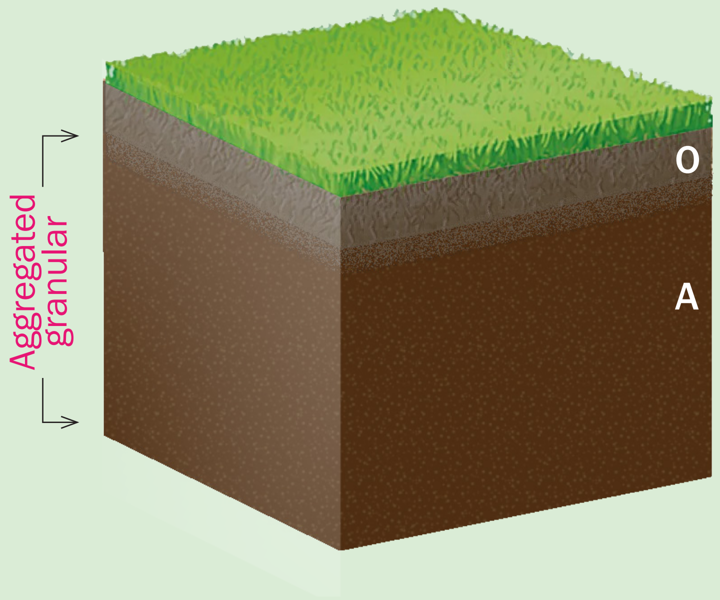
Sample Notes:
Amended; high organic content at surface; clayey sub-base

Compaction Analysis
NMAI





Donald W. Reynolds Center and Kogod Courtyard



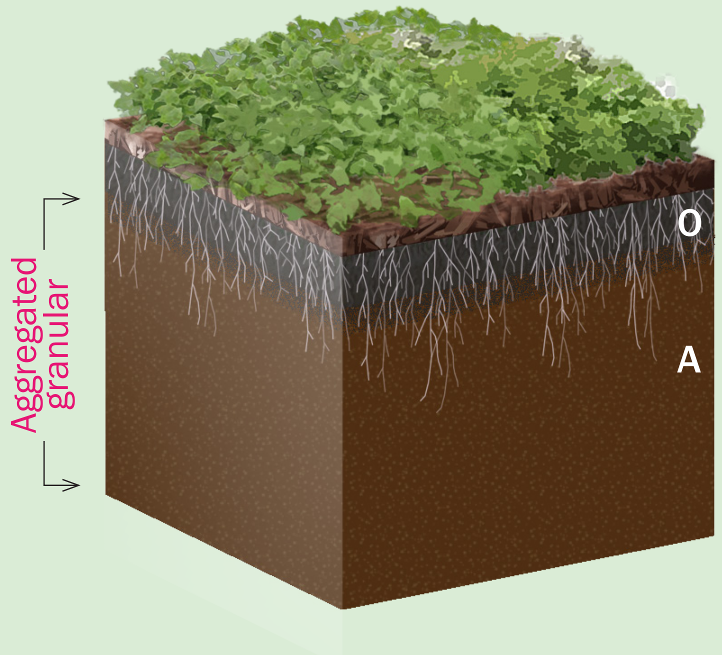
Lawn On-grade

DWRC - L

Sandy Loam

OM	2.8	**Est. N Release**	94 lbs/ac
CEC	8.1	**Sol. Salts**	0.23 ppm
pH	6.4	**Mycorrhizal %**	N/A
Buffer pH	6.86	**Fungal Spores**	N/A
P	79		
K	174		
Ca	1067		
Mg	185		

Sample Notes:
Some clay content in top 4” only (resodded recently?)



Planting On-grade

DWRC - B

Loam

OM	6.9	**Est. N Release**	150 lbs/ac
CEC	15.1	**Sol. Salts**	0.17 ppm
pH	6.9	**Mycorrhizal %**	Poor
Buffer pH	6.91	**Fungal Spores**	2 per gram
P	30		
K	102		
Ca	2460		
Mg	269		

Sample Notes:
Amended; high organic content at surface

Kogod Courtyard

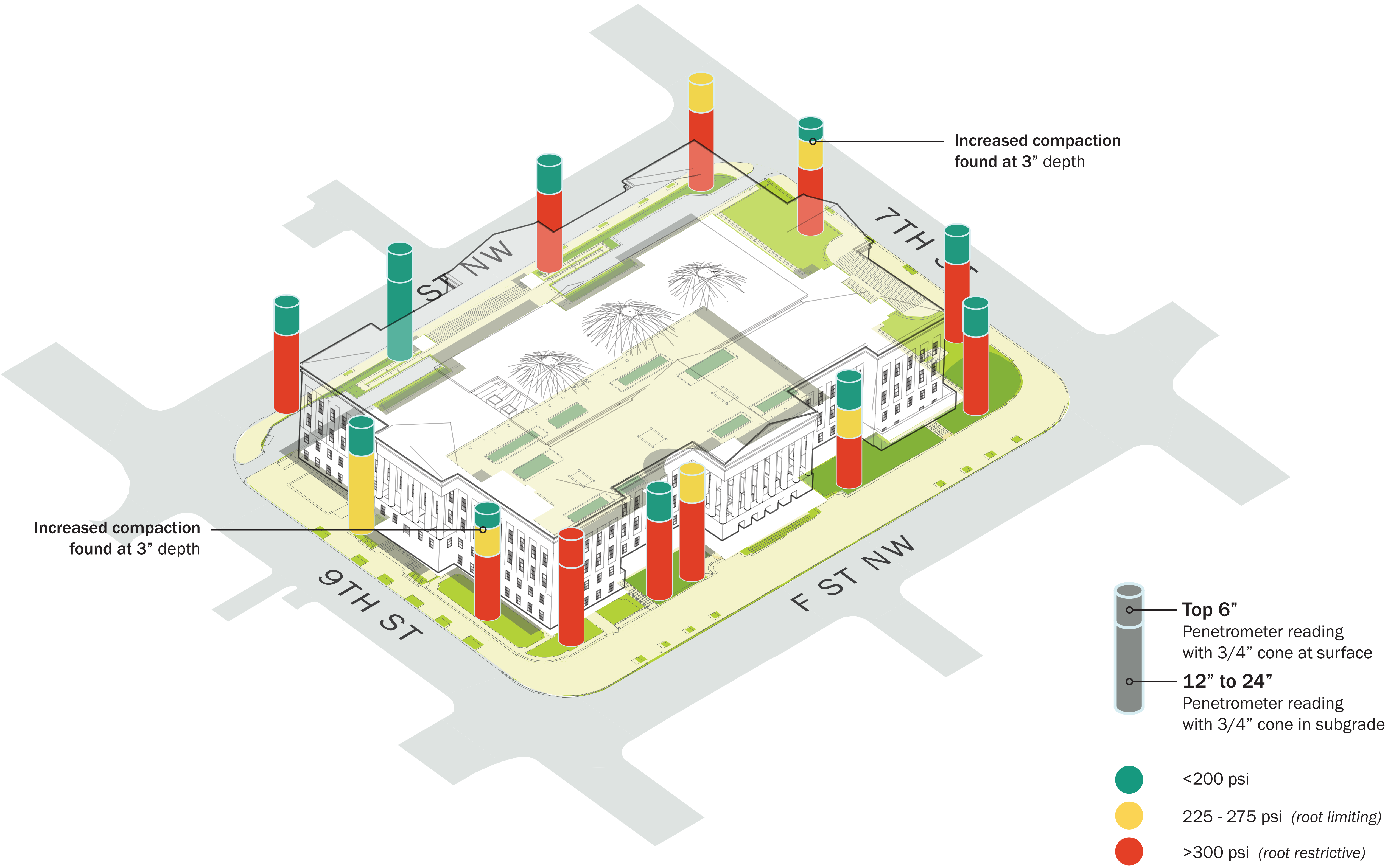
DWRC - C

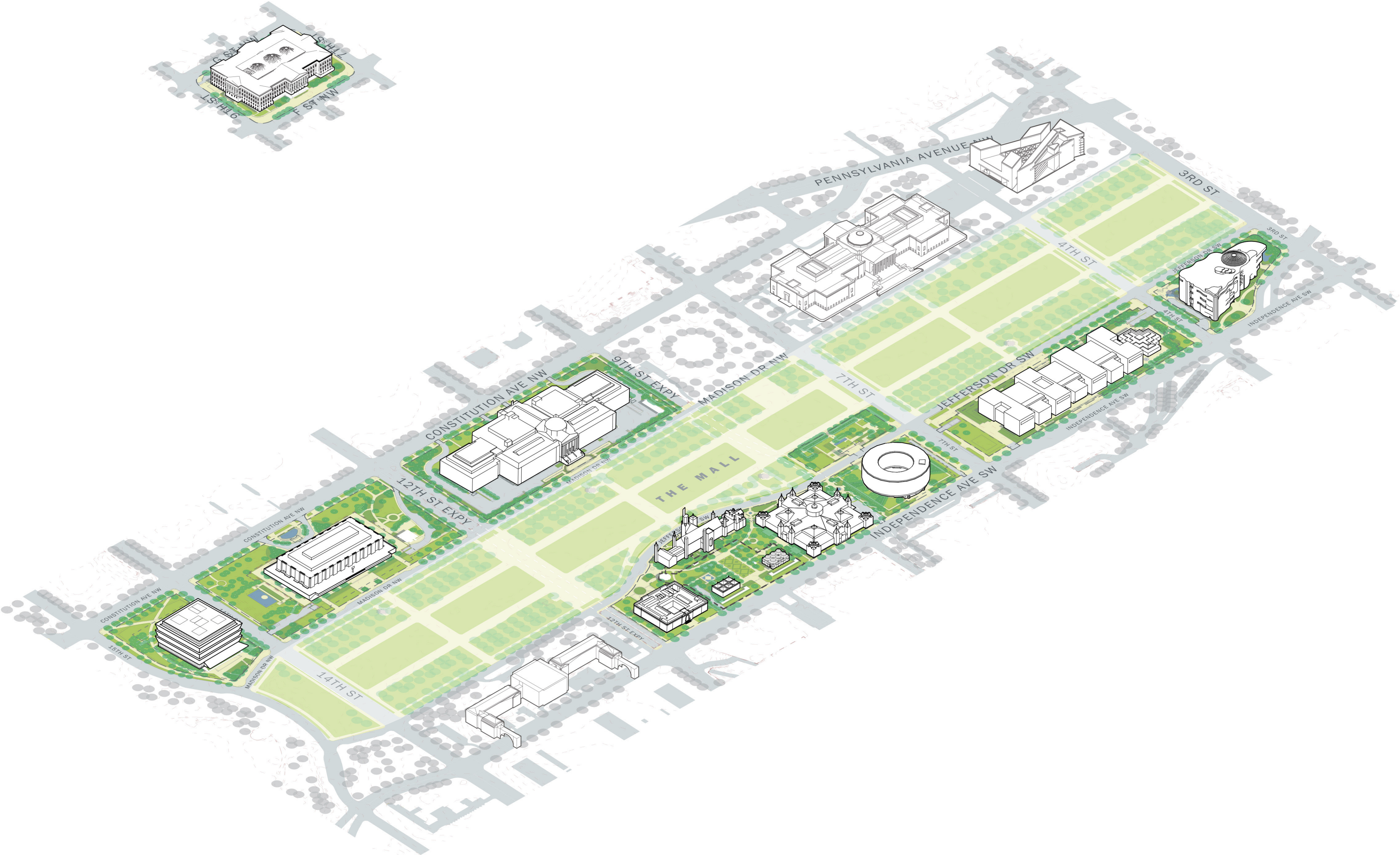
Peat Moss mix (SuccesSoil)

OM	6.9	**Est. N Release**	150 lbs/ac
CEC	20	**Sol. Salts**	0.18 ppm
pH	6.4	**Mycorrhizal %**	N/A
Buffer pH	6.75	**Fungal Spores**	N/A
P	136		
K	150		
Ca	2806		
Mg	440		

Sample Notes:
Soil supports millipeads, frogs, spiders, moths, mushrooms

Compaction Analysis
DWRC





Smithsonian Gardens

gardens.si.edu

SMITHSONIAN GARDENS
SOILS MANAGEMENT PLAN

APPENDICES

E. New Project Specifications and Details - 32 9100 Planting Soils

F. Small Projects Narrative for Soil Installation and Restoration

G. Site Protection Specification and Details - 01 5639 Site Protection

H. Soil Resources: Amendments and Tools

Smithsonian Gardens

gardens.si.edu

Soils Management Plan

September 3, 2021

Appendices E - H

Client Team

SMITHSONIAN GARDENS

Marisa Scalera, Landscape Architect
Jake Hendee, Arborist
Sarah Hedean, Manager - Living Collections
Joy Columbus, Director
Jeff Schneider, Deputy Director and Grounds Manager
Eric Calhoun, Supervisory Horticulturalist
James Gagliardi, Supervisory Horticulturalist
Melinda Whicher, Supervisory Horticulturalist

Design Team

WOLF JOSEY LANDSCAPE ARCHITECTS

Paul Josey, Principal, PLA
Mary Wolf, Principal, PLA
Dustin Smith, Associate, PLA

OLSSON

Ted Hartsig, Soil Scientist

This project received Federal support from the Smithsonian ***Collections Care Initiative (CCI)****, administered by the National Collections Program*

APPENDIX E

New Project Specifications and Details
32 9100 - Planting Soils

Short Spec

Smithsonian Gardens

This specification is the result of a comprehensive review of the Smithsonian soil and tree conditions across the 13 primary Smithsonian gardens in Washington, D.C. Designed and installed over generations, the assessment conveyed an increasing trend of custom soil mixing throughout the past 40 years leading to a higher level of variability in the planting soil textures. This was a departure from the first 120 years of museum development when there was a more consistent use of imported unscreened silt loam and loam within the gardens.

Analysis of the soil and associated plant health has revealed that the imported loam-based soils from the first 120 years have provided more long term stability, consistency and resilience than the custom mixed soils. Trees were living longer, showing less signs of stress and requiring less irrigation in the imported loam-based soils whereas the custom mixed soils have led to higher nutrient leaching, lower soil organic matter levels (due to decomposition of the compost mix component) and more plant stress over time.

In addition to increased plant benefits associated with returning to a naturally occurring loam-based soil approach, it provides a vital consistency and uniform soil condition across the museum sites to help standardize soil sourcing, maintenance and remediation following construction activities.

While it may seem more straightforward to use unscreened imported soils, there are a few critical aspects regarding the correct installation of these soil types that are outlined in the attached specification. Due to its resilient structure, loam textures – sandy clay loam, loam, and sandy loam, common in neighboring Piedmont soils of northern Virginia, is the specified base soil type. Pretested and approved suppliers have been identified for ease of use.

These soils are not to be screened unless used as the lesser component of a specific bioretention or high-use lawn soil. When used as the dominant component in a soil, protecting naturally occurring clumps (or peds) helps create the vital void space in planting soils for roots, air and water movement. It is critical that the soil is not screened, transported or installed when wet or over-compacted during installation. While straightforward, this needs to be repeatedly conveyed to the contractor and factored into the project schedule and installation plans.

Finally, while reuse of existing soils is encouraged, this is not addressed in this specification. Reuse of planting soils requires additional storage planning on-site or at a separate location, and assessment and coordination throughout the construction documents that would be determined on a case by case basis.

Thank you for your role in building healthy soils for the next generations of Smithsonian Gardens plants and visitors. Happy reading!

Smithsonian Gardens

Smithsonian Institution Planting Soil Specification TEMPLATE

Disclaimer and Responsibility of the User:

How to Use this Template:

1. These instructions are intended to guide you, the specification writer (the specifier), through the process of editing this document into a Planting Soil specification. Be sure to delete these instructions (i.e. all the text in **blue** displayed in this specification) before issuing the specifications.

2. This specification is designed to be used in conjunction with standard Division 01 specifications, which cover project general conditions and project wide contract elements. THIS IS NOT A STAND-ALONE SPECIFICATION and should not be used as a contract for the modification, purchase of and installation of planting soil. Important issues of project ownership, liability, insurance, contract language, project controls, Instructions to bidders, change orders and review and approval of the work are normally in the Division 01 specifications.

3. This specification is broken into three sections:
    a. **Division 1 General Requirements**
        i. Includes an overview of contractor requirements including Scheduling, Testing, Submittals, Mockups and site conditions, among other items.
    b. **Division 2 Products**
        i. Includes a definition for each product
        ii. It is critical that the terms in this section match what is on the Construction Documents (ex. On drawings, installed planting soil is labeled “Planting Soil”, not “Soil Mix” or another unreferenced term)
    c. **Division 3 Execution**
        i. Includes step by step process for installation of planting soils.

4. **Related specification sections:** This specification requires an additional specification section to describe several important related parts of the planting process.
    a. **Site Protection:** This specification assumes that there is a separate specification section and construction drawings and details for tree and soil protection.
    b. **Planting:** This specification assumes that there is a separate specification section and construction drawings for installation of plants.
    c. **Irrigation:** This specification assumes that there is a separate specification section for irrigation and construction drawings associated with the project planting.

5. Before issuing the document, be sure to remove all “**Note to specifier**” incorporated into this document in **blue** text after you have read them and responded to the recommendations

6. This specification is designed for planting soils specific within the Washington, D.C. region and is not recommended for use outside of the region. Lightweight extensive soils (100mm-200mm (4”-8”)), lawn soils, and biofiltration soils are not included in this specification.

SECTION 32 9100

PLANTING SOIL

PART 1 – GENERAL

1.1 SUMMARY

A. The scope of work includes all labor, materials, tools, supplies, equipment, facilities, transportation and services necessary for, and incidental to performing all operations in connection with furnishing, delivery, and installation of Planting Soil and /or the modification of existing site soil for use as Planting Soil, complete as shown on the drawings and as specified herein.

B. The scope of work in this section includes, but is not limited to, the following:

1. Locate, purchase, deliver and install the components that make up the Planting Soil:
   a. Base Soil
   b. Compost
   c. Coarse Sand

2. Prepare, deliver and install the Soil Mix:
   a. Planting Soil

3. Testing and analysis for specification conformance, prior to placement of soils.

4. Finish Grading of Planting Soil area surfaces.

5. Clean up and disposal of all excess and surplus material.

1.2 CONTRACT DOCUMENTS

A. Shall consist of specifications, general conditions, and the drawings. The intent of these documents is to include all labor, materials, and services necessary for the proper execution of the work. The documents are to be considered as one. Whatever is called for by any parts shall be as binding as if called for in all parts.

1.3 RELATED DOCUMENTS AND REFERENCES

A. Related Documents:

1. Drawings and general provisions of contract, including general and supplementary conditions and Division I specifications, apply to work of this section.

2. Related Specification Section **(insert any associated sections that reference soil)**
   a. **Section 01 5639 – Site Protection**
   b. **Section 00 0000 – Site Clearing**
   c. **Section 00 0000 – Earth Moving**
   d. **Section 00 0000 – Planting Irrigation**
   e. **Section 00 0000 – Turf and Grasses**
   f. **Section 00 0000 – Exterior Plants**
   g. **Section 00 0000 – Storm Utility Drainage Piping**

B. References: The following specifications and standards of the organizations and documents listed in this paragraph form a part of the Specification to the extent required by the references thereto. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail.

1. ASTM: American Society of Testing Materials cited section numbers.

2. U.S. Department of Agriculture, Natural Resources Conservation Service, 2003. National Soil

Survey Handbook, title 430-VI. Available Online.

3. US Composting Council www.compostingcouncil.org and the Digital Resource Center https://www.compostingcouncil.org/page/DigitalResourceCenter, including “Compost and its Benefits”.

4. Methods of Soil Analysis, as published by the Soil Science Society of America (http://www.soils.org/).

1.4 PERMITS AND REGULATIONS

A. The Contractor shall obtain and pay for all permits related to this section of the work unless previously excluded under provision of the contract or general conditions. The Contractor shall comply with all laws and ordinances bearing on the operation or conduct of the work as drawn and specified. If the Contractor observes that a conflict exists between permit requirements and the work outlined in the contract documents, the Contractor shall promptly notify the SMITHSONIAN Contracting Officer’s Technical Representative (COTR) in writing including a description of any necessary changes and changes to the contract price resulting from changes in the work.

B. Wherever references are made to standards or codes in accordance with which work is to be performed or tested, the edition or revision of the standards and codes current on the effective date of this contract shall apply, unless otherwise expressly set forth.

C. In case of conflict among any referenced standards or codes or among any referenced standards and codes and the specifications, the more restrictive standard shall apply, or the SMITHSONIAN COTR shall determine which shall govern.

1.5 PROTECTION OF WORK, PROPERTY AND PERSON

A. The Contractor shall adequately protect the work, adjacent property, and the public, and shall be responsible for any damages or injury due to the Contractor’s actions. Reference Specification **Section 01 5639 – Site Protection** for the specific requirements governing this work.

1.6 CHANGES IN WORK

A. All changes in the work, notifications and contractor’s request for information (RFI) shall conform to the contract general condition requirements.

1.7 CORRECTION OF WORK

A. The Contractor shall re-execute any work that fails to conform to the requirements of the contract and shall remedy defects due to faulty materials or workmanship upon written notice from the SMITHSONIAN COTR, at the soonest possible time that can be coordinated with other work and seasonal weather demands but not more than 180 (one hundred and eighty) days after notification.

1.8 DEFINITIONS

A. Acceptance, Acceptable, or Accepted: Formal approval by the SMITHSONIAN COTR in writing.

B. Aesthetic Acceptance of Grades: Formal approval by the SMITHSONIAN COTR in writing of the aesthetic correctness of the contours. Aesthetic acceptance does not address whether an area drains properly, whether the areas are at the correct elevations, or whether it has been compacted properly.

C. Base Soil: naturally produced and harvested soil from the A, B and C horizons and that the soil as further defined in this specification.

D. Compacted soil: soil where the density of soil is greater than the maximum allowable resistance to penetrometer (measured in psi) as defined later in this specification.

E. Compaction: The process by which a force is applied to the soil to achieve a desired soil density as defined in this specification.

F. Compost: well decomposed stable organic material as defined by the US Composting Council and further defined in this specification.

G. Drainage: The rate at which soil water moves through the soil transitioning the soil from saturated condition to field capacity. Most often expressed as saturated hydraulic conductivity (Ksat; units are inches per hour).

H. End of Warranty Acceptance: The date when the SMITHSONIAN COTR accepts that the plants and work in this section meet all the requirements of the warranty. It is intended that the materials and workmanship warranty for Planting, Planting Soil, and Irrigation (if applicable) work run concurrent with each other, and further defined in this specification.

I. Final Acceptance: The date at the end of the Planting Soil installation where the SMITHSONIAN COTR accepts that all work in these sections is complete and the Warranty period has begun. This date may be different than the date of substantial completion for the other sections of the project, and further defined in this specification.

J. Fine grading: The final grading of the soil to achieve exact contours and positive drainage, often accomplished by hand rakes or drag rakes other suitable devices, and further defined in this specification, and further defined in this specification.

K. Finished grade: surface or elevation of Planting Soil after final grading and 12 months of settlement of the soil, and further defined in this specification.

L. Minor disturbance: Minor grading as part of agricultural work that only adjusts the A horizon soil.

M. Ped: a clump or clod of soil held together by a combination of clay, organic matter, and fungal hyphae, retaining the original structure of the harvested soil.

N. Scarify: Loosening and roughening the surface of soil and sub soil prior to adding additional soil on top, and further defined in this specification.

O. Smithsonian Contracting Officer's Technical Representative (COTR): The person or entity, appointed by the Owner to represent their interest in the review and approval of the work and to serve as the contracting authority with the Contractor. The Smithsonian COTR may appoint other persons to review and approve any aspects of the work.

P. Soil Horizons: distinct layers of the soil profile distinguished by differences in such features as color, texture, organic matter content, and other characteristics as defined in the USDA National Soil Survey Handbook

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242.

Q. Soil Mix: Specialized soil types produced as a result of the combination of Base Soil with soil components (such as Coarse Sand and Compost) as defined in ***Part 2 – Section 2.4.A***.

R. Soil Tilling: Loosening the surface of the soil to the depths specified with acceptable mechanical equipment as further defined in this specification.

S. Soil Organic Matter: natural occurring organic matter that is a stable part of the soil matrix. Compost is not considered soil organic matter.

T. Subgrade: surface or elevation of subsoil remaining after completing excavation, or top surface of a fill or backfill, or the top elevation of required drainage layers above structure before placing Planting Soil.

U. Weeds: Any plant that is not on the planting plan.

1.9 LONG LEAD ITEM

A. The Contractor shall be advised that the sourcing, testing, procurement and installation of Planting Soil is a CRITICAL PATH item, requiring timely attention to meet the requirements of the Documents. Having been informed that all aspects of planting soil, the Contractor shall consider this to be A LONG LEAD TIME ITEM. Contractor's failure to heed this notice shall not be a reason for substitution of unacceptable material(s). The SMITHSONIAN COTR will not accept materials that do not meet requirements.

1.10 SUBMITTALS

A. See the contract General Conditions for policy and procedures related to submittals.

B. Planting Soil Installation Plan: Submit, a minimum of twelve (12) weeks prior to the anticipated date of the start of soil installation, a Planting Soil Installation Plan that includes a written narrative of soil procurement, testing, mixing, delivery, storage and handling; mock up preparation, locations and installation process.

The plan shall include the projected timeline for soil work and describe all equipment to be used to mix, deliver, spread, grade and compact the soil. Particular attention should be paid to contingency plans and/or schedule modification options due to the impact of weather on soil moisture, delivery, storage, and handling.

C. Base Soil Source:

1. Submit source information of Base Soil including:
   a. Soil supplier name
   b. Name of contact
   c. Mailing address
   d. Physical address of soil harvesting site or soil stock pile
   e. Phone number

D. Submit all product submittals twelve (12) weeks prior to the start of the soil work.

E. Soil Mix components' Product Data and Samples: For each type of manufactured product, submit data and certificates that the product meets the specification requirements, signed by the product manufacturer, and complying with the following:

1. Submit manufacturers or supplier's product data and literature, and certified analysis for standard products and bulk materials, complying with testing requirements and referenced standards and specific requested testing.

2. Submit soil analytical test results as described in ***Section 1.10.F.2*** below.

F. Soil Testing for Base Soil and Planting Soil

1. Submit soil test analysis report for each sample of Base Soil and Planting Soil from an approved soil-testing laboratory and where indicated in Part 2 of the specification as follows:
   a. Submit Base Soil for testing at least twelve (12) weeks before scheduled installation of the Soil Mix.
   b. Submit Planting Soil tests no more than two (2) weeks after the approval of the Base Soil, Compost, and Coarse Sand. Do not send any Soil Mix (Planting Soil) to the testing laboratory for testing until the Base Soil, Compost, and Coarse Sand have been approved.
   c. If tests fail to meet the specifications, obtain other sources of material, retest and resubmit until accepted by the SMITHSONIAN COTR.
   d. No soil components shall be used until certified test reports by an approved Testing Agency have been approved by the SMITHSONIAN COTR.
   e. No Soil Mix (Planting Soil) shall be used until certified test reports by an approved testing laboratory have been received and approved by the SMITHSONIAN COTR.
   f. If, at any time during the project, the Base Soil, Planting Soil components or Planting Soil

mixes requires adjustment to meet the specifications and/or performance criteria, the Contractor shall submit the adjusted soil components and/or mixes for testing as specified herein.

g. All soil testing will be at the expense of the Contractor.

h. Failure to complete tests as specified will result in rejection of test results

2. For each type of test required, select and use the same testing laboratory throughout the work from the provided list below. Notify the SMITHSONIAN COTR of any change in laboratory and do not proceed until the SMITHSONIAN COTR has provided pre-approval of the change.

   a. Laboratory shall be an independent, certified laboratory with experience and capability to conduct the testing indicated and that specializes in the types of tests to be performed. Tests shall be made in strict compliance with the standards of the Association of Official Analytical Chemists and ASTM.

   b. The following table lists testing parameters, approved soil testing facilities, and specific laboratory testing packages that will provide required data. Testing agencies not listed below shall be approved by the SMITHSONIAN COTR.

Soil Test Requirements, Parameters, Approved Laboratories and Analytical Packages			
Soil Component	Test Parameter	Approved Labs	Laboratory Analytical Suite
Soil Compaction Curve	ASTM D698 - 12e2 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort	Terracon 4545 42nd St., NW, Suite 307 Washington, DC 20016 Phone: (202) 375 7900 Or approved equal	
Soil Gradation (Particle Size	Sieve Analysis (ASTM D6913M - 17 Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis) Sieve Nos. 4, 10, 18, 35, 60, 140, 270, Silt and Clay (pan)	Turf and Soil Diagnostics 613 E 1st St Linwood, KS 66052 Phone: 913-723-3700 Or approved equivalent	Particle Size Analysis
Soil Nutrient and Chemical Tests (Select 1 lab for testing for the duration of the project)	Soil Organic Matter Soil pH (active pH) Cation Exchange Capacity Electrical Conductivity (EC) Total Nitrogen (Kjeldahl N) Nitrate-N Available Phosphorus Potassium Magnesium Calcium Sodium Manganese Zinc Lead Boron Ammonium-N	Ward Laboratories 4007 Cherry Ave, Kearney, NE 68847 Phone: (800) 887-7645	S-4 + Ammonium-N, Total N, Exchangeable Aluminum, Wet Aggregate Stability
		Waypoint Analytical Laboratories 7621 Whitepine Rd Richmond, VA 23237 Phone: 804.743.9401	S3M + Nitrate-Nitrogen, Ammonium-Nitrogen, Electrical Conductivity (EC), and Exch. Aluminum (Waypoint does not offer Total-N)

Soil Test Requirements, Parameters, Approved Laboratories and Analytical Packages			
		Or approved equivalent	
Compost Testing (Select 1 lab for testing for the duration of the project)	pH Boron Calcium Copper Iron Magnesium Manganese Total nitrogen Ammonium-nitrogen Nitrate-nitrogen Organic-nitrogen C:N Ratio Phosphorus Potassium Sulfur Zinc Soluble salts Moisture Dry matter Wet Density	Woods End Laboratory 290 Belgrade Road Mt. Vernon ME 04352 Phone: 207-293-2457	Premium Analysis
		Ward Laboratories 4007 Cherry Ave, Kearney, NE 68847 Phone: (800) 887-7645	Manure & Compost Complete
		Or approved equivalent	
Soil Biological Tests (Both labs required)	PLFA (phospholipid-fatty acid) test Mycorrhizal spore counts Mycorrhizal root colonization	Ward Laboratories 4007 Cherry Ave, Kearney, NE 68847 MIDI Labs 125 Sandy Drive Newark, DE 19713	PLFA Wet Aggregate Stability
		Mycoroots 1970 NW Lance Way, Corvallis, OR 97330	Mycorrhizal spore count Mycorrhizal root colonization

G. Soil Samples for Base Soil and Planting Soil: Submit samples of each product, concurrently with the submission of the laboratory test reports to the SMITHSONIAN COTR for approval. Samples shall be submitted in two-gallon bags and labeled to indicate product, characteristics, and locations in the work. Samples arriving without labels will be rejected. Samples will be reviewed for consistency with specification requirements as can be reasonably ascertained and with certified data.

1. Submit samples a minimum of twelve (12) weeks prior to the anticipated date of the start of soil installation.

2. Samples of Base Soil and Planting Soil shall be submitted at the same time as the required soil testing analysis of that material, per ***Section 1.10.F.2*** above. Analysis data and Samples that don't arrive together, thereby verifying the sample matches the data, will be rejected.

H. Subgrade Infiltration and Density testing reports:

1. See requirements for testing in ***Section 1.15B*** below.

1.11 SOIL INSTALLATION MOCKUP

A. Prior to installation of the planting soil, construct at the site, a mockup of each soil mix required and configuration using the means and methods and equipment proposed by the Contractor to complete the work. Installation of the mockup shall be in the presence of the SMITHSONIAN COTR. The purpose of the mockup is to test the methods of installation, finish grading and compaction of the soil and to serve as a benchmark for completed soil compaction. The mockup shall be as follows:

1. Mockup of the following Soil Mix to be provided:
   a. Planting Soil
2. The mockup area may remain as part of the installed work at the end of the project if protected from further compaction, contamination, or other disturbance.
   a. Locate mock-up on site in a proposed planting area easily referenced by workers performing soil installation and finish grading operations.
3. Where soil mockups are intended to remain in place, complete subgrade soil infiltration and density testing per the requirements outlined in ***Section 1.15B*** below, before construction of the soil mockup.
4. Following acceptance of the soil submittals, in areas that can be protected from disturbance and further compaction, install mockups of each soil type, configuration and soil modification, 3-meter X 6 meter (10-foot X 20-foot) X the full depth of the deepest installation, using the requirements of these specifications. Compaction methods, including the type of compaction equipment and number of passes required to achieve the required compaction shall be evaluated and results measured.
5. Compaction in the mockup soil shall be examined and tested as described below:
   a. Soil density and moisture shall be tested using a nuclear soil density gauge (nuclear densometer) if required by the SMITHSONAIN COTR. Soil density (measured as the percent derived from the dry density divided by the maximum dry density) shall be tested to confirm that soil installation methods will achieve specified soil conditions (density and moisture). Results of nuclear soil density testing shall be used to compare to other soil density and compaction testing methods that are specified in this section.
   b. Cone penetrometer (see ***Part 1.14.G*** below). A cone penetrometer will be used to test for compacted layers or changes in soil density within an installed soil profile. A minimum of four readings from each Soil Mix shall be taken at the specified depths of the soil profile. Readings from the cone penetrometer will be compared to results of the nuclear soil density gauge to provide a relative basis of soil compaction measurements.
   c. Cone penetrometer must only be used in dry to moist soils (described as the Acceptable Condition in ***Section 1.16.A***). The Penetrometer cannot be used in excessively dry or very moist or wet soils. Refer to the section noted above for requirements concerning soil moisture levels.
   d. In the event that the nuclear soil density gauge or the cone penetrometer readings exceed the specified densities, reconstruct the mockup, adjusting the soil compaction methods to achieve the desired results.
   e. Conduct visual observations of soil structure. Record changes in soil particle configuration, such as platy (soil forms plate-like structure), massive (soil appears to have no form, with no observable soil pores), or granular (soil has distinct peds, or soil particles that are friable and break easily).
   f. Where the modification requires ripping, tilling or fracturing soils that are over compacted, start the procedure in a new location so that the process is working on soil that is similar to the density of the expected soil.
6. Contractor shall submit a report of the final methods of soil installation to the SMITHSONIAN COTR. This shall include all penetrometer, nuclear densometer, and soil moisture readings that were catalogued during the mockup process.
7. Provide a protective 1.2-meter-high (4-foot) fence around each mockup to keep all work and equipment from entering the surface of the mockup area.

1.12 OBSERVATION OF THE WORK

A. The SMITHSONIAN COTR may observe the work at any time. They may remove samples of materials for conformity to specifications. Rejected materials shall be immediately removed from the site and replaced at the Contractor's expense. The cost of testing materials not meeting specifications shall be paid by the Contractor.

1. Should the SMITHSONIAN COTR determine the need for nuclear densometer testing, he/she may request use of the Contractor’s nuclear densometer (by a qualified professional) or cone penetrometer at any time to check soil compaction and moisture.

B. The SMITHSONIAN COTR shall be informed of the progress of the work, so the work may be observed at the following key times in the construction process. The SMITHSONIAN COTR shall be afforded sufficient time to schedule visit to the site. Each required review may require multiple visits to reflect the phasing of work. Failure of the SMITHSONIAN COTR to make field observations shall not relieve the Contractor from meeting all the requirements of this specification.

1. SOIL MOCKUP REVIEW: At the time of construction of all soil mockups.
2. SUBGRADE REVIEW: Observe each area of soil installation including planter drainage and waterproofing work prior to the installation of any Planting Soil.
3. COMPLETION of PLANTING SOIL INSTALLATION: Upon completion of all soil modification and installation of planting soil.
4. COMPLETION OF FINE GRADING AND SURFACE SOIL MODIFICATIONS REVIEW: Upon completion of all surface soil modifications and fine grading but prior to the installation of shrubs, ground covers, or lawns.

1.13 PRE-CONSTRUCTION MEETING

A. Schedule a pre-construction meeting with the SMITHSONIAN COTR at least seven (7) days before beginning work to review any questions the Contractor may have regarding the work, administrative procedures during construction and project work schedule.

1.14 QUALITY ASSURANCE

A. Installer Qualifications: The installer shall be a firm having at least ten(10) years of experience of a scope similar to that required for the work, including the preparation, mixing and installation of soil mixes to support planting. The installer shall be experienced with the installation of plants and soil in on-grade and over-structure conditions.

1. The bidders list for work under this section shall be approved by the SMITHSONIAN COTR.
2. Installer Field Supervision: When any planting soil work is in progress, installer shall maintain, on site, an experienced full-time supervisor who can communicate in English with the SMITHSONIAN COTR.
3. Installer’s Field Supervisor shall have a minimum of five (5) years’ experience as a field supervisor installing soil in on-grade and over-structure conditions, shall be trained and proficient in the use of field surveying equipment to establish grades and can communicate in English with the SMITHSONIAN COTR.
4. The installer’s crew shall be experienced in the installation of planting soil, plantings, and interpretation of planting plans, and soil installation plans.
5. Submit references of past projects and employee training certifications that support that the Contractors meet all of the above installer qualifications and applicable licensures.

B. Soil Supplier Qualifications: The soil supplier shall be a firm having at least five (5) years of experience of a scope similar to that required for the work, including the preparation, mixing and delivery of soil to support planting, including experience with the installation of plants and soil in Washington, D.C***. It is the intent of this specification to use unscreened naturally formed loam soils sourced from the Piedmont region in Virginia and local parts of Maryland (generally west of I-95). These soils typically have characteristics (soil clay content, structural stability, and native organic matter content) that favor stable aggregate structure formation, drainage, and compaction resistance.*** The soil supplier shall be located in the area where these soils are found.

C. Installer and Soil Supplier Bidders List: The bidders list for work under this section shall be approved by the SMITHSONIAN COTR prior to the start of the bidding process. Submit bidders list for approval.

1. Pre-approved soil supplier:

   a. JK Enterprise Landscape Supply
   15900 Lee Highway
   Culpepper, VA 20121
   P: 703-926-1967

   b. Luck Ecosystems
   PO Box 29682
   Richmond, VA 23242
   P: 877-904-5825

   c. Or approved equal

2. Pre-approved compost supplier:

   a. Leafgro
   Multiple bulk distributors available

   b. WeCare Denali
   7800 Kabik Ct.
   Woodbine, MD 21797
   P: 410-795-7666

D. Soil testing laboratory qualifications: an independent, certified and accredited testing laboratory, with the experience and capability to conduct the testing indicated and that specializes in USDA agricultural soil testing, planting soil, and the types of tests to be performed. Geotechnical engineering testing labs shall not be used for chemical analyses.

E. Base Soil source inspection: The SMITHSONIAN COTR may inspect the Base Soil source stock piles as part of the approval process. The Soil Supplier shall accompany the SMITHSONIAN COTR. If multiple sites or options are to be considered, arrange the inspection trip such that all optional locations can be inspected in one day. The SMITHSONIAN COTR may remove samples of the material as a record of the inspection and independent testing as needed.

F. All delivered and installed Planting Soil shall conform to the approved submittals sample color, ped sizes and distribution, texture and approved test analysis.

1. The SMITHSONIAN COTR may request samples of the delivered or installed soil be tested for analysis to confirm the Planting Soil conforms to the approved material.

2. All testing shall be performed by the same soil lab that performed the original Planting Soil testing.

3. Testing results shall be within 10% plus or minus of the values measured in the approved Planting Soil.

4. Any Planting Soil that fails to meet the above criteria, if requested by the SMITHSONIAN COTR, shall be removed and new soil installed.

G. Soil compaction testing: following installation or modification of soil, test soil compaction as follows:

1. Soil density shall be measured using a nuclear densometer (Troxler nuclear soil density gauge or equivalent) if required by the SMITHSONIAN COTR. Soil density shall be reported as a measured percentage derived from the dry density divided by the maximum dry density (See ***Section 1.10.F.2***).
   a. Soil density testing using a nuclear densometer must be completed by a certified operator.
   b. One soil density measurement shall be completed after the second 12" lift of soil. This will be used to calibrate acceptable soil density and establish the approved cone pentrometer readings.
   c. Soil density results must be within the range specified in Part 3 of this Section.

2. Soil compaction for detection of compacted layers shall be tested using a static cone penetrometer using method ASTM D3441 - 16 Standard Test Method for Mechanical Cone Penetration Testing of Soils. This test shall not be used on wet soils.
   a. Maintain at the site, at all times, a soil cone penetrometer with pressure dial and a soil moisture meter to check soil compaction and soil moisture.
   b. Penetrometer shall be AgraTronix Soil Compaction Meter distributed by Forestry Suppliers, www.forestry-suppliers.com or approved equal.
   c. Prior to testing the soil with the penetrometer check the penetrometer readings in the mockup soils. Penetrometer readings are impacted by soil moisture and excessively wet or dry soils will read significantly lower or higher than soils at optimum moisture.
      1.) Refer to ***Section 1.16.A*** for requirements concerning soil moisture levels.

3. Soil penetrometer readings shall be completed at 150mm (12-inch) intervals for the full depth of the soil profile. These shall be recorded for review by the SMITHSONIAN COTR.

4. The penetrometer readings shall be within 20% plus or minus of the readings in the approved mockup when at similar moisture levels.

H. Soil infiltration testing shall be completed for each Planting Soil or area installed. Soil infiltration testing shall be conducted using ASTM D3385 - 18: Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer (Falling head method).
   a. A 150mm (6") inner ring / 300mm (12") outer ring Double Ring Infiltrometer shall be used.
      1.) Turf-Tec IN7-W Infiltration Rings, 12˝ OD/6˝ ID by 4˝ Tall distributed by Forestry Suppliers, www.forestry-suppliers.com or approved equal.
      2.) Maintain the Double-Ring Inflitrometer at the site at all times.
   b. One infiltration test per planting area shall be sufficient.

1.15 SITE CONDITIONS

A. It is the responsibility of the Contractor to be aware of all surface and subsurface conditions, and to notify the SMITHSONIAN COTR, in writing, of any circumstances that would negatively impact the health of plantings. Do not proceed with work until unsatisfactory conditions have been corrected.

1. Should subsurface drainage or soil conditions be encountered which would be detrimental to growth or survival of plant material, the Contractor shall notify the SMITHSONIAN COTR in writing, stating the conditions and submit a proposal covering cost of corrections. If the Contractor fails to notify the SMITHSONIAN COTR of such conditions, they shall remain responsible for plant material under the warrantee clause of the specifications.

2. This specification requires that all planting soil and irrigation (if applicable) work be completed and accepted prior to the installation of any plants.

B. Subgrade (subsoil) drainage:

1. Perform infiltration and density tests on subsoil:
   a. Infiltration rate for <u>subgrade</u>, Min. 0.25” per hour
      1.) See ***Section 1.14.H*** for testing procedure.
   b. Compaction rate for <u>subgrade</u>, static cone penetrometer method:
      1.) 0 -150mm (0-6”) depth: Range 120 to 180 pounds per square in (psi)
      2.) 150mm - 300mm (6”-12”) depth: Range 160 to 220 psi.
      3.) See ***Section 1.14.G.2*** for testing procedure.

2. Submit test results as part of the Submittals in ***Section 1.10*** above.

1.16 DELIVERY, STORAGE, AND HANDLING

A. Weather: Do not mix, deliver, place or grade soils when frozen or with moisture greater than 70 percent of moisture level for optimum soil compaction as determined from Standard Proctor tests. Doing so is cause for the SMITHSONIAN COTR to reject the soil outright.

   1. In addition to obtaining soil moisture levels from a nuclear soil density gauge, moisture can be determined by feel in the following manner:

      a. With a handful of soil, form a ball by compressing the soil together.
         1.) Above Field Capacity: If the ball glistens or is plastic (can form a ribbon or be molded), it is too wet.
         2.) Nearing Field Capacity: If the ball breaks fractures into large pieces but not individual peds, it is too moist for handling.
         3.) Acceptable Condition: If the ball breaks into individual soil peds with little hand pressure, it is then suitable for handling and spreading.
         4.) At or Below Wilt Point: If the soil is unable to form a ball with hand pressure, it is unsuitable for handling and spreading.

B. Protect soil and soil stockpiles, including the stockpiles at the soil blender’s yard, from wind, rain and washing that can erode soil or separate fines and coarse material, and contamination by chemicals, dust and debris that may be detrimental to plants or soil drainage. Cover stockpiles with plastic sheeting or fabric at the end of each workday.

C. Planting Soil shall be stockpiled, loaded, unloaded and transported using methods that protect the size percentage range and distribution of soil peds within the soil.

   1. Soils shall not be allowed to remain in stockpiles for longer than six (6) weeks, either at the soil source or the project site. If the soil will be stockpiled for longer than six (6) weeks, it must be planted to a cover crop or covered with mulch to protect it from sun/heat, rain, and wind erosion. ***The intent of this requirement is to harvest soil from the source only as it is needed and have it directly delivered to the project site, and then installed very soon after delivery. This minimizes soil handling and resulting soil degradation and saves storage space and maintenance. Careful planning and close coordination between the contractor and soil provider is essential.***

   2. Use of soil shooters, soil blowers, augers, and conveyors with drops greater than 1-meter (3 feet) or other soil conveyance devices that break up soil peds shall be prohibited. Craned soil in large bulk bags are permitted provided that the process to place the soil into the bags and empty them at the site respects the need to protect soil peds.

D. All manufactured packaged products and material shall be delivered to the site in unopened containers and stored in a dry enclosed space suitable for the material and meeting all environmental regulations. All products shall be freshly manufactured and dated for the year in which the products are to be used.

E. Bulk material: Coordinate delivery and storage with the SMITHSONIAN COTR and confine materials to neat piles in areas acceptable to the SMITHSONIAN COTR.

1.17 EXCAVATING AND GRADING AROUND UTILITIES

A. Contractor shall carefully examine the civil, record, and survey drawings to become familiar with the existing underground conditions before digging.

B. Determine location of underground utilities including irrigation and electrical systems and perform work in a manner that will avoid damage. Hand excavate as required. Maintain grade stakes set by others until parties concerned mutually agree upon removal.

1. Prior to Work commencement review and clearly mark in field horizontal and vertical locations of existing public underground utilities and structures with respective utility companies.

2. Prior to Work commencement review and clearly mark in field horizontal and vertical locations of existing private underground utilities and structures with the SMITHSONIAN COTR or the qualified party responsible for completing this work.

PART 2 – PRODUCTS

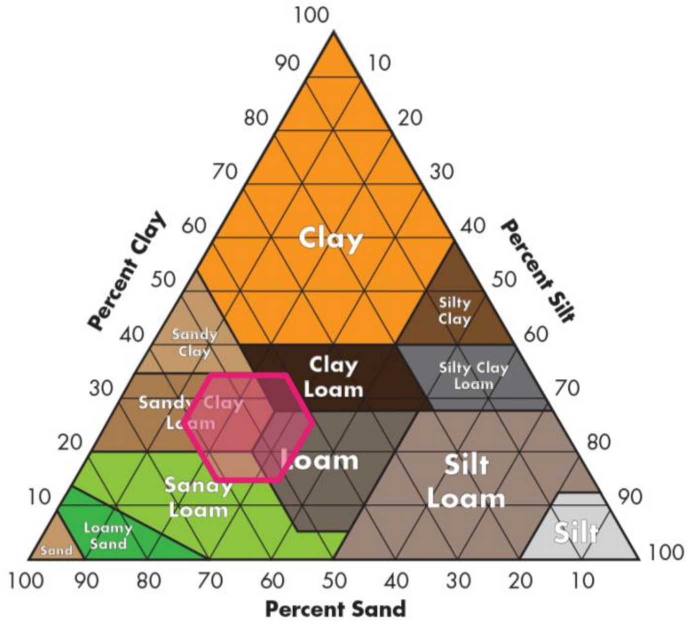
2.1 BASE SOIL

A. Base Soil definition: Fertile, friable soil containing 15% or less of a total volume of the combination of subsoil, refuse, roots larger than 25mm (1-inch) diameter, clumps of heavy, sticky or stiff clay, stones larger than 75mm (3 inches) in diameter, noxious seeds, sticks, brush, litter, or any substances deleterious to plant growth. The percent (%) of the above objects shall be controlled by source selection, *not by screening the soil*. Base Soil shall be suitable for the germination of seeds and the support of vegetative growth. Base Soil shall not contain weed seeds in quantities that cause noticeable weed growth and hazardous weed species in the planting beds. *This can be controlled by selection of the soil source site and soil management/cover crops*. The contractor shall remove all weeds as they emerge.

B. Base Soil shall be a defined as a ***Clay Loam, Loam, Sandy Loam, or Sandy Clay Loam*** having between 17 to 37 percent clay, between 15 to 35 percent silt, and between 40 to 62 percent sand; that will be similar to or match the surrounding topsoil layer. For example, if the topsoil layer is loam soil, the imported soil must also be loam soil with similar organic matter content. Soils imported for subsoil layers, if necessary, must be similar to or match the surrounding subsoil. Soil with greater than 35 percent silt will be rejected.

1. If required, Base soil may be tested for wet aggregate stability, with results showing more than 60 percent stable soil aggregates greater than 0.20 mm

2. Soil structure should have an identifiably strong aggregation of particles in the form of peds, or small clumps, commonly seen in soils characterized as granular or subangular blocky.



3. Chemical properties: Base Soil shall have the following soil chemical properties:

Item	Units	Range
Organic Matter Content	%	2.5 - 6
Total Nitrogen	mg kg^{-1}	>200
Ammonium-nitrogen	mg kg^{-1}	>10
Nitrate-nitrogen	mg kg^{-1}	>5
Available Phosphorus	mg kg^{-1}	>50
pH	Std Units	5.5 – 7.3
Cation Exchange Capacity (CEC)	meq/ 100 gm soil	>17
Soluble Salts/ Electrical Conductivity (EC)	dS.m- 1	<1
Potassium	mg kg^{-1}	>90
Calcium	mg kg^{-1}	>800
Magnesium	mg kg^{-1}	>200
Sodium	mg kg^{-1}	<180
Sulphate-S	mg kg^{-1}	>20
Lead	mg kg^{-1}	<50
Manganese	mg kg^{-1}	<200
zinc	mg kg^{-1}	<150
boron	mg kg^{-1}	<3
Exch. Aluminum	mg kg^{-1}	< 200

C. Base Soil may be a harvested soil from fields or development sites. The organic content and particle size distribution shall be the result of natural soil formation. Manufactured soils where Coarse Sand, composted organic material or chemical additives has been added to the soil to meet the requirements of this specification section shall not be acceptable. Retained soil peds shall be the same color on the inside as is visible on the outside.

D. Base Soil shall NOT have been screened. Soil may retain soil peds or clods larger than 2 inches in diameter throughout the stockpile after harvesting as determined by visual inspection by the SMITHSONIAN COTR.

E. Base Soil Moisture: Protect the Base Soil from rain as required. Soil moisture shall be sufficient when it retains moisture, enabling a friable structure when squeezed, but not in such a wet condition as to leave mud on the hand (see field moisture determination procedure above). Cover the piles after harvesting and uncover during mid-summer/fall drought periods to dry out the soil if project schedule permits.

F. Submit sample from the Base Soil source location per requirements outlined in ***Section 1.10.G.*** The sample shall be a mixture of the random samples taken around the source stockpile or field. The soil sample shall be delivered with soil peds intact that represent the size and quantity of expected peds in the final delivered soil.

2.2 COARSE SAND

A. Coarse Sand for amending the Base Soil (if required) shall be uniformly graded coarse sand consisting of clean, inert, rounded to sub-angular grains of quartz or other durable rock free from loam or clay, surface coatings, mica, and other deleterious materials. There shall be no coarse fragments over 1.0 cm in size or visible organic matter present. Particle size distribution for material passing a Number 4 Sieve shall be:

U.S. Sieve Size	% Passing Minimum	% Passing Maximum
4	90	100
10	75	95
18	48	75
35	20	45
60	0	20
140	0	5
270	0	3
0.002 mm	0	1

1. The pH shall not exceed 7.8 as determined from a 1:1 soil-distilled water suspension using a glass electrode pH meter American Society of Agronomy Methods of Soil Analysis, Part 2, 1986.

B. Submit testing sample per requirements outlined in ***Section 1.10.E***.

2.3 COMPOST

A. Compost shall be a stable, humus-like material produced from the aerobic decomposition and curing of organic vegetative residues derived from feedstock consisting of woody stems, leaves, grass cuttings, and livestock manure (up to 10 percent of the compost mix by volume). No food products are acceptable as part of the compost feedstock. The compost shall be a dark brown to black color and be capable of supporting plant growth with appropriate management practices with no visible free water or dust, with no unpleasant odor. Compost shall contain no more than 1 percent foreign materials by weight, and be capable of passing through a one-half inch screen. Compost shall not have become anaerobic during the processing and storage process.

B. Compost shall be commercially prepared Compost and meet US Compost Council STA/TMECC criteria or as modified in this section for “Compost as a Landscape Backfill Mix Component”.

http://compostingcouncil.org/admin/wp-content/plugins/wp-pdfupload/pdf/191/LandscapeArch_Specs.pdf

C. Chemical Properties - Compost shall conform to the following values:

Item	Units	Range
Organic Matter	Percent	>35%
Total Nitrogen	ppm	>1500
Carbon:Nitrogen Ratio	No units	Between 10:1 to 20:1
Extractable Nitrate	ppm	20-200
Total Phosphorus	ppm	5-2000
Available Phosphorus	ppm	5-200
pH	Std Units	5.5 - 8.0
Salt concentration	dS.m- 1	<6
Moisture	% wt	30-55

1. One hundred percent of the material shall pass a 1/2-inch (or smaller) screen. Debris such as metal, glass, plastic, wood (other than residual chips), asphalt or masonry shall not be visible and shall not exceed one percent dry weight.
2. The Compost shall be screened to ½-inch maximum particle size and shall contain no more that 3 percent material finer than 1.0mm (No. 18 sieve) as determined by sieve analysis.
   a. Additional tests defined in Part I as Chemical Properties shall be performed and the results shall be utilized to evaluate amendments to the Soil Mixes that may be required.
3. Maturity:
   a. C02 test: Compost respiration shall be no more than 6 mg C02-ClgBVS day.
   b. Solvita test: The compost must achieve a maturity index of 6 or more.
4. Biological Values:
   a. Active bacteria and fungi are not to be higher than 10 percent of total bacteria and fungi respectfully.
   b. Total bacteria to be a minimum of 1500 ng/g
   c. Total fungi to be a minimum of 400 ng/g
   d. Protozoa to be 100,000 (amoeba and flagellates with no more 3000 ciliates)
5. Pathogens/Metals/Vector Attraction reduction shall meet 40 CFR Part 503 rule, Table 3, page 9392, Vol. 58 No. 32.

D. Submit testing and sample per requirements outlined in ***Section 1.10.E***.

2.4 SOIL MIXES

A. All Soil Mixes shall be blended and prepared with the components (Base Soil, Compost and Coarse Sand) in the ratios summarized below. Preparation of Planting Soil shall follow the requirement of Part 3 – Execution. Specific blending details are outlined per Soil Mix below.

SOIL MIX	**Base Material**	**Second Component**	**Third Component**	**Ratio by Volume**
Planting Soil	Base Soil	Compost *(if req'd)*		5 pts base soil to 1 pt compost *(if req'd)*

B. Estimated Soil Mix Densities for determining structural bearing capacity in applications over-structure are provided below. Estimated densities assume approximately 50 percent porosity and 2.5 percent organic matter in Planting Soil; and 35 percent porosity and no organic matter in Coarse Sand.

SOIL MIX OR COMPONENTS	**Dry Density**	**Saturated Density**
Planting Soil	82 to 87 lbs/cu ft	110 to 114 lbs/cu ft
Coarse Sand	109 to 115 lbs/cu ft	127 to 132 lbs/cu ft

2.5 PLANTING SOIL

A. Planting Soil shall consist of Base Soil harvested from the soil source site. If the Base Soil has organic matter greater than 3.0 percent, and the soil is dark brown with strong aggregate structure (with discernable peds indicating granular or subangular blocky compostion), no blending of amendments shall be done and the soil shall be used without further processing unless large rocks, sticks, or other debris greater than 75mm (3 inches) are present. Large items may be manually removed from the soil (preferred) or, if necessary, screened through a screen with 50mm – 75mm (2- to 3-inch) openings (only if large objects are greater than 10 percent of the harvested soil material). Soils must be examined and approved of by the SMITHSONIAN COTR.

1. If the soil organic matter content is less than 3.0 percent, the Planting Soil shall be blended with compost in a ratio of 10 parts Base Soil to 1 part Compost for each percentage point less than 3 percent. The Soil Mix shall be blended to be a uniform, homogenous mixture of the soil components. Additives to achieve specified criterial are not acceptable.

2. Mix Compost into the soil with a loader bucket to loosely incorporate it into the Base Soil as follows.
   a. Soil moisture shall not be greater than 17 percent by weight of the Base Soil mass. Wetter soil will remain cohesive and not blend with compost well.
   b. Spread the Base Soil out as a layer approximately 380mm - 500mm (15-20 inches) deep.
   c. Place the Compost over the soil in a layer 75mm – 100mm (3- to 4-inches) thick.
   d. Using the loader bucket, push and lift the soil and compost into a pile, back-drag the pile only once and lift the soil/compost blend in the bucket and allow it to roll [gently] out of the bucket back into the pile.

3. DO NOT OVER MIX! Do not mix with a soil blending machine. Do not screen the soil. This specification assumes that the various other operations of loading and delivery and final spreading of the soil at the site will further mix the two components to an acceptable amount.

4. Base Soil moisture: Prior to mixing Planting Soil (*if required*), protect the Base Soil required for this mix from rain so that the soil moisture remains above wilt point and below field capacity. Soil moisture shall be between 8 to 17 percent by weight of the soil mass when blending with amendments or when handling. Soil with greater than approximately 15 percent moisture may lose critical soil structure if handled too much. Soil with less than 8 percent moisture by weight may be too brittle and soil peds may shatter into structureless soil particles that will become cemented or compacted when re-wetted.
   a. Cover the piles after harvesting and uncover during summer/fall drought periods to dry out the soil required and if project schedule permits.
   b. See additional requirements for soil moisture as defined in ***Section 1.16.A***.

5. Planting Soil moisture: After mixing Planting Soil, protect from rain so that the soil moisture is sufficient to be friable and crumble when squeezed and not leave mud on the hand. Cover the piles after mixing and uncover during mid-summer/fall drought periods to dry out the soil if soil moisture requires and project schedule permits.

   a. See additional requirements for soil moisture as defined in ***Section 1.16.A***.

6. Submit Planting Soil sample per requirements outlined in ***Section 1.10.G.*** The sample should represent the size and distribution of the soil peds in the soil. Sample shall be marked with the proportion of Base soil to Compost. Submit testing data per requirements outlined in ***Section 1.10.F.***

   a. Planting Soil chemical qualities shall be tested and include:

Item	Units	Range
Total Organic Matter	Percent	3.0 – 5.0%
Total Nitrogen	mg kg^{-1}	>750
Ammonium-nitrogen	mg kg^{-1}	>20
Nitrate-nitrogen	mg kg^{-1}	>25
Available Phosphorus	mg kg^{-1}	>50
pH	Std Units	5.5 – 7.3
Cation Exchange Capacity (CEC	meq/ 100 gm soil	>17
Soluble Salts/ Electrical Conductivity (EC)	$dS.m^{-1}$	<1.0
Potassium	mg kg^{-1}	>90
Calcium	mg kg^{-1}	>700
Magnesium	mg kg^{-1}	>200
Sodium	mg kg^{-1}	<100
Sulphate-S	mg kg^{-1}	>20
Lead	mg kg^{-1}	<50
Manganese	mg kg^{-1}	<200
Exchangeable aluminum	mg kg^{-1}	<180
zinc	mg kg^{-1}	<50
boron	mg kg^{-1}	<3
Exch. Aluminum	mg kg^{-1}	<200

PART 3 – EXECUTION

3.1 COORDINATION WITH PROJECT WORK

A. The Contractor shall coordinate with all other work that may impact the completion of the work.

B. Prior to the start of work, submit and obtain approval of the Planting Soil Installation Plan and prepare a detailed schedule of the work for coordination with other trades.

C. Coordinate the relocation of any irrigation lines, heads or the conduits of other utility lines that are in conflict with tree locations. Root balls shall not be altered to fit around lines. Notify the SMITHSONIAN COTR of any conflicts encountered.

3.2 PRE-EXAMINATION, VERIFICATION AND ACCEPTANCE

A. A Pre-installation Examination with the SMITHSONIAN COTR is required for the work of this section. Schedule the examination at least five days before the installation process begins.

   1. As the work proceeds, the Contractor shall schedule a pre-installation examination with the

SMITHSONIAN COTR for each area of planting soil installation.

2. Reference ***Section 1.12*** for further requirements governing pre-installation examinations.

B. Upon receipt of delivery of planting soil, the Contractor shall visually inspect the soil for moisture content, non-aggregated soil particles, clumping, debris, deleterious or foreign materials, or any other physical conditions that could affect the quality of the planting soil and the Contractor's installation operations.

1. The Contractor shall immediately notify the SMITHSONIAN COTR of any soil deliveries that exhibit any of the physical conditions noted above.

2. The Contractor shall not accept or use soil that exhibits any of the physical conditions noted above.

C. The Contractor shall be responsible for verification that all of the planting areas receiving planting soil have been prepared in conformance with the Contract Documents.

1. Verify that utilities have been installed and accepted.

2. Verify that irrigation mainlines have been installed.

3. Verify that there is a sufficient means for on-site watering of installed plants.

4. Verify that the rough grading has been accepted by the SMITHSONIAN COTR.

D. Examine subgrade for deficiencies including:

1. Construction debris present within the area to receive planting soil.

2. Puddling of water, muddy soil conditions, or expressing of water from the subgrade or adjacent areas.

3. The subgrade is not at the correct depths for installing the planting soil.

4. Incomplete utility, irrigation and /or subsurface drainage installation.

5. Insufficient compaction of subgrade. Refer back to ***Section 1.15.B*** or the geotechnical subgrade requirements (*if applicable*) outlined in Specification **Section 00 0000 -- Earthwork**.

E. Submit all noted deficiencies that will impact the proper installation or execution of the Work to the SMITHSONIAN COTR in writing prior to beginning soil installation operations. The Contractor assumes responsibility for all subgrade work and conditions upon beginning soil installation operations.

3.3 GRADE AND ELEVATION CONTROL

A. Provide grade and elevation control during installation of the planting soil. Utilize grade stakes, surveying equipment, and other means and methods to assure that grades and contours conform to the grades indicated on the plans.

1. Establish lines and levels, locate and lay out by instrumentation and similar appropriate means for planting area finish grades.

2. Provide as many grade stakes and string lines as required to achieve smooth finish grades acceptable to the SMITHSONIAN COTR with positive surface drainage.

3. High Points and Low Points: Provide grade stakes at high points and low points including top of berms, catch basin rims and area drain rims.

3.4 SUBGRADE PREPARATION FOR ON-GRADE CONDITIONS

A. Protection of Existing Conditions:

1. Refer to Specification **Section 01 5639 – Site Protection** for requirements governing this work.
2. Submit written notification of conditions damaged during construction to the SMITHSONIAN COTR immediately.

B. Excavate to the proposed subgrade where applicable. Maintain all required angles of repose of the adjacent materials as shown on the drawings or as required by this specification. Do not over excavate compacted subgrades of adjacent pavement or structures. Maintain a supporting 1:1 side slope of compacted subgrade material along the edges of all paving and structures where the bottom of the paving or structure is above the bottom elevation of the excavated planting area.

C. Remove all construction debris and material including any construction materials from the subgrade.

D. Confirm that the subgrade is at the proper elevation and compacted if required. Subgrade elevations shall slope approximately parallel to the finished grade and/or toward the subsurface drain lines as shown in the Drawings.

E. Subgrade shall be scarified (roughened) to a depth of 75 – 150mm (3-6 inches) prior to placement of subsoil and planting soil to create an uneven, broken surface in which the subgrade can be mixed with the first lift of planting soil placed. Scarification can be accomplished using a mini-disc, reverse tiller, or other suitable device as approved by the SMITHSONIAN COTR.

F. Perform infiltration and density tests on subsoil as described in ***Section 1.15.B***.

G. Protect adjacent walls, walks and utilities from damage or staining by the soil. Use 12.5mm (1/2-inch) plywood as directed to cover existing concrete, metal and masonry work and other items as directed during the progress of the work.

1. At the end of each working day, clean up any soil or dirt spilled on any paved surface.
2. Any damage to the paving or site features or work shall be repaired at the Contractor’s expense.

3.5 PREPARATION FOR OVER-STRUCTURE CONDITIONS

A. Protection of Existing Conditions:

1. Refer to Specification **Section 01 5639 – Site Protection** for requirements governing this work.
2. Submit written notification of conditions damaged during construction to the SMITHSONIAN COTR immediately.

B. In areas of work over structure, confirm that all waterproofing and drainage layers are complete. Remove any debris from the surface of the drainage layer.

3.6 SOIL MOISTURE

A. Volumetric soil moisture level, in the Planting Soil and the root balls of all plants, prior to, during and after soil installation and planting shall be above permanent wilt point and below field capacity. Reference ***Section 1.16.A.1*** for determining acceptable soil moisture levels for delivering, handling, placing, and grading activities. Failure to adhere to these requirements is cause for the SMITHSONIAN COTR to reject the soil outright.

3.7 SOIL INSTALLATION

A. **General**

1. Phase work such that equipment to deliver or grade soil and install planting soil does not have to operate over previously installed soil work including lower lifts. Work in rows of lifts the width of the extension of the bucket on the loader. Install all lifts of the entire assembly in one row before proceeding to the next. Work out from the furthest part of each bed from the soil delivery point to the edge of each bed area.

2. The contractor shall continuously check the compaction of the soil installation with a cone penetrometer (at 150mm (12-inch) intervals), as the work progresses, to assure that penetration resistance conforms to the values of the mock up. Final compaction readings with the cone penetrometer should be taken for each planting area at the completion of soil installation (see ***Section 3.9***).

3. Installing soil using soil or mulch blowers or soil slingers shall not be permitted for planting soil due to the over mixing and soil ped breakdown cause by this type of equipment. Use of soil "Gaylord" bags craned into the site is permitted

4. Where travel over installed soil is unavoidable, limit paths of traffic to reduce the impact of compaction in planting soil.
   a. Wheel-driven vehicles are expressly forbidden to be allowed on installed soils. Only low-ground pressure (less than 6 psi), wide track 400mm to 600mm (18-24 inches) equipment may be allowed on installed soils and only along pre-approved corridors or lanes.
   b. All grading and soil delivery equipment shall have buckets equipped with 100 mm (6-inch) long teeth to scarify any soil that becomes compacted.
   c. Protect the surface of the soil in any areas that will receive repeated passes with motorized equipment with 19mm (3/4-inch) plywood matting.
      1.) 3/4" plywood shall only be used when the duration of use does not exceed three days. This is considered for temporary use only.
      2.) No part of any plywood matting shall be moved, altered, or changed in any way until access across, adjacent to, or through installed soil zones is no longer necessary or until the temporary use period has concluded.
   d. Till the surface of the soil with a mini-disc or reverse tiller to a depth of 150mm to 200mm (6-8 inches) when the plywood is removed.
   e. Each time equipment passes over the installed soil it shall reverse out of the area along the same path with the teeth of the bucket dropped to scarify the soil. In the event that the planting soil becomes over compacted, thereby failing to comply with ***Section 3.9***, the soil shall be removed in 12" lifts and the compaction retested until specified compaction levels are observed before proceeding with new soil installation.

5. Prior to installing planting soil, the SMITHSONIAN COTR shall approve the condition of the subgrade and the previous scarification.
   a. Immediately install the planting soil. Protect the loosened area from traffic. DO NOT allow the loosened subgrade to become compacted.

6. Compaction of soils to specified soil densities shall be accomplished using rollers, foot pressure, or manual tools.
   a. Vibratory, plate and jumping jack compactors, or impact methods (using a backhoe bucket or similar to impact or "hammer" the soil) are strictly prohibited.

7. In the event that the loosened area becomes overly compacted, loosen the area again prior to installing planting soil.

8. Where possible place trees on soil pedestals such that the elevation of the tree root flare will be at the planned finished soil elevation. Tree pedestals will be compacted to 90- to 95% of the soil's maximum dry density, using the Standard Proctor method, to resist settling of the soil from the weight of the tree.

B. **Planting Soil Installation**

1. After inspecting the base grade of the soil, the Planting Soil shall be installed in lifts not to exceed 300mm (12-inch) to the required depths as shown in the Drawings.
   a. Compact each lift gently and evenly compact soil to approximately 80 to 84 percent of the soil's maximum dry density using the Standard Proctor method.

b. After each lift has been successfully compacted, scarify the surface of the lift to a depth of 38mm (1.5 inches) and place the next soil lift. Repeat the placement of soil lifts for each soil layer until the Planting Soil grade elevation has been achieved.
c. Measure soil compaction using a nuclear soil density gauge to attain the required soil density approved in the soil mock up.

2. Where trees will be planted / installed, pack each lift of Planting Soil around the base and rootball of the tree using manual tools (shovels, rakes) to assure that no voids are present around the rootball and that soil is firmly in place.
   a. Place the Planting soil in 300 mm (12-inch) lifts.
      1.) Compact each lift gently and evenly compact the soil to approximately 80 to 84 percent of the soil's maximum dry density using the Standard Proctor method.
      2.) Scarify each lift to a depth of approximately 25mm (1 inch) prior to placement of each successive lift.
   b. After the final Planting Soil lift has been installed, grade the surface of the Planting Soil smooth and even. Scarify the final soil lift to create a firm, friable planting surface.

C. **Planting Soil Installation in Soil Cells**

1. Refer to Section 32 94 51 – Soil Cells

D. **Planting Soil Installation in Raised Planters**

*(**Note to Specifier:** Section only required if raised planters used. Remove reference if not used)*

1. Planter Soils are expected to be installed in areas with limited space and access. Planter soils shall consist of a Planting Soil layer and a Compost till layer (surface).

2. Install the Planting Soil in lifts not to exceed 300mm (12-inch) to the required depths as shown on the Plans. Compact each lift using foot pressure or equivalent to gently and evenly compact soil to approximately 80 to 84 percent of the soil's maximum dry density using the Standard Proctor method. After each lift has been successfully compacted, scarify the surface of the lift to a depth of 38mm (1.5 inches) and place the next soil lift. Repeat the placement of soil lifts for each soil layer until the Planting Soil grade elevation has been achieved. Measure soil compaction using the cone penetrometer as required to attain the soil density approved in the soil mock up.

   a. Prior to placement of successive lifts, determine soil density using the cone penetrometer. Resistance to penetrometer push shall be 110 to 170 psi.
   b. Pack each lift of Planting Soil firmly up to edges or walls of planter boxes using manual tools (shovels, rakes) to assure that no voids are present and that soil is firmly in place.
   c. After placement of all Planting Soil, the soil density shall be measure for the whole depth of the Planting Soil layer to check for uniform density and that clay or compaction pans are not present.

3. The Planting Soil shall be finished with a firm, friable planting surface.

3.8 INSTALLATION OF COMPOST TILL LAYER

***Note to specifier:** The following paragraph is critical to establishing an organic-rich O horizon in installed Planting Soil. This added layer of Compost must be shown on the soil details in the Drawings*

A. After Planting Soil is installed in planting bed areas and just prior to the installation of shrub or groundcover plantings, spread 50mm (2 inches) of Compost over the beds and roto till into the top 100mm (4 inches) of the Planting Soil. This step will raise grades slightly, refer to ***Section 3.10.A***.

3.9 POST SOIL INSTALLATION TESTING

A. Soil density, soil compaction, and soil infiltration testing shall be completed as soil is installed and at completion of soil installation to assure that soils comply with specified requirements as established in this Section.

1. Soil density shall be measured using a nuclear soil density gauge as described in ***Part 1.14.G*** of this section.
   a. Soil density measurements shall be completed for each planting area smaller than 100 square meters, or one test for each 100 square meters of a larger planting area.
   b. Soil density shall be between 80 to 84 percent of the soil's maximum dry density using the Standard Proctor method in all areas. If soil density exceeds this range, additional soil density tests shall be conducted offset by 5 feet in each direction from the point of exceedance to determine extent of excessive soil density. The SMITHSONIAN COTR shall be consulted for corrective actions.
   c. Soils with high compost or organic matter concentrations may not achieve the specified soil density range. Advise the SMITHSONIAN COTR if soil density measurements and the location of soil density measurements not meeting the specified range.

2. Compaction testing, including surface as well as subsurface compaction layers, shall be tested using a cone penetrometer as described in ***Part 1.14G*** of this Section.
   a. Compaction testing shall be done for each 25 square meters of planting area at a minimum.
   b. Compaction measured as resistance to penetration of the cone penetrometer in pounds per square inch (psi) shall not exceed 140 psi in the surface 150mm (6 inches), 180 psi in the 150 – 300 mm (6- to 12-inch) depth interval, or 200 psi at depths greater than 300 mm in the soil profile.
      1.) If compaction testing detected compacted layers exceeding the allowances described above, soil shall be removed to the depth of compaction, and compacted soils shall be loosened with hand tools to break compacted layers and achieve appropriate soil density.

3. Infiltration testing shall be conducted as described in ***Section 1.14H***. Infiltration testing shall be completed using the Double-Ring Infiltrometer.
   a. Infiltration testing shall be done for each planting area of 100 square meters or less. Infiltration testing shall be done at a rate of one test per 100 square meters for panting areas greater than 100 square meters.
   b. Infiltration rates shall be greater than 15mm per hour (0.6 inches/hour). If infiltration rates are not greater than 15mm/hr, consult with the SMITHSONIAN COTR to determine corrective actions.

3.10 FINISH GRADING

A. The finish grades of all planted areas shown in the Drawings are the elevations after settlement and shrinkage of the Compost Till Layer and planting soil. This settlement is anticipated to be within a few months after installation as the Compost breaks down. A minimum settlement of approximately 25mm (1-inch) of the soil depth is expected. The Contractor shall install the planting soil at a higher level to anticipate this reduction of planting soil volume (approximately 25mm (1-inch)).

1. Grade the edges of shrub areas and ground cover areas soil surfaces to an elevation 50mm (2 inches) below the finished surface of adjacent paving and curbs, after initial soil settlement, unless indicated otherwise.

2. The grades in bed areas shown in the Drawings is the soil line before mulch is added and after soil settlement. The grades in lawn areas shown in the Drawings in the thatch line of the sod after initial soil settlement, unless indicated otherwise.

B. Utilize hand tools to keep surface rough without further compaction. Do not use the flat bottom of a loader bucket to fine grade, as it will cause the finished grade to become overly smooth and or slightly compressed.

C. Inspect and survey finished soil grades for positive drainage from all areas toward the existing inlets, drainage structures and or the edges of planting beds consistent with soil grade designs unless indicated otherwise. Adjust grades as directed to reflect actual constructed field conditions of paving, wall and inlet elevations as shown in the Drawings. Notify the SMITHSONIAN COTR in the event that conditions make it impossible to achieve positive drainage.

1. Grade soil surface smooth to be free of high and low areas which will inhibit surface drainage.
2. Provide smooth, rounded transitions between slopes of different gradients and direction.

3.11 TOLERANCES

A. Grade soil surface to within 0.10-foot of grades indicated in the Drawings, except bring soil surface grades along headers, paving, curbs, and other structures to within 0.01-foot of grades indicated in the Drawings.

B. Transition soil surface grades along paving, curbs and other structures to areas of less strict tolerance over a 5-foot distance.

C. Fill all depressions and remove any rises or mounds in the overall plane of the slope. The tolerance for dips and bumps in shrub and ground cover planting areas shall be a 50mm (2-inch) deviation from the plane in 3-meters (10 feet). The tolerance for dips and bumps in lawn areas shall be a 25mm (1-inch) deviation from the plane in 3-meters (10 feet).

3.12 PROTECTION AND REPAIRS

A. The Contractor shall take every precaution to ensure the integrity of the underdrainage, aeration and irrigation systems during and after soil placement. Any damage caused by the Contractor shall be repaired at no additional expense to the Owner.

B. The Contractor shall be responsible to ensure that no soil disturbance will occur from construction traffic or other construction activities after placement of planting soil is complete. Disturbance shall be repaired by the Contractor at no additional expense to the Owner.

1. The Contractor shall place barricades to prevent compaction of planting soil from vehicles, equipment, or pedestrian traffic.
2. Coordinate activities with other project contractors so that there is no soil disturbance from traffic or other construction activities subsequent to placement.

C. Protect newly graded areas from traffic and erosion. Keep free of trash, debris or construction materials from other work.

D. Repair and re-establish grades where completed or partially competed surfaces become eroded, rutted or compacted. Scarify, or, if directed by the SMITHSONIAN COTR, remove and replace soil to a depth as directed. Reshape and re-compact to the required density while soil is at a moisture content between permanent wilting point and field capacity.

E. Where settling greater than 50mm (2-inches) occurs, before final acceptance or during the warranty period, remove finish surfacing, backfill with additional approved material, compact to specified rates, and restore any disturbed areas to a condition acceptable to the SMITHSONIAN COTR.

1. Repaired or restored areas shall follow the same procedures as specified for installation of new Soil Mixes.

F. Any soil that becomes compacted to a density greater than 85 proctor density and/or the density in the approved mockup shall be dug up and reinstalled. This requirement includes compaction caused by other sub-contractors after the Soil Mix (Planting Soil) is installed and approved.

G. Surface tilling shall not be considered adequate to reduce over compaction at levels 150mm (6 inches) or greater below finished grade. See ***Section 3.7.A.4*** for remediating over-compaction.

3.13 FINAL ACCEPTANCE / SOIL SETTLEMENT

A. Upon written notice from the Contractor, the SMITHSONIAN COTR shall review the work and make a determination if the work is substantially complete.

B. The date of substantial completion of the planting soil shall be the date when the SMITHSONIAN COTR accepts that all work in Planting, Planting Soil, and Irrigation installation sections is complete.

C. Aesthetic Acceptance of Grades:

1. Upon completion of finish grading Work, schedule with the SMITHSONIAN COTR a review to obtain aesthetic acceptance.
2. Provide three (3) days advance written notification.
3. Do not commence planting or sodding Work until receiving aesthetic acceptance.

D. At the end of the plant warrantee and maintenance period, (see **Specification Section 00 0000 -- Planting**) the SMITHSONIAN COTR shall observe the soil installation work and establish that all provisions of the contract are complete, and the work is satisfactory.

1. Restore any soil settlement and or erosion areas to the grades shown in the Drawings. When restoring soil grades remove plants and mulch and add soil before restoring the planting. Do not add soil over the root balls of plants or on top of mulch.

E. Failure to pass acceptance: If the work fails to pass final acceptance, any subsequent observations must be rescheduled as per above. The cost to the Owner for additional observations will be charged to the Contractor at the prevailing hourly rate of the SMITHSONIAN COTR.

3.14 EXCESS MATERIALS

A. Excess Planting Soil: Remove the excess planting soil mixture and materials from the project area at no additional cost to the Owner.

END OF SECTION 32 91 00

Full Spec

Smithsonian Gardens

This specification is the result of a comprehensive review of the Smithsonian soil and tree conditions across the 13 primary Smithsonian gardens in Washington, D.C. Designed and installed over generations, the assessment conveyed an increasing trend of custom soil mixing throughout the past 40 years leading to a higher level of variability in the planting soil textures. This was a departure from the first 120 years of museum development when there was a more consistent use of imported unscreened silt loam and loam within the gardens.

Analysis of the soil and associated plant health has revealed that the imported loam-based soils from the first 120 years have provided more long term stability, consistency and resilience than the custom mixed soils. Trees were living longer, showing less signs of stress and requiring less irrigation in the imported loam-based soils whereas the custom mixed soils have led to higher nutrient leaching, lower soil organic matter levels (due to decomposition of the compost mix component) and more plant stress over time.

In addition to increased plant benefits associated with returning to a naturally occurring loam-based soil approach, it provides a vital consistency and uniform soil condition across the museum sites to help standardize soil sourcing, maintenance and remediation following construction activities.

While it may seem more straightforward to use unscreened imported soils, there are a few critical aspects regarding the correct installation of these soil types that are outlined in the attached specification. Due to its resilient structure, loam textures – sandy clay loam, loam, and sandy loam, common in neighboring Piedmont soils of northern Virginia, is the specified base soil type. Pretested and approved suppliers have been identified for ease of use.

These soils are not to be screened unless used as the lesser component of a specific bioretention or high-use lawn soil. When used as the dominant component in a soil, protecting naturally occurring clumps (or peds) helps create the vital void space in planting soils for roots, air and water movement. It is critical that the soil is not screened, transported or installed when wet or over-compacted during installation. While straightforward, this needs to be repeatedly conveyed to the contractor and factored into the project schedule and installation plans.

Finally, while reuse of existing soils is encouraged, this is not addressed in this specification. Reuse of planting soils requires additional storage planning on-site or at a separate location, and assessment and coordination throughout the construction documents that would be determined on a case by case basis.

Thank you for your role in building healthy soils for the next generations of Smithsonian Gardens plants and visitors. Happy reading!

Smithsonian Gardens

Smithsonian Institution Planting Soils Specification TEMPLATE

Disclaimer and Responsibility of the User:

How to Use this Template:

1. These instructions are intended to guide you, the specification writer (the specifier), through the process of editing this document into a Planting Soil specification. Be sure to delete these instructions (i.e. all the text in **blue** displayed in this specification) before issuing the specifications.

2. This specification is designed to be used in conjunction with standard Division 01 specifications, which cover project general conditions and project wide contract elements. THIS IS NOT A STAND-ALONE SPECIFICATION and should not be used as a contract for the modification, purchase of and installation of planting soil. Important issues of project ownership, liability, insurance, contract language, project controls, Instructions to bidders, change orders and review and approval of the work are normally in the Division 01 specifications.

3. This specification is broken into three sections:
    a. **Division 1 General Requirements**
        i. Includes an overview of contractor requirements including Scheduling, Testing, Submittals, Mockups and site conditions, among other items.
    b. **Division 2 Products**
        i. Includes a definition for each product
        ii. It is critical that the terms in this section match what is on the Construction Documents (ex. On drawings, installed planting soil is labeled “Planting Soil”, not “Soil Mix” or another unreferenced term)
    c. **Division 3 Execution**
        i. Includes step by step process for installation of planting soils.

4. **Related specification sections:** This specification requires an additional specification section to describe several important related parts of the planting process.
    a. **Site Protection:** This specification assumes that there is a separate specification section and construction drawings and details for tree and soil protection.
    b. **Planting:** This specification assumes that there is a separate specification section and construction drawings for installation of plants.
    c. **Irrigation:** This specification assumes that there is a separate specification section for irrigation and construction drawings associated with the project planting.

5. Before issuing the document, be sure to remove all “**Note to specifier**” incorporated into this document in **blue** text after you have read them and responded to the recommendations

6. This specification is designed for planting soils specific within the Washington, D.C. region and is not recommended for use outside of the region.

SECTION 32 9100

PLANTING SOILS

PART 1 – GENERAL

1.1 SUMMARY

A. The scope of work includes all labor, materials, tools, supplies, equipment, facilities, transportation and services necessary for, and incidental to performing all operations in connection with furnishing, delivery, and installation of Planting Soils and /or the modification of existing site soil for use as Planting Soils, complete as shown on the drawings and as specified herein.

B. The scope of work in this section includes, but is not limited to, the following:

1. Locate, purchase, deliver and install the components that make up the Planting Soils:
   a. Base Soil
   b. Coarse Sand
   c. Compost
   d. **Lightweight Aggregate**
   e. **No. 8 Pea Gravel**
   f. **No. 57 Stone**

2. Prepare, deliver and install the Soil Mixes:
   a. **Planting Soil**
   b. **Lawn Soil**
   c. **High-Use Lawn Soil**
   d. **Biofiltration Soil (Bioswales, Bioretention, Raingardens)**
   e. **Lightweight Extensive Soil**

3. Testing and analysis for specification conformance, prior to placement of soils.

4. Finish Grading of Planting Soil area surfaces.

5. Clean up and disposal of all excess and surplus material.

1.2 CONTRACT DOCUMENTS

A. Shall consist of specifications, general conditions, and the drawings. The intent of these documents is to include all labor, materials, and services necessary for the proper execution of the work. The documents are to be considered as one. Whatever is called for by any parts shall be as binding as if called for in all parts.

1.3 RELATED DOCUMENTS AND REFERENCES

A. Related Documents:

1. Drawings and general provisions of contract, including general and supplementary conditions and Division I specifications, apply to work of this section.

2. Related Specification Section **(insert any associated sections that reference soil)**
   a. **Section 01 5639 – Site Protection**
   b. **Section 00 0000 – Site Clearing**
   c. **Section 00 0000 – Earth Moving**
   d. **Section 00 0000 – Planting Irrigation**
   e. **Section 00 0000 – Turf and Grasses**
   f. **Section 00 0000 – Exterior Plants**
   g. **Section 00 0000 – Storm Utility Drainage Piping**

B. References: The following specifications and standards of the organizations and documents listed in this paragraph form a part of the Specification to the extent required by the references thereto. In the event that the requirements of any of the following referenced standards and specifications conflict with each other the more stringent requirement shall prevail.

1. ASTM: American Society of Testing Materials cited section numbers.
2. U.S. Department of Agriculture, Natural Resources Conservation Service, 2003. National Soil Survey Handbook, title 430-VI. Available Online.
3. US Composting Council www.compostingcouncil.org and the Digital Resource Center https://www.compostingcouncil.org/page/DigitalResourceCenter, including “Compost and its Benefits”.
4. Methods of Soil Analysis, as published by the Soil Science Society of America (http://www.soils.org/).

1.4 PERMITS AND REGULATIONS

A. The Contractor shall obtain and pay for all permits related to this section of the work unless previously excluded under provision of the contract or general conditions. The Contractor shall comply with all laws and ordinances bearing on the operation or conduct of the work as drawn and specified. If the Contractor observes that a conflict exists between permit requirements and the work outlined in the contract documents, the Contractor shall promptly notify the SMITHSONIAN Contracting Officer’s Technical Representative (COTR) in writing including a description of any necessary changes and changes to the contract price resulting from changes in the work.

B. Wherever references are made to standards or codes in accordance with which work is to be performed or tested, the edition or revision of the standards and codes current on the effective date of this contract shall apply, unless otherwise expressly set forth.

C. In case of conflict among any referenced standards or codes or among any referenced standards and codes and the specifications, the more restrictive standard shall apply, or the SMITHSONIAN COTR shall determine which shall govern.

1.5 PROTECTION OF WORK, PROPERTY AND PERSON

A. The Contractor shall adequately protect the work, adjacent property, and the public, and shall be responsible for any damages or injury due to the Contractor’s actions. Reference Specification **Section 01 5639 – Site Protection** for the specific requirements governing this work.

1.6 CHANGES IN WORK

A. All changes in the work, notifications and contractor’s request for information (RFI) shall conform to the contract general condition requirements.

1.7 CORRECTION OF WORK

A. The Contractor shall re-execute any work that fails to conform to the requirements of the contract and shall remedy defects due to faulty materials or workmanship upon written notice from the SMITHSONIAN COTR, at the soonest possible time that can be coordinated with other work and seasonal weather demands but not more than 180 (one hundred and eighty) days after notification.

1.8 DEFINITIONS

A. Acceptance, Acceptable, or Accepted: Formal approval by the SMITHSONIAN COTR in writing.

B. Aesthetic Acceptance of Grades: Formal approval by the SMITHSONIAN COTR in writing of the aesthetic correctness of the contours. Aesthetic acceptance does not address whether an area drains properly, whether the areas are at the correct elevations, or whether it has been compacted properly.

C. Base Soil: naturally produced and harvested soil from the A, B and C horizons and that the soil as further defined in this specification.

D. Compacted soil: soil where the density of soil is greater than the maximum allowable resistance to penetrometer (measured in psi) as defined later in this specification.

E. Compaction: The process by which a force is applied to the soil to achieve a desired soil density as defined in this specification.

F. Compost: well decomposed stable organic material as defined by the US Composting Council and further defined in this specification.

G. Drainage: The rate at which soil water moves through the soil transitioning the soil from saturated condition to field capacity. Most often expressed as saturated hydraulic conductivity (Ksat; units are inches per hour).

H. End of Warranty Acceptance: The date when the SMITHSONIAN COTR accepts that the plants and work in this section meet all the requirements of the warranty. It is intended that the materials and workmanship warranty for Planting, Planting Soil, and Irrigation (if applicable) work run concurrent with each other, and further defined in this specification.

I. Final Acceptance: The date at the end of Planting Soils installation where the SMITHSONIAN COTR accepts that all work in these sections is complete and the Warranty period has begun. This date may be different than the date of substantial completion for the other sections of the project, and further defined in this specification.

J. Fine grading: The final grading of the soil to achieve exact contours and positive drainage, often accomplished by hand rakes or drag rakes other suitable devices, and further defined in this specification, and further defined in this specification.

K. Finished grade: surface or elevation of Planting Soils after final grading and 12 months of settlement of the soil, and further defined in this specification.

L. Minor disturbance: Minor grading as part of agricultural work that only adjusts the A horizon soil.

M. Ped: a clump or clod of soil held together by a combination of clay, organic matter, and fungal hyphae, retaining the original structure of the harvested soil.

N. Scarify: Loosening and roughening the surface of soil and sub soil prior to adding additional soil on top, and further defined in this specification.

O. Smithsonian Contracting Officer's Technical Representative (COTR): The person or entity, appointed by the Owner to represent their interest in the review and approval of the work and to serve as the contracting authority with the Contractor. The Smithsonian COTR may appoint other persons to review and approve any aspects of the work.

P. Soil Horizons: distinct layers of the soil profile distinguished by differences in such features as color, texture, organic matter content, and other characteristics as defined in the USDA National Soil Survey Handbook

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242.

Q. Soil Mix: Specialized soil types produced as a result of the combination of Base Soil with soil components (such as Coarse Sand, Compost, or **Lightweight Aggregate**) as defined in ***Part 2 – Section 2.4.A***.

R. Soil Tilling: Loosening the surface of the soil to the depths specified with acceptable mechanical equipment as further defined in this specification.

S. Soil Organic Matter: natural occurring organic matter that is a stable part of the soil matrix. Compost is not considered soil organic matter.

T. Subgrade: surface or elevation of subsoil remaining after completing excavation, or top surface of a fill or backfill, or the top elevation of required drainage layers above structure before placing planting soil.

U. Weeds: Any plant that is not on the planting plan.

1.9 LONG LEAD ITEM

A. The Contractor shall be advised that the sourcing, testing, procurement and installation of Planting Soil is a CRITICAL PATH item, requiring timely attention to meet the requirements of the Documents. Having been informed that all aspects of planting soil, the Contractor shall consider this to be A LONG LEAD TIME ITEM. Contractor's failure to heed this notice shall not be a reason for substitution of unacceptable material(s). The SMITHSONIAN COTR will not accept materials that do not meet requirements.

1.10 SUBMITTALS

A. See the contract General Conditions for policy and procedures related to submittals.

B. Planting Soils Installation Plan: Submit, a minimum of twelve (12) weeks prior to the anticipated date of the start of soil installation, a Planting Soils Installation Plan that includes a written narrative of soil procurement, testing, mixing, delivery, storage and handling; mock up preparation, locations and installation process.

The plan shall include the projected timeline for soil work and describe all equipment to be used to mix, deliver, spread, grade and compact the soil. Particular attention should be paid to contingency plans and/or schedule modification options due to the impact of weather on soil moisture, delivery, storage, and handling.

C. Base Soil Source:

1. Submit source information of Base Soil including:
   a. Soil supplier name
   b. Name of contact
   c. Mailing address
   d. Physical address of soil harvesting site or soil stock pile
   e. Phone number

D. Submit all product submittals twelve (12) weeks prior to the start of the soil work.

E. Soil Mix components' Product Data and Samples: For each type of manufactured product, submit data and certificates that the product meets the specification requirements, signed by the product manufacturer, and complying with the following:

1. Submit manufacturers or supplier's product data and literature, and certified analysis for standard products and bulk materials, complying with testing requirements and referenced standards and specific requested testing.

2. Submit soil analytical test results as described in ***Section 1.10.F.2*** below.

F. Soil Testing for Base Soil, **Planting Soil**, **Lawn Soil**, **High-Use Lawn Soil**, **Biofiltration Soil** and **Lightweight Extensive Soil**.

1. Submit soil test analysis report for each sample of Base Soil and the Soil Mixes from an approved soil-testing laboratory and where indicated in Part 2 of the specification as follows:
   a. Submit Base Soil for testing at least twelve (12) weeks before scheduled installation of the Soil Mix.
   b. Submit Soil Mix tests no more than two (2) weeks after the approval of the Base Soil, Compost, Coarse Sand, and **Lightweight Aggregate**. Do not send any Soil Mix to the testing

laboratory for testing until the Base Soil, Compost, Coarse Sand, and **Lightweight Aggregate** have been approved.

c. If tests fail to meet the specifications, obtain other sources of material, retest and resubmit until accepted by the SMITHSONIAN COTR.
d. No soil components shall be used until certified test reports by an approved Testing Agency have been approved by the SMITHSONIAN COTR.
e. No Soil Mix shall be used until certified test reports by an approved testing laboratory have been received and approved by the SMITHSONIAN COTR.
f. If, at any time during the project, the Base Soil, soil components or Soil Mixes requires adjustment to meet the specifications and/or performance criteria, the Contractor shall submit the adjusted soil components and/or mixes for testing as specified herein.
g. All soil testing will be at the expense of the Contractor.
h. Failure to complete tests as specified will result in rejection of test results

2. For each type of test required, select and use the same testing laboratory throughout the work from the provided list below. Notify the SMITHSONIAN COTR of any change in laboratory and do not proceed until the SMITHSONIAN COTR has provided pre-approval of the change.
   a. Laboratory shall be an independent, certified laboratory with experience and capability to conduct the testing indicated and that specializes in the types of tests to be performed. Tests shall be made in strict compliance with the standards of the Association of Official Analytical Chemists and ASTM.
   b. The following table lists testing parameters, approved soil testing facilities, and specific laboratory testing packages that will provide required data. Testing agencies not listed below shall be approved by the SMITHSONIAN COTR.

Soil Test Requirements, Parameters, Approved Laboratories and Analytical Packages			
Soil Component	Test Parameter	Approved Labs	Laboratory Analytical Suite
Soil Compaction Curve	ASTM D698 - 12e2 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort	Terracon 4545 42nd St., NW, Suite 307 Washington, DC 20016 Phone: (202) 375 7900 Or approved equal	
Soil Gradation (Particle Size	Sieve Analysis (ASTM D6913M - 17 Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis) Sieve Nos. 4, 10, 18, 35, 60, 140, 270, Silt and Clay (pan)	Turf and Soil Diagnostics 613 E 1st St Linwood, KS 66052 Phone: 913-723-3700 Or approved equivalent	Particle Size Analysis
Soil Nutrient and Chemical Tests (Select 1 lab for testing for the duration of the project)	Soil Organic Matter Soil pH (active pH) Cation Exchange Capacity Electrical Conductivity (EC) Total Nitrogen (Kjeldahl N) Nitrate-N Available Phosphorus Potassium Magnesium Calcium	Ward Laboratories 4007 Cherry Ave, Kearney, NE 68847 Phone: (800) 887-7645	S-4 + Ammonium-N, Total N, Exchangeable Aluminum, Wet Aggregate Stability
		Waypoint Analytical Laboratories 7621 Whitepine Rd	S3M + Nitrate-Nitrogen, Ammonium-

Soil Test Requirements, Parameters, Approved Laboratories and Analytical Packages			
	Sodium Manganese Zinc Lead Boron Ammonium-N	Richmond, VA 23237 Phone: 804.743.9401	Nitrogen, Electrical Conductivity (EC), and Exch. Aluminum (Waypoint does not offer Total-N)
		Or approved equivalent	
Compost Testing (Select 1 lab for testing for the duration of the project)	pH Boron Calcium Copper Iron Magnesium Manganese Total nitrogen Ammonium-nitrogen Nitrate-nitrogen Organic-nitrogen C:N Ratio Phosphorus Potassium Sulfur Zinc Soluble salts Moisture Dry matter Wet Density	Woods End Laboratory 290 Belgrade Road Mt. Vernon ME 04352 Phone: 207-293-2457	Premium Analysis
		Ward Laboratories 4007 Cherry Ave, Kearney, NE 68847 Phone: (800) 887-7645	Manure & Compost Complete
		Or approved equivalent	
Soil Biological Tests (Both labs required)	PLFA (phospholipid-fatty acid) test Mycorrhizal spore counts Mycorrhizal root colonization	Ward Laboratories 4007 Cherry Ave, Kearney, NE 68847 MIDI Labs 125 Sandy Drive Newark, DE 19713	PLFA Wet Aggregate Stability
		Mycoroots 1970 NW Lance Way, Corvallis, OR 97330	Mycorrhizal spore count Mycorrhizal root colonization

G. Soil Samples for Base Soil, **Planting Soil**, **Lawn Soil**, **High-Use Lawn Soil**, **Biofiltration Soil** and **Lightweight Extensive Soil**:

Submit samples of each product, concurrently with the submission of the laboratory test reports to the SMITHSONIAN COTR for approval. Samples shall be submitted in two-gallon bags and labeled to indicate product, characteristics, and locations in the work. Samples arriving without labels will be rejected. Samples will be reviewed for consistency with specification requirements as can be reasonably ascertained and with certified data.

1. Submit samples a minimum of twelve (12) weeks prior to the anticipated date of the start of soil installation.

2. Samples of Base Soil and the Soil Mixes shall be submitted at the same time as the required soil testing analysis of that material, per ***Section 1.10.F.2*** above. Analysis data and Samples that don't arrive together, thereby verifying the sample matches the data, will be rejected.

H. Subgrade Infiltration and Density testing reports:

1. See requirements for testing in ***Section 1.15B*** below.

1.11 SOIL INSTALLATION MOCKUP

A. Prior to installation of Planting Soils, construct at the site a mockup of each Soil Mix required and configuration using the means and methods and equipment proposed by the Contractor to complete the work. Installation of the mockup shall be in the presence of the SMITHSONIAN COTR. The purpose of the mockup is to test the methods of installation, finish grading and compaction of the soil and to serve as a benchmark for completed soil compaction. The mockup shall be as follows:

1. Mockup of the following Soil Mix to be provided:
   a. **Planting Soil**
   b. **Lawn Soil**
   c. **High-Use Lawn Soil**
   d. **Biofiltration Soil**
   e. **Lightweight Extensive Soil**

2. The mockup area may remain as part of the installed work at the end of the project if protected from further compaction, contamination, or other disturbance.
   a. Locate mock-up on site in a proposed planting area easily referenced by workers performing soil installation and finish grading operations.

3. Where soil mockups are intended to remain in place, complete subgrade soil infiltration and density testing per the requirements outlined in ***Section 1.15B*** below, before construction of the soil mockup.

4. Following acceptance of the soil submittals, in areas that can be protected from disturbance and further compaction, install mockups of each Soil Mix, configuration and soil modification, 3-meter X 6 meter (10-foot X 20-foot) X the full depth of the deepest installation, using the requirements of these specifications. Compaction methods, including the type of compaction equipment and number of passes required to achieve the required compaction shall be evaluated and results measured.

5. Compaction in the mockup soil shall be examined and tested as described below:
   a. Soil density and moisture shall be tested using a nuclear soil density gauge (nuclear densometer) if required by the SMITHSONAIN COTR. Soil density (measured as the percent derived from the dry density divided by the maximum dry density) shall be tested to confirm that soil installation methods will achieve specified soil conditions (density and moisture). Results of nuclear soil density testing shall be used to compare to other soil density and compaction testing methods that are specified in this section.
   b. Cone penetrometer (see ***Part 1.14.G*** below). A cone penetrometer will be used to test for compacted layers or changes in soil density within an installed soil profile. A minimum of four readings from each Soil Mix shall be taken at the specified depths of the soil profile. Readings from the cone penetrometer will be compared to results of the nuclear soil density gauge to provide a relative basis of soil compaction measurements.
   c. Cone penetrometer must only be used in dry to moist soils (described as the Acceptable Condition in ***Section 1.16.A***). The Penetrometer cannot be used in excessively dry or very moist or wet soils. Refer to the section noted above for requirements concerning soil moisture levels.
   d. In the event that the nuclear soil density gauge or the cone penetrometer readings exceed the specified densities, reconstruct the mockup, adjusting the soil compaction methods to

achieve the desired results.

e. Conduct visual observations of soil structure. Record changes in soil particle configuration, such as platy (soil forms plate-like structure), massive (soil appears to have no form, with no observable soil pores), or granular (soil has distinct peds, or soil particles that are friable and break easily).

f. Where the modification requires ripping, tilling or fracturing soils that are over compacted, start the procedure in a new location so that the process is working on soil that is similar to the density of the expected soil.

6. Contractor shall submit a report of the final methods of soil installation to the SMITHSONIAN COTR. This shall include all penetrometer, nuclear densometer, and soil moisture readings that were catalogued during the mockup process.

7. Provide a protective 1.2-meter-high (4-foot) fence around each mockup to keep all work and equipment from entering the surface of the mockup area.

1.12 OBSERVATION OF THE WORK

A. The SMITHSONIAN COTR may observe the work at any time. They may remove samples of materials for conformity to specifications. Rejected materials shall be immediately removed from the site and replaced at the Contractor's expense. The cost of testing materials not meeting specifications shall be paid by the Contractor.

1. Should the SMITHSONIAN COTR determine the need for nuclear densometer testing, he/she may request use of the Contractor’s nuclear densometer (by a qualified professional) or cone penetrometer at any time to check soil compaction and moisture.

B. The SMITHSONIAN COTR shall be informed of the progress of the work, so the work may be observed at the following key times in the construction process. The SMITHSONIAN COTR shall be afforded sufficient time to schedule visit to the site. Each required review may require multiple visits to reflect the phasing of work. Failure of the SMITHSONIAN COTR to make field observations shall not relieve the Contractor from meeting all the requirements of this specification.

1. SOIL MOCKUP REVIEW: At the time of construction of all soil mockups.

2. SUBGRADE REVIEW: Observe each area of soil installation including planter drainage and waterproofing work prior to the installation of any the Planting Soils.

3. COMPLETION of PLANTING SOILS INSTALLATION: Upon completion of all soil modification and installation of the Planting Soils.

4. COMPLETION OF FINE GRADING AND SURFACE SOIL MODIFICATIONS REVIEW: Upon completion of all surface soil modifications and fine grading but prior to the installation of shrubs, ground covers, or lawns.

1.13 PRE-CONSTRUCTION MEETING

A. Schedule a pre-construction meeting with the SMITHSONIAN COTR at least seven (7) days before beginning work to review any questions the Contractor may have regarding the work, administrative procedures during construction and project work schedule.

1.14 QUALITY ASSURANCE

A. Installer Qualifications: The installer shall be a firm having at least ten(10) years of experience of a scope similar to that required for the work, including the preparation, mixing and installation of soil mixes to support planting. The installer shall be experienced with the installation of plants and soil in on-grade and over-structure conditions.

1. The bidders list for work under this section shall be approved by the SMITHSONIAN COTR.

2. Installer Field Supervision: When any planting soil work is in progress, installer shall maintain, on site, an experienced full-time supervisor who can communicate in English with the SMITHSONIAN COTR.

3. Installer's Field Supervisor shall have a minimum of five (5) years' experience as a field supervisor installing soil in on-grade and over-structure conditions, shall be trained and proficient in the use of field surveying equipment to establish grades and can communicate in English with the SMITHSONIAN COTR.

4. The installer's crew shall be experienced in the installation of planting soil, plantings, and interpretation of planting plans, and soil installation plans.

5. Submit references of past projects and employee training certifications that support that the Contractors meet all of the above installer qualifications and applicable licensures.

B. Soil Supplier Qualifications: The soil supplier shall be a firm having at least five (5) years of experience of a scope similar to that required for the work, including the preparation, mixing and delivery of soil to support planting, including experience with the installation of plants and soil in Washington, D.C***. It is the intent of this specification to use unscreened naturally formed loam soils sourced from the Piedmont region in Virginia and local parts of Maryland (generally west of I-95). These soils typically have characteristics (soil clay content, structural stability, and native organic matter content) that favor stable aggregate structure formation, drainage, and compaction resistance.*** The soil supplier shall be located in the area where these soils are found.

C. Installer and Soil Supplier Bidders List: The bidders list for work under this section shall be approved by the SMITHSONIAN COTR prior to the start of the bidding process. Submit bidders list for approval.

1. Pre-approved soil supplier:
   a. JK Enterprise Landscape Supply
      15900 Lee Highway
      Culpepper, VA 20121
      P: 703-926-1967

   b. Luck Ecosystems
      PO Box 29682
      Richmond, VA 23242
      P: 877-904-5825

   c. Or approved equal

2. Pre-approved compost supplier:
   a. Leafgro
      Multiple bulk distributors available

   b. WeCare Denali
      7800 Kabik Ct.
      Woodbine, MD 21797
      P: 410-795-7666

D. Soil testing laboratory qualifications: an independent, certified and accredited testing laboratory, with the experience and capability to conduct the testing indicated and that specializes in USDA agricultural soil testing, planting soil, and the types of tests to be performed. Geotechnical engineering testing labs shall not be used for chemical analyses.

E. Base Soil source inspection: The SMITHSONIAN COTR may inspect the Base Soil source stock piles as part of the approval process. The Soil Supplier shall accompany the SMITHSONIAN COTR.

If multiple sites or options are to be considered, arrange the inspection trip such that all optional locations can be inspected in one day. The SMITHSONIAN COTR may remove samples of the material as a record of the inspection and independent testing as needed.

F. All delivered and installed Planting Soils shall conform to the approved submittals sample color, ped sizes and distribution, texture and approved test analysis.

1. The SMITHSONIAN COTR may request samples of the delivered or installed soil be tested for analysis to confirm the Soil Mix conforms to the approved material.
2. All testing shall be performed by the same soil lab that performed the original Soil Mix testing.
3. Testing results shall be within 10% plus or minus of the values measured in the approved Soil Mix.
4. Any Soil Mix that fails to meet the above criteria, if requested by the SMITHSONIAN COTR, shall be removed and new soil installed.

G. Soil compaction testing: following installation or modification of soil, test soil compaction as follows:

1. Soil density shall be measured using a nuclear densometer (Troxler nuclear soil density gauge or equivalent) if required by the SMITHSONIAN COTR. Soil density shall be reported as a measured percentage derived from the dry density divided by the maximum dry density (See ***Section 1.10.F.2***).
   a. Soil density testing using a nuclear densometer must be completed by a certified operator.
   b. One soil density measurement shall be completed after the second 12" lift of soil. This will be used to calibrate acceptable soil density and establish the approved cone pentrometer readings.
   c. Soil density results must be within the range specified in Part 3 of this Section.
2. Soil compaction for detection of compacted layers shall be tested using a static cone penetrometer using method ASTM D3441 - 16 Standard Test Method for Mechanical Cone Penetration Testing of Soils. This test shall not be used on wet soils.
   a. Maintain at the site, at all times, a soil cone penetrometer with pressure dial and a soil moisture meter to check soil compaction and soil moisture.
   b. Penetrometer shall be AgraTronix Soil Compaction Meter distributed by Forestry Suppliers, www.forestry-suppliers.com or approved equal.
   c. Prior to testing the soil with the penetrometer check the penetrometer readings in the mockup soils. Penetrometer readings are impacted by soil moisture and excessively wet or dry soils will read significantly lower or higher than soils at optimum moisture.
      1.) Refer to ***Section 1.16.A*** for requirements concerning soil moisture levels.
3. Soil penetrometer readings shall be completed at 150mm (12-inch) intervals for the full depth of the soil profile. These shall be recorded for review by the SMITHSONIAN COTR.
4. The penetrometer readings shall be within 20% plus or minus of the readings in the approved mockup when at similar moisture levels.

H. Soil infiltration testing shall be completed for each Soil Mix or area installed. Soil infiltration testing shall be conducted using ASTM D3385 - 18: Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer (Falling head method).
   a. A 150mm (6") inner ring / 300mm (12") outer ring Double Ring Infiltrometer shall be used.
      1.) Turf-Tec IN7-W Infiltration Rings, 12˝ OD/6˝ ID by 4˝ Tall distributed by Forestry Suppliers, www.forestry-suppliers.com or approved equal.
      2.) Maintain the Double-Ring Inflitrometer at the site at all times.
   b. One infiltration test per planting area shall be sufficient.

1.15 SITE CONDITIONS

A. It is the responsibility of the Contractor to be aware of all surface and subsurface conditions, and to notify the SMITHSONIAN COTR, in writing, of any circumstances that would negatively impact the health of plantings. Do not proceed with work until unsatisfactory conditions have been corrected.

1. Should subsurface drainage or soil conditions be encountered which would be detrimental to growth or survival of plant material, the Contractor shall notify the SMITHSONIAN COTR in writing, stating the conditions and submit a proposal covering cost of corrections. If the Contractor fails to notify the SMITHSONIAN COTR of such conditions, they shall remain responsible for plant material under the warrantee clause of the specifications.

2. This specification requires that all planting soil and irrigation (if applicable) work be completed and accepted prior to the installation of any plants.

B. Subgrade (subsoil) drainage:

1. Perform infiltration and density tests on subsoil:
   a. Infiltration rate for subgrade, Min. 0.25” per hour
      1.) See ***Section 1.14.H*** for testing procedure.
   b. Compaction rate for subgrade, static cone penetrometer method:
      1.) 0 -150mm (0-6”) depth: Range 120 to 180 pounds per square in (psi)
      2.) 150mm - 300mm (6”-12”) depth: Range 160 to 220 psi.
      3.) See ***Section 1.14.G.2*** for testing procedure.

2. Submit test results as part of the Submittals in ***Section 1.10*** above.

1.16 DELIVERY, STORAGE, AND HANDLING

A. Weather: Do not mix, deliver, place or grade soils when frozen or with moisture greater than 70 percent of moisture level for optimum soil compaction as determined from Standard Proctor tests. Doing so is cause for the SMITHSONIAN COTR to reject the soil outright.

1. In addition to obtaining soil moisture levels from a nuclear soil density gauge, moisture can be determined by feel in the following manner:

   a. With a handful of soil, form a ball by compressing the soil together.
      1.) Above Field Capacity: If the ball glistens or is plastic (can form a ribbon or be molded), it is too wet.
      2.) Nearing Field Capacity: If the ball breaks fractures into large pieces but not individual peds, it is too moist for handling.
      3.) Acceptable Condition: If the ball breaks into individual soil peds with little hand pressure, it is then suitable for handling and spreading.
      4.) At or Below Wilt Point: If the soil is unable to form a ball with hand pressure, it is unsuitable for handling and spreading.

B. Protect soil and soil stockpiles, including the stockpiles at the soil blender’s yard, from wind, rain and washing that can erode soil or separate fines and coarse material, and contamination by chemicals, dust and debris that may be detrimental to plants or soil drainage. Cover stockpiles with plastic sheeting or fabric at the end of each workday.

C. Planting Soils shall be stockpiled, loaded, unloaded and transported using methods that protect the size percentage range and distribution of soil peds within the soil.

1. Soil Mixes shall not be allowed to remain in stockpiles for longer than six (6) weeks, either at the soil source or the project site. If the soil will be stockpiled for longer than six (6) weeks, it must be planted to a cover crop or covered with mulch to protect it from sun/heat, rain, and wind erosion. ***The intent of this requirement is to harvest soil from the source only as it is needed and have it directly delivered to the project site, and then installed very soon after delivery. This minimizes soil handling and resulting soil degradation and saves storage space and***

maintenance. Careful planning and close coordination between the contractor and soil provider is essential.

2. Use of soil shooters, soil blowers, augers, and conveyors with drops greater than 1-meter (3 feet) or other soil conveyance devices that break up soil peds shall be prohibited. Craned soil in large bulk bags are permitted provided that the process to place the soil into the bags and empty them at the site respects the need to protect soil peds.

D. All manufactured packaged products and material shall be delivered to the site in unopened containers and stored in a dry enclosed space suitable for the material and meeting all environmental regulations. All products shall be freshly manufactured and dated for the year in which the products are to be used.

E. Bulk material: Coordinate delivery and storage with the SMITHSONIAN COTR and confine materials to neat piles in areas acceptable to the SMITHSONIAN COTR.

1.17 EXCAVATING AND GRADING AROUND UTILITIES

A. Contractor shall carefully examine the civil, record, and survey drawings to become familiar with the existing underground conditions before digging.

B. Determine location of underground utilities including irrigation and electrical systems and perform work in a manner that will avoid damage. Hand excavate as required. Maintain grade stakes set by others until parties concerned mutually agree upon removal.

1. Prior to Work commencement review and clearly mark in field horizontal and vertical locations of existing public underground utilities and structures with respective utility companies.

2. Prior to Work commencement review and clearly mark in field horizontal and vertical locations of existing private underground utilities and structures with the SMITHSONIAN COTR or the qualified party responsible for completing this work.

PART 2 – PRODUCTS

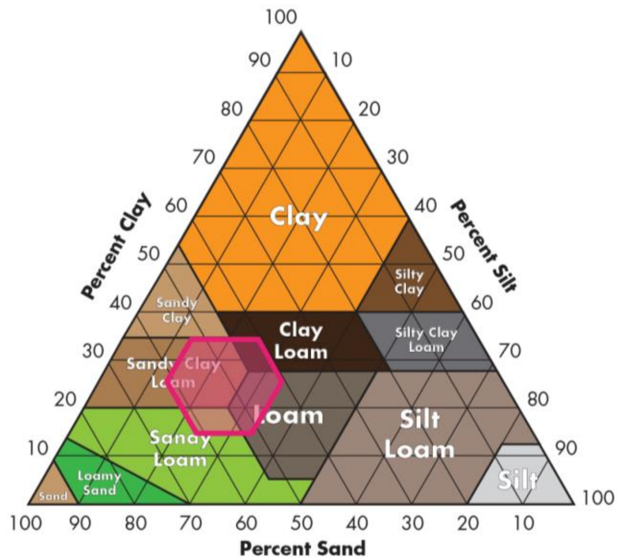
2.1 BASE SOIL

A. Base Soil definition: Fertile, friable soil containing 15% or less of a total volume of the combination of subsoil, refuse, roots larger than 25mm (1-inch) diameter, clumps of heavy, sticky or stiff clay, stones larger than 75mm (3 inches) in diameter, noxious seeds, sticks, brush, litter, or any substances deleterious to plant growth. The percent (%) of the above objects shall be controlled by source selection, *not by screening the soil*. Base Soil shall be suitable for the germination of seeds and the support of vegetative growth. Base Soil shall not contain weed seeds in quantities that cause noticeable weed growth and hazardous weed species in the planting beds. *This can be controlled by selection of the soil source site and soil management/cover crops*. The contractor shall remove all weeds as they emerge.

B. Base Soil shall be a defined as a ***Clay Loam, Loam, Sandy Loam, or Sandy Clay Loam*** having between 17 to 37 percent clay, between 15 to 35 percent silt, and between 40 to 62 percent sand; that will be similar to or match the surrounding topsoil layer. For example, if the topsoil layer is loam soil, the imported soil must also be loam soil with similar organic matter content. Soils imported for subsoil layers, if necessary, must be similar to or match the surrounding subsoil. Soil with greater than 35 percent silt will be rejected.

1. If required, Base soil may be tested for wet aggregate stability, with results showing more than 60 percent stable soil aggregates greater than 0.20 mm

2. Soil structure should have an identifiably strong aggregation of particles in the form of peds, or small clumps, commonly seen in soils characterized as granular or subangular blocky.



3. Chemical properties: Base Soil shall have the following soil chemical properties:

Item	Units	Range
Organic Matter Content	%	2.5 - 6
Total Nitrogen	mg kg^{-1}	>200
Ammonium-nitrogen	mg kg^{-1}	>10
Nitrate-nitrogen	mg kg^{-1}	>5
Available Phosphorus	mg kg^{-1}	>50
pH	Std Units	5.5 – 7.3
Cation Exchange Capacity (CEC)	meq/ 100 gm soil	>17
Soluble Salts/ Electrical Conductivity (EC)	dS.m- 1	<1
Potassium	mg kg^{-1}	>90
Calcium	mg kg^{-1}	>800
Magnesium	mg kg^{-1}	>200
Sodium	mg kg^{-1}	<180
Sulphate-S	mg kg^{-1}	>20
Lead	mg kg^{-1}	<50
Manganese	mg kg^{-1}	<200
zinc	mg kg^{-1}	<150
boron	mg kg^{-1}	<3
Exch. Aluminum	mg kg^{-1}	< 200

C. Base Soil may be a harvested soil from fields or development sites. The organic content and particle size distribution shall be the result of natural soil formation. Manufactured soils where Coarse Sand, composted organic material or chemical additives has been added to the soil to meet the requirements of this specification section shall not be acceptable. Retained soil peds shall be the same color on the inside as is visible on the outside.

D. Base Soil shall NOT have been screened. Soil may retain soil peds or clods larger than 2 inches in diameter throughout the stockpile after harvesting as determined by visual inspection by the SMITHSONIAN COTR.

E. Base Soil Moisture: Protect the Base Soil from rain as required. Soil moisture shall be sufficient when it retains moisture, enabling a friable structure when squeezed, but not in such a wet condition as to leave mud on the hand (see field moisture determination procedure above). Cover the piles after harvesting and uncover during mid-summer/fall drought periods to dry out the soil if project schedule permits.

F. Submit sample from the Base Soil source location per requirements outlined in ***Section 1.10.G.*** The sample shall be a mixture of the random samples taken around the source stockpile or field. The soil sample shall be delivered with soil peds intact that represent the size and quantity of expected peds in the final delivered soil.

2.2 COARSE SAND

A. Coarse Sand for amending the Base Soil (if required) shall be uniformly graded coarse sand consisting of clean, inert, rounded to sub-angular grains of quartz or other durable rock free from loam or clay, surface coatings, mica, and other deleterious materials. There shall be no coarse fragments over 1.0 cm in size or visible organic matter present. Particle size distribution for material passing a Number 4 Sieve shall be:

U.S. Sieve Size	% Passing Minimum	% Passing Maximum
4	90	100
10	75	95
18	48	75
35	20	45
60	0	20
140	0	5
270	0	3
0.002 mm	0	1

1. The pH shall not exceed 7.8 as determined from a 1:1 soil-distilled water suspension using a glass electrode pH meter American Society of Agronomy Methods of Soil Analysis, Part 2, 1986.

B. Submit testing sample per requirements outlined in ***Section 1.10.E***.

2.3 COMPOST

A. Compost shall be a stable, humus-like material produced from the aerobic decomposition and curing of organic vegetative residues derived from feedstock consisting of woody stems, leaves, grass cuttings, and livestock manure (up to 10 percent of the compost mix by volume). No food products are acceptable as part of the compost feedstock. The compost shall be a dark brown to black color and be capable of supporting plant growth with appropriate management practices with no visible free water or dust, with no unpleasant odor. Compost shall contain no more than 1 percent foreign materials by weight, and be capable of passing through a one-half inch screen. Compost shall not have become anaerobic during the processing and storage process.

B. Compost shall be commercially prepared Compost and meet US Compost Council STA/TMECC criteria or as modified in this section for “Compost as a Landscape Backfill Mix Component”.

http://compostingcouncil.org/admin/wp-content/plugins/wp-pdfupload/pdf/191/LandscapeArch_Specs.pdf

C. Chemical Properties - Compost shall conform to the following values:

Item	Units	Range
Organic Matter	Percent	>35%
Total Nitrogen	ppm	>1500
Carbon:Nitrogen Ratio	No units	Between 10:1 to 20:1
Extractable Nitrate	ppm	20-200
Total Phosphorus	ppm	5-2000
Available Phosphorus	ppm	5-200
pH	Std Units	5.5 - 8.0
Salt concentration	dS.m- 1	<6
Moisture	% wt	30-55

1. One hundred percent of the material shall pass a 1/2-inch (or smaller) screen. Debris such as metal, glass, plastic, wood (other than residual chips), asphalt or masonry shall not be visible and shall not exceed one percent dry weight.

2. The Compost shall be screened to ½-inch maximum particle size and shall contain no more that 3 percent material finer than 1.0mm (No. 18 sieve) as determined by sieve analysis.
   a. Additional tests defined in Part I as Chemical Properties shall be performed and the results shall be utilized to evaluate amendments to the Soil Mixes that may be required.

3. Maturity:
   a. C02 test: Compost respiration shall be no more than 6 mg C02-ClgBVS day.
   b. Solvita test: The compost must achieve a maturity index of 6 or more.

4. Biological Values:
   a. Active bacteria and fungi are not to be higher than 10 percent of total bacteria and fungi respectfully.
   b. Total bacteria to be a minimum of 1500 ng/g
   c. Total fungi to be a minimum of 400 ng/g
   d. Protozoa to be 100,000 (amoeba and flagellates with no more 3000 ciliates)

5. Pathogens/Metals/Vector Attraction reduction shall meet 40 CFR Part 503 rule, Table 3, page 9392, Vol. 58 No. 32.

D. Submit testing and sample per requirements outlined in ***Section 1.10.E***.

2.4 LIGHTWEIGHT AGGREGATE

A. Shall be a 5/8” lightweight expanded shale or clay, produced by the rotary kiln process and meeting the requirements of ASTM E2278-M18. Lightweight expanded shale shall have a proven record of durability and be non-corrosive, with the following properties:

1. Soundness Loss: Max 30% with 4 cycles of Magnesium sulfate, in accordance with AASHTO T104

2. Abrasion Resistance: Max 40% in accordance with ASTM C131.

3. Chloride Content: Max. 100 ppm in accordance with AASHTO T 291.

2.5 NO. 8 PEA GRAVEL

A. Shall be clean, dried and free of organic/deleterious materials, conforming to ASTM C-33 specifications for 3/8" aggregate.

2.6 NO. 57 STONE

1. Shall be clean, coarse, open-graded, self-compacting aggregate blend of size 5, 6, & 7 stone.
   a. NO. 57 Stone shall conform to the following particle size:

U.S. Sieve Size	% Passing Minimum	% Passing Maximum
1.5 inch	100	100
1 inch	95	100
0.5 inch	25	60
#4	0	10
#8	0	8
18	0	0
270	0	0
0.002 mm	0	0

2.7 SOIL MIXES

A. All Soil Mixes shall be blended and prepared with the components (Base Soil, Compost, Coarse Sand, and **Lightweight Aggregate**) in the ratios summarized below. Preparation of Soil Mixes shall follow the requirement of Part 3 – Execution. Specific blending details are outlined per Soil Mix below.

SOIL MIX	**Base Material**	**Second Component**	**Third Component**	**Ratio by Volume**
Planting Soil	Base Soil	Compost *(if req'd)*		5 pts base soil to 1 pt compost *(if req'd)*
Lawn Soil	Base Soil	Compost *(if req'd)*		4 pts base soil to 1 part compost
High-Use Lawn Soil	Base Soil *(Clay Loam or Sandy Clay Loam)*	Coarse Sand	Compost	2 pts base soil to 3 pts coarse sand to 1 pt compost
	Base Soil *(Loam or Sandy Loam)*	Compost	Coarse Sand *(if req'd)*	4 pts base soil to 1 pts compost *(add 1 pt coarse sand if req'd)*
Biofiltration Soil	Base Soil *(Clay Loam or Sandy Clay Loam)*	Coarse Sand	Compost	2 pts base soil to 4 pts coarse sand to 1 pt compost
	Base Soil *(Loam or Sandy Loam)*	Compost	Coarse Sand *(if req'd)*	3 pts base soil to 2 pts compost *(add 1 pt coarse sand if req'd)*
Lightweight Extensive Soil	Base Soil	Lightweight Aggregate	Compost	4 pts base soil to 4 pts lightweight aggregate to 1 pt compost

B. Estimated Soil Mix Densities for determining structural bearing capacity in applications over-structure are provided below. Estimated densities assume approximately 50 percent porosity and 2.5 percent organic matter in Planting Soil; 47 percent pore space for Lawn Soils, and 35 percent porosity and no organic matter in Coarse Sand.

SOIL MIX OR COMPONENTS	**Dry Density**	**Saturated Density**
Planting Soil	82 to 87 lbs/cu ft	110 to 114 lbs/cu ft
Lawn Soils	85 to 90 lbs/cu ft	113 to 118 lbs/cu ft
Biofiltration Soil	106 to 110 lbs/cu ft	125 to132 lbs/cu ft
Lightweight Extensive Soil	69 to 75 lbs/cu ft	92 to 101 lbs/cu ft
Coarse Sand	109 to 115 lbs/cu ft	127 to 132 lbs/cu ft

2.8 PLANTING SOIL

A. Planting Soil shall consist of Base Soil harvested from the soil source site. If the Base Soil has organic matter greater than 3.0 percent, and the soil is dark brown with strong aggregate structure (with discernable peds indicating granular or subangular blocky composition), no blending of amendments shall be done and the soil shall be used without further processing unless large rocks, sticks, or other debris greater than 75mm (3 inches) are present. Large items may be manually removed from the soil (preferred) or, if necessary, screened through a screen with 50mm – 75mm (2- to 3-inch) openings (only if large objects are greater than 10 percent of the harvested soil material). Soils must be examined and approved of by the SMITHSONIAN COTR.

1. If the soil organic matter content is less than 3.0 percent, the Planting Soil shall be blended with compost in a ratio of 10 parts Base Soil to 1 part Compost for each percentage point less than 3 percent. The Planting Soil shall be blended to be a uniform, homogenous mixture of the soil components. Additives to achieve specified criteria are not acceptable.

2. Mix Compost into the soil with a loader bucket to loosely incorporate it into the Base Soil as follows.
    a. Soil moisture shall not be greater than 17 percent by weight of the Base Soil mass. Wetter soil will remain cohesive and not blend with compost well.
    b. Spread the Base Soil out as a layer approximately 380mm - 500mm (15-20 inches) deep.
    c. Place the Compost over the soil in a layer 75mm – 100mm (3- to 4-inches) thick.
    d. Using the loader bucket, push and lift the soil and compost into a pile, back-drag the pile only once and lift the soil/compost blend in the bucket and allow it to roll [gently] out of the bucket back into the pile.

3. DO NOT OVER MIX! Do not mix with a soil blending machine. Do not screen the soil. This specification assumes that the various other operations of loading and delivery and final spreading of the soil at the site will further mix the two components to an acceptable amount.

4. Base Soil moisture: Prior to mixing Planting Soil (*if required*), protect the Base Soil required for this mix from rain so that the soil moisture remains above wilt point and below field capacity. Soil moisture shall be between 8 to 17 percent by weight of the soil mass when blending with amendments or when handling. Soil with greater than approximately 15 percent moisture may lose critical soil structure if handled too much. Soil with less than 8 percent moisture by weight may be too brittle and soil peds may shatter into structureless soil particles that will become cemented or compacted when re-wetted.
    a. Cover the piles after harvesting and uncover during summer/fall drought periods to dry out the soil required and if project schedule permits.

b. See additional requirements for soil moisture as defined in ***Section 1.16.A***.

5. Planting Soil moisture: After mixing Planting Soil, protect from rain so that the soil moisture is sufficient to be friable and crumble when squeezed and not leave mud on the hand. Cover the piles after mixing and uncover during mid-summer/fall drought periods to dry out the soil if soil moisture requires and project schedule permits.

    a. See additional requirements for soil moisture as defined in ***Section 1.16.A***.

6. Submit Planting Soil sample per requirements outlined in ***Section 1.10.G.*** The sample should represent the size and distribution of the soil peds in the soil. Sample shall be marked with the proportion of Base soil to Compost. Submit testing data per requirements outlined in ***Section 1.10.F.***

    a. Planting Soil chemical qualities shall be tested and include:

Item	Units	Range
Total Organic Matter	Percent	3.0 – 5.0%
Total Nitrogen	mg kg^{-1}	>750
Ammonium-nitrogen	mg kg^{-1}	>20
Nitrate-nitrogen	mg kg^{-1}	>25
Available Phosphorus	mg kg^{-1}	>50
pH	Std Units	5.5 – 7.3
Cation Exchange Capacity (CEC	meq/ 100 gm soil	>17
Soluble Salts/ Electrical Conductivity (EC)	$dS.m^{-1}$	<1.0
Potassium	mg kg^{-1}	>90
Calcium	mg kg^{-1}	>700
Magnesium	mg kg^{-1}	>200
Sodium	mg kg^{-1}	<100
Sulphate-S	mg kg^{-1}	>20
Lead	mg kg^{-1}	<50
Manganese	mg kg^{-1}	<200
Exchangeable aluminum	mg kg^{-1}	<180
zinc	mg kg^{-1}	<50
boron	mg kg^{-1}	<3
Exch. Aluminum	mg kg^{-1}	<200

2.9 LAWN SOIL

A. Lawn Soil shall consist of Base Soil harvested from the soil source site that will be blended with Compost in a ratio of 4 parts Base Soil to 1 part Compost. If the Base Soil has organic matter greater than 3.0 percent, and the soil is dark brown with strong aggregate structure, no blending of is necessary and the soil shall be used without further processing unless large rocks, sticks, or other debris greater than 4 inches are present. The soil components shall be blended to a homogenous, uniform mix free of large clay clods, rocks or sticks greater than 50mm (2 inches) in any dimension, or debris that could affect plant growth and development.

If the combined fine (no. 140 screen) and very fine (no. 270 screen) sand fraction of the soil particle size is greater than 30 percent of the total soil texture, then Coarse Sand shall be added to the soil blend with a final ratio of 3 parts Base Soil to 1 part Compost to 1 part Coarse Sand. Additives to achieve specified criteria are not acceptable.

1. The soil components may first be blended using a loader bucket to loosely incorporate the Compost (and Coarse Sand, if required) into the Base Soil as follows.
   a. Spread the Base Soil out as a layer approximately 380mm - 500mm (15-20 inches) deep.
   b. Place the Compost over the soil in a layer 100mm (4 inches) thick.
   c. If coarse sand is required to be added to the blended soil, the Base Soil shall be placed in a layer approximately 380mm (15 inches) thick, upon which a 100mm (4-inch) layer of Compost and a 100mm (4-inch) layer of Coarse Sand will be placed over the Base Soil.
   d. Using the loader bucket, push and lift the soil and compost into a pile, back-drag the pile only once and lift the soil/compost blend in the bucket and allow it to roll [gently] out of the bucket back into the pile.
2. Blending shall be completed by use of a rotating mixer or a 50mm (2-inch) screen to more evenly mix the soil components.

B. Submit Lawn Soil sample per requirements outlined in ***Section 1.10.G***. Submit testing data per requirements outlined in ***Section 1.10.F***. Soil chemical qualities shall be tested and include:

Item	Units	Range
Total Organic Matter	Percent	>3.0%
Total Nitrogen	mg kg^{-1}	>700
Ammonium-nitrogen	mg kg^{-1}	>20
Nitrate-nitrogen	mg kg^{-1}	>25
Available Phosphorus	mg kg^{-1}	>50
pH	Std Units	6.5 – 7.8
Cation Exchange Capacity (CEC	meq/ 100 gm soil	>14
Soluble Salts/ Electrical Conductivity (EC)	dS.m^{-1}	<1.0
Potassium	mg kg^{-1}	>90
Calcium	mg kg^{-1}	>500
Magnesium	mg kg^{-1}	>200
Sodium	mg kg^{-1}	<100
Sulphate-S	mg kg^{-1}	>20
Lead	mg kg^{-1}	<50
Manganese	mg kg^{-1}	<200
Exchangeable aluminum	mg kg^{-1}	<180
Zinc	mg kg^{-1}	<50
Boron	mg kg^{-1}	<3
Exch. Aluminum	mg kg^{-1}	<200

1. Soil moisture shall be as defined in Section ***1.16.A***.
2. Protect prepared soils from rain during storage to prevent soils from becoming saturated during

storage. Cover the piles after mixing and uncover during mid-summer/fall drought periods to dry out the soil if soil moisture requires and project schedule permits.

2.10 HIGH-USE LAWN SOIL

A. High-Use Lawn Soil shall consist of Base Soil harvested from the soil source site that will be blended in a ratio per Soil Mix Table in ***Section 2.7.A***. If the Base Soil has organic matter greater than 3.0 percent, and the soil is dark brown with strong aggregate structure, no blending of is necessary and the soil shall be used without further processing unless large rocks, sticks, or other debris greater than 4 inches are present. The soil components shall be blended to a homogenous, uniform mix free of large clay clods, rocks or sticks greater than 50mm (2 inches) in any dimension, or debris that could affect plant growth and development.

1. The soil components may first be blended using a loader bucket to loosely incorporate the Coarse Sand and Compost into the Base Soil as follows.
   a. Spread the Base Soil out as a layer approximately 380mm - 500mm (15-20 inches) deep.
   b. Place the Compost over the soil in a layer 100mm (4 inches) thick.
   c. Add the Coarse Sand over the soil in a layer 100mm (4-inch) thick.
   d. Using the loader bucket, push and lift the soil and compost into a pile, back-drag the pile only once and lift the soil/compost blend in the bucket and allow it to roll [gently] out of the bucket back into the pile.

2. Blending shall be completed by use of a rotating mixer or a 50mm (2-inch) screen to more evenly mix the soil components.

B. Submit High-Use Lawn Soil sample per requirements outlined in ***Section 1.10.G***. Submit testing data per requirements outlined in ***Section 1.10.F***. Soil chemical qualities shall be tested and include:

Item	Units	Range
Total Organic Matter	Percent	>3.0%
Total Nitrogen	mg kg^{-1}	>700
Ammonium-nitrogen	mg kg^{-1}	>20
Nitrate-nitrogen	mg kg^{-1}	>25
Available Phosphorus	mg kg^{-1}	>50
pH	Std Units	6.5 – 7.8
Cation Exchange Capacity (CEC	meq/ 100 gm soil	>14
Soluble Salts/ Electrical Conductivity (EC)	dS.m^{-1}	<1.0
Potassium	mg kg^{-1}	>90
Calcium	mg kg^{-1}	>500
Magnesium	mg kg^{-1}	>200
Sodium	mg kg^{-1}	<100
Sulphate-S	mg kg^{-1}	>20
Lead	mg kg^{-1}	<50
Manganese	mg kg^{-1}	<200
Exchangeable aluminum	mg kg^{-1}	<180
Zinc	mg kg^{-1}	<50
Boron	mg kg^{-1}	<3

Exch. Aluminum	mg kg^{-1}	<200

1. Soil moisture shall be as defined in Section ***1.16.A***.
2. Protect prepared soils from rain during storage to prevent soils from becoming saturated during storage. Cover the piles after mixing and uncover during mid-summer/fall drought periods to dry out the soil if soil moisture requires and project schedule permits.

2.11 BIOFILTRATION SOIL

A. The Biofiltration Soil shall consist of the Base Soil blended in a ratio per Soil Mix Table in ***Section 2.7.A***, blended to a uniform, homogenous mix of soil components. The soil blend shall be free of large clay clods, rocks or sticks greater than 38mm (1.5 inches), or foreign debris.

1. Submit Biofiltration Soil sample per requirements outlined in ***Section 1.10.G***. Submit testing data per requirements outlined in ***Section 1.10.F***. Soil chemical qualities shall be tested and include:

Item	Units	Range
Total Organic Matter	Percent	2.0 – 6.0
Total Nitrogen	mg kg^{-1}	>450
Ammonium-nitrogen	mg kg^{-1}	>20
Nitrate-nitrogen	mg kg^{-1}	>25
Available Phosphorus	mg kg^{-1}	>50
pH	Std Units	6.0 – 7.8
Cation Exchange Capacity (CEC	meq/ 100 gm soil	>12
Soluble Salts/ Electrical Conductivity (EC)	dS.m^{-1}	<1.0
Potassium	mg kg^{-1}	>90
Calcium	mg kg^{-1}	>800
Magnesium	mg kg^{-1}	>200
Sodium	mg kg^{-1}	<100
Sulphate-S	mg kg^{-1}	>20
Lead	mg kg^{-1}	<50
Manganese	mg kg^{-1}	<200
Exchangeable aluminum	mg kg^{-1}	<180
Zinc	mg kg^{-1}	<50
Boron	mg kg^{-1}	<3
Exch. Aluminum	mg kg^{-1}	<200

B. Biofiltration drainage layers shall consist of the following:

1. No. 8 Pea Gravel as described in ***Part 2.5*** of this Section
2. No. 57 Stone as described in ***Part 2.6*** of this Section

C. The Biofiltration Soil shall comply with DOEE Filter Media Criteria for Bioretention.

2.12 LIGHTWEIGHT EXTENSIVE SOIL

A. Lightweight Extensive Soil shall be a blend of 50 percent Base Soil to 50 percent Lightweight Aggregate (1:1 blend ratio) to provide a uniform, homogenous blend of the soil components. The blended Soil/EC mix shall then be blended with compost in a ratio of 5 parts Soil/EC mix to 1 part compost. Blending using a rotating or tumbling drum or screen is recommended. The soil shall be tested for particle size distribution after blending to assure the proper ratio of expanded clay particles and soil particle sizes.

B. Submit Lightweight Extensive Soil sample per requirements outlined in ***Section 1.10.G***. Submit testing data per requirements outlined in ***Section 1.10.F***. Soil chemical qualities shall be tested and include:

Item	Units	Range
Total Organic Matter	Percent	>2.0%
Total Nitrogen	mg kg^{-1}	>500
Ammonium-nitrogen	mg kg^{-1}	>20
Nitrate-nitrogen	mg kg^{-1}	>25
Available Phosphorus	mg kg^{-1}	>50
pH	Std Units	6.5 – 7.8
Cation Exchange Capacity (CEC	meq/ 100 gm soil	>10
Soluble Salts/ Electrical Conductivity (EC)	dS.m^{-1}	<1.0
Potassium	mg kg^{-1}	>90
Calcium	mg kg^{-1}	>800
Magnesium	mg kg^{-1}	>200
Sodium	mg kg^{-1}	<100
Sulphate-S	mg kg^{-1}	>20
Lead	mg kg^{-1}	<50
Manganese	mg kg^{-1}	<200
Exchangeable aluminum	mg kg^{-1}	<180
Zinc	mg kg^{-1}	<50
Boron	mg kg^{-1}	<3

1. See additional requirements for soil moisture as defined in Section ***1.16.A***.

PART 3 – EXECUTION

3.1 COORDINATION WITH PROJECT WORK

A. The Contractor shall coordinate with all other work that may impact the completion of the work.

B. Prior to the start of work, submit and obtain approval of the Planting Soils Installation Plan and prepare a detailed schedule of the work for coordination with other trades.

C. Coordinate the relocation of any irrigation lines, heads or the conduits of other utility lines that are in conflict with tree locations. Root balls shall not be altered to fit around lines. Notify the SMITHSONIAN COTR of any conflicts encountered.

3.2 PRE-EXAMINATION, VERIFICATION AND ACCEPTANCE

A. A Pre-installation Examination with the SMITHSONIAN COTR is required for the work of this section. Schedule the examination at least five days before the installation process begins.

1. As the work proceeds, the Contractor shall schedule a pre-installation examination with the SMITHSONIAN COTR for each area of planting soil installation.

2. Reference ***Section 1.12*** for further requirements governing pre-installation examinations.

B. Upon receipt of delivery of the Soil Mixes, the Contractor shall visually inspect the soil for moisture content, non-aggregated soil particles, clumping, debris, deleterious or foreign materials, or any other physical conditions that could affect the quality of the soils and the Contractor's installation operations.

1. The Contractor shall immediately notify the SMITHSONIAN COTR of any soil deliveries that exhibit any of the physical conditions noted above.

2. The Contractor shall not accept or use soil that exhibits any of the physical conditions noted above.

C. The Contractor shall be responsible for verification that all of the planting areas receiving Soil Mixes have been prepared in conformance with the Contract Documents.

1. Verify that utilities have been installed and accepted.

2. Verify that irrigation mainlines have been installed.

3. Verify that there is a sufficient means for on-site watering of installed plants.

4. Verify that the rough grading has been accepted by the SMITHSONIAN COTR.

D. Examine subgrade for deficiencies including:

1. Construction debris present within the area to receive Soil Mixes.

2. Puddling of water, muddy soil conditions, or expressing of water from the subgrade or adjacent areas.

3. The subgrade is not at the correct depths for installing the planting soil.

4. Incomplete utility, irrigation and /or subsurface drainage installation.

5. Insufficient compaction of subgrade. Refer back to ***Section 1.15.B*** or the geotechnical subgrade requirements (*if applicable*) outlined in Specification **Section 00 0000 -- Earthwork**.

E. Submit all noted deficiencies that will impact the proper installation or execution of the Work to the SMITHSONIAN COTR in writing prior to beginning soil installation operations. The Contractor assumes responsibility for all subgrade work and conditions upon beginning soil installation operations.

3.3 GRADE AND ELEVATION CONTROL

A. Provide grade and elevation control during installation of the Soil Mixes. Utilize grade stakes, surveying equipment, and other means and methods to assure that grades and contours conform to the grades indicated on the plans.

1. Establish lines and levels, locate and lay out by instrumentation and similar appropriate means for planting area finish grades.

2. Provide as many grade stakes and string lines as required to achieve smooth finish grades acceptable to the SMITHSONIAN COTR with positive surface drainage.

3. High Points and Low Points: Provide grade stakes at high points and low points including top of

berms, catch basin rims and area drain rims.

3.4 SUBGRADE PREPARATION FOR ON-GRADE CONDITIONS

A. Protection of Existing Conditions:

1. Refer to Specification **Section 01 5639 – Site Protection** for requirements governing this work.

2. Submit written notification of conditions damaged during construction to the SMITHSONIAN COTR immediately.

B. Excavate to the proposed subgrade where applicable. Maintain all required angles of repose of the adjacent materials as shown on the drawings or as required by this specification. Do not over excavate compacted subgrades of adjacent pavement or structures. Maintain a supporting 1:1 side slope of compacted subgrade material along the edges of all paving and structures where the bottom of the paving or structure is above the bottom elevation of the excavated planting area.

C. Remove all construction debris and material including any construction materials from the subgrade.

D. Confirm that the subgrade is at the proper elevation and compacted if required. Subgrade elevations shall slope approximately parallel to the finished grade and/or toward the subsurface drain lines as shown in the Drawings.

E. Subgrade shall be scarified (roughened) to a depth of 75 – 150mm (3-6 inches) prior to placement of subsoil and Soil Mixes to create an uneven, broken surface in which the subgrade can be mixed with the first lift of Soil Mix placed. Scarification can be accomplished using a mini-disc, reverse tiller, or other suitable device as approved by the SMITHSONIAN COTR.

F. Perform infiltration and density tests on subsoil as described in ***Section 1.15.B***.

G. Protect adjacent walls, walks and utilities from damage or staining by the soil. Use 12.5mm (1/2-inch) plywood as directed to cover existing concrete, metal and masonry work and other items as directed during the progress of the work.

1. At the end of each working day, clean up any soil or dirt spilled on any paved surface.

2. Any damage to the paving or site features or work shall be repaired at the Contractor's expense.

3.5 PREPARATION FOR OVER-STRUCTURE CONDITIONS

A. Protection of Existing Conditions:

1. Refer to Specification **Section 01 5639 – Site Protection** for requirements governing this work.

2. Submit written notification of conditions damaged during construction to the SMITHSONIAN COTR immediately.

B. In areas of work over structure, confirm that all waterproofing and drainage layers are complete. Remove any debris from the surface of the drainage layer.

3.6 SOIL MOISTURE

A. Volumetric soil moisture level, in the Soil Mixes and the root balls of all plants, prior to, during and after soil installation and planting shall be above permanent wilt point and below field capacity. Reference ***Section 1.16.A.1*** for determining acceptable soil moisture levels for delivering, handling, placing, and grading activities. Failure to adhere to these requirements is cause for the SMITHSONIAN COTR to reject the soil outright.

3.7 SOIL INSTALLATION

A. **General**

1. Phase work such that equipment to deliver or grade soil and install Soil Mixes does not have to operate over previously installed soil work including lower lifts. Work in rows of lifts the width of the extension of the bucket on the loader. Install all lifts of the entire assembly in one row before proceeding to the next. Work out from the furthest part of each bed from the soil delivery point to the edge of each bed area.
2. The contractor shall continuously check the compaction of the soil installation with a cone penetrometer (at 150mm (12-inch) intervals), as the work progresses, to assure that penetration resistance conforms to the values of the mock up. Final compaction readings with the cone penetrometer should be taken for each planting area at the completion of soil installation (see ***Section 3.9***).
3. Installing soil using soil or mulch blowers or soil slingers shall not be permitted for planting soil due to the over mixing and soil ped breakdown cause by this type of equipment. Use of soil "Gaylord" bags craned into the site is permitted
4. Where travel over installed soil is unavoidable, limit paths of traffic to reduce the impact of compaction in planting soil.
    a. Wheel-driven vehicles are expressly forbidden to be allowed on installed soils. Only low-ground pressure (less than 6 psi), wide track 400mm to 600mm (18-24 inches) equipment may be allowed on installed soils and only along pre-approved corridors or lanes.
    b. All grading and soil delivery equipment shall have buckets equipped with 100 mm (6-inch) long teeth to scarify any soil that becomes compacted.
    c. Protect the surface of the soil in any areas that will receive repeated passes with motorized equipment with 19mm (3/4-inch) plywood matting.
        1.) 3/4" plywood shall only be used when the duration of use does not exceed three days. This is considered for temporary use only.
        2.) No part of any plywood matting shall be moved, altered, or changed in any way until access across, adjacent to, or through installed soil zones is no longer necessary or until the temporary use period has concluded.
    d. Till the surface of the soil with a mini-disc or reverse tiller to a depth of 150mm to 200mm (6-8 inches) when the plywood is removed.
    e. Each time equipment passes over the installed soil it shall reverse out of the area along the same path with the teeth of the bucket dropped to scarify the soil. In the event that the planting soil becomes over compacted, thereby failing to comply with ***Section 3.9***, the soil shall be removed in 12" lifts and the compaction retested until specified compaction levels are observed before proceeding with new soil installation.
5. Prior to installing Planting Soils, the SMITHSONIAN COTR shall approve the condition of the subgrade and the previous scarification.
    a. Immediately install the Soil Mix. Protect the loosened area from traffic. DO NOT allow the loosened subgrade to become compacted.
6. Compaction of soils to specified soil densities shall be accomplished using rollers, foot pressure, or manual tools.
    a. Vibratory, plate and jumping jack compactors, or impact methods (using a backhoe bucket or similar to impact or "hammer" the soil) are strictly prohibited.
7. In the event that the loosened area becomes overly compacted, loosen the area again prior to installing planting soil.
8. Where possible place trees on soil pedestals such that the elevation of the tree root flare will be at the planned finished soil elevation. Tree pedestals will be compacted to 90- to 95% of the soil's maximum dry density, using the Standard Proctor method, to resist settling of the soil from the weight of the tree.

B. **Planting Soil Installation**

1. After inspecting the base grade of the soil, the Planting Soil shall be installed in lifts not to exceed 300mm (12-inch) to the required depths as shown in the Drawings.
   a. Compact each lift gently and evenly to approximately 80 to 84 percent of the soil's maximum dry density using the Standard Proctor method
   b. After each lift has been successfully compacted, scarify the surface of the lift to a depth of 38mm (1.5 inches) and place the next soil lift. Repeat the placement of soil lifts for each soil layer until the Planting Soil grade elevation has been achieved.
   c. Measure soil compaction using a nuclear soil density gauge to attain the required soil density approved in the soil mock up.

2. Where trees will be planted / installed, pack each lift of Planting Soil around the base and rootball of the tree using manual tools (shovels, rakes) to assure that no voids are present around the rootball and that soil is firmly in place.
   a. Place the Planting soil in 300 mm (12-inch) lifts.
      1.) Compact each lift gently and evenly to approximately 80 to 84 percent of the soil's maximum dry density using the Standard Proctor method.
      2.) Scarify each lift to a depth of approximately 25mm (1 inch) prior to placement of each successive lift.
   b. After the final Planting Soil lift has been installed, grade the surface of the Planting Soil smooth and even. Scarify the final soil lift to create a firm, friable planting surface.

C. **Planting Soil Installation in Soil Cells**

1. Refer to Section 32 94 51 – Soil Cells

*(**Note to Specifier:** Specifications can be downloaded directly from Deeproot.com)*

D. **Planting Soil Installation in Raised Planters**

*(**Note to Specifier:** Section only required if raised planters used. Remove reference if not used)*

1. Planter Soils are expected to be installed in areas with limited space and access. Planter soils shall consist of a Planting Soil layer and a Compost till layer (surface).

2. Install the Planting Soil in lifts not to exceed 300mm (12-inch) to the required depths as shown on the Plans. Compact each lift using foot pressure or equivalent to gently and evenly compact soil to approximately 82 to 84 percent of optimum Standard Proctor soil density. After each lift has been successfully compacted, scarify the surface of the lift to a depth of 38mm (1.5 inches) and place the next soil lift. Repeat the placement of soil lifts for each soil layer until the Planting Soil grade elevation has been achieved. Measure soil compaction using the cone penetrometer as required to attain the soil density approved in the soil mock up.

   a. Prior to placement of successive lifts, determine soil density using the cone penetrometer. Resistance to penetrometer push shall be 110 to 170 psi.
   b. Pack each lift of Planting Soil firmly up to edges or walls of planter boxes using manual tools (shovels, rakes) to assure that no voids are present and that soil is firmly in place.
   c. After placement of all Planting Soil, the soil density shall be measure for the whole depth of the Planting Soil layer to check for uniform density and that clay or compaction pans are not present.

3. The Planting Soil shall be finished with a firm, friable planting surface.

E. **Lawn Soil Installation**

1. The Lawn Soil profile shall include the Planting Soil layer and the Lawn Soil.

2. Install the Planting Soil in lifts not to exceed 300mm (12-inch) to the required depths as shown in the Drawings. Compact each lift gently and evenly compact soil to approximately 82 to 84 percent of the soil's maximum dry density using the Standard Proctor method. After each lift has been successfully compacted, scarify the surface of the lift to a depth of 38mm (1.5 inches) and place the next soil lift. Repeat the placement of soil lifts for each soil layer until the Planting Soil grade elevation has been achieved. Measure soil compaction using the cone penetrometer as required to attain the required soil density approved in the soil mock up.
   a. Prior to placement of successive materials or lifts, determine soil density using the cone penetrometer. Resistance to penetrometer push shall be 110 to 170 psi.
   b. Where trees will be planted / installed, pack each lift of Planting Soil around the base and rootball of the tree using manual tools (shovels, rakes) to assure that no voids are present around the rootball and that soil is firmly in place.

3. Install the Lawn Soil in lifts not to exceed 300mm (12-inch) to the required depths as shown on the Plans. Compact each lift gently and evenly compact soil to approximately 82 to 84 percent of the soil's maximum dry density using the Standard Proctor method. After each lift has been successfully compacted, scarify the surface of the lift to a depth of 38mm (1.5 inches) and place the next soil lift. Repeat the placement of soil lifts for each soil layer until the final grade of the soil profile has been achieved, as required to attain the required compaction approved in the soil mock up.
   a. Prior to placement of successive materials or lifts, determine soil density using the cone penetrometer. Resistance to penetrometer push shall be 110 to 170 psi.
   b. After placement of all Lawn Soil, the soil density shall be measure for the whole depth of the Lawn Soil layer to check for uniform density and that clay or compaction pans are not present.
   c. The Lawn Soil shall be finished with a firm, friable planting surface.

F. **High-Use Lawn Soil Installation**

1. The High Use Lawn Soil profile shall include the Planting Soil layer, a Coarse Sand drainage layer and a Lawn Soil layer.

2. Install the Planting Soil in lifts not to exceed 300mm (12-inch) to the required depths as shown on the Plans. Compact each lift gently and evenly compact soil to approximately 82 to 84 percent of the soil's maximum dry density using the Standard Proctor method. After each lift has been successfully compacted, scarify the surface of the lift to a depth of 38mm (1.5 inches) and place the next soil lift. Repeat the placement of soil lifts for each soil layer until the Planting Soil grade elevation has been achieved. Measure soil compaction using a nuclear soil density gauge to assure the required soil density approved in the soil mock up.

3. Install the 150mm (6-inch) Coarse Sand drainage layer over the Planting Soil, taking care to minimize damage, including excess compaction, to the Planting Soil layer.
   a. The Coarse Sand drainage layer shall be installed evenly and raked smooth to a firm, smooth surface.
   b. The Coarse Sand drainage layer shall not be compacted.

4. Install the High-Use Lawn Soil in lifts not to exceed 200mm (8-inch) to the required depths as shown on the Plans. Compact each lift gently and evenly compact soil to approximately 82 to 84 percent of the soil's maximum dry density using the Standard Proctor method. After each lift has been successfully compacted, scarify the surface of the lift to a depth of 38mm (1.5 inches) and place the next soil lift. Repeat the placement of soil lifts for each soil layer until the final grade of the soil profile has been achieved, as required to attain the required compaction approved in the soil mock up.
   a. Prior to placement of successive materials or lifts, determine soil density using the cone penetrometer. Resistance to penetrometer push shall be 110 to 170 psi.
   b. After placement of all High-Use Lawn Soil, the soil density shall be measure for the whole

depth of the Lawn Soil layer to check for uniform density and that clay or compaction pans are not present.

c. The Lawn Soil layer shall be graded smooth and even and compacted using a roller, or previously approved means. Any uneven surface areas shall be graded smooth.

d. The Lawn Soil shall be finished with a firm, friable planting surface.

G. **Biofiltration Soil Installation**

1. Biofiltration Soil profiles shall be installed as shown in the plans to comply with DOEE requirements.

2. Prior to installation of the Biofiltration soil profile, check that all subgrade preparation has been completed and accepted. The base of each biofiltration areas shall be scarified to a depth of 50mm (2-inches) and graded smooth with a rough, porous surface.

3. A rock drainage layer consisting of clean No. 57 stone (1” to 1.5” stone) shall be placed to the depth shown in the Drawings above the base grade concurrent with the installation of the bioretention drainage system. The stone drainage layer will be raked or graded smooth.

4. A layer of 3/8” No. 8 pea gravel shall be installed above the stone drainage layer. The pea gravel layer shall be placed as an even layer raked smooth.

5. The Biofiltration Soil shall be installed to the depths according to the plan details. For installation, the soil shall be installed in 200mm – 300mm (8- to 12-inch) lifts. Each lift shall be graded smooth and scarified prior to the placement of the next subsequent lift. Biofiltration Soil lifts shall not be compacted, but each lift must be raked to assure that soil voids have been eliminated.

6. After placement of the Biofiltration Soil, the full profile shall be wetted to allow for natural settling and compaction. This process shall be conducted a minimum of two times. The final grade elevation of the Biofiltration Soil shall be measured. Any resulting settling or voids shall be filled with added Biofiltration Soil to the final grade.

7. The final Biofiltration Soil shall be graded smooth and a firm, friable planting bed shall be prepared.

H. **Lightweight Extensive Soil Installation**

1. The structural base upon which the soil will be installed, including waterproofing and the drainage system, shall be provided by others.

2. After completion of the structural surface, waterproofing, and drainage layers, the installation of the protection layer, root barrier and separation geotextile should follow.

3. Next, the Lightweight Planting Soil shall be installed as shown in the Drawings.

a. The Lightweight Planting Soil shall be installed to the depth shown in the drawings in a single lift and raked and graded smooth. Compaction of this lift is not necessary.

3.8 INSTALLATION OF COMPOST TILL LAYER

Note to specifier: *The following paragraph is critical to establishing an organic-rich O horizon in installed Planting Soil. This added layer of Compost must be shown on the soil details in the Drawings*

A. After Planting Soils are installed and just prior to the installation of shrub or groundcover plantings, spread 50mm (2 inches) of Compost over the beds and roto till into the top 100mm (4 inches) of the Planting Soil. This step will raise grades slightly, refer to ***Section 3.10.A***.

1. Planting Soils here refer to ***Sections 3.7B*** (Planting Soil), ***3.7D*** (Planting Soil in Raised Planters), and ***3.7G*** (Biofiltration Soil).

3.9 POST SOIL INSTALLATION TESTING

A. Soil density, soil compaction, and soil infiltration testing shall be completed as soil is installed and at completion of soil installation to assure that soils comply with specified requirements as established in this Section.

1. Soil density shall be measured using a nuclear soil density gauge as described in ***Part 1.14.G*** of this section.
   a. Soil density measurements shall be completed for each planting area smaller than 100 square meters, or one test for each 100 square meters of a larger planting area.
   b. Soil density shall be between 80 to 84 percent of the soil's maximum dry density using the Standard Proctor method in all areas. If soil density exceeds this range, additional soil density tests shall be conducted offset by 5 feet in each direction from the point of exceedance to determine extent of excessive soil density. The SMITHSONIAN COTR shall be consulted for corrective actions.
   c. Soils with high compost or organic matter concentrations may not achieve the specified soil density range. Advise the SMITHSONIAN COTR if soil density measurements and the location of soil density measurements not meeting the specified range.

2. Compaction testing, including surface as well as subsurface compaction layers, shall be tested using a cone penetrometer as described in ***Part 1.14G*** of this Section.
   a. Compaction testing shall be done for each 25 square meters of planting area at a minimum.
   b. Compaction measured as resistance to penetration of the cone penetrometer in pounds per square inch (psi) shall not exceed 140 psi in the surface 150mm (6 inches), 180 psi in the 150 – 300 mm (6- to 12-inch) depth interval, or 200 psi at depths greater than 300 mm in the soil profile.
      1.) If compaction testing detected compacted layers exceeding the allowances described above, soil shall be removed to the depth of compaction, and compacted soils shall be loosened with hand tools to break compacted layers and achieve appropriate soil density.

3. Infiltration testing shall be conducted as described in ***Section 1.14H***. Infiltration testing shall be completed using the Double-Ring Infiltrometer.
   a. Infiltration testing shall be done for each planting area of 100 square meters or less. Infiltration testing shall be done at a rate of one test per 100 square meters for panting areas greater than 100 square meters.
   b. Infiltration rates for Planting Soil and Lawn Soil shall be greater than 15 mm per hour (0.6 inches/hour). If infiltration rates are not greater than 15 mm/hr, consult with the SMITHSONIAN COTR to determine corrective actions.
   c. Infiltration rates for High-Use Lawn and Biofiltration Soils shall be greater than 25 mm per hour (1.0 inches/hour). If infiltration rates are not greater than 25 mm/hr, consult with the SMITHSONIAN COTR to determine corrective actions.

3.10 FINISH GRADING

A. The finish grades of all planted areas shown in the Drawings are the elevations after settlement and shrinkage of the Compost Till Layer and planting soil. This settlement is anticipated to be within a few months after installation as the Compost breaks down. A minimum settlement of approximately 25mm (1-inch) of the soil depth is expected. The Contractor shall install the planting soil at a higher level to anticipate this reduction of planting soil volume (approximately 25mm (1-inch)).

1. Grade the edges of shrub areas and ground cover areas soil surfaces to an elevation 50mm (2 inches) below the finished surface of adjacent paving and curbs, after initial soil settlement, unless indicated otherwise.

2. The grades in bed areas shown in the Drawings is the soil line before mulch is added and after soil settlement. The grades in lawn areas shown in the Drawings in the thatch line of the sod after initial soil settlement, unless indicated otherwise.

B. Utilize hand tools to keep surface rough without further compaction. Do not use the flat bottom of a loader bucket to fine grade, as it will cause the finished grade to become overly smooth and or slightly compressed.

C. Inspect and survey finished soil grades for positive drainage from all areas toward the existing inlets, drainage structures and or the edges of planting beds consistent with soil grade designs unless indicated otherwise. Adjust grades as directed to reflect actual constructed field conditions of paving, wall and inlet elevations as shown in the Drawings. Notify the SMITHSONIAN COTR in the event that conditions make it impossible to achieve positive drainage.

1. Grade soil surface smooth to be free of high and low areas which will inhibit surface drainage.

2. Provide smooth, rounded transitions between slopes of different gradients and direction.

3.11 TOLERANCES

A. Grade soil surface to within 0.10-foot of grades indicated in the Drawings, except bring soil surface grades along headers, paving, curbs, and other structures to within 0.01-foot of grades indicated in the Drawings.

B. Transition soil surface grades along paving, curbs and other structures to areas of less strict tolerance over a 5-foot distance.

C. Fill all depressions and remove any rises or mounds in the overall plane of the slope. The tolerance for dips and bumps in shrub and ground cover planting areas shall be a 50mm (2-inch) deviation from the plane in 3-meters (10 feet). The tolerance for dips and bumps in lawn areas shall be a 25mm (1-inch) deviation from the plane in 3-meters (10 feet).

3.12 PROTECTION AND REPAIRS

A. The Contractor shall take every precaution to ensure the integrity of the underdrainage, aeration and irrigation systems during and after soil placement. Any damage caused by the Contractor shall be repaired at no additional expense to the Owner.

B. The Contractor shall be responsible to ensure that no soil disturbance will occur from construction traffic or other construction activities after placement of planting soil is complete. Disturbance shall be repaired by the Contractor at no additional expense to the Owner.

1. The Contractor shall place barricades to prevent compaction of planting soil from vehicles, equipment, or pedestrian traffic.

2. Coordinate activities with other project contractors so that there is no soil disturbance from traffic or other construction activities subsequent to placement.

C. Protect newly graded areas from traffic and erosion. Keep free of trash, debris or construction materials from other work.

D. Repair and re-establish grades where completed or partially competed surfaces become eroded, rutted or compacted. Scarify, or, if directed by the SMITHSONIAN COTR, remove and replace soil to a depth as directed. Reshape and re-compact to the required density while soil is at a moisture content between permanent wilting point and field capacity.

E. Where settling greater than 50mm (2-inches) occurs, before final acceptance or during the warranty period, remove finish surfacing, backfill with additional approved material, compact to specified rates, and restore any disturbed areas to a condition acceptable to the SMITHSONIAN COTR.

1. Repaired or restored areas shall follow the same procedures as specified for installation of new Soil Mixes.

F. Any soil that becomes compacted to a density greater than 85 proctor density and/or the density in the approved mockup shall be dug up and reinstalled. This requirement includes compaction caused by other sub-contractors after the Soil Mix (Planting Soil) is installed and approved.

G. Surface tilling shall not be considered adequate to reduce over compaction at levels 150mm (6 inches) or greater below finished grade. See ***Section 3.7.A.4*** for remediating over-compaction.

3.13 FINAL ACCEPTANCE / SOIL SETTLEMENT

A. Upon written notice from the Contractor, the SMITHSONIAN COTR shall review the work and make a determination if the work is substantially complete.

B. The date of substantial completion of the planting soil shall be the date when the SMITHSONIAN COTR accepts that all work in Planting, Planting Soil, and Irrigation installation sections is complete.

C. Aesthetic Acceptance of Grades:

1. Upon completion of finish grading Work, schedule with the SMITHSONIAN COTR a review to obtain aesthetic acceptance.
2. Provide three (3) days advance written notification.
3. Do not commence planting or sodding Work until receiving aesthetic acceptance.

D. At the end of the plant warrantee and maintenance period, (see **Specification Section 00 0000 -- Planting**) the SMITHSONIAN COTR shall observe the soil installation work and establish that all provisions of the contract are complete, and the work is satisfactory.

1. Restore any soil settlement and or erosion areas to the grades shown in the Drawings. When restoring soil grades remove plants and mulch and add soil before restoring the planting. Do not add soil over the root balls of plants or on top of mulch.

E. Failure to pass acceptance: If the work fails to pass final acceptance, any subsequent observations must be rescheduled as per above. The cost to the Owner for additional observations will be charged to the Contractor at the prevailing hourly rate of the SMITHSONIAN COTR.

3.14 EXCESS MATERIALS

A. Excess Planting Soil: Remove the excess planting soil mixture and materials from the project area at no additional cost to the Owner.

END OF SECTION 32 91 00

Spec Checklist

Smithsonian Gardens

Spec Checklist Template

Section 32 9100

PART 1

	Product	Using?	Notes
1.1.B.1	**Base Soil**	Y	Indicate scope of work by denoting soil components used in the project and removing those that are not
	Coarse Sand	Y	
	Compost	Y	
	Lightweight Aggregate	N	
	No. 8 Pea Gravel	N	
	No. 57 Stone	N	
1.1.B.2	**Planting Soil**	Y	Indicate scope of work by denoting soil mixes used in the project and removing those that are not
	Lawn Soil	Y	
	High-Use Lawn Soil	N	
	Biofiltration Soil	N	
	Lightweight Extensive Soil	N	

1.13	Pre-Construction Meeting	Reviewed?	Meeting Date	SG Follow-up Review Date	Contractor Confirmation & Date	Notes
1.9	**Long Lead Item**	Y	-	-	-	The spec should be reviewed in its entirety during the landscape pre-construction meeting. The list indicates the most important review items. Denote whether the spec section was reveiwed, and the date if reviewed separate from the date of the Pre-Con meeting. Log the contractor confirmation date and note any agreed upon changes or variations from the original spec requirements.
1.10.B	**Planting Soils Installation Plan**	Y	-	-	-	
1.10D	**Submittals Timeframe**	Y	-	-	-	
1.10E	**Soil Components Product Data and Samples**	Y	-	-	-	
1.10F	**Soil Mix Testing Procedures**	Y	-	-	-	
1.10G	**Soil Mix Samples**	Y	-	-	-	
1.11	**Soil Installation Mockup**	N	-	-	-	
1.14.B	**Base Soil Source**	Y	-	-	-	
1.14.E	**Base Soil Souce Inspection**	Y	-	-	-	
1.15.B	**Subgrade Infiltration Testing**	Y	-	-	-	
1.16	**Delivery, Storage, Handling**	Y	-	-	-	
2.7.A	**Soil Mixes**	Y	-	-	-	

DELETE ANY SOIL COMPONENT OR SOIL TYPE BELOW THAT IS NOT BEING USED IN THE PROJECT

	Submittal	Date Due	Date Received	Testing	Approved Range	Received Range	Status	Date Approved	Notes
1.10.B	**Planting Soils Installation Plan**	12 wks	-	-	-	-	*received*	-	
1.10.C	**Base Soil Source**	12 wks	-	-	-	-	*received*	-	Note supplier and contact info here
1.14.E	*Place date of Base Soil inspection here >>>>>>>*		-				*approved*		
1.10.E 2.3.A	**Compost Product Data and Sample**	12 wks	-	Organic Matter	>35%	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Size (passing)	1/2 screen or less			-	
			-	Total Nitrogen	>1500 ppm	-		-	
			-	Carbon:Nitrogen Ratio	10:1 to 20:1	-		-	
			-	Extractable Nitrate	20-200 ppm	-		-	
			-	Total Phosphorous	5 - 2000 ppm	-		-	
			-	Available Phosphorous	5 - 200 ppm	-		-	
			-	pH	5.5 - 8.0	-		-	
			-	Salt concentration	<6 dS.m- 1	-		-	
			-	Moisture	30-55 %wt	-		-	
			-	CO2 test (max.)	6 mg CO2-ClgBVS / day	-		-	
			-	Solvita test	6 or more	-		-	
			-	Active bacteria (max.)	10%	-		-	
			-	Total bacteria (min.)	1500 ng/g	-		-	
			-	Total fungi (min.)	400 ng/g	-		-	
			-	Pathogens	see 2.3.C.5	-		-	
1.10.E 2.2.A	**Coarse Sand Product Data and Sample**	12 wks	-	pH	< 7.8	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Sieve #4	min. 90 - max. 100	-		-	
			-	Sieve #10	min. 75 - max. 95	-		-	
			-	Sieve #18	min. 48 - max. 75	-		-	
			-	Sieve #35	min. 20 - max. 45	-		-	
			-	Sieve #60	min. 0 - max. 20	-		-	
			-	Sieve #140	min. 0 - max. 5	-		-	
			-	Sieve #270	min. 0 - max. 0	-		-	
			-	Sieve .002mm	min. 0 - max. 1	-		-	
1.10.E 2.4.A	**Lightweight Aggregate Product Data and Sample**	12 wks	-	Size	5/8" expanded shale or clay	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Soundness loss	<30% per AASHTO T104	-		-	
			-	Abrasion resistence	<40% per ASTM C131	-		-	
			-	Chloride content	<100ppm AASHTO T291	-		-	
1.10.E	**No.8 Pea Gravel Product Data and Sample**	12 wks	-	Size	3/8" clean, dried per ASTM C33	-	*outstanding*	-	All samples to be submitted along with required testing & product data
1.10.E	**No.57 Stone Product Data and Sample**	12 wks	-	Physical	Clean, double-washed, open graded	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Sieve 1.5 inch	min. 100 - max. 100	-		-	
			-	Sieve 1 inch	min. 95 - max. 100	-		-	
			-	Sieve 1/2 inch	min. 25 - max. 60	-		-	
			-	Sieve #4	min. 0 - max. 10	-		-	
			-	Sieve #8	min. 0 - max. 8	-		-	
			-	Sieve #18	min. 0 - max. 0	-		-	
			-	Sieve #270	min. 0 - max. 0	-		-	
			-	Sieve .002mm	min. 0 - max. 0	-		-	

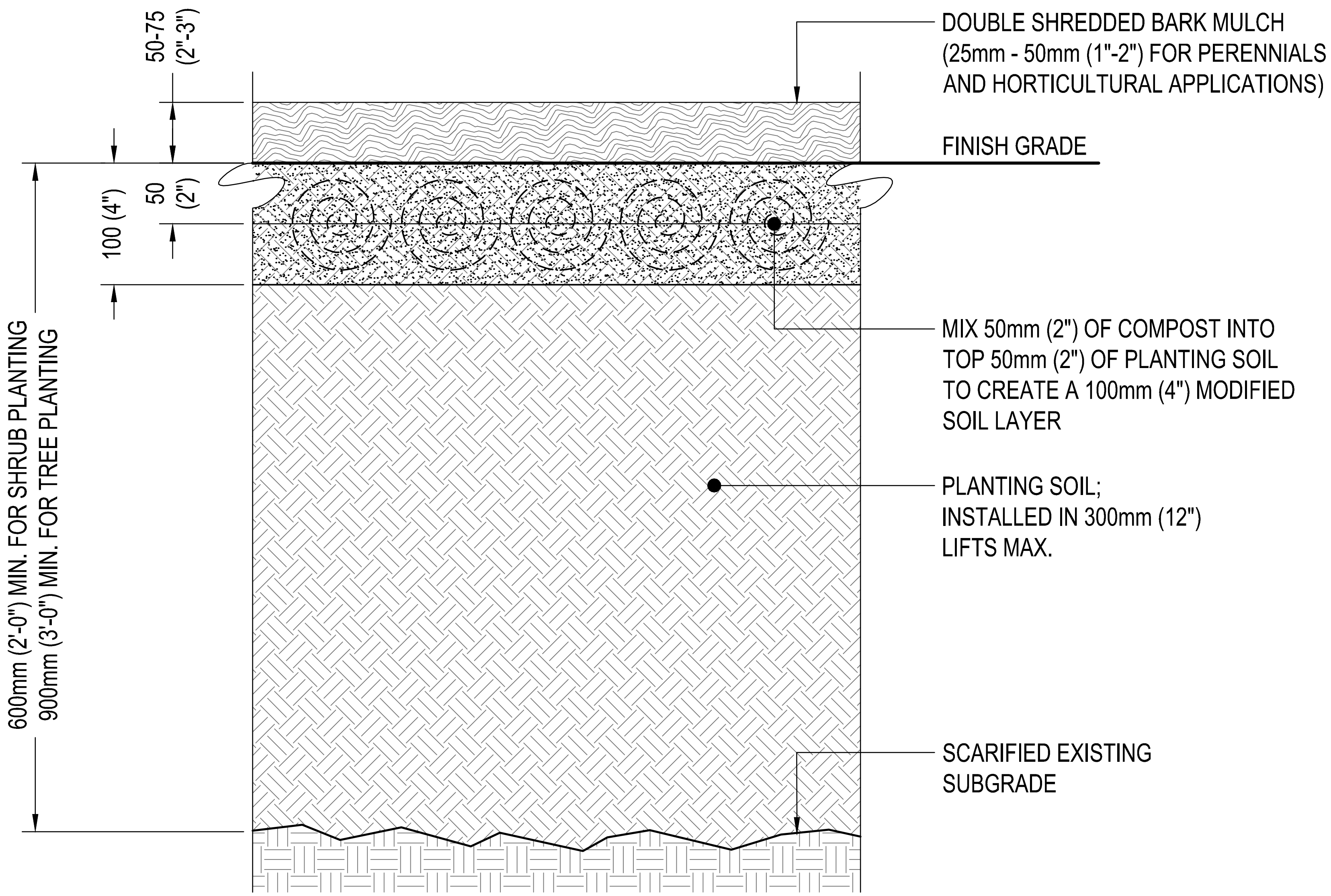
	Submittal	Date Due	Date Received	Testing	Approved Range	Received Range	Status	Date Approved	Notes
1.10.F 2.1.A	**Base Soil Testing and Sample**	12 wks	-	USDA soil texture (Clay Loam, Loam, Sandy Loam, Sandy Clay Loam)	17-37% Clay 15-35% Silt 40-62% Sand	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Wet Agg. Stability	60% > 0.20mm	-		-	
			-	Organic Matter	2.5 - 6%	-		-	
			-	Total Nitrogen	>200 mg kg-1	-		-	
			-	Ammonium-Nitrogen	>10 mg kg-1	-		-	
			-	Nitrate-Nitrogen	>5 mg kg-1	-		-	
			-	Available Phosphorous	>50 mg kg-1	-		-	
			-	pH	5.5 - 7.3	-		-	
			-	CEC	>17 meq / 100 gm soil	-		-	
			-	Soluble Salts/ EC	<1 dS.m-1	-		-	
			-	Potassium	>90 mg kg-1	-		-	
			-	Calcium	>800 mg kg-1	-		-	
			-	Magnesium	>200 mg kg-1	-		-	
			-	Sodium	<180 mg kg-1	-		-	
			-	Sulphate-S	>20 mg kg-1	-		-	
			-	Lead	<50 mg kg-1	-		-	
			-	Manganese	<200 mg kg-1	-		-	
			-	Zinc	<50 mg kg-1	-		-	
			-	Boron	<3 mg kg-1	-		-	
			-	Exch. Aluminum	<200 mg kg-1	-		-	
1.10.F 2.8.A	**Planting Soil Testing and Sample**	2 wks after approval of Base Soil / soil components	-	Mix Ratio by Volume	**5 pts Base Soil to 1 pt Compost (if req'd) see 2.7.A**	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Organic Matter	3.0 - 5%	-		-	
			-	Total Nitrogen	>750 mg kg-1	-		-	
			-	Ammonium-Nitrogen	>20 mg kg-1	-		-	
			-	Nitrate-Nitrogen	>25 mg kg-1	-		-	
			-	Available Phosphorous	>50 mg kg-1	-		-	
			-	pH	5.5 - 7.3	-		-	
			-	CEC	>17 meq / 100 gm soil	-		-	
			-	Soluble Salts/ EC	<1 dS.m-1	-		-	
			-	Potassium	>90 mg kg-1	-		-	
			-	Calcium	>700 mg kg-1	-		-	
			-	Magnesium	>200 mg kg-1	-		-	
			-	Sodium	<100 mg kg-1	-		-	
			-	Sulphate-S	>20 mg kg-1	-		-	
			-	Lead	<50 mg kg-1	-		-	
			-	Manganese	<200 mg kg-1	-		-	
			-	Zinc	<50 mg kg-1	-		-	
			-	Boron	<3 mg kg-1	-		-	
			-	Exch. Aluminum	<180 mg kg-1	-		-	
1.10.F 2.9.A	**Lawn Soil Testing and Sample**	2 wks after approval of Base Soil / soil components	-	Mix Ratio by Volume	**4 pts Base Soil to 1 pt Compost see 2.7.A**	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Organic Matter	>3.0	-		-	
			-	Total Nitrogen	>700 mg kg-1	-		-	
			-	Ammonium-Nitrogen	>20 mg kg-1	-		-	
			-	Nitrate-Nitrogen	>25 mg kg-1	-		-	
			-	Available Phosphorous	>50 mg kg-1	-		-	
			-	pH	6.5 - 7.8	-		-	
			-	CEC	>14 meq / 100 gm soil	-		-	
			-	Soluble Salts/ EC	<1 dS.m-1	-		-	
			-	Potassium	>90 mg kg-1	-		-	
			-	Calcium	>500 mg kg-1	-		-	
			-	Magnesium	>200 mg kg-1	-		-	
			-	Sodium	<100 mg kg-1	-		-	
			-	Sulphate-S	>20 mg kg-1	-		-	
			-	Lead	<50 mg kg-1	-		-	
			-	Manganese	<200 mg kg-1	-		-	
			-	Zinc	<50 mg kg-1	-		-	
			-	Boron	<3 mg kg-1	-		-	
			-	Exch. Aluminum	<180 mg kg-1	-		-	
1.10.F 2.10.A	**High-Use Lawn Soil Testing and Sample**	2 wks after approval of Base Soil / soil components	-	Mix Ratio by Volume	**Dependant on Base Soil Texture see 2.7.A**	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Organic Matter	>3.0	-		-	
			-	Total Nitrogen	>700 mg kg-1	-		-	
			-	Ammonium-Nitrogen	>20 mg kg-1	-		-	
			-	Nitrate-Nitrogen	>25 mg kg-1	-		-	
			-	Available Phosphorous	>50 mg kg-1	-		-	
			-	pH	6.5 - 7.8	-		-	
			-	CEC	>14 meq / 100 gm soil	-		-	
			-	Soluble Salts/ EC	<1 dS.m-1	-		-	
			-	Potassium	>90 mg kg-1	-		-	
			-	Calcium	>500 mg kg-1	-		-	
			-	Magnesium	>200 mg kg-1	-		-	
			-	Sodium	<100 mg kg-1	-		-	
			-	Sulphate-S	>20 mg kg-1	-		-	
			-	Lead	<50 mg kg-1	-		-	
			-	Manganese	<200 mg kg-1	-		-	
			-	Zinc	<50 mg kg-1	-		-	
			-	Boron	<3 mg kg-1	-		-	
			-	Exch. Aluminum	<180 mg kg-1	-		-	

1.10.F 2.11.A	**Biofiltration Soil Testing and Sample**	2 wks after approval of Base Soil / soil components	-	Mix Ratio by Volume	**Dependant on Base Soil Texture see 2.7.A**	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Organic Matter	2.0 - 6.0	-		-	
			-	Total Nitrogen	>450 mg kg-1	-		-	
			-	Ammonium-Nitrogen	>20 mg kg-1	-		-	
			-	Nitrate-Nitrogen	>25 mg kg-1	-		-	
			-	Available Phosphorous	>50 mg kg-1	-		-	
			-	pH	6.0 - 7.8	-		-	
			-	CEC	>12 meq / 100 gm soil	-		-	
			-	Soluble Salts/ EC	<1 dS.m-1	-		-	
			-	Potassium	>90 mg kg-1	-		-	
			-	Calcium	>800 mg kg-1	-		-	
			-	Magnesium	>200 mg kg-1	-		-	
			-	Sodium	<100 mg kg-1	-		-	
			-	Sulphate-S	>20 mg kg-1	-		-	
			-	Lead	<50 mg kg-1	-		-	
			-	Manganese	<200 mg kg-1	-		-	
			-	Zinc	<50 mg kg-1	-		-	
			-	Boron	<3 mg kg-1	-		-	
			-	Exch. Aluminum	<180 mg kg-1	-		-	
1.10.F 2.12.A	**Lightweight Extensive Soil Testing and Sample**	2 wks after approval of Base Soil / soil components	-	Mix Ratio by Volume	**4 pts Base Soil to 4 pts Lightweight Agg. to 1 pt Compost see 2.7.A**	-	*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Organic Matter	>2.0%			-	
			-	Total Nitrogen	>500 mg kg-1	-		-	
			-	Ammonium-Nitrogen	>20 mg kg-1	-		-	
			-	Nitrate-Nitrogen	>25 mg kg-1	-		-	
			-	Available Phosphorous	>50 mg kg-1	-		-	
			-	pH	6.5 - 7.8	-		-	
			-	CEC	>10 meq / 100 gm soil	-		-	
			-	Soluble Salts/ EC	<1 dS.m-1	-		-	
			-	Potassium	>90 mg kg-1	-		-	
			-	Calcium	>800 mg kg-1	-		-	
			-	Magnesium	>200 mg kg-1	-		-	
			-	Sodium	<100 mg kg-1	-		-	
			-	Sulphate-S	>20 mg kg-1	-		-	
			-	Lead	<50 mg kg-1	-		-	
			-	Manganese	<200 mg kg-1	-		-	
			-	Zinc	<50 mg kg-1	-		-	
			-	Boron	<3 mg kg-1	-		-	
			-	Exch. Aluminum	<180 mg kg-1	-		-	

	Submittal	Date Due	Date Received	Testing	Approved Range		Status	Date Approved	Notes
	DELETE ANY SOIL TYPE SAMPLE BELOW THAT IS NOT BEING USED IN THE PROJECT								
1.10.G	**Samples**	2 wks after approval of Base Soil / soil components	-	Base Soil	2 gallon		*outstanding*	-	All samples to be submitted along with required testing & product data
			-	Planting Soil	2 gallon			-	
			-	Lawn Soil	2 gallon			-	
			-	High-Use Lawn Soil	2 gallon			-	
			-	Biofiltration Soil	2 gallon			-	
			-	Lightweight Ext. Soil	2 gallon			-	
1.10.H 1.15.B	**Subgrade Infiltration and Density**	-	-	Infiltration	Min. 0.25" per hour	**-**	*received*	-	Testing data must be received a minimum of 7 days before soil installation occurs.
			-	Compaction (0-6")	120 - 180 psi	-		-	
			-	Compaction (6-12")	160 - 220 psi	-		-	

1.11	Soil Installation Mockup	Reviewed?	Mockup Date	SG Follow-up Review Date	Contractor Confirmation & Date			Date Due	Notes
1.15.B	**Subgrade Infiltration Testing**	Y	-	-	-				
1.16	**Delivery, Storage, Handling**	Y	-	-	-				Denote whether the spec section was reveiwed.
3.3	**Grade and Elevation Control**	Y	-	-	-				
3.4	**Subgrade Preparation**	Y	-	-	-				
3.6	**Soil Moisture**	Y	-	-	-				Log the contractor confirmation date and note any agreed upon changes or variations from the original spec requirements.
3.7	**Soil Installation**	Y	-	-	-				
3.8	**Installation of Compost Till Layer**	Y	-	-	-				
3.9	**Post Soil Installation Testing**	Y	-	-	-				
1.11.A.6	**Soil Mockup Installation Report**	-	-	-	-	-	*outstanding*	*Within 3-5 days following approved mockup*	Report shall include the final methods of soil installation, including all penetrometer, nuclear densometer, and soil moisture reading catalogued during the mockup.
	Place date of Mockup approval here **>>>>>>>>>**		-						

Details



XX
A00 | A00

PLANTING SOIL (ON-GRADE)

SCALE: 1:5

SF PROJECT #:

DATE:

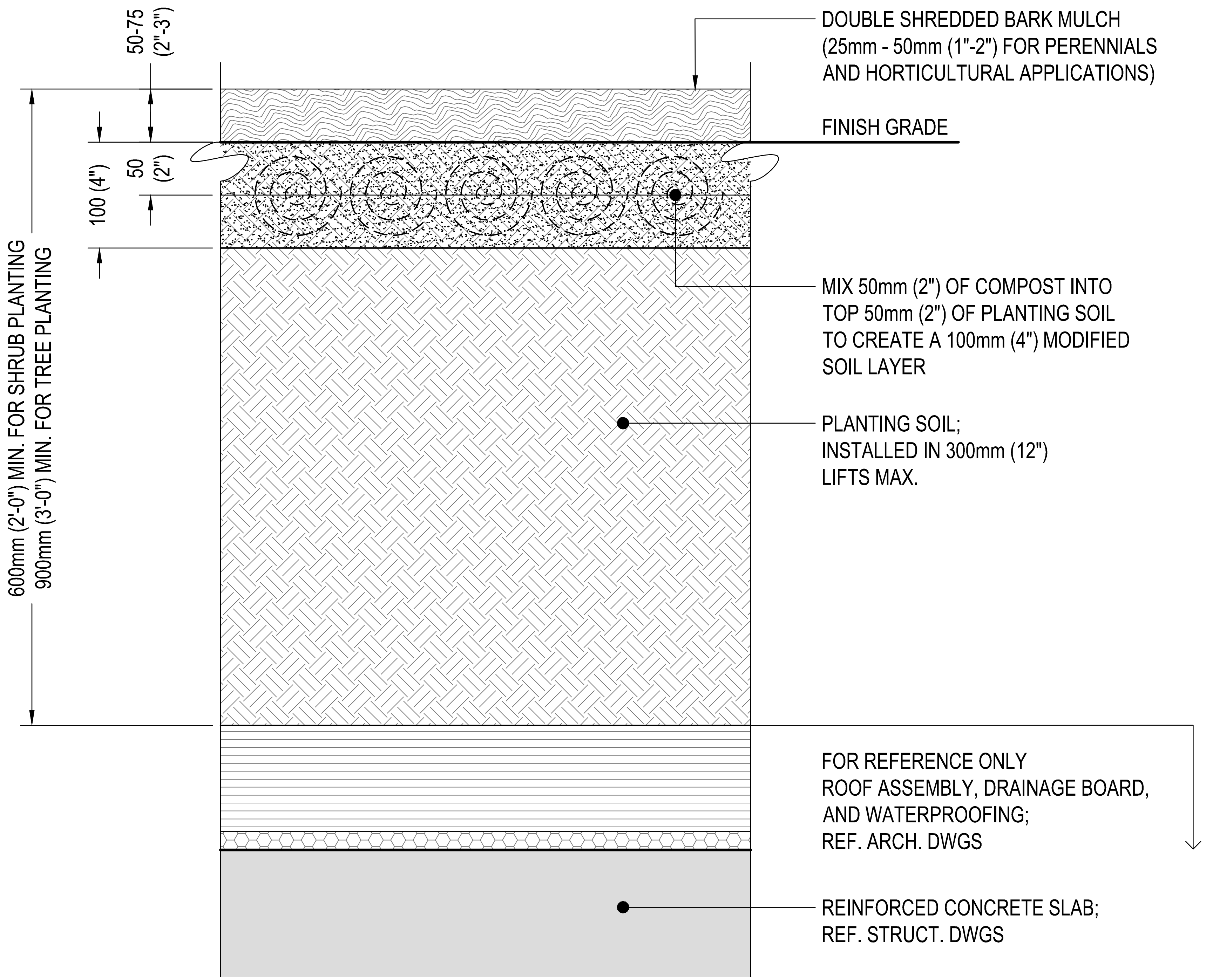
DRAWN BY:

SCALE:

BUILDING NAME:

PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



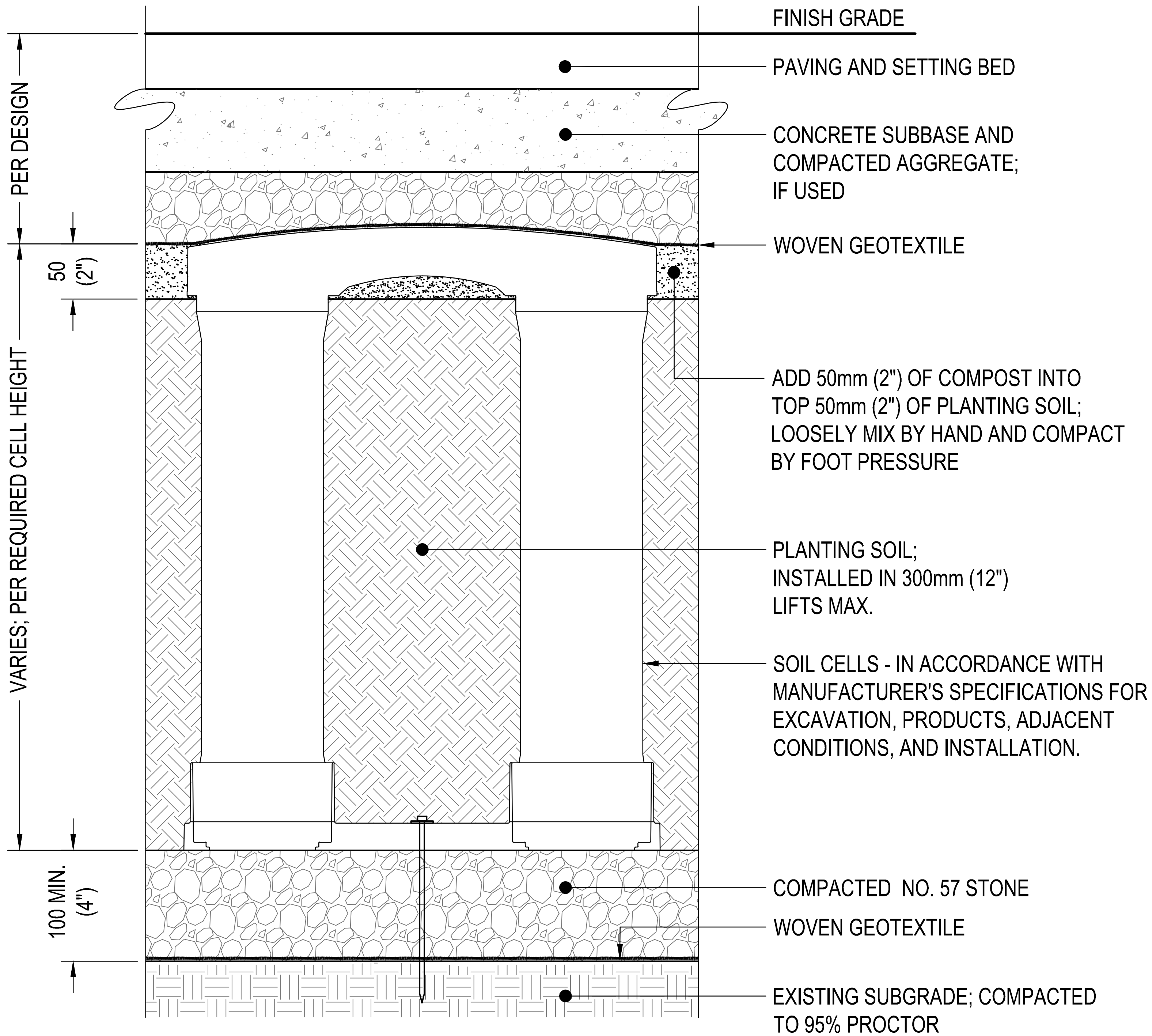
XX
A00 | A00

PLANTING SOIL (OVER-STRUCTURE)

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



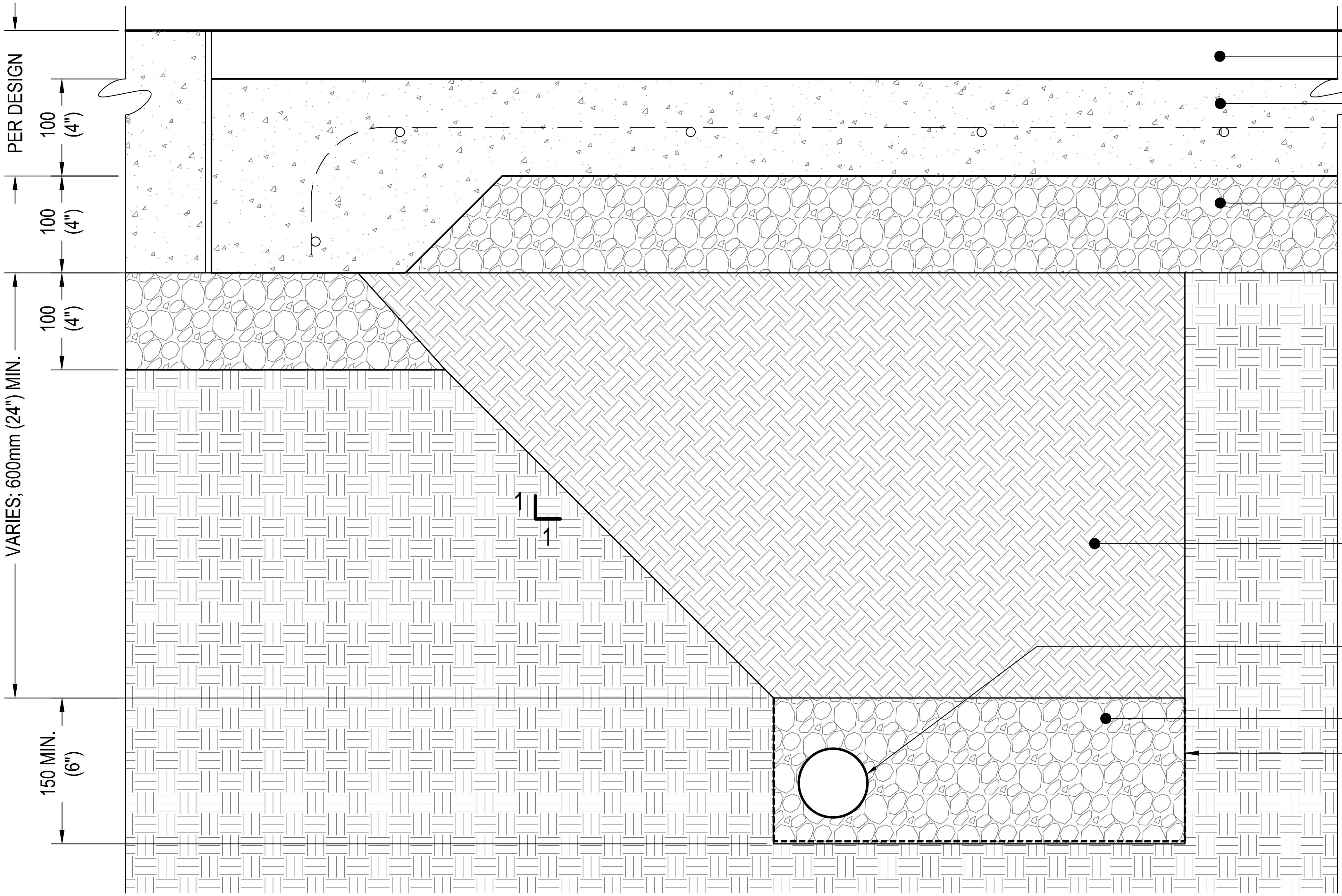
XX
A00 | A00

PLANTING SOIL (IN SOIL CELLS)

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



NOTES ON CONCRETE REINFORCEMENT

1. #4 REBAR CONTINUOUS THROUGH SLAB WIDTH; 300mm (12") O.C. MAX CONC. SPAN = 1.8 M (6'-0")
2. PROVIDE CONTINUOUS BAR SUPPORTS AT 900 mm (3'-0") O.C.
3. 6x6 #2x#2 WWM CONTINUOUS WITHIN CONCRETE SLAB

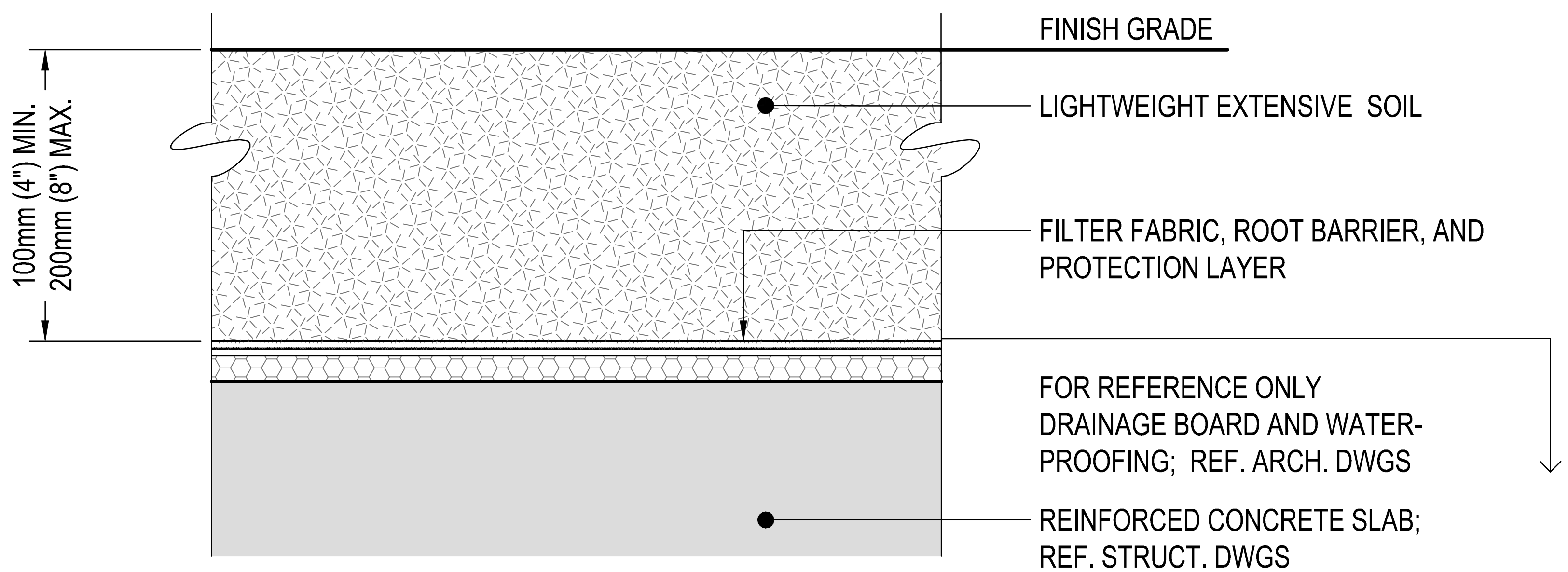
XX
A00 | A00

PLANTING SOIL (BELOW SUSPENDED SLAB)

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



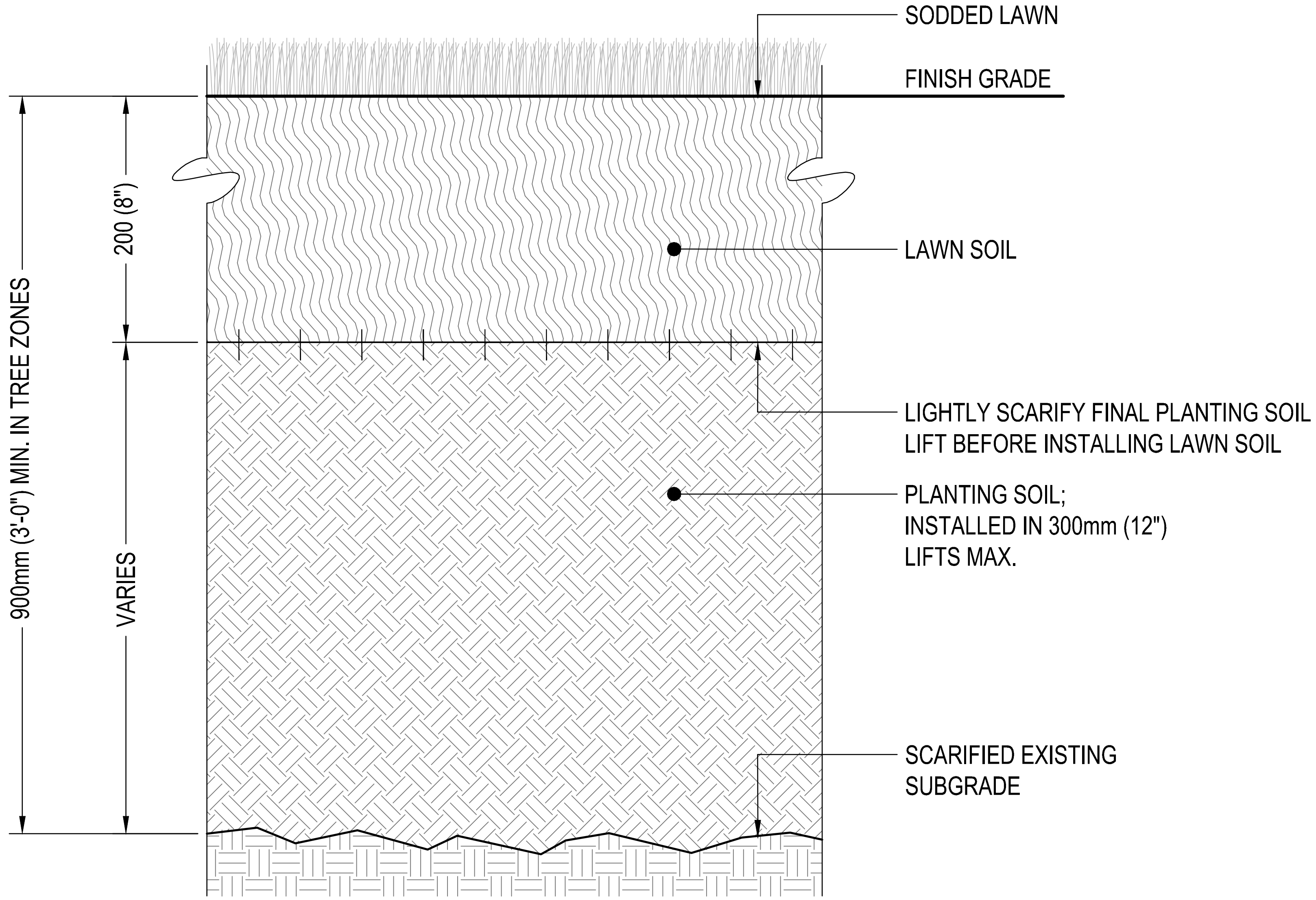
XX
A00 | A00

LIGHTWEIGHT EXTENSIVE SOIL

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



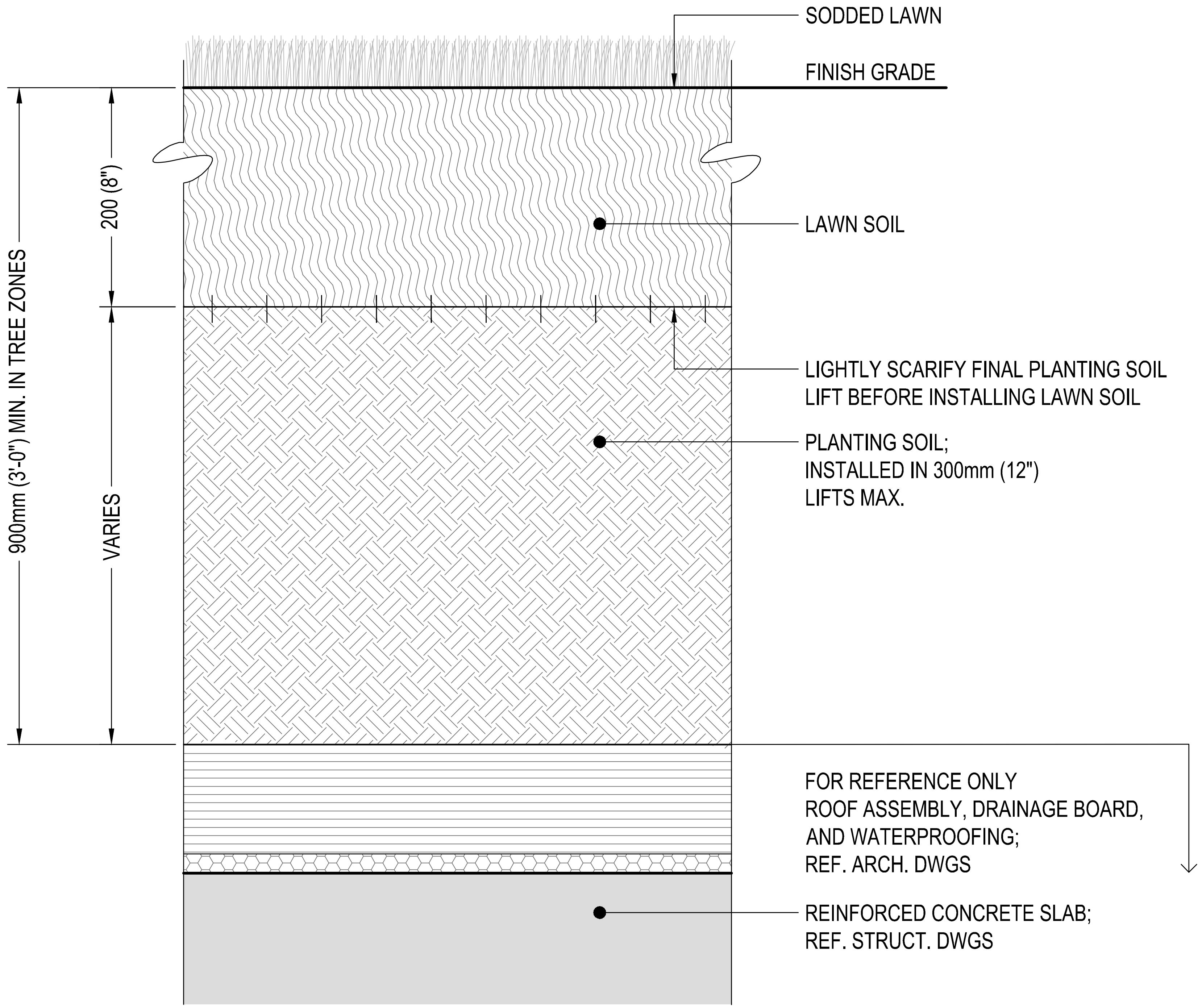
XX
A00 | A00

LAWN SOIL (ON-GRADE)

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



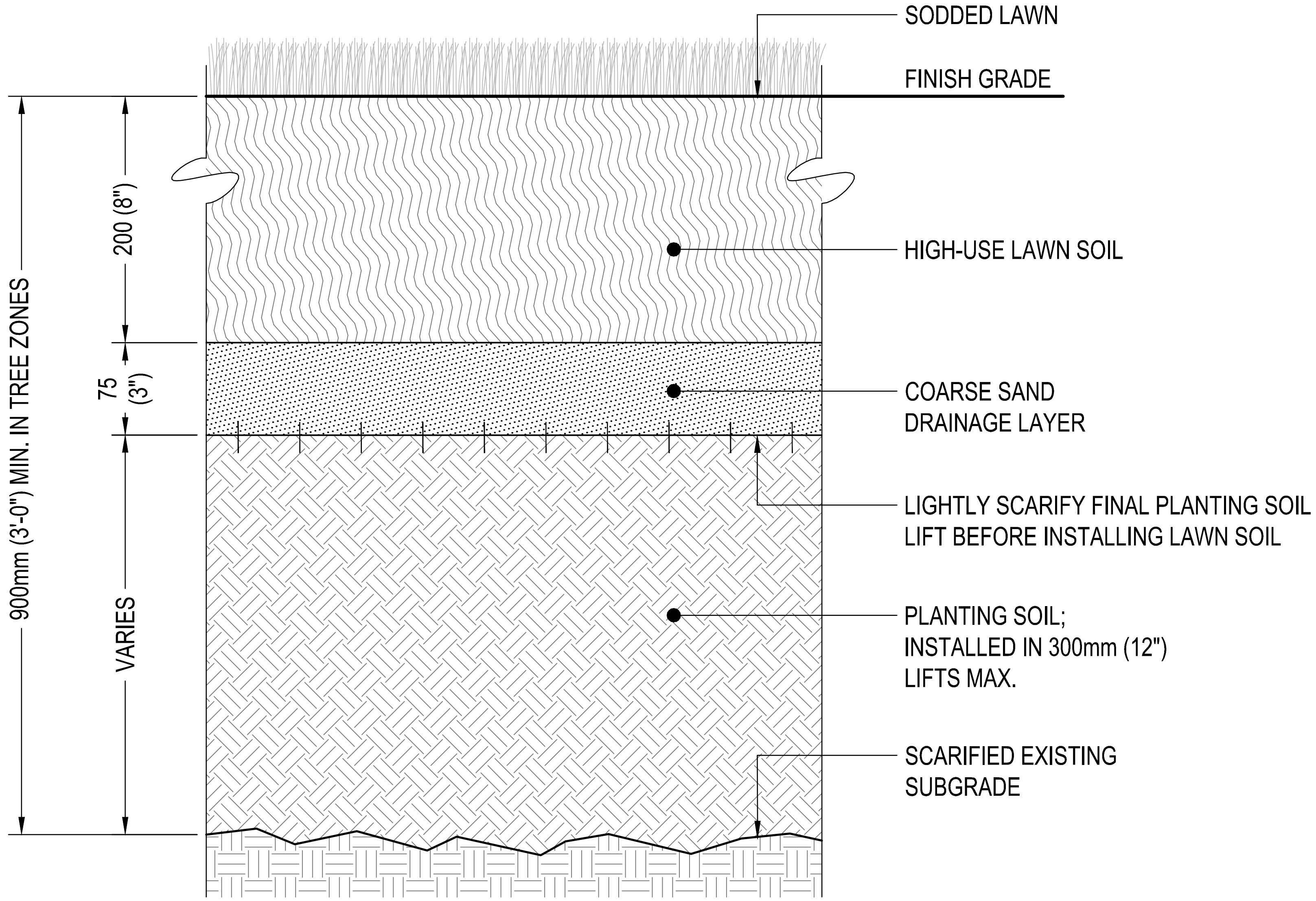
XX
A00 | A00

LAWN SOIL (OVER-STRUCTURE)

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



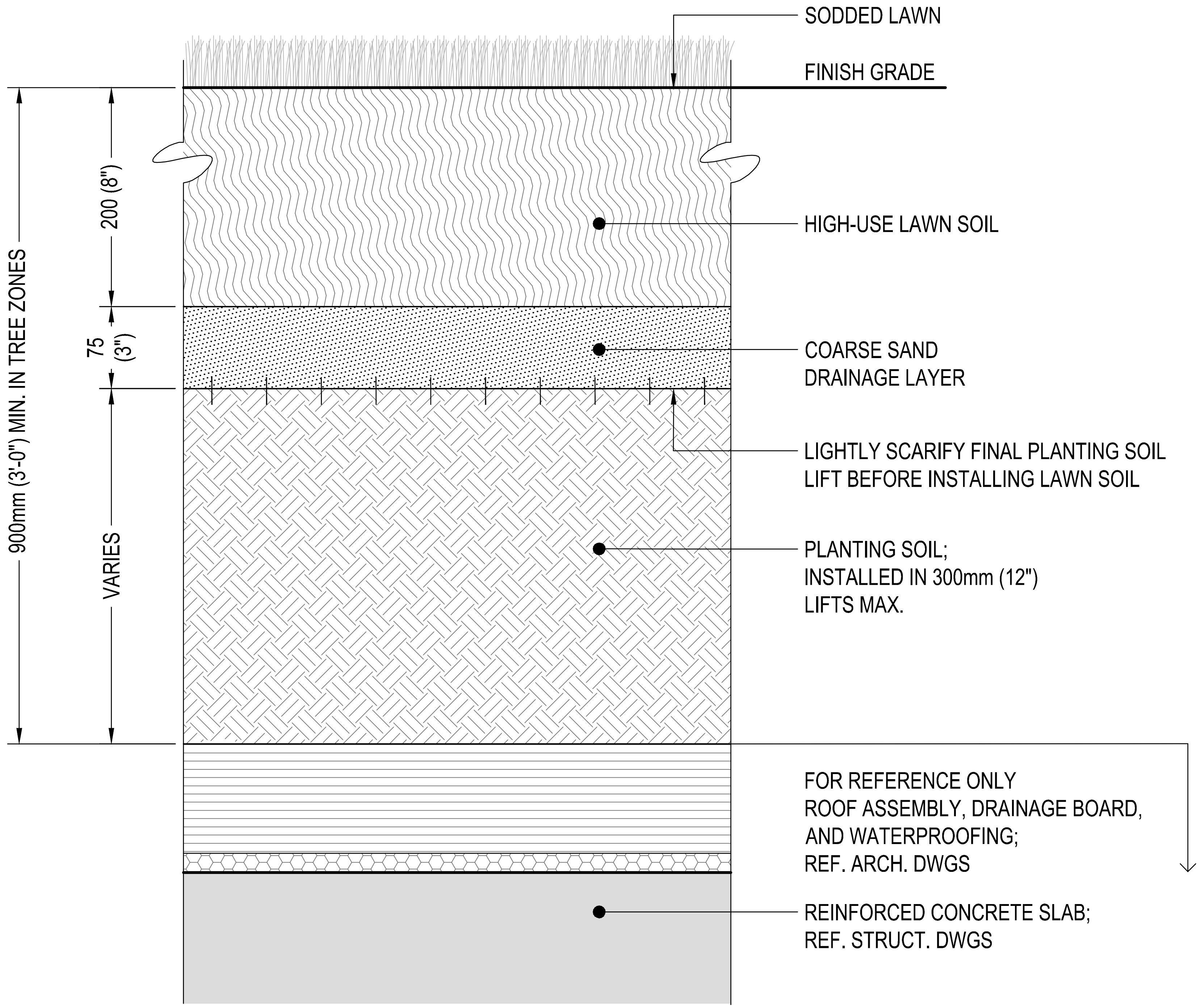
XX
A00 A00

HIGH-USE LAWN SOIL (ON-GRADE)

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



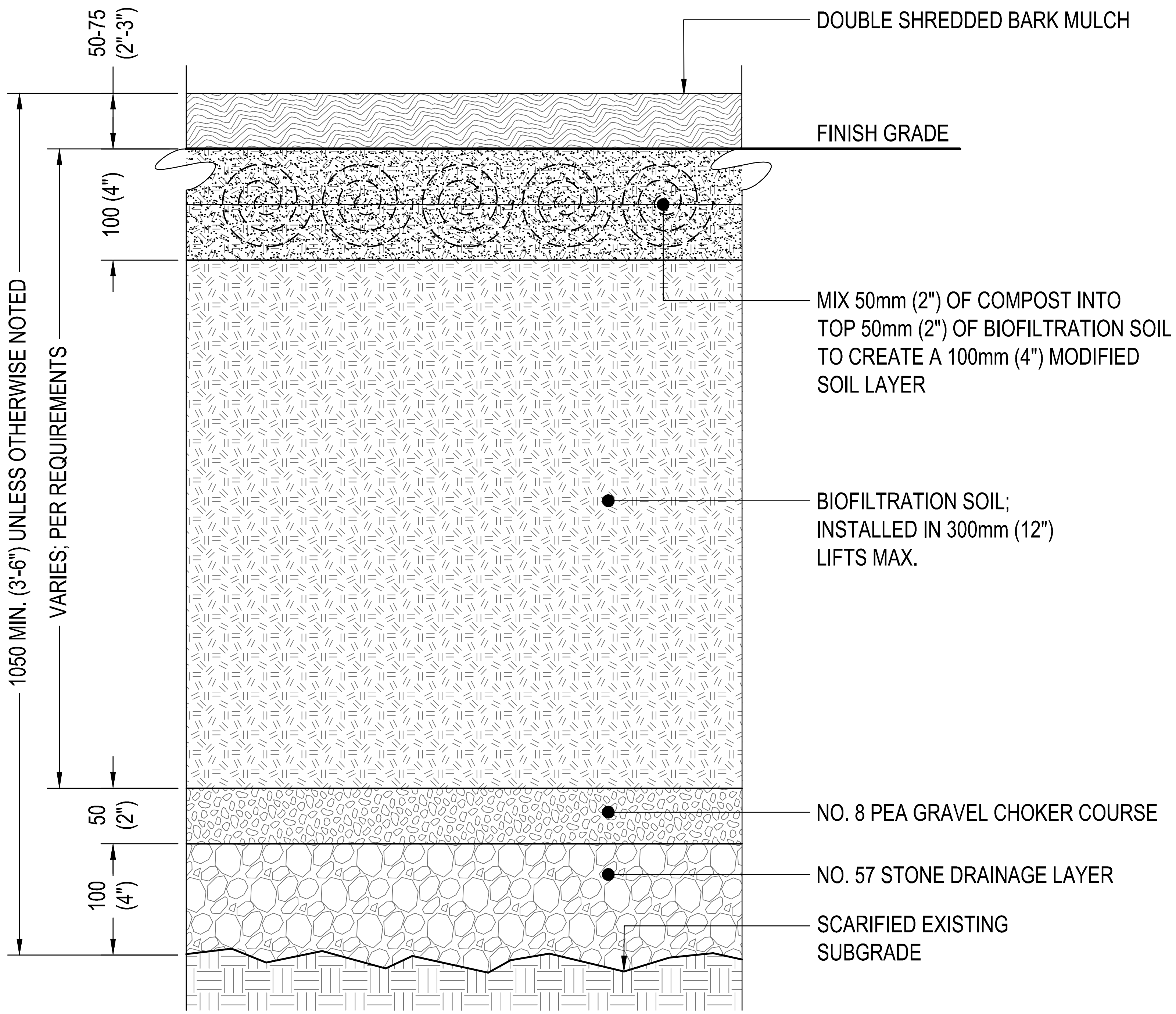
XX
A00 | A00

HIGH-USE LAWN SOIL (OVER-STRUCTURE)

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



XX
A00 | A00

BIOFILTRATION SOIL

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560

APPENDIX F

Small Projects Narrative for Soil Installation and Restoration

Smithsonian Gardens

Guidance for Installation and Restoration of Soils on Small Landscape Projects

Overview

Soils in all landscapes have unique and diverse functions that are critical to supporting healthy plants, draining and retaining water, and for supporting everyday uses. The purpose of this guidance document is to provide instruction for installing and/or repairing soils that have been disturbed by construction of in execution of new landscape projects that involve less than 45 square meters (500 square feet).

This guidance will provide information about examining, conditioning, and replacement of existing excavated soil, use of new, imported soil, and preparing soils for restoration of vegetation. Most projects are generally similar in nature, but many projects will involve situations that require considerations of the local environment (for example, street-side projects, localized drainage, nearby structures, or special planting concerns and potential pedestrian traffic and use).

Examine and Assess Soil Condition

Prior to restoring, replacing, or repairing damaged soil, examination of the soil condition will provide information about whether the soil can be re-used or needs to be replaced. Examination of the soil will also provide information to aide in understanding the depth and extent of potential soil damage and how soil needs to be restored. Examination of soil conditions focusses primarily on compaction and soil structure, and soil drainage.

<table>
<tr><td colspan="2">• Assessing Soil Condition: Examination of soil to assess its suitability for remediation, restoration, or replacement involves the following:</td></tr>
<tr><td colspan="2">First observation; soil color and hardness:</td></tr>
<tr><td>Is the soil very hard and difficult to break?</td><td>Yes – soil is compacted or has high soil density. (See item 2: assessing soil compaction)
No – soil likely has good structure and porosity</td></tr>
<tr><td>Is the soil light- to dark brown without changes in colors or hues within the overall soil?</td><td>Yes – soil likely has reasonable drainage and soil chemistry
No – soil drainage may be an issue *See item 3: assessing soil drainage)</td></tr>
<tr><td colspan="2">• Determine the extent of compacted soil conditions</td></tr>
<tr><td>Use a static cone penetrometer (compaction tester) with a 12.5mm (0.5 inch) tip to determine the lateral and vertical extent of soil compaction, if any. Areas where soil resistance to penetration exceeds approximately 21 kg cm^{-2} (300 pounds per square inch, or psi) soil compaction is too restrictive for root growth.

The static cone penetrometer is most accurate and effective when used in soil that is not excessively dry (when plants are not wilting or the soil is dusty when rubbed in your hand), nor when the soil is too moist (soil is easily smeared in situ or can form ribbons or a ball when compressed in your hand). When soils are too dry, penetrometer results may indicate false reading of high soil compaction or density. When soils are too wet, the penetrometer may not detect compacted or dense soil layers.</td><td>• if the soil is hard and stiff (even if moist), the soil density is too high and may be restrictive of root growth.
- If soil cannot be broken, it must be replaced.
- If the soil can be broken into smaller clods or crumbs, it may be able to be restored.
• If the soil is hard but can break into flat, plate-like structures or crumbs, or has flat, plate-like soil structure is observed, soil is severely compacted. Soil must be replaced.
• If the soil the soil has loose, aggregate structure (soil crumbs or peds that readily fall apart), the soil may be able to be re-used.</td></tr>
</table>

<table>
<tr><td colspan="2">• Assessing Soil Texture</td></tr>
<tr><td>Place enough soil in the palm of your hand to wet and make a ball. Curl your forefinger and form a ribbon within the curl of your finger using your thumb to push the soil through.</td><td>• Ribbon length is less than 12.5 mm (0.5 inches), it is likely a loamy sand or sand. If the depth of sandy soil is greater than 100 mm (4 inches) in depth, it may need to be replaced.
• Ribbon length is from 12.5 mm (0.5 inch) to nearly 25 mm (1 inch) is likely loam or sandy loam soil. Soil may be restored and re-used.
• If the ribbon length is greater than 25 mm, it is likely clay loam or silt loam. Soil re-use is dependent on soil structure condition.
• If the ribbon in greater than 25 mm, the soil has a high clay percentage. Soil needs to be replaced.</td></tr>
<tr><td colspan="2">Assessing Soil Color (for Drainage)</td></tr>
<tr><td>Soil color is a primary (first level) indicator of potential drainage characteristics, particularly in the absence of standing water.</td><td>• Soil color is uniform brown or dark brown. The soil is sufficiently drained and suitable for re-use.
• Soil color is mostly brown but has grey or red colorations. Soil may be slowly draining, but may be suitable for re-use.
• Soil color has grey or greenish tint. Soil is poorly drained and may need to be replaced.
• Soil is dominantly grey with red, yellow, or orange discolorations. Soil is poorly drained and must be replaced.</td></tr>
<tr><td colspan="2">Assessing Soil Drainage</td></tr>
<tr><td>Assess soil drainage after rainfall or irrigation events.</td><td>• After recent rain or irrigation determine if water is moving into and through the soil profile.
a. Is the surface (0 – 75 mm [0-3 inches]) wet but subsoil dry?
i. Insufficient irrigation or light rain: monitor soil
ii. Poor soil infiltration: soil surface needs remediation
b. Is the soil saturated several hours after irrigation or rainfall?
i. Poor soil drainage: subsoil likely needs remediation or replacement.</td></tr>
</table>

	ii. Insufficient surface drainage: **soil surface contours may need to be regraded.** c. Is the soil very dry soon after irrigation or rainfall? i. If sandy soil, soil is excessively drained: **Soil may need amendment or replacement.** ii. If fine-textured soil - soil is not infiltrating: **soil replacement may be necessary.**

Using Imported Soils for Landscape Restoration

Often, soil excavated from a project site cannot be re-used because it has been damaged by excessive compaction or it may consist of tight, structureless (massive) structure that will not adequately support vegetation. Soil replacement should be executed as described above, with imported soils used for the B horizon subsoil and the A horizon topsoil.
Imported soils need to match the surrounding soils as much as possible. Imported soil must have the following qualities:

1. The Smithsonian COTR will have a list of pre-approved soil providers from which imported soils shall be obtained.

2. At most locations imported soil will be Sandy Clay Loam, Loam, or Sandy Loam. Sand, loamy sand, silt loam, and clay are not acceptable soil types. All imported soils must be tested for soil texture.

3. Soil must have strong, stable aggregate structure with minimum 2 mm (0.1 inch) soil peds (crumbs or aggregates) that are stable in water (they don't fall apart to small grains when placed in a small dish of water for 30 seconds).

4. Imported soils must be tested to demonstrate the following:
   a. Soil pH between 5.5 and 7.3 standard units
   b. Electrical conductivity less than 1.0 mS cm-1
   c. Soil organic matter content greater than 3 percent by weight

Restoration of Soils in Excavations

The replacement and restoration of soils in excavations involves up-front planning to assure that when completed, the soil in the project area will perform similarly to (or better than) adjacent and nearby soils. Restoration of soils in excavations involves the following:

1. As excavation for a project begins, carefully remove and segregate soil by each horizon identified. If soil horizons have not been characterized, remove and segregate the top 300 mm (12 inches) of soil as the topsoil (A horizon); removed and segregate the next 450 mm (18 inches) of soil as subsoil (B horizon); and then remove and segregate soil deeper than 750 mm (30 inches) as base soils. Use care when excavating soil around buried utilities. If soil will not be reused, then it must be removed from the site immediately.
2. Remove large debris, such as logs, large rocks, or other debris from the soils. Check the soil for moisture. This can be accomplished by squeezing a handful of soil into a ball. If the ball falls apart with minimal finger pressure, it is ready for preparation for re-use. If the ball does not fall apart into smaller pieces, it is too wet and must dry before it can be prepared for re-use.
3. If and when the soil is sufficiently dry, break large soil clods (greater than 75mm [3 inches] in any dimension) into smaller soil peds. Manually break up any large clods to loosen the soil, or use a power tiller to turn and loosen the soil in a large garden bed. Avoid over tilling, which breaks down soil too much and prevents good water drainage.
4. Prior to replacement of excavated soil, prepare and protect buried utilities as directed by the project designer or engineer.
5. Scarifiy the floor and sidewalls of the excavation to provide a rough, broken surface to prevent slickened or compacted surfaces.
6. Replace soils into the excavation in reverse order of their removal (replacement of the deeper base soils first, followed by the B horizon subsoil, and finally the A horizon topsoil).
    a. Soil shall be replaced in 300-mm (12-inch) lifts.
    b. Each lift must be compacted using foot pressure or a 350-pound roller. Be careful not to over compact soils from excess foot traffic or more than roller pass over each lift.
    c. Each lift must be scarified and raked smooth before each subsequent soil lift is placed. Use shovels or rakes to break any voids in each soil lift.
7. After the final lift of A horizon topsoil has been installed, place 50 mm (2 inches) of compost over the final soil lift and incorporating into the soil to a depth of 150 mm (6 inches).
    a. Compost must be fully-prepared compost approved by the Smithsonian Contracting Officer’s Technical Representative (COTR).
8. After completion of the soil replacement, the final surface shall be compacted with a 160 kg roller and raked smooth with a firm, friable planting or seeding surface.

Soil Restoration for Lawn Areas

Lawns are defined as open areas of limited to turf grass vegetation only. Often, lawns become stressed or worn out due to compaction (typically from heavy pedestrian use), poor drainage, or too much shade. Key to success for sustainable, healthy lawns is providing soil that enables deep root growth, good drainage, and nutrient retention. Sometimes, such as with over-shaded areas, soil condition may not help poor turf conditions and another planting scheme or different, more shade-tolerant grass species may be needed.

Restoration of soil for lawns includes the following:

1. Remove turf grass and weeds from the affected area. Assess soil condition (see "Examine and Assess Soil Condition [above]).

2. Compacted soil
   a. **Deep compaction** (typically hard, dense soil greater than 200 mm (8 inches) deep): Remove soil that exhibits penetration to resistance is greater than approximately 19 kg cm^{-1}, or to no more than 450 mm (18 inches) below the surface. Scarify the floor and sides of the excavation and replace with imported soil of similar texture.
   b. **Intermediate compaction** (typically hard, dense soil to a depth between 100 to 200 mm [4 – 8 inches]. Assumes soil below 200 mm depth has resistance to penetration less than 19 kg cm^{-1} and infiltration rate greater than 12.5 mm hr^{-1}):
      i. **Alternative 1 – immediate repair**
         1. Remove the surface 100 mm (4 inches) of soil.
         2. Place a 25 mm (1-inch) layer of compost on the resulting soil surface and till into the soil using a rotating shovel or rototiller to a depth of 100 mm (4 inches).
         3. Compact the tilled soil using a 160 kg roller.
         4. Scarify the soil surface and rake the surface to an even grade
         5. Break large clods and remove large rocks from the excavated soil and replace over the tilled soil layer.
         6. Place a 25 mm (1-inch) layer of compost on the soil and till to a depth of 125 mm (5 inches).
         7. Rake the surface of the soil smooth and even. Compact with a 160 kg roller. Scarify the soil surface and prepare a firm, friable seed or planting bed for turf establishment.
         8. For areas less than approximately 10 m2, excavation of soil can be eliminated. Place 50 mm (2 inches) of compost on the surface of the soil and blend into the soil to a depth of 200 mm (8 inches) using shovels, simultaneously breaking compaction and large soil clods. The soil can be finished with a rototiller to a depth of 200 mm (8 inches), and graded even with rakes.
         9. Prepare a firm, friable seed- or planting bed for new turf establishment.

   ii. **Alternative 2: Minimally invasive repair**
      1. Conduct deep soil aeration with 150 mm-long (6 inches), 25 mm (1-inch) diameter cores on 300 mm to 450 mm (12 inch to 18 inch) centers.
      2. Place a 25 mm (1-inch) layer of compost over the area, working the compost into the soil surface to a depth of 10- to 20 mm.
      3. Allow the compost to remain on the soil surface for several weeks with little to no pedestrian, vehicle, or other traffic allowed on the area.

c. **Shallow compaction** (typically hard, dense soil, often with platy structure, less than 100 mm [4 inches] deep):
   i. Place a 30 mm layer of compost across the surface of the soil.
   ii. Incorporate the compost into the soil to a depth of 100- to 150 mm (4 to 6 inches) using a rotating shovel or rototiller. NOTE: it is important not to over-utilize a rototiller as it may create a plow pan at the depth of the tilling action. If possible, a rotating shovel is preferred.
   iii. Rake and grade the soil surface smooth and even. Prepare a firm, friable seeding- or planting bed for turf establishment.

3. Drainage

a. Soil drainage may be affected by poor draining conditions in which water does not infiltration or move through the soil, or excessive drainage in which water moves through the soil too fast. Both conditions will result in poor lawn health.
b. **Poorly Drained Soils:** Poorly drained soils can be a result of compaction (see above), fine textured soil with poor structure (but not necessarily compacted), or a confining layer of soil; either a clay or plow pan, or a deeper fine-textured (typically clayey) horizon. Poorly drained soils cannot be repaired until water can be moved deeper into the soil or horizontally out of the soil through a more porous soil layer (typically sand) or over the soil surface.
   i. Assess soil drainage by observing drainage patterns in the surrounding area of the impacted soil.
      1. Determine if drainage from a larger area is concentrating into a limited area affecting soil conditions.
      2. Determine if the affected soil is in a low spot where surface drainage is impeded.
   ii. Assess soil condition of the affected area.
      1. Determine if the surface soil has “silted in” with a layer of silt that has accumulated at the surface.
      2. Using a soil core or a shovel to open a hole, determine if a confining layer of high clay soil – either as a thin seam or layer, or as a subsoil layer – is present within 300 mm (12 inches) of the soil surface.
   iii. Repair of poorly-drained soils
      1. Remove any accumulated silt or clays at the soil surface, if present.

2. If fine-textured (silt and clay) with no structure (massive) is present within 300 mm (12 inches) of the surface, blend compost into the soil by placing 50 mm of compost over the soil surface and incorporating it to a minimum depth of 150 mm (6 inches) below the soil surface.
3. If the affected area is in a low area in which surface drainage of runoff concentrates, raise the elevation of the affected area to be approximately 25 mm (1-inch) higher than surrounding soils by adding soil to establish positive drainage.
4. Blend soil together with a rototiller or rotating plow, taking care not to over-till the soil (this will create a potential confining plow layer within the soil). Prepare a firm, friable seed- or planting bed to restore turf grass.

Soil Management for Trees

Management and repair of soil that is the base of growing trees must be conducted with caution and care due to the sensitivity of tree roots. Primary methods used to restore or improve soil conditions within tree root zones include:

1. Mulching – both surface mulching and vertical mulching
2. Air Spading
3. Radial Trenching

These methods are summarized below.

<table>
<tr><td colspan="2">1. Mulching: Mulching involves the application of compost and/or wood mulch near the surface soils of root areas. Two approaches are often used: Surface mulching and vertical mulching.
- Surface mulching is a passive method of soil management that typically involves the placement of shredded wood mulch or compost in a 50 to 75 mm (2- to 3-inch) layer within the root zone of the trees. To help in breaking surface compaction or sealing of soils, the soil surface is often lightly scarified to open porosity.
- Vertical mulching involves augering 50 to 75 mm (2- to 3-inch) holes into compacted soil – and often through a compacted clay pan – to decrease soil bulk density and open pore space. The holes are often filled with compost or less-dense soil material that promotes drainage and oxygen exchange.
Both methods of mulching can be used in combination with other soil management techniques.</td></tr>
<tr><td>Pros:
- Surface mulching
o Minimal to now damage of existing tree roots
o Mulch/compost layer provides a protective layer for roots
o Conserves water in soil around the tree
o Provides nutrient additions.
- Vertical Mulching
o Opens soil to reduce soil density
o Promotes drainage and aeration
o Source of nutrients and water for tree roots
o Improves soil microbial environment</td><td>Cons:
- Surface Mulching
o Very passive, slow means of improving soil
o Must be repeated at least every year.
- Vertical Mulching
o Could damage roots. Care must be taken to avoid major roots.
o Semi-passive approach that does not remediate the whole soil in tree root zones.</td></tr>
<tr><td colspan="2">Methods:
- Surface Mulching
o If possible (but not necessary), scarify the surface soil to a depth of 25 to 50 mm (1- to 2 inches) taking care not to damage roots</td></tr>
</table>

<table>
<tr><td colspan="2">
<li style="list-style:none">

Spread a 50 to 75 mm (2- to 3-inch) layer of good quality compost or shredded mulch over the designated area, packing the compost or mulch to be firm near the soil.
Sand can be blended with the compost/mulch (1 part sand to 3 parts compost or mulch) to provide stability from erosion, wind, or other factors that could move the surface material.

Vertical Mulching

Carefully select locations where holes can be augured within tree root zones that will minimize damage to tree roots.
Using a 50 to 75 mm (2- to 3-inch) power augur, advance holes to depths of 375 to 450 mm (15 to 18 inches) below the surface.
Fill holes with a sand/compost blend (1 part sand to 1 part compost), packing the sand/compost blend into the hole to assure firm filling/placement of the material.

</td></tr>
<tr><td colspan="2">2. Air Spading: Removal of soil in the critical root zone of trees using an air spade that uses compressed air to decompact soil near the tree or to blow soil away from tree roots, reducing the potential for physical root damage.</td></tr>
<tr><td>Pros:

Removes soil while reducing physical damage to soil roots. Removal must be done in layers.
Soil removal leaves exposed tree roots around which new soil can be placed.
Air spading can also be used to loosen compacted soil and mix compost into subsurface layers around tree roots
Gives access to tree roots and allows for easier disease/pest treatment.
Can be used to perform radial trenching without major root damage.
Can be used to advance vertical mulching holes with reduced root damage.
</td>
<td>Cons:

If air pressure is too high, it can damage roots.
Air spading also removes critical soil microorganisms such as bacteria, fungi, protozoa, and other microflora essential for tree health.
Air spading will not improve soil structure unless new soil or compost is placed around the tree.
Air spading is difficult in fine-textured soils
Requires the use of specialized equipment and personal protective equipment.
</td></tr>
<tr><td colspan="2">Methods:

Air spading is performed by specialized equipment and operators using high pressure air compressors.
Delineate the area and depth to be treated by air spading. Remove objects and debris that can be damaged from the compressed air forces.
If appropriate, wet the ground before use of the air spade to soften soil and reduce potential root damage.
Follow applicable manuals and instructions for the use of air spades for loosening or removing and replacing soil.
After the air spade process is complete (by a qualified operator), soil restoration shall
</td></tr>
</table>

include placement of new soil with amendments (including compost) if specified. It is appropriate to inoculate the new soil with mycorrhizal fungi spores to restore essential soil microbial populations to support tree recovery.

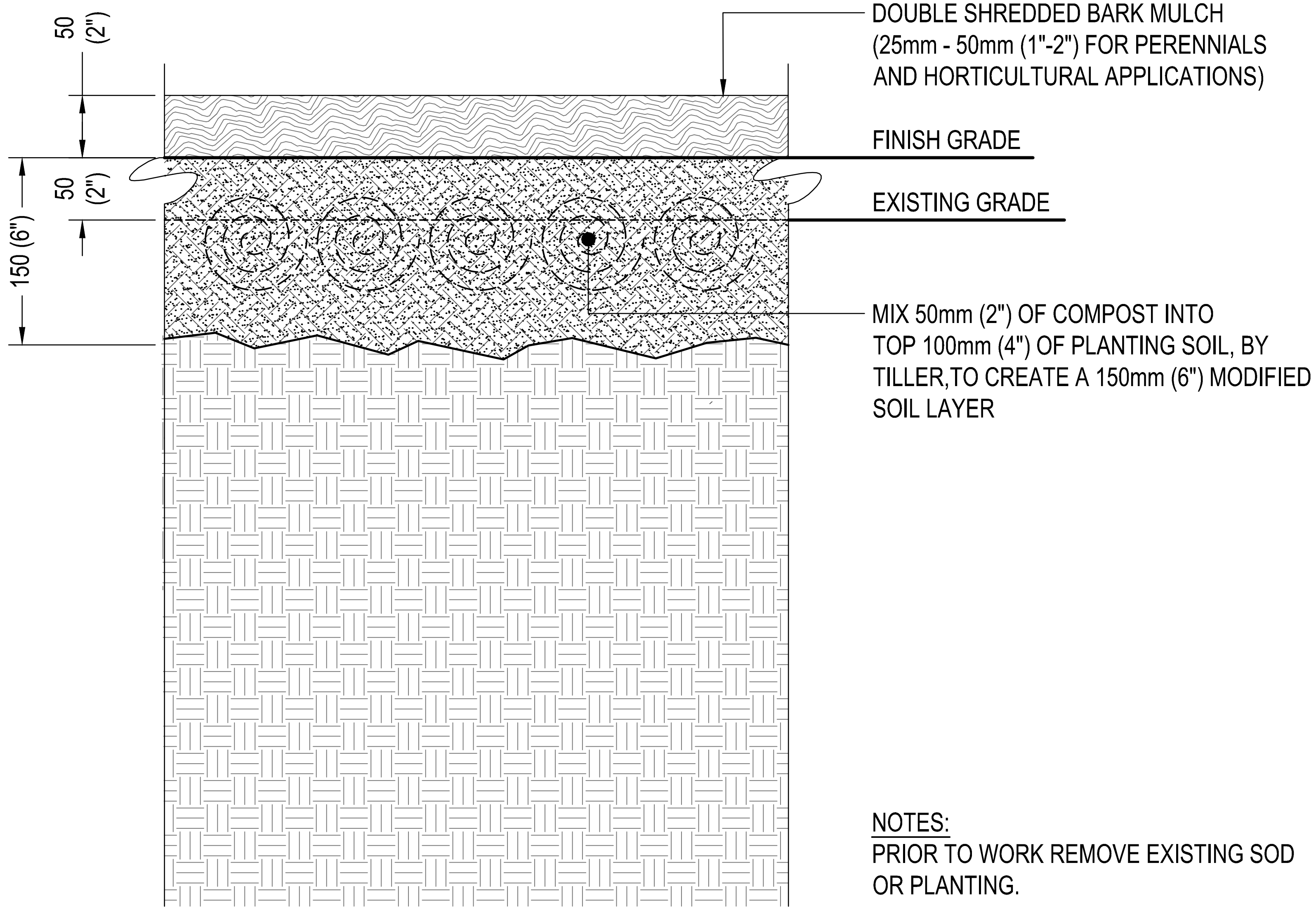
3. Radial Trenching: Radial trenching involves the excavation of narrow trenches radially from the tree trunk (typically several feet from the tree trunk) to open compacted soil to improved aeration and drainage. The trench is often filled with a mix of the expelled soil and less dense, more porous media (sandier soil and/or compost) to allow deep exchange of oxygen and water, and enable tree roots to grow in less compacted soil.

Pros:	Cons:
- Does not disturb the entire soil layer and will not disturb all the entire system of critical microorganisms in the soil. - Radial Trenching can be used to loosen compacted soil and mix compost into soil layers near tree roots. - Through use of an air spade, radial trenching avoids potential damage and harm that manual or mechanical excavation could cause to tree roots	- Lower layers of soil may be unreachable without causing major damage to roots. - Improves aerations and nutrient availability but may not improve the larger soil structure. - Accessing roots by air spade is more costly than with the use of manual or mechanical excavation.

Methods:

- Identify and mark locations where trenches will be excavated in a radial pattern within the tree root zone.
- Trenches of varying length (typically 3.65 meters [12 ft] or less), approximately 300 mm (1-foot) deep, and 150 to 300 mm (6- to 12 inches wide are excavated radially from the tree truck. Trenches must be outside of critical primary roots
- After each trench is completed, a compost-soil blend is replaced into the trench (refer to SG standard detail for mix ratio). The soil-compost blend must be firmly packed into the trench to minimize open voids and subsidence of the soils.
    - Replacement soil may be recovered soil from the trench, or may be imported soil consisting of a sandy loam soil.
- Installed soils for each trench are graded even with the surrounding soils and packed firm.
- Replenishment of soil into each trench may be necessary if additional settlement occurs.
- Inoculation of replaced soils with mycorrhizal spores will support tree recovery and root growth.

Details



NOTES:
PRIOR TO WORK REMOVE EXISTING SOD OR PLANTING.

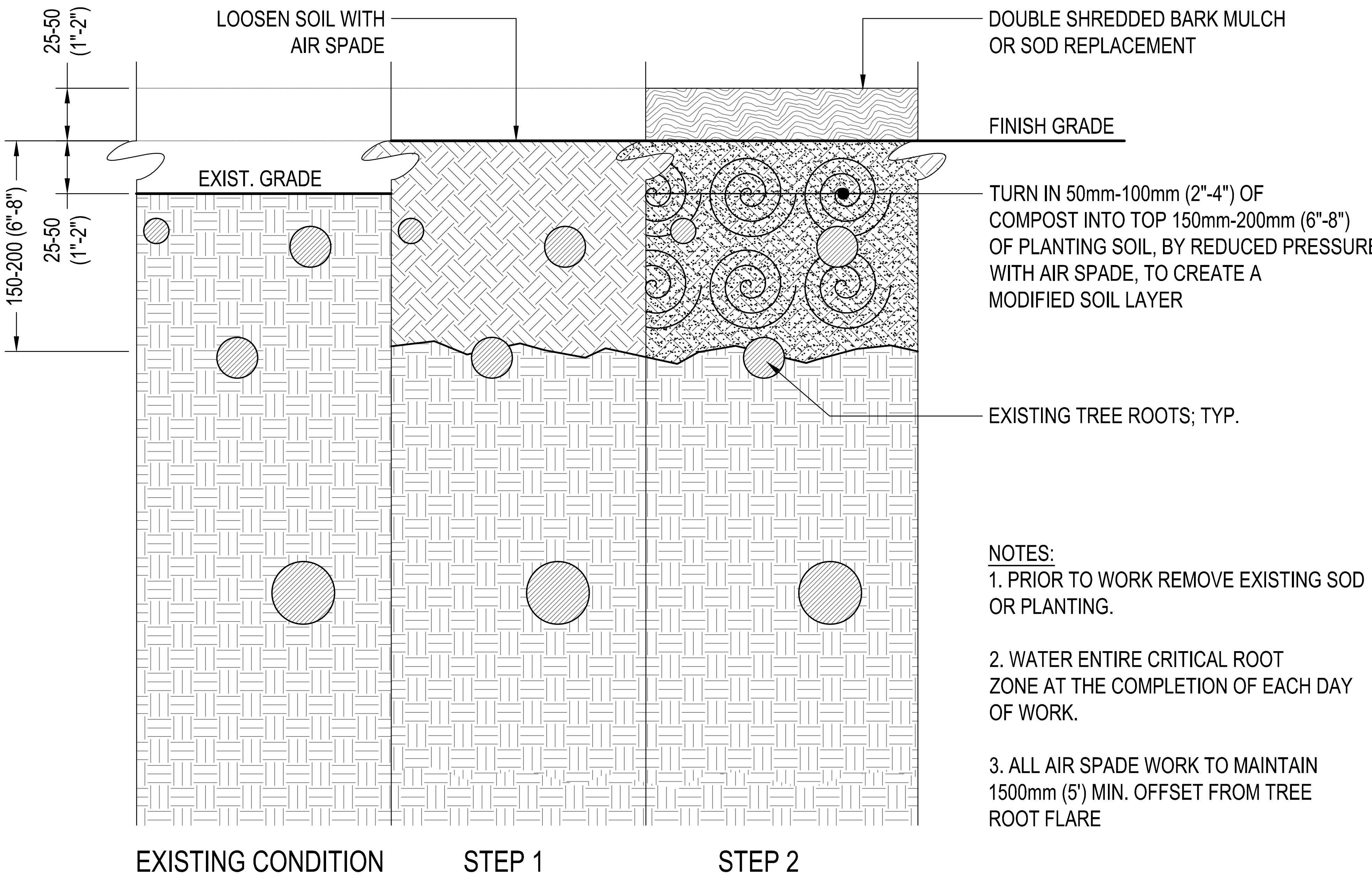
XX
A00 | A00

AMENDING EXISTING SOIL

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



NOTES:

1. PRIOR TO WORK REMOVE EXISTING SOD OR PLANTING.

2. WATER ENTIRE CRITICAL ROOT ZONE AT THE COMPLETION OF EACH DAY OF WORK.

3. ALL AIR SPADE WORK TO MAINTAIN 1500mm (5') MIN. OFFSET FROM TREE ROOT FLARE

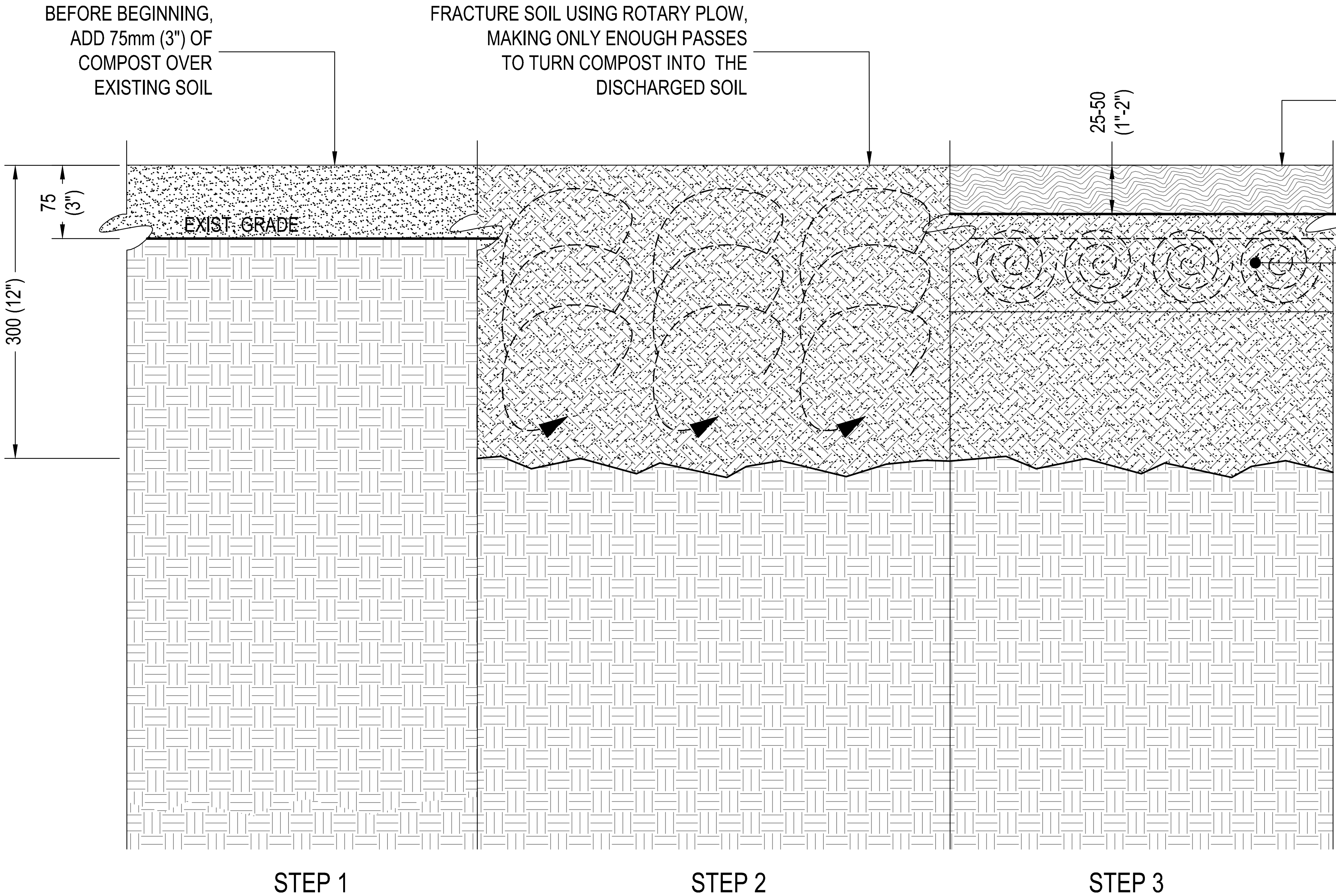
XX
A00 | A00

SOIL SURFACE REMEDIATION - IN TREE CRZ

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



NOTES:

1. PRIOR TO WORK REMOVE PLANTING OR CUT LAWN AS LOW AS POSSIBLE.
2. IF REMEDIATING LAWN, PROCESS IS COMPLETE AT STEP 2, DO NOT COMPLETE STEP 3.
3. FINAL GRADE IS ASSUMED TO BE 1" TO 2" HIGHER THAN EXISTING GRADE.
4. FOR SOIL RE-BUILDING ADJACENT TO PAVING AND BUILDING STRUCTURES, MAINTAIN A MIN. 600mm (2'-0") OFFSET TO PREVENT DISTURBING SUBBASES

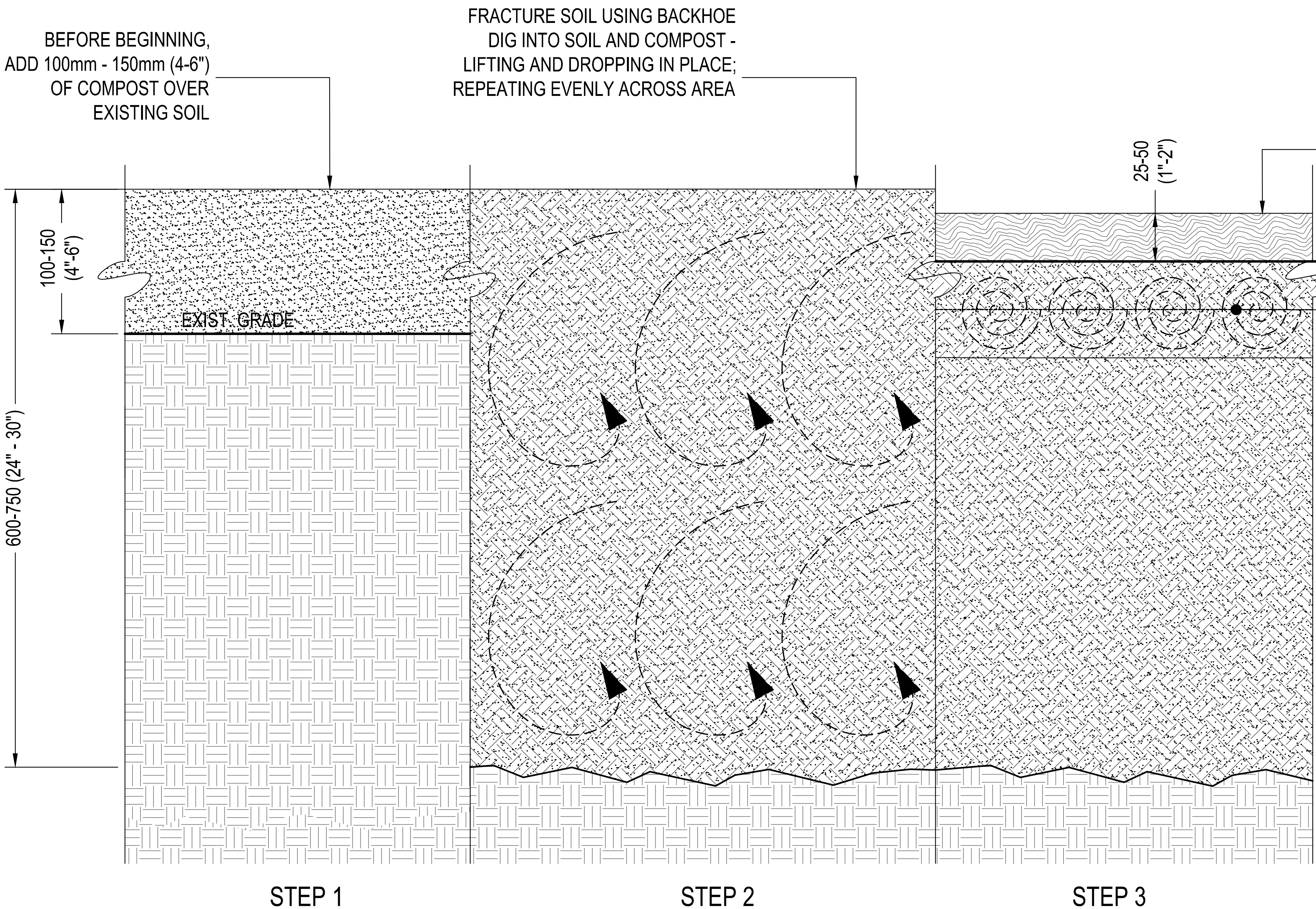
XX
A00 | A00

SOIL PROFILE REBUILDING - 300mm (12") DEPTH

SCALE: 1:5

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



NOTES:

1. PRIOR TO WORK REMOVE PLANTING OR CUT LAWN AS LOW AS POSSIBLE.

2. IF REMEDIATING LAWN, PROCESS IS COMPLETE AT STEP 2, DO NOT COMPLETE STEP 3.

3. FINAL GRADE IS ASSUMED TO BE 1" TO 2" HIGHER THAN EXISTING GRADE.

4. FOR SOIL RE-BUILDING ADJACENT TO PAVING AND BUILDING STRUCTURES, MAINTAIN A MIN. 600mm (2'-0") OFFSET TO PREVENT DISTURBING SUBBASES

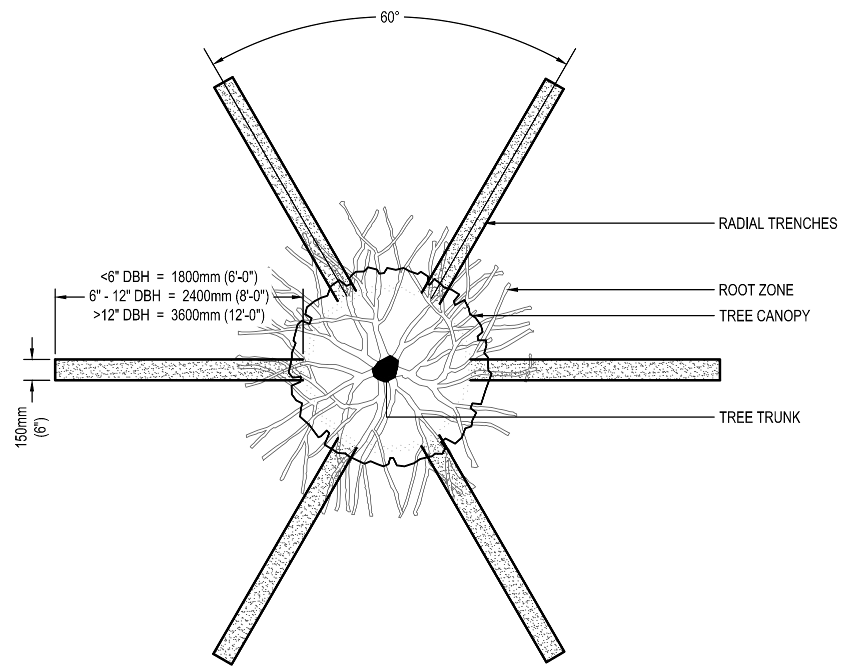
XX
A00 | A00

SOIL PROFILE REBUILDING - 600mm-750mm (24''-30'') DEPTH

SCALE: 1:5

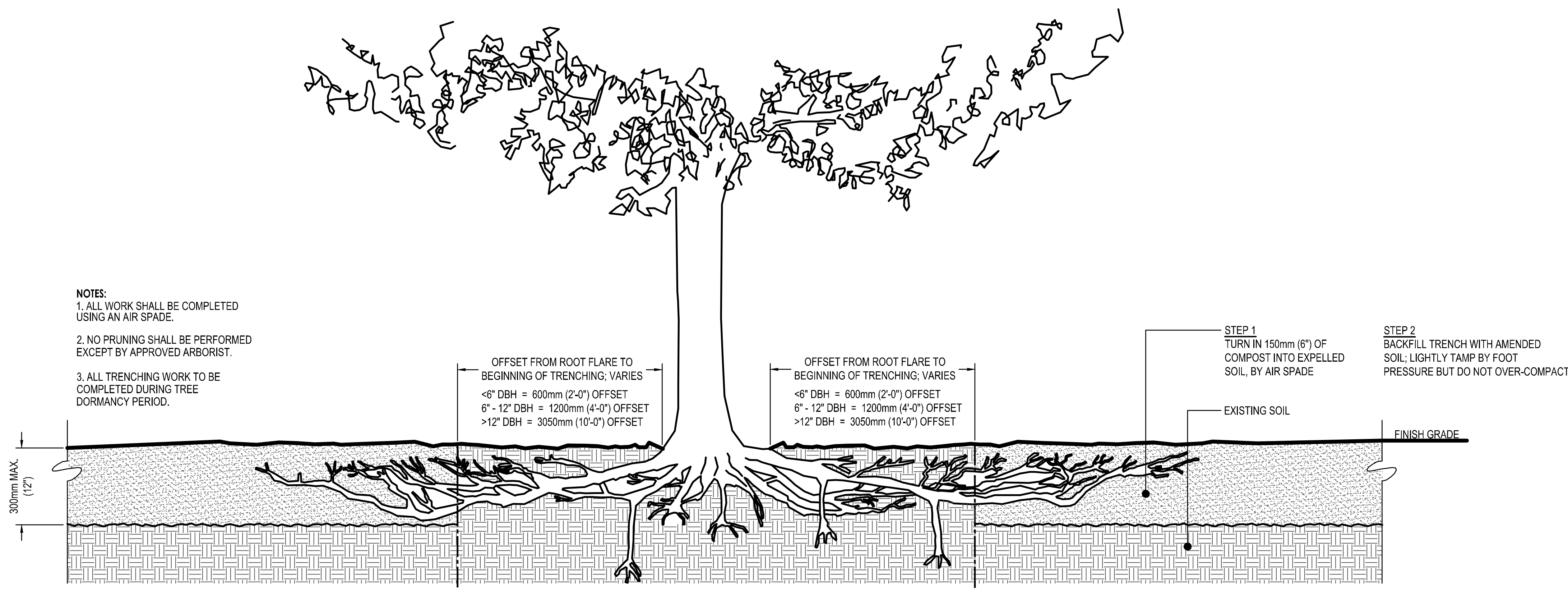
SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



PLAN VIEW: NTS

NOTES:
1. ALL WORK SHALL BE COMPLETED USING AN AIR SPADE.
2. NO PRUNING SHALL BE PERFORMED EXCEPT BY APPROVED ARBORIST.
3. ALL TRENCHING WORK TO BE COMPLETED DURING TREE DORMANCY PERIOD.



SECTION VIEW

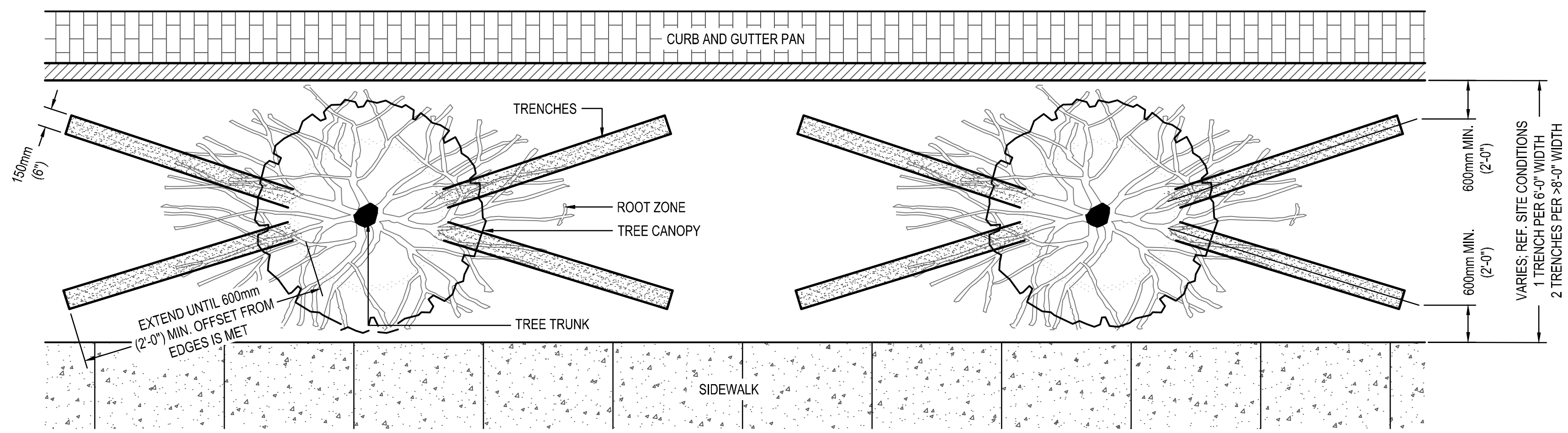
XX A00 A00

RADIAL TRENCHING IN OPEN SPACE - IN TREE CRZ

SCALE: 1:20

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

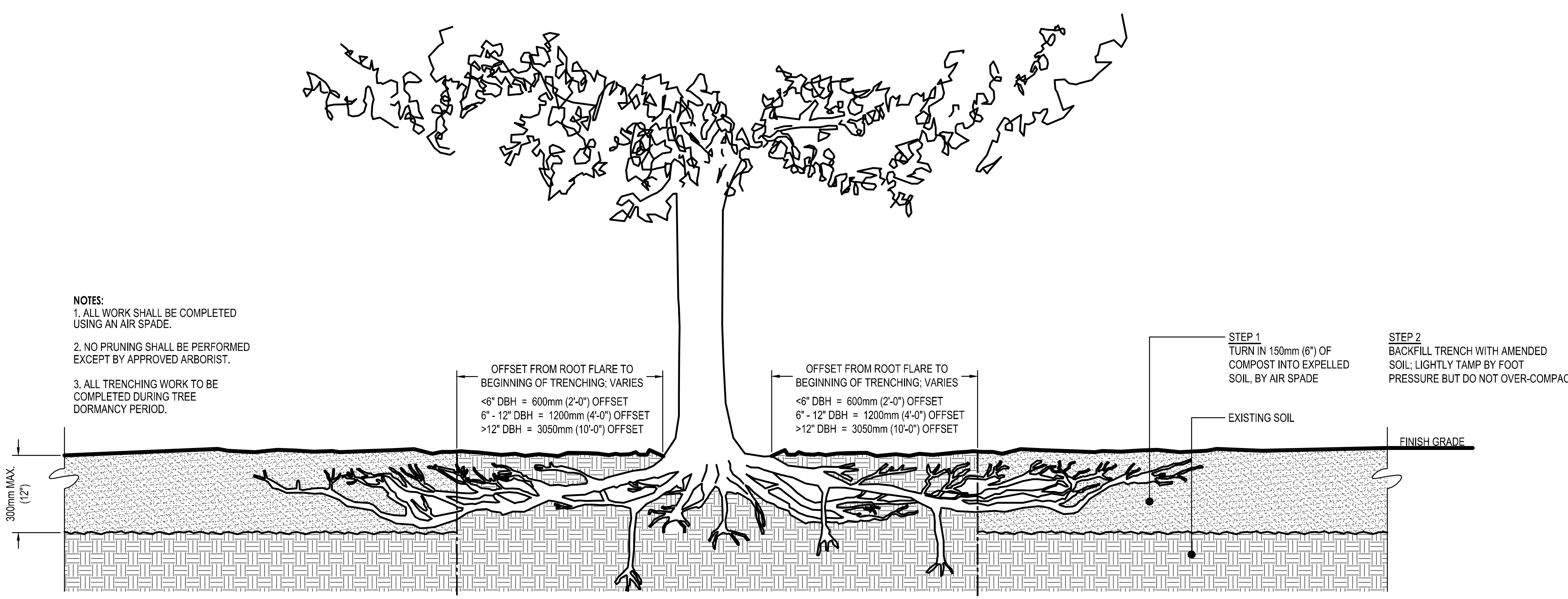
Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



PLAN VIEW: NTS

NOTES:

1. ALL WORK SHALL BE COMPLETED USING AN AIR SPADE.
2. NO PRUNING SHALL BE PERFORMED EXCEPT BY APPROVED ARBORIST.
3. ALL TRENCHING WORK TO BE COMPLETED DURING TREE DORMANCY PERIOD.



LONGITUDINAL SECTION VIEW

XX
A00 A00

RADIAL TRENCHING IN STREETSCAPE PLANTER - IN TREE CRZ

SCALE: 1:20

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560

APPENDIX G

Site Protection Specification and Details
01 5639 - Site Protection

Smithsonian Gardens

SG SPECIFICATIONS

SECTION 01 5639 – SITE PROTECTION

26.1. Tree Protection: The following procedures shall be followed for any project taking place on Smithsonian Institution grounds when any tree may be impacted.

26.1.1 Prior to any work taking place or vehicles and equipment being brought on site, the Contractor shall meet with the Smithsonian Gardens (SG) Arborist, Landscape Architect, and other appropriate staff to discuss and plan for tree protection measures.

26.1.2 The project site shall be defined, and all trees that may be impacted identified.

A. Where proposed utility work and connections cross roadways into adjacent SG property, the project site will include tree protection within the adjacent property if deemed necessary by the Smithsonian Gardens Arborist and/or other qualified SG staff.

26.1.3 For every tree that may be impacted, the Critical Root Zone (CRZ) shall be identified.

The CRZ shall be determined by the following method:

A. Measure the diameter of the tree at breast height (4.5 feet above grade), and for every inch of diameter, measure a distance of 1.5 feet from the trunk. The area inside this circle is the CRZ.

26.1.4 The following activities shall **NOT** take place in the CRZ, unless specified in a written tree protection plan pre-approved by SG:

A. Stockpiling of materials, soil, mulch, or debris.
B. Parking or driving of equipment or vehicles.
C. Compaction of soil from any activity, including the placement of vehicles, materials, equipment, or outriggers.
D. Trenching, tunneling, grade changing, or removing soil.
E. Cutting, tearing, or grubbing of tree roots.
F. Wounding trees in any way.

G. Changing the site drainage.
H. Dumping or spraying gasoline, oil, dirty water, or any chemical or material that can damage a tree.
I. Using trees as backstops, winch supports, or anchors.
J. Attaching anything to trees, including, but not limited to, signage, nails, screws, spikes, ropes, and wires.

26.1.5 Once the CRZ's have been identified, fencing shall be erected on the edge of the CRZ to prevent any activities from taking place in those zones. Fencing should consist of minimum 48" height (72" preferred) chain link or welded wire fence with steel posts set into the ground. Refer to Smithsonian Gardens standard Tree Protection Fence Detail. Alterations to or deviations from this detail shall be pre-approved by SG through the COTR. Orange construction fencing should NOT be used without advance approval from SG Arborist.

Warning signs shall be placed on each CRZ fence, be a minimum size of 8.5 x 11 inches, and state the following: "TREE PROTECTION ZONE. This fence shall not be removed." Removal of fences, even temporarily, to allow deliveries or equipment access is not allowed without the prior approval of the Smithsonian Gardens Arborist or other qualified SG staff.

26.1.6 In the event that it is impossible to complete a project without some activity in a CRZ, a written tree protection plan pre-approved by SG shall be implemented. Tree protection plan requirements may include impact avoidance, root protection groundcover, air excavation and root pruning, supplemental watering, chemical applications, branch pruning and/or tiebacks, and/or any number of other industry standard tree protection methods generally reviewed in the *Managing Trees During Construction Best Management Practices* manual (Fite and Smiley 2016) and other literature reviewing tree care industry standard tree protection practices.

A. Boring of utilities under protected root zones shall be required in circumstances where it is not possible to trench around a CRZ. Refer to Smithsonian Gardens standard Tree Protection Utility Boring Detail.

26.1.7 During the project, project activities shall not physically impact the tree or delineated CRZ, unless described in tree protection plan pre-approved by SG. The impacted trees shall also be closely monitored for signs of shock or stress. Any decline in tree condition that is noted by the Contractor shall be immediately reported to the SG Arborist or other staff. The Contractor shall be prepared to provide temporary water to irrigate.

26.1.8 Upon completion of the project, all trees within the project area will be inspected by the SG Arborist and/or other qualified SG staff for any signs of tree damage, soil compaction, and/or other negative impacts to the site. If any issues are found, the

Contractor shall be responsible for remediation activities including, but not limited to, root zone invigoration/air spading, liquid fertilization/bio-stimulant injections, root pruning, branch pruning, bark tracing, and/or supplemental watering.

26.1.9 If a tree is found by the SG staff to be irreversibly damaged, the Contractor may be required to install a replacement tree of matching size, quality, and variety, using a contractor designated by SG. If an acceptable tree is not available, the Contractor may be required to pay damages to SG for the value of the damaged tree in accordance with the guidelines set forth in the *Guide for Plant Appraisal, 10th Edition*, using the Trunk Formula Method.

26.2 Flora Protection: The Contractor is expressly prohibited from collecting plant materials on Smithsonian property.

26.3 Soil, Turf and Planting Bed Protection: Vehicular traffic or parking on turf areas or on planting beds is not permitted without prior approval of the Smithsonian Gardens through the COTR. If turf areas or planting beds must be crossed by vehicles, beds bridging is required. The Contractor shall meet with the Smithsonian Gardens (SG) Arborist, Landscape Architect, and other appropriate staff to discuss required protection measures. The scope of work and types of vehicles or machinery being used will determine the selection of the following ground protection techniques. Install any underlayment or drainage for these protection measures as directed by the associated standard details.

A. ¾' Temporary Plywood Matting – used in zones of low vehicle traffic, including lighter weight vehicles (lulls, skid steer loaders, or equivalent) where the duration of use does not exceed three days. Refer to Smithsonian Gardens standard Temporary Soil Protection – Plywood Matting Detail.

B. Rigid Plastic Decking (Geoterra Mats) – used in main circulation zones with high vehicle traffic, including wheeled vehicles or machinery of H20-rated loading or greater; and where sensitive and newly installed soil is located. Refer to Smithsonian Gardens standard Soil Protection – Geoterra Mats Detail.

C. Timber Mats – used in zones of high vehicle traffic, where heavy (H20-rated loading) vehicles and machinery are entering or exiting the project site; and where sensitive and newly installed soil is located. Refer to Smithsonian Gardens standard Soil Protection – Timber Mats Detail.

26.3.1 The Contractor shall be responsible to ensure that no soil disturbance, compaction, or other damages will occur from construction traffic or other construction activities. Any such disturbance, compaction, and/or damage shall be repaired by the Contractor at no additional expense to Smithsonian Gardens.

26.3.2 Repair and re-establish grades where turf and bed surfaces have become eroded, rutted, or compacted. Scarify, or, if directed by the COTR or other appropriate SG staff, remove and replace soil (with approved soil material) to the depth as directed.

26.3.3 Any soil area that becomes compacted to a density greater than 85% Standard Proctor (or 300 lbs per sq ft) and/or the determined maximum by the COTR or SG staff shall be dug up and reinstalled. Surface tilling shall not be considered adequate to reduce over-compaction at levels 6" or greater below finish grade.

26.4 If a generator is placed on the turf, Smithsonian Gardens must have approved its placement. Generator shall be place on anti-compactor boards. The generator must be placed in a drip containment basin.

26.5 Where aerial work is being performed above shrub/planting beds, the Contractor shall protect them with an approved protective framework installed at least 300 mm above the tops of the plant materials. The Contractor shall submit the proposed method of protection to the COTR and Smithsonian Gardens for approval. Trees and shrubs shall only be tied back with the approval of the COTR and Smithsonian Gardens.

A. Trees in proximity to construction equipment with moving arms at heights above standard protection fencing shall have their trunks protected. Refer to Smithsonian Gardens standard Trunk Protection Detail.

B. Once work is complete, all fallen debris within a 10' radius of scaffolding shall be removed from the surface of the soil and any plants beneath. The Contractor shall utilize magnetic sweepers and metal detectors to remove any fallen metal debris and construction materials.

26.6 Irrigation Protection: Smithsonian Gardens should be notified immediately, should any damage occur to existing irrigation systems during construction. Any damage to the existing irrigation systems during construction shall be repaired by the Contractor within two calendar days from when the damage occurred. All repairs to the irrigation system shall be made by a certified irrigation contractor to work on Rain Bird Maxicom computer controlled irrigation systems. Certification is required.

26.6.2 Damaged piping shall be replaced using approved materials per section Division Two, "Site Work, Irrigation Systems".

26.6.3 The Contractor shall bear all costs for repairs to the damaged irrigation system. Where the low voltage control wiring is damaged due to construction then said wiring shall be replaced from the zone valve to controller. No splicing will be permitted.

26.6.4 Mainlines damaged during the construction process shall be replaced with an identification wire from valve to controller.

26.6.5 All damaged irrigation piping shall be cleared of debris prior to making the permit connections.

26.7 Replacement Plants: The Contractor shall bear all costs for replacement of damaged plant materials. Replacement plant materials shall meet the criteria established by the Smithsonian Gardens. Any plant material destroyed and/or damaged by the Contractor during construction shall be replaced with like genus and species of the same size, at no additional cost to the Smithsonian.

26.8 Replacement Turf: Turf areas damaged during construction shall be repaired by the Contractor according to Smithsonian Gardens Lawns and Grasses Specifications (329200). Replacement turf shall be sod, not seed. Contractor shall request a copy of Lawns and Grasses Specifications prior to commencing repair. Specifications include roto-tilling a minimum depth of 6 inches, backfilled with sandy-loam topsoil. Prior to installing sod, contractor shall obtain Smithsonian Gardens acceptance of finish grading. Sod shall be certified sod, non-netted and a minimum of one year old. Sod shall be 90:10, consisting of a minimum of three varieties tall fescues and one Kentucky Bluegrass. Smithsonian Gardens through the COTR must approve the source of the sod. Following installation, sod shall be rolled by hand with a water roller to ensure contact with subgrade, eliminate air pockets, and form a smooth surface. The Contractor shall bear all costs for these repairs. Suggested sources are:

1. Oakwood Sod Farm, Inc.
29307 Waller Road
Delmar, MD 21875
Phone: (410) 896-4009
Toll-Free: (800)379-8488

2. Collins Wharf Sod
25361 Collins Wharf Rd
Eden, MD 21822
Phone 410-334-6676
Fax 410-749-3815

3. Summit Hall Sod Farm
21300 River Road
Poolesville, MD 20837-9114
Phone: 301-948-2900
Fax: 301-349-2668

26.9 Replacement Soil: Planting soil damaged by compaction or removed during construction shall be repaired or replaced. All removed soil shall be stored on site, protected properly, and used for replacement. Any replacement soil brought from off-site shall match the existing soil texture. Smithsonian Gardens, through the COTR, must approve the source of any replacement soil before procuring and transporting the soil to the site.

26.10 Compacted Soil: Planting soil damaged by compaction during construction shall be repaired or replaced. Before the Contractor concludes their Work (at time of Substantial Completion or Final Review), they must notify Smithsonian Gardens, through the COTR, to check for compaction. If compaction has occurred, the Smithsonian COTR will direct the Contractor to the proper remediation process and details based on the depth of compaction found to be present.

26.11 Artifacts and Furniture Collection Pieces: Smithsonian Gardens requires (5) working day notice should any of the artifacts or furniture collection need to be removed to facilitate construction. Any artifacts or furniture collection piece damaged during the construction process must be replaced prior to final payment.

26.12 Trash and Debris Removal: The Contractor shall be responsible for the daily removal of trash and construction debris from turf and flower/shrub beds within the limits of construction.

26.13 Scaffolding: Any construction scaffolding on turf and planted beds must be coordinated with the Smithsonian Gardens through the COTR to ensure that its installation will not damage
or destroy existing plant materials or turf area or interfere with daily maintenance of the grounds. Trees may be tied back to permit erection of scaffolding, no more than 4 feet if possible. The tying back must be performed by a certified Arborist with the approval of Smithsonian Gardens and the COTR. Where scaffolding is necessary to facilitate construction, Smithsonian Gardens requires a three (3) workday notice for said work.

26.14 Haupt Garden: Due to structural weight limits, vehicular traffic is permitted inside the Smithsonian's Enid A. Haupt Garden only with prior approval by the COTR and Smithsonian Gardens.

26.15 Fauna Protection: The Contractor is prohibited from hunting, collecting, or feeding animals on Smithsonian property. All food and food wrapping brought on the premises must be properly disposed of in approved containers which are secured from animals.

Details

Tree Preservation
identifying impacts and tolerances

1 PERCENTAGE OF CRZ IMPACTED

The number of quadrants, or "sides," of the critical root zone that are impacted will significantly affect tree preservation. The consequences become more severe with each additional quadrant impacted.

The root plate is the "base of the wine glass" around each tree that is responsible for structural support. It is very important to avoid severing these roots because damage to them can result in catastrophic windthrow failure.

% CRZ Impacted	% SRP Impacted	Survivability
0 - 30%		Good - Great
31 - 40%		Moderate
41 - 50%	0 - 25%	50 / 50 Chance
> 50%	> 25%	Remove Tree

2 EXISTING TREE HEALTH

Tree condition is categorized from excellent to dying. This is a conclusion based upon visual inspection of growth rates, consistency of growth, percentage of live crown, live crown ratio, history of failure, structural defects and anticipated life span. For tree preservation purposes, only trees with a condition rating of fair, or better, should be considered as preservation candidates.

- Excellent
- Good
- Fair
- Poor
- Dying or dead

3 SEASON OF IMPACT

The least impactful season for severing roots is the dormant season. This is because of the low energy demand for the tree during this time. Alternatively, the most stressful time are the spring months when energy demands are at their highest.

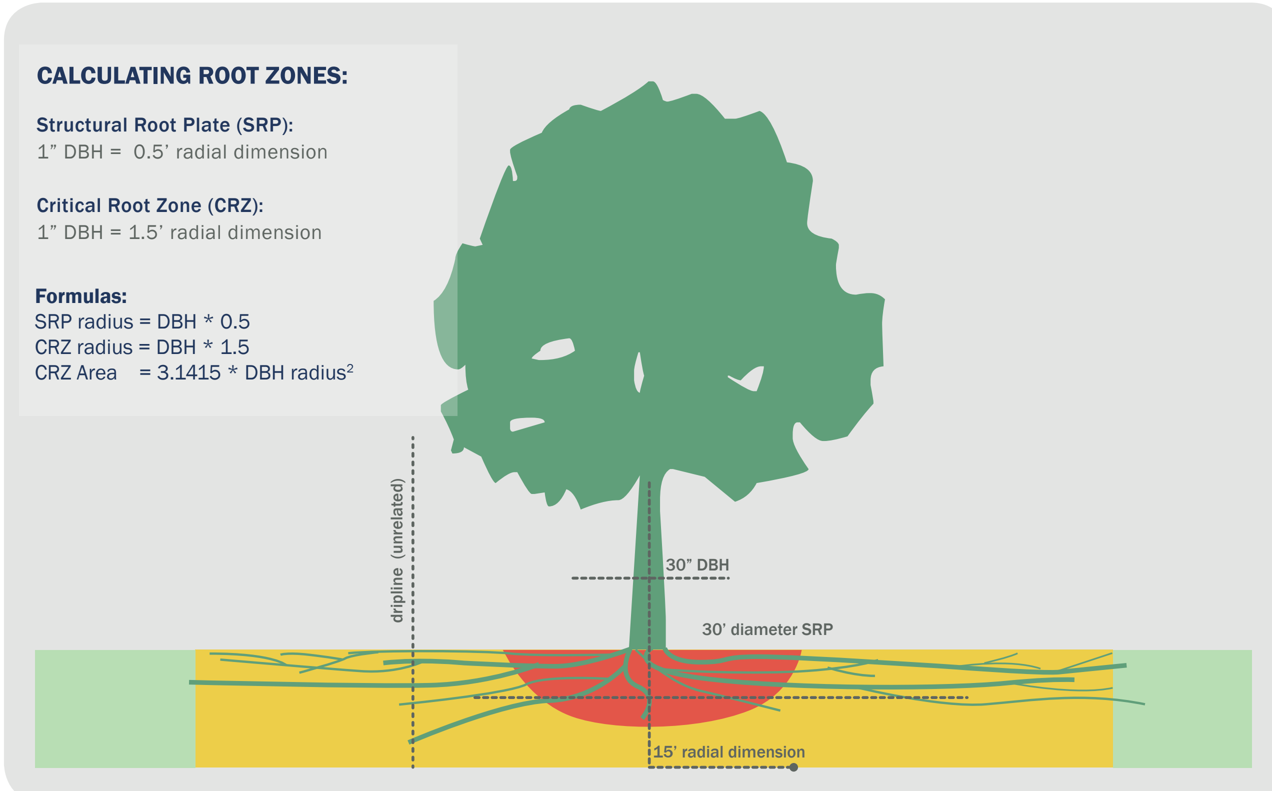
Season	Energy Needs	Recovery Time
Winter	Low	1 year
Fall	Medium-Low	2 years
Summer	Medium-High	3 years
Spring	High	4 years

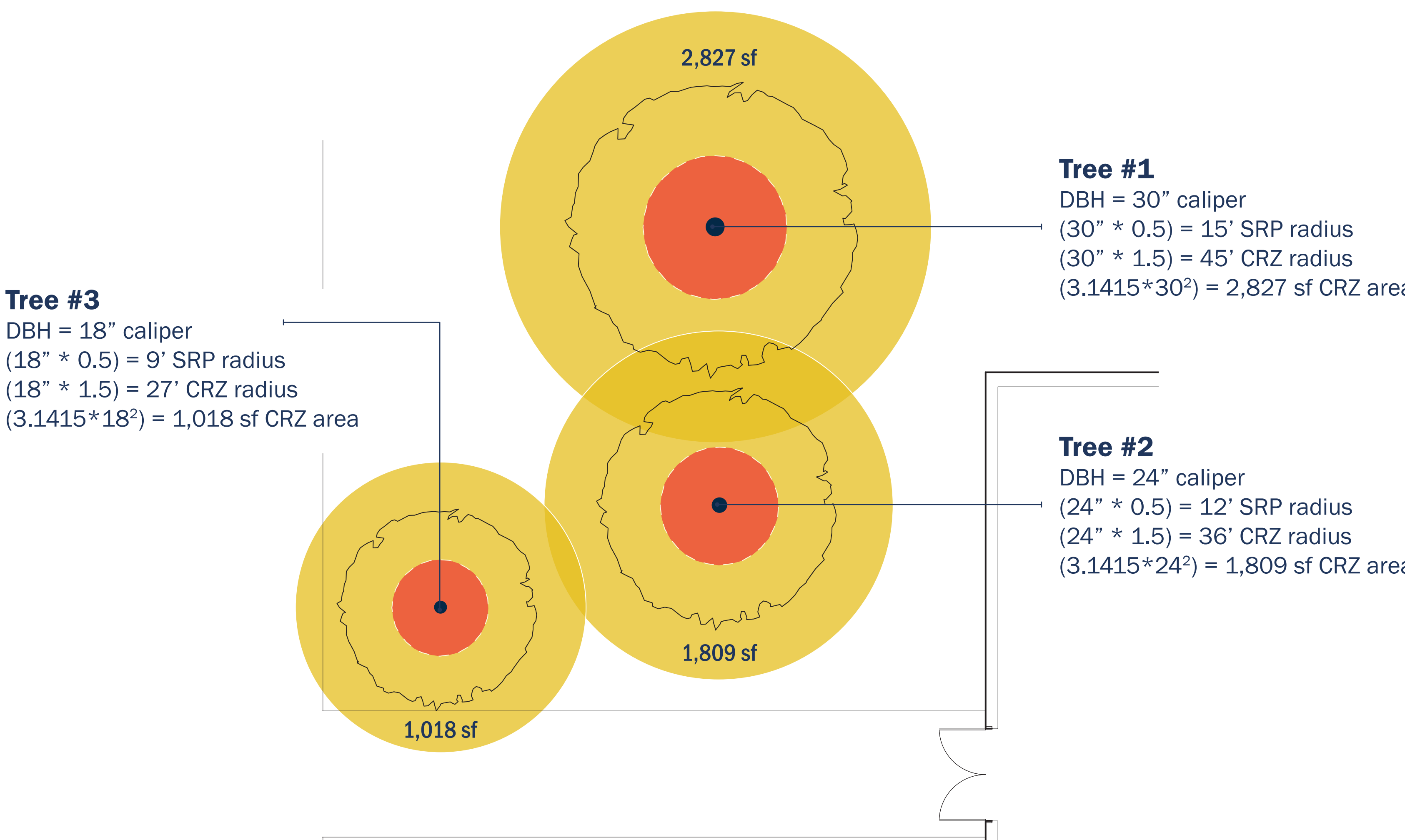
4 TOLERANCE TO IMPACT

The assessed trees typically fall into one of three tolerance categories – high, moderate and low. This is typical of trees in the Mid-Atlantic region.

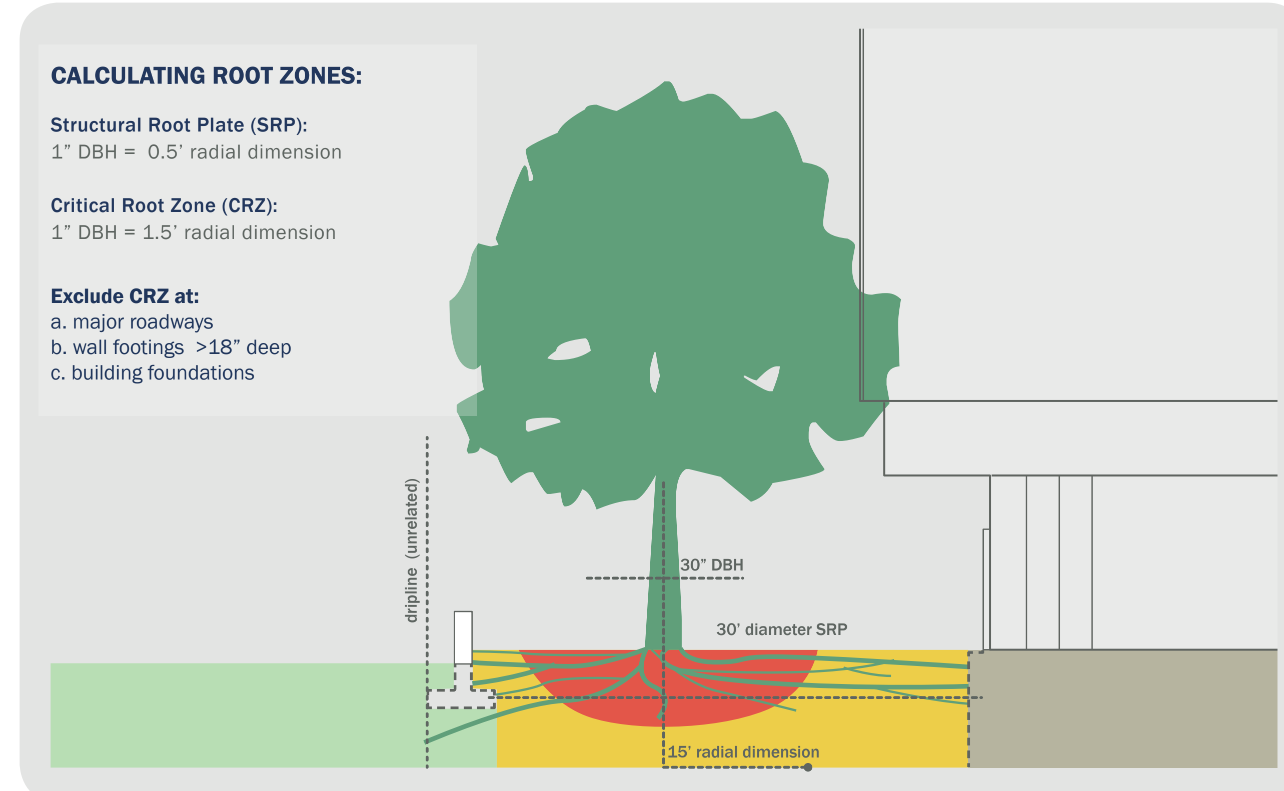
High Tolerance	Moderate Tolerance	Low Tolerance
White Oak	Hickory	Tulip poplar
Willow oak	Sugar maple	Black walnut
Red Maple	Southern magnolia	Dogwood
Catalpa	Eastern white pine	Sourwood
Elm	Eastern red cedar	Cherries
Sycamore		Linden
Hackberry		Yellowwood

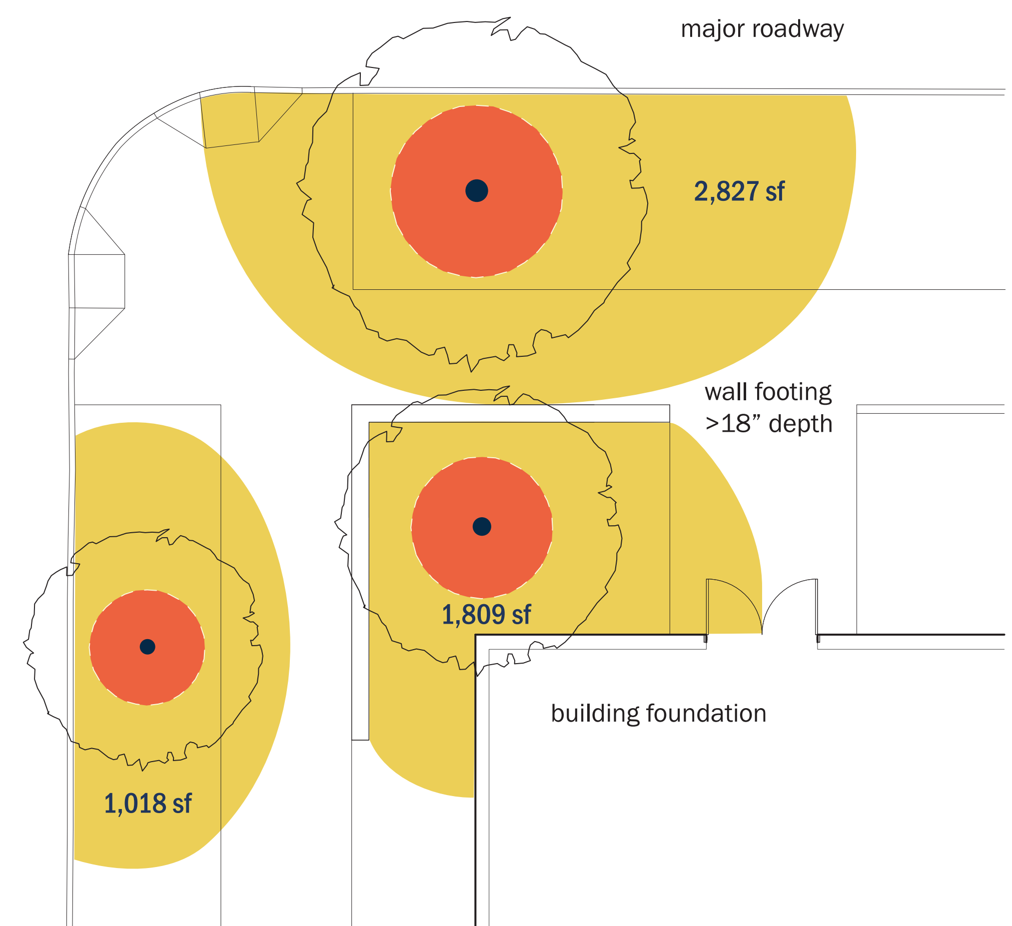
CRZ IN OPEN SOIL VOLUMES

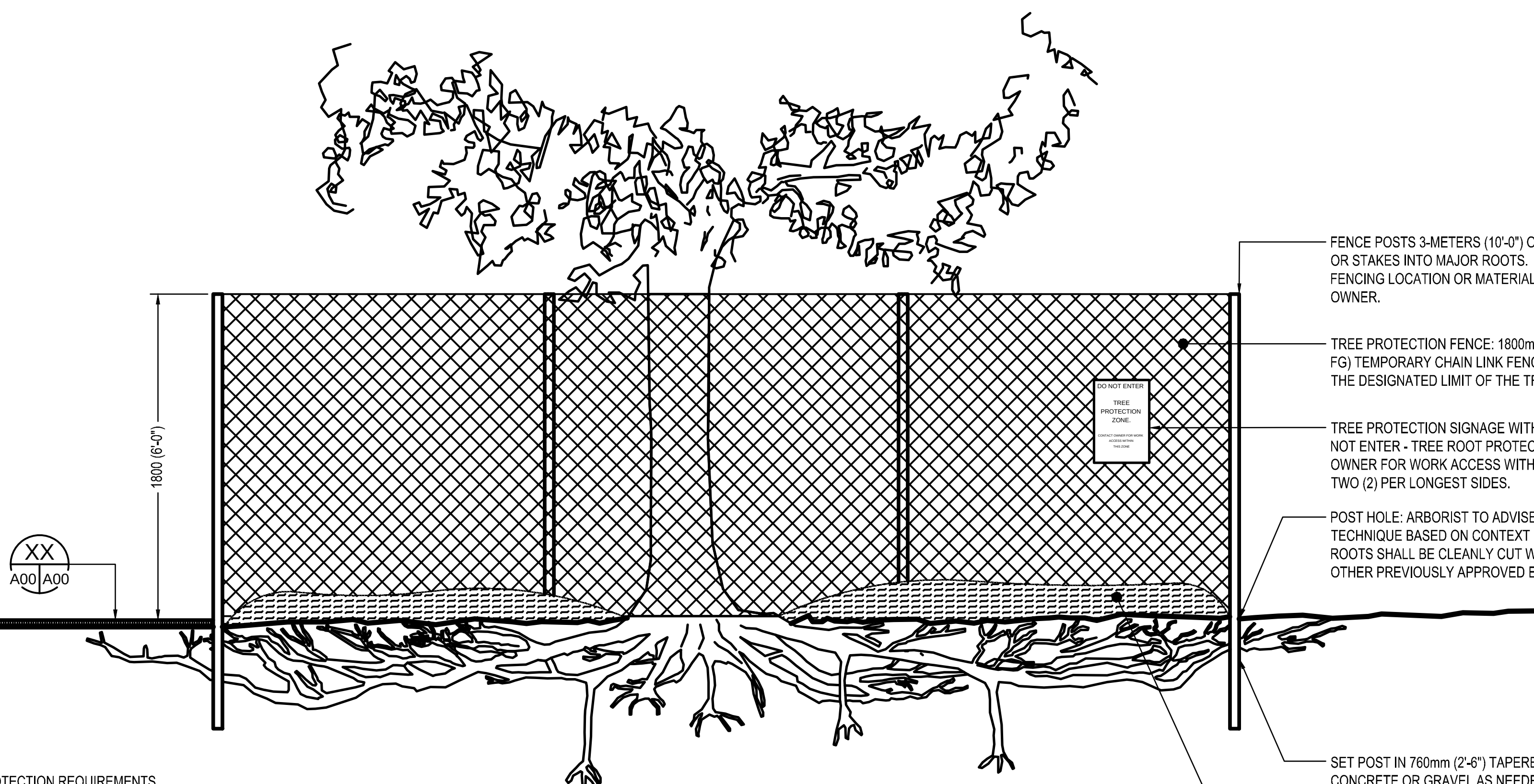




CRZ IN CONSTRAINED SOIL VOLUMES







ROOT AND SOIL PROTECTION MATTING OVER CRITICAL ROOT ZONE; AS REQUIRED ON TREE AND SOIL PROTECTION PLANS

FENCE POSTS 3-METERS (10'-0") O.C. MAX. AVOID POSTS OR STAKES INTO MAJOR ROOTS. MODIFICATIONS TO FENCING LOCATION OR MATERIAL MUST BE APPROVED BY OWNER.

TREE PROTECTION FENCE: 1800mm (6'-0") HIGH (ABOVE FG) TEMPORARY CHAIN LINK FENCE SHALL BE PLACED AT THE DESIGNATED LIMIT OF THE TREE PROTECTION AREA.

TREE PROTECTION SIGNAGE WITH TEXT TO INCLUDE "DO NOT ENTER - TREE ROOT PROTECTION ZONE. CONTACT OWNER FOR WORK ACCESS WITHIN THIS ZONE." LOCATE TWO (2) PER LONGEST SIDES.

POST HOLE: ARBORIST TO ADVISE ON SOIL REMOVAL TECHNIQUE BASED ON CONTEXT OF INSTALLATION. ROOTS SHALL BE CLEANLY CUT WITH VIBRATING KNIFE OR OTHER PREVIOUSLY APPROVED EQUIPMENT

SET POST IN 760mm (2'-6") TAPERED HOLE; SECURE WITH CONCRETE OR GRAVEL AS NEEDED TO MAINTAIN STABILITY OF FENCE

150mm (6") MIN. THICK LAYER OF WOOD CHIPS WITHIN FENCING AREA. MAINTAIN 50mm-75mm CLEAR OF TRUNK. DO NOT PACK WOOD CHIPS AGAINST TREE TRUNK AND ROOT FLARE.

NOTES:

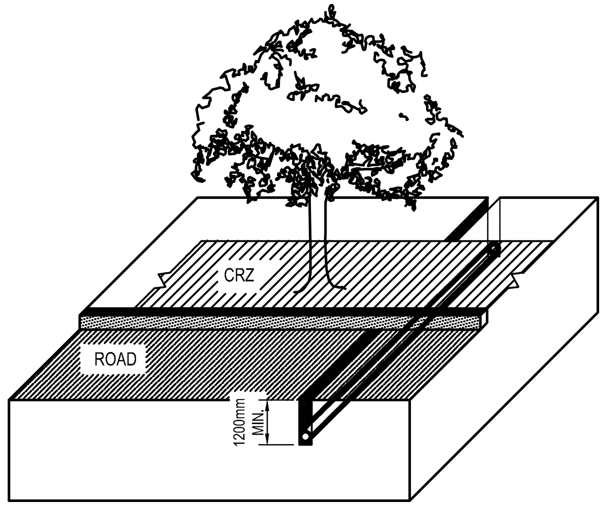
1. SEE SPEC FOR ADDITIONAL TREE PROTECTION REQUIREMENTS.
2. IF THERE IS NO EXISTING IRRIGATION, SEE SPECS FOR WATERING REQUIREMENTS.
3. NO PRUNING SHALL BE PERFORMED EXCEPT BY APPROVED ARBORIST.
4. NO EQUIPMENT SHALL OPERATE INSIDE THE PROTECTIVE FENCING INCLUDING DURING FENCE INSTALLATION AND REMOVAL.
5. SEE SITE PREPARATION PLAN FOR ANY MODIFICATIONS WITH THE TREE PROTECTION AREA.
6. NO STOCKPILING OF MATERIALS, VEHICULAR TRAFFIC, OR STORAGE OF EQUIPMENT OR MACHINERY IS ALLOWED WITHIN FENCING LIMITS.
7. FENCING SHALL NOT BE MOVED UNLESS APPROVED BY OWNER.
8. WORK WITHIN FENCING SHALL BE DONE MANUALLY AND UNDER THE SUPERVISION OF THE ARBORIST/OWNER AND WITH OWNERS PRIOR APPROVAL.
9. NO PART OF ANY TREE PROTECTION SHALL BE MOVED, ALTERED, OR CHANGED IN ANY WAY FOR THE ENTIRE LENGTH OF THE CONSTRUCTION PROJECT
10. IF ANY PART OF THE TREE PROTECTION MUST BE ACCESSED, CONTRACTOR MUST CALL XXXXX XXXX AT XXX-XXX-XXXX TO REQUEST PERMISSION TO ACCESS TREE PROTECTION AREAS.

XX A00 A00 TREE PROTECTION FENCE
SCALE: 1:20

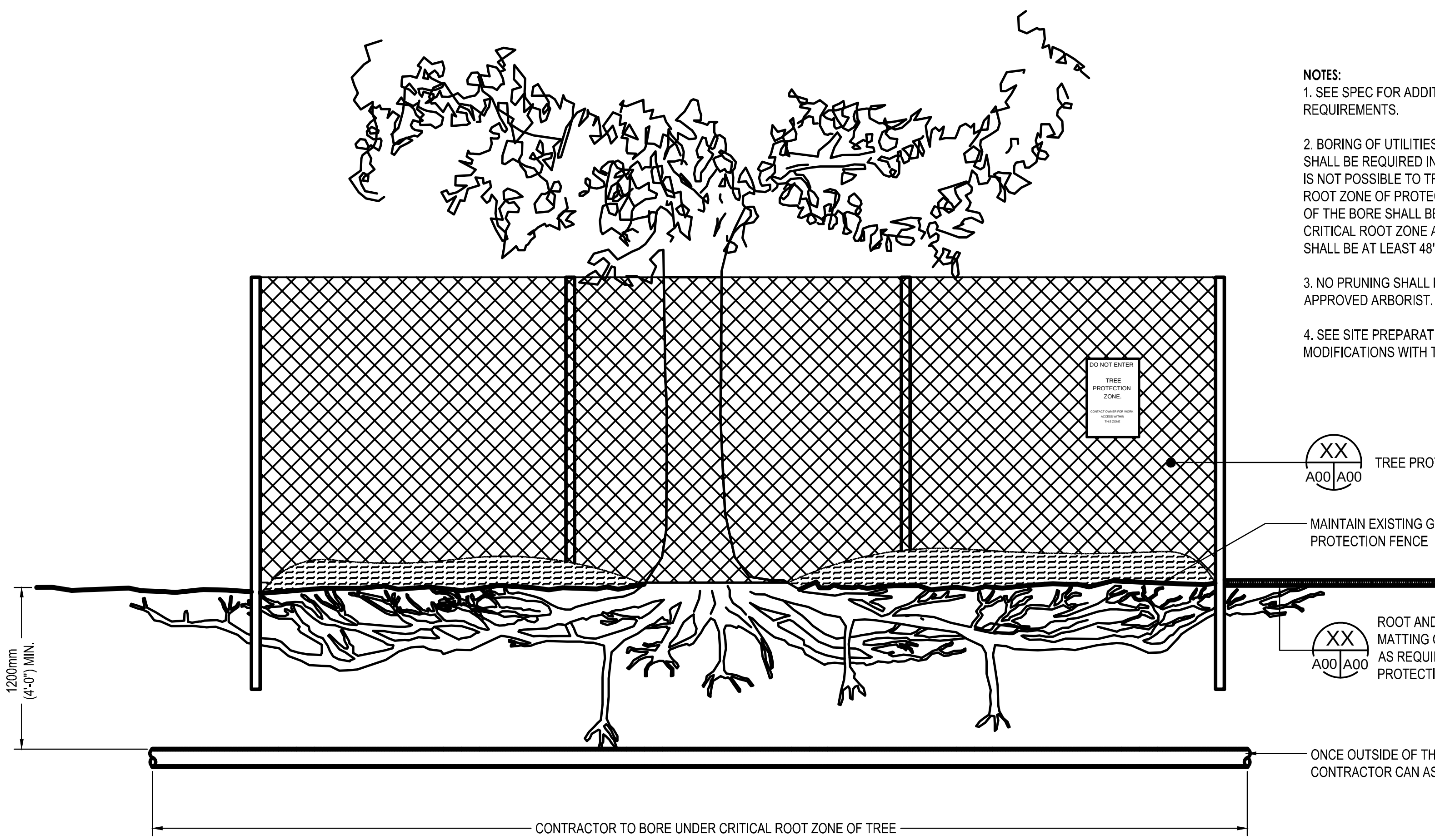
SF PROJECT #:
DATE:
DRAWN BY:
SCALE:

BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



AXON: NTS



NOTES:

1. SEE SPEC FOR ADDITIONAL TREE PROTECTION REQUIREMENTS.

2. BORING OF UTILITIES UNDER PROTECTED TREES SHALL BE REQUIRED IN CIRCUMSTANCES WHERE IT IS NOT POSSIBLE TO TRENCH AROUND THE CRITICAL ROOT ZONE OF PROTECTED TREES. THE LENGTH OF THE BORE SHALL BE THE WIDTH OF THE CRITICAL ROOT ZONE AT A MINIMUM. THE DEPTH SHALL BE AT LEAST 48"

3. NO PRUNING SHALL BE PERFORMED EXCEPT BY APPROVED ARBORIST.

4. SEE SITE PREPARATION PLAN FOR ANY MODIFICATIONS WITH THE TREE PROTECTION AREA.

XX
A00 A00

TREE PROTECTION - UTILITY BORING

SCALE: 1:20

SF PROJECT #:

DATE:

DRAWN BY:

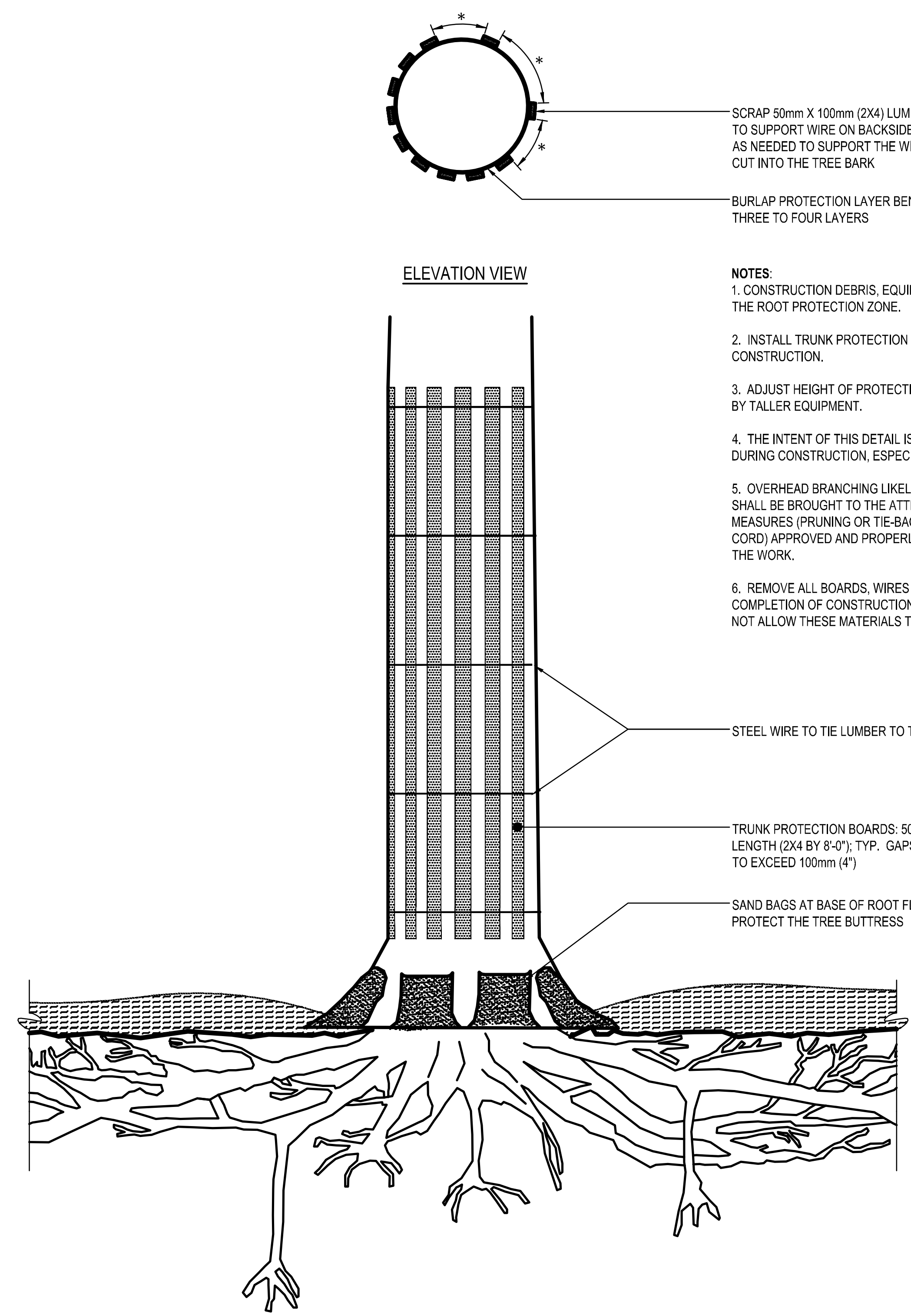
SCALE:

BUILDING NAME:

PROJECT TITLE:

Smithsonian Institution

Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



NOTES:

1. CONSTRUCTION DEBRIS, EQUIPMENT AND FILL SHOULD NOT BE STORED IN THE ROOT PROTECTION ZONE.

2. INSTALL TRUNK PROTECTION PRIOR TO BEGINNING DEMOLITION OR CONSTRUCTION.

3. ADJUST HEIGHT OF PROTECTIVE BOARDS TO PREVENT ANTICIPATED DAMAGE BY TALLER EQUIPMENT.

4. THE INTENT OF THIS DETAIL IS TO PROTECT EXISTING TREES FROM DAMAGE DURING CONSTRUCTION, ESPECIALLY FROM BACKHOE ARM SWING.

5. OVERHEAD BRANCHING LIKELY TO BE DAMAGED BY EQUIPMENT OPERATION SHALL BE BROUGHT TO THE ATTENTION OF OWNER WITH PREVENTATIVE MEASURES (PRUNING OR TIE-BACK OF BRANCHES WITH HEAVY DUTY JUTE CORD) APPROVED AND PROPERLY EXECUTED BEFORE COMMENCEMENT OF THE WORK.

6. REMOVE ALL BOARDS, WIRES AND SAND BAGS IMMEDIATELY AFTER COMPLETION OF CONSTRUCTION. IF CONSTRUCTION TIME IS EXTENDED, DO NOT ALLOW THESE MATERIALS TO STRANGULATE TREE OR DAMAGE BARK.

XX
A00 A00

TREE PROTECTION - TRUNK PROTECTION

SCALE: 1:15

SF PROJECT #:

DATE:

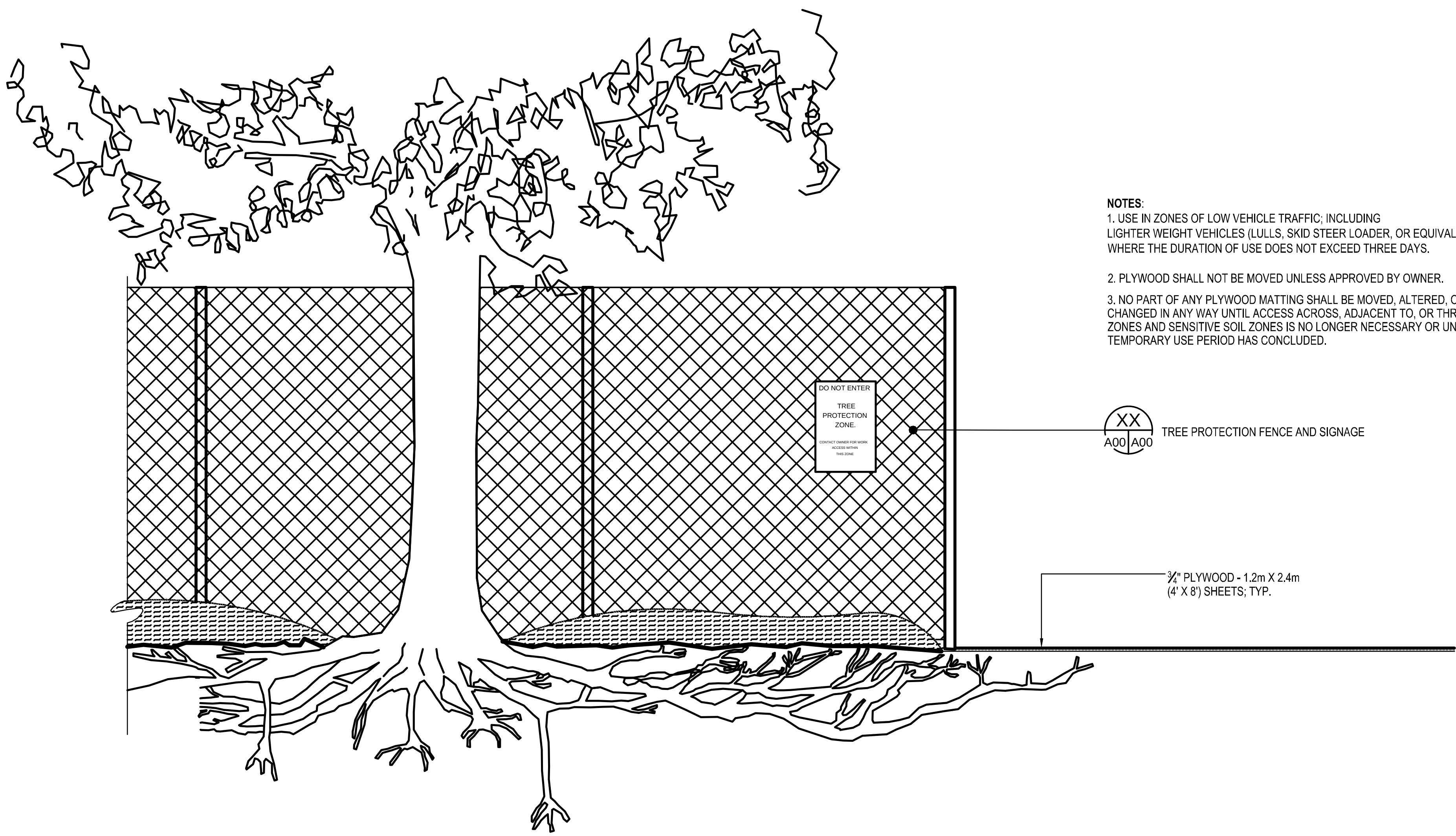
DRAWN BY:

SCALE:

BUILDING NAME:

PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



NOTES:

1. USE IN ZONES OF LOW VEHICLE TRAFFIC; INCLUDING LIGHTER WEIGHT VEHICLES (LULLS, SKID STEER LOADER, OR EQUIVALENT) WHERE THE DURATION OF USE DOES NOT EXCEED THREE DAYS.
2. PLYWOOD SHALL NOT BE MOVED UNLESS APPROVED BY OWNER.
3. NO PART OF ANY PLYWOOD MATTING SHALL BE MOVED, ALTERED, OR CHANGED IN ANY WAY UNTIL ACCESS ACROSS, ADJACENT TO, OR THROUGH CRZ ZONES AND SENSITIVE SOIL ZONES IS NO LONGER NECESSARY OR UNTIL THE TEMPORARY USE PERIOD HAS CONCLUDED.

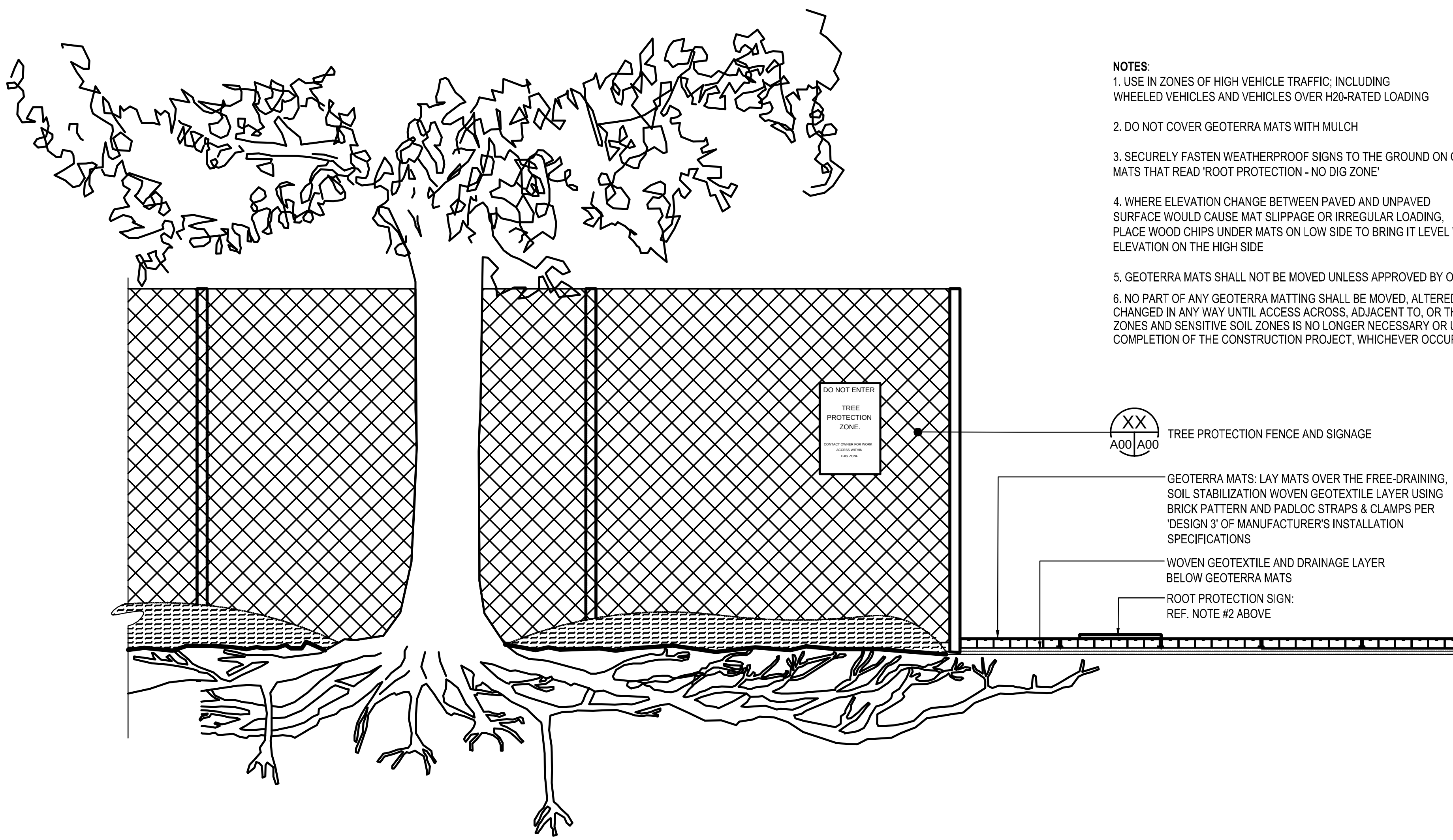
XX
A00 A00

TEMPORARY SOIL PROTECTION - PLYWOOD MATTING

SCALE: 1:15

SF PROJECT #:
DATE:
DRAWN BY:
SCALE:
BUILDING NAME:
PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



NOTES:

1. USE IN ZONES OF HIGH VEHICLE TRAFFIC; INCLUDING WHEELED VEHICLES AND VEHICLES OVER H20-RATED LOADING

2. DO NOT COVER GEOTERRA MATS WITH MULCH

3. SECURELY FASTEN WEATHERPROOF SIGNS TO THE GROUND ON GEOTERRA MATS THAT READ 'ROOT PROTECTION - NO DIG ZONE'

4. WHERE ELEVATION CHANGE BETWEEN PAVED AND UNPAVED SURFACE WOULD CAUSE MAT SLIPPAGE OR IRREGULAR LOADING, PLACE WOOD CHIPS UNDER MATS ON LOW SIDE TO BRING IT LEVEL WITH THE ELEVATION ON THE HIGH SIDE

5. GEOTERRA MATS SHALL NOT BE MOVED UNLESS APPROVED BY OWNER.

6. NO PART OF ANY GEOTERRA MATTING SHALL BE MOVED, ALTERED, OR CHANGED IN ANY WAY UNTIL ACCESS ACROSS, ADJACENT TO, OR THROUGH CRZ ZONES AND SENSITIVE SOIL ZONES IS NO LONGER NECESSARY OR UNTIL THE COMPLETION OF THE CONSTRUCTION PROJECT, WHICHEVER OCCURS FIRST.

XX
A00 A00

TREE AND SOIL PROTECTION - GEOTERRA MATS

SCALE: 1:15

SF PROJECT #:

DATE:

DRAWN BY:

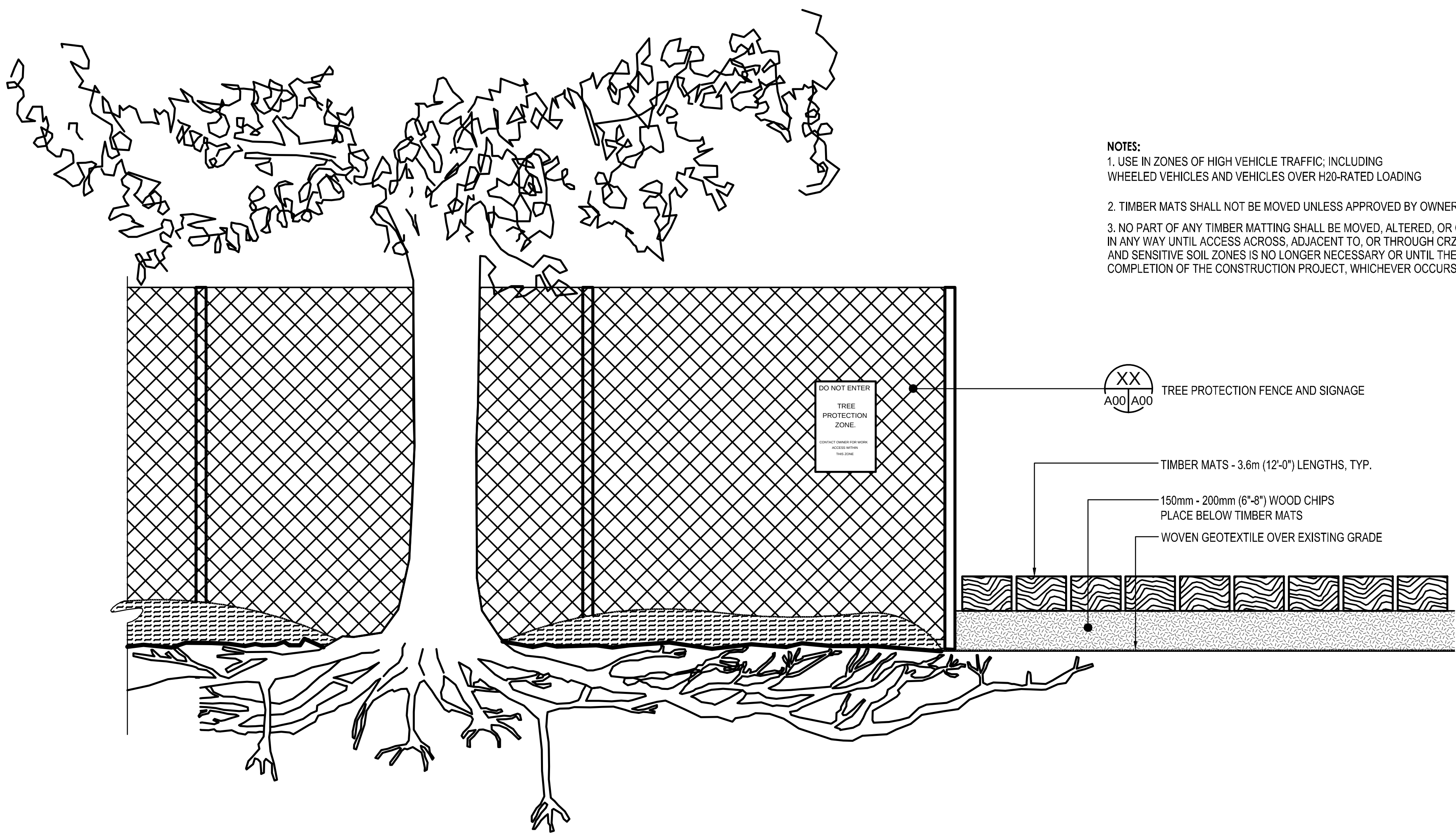
SCALE:

BUILDING NAME:

PROJECT TITLE:

Smithsonian Institution

Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560



NOTES:

1. USE IN ZONES OF HIGH VEHICLE TRAFFIC; INCLUDING WHEELED VEHICLES AND VEHICLES OVER H20-RATED LOADING

2. TIMBER MATS SHALL NOT BE MOVED UNLESS APPROVED BY OWNER.

3. NO PART OF ANY TIMBER MATTING SHALL BE MOVED, ALTERED, OR CHANGED IN ANY WAY UNTIL ACCESS ACROSS, ADJACENT TO, OR THROUGH CRZ ZONES AND SENSITIVE SOIL ZONES IS NO LONGER NECESSARY OR UNTIL THE COMPLETION OF THE CONSTRUCTION PROJECT, WHICHEVER OCCURS FIRST.

XX
A00 A00

TREE AND SOIL PROTECTION - TIMBER MATS

SCALE: 1:15

SF PROJECT #:

DATE:

DRAWN BY:

SCALE:

BUILDING NAME:

PROJECT TITLE:

Smithsonian Institution
Smithsonian Facilities
600 Maryland Avenue SW
Suite 5001 Washington, DC 20560

APPENDIX H

Soil Resources: Amendments and Tools

Smithsonian Gardens

SOIL RESOURCES

Soil Amendments

In nature, the soil is continually built upon and improved through nutrient and organic matter cycling, natural soil microbial populations, rainfall, and the growth of plants. Natural cycling of nutrients, organic matter coupled with plant growth and development and microbial action of the soil enable the soil to build strong structure, infiltrate and retain water needed for vegetation, and yet also shed excessive water. In environments such as those of the Smithsonian Gardens, man-made features have dramatically truncated the natural processes of nutrient and organic matter cycling in the soils, and regular heavy use by visitors to the museum landscapes exert added pressure to the soil. As a result, soil amendments are often needed to restore nutrients, organic matter, and soil function in a generally imbalanced environment.

The goal of soil management for the Smithsonian Gardens is to restore and build soils to be as close to natural functioning soils as possible. This includes the natural recycling of nutrients and organic matter, infiltration of water, and maintaining strong soil structure. As close as we may get, however, soil amendments are sometimes necessary to maintain healthy soil and vibrant landscapes.

The following soil amendments are recommended for the Smithsonian Gardens.

Compost: The benefits of compost include opening soil porosity to enable root growth and water infiltration as well as release of plant nutrients as compost decomposes. Compost is not stable or permanent soil organic matter however, and it does not by itself have the diverse and abundance microflora needed by healthy soils. It is, essentially, a tool for process of restoring and building healthy soils.

Compost to be used for the Smithsonian Gardens must be stable, humus-like material produced from the aerobic decomposition and curing of organic vegetative residues derived from feedstock consisting of woody stems, leaves, grass cuttings, and no more than about 10 percent livestock manure (livestock manure adds excess salts, particularly sodium that needs to be limited). No food products are acceptable as part of the compost feedstock. The compost must be dark brown to black color and be capable of supporting plant growth with appropriate management practices with no visible free water or dust, with no unpleasant odor. Compost needs to generally pass through a 125mm (1/2 inch) screen with less than 3 percent of the compost passing a 1.0 mm screen.

Compost used for the Smithsonian Gardens needs to have the following qualities in its ready to use form:

Compost Parameter	Units	Range
Organic Matter content	Percent	>37%
Total Nitrogen	ppm	>1500
Carbon:Nitrogen Ratio*	No units	Between 10:1 to 20:1
Extractable Nitrate	ppm	20-200
Total Phosphorus	ppm	50-2000
Available Phosphorus	ppm	5-200
pH	Std Units	5.5 - 8.0
Salt concentration	dS.m- 1	<6
Moisture	% wt	30-55

*The carbon to nitrogen (C:N) ratio is an important variable that defines the amount of nitrogen to carbon in the compost, wherein carbon (elemental) should not exceed 20 times the amount of elemental nitrogen (whether it be in organic or mineral form). The C:N ratio is a primary factor in determining compost maturity.

Prior to be accepted for use at the Smithsonian Gardens, compost needs to be tested by a certified laboratory to determine suitable quality.

Fertilizer: Smithsonian Gardens staff have a good history of using primarily organic fertilizers to meet soil and plant nutrient needs. Standard horticultural practices have often followed guidance in which set amounts of nutrients as fertilizers are added to the soil each year. Most nutrients, however, are naturally cycled through the healthy soil/plant system, with minor nutrient losses due to leaching with water infiltration or volatilization as gasses to the atmosphere. Unfortunately, many of the nutrient losses occur with excess irrigation of gardens, lawns or trees.

Excess fertilizer applications favor the growth of unwanted weedy species. Organic fertilizers are slow-release sources of nutrients that regulate how much of the primary nutrients are available to plants, limiting the amounts that would be available to weedy species. Likewise, organic fertilizers are beneficial to healthy soil microbial populations that are essential for good plant growth and development of strong soil structure. Inorganic fertilizers, in contrast, often have rapid-release and availability of nutrients that enable a good plant response, but may also support weedy plant growth due to the higher concentrations of available nutrients. Mineral fertilizers are not beneficial to soil microorganisms because plant uptake of the easily available nutrients in the soil solution limit the transfer of polysaccharides from plants that support microbial diverse populations. Excess fertilizer applications also contribute to groundwater and surface water pollution.

To know how much fertilizer should be applied to landscape and garden areas soil samples need to be collected and analyzed on a regular basis. Based on the results of soil sample analyses, the amounts of fertilizers to apply can be determined. Fertilizers need to be applied in amounts only to meet plant needs. Many secondary nutrients (calcium, magnesium and iron) and nearly all micronutrients (boron and manganese, among many) are present in the soil in sufficient amounts to support good plant growth. The primary nutrients – nitrogen, phosphorus, potassium, and sulfur – are often present in near optimal concentrations to support healthy plant growth, but additional fertilizer amendment may be needed. Typical plant needs for nutrients include:

Lawn: Healthy lawns need about 1.5 to 2.0 kg (3 to 4 pounds) of elemental nitrogen per 100 square meters per year. Much of this may already be present in the soil and undergo natural cycling processes as grass roots grow and decay through seasons. Similarly, as soil microbial populations grow and then die, nitrogen will be released that becomes available for uptake by grasses. Nitrogen that is lost through leaching or volatilization needs to be made up through fertilizer applications. Soil testing will provide information about how much nitrogen is needed to fill the plant need. Because phosphorus and potassium tend to be reasonably stable in soils, less phosphorus and potassium fertilization is needed.

Trees: Trees and shrubs need very little fertilizer needs unless soil samples show specific nutrient deficiencies. Most nutrients come from natural recycling of nutrients that leach into the soil through leaf-fall or mulches over root zones. Nutrient uptake is dominantly by mycorrhizal fungi and therefore nutrients can come from a large area of the soil. Fertilizing trees with damaged roots is not recommended as the roots are not ready to accept nutrients until they have been repaired and re-established mycorrhizal associations.

Gardens: Generally, about 0.75 to 1.0 kg of elemental nitrogen per 100 square meters per year. Much of this nitrogen as well as associated phosphorus, potassium, and other nutrients can be supplied through compost as it decomposes. If compost is used for garden areas, then fertilizer is often not needed for gardens.

Native Plantings: As with trees and shrubs, most native plants are able to obtain their nutrient needs through mycorrhizal associations and the natural cycling of nutrients into and through the soil. As native plants (forbs and grasses) senesce for the winter, their root systems tend to die back, cycling many of the plant-bound nutrients into the soil. Generally, about 0.5 kg of nitrogen per 100 square meters is needed per year to sustain native grasses and forbs, with little to no phosphorus other than what is present in soils, and not more than about 0.25 kg of potassium per 100 square meters per year. Most of these nutrient needs are naturally present in the soils.

Summary: Nutrient deficiencies will occur in Smithsonian Garden soils, especially in soils where excess irrigation is used to sustain vegetation or where sandier soils dominate the landscape. The following practices are recommended for maintaining proper soil nutrient levels:

1. Use compost – both blended with soils initially or as topdressing – as a primary source of nutrients for plants. Compost will not only add necessary nutrients for plants in the landscape, but it will add humic and fulvic acids that carry nutrients and carbon to soil microbial communities that will grow and, in turn, build good soil structure.
2. If compost is not used, organic fertilizers are appropriate for supplying plant nutrients.
3. Reduce irrigation if possible. Reducing water applications in support of vegetation causes the plants to rely on soil fungi that will bring water to the plants and also foster

deeper root growth. Reduced irrigation decreases nutrient loss through leaching as well as volatilization from gaseous formation of nitrogen compounds (nitrite).

4. Test soils on a regular basis. Collecting soil samples from each garden area, or areas for each 2,000 square meters in expansive landscapes, is recommended every three years. The process will provide essential information about plant nutrient needs and fertilizer (or compost) applications but will demonstrate trends in soil dynamics that guide Smithsonian Gardens staff in manage soils for healthy plant production.

Soil Tools

Most tools used for working with soil are well known: shovels of many varying types, hand spades, hoes, and rakes, to rototillers, rotating shovels, to small agricultural implements such as disks, harrows, and V-rippers. This list, of course, does not include the equipment used by contractors to excavate, grade, and move soil. Selecting the right tool for the right job is always important and should be done correctly. The right tool is often related to the size of the project, the depth and structure of the soil, and site conditions that may require special tools.

The following tools are often used for landscape and soil management.

1. **Hand spades and soil knives**: Hand spades and soil knives are the smallest tools usually selected for working with soils. By nature of their small size, they are typically limited to working in small areas to accomplish minor repairs or manipulations of the soil, whether to improve soil condition by breaking localized areas of compacted soils or for opening relatively small holes for planting vegetation.
    a. *Benefits*: These tools are effective for more precise management of soils with minimal to no soil damage.
    b. *Limitations*: The limitation of these tools are that they are useful only for small areas and shallow depths.

2. **Shovels**: shovels are the most common soil tools used for digging small holes into the soil for a number of purposes, from installing plants to mitigating soil problems such as compaction, erosion, or improving soil structure. Shovels should be used for small projects or access into soil in limited spaces.
    a. *Benefits*: The benefit of using a manual shovel is that it provides the user flexibility in manipulating the soil and minimizing soil damage. The shovel can be used to excavate soil, roughen the edges of soil excavations, break large soil clods, and to blend soil components together to create improved soil conditions. Use of a shovel typically results in well-scarified soil surfaces that are not

compacted, slickened, or substantially altered in their structure that could affect soil performance.

b. *Limitations*: The limitations of shovels are they are limited to relatively small areas, limited depths, and substantial labor.

3. **Rakes and hoes**: rakes and hoes are hand tools for "finishing" soils, including breaking soil structure and doing fine grading of soils, leaving firm, friable planting surfaces. Hoes are most often used for breaking hard or large soil clods or surfaces, particularly in tight, small spaces and near or around established vegetation. Rakes are used for grading rough soil surfaces and preparing firm, friable seedbeds for new vegetation.
    a. *Benefits*: The benefits of using rakes include precision in soil preparation, the ability of working in tight spaces with minimal damage to surrounding areas, and fine control of soil surfaces.
    b. *Limitations*: The limitations of rakes and hoes includes difficulty in working with hard, compacted or cloddy soils, and in working in relatively limited areas, although work with a rake can cover several hundred square feet in little time.

4. **Rototillers**: Rototillers are motor-driven tillage machines that rotate a series of angled- or bent tynes (much like knives) into the soil to break the soil surface, break compacted and structureless soils, and to create a friable, more open-pored soil for plant establishment. Rototillers may be two-wheeled machines managed by an operator on foot, or box rototillers that are powered by tractors or skid steers with larger blades and deeper penetration. The advantage of rototillers is that they effectively break hard, often poorly-structured soil into small clods that are more manageable for planting soils. they are often used for tilling installed soils and preparation of final planting best and blending soil amendments into the soil.

    a. *Benefits*: The benefits of rototillers is that they can be used in relatively small areas to larger expansive areas to create friable, well blended soils that are acceptable as planting soils in a relatively short amount of time. They result in generally firm yet friable, open porous soils.

b. *Limitations*: The limitations of rototillers is that in rapidly breaking and manipulating soil, they often break and degrade good soil structure that may exist in the soil, leading to more rapid breakdown of the soil into more dense, formless soil that becomes dominated by small micropores and solid soil structure. The bent tynes of rototillers also can push the soil at the bottom of the tilled area and created a compacted "plow pan" that limits water percolation and root growth. Rototillers typically perform their tillage operation to a depth from 100mm to 150mm below the soil surface.

5. **Rotary Plows**: Walk behind motor driven machine that plows and decompacts soil to a depth of 10" – 12". The horizontal movement of the blades cause little to no hardpan or deeper compaction created by some forward rototillers, which discharge soil for the side of the machine. A single pass of a rotary plow is 8" – 10" wide and can be adjusted to a depth of 6".
   a. *Benefits*: Unlike the fine tines of the tiller that can pulverize soil texture, the rotary plow reduces the impact on the structure with its reduced manipulation, utilizing only 4 large blades in a rotary direction.
   b. *Limitations*: The narrow 8" width passes create more time intensive work for large areas. Due to the increased pore space in the soil after use, it can lead to "extra" soil above existing finish grade, giving the appearance of a raised bed. If heavily compacted, a second pass of the rotary plow may be needed to achieve decompaction at depths greater than 6". Availability of these plows may be limited.

6. **Disks (mini-disks)**: Disks are often used in agriculture for tilling fields in preparation of planting soils. The disk effectively breaks hard, often structureless soils creating soils with more open porosity and smaller soil clods or clusters. Often a disk is used for multiple passes to break soils into smaller pieces. Disks area also effective for blending soil amendments into the soil. Disks are pulled by a tractor and operate best at moderate speed, with tillage depth from 150 to as much as 300mm and covering large areas in a relatively short time.
    a. *Benefits*: Disks can break hard, massive soils to open porous, friable soils ready for planting of vegetation in a relatively small amount of time. Disks can be destructive of soil structure, but this action is not as severe as use of rototillers as described above.
    b. *Limitations*: The use of disks are limited to relatively large areas in which a tractor can operate for effective tillage of the soil. As noted, disks often require multiple passes to create a desirable planting bed. They will often be used in tandem with a harrow – a large, flat rake, to smooth and finish the soil.

7. **V-Rippers**: V-Rippers are a series of curved steel shanks with a triangular tooth at the lowest part and mounted to a v-shaped boom used to rip very hard, massive or compacted soils. The V-Ripper is pulled by tractors and can cover relatively large areas. This operation is often used for the initial breakage of old, hardened soils that can then be further broken down with a disk or rototiller. The depth of V-Ripper effectiveness is about 300 to 450 mm, typically resulting in mid-sized to large clumps of soils that must be broken down. V-Rippers are often used for breaking buried compacted layers, such as plow pans that are otherwise very difficult to effectively remove.

a. *Benefits*: V-Rippers are very effective as the first step for remediating dense, often compacted soils and for mitigating buried plow pans. The process is rapid and can cover large areas in relatively short periods.
b. *Limitations*: V-Rippers are limited to operations in large areas in which a tractor can be used at the speed necessary to allow the V-Rippers to work most effectively. There is little precision in the areas covered and the results usually require the action of a second soil management tool such as disk or rototiller.

8. **Compactors**: Compaction tools for compacting soils to a desired soil density include drum rollers, and plate compactors. Each are described below:

    a. Drum roller: a drum roller is a steel drum used to pull over loose, non-compacted soils to compact them to a desired density. Drum rollers are often filled with water to increase the weight. By slowly pulling the drum roller over the soil an even compression pushes the soil to uniform density without substantially disturbing soil structure.
        i. Benefit: drums come in various sizes that can be used in small, tight areas, or larger, machine-driven rollers that can be used in large areas.
        ii. Limitation: The action of the drum does leave a slickened surface that must be scarified.
    b. Plate compactor: Plate compactors exert force on the ground using a large steel plate that vibrates rapidly. The force compacts the soil and the vibration encourages the grains to move closer together, eliminating air pockets and providing tighter compaction.
        i. Benefit: Plate compactors come in varying sizes and can be used in tight spaces.
        ii. Limitations: Plate compactors are not practical in large areas. Plate compactors also destroy soil structure and overly compact soil,

particularly within 25- to 50mm of the soil surface. Plate contractors should not be used on horticultural planting soils.

c. Other equipment: compaction of soils can also be accomplished with controlled use of low ground pressure, tracked equipment that is used for grading soils, such as skid steers or small bull dozers.

Smithsonian Gardens

gardens.si.edu