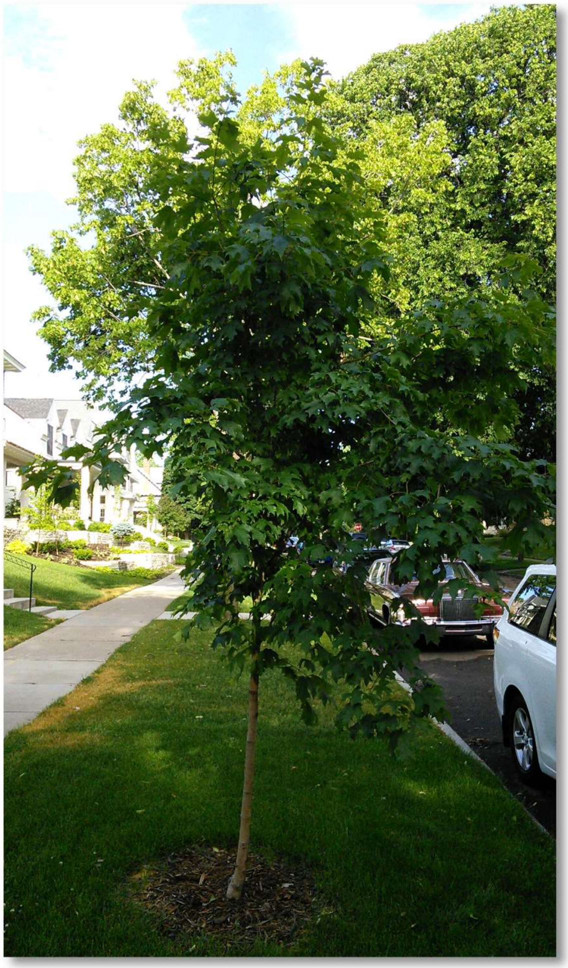

WIDER IS BETTER

A Plan For Preserving Trees on the University of Minnesota Twin Cities Campus

Christopher Brittain
Myles Campbell
Shannon Crabtree
Leonardo de Sousa Rosa
Jessica Donoian
Sadie Gannett
Danny Heinze
Maureen Hoffman
Trevor Host
Adam Kadisak
Tim Markoe
Monica Randazzo
Gratia Ratzloff
Jill Rook
Tyler Schmidt
Jorden Smith

University of Minnesota
Department of Forest Resources
FNRM 4501/5501 Managing Greespaces for People
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Introduction:

Trees are an important part of the University of Minnesota Twin Cities campus and provide many benefits to the school and students. Trees do everything from adding scenic value to providing essential stormwater runoff management functions. The University's campus is a public space that plays many roles in the lives of the students, staff, faculty, and visitors to campus and its landscape and design has major impacts on people and their perceptions. One only needs to walk around the lawn in front of Northrop Auditorium on a warm day to see that students enjoy being in this space. However, not all areas of campus share this appreciable sense of design. Boulevards around campus are often too narrow, to the detriment of both the trees planted within them and the walking paths that border them. In these cases, pavement can buckle and crack, which can create trip hazards for pedestrians. The trees in these boulevards (Harvard Street, Delaware Street, Oak Street Walnut Street and Washington Avenue) are also less healthy, and shorter-lived than their counterparts that have adequate room to grow. In the long term, the trees can become an economic liability and cause safety risks.

Trees also provide a number of ecosystem services that are valuable to the campus, both because of the economic savings and because the University has made commitments to increasing environmental sustainability and green design practices. The University of Minnesota occupies an interesting piece of geography, as the Minneapolis campus crosses the Mississippi River and runs south through Minneapolis towards Saint Paul. Due to the proximity of the Mississippi River, it is important to consider the impact of the impermeable surfaces on stormwater runoff that could enter the Mississippi River or other nearby watersheds. The campus has many streets, sidewalks, parking lots, and other impermeable surfaces that block infiltration of stormwater into the ground and put strain on nearby drainage systems. Well-designed boulevards that include best management practices for stormwater runoff will greatly alleviate the stress on water systems. Trees can slow runoff and improve water quality as well through storage of water and filtration of water entering the ground.

The University of Minnesota recently redeveloped Pleasant Street to include permeable pavers, trees supported by structural soil, a vegetated median in the center of the street, and bike lanes. The resulting street not only is aesthetically pleasing, but serves as a functional green area. The Academic Health area on campus currently is another opportunity to design an ecologically balanced landscape. Bordered by Harvard Street, Washington Avenue, Oak Street, and Fulton Street SE, this area is scheduled for redevelopment, and there is no better time to introduce better boulevard design to this area of campus. It can be expensive to dig up streets, sidewalks, and other existing infrastructure in order to increase the width of a boulevard to support healthy tree growth, but if the infrastructure is already being removed or repaired, it is easier to build a better boulevard. As the University replaces aging sidewalks, streets, or other infrastructure adjacent to boulevards or along right of ways, it should seize the opportunity to build a more pleasing and functional design.

Better Boulevards as an Extension of Current University Goals:

Better boulevards, such as Pleasant Street, are not only beneficial to campus; they directly align with current University goals, and their implementation will further the ideas set forth in the University of Minnesota Twin Cities Campus Master Plan, which was written in 2009 to advise all future developments for planners and designers, as well as guide the decisions of the University Administration and the Board of Regents. It is therefore important to tie the benefits of good boulevard design to the goals set forth in the Master Plan document. Several of the Guiding Principles laid out in the Master Plan are met through well-designed boulevards, to wit[4]:

3. "Create a cohesive, memorable system of public spaces.

4. Provide a compatible and distinctive built environment.

7. Preserve and enhance natural systems and features.

8. Integrate transportation systems to emphasize pedestrians, bicycles and transit.

9. Optimize the use of campus land and facilities and apply best practices.

11. Make the campus environmentally and operationally sustainable."

In addition to these Guiding Principles, the Plan Elements and Guidelines further support better boulevards. The most relevant guidelines are listed below[4]:

3. Participate in initiatives that improve the visual image of the campus along pedestrian access routes.

12. Protect the Mississippi River water quality form negative impacts of campus development and activities.

14. Manage compliance with state and federal standards, and apply surface water performance standards to guide management, future planning and design.

16. Respect and respond to existing natural systems and green infrastructure elements.

31. Encourage use of campus public spaces with high quality design and maintenance.

The installation of well-designed boulevards - above and below ground - will further the visions laid out in the Master Plan and follow its guidelines. By building boulevards that allow for healthy tree growth, the need for maintenance will be reduced. Well-designed areas are more attractive, and will lead to higher use of the public spaces along roads through campus. Pedestrians, too, will be more comfortable walking along tree lined streets on warm days, when the shade provided by tree canopy keeps them comfortably cool. Further, making more areas around campus resembling Pleasant Street will give campus a consistent, distinctive aesthetic that supports natural systems and leads to less disruption to the surrounding environment.

The environmental benefits of trees are many, and trees can form the cornerstone of campus sustainability initiatives. Trees can lower temperatures on warm days (which are becoming more frequent in Minnesota) and moderate the heat island effect that results in higher evening temperatures by providing shade and evaporative cooling and blocking the absorption of solar rays and heat by built infrastructure. Trees sequester carbon and can store stormwater runoff. Their roots keep soil from eroding and filter pollutants out of water passing through the soil. Few other things can be added to campus that will provide so many benefits to the environment at the same time. Encouraging the installation of more trees that are healthier, therefore, is one of the biggest steps the University can take to follow the guidelines laid out in the Master Plan.

Inventory of Study Area:

An aerial view of the study area (the Academic Health area of the University of Minnesota - Twin Cities found on the southeast side of campus by the Mississippi River) detailing the current land cover is appended to this document, with a table detailing the amount of pervious and impervious surface in the area and a current inventory of existing infrastructure, utilities, and trees. There are several things of note from the inventory. First, there are many utilities in the area. There are fire hydrants and a gas pipeline, suggesting significant underground utilities, as well as overhead power lines, which can cause problems for large trees. There are also areas dedicated to on-street parking on some of the streets. When redesigning streets it is important to recall that, under the Master Plan, the University of Minnesota wishes to prioritize pedestrians, bicycles, and transit. It is then worth considering lowering the amount of on-street parking in the area, especially since there are nearby parking garages as well. With the space created by removing on-street parking, boulevards could be introduced into the area or sidewalks could be widened, allowing for the planting of trees or other vegetation in planters within the sidewalk, such as native shrubs and flowering plants.

Given the functions of the buildings in the area, some things will have to remain the way they are. Harvard Street, for example, provides access to the hospital buildings. Lowering the amount of traffic that can use it at once could have unintended consequences on the response time to medical emergencies. Other buildings, such as Pioneer Hall, are dorms, and therefore must be supplied with utilities. Power lines and fire hydrants cannot simply be removed. They can be integrated into a new, greener design, however. Because the streets will be torn up as redevelopment occurs, the utilities will be easier to change than at any other time. It is essential to seize the opportunity to change the built environment to support both trees and existing infrastructure during this time. By using technologies such as structural cells (which will be discussed at length later in this paper), existing utilities can be integrated with soil volumes that can easily support large, healthy trees.

How Wide Is Wide Enough?:

Infrastructure is not a permanent utility. Maintenance and construction activities need to be performed periodically to replace boulevard components such as sidewalks and curbs. Trees both impact the frequency of this maintenance, and are impacted by the construction activities.

Trees have opportunistic roots. This means they will grow where the essential “elements of life” are most present, i.e.; water, oxygen, and space. Oftentimes, there is more water available near the boundary between soil and infrastructure, such as curbs and sidewalks. This often causes problems like sidewalk heaving and curb damage when the roots occupy this in-between space and proceed to grow. The damage caused by the tree’s root system then sets a maintenance schedule into motion.

The maintenance of curbs and sidewalks often involves the complete removal of the old materials, followed by the installation of new ones. This means the old curbs and sidewalks must be cut out to make room for new ones. This action also has the consequence of cutting and removing tree roots in order to make room for new pieces of infrastructure. Root severance has an exponentially detrimental impact to tree health; the closer the construction occurs to them, the greater the disruption of the root system and the greater the impact on health and stability.

Minimum boulevard widths should be implemented to ensure the vitality of the planted trees in order to reach maturity, taking the potential for construction damage into account. *The Road to a Thoughtful Street Tree Master Plan* lays out suggested minimal boulevard widths according to tree diameter at breast height (DBH). The DBH suggestions range from 12 inches and less, to greater than 48 inches. The corresponding boulevard widths range from 5 feet to 14 feet.[6] This greatly contrasts with the specifications laid out by the Minneapolis Park and Recreation Board. The Park Board specifies a minimum of a 3-foot boulevard for small trees, 4 to 6 feet for medium trees, and greater than 5 feet for large trees.[13] These values are about ½ the boulevard width of the above listed. Research done by Hauer et al. further supports the need for larger boulevards. They found significant differences in tree survival in tree lawn widths of greater than 10 feet, as compared to less than 8 feet, over a 10-year study.[11] Therefore, the optimal boulevard width for long-term tree vitality and stability is 10 feet (See appendix 3).

Another consideration to long-term urban ecosystem vitality is the spacing from tree-to-tree. Spacing requirements are laid out in Appendix 3, and are based on potential for mature tree canopy size and or DBH conversion equations. This spacing should be used as a basis for planting distances, but can be modified based on tree stock used, planting pattern, and considerations for tree tolerances related to environmental stressors and disease. The dynamic nature of street tree composition and design requires the architect to be well informed on tree species history and behavior. Dutch elm disease, for example has been known to travel underground via root grafts. “The root grafts of young elms allow transmission of the fungal disease if they are spaced less than 30’ apart. For large mature trees, this distance increases to 60 feet from tree to tree.[15]” Taking this into consideration while introducing new varieties of elm, it would be wise to consider alternating species of elm, with species of another genus to increase root distances between susceptible elms..

One theory for tree species selection for urban settings is to use early to mid-successional species. A comparison of settings of urban areas to those of a post-disturbed ecosystem often reveals stark similarities. After an environmental disturbance such as a wildfire, there is an increase in sunlight, more extreme temperatures (ground and air), higher wind velocities, and lower levels of relative humidity and moisture in the surface soil.[14]" These traits directly apply to those seen through anthropogenic land use. The common characteristics of early to mid-successional trees are that they are drought tolerant, somewhat fast growing, and require moderate to full sun (see Appendix 5 for example trees).

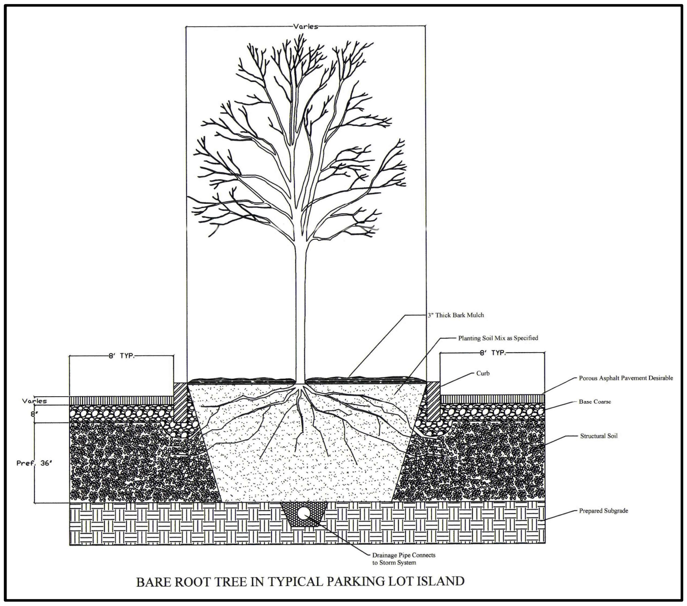
If tree growth can be determined, specifically the ratio of potential tree growth in a heavily urbanized setting - to the potential for fully matured tree growth in a natural setting spacing may be optimized to increase canopy density and closure. This could be calculated in part by the amount of available nutrients in the soil complex for the trees. Decreasing tree spacing might have a positive effect on traffic behavior, by increasing the rate at which trees are passed. This might serve as an alternative for the current planting practice, which involves controlling traffic by placing trees closer to street curbs. Tree distance to the curb is a primary risk to tree root health.

The amount of soil volume needed to support an individual tree varies depending on the size of the tree, and there is some debate on how much exact space a tree needs. The State of Minnesota Sustainable Building Guidelines, for example, currently suggest that 500 cubic feet of soil is necessary to support a tree.[3] Another study, however, suggests that urban trees (with a 32 foot wide canopy) should have access to at least 1,000 cubic feet of soil, though less is necessary if multiple trees share soil.[2] This volume of soil not only has a large, positive impact on tree canopy, but can aid in stormwater runoff management by holding at least 200 cubic feet of water.[2] A survey of other studies on urban trees reveals that the minimum amount of soil needed per tree ranges between 1,000 to 1,500 cubic feet of soil or 1-3 cubic feet of soil per square foot of canopy cover.[16] A table showing the different studies and their findings and a table detailing the soil recommendations in other regions are appended to this report (see Appendix 2). Also found in the appendix, are findings on the spacing from tree to tree, as well as distances from existing infrastructure. (See Appendix 3).

Soil Alternatives and Stormwater Runoff Management - Integrated Solutions:

Well-designed boulevards will not only support large, healthy trees but act as a key part of a stormwater runoff management system. The University of Minnesota Twin Cities campus has a lot of impervious surface, especially in some areas such as the West Bank campus. Increasing boulevard width will increase the amount of permeable surface around campus, and therefore the amount of area where water can infiltrate into the ground instead of becoming runoff. However, because there are areas of campus where drastically increasing boulevard width may not be an option, it is worth considering some alternatives to simply using soil as a growth medium for trees. The Academic Health area of campus, for example, currently lacks significant boulevard areas. Sidewalks run directly alongside roads and are only around 10 feet wide throughout this area. Without taking space from the roads (which could be done and would follow the Master Plan's guiding principle of prioritizing pedestrian spaces) or from the areas between the buildings and sidewalks (already valuable green space which should be expanded through the creation of boulevards, not simply built over with new green infrastructure), there is little that can be done to support trees with soil. However, there are two alternative options, namely structural soil and suspended pavement, which have been used in street design to improve conditions for tree growth while reducing the loss of solid surfaces that act as roads and sidewalks.

The University of Minnesota has experience using structural soil, which is an important part of the current Pleasant Street design. Structural soil is useful because it can support weight-bearing surfaces such as pavement, while also providing empty space and dirt filled spaces in which tree roots can grow easily and without causing damage to the surrounding infrastructure. Structural soil varies in composition, some are rock based while others are sand based, and the amount of actual soil in the mix can differ. Designs that include structural soil, such as the one shown in **Figure 1**, allow tree roots to grow under sidewalks or other paved surfaces without causing damage to either. One should note that there is an optimal depth of 90 centimeters for structural soil. Damage may still occur to sidewalks even with the addition of structural soil if they are not installed deep enough.[9] When structural soil is used in combination with permeable pavers (again, recall the Pleasant Street design) or other weight bearing, permeable surfaces such as permeable pavement, structural soil can facilitate stormwater infiltration. Water drains quickly through structural soil, which can be useful but also means that the trees planted in structured soils must be able to deal with drier conditions.[9] Further, because structural soils contain a lower amount of total soil content (20-25%)[1], less water can be stored in structured soil than normal soil. For trees, this means that about twice the amount of structural soil is needed to provide enough water to support a healthy tree compared to normal soil.[1] However, if pure soil is used directly around the root ball of a tree, only 50% more structural soil is needed than the necessary volume of soil.[1] Landscape architect James Urban further supports this point by reiterating the small proportion of soil compared to rock in structural soil. He goes on to state that, "To create 1 cubic foot of usable soil under the sidewalk, approximately 5 cubic feet of structural soil must be installed.[12]" These numbers are not meant to discourage the use of structural soil, but to point out that there are potential nutrient limitations for trees as they reach maturity when using them. Because of the diminished nutrient content in structural soil, trees tend to develop a larger root system to gather necessary nutrients. The larger root to crown ratio leads to increased below-ground anchoring capabilities of the tree, making it more able to withstand the force of strong winds on east bank.[9] See an example of structural soil use in **Figure 1**.



Another popular technology that can support trees without damaging nearby infrastructure is suspended pavement (also known as structural cells). Suspended pavement, like structural soil, is not one specific technology, but rather a class of different

Figure 1: Structural Soil in Use

designs that all function in the same way. In this case, a load-bearing surface (such as pavement) is “suspended” by a structure, keeping it slightly raised above soil. This allows roots to grow freely without compaction. The increased pore space has the benefits of faster percolation of precipitation, as well as increased penetration of oxygen, which is essential to root growth.

Further, the area beneath the load-bearing surface can contribute to stormwater runoff management through bioretention. Newer options for suspended pavement have made progress towards making the use of suspended pavement more affordable and flexible. Structural cells, such as Silva Cells, are structural components that are pre-engineered and modular, meaning that single cells can be placed adjacent to other cells in any direction to fit the area. However, due to their status as proprietary products[1], specific prescriptions on which version of structural cells to use in future products is not possible. However, future projects on the Twin Cities campus should look into the available structural cells as well as other designs which can suspend pavement (the City of Charlotte, in one of the earliest examples of suspended pavement simply used poured concrete columns to support sidewalks) to best determine how to incorporate suspended pavement into new designs. Suspended pavement can initially be costly, especially when using proprietary structural cells, but is often the best choice for supporting healthy trees and bioretention. In narrow areas, for example, where it is difficult to get the necessary amount of structural soil to support trees, suspended pavement can have huge benefits. Bartlett Tree Experts conducted a study which found that suspended pavement with loamy soil outperformed structural soils and compacted soils in terms of tree growth and health.[1] A 5 foot trench of structural cells performs better than a 20 foot wide trench of structural soil.[1] Because suspended pavement systems use soil instead of structural soil, less area is needed to support a tree. It is also worth noting that in narrow areas, suspended pavement is the best choice, followed by soil, and then lastly structural soils, due to the amount needed. Suspended pavement designs, if done correctly, can also support underground infrastructure and utilities, though it requires planning to integrate these systems together.

Recommendations:

There is no single, one-size-fits-all boulevard design that will best serve the University of Minnesota in every aspect. There are clear indications of where the University wishes to go as it grows and changes. The guidelines in the Master Plan are very helpful, but can sometimes come into conflict with each other. Prioritizing the pedestrian experience, for example, may lead to less than the ideal number of trees being planted, as some open space is desired. What this report hopes to make clear, however, is that trees are beneficial to campus in many ways that align with the vision laid out in the Master Plan. The question that remains is which designs will be the best for promoting healthy trees. Again, there is no silver bullet. The functional and spatial contexts of a development are two important considerations when choosing to plant trees in soil, structured soil, or in suspended pavement. In areas where there is enough room to give each large tree approximately 1,000 cubic feet of soil, there is no reason to spend the money installing structural soils or suspended pavement. In smaller areas, suspended pavement, while the more expensive option, is often the better choice when compared to structural soils. The monetary cost may be prohibitive for some projects, in which case structured soil may be a more efficient option, especially when combined with pure soil planting pits. The long-term benefits of suspended pavement, however, far outweigh the initial costs through promoting better tree growth and being able to retain large amounts of water. Even then, suspended pavement is only a small part of the picture. The bioretention capacity of the soil under suspended pavement depends on the ability of water to reach it in the first place, which is determined by the amount of nearby permeable surface. Including porous pavement or permeable pavers in the structure of the load-bearing surface on top of structural cells would best help manage stormwater runoff. Of the options between porous pavement and permeable pavers, it would be wise to assess the risk of root conflict with these structures before choosing one. Although they all have a similar design life, if potential for earlier maintenance can be determined, it might be better to choose permeable pavers, as they may be pulled up and placed back into position upon grade modification (see Appendix 4 for examples of permeable surfaces). There are a few ideas which can guide all permeable infrastructure developments:

1. Where possible, use existing soil to plant trees at a density that allows for at least 1,000 cubic feet of soil per large tree.
    a. Follow the spacing guidelines laid out in Appendix 3.
    b. If using structural soil, consider water and nutrient holding limitations.
2. Evaluate the amount of stormwater runoff in an area, as well as the potential pollutants it carries, to determine whether infiltration is sufficient or if filtration or bioretention is needed as well.

   a. Structural soil allows water to infiltrate quickly, which leaves little time for filtration. This could be problematic if large amounts of pollutants are found in runoff.
3. Choose the best growth media for the area
   a. Structural soil can be good for areas where full compaction of the media is required.
   b. Soil can be used as is in open spaces around campus or where wide boulevards are viable.
   c. Suspended pavement is flexible and can be used in any area where sidewalks or other pedestrian areas are desired.
4. Consider other design aspects, which help or encourage the functionality of the trees and the growth media.
   a. Use rain gardens, bioswales, permeable pavers, permeable pavement, etc. to either allow water to enter the soil/ structural soil or to manage excess stormwater runoff, which cannot be captured by the trees.
5. Emphasize the multiple roles trees play in building a sense of place, improving environmental conditions, and enhancing/ preserving multiple natural systems.

A tree-filled campus will not only lead to direct benefits, but will help show that the University of Minnesota is committed to addressing the biggest environmental challenges of our time. In addition to the many aspects discussed in this report, trees sequester carbon and are a symbol for environmentalism around the globe. Encouraging their health and wellbeing will prove the university prioritizes sustainability, which is becoming more important each day.

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<u>Appendix 1 - Inventory of Study Area:</u>

Map 1. Current Land Use in Study Area

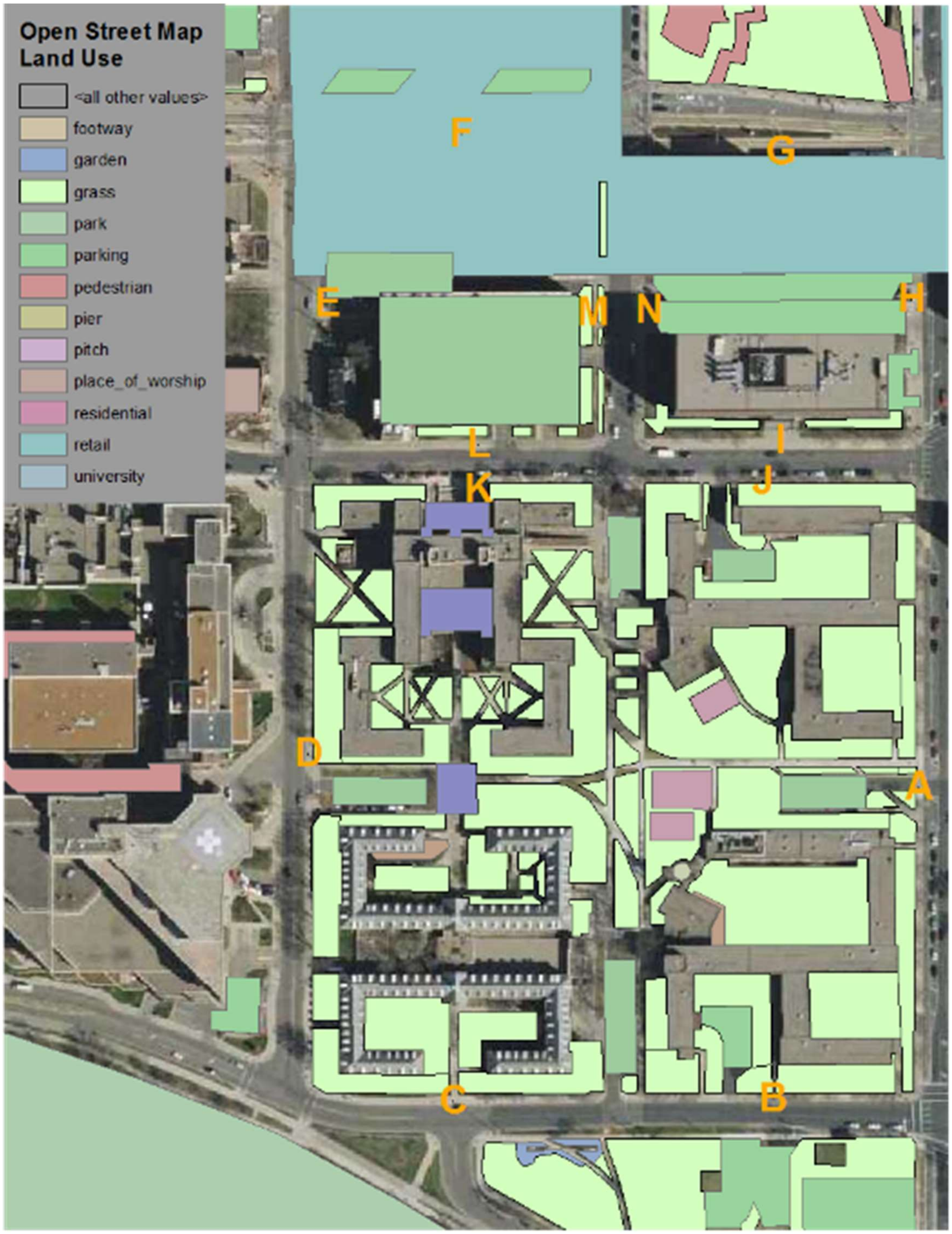


Table 1. Pervious and Impervious Cover, by Section

(Note: The street sections are labeled by letter corresponding to the lettered areas on the map above)

Street Section	Impervious			Pervious	
	Width (ft.)	Length (ft.)	Area (sq. ft.)	Area (sq. ft.)	% of Area
A	8.75	770	6738	14052	67.59%
B	10.25	369.25	3785	12941	77.37%
C	10.25	370	3793	10856	74.11%
D	9.9	770	7623	17300	69.41%
E	10.1	350	3535	0	0.00%
F	11.1	348	3862.8	0	0.00%
G	11.1	350	3885	0	0.00%
H	9.1	330	3003	0	0.00%
I				3454	100.00%
J	10.2	365	3723	10245	73.35%
K	10.6	365	3869	7637	66.37%
L	11.1	355	3940.5	3457	46.73%
M	9.1	349	3175.9	4094	56.31%
N	11.8	349	4118.2	0	0.00%

Table 2. Existing Utilities, Infrastructure, and Trees by Section

Street Section	Utilities	Tree Comments	Additional Infrastructure Comments
A	2 fire hydrants	19 trees near sidewalk	On street parking meters along street, bike lane adjacent to sidewalk, traffic lights on both ends of block, bus stop on Oak Street and Delaware Street
B	1 fire hydrant	7 trees near sidewalk	
C			

D	2 fire hydrants, 6 light posts	6 trees near sidewalk	
E			
F			
G			
H		1 tree on sidewalk	An entrance to the underground parking on Oak Street and Delaware Street Traffic lights on Washington Avenue and Oak Street 2 bins (recycle and trash) near the traffic lights
I			
J	3 utility poles, power line above sidewalk along entire block	7 trees near sidewalk (signs of heaving sidewalks)	Traffic light on Oak Street and Delaware Street
K	Gas pipeline, 4 traffic signs, 1 light post	6 trees near sidewalk	Traffic light on Delaware Street and Harvard Street SE
L			
M			
N			

Appendix 2 - Soil Volume:

Table 3. Minimum Soil Volume Recommendations for Urban Trees

Reference	Recommendation for minimum soil volume
Lindsey, P. and N. Bassuk. 1991. Specifying Soil Volumes to Meet the Water Needs of Mature Urban Street Trees and Trees in Containers. Journal of Arboriculture 17(6): 141-149.	**2 c.f. soil/ 1 s.f.** crown projection
Kopinga, J. 1991. The Effect of Restricted Volumes of Soil on the Growth and development of Street Trees. Journal of Arboriculture 17(3): 57-63	Need **1500 cf.** rootable soil volume for large tree; trees with only 10 m^3 (353 c.f.) "reach the limits" in 10 to 20 years.
Urban, J. 1992. Bringing Order to the Technical Dysfunction Within the Urban Forest. Journal of Arboriculture 18(2): 85-90	**1 to 3 c.f. soil/ 1 s.f. crown projection**
Halcrow. 2006. Soil Volume and Tree Condition in Walt Disney World Parking Lots. Landscape Journal 25:1–06	Minimum soil volume requirements species dependent, but in general, **1,500 c.f.** was required to ensure that a Disney tree would be in good condition, and 1000 c.f. of soil for a 95% chance that a tree would be in good condition

Table 4. Minimum Soil Volume Guidelines by Jurisdiction

Jurisdiction	Minimum Tree Soil Volume
Kitchener, Ontario, Canada	For all boulevards where trees are planted, the minimal soil depth will • Large stature trees (≥24" diameter at maturity): 1589 c.f for single trees; 1059 cf for trees sharing soil volume; 530 c.f. allowable shared soil volume • Medium Stature trees: (≥16" diameter at maturity): 989 c.f for single trees; 653 cf for trees sharing soil volume; 336 c.f. allowable shared soil volume • Small stature trees: (≥8" diameter at maturity): 600 c.f for single trees; 389 cf for trees sharing soil volume; 212 c.f. allowable shared soil volume
Toronto, Ontario, Canada	• 30 cubic meters (1059 cubic feet) of soil per tree • 20 cubic meters (706 cubic feet) per tree for trees with shared volume • Minimum 0.9 m (3') and maximum 1.2 m (4') depth
North Vancouver Lonsdale Street Guideline, British Columbia, Canada	• 15 cubic meters (530 cubic feet) per tree for trees with shared volume
Winnipeg, Manitoba, Canada, Tree Planting Details and Specifications, Downtown Area and Regional Streets	• 8.5 cu.m. (300 c.f.) to 12.75 cu.m. (450 c.f.) of soil per tree • 17.0 cu.m. (600 c.f.) to 25.5 cu.m. (900 c.f.) per tree for trees with shared volume Optimal planting medium depth 900mm (36in.). Minimum planting medium depth of 760mm (30in.) will be accepted where 900mm is not feasible.

Appendix 3 - Tree Spacing:

Source: *Plant Healthcare for Woody Ornamentals* by John Lloyd

Tree setback distances:

- 30 feet from intersections
- 15 feet from driveways or alleys
- 10 feet from hydrants
- 10 feet from utility poles

Source: *The Road to a Thoughtful Street Tree Master Plan* - Gary Johnson and Ken Simmons

Tree to tree spacing:

- For crowns less than 20 feet in diameter, use 10 feet to 20 feet spacing
- For crowns between 20 feet and 35 feet, use 15 feet to 35 feet spacing
- For crowns between 35 feet and 50 feet, use 30 feet to 50 feet spacing
- For crowns between 50 feet and 75 feet, use 45 feet to 75 feet spacing

Offsets from other structures:

- 18 feet from standard lights
- 10 feet to 18 feet from utility poles
- 15 feet from hydrants
- 15 feet from gate valves
- 10 feet from driveways
- 5 feet from crosswalks
- 6 feet from transformers and connection boxes

- 15 feet from underground utility connections
- 6 feet from street signs
- At least the distance of the crown width from adjacent buildings, in any direction

Setbacks from curbs and sidewalks:

- For trunks less than 12 inches in diameter, minimum boulevard width of 5 feet
- For trunks between 12 inches and 24 inches in diameter, minimum boulevard width of 8 feet
- For trunks between 24 inches and 36 inches in diameter, minimum boulevard width of 10 feet
- For trunks between 36 inches and 48 inches in diameter, minimum boulevard width of 12 feet
- For trunks greater than 48 inches in diameter, minimum boulevard width of 14 feet

On intersection design:

- At least 50 feet from the nearest perpendicular curb line and at least 35 feet from nearest perpendicular lot line.

Source: Minneapolis Parks and Recreation Board

https://www.minneapolisparks.org/park_care__improvements/trees/boulevard_trees/

All trees:

- Planted at least 10 feet away from hydrants, driveways, and utility poles.
- Avoid interference with underground utilities
- 30 feet away from stop signs, traffic signs, traffic signals, street lights, and the interdivision of curbs from crossing streets.

Small trees:

- Up to 30 feet tall

- Boulevards wider than 3 feet
- At least 25 feet to 30 feet away from other trees

Medium trees:

- Grow up to 30 feet to 50 feet tall
- Planted in boulevards ranging from 4 feet to 6 feet wide
- Planted at least 30 feet to 40 feet away from other trees

Large trees:

- Grow taller than 50 feet
- Planted in boulevards wider than 5 feet
- Planted more than 35 feet away from other trees

Source: STREET TREE DECLINE AND CONSTRUCTION DAMAGE - Richard J. Hauer, Robert W. Miller and Daniel M. Ouimet

- Significant differences in tree survival were seen in tree lawn widths of >10 feet as compared to <8 feet over a 10 year study.

Source: Trunk flare diameter predictions as an infrastructure-planning tool to reduce tree and sidewalk conflicts - Eric North, Gary Johnson, Thomas Burk

- Injuries to tree roots that occur within 1.2 meters of the trunk are the most damaging to tree health (Hauer et al., 1994)
- The probability of root and sidewalk conflicts increases when large mature trees are less than 3 meters from sidewalks and the trees are 25.4 centimeters at DBH or greater (Sydnor *et al*., 2000 ; Randup *et al*., 2001).

Appendix 4 - Permeable Surfaces:

Table 5. Comparison of 3 Major Permeable Surfaces

Design Factor	Porous Concrete (PC)	Porous Asphalt (PA)	Interlocking Pavers (IP)
Scale of Application	Small and large scale paving applications	Small and large scale paving applications	Micro, small and large scale paving applications
Pavement Thickness 1	5 to 8 inches	3 to 4 inches	3 inches 1, 8
Bedding Layer 1, 8	None	2 inches No. 57 stone	2 inches of No. 8 stone
Reservoir Layer 2, 8	No. 57 stone	No. 2 stone	No. 2 stone 3-4 inches of No.57 stone
Construction Properties 3	Cast in place, seven day cure, must be covered	Cast in place, 24 hour cure	No cure period; manual or mechanical installation of pre-manufactured units, over 5000 sf/day per machine
Design Permeability 4	10 feet/day	6 feet/day	2 feet/day
Construction Cost 5	$ 2.00 to $6.50/sq. ft.	$ 0.50 to $1.00/ sq. ft.	$ 5.00 to $ 10.00/ sq. ft.
Min. Batch Size	500 sq. ft.		NA
Longevity 6	20 to 30 years	15 to 20 years	20 to 30 years
Overflow	Drop inlet or overflow edge	Drop inlet or overflow edge	Surface, drop inlet or overflow edge
Temperature Reduction	Cooling in the reservoir layer	Cooling in the reservoir layer	Cooling at the pavement surface & reservoir layer
Colors/Texture	Limited range of colors and textures	Black or dark grey color	Wide range of colors, textures, and patterns
Traffic Bearing Capacity 7	Can handle all traffic loads, with appropriate bedding layer design.		
Surface Clogging	Replace paved areas or install drop inlet	Replace paved areas or install drop inlet	Replace permeable stone jointing materials
Other Issues		Avoid seal coating	Snowplow damage
Design Reference	American Concrete Institute # 522.1.08	Jackson (2007) NAPA	Smith (2006) ICPI

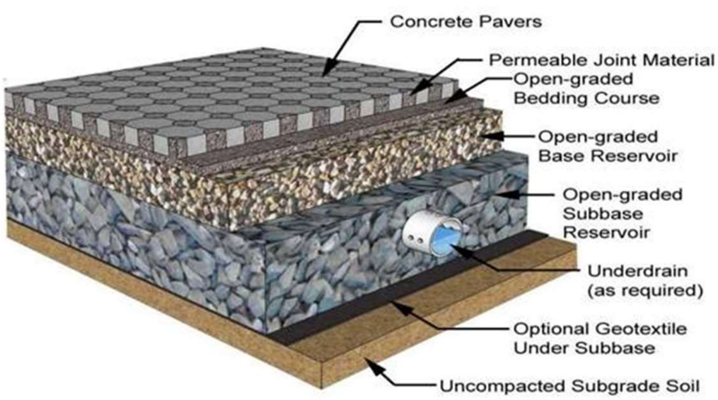
1 Individual designs may depart from these typical cross-sections, due to site, traffic and design conditions.
2 Reservoir storage may be augmented by corrugated metal pipes, plastic arch pipe, or plastic lattice blocks.
3 ICPI (2008)
4 NVRA (2008)
5 WERF 2005 as updated by NVRA (2008)
6 Based on pavement being maintained properly, Resurfacing or rehabilitation may be needed after the indicated period.
7 Depends primarily on on-site geotechnical considerations and structural design computations.
8 Stone sizes correspond to ASTM D 448: *Standard Classification for Sizes of Aggregate for Road and Bridge Construction.*

Permeable Concrete

(*Pervious Concrete)*

Permeable Asphalt

Permeable Paver Design



Appendix 5: Early to Mid-Successional Trees for Central MN
According to: MN DOT Plant Selector

Early Successional
American plum
Black cherry
Black walnut
Cockspur hawthorn (thornless variety)
Common thornless honeylocust
Kentucky coffeetree
Northern catalpa
Crabapple (Adams or other resistant variety)
Common hackberry
River birch
European mountain-ash
European alder
Pagoda dogwood
Ussarian pear

Mid Successional
Ginkgo (seedless)
Amur corktree
Red mulberry
Shagbark hickory
Bitternut hickory
Vanguard elm (or other resistant variety)
Amur maackia
Allegheny serviceberry
Japanese zelkova