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Waukesha County - 2024 Stormwater Workshop

April 3, 2024

Complete Green Streets in Madison, WI: Enhanced Distributed Green Infrastructure and Tree Canopy Guidance

Jon Lindert, P.E., **Strand Associates, Inc.®**

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LEADING THE WAY

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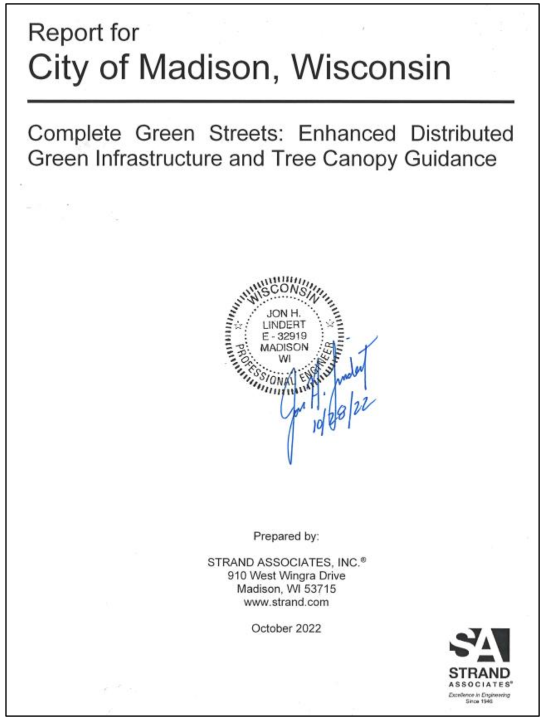
Presentation Outline

- Timeline
- Project Goals
- Street Typologies and Overlays
- Decision-Making Process
- Enhanced DGI and Tree Canopy Guidance
  - Street Tree Guidance – Suspended Pavement Systems
  - Permeable Pavement Systems
  - Non-Permeable Pavement Green Infrastructure Systems
- Enhanced DGI and Tree Canopy Decision Making Flow Chart


Report for
City of Madison, Wisconsin

Complete Green Streets: Enhanced Distributed Green Infrastructure and Tree Canopy Guidance

WISCONSIN
JON H. LINDERT
E - 32919
MADISON
WI
PROFESSIONAL ENGINEER

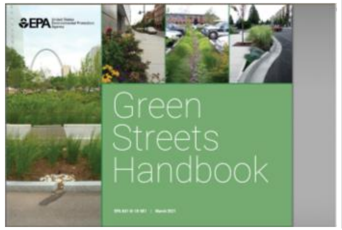
Prepared by:

STRAND ASSOCIATES, INC.®
910 West Wingra Drive
Madison, WI 53715
www.strand.com

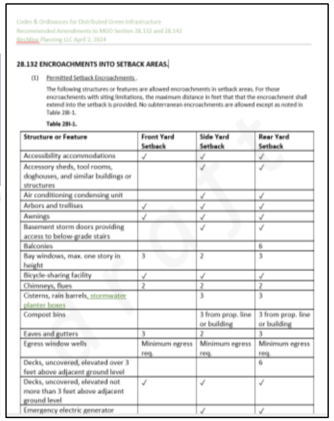
October 2022

Timeline

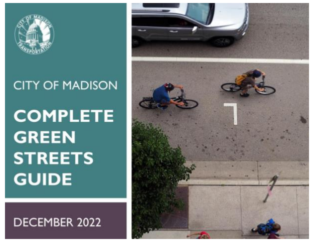
Green Streets Handbook-2021
US EPA



DGI Codes Project
Birchline Planning, LLC

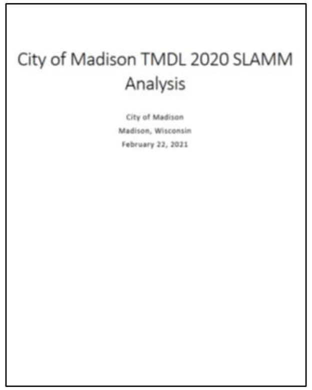


Complete Green Streets Guide
Toole Design
EQT by Design
Strand Associates, Inc.



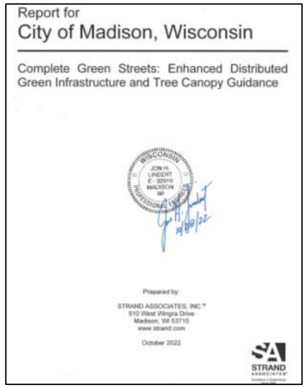
2019 → 2020 → 2021 → 2022 → 2023 → 2024

Urban Forestry Task Force Report
City of Madison



TMDL 2020 SLAMM Analysis
City of Madison

Green Infrastructure for Purposes of Flood Control Study
City of Madison



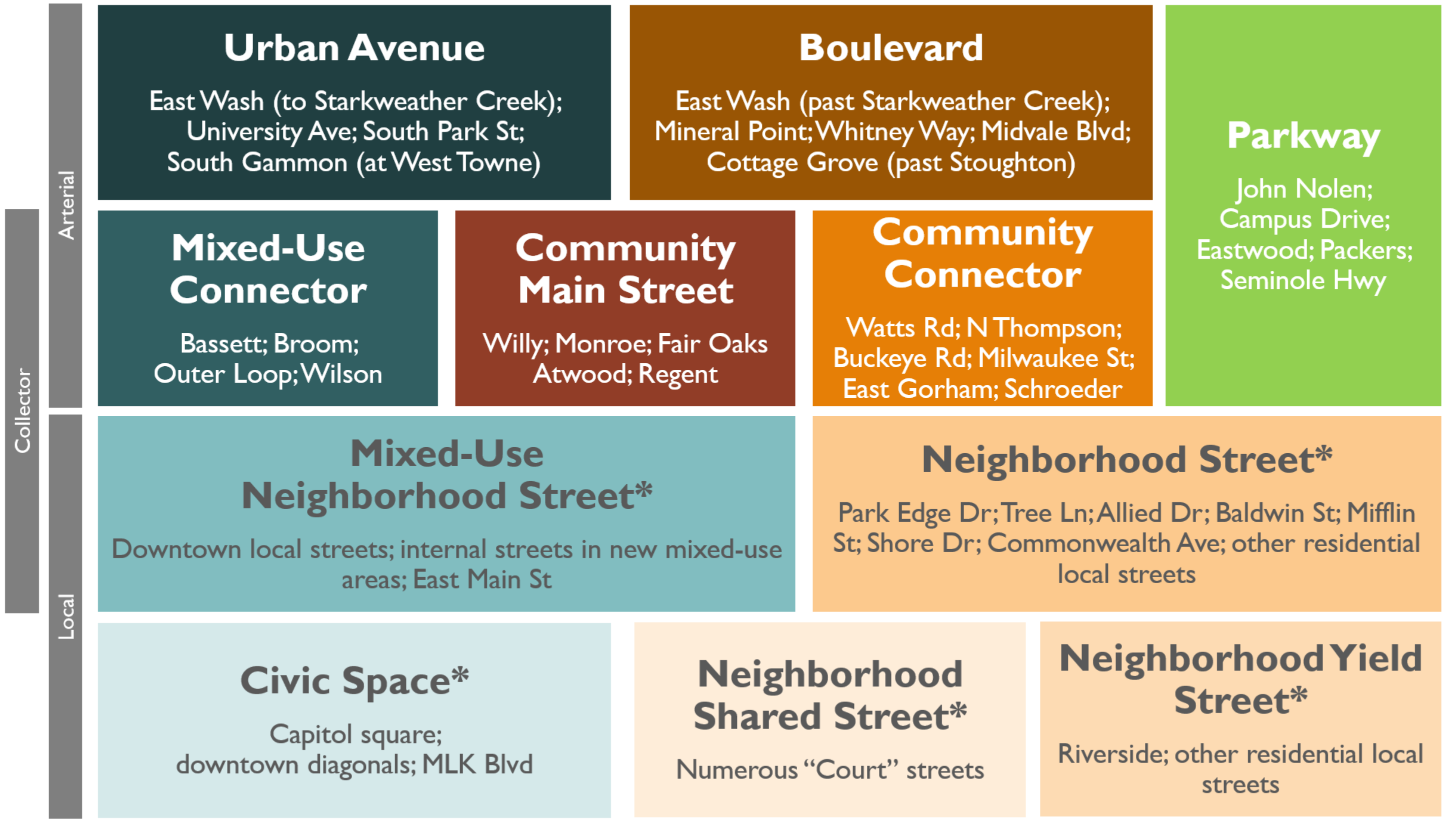
Project Goals

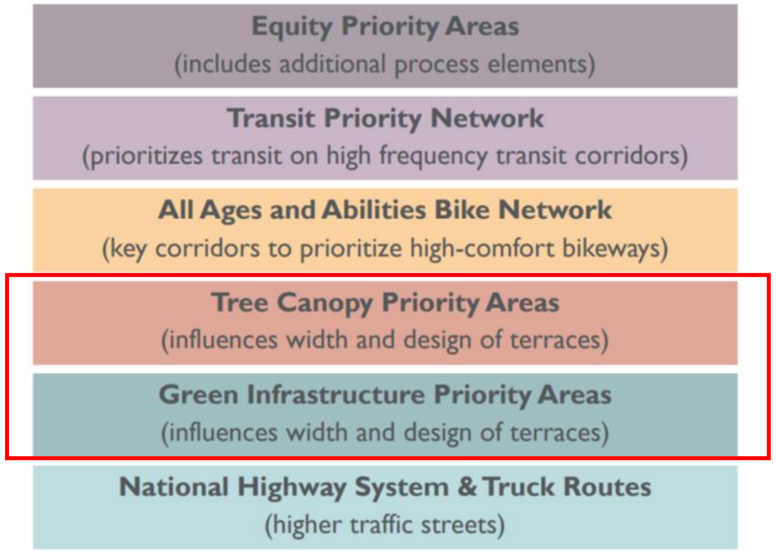
- Complete Green Streets
  - Consistent process for planning, designing, building, and operating streets in a way that better reflects our community values and increases safety and equity.
  - Ensuring the green infrastructure needs of a resilient city.
  - Guard against starting from scratch on each project given the multiple competing demands for right-of-way in the city.
- Enhanced Distributed Green Infrastructure and Tree Canopy
  - Provide practical guidance related to DGI and Tree Canopy to assist with decision making for plan, design, and implementation of different street types (typologies).
  - Coordinate amongst City departments: City of Madison Engineering, Streets, Planning, Fire, Traffic Engineering, and Forestry Departments and Birchline Planning LLC.

When we use the word "street," we are referring to the sidewalks, terraces, roadway, and everything in between. As a more holistic approach to design, the Complete Green Streets Guide provides:

- **A process centered in community values**
- **Clear direction on priorities**
- **Defined street types to use as starting point for design**
- **Explicit equity framework and associated process**
- **Flexible tool that will evolve over time as Madison evolves**

Street Typologies and Overlays

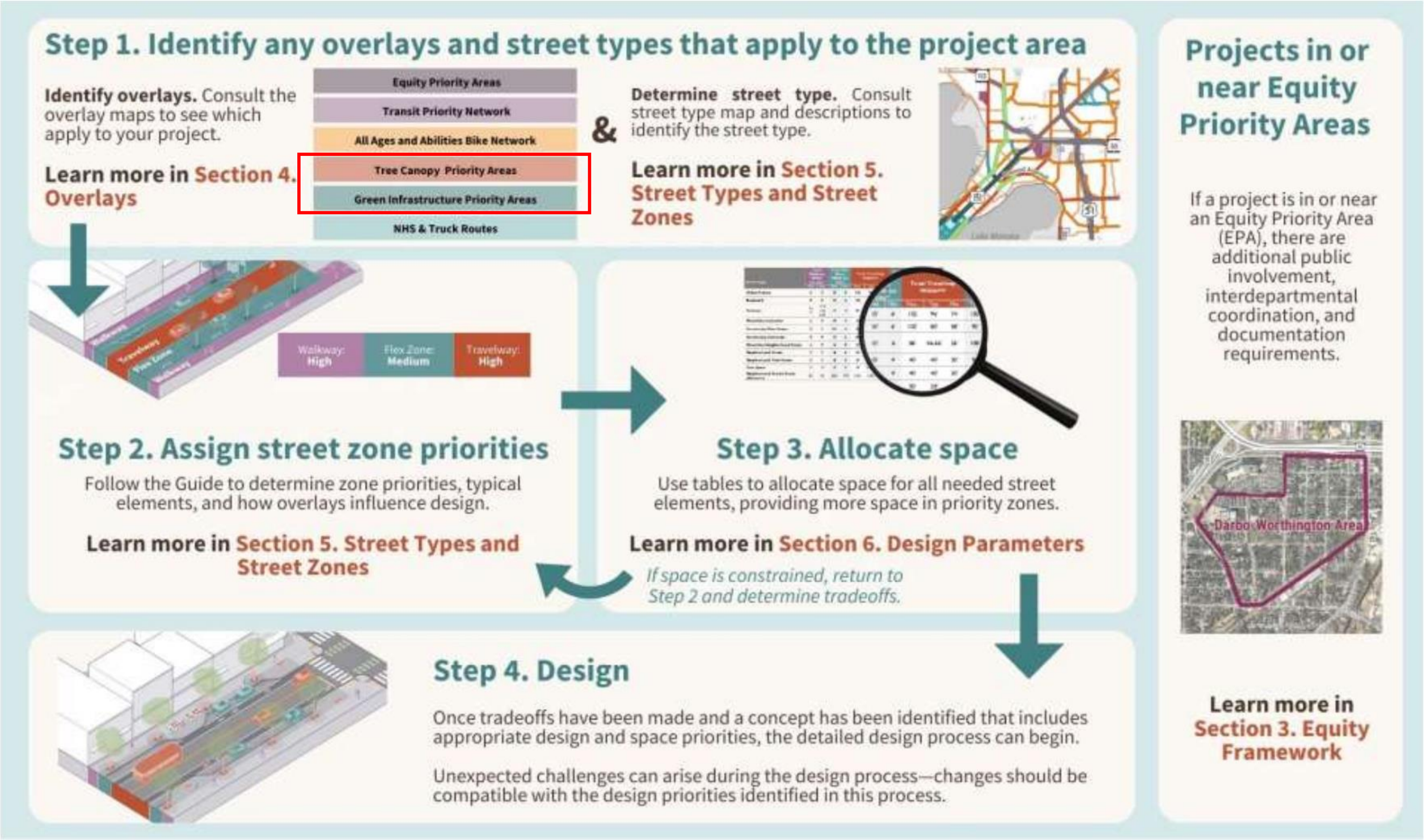




Complete Green Streets Guide: Street Typologies in Madison
https://www.cityofmadison.com/transportation/documents/complete-green-streets/CGS%20Guide%20Final.pdf

Decision Making Overlays

Decision-Making Process



Street Tree Guidance – Suspended Pavement Systems

- Street Tree Guidance – Tree Canopy Criteria
- Suspended pavement system - description
  - Proprietary suspended pavement systems
  - Nonproprietary suspended pavement system
  - Custom suspended pavement system
- Side-by-side cost comparison

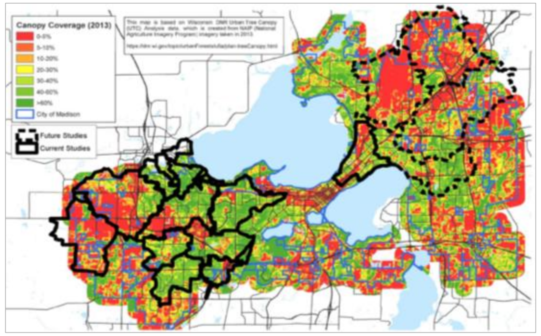
Source: www.citygreen.com

Tree Canopy Enhancement Decision-Making Criteria

- Tree canopy priority
  - Existing tree canopy in ROW
  - Tree equity score

[Tree Equity Score National Explorer]

- Optimal tree size factors
  - Street typology
  - Terrace width



Tree Canopy Priority	Existing Percent Tree Canopy in ROW	Tree Equity Score[1]
High	<15%	40 to 75
Moderate	15% to 35%	75 to 90
Low	>35%	90 to 100

[1]Madison Score: https://www.treeequityscore.org/map/#11/43.0699/-89.4111)
[2]Methodology: https://www.treeequityscore.org/methodology/

Table 1 Tree Canopy Priority

		Street Typology	Optimal Tree Size (No Overhead Utility Conflicts[2])	Recommended Terrace Width (ft)[1]	Terrace Minimum Width (ft)[3]	Suspended Pavement Use ○: Yes ●: Maybe ■: No
	Arterial	Urban Avenue	Small, Medium	12	8	●
	Arterial	Boulevard	Small, Medium	12	8	■
	Arterial	Parkway	Small, Medium	10 to 12	8	■
Collector	Arterial	Mixed-Use Connector	Small, Medium, Large	10 to 12	8	●
Collector	Arterial	Community Main Street	Small, Medium, Large	10 to 12	8	○
Collector	Arterial	Community Connector	Medium, Large	10 to 12	8	■
Collector	Local	Mixed-Use Neighborhood Street	Small, Medium	10	8	●
	Local	Neighborhood Street	Medium, Large	10	8	■
	Local	Neighborhood Yield Street	Medium, Large	10	8	■
	Local	Civic Space	Small, Medium	10	8	○
	Local	Neighborhood Shared Street[4]	Small, Medium	NA	NA	●

Note: ft=feet
[1]2019 *Urban Forestry Task Force Report*
[2]Maximum Height of Tree if Have Overhead Utility Conflict=25 feet
[3]Terrace Minimum Width should be no less than 8 feet without the use of suspended pavement.
[4]Consider curb extensions with street trees or private property tree planting if trees desired.

Table 2 Tree Size, Terrace Width, and Suspended Pavement Appropriateness Per Street Type

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Suspended Pavement System – Description

- Ideal for compact urban development
- Promotes tree growth in uncompacted soil
- If connect to storm sewer or underlying soils conducive to infiltration, can also serve as bioretention

Martin Luther King Jr. Boulevard
GreenBlue Root Space

State Street
Madison Non-Proprietary System

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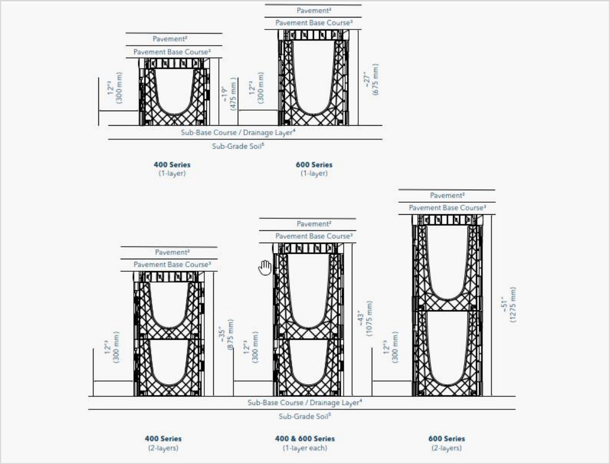
Proprietary Suspended Pavement Systems

- Deeproot Silva Cell
- GreenBlue Rootspace
- Citygreen Stratavault



GreenBlue Rootspace

Tree Size Goal[1]	Expected Tree Height[1]	Engineered Soil Volume Required		
	(ft)	(cu ft)	(cu yd)	Depth (in)[2]
Small	< 25	300	11.1	30 to 40
Medium	25 to 40	400	14.8	30 to 40
Large	40 to 100	500	18.5	30 to 40

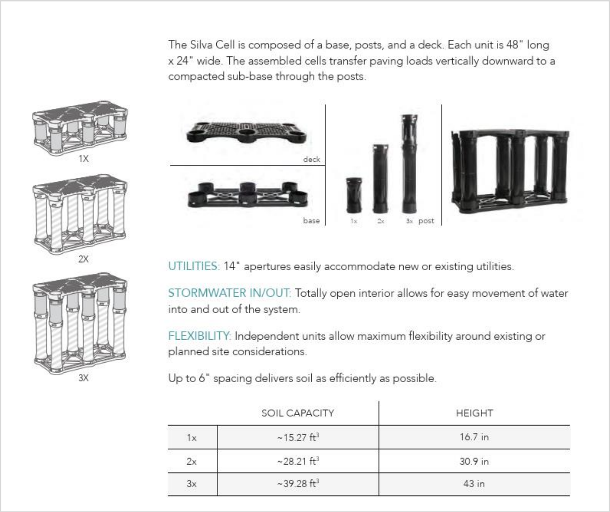
Note: cu ft=cubic feet; cu yd=cubic yards; in=inches

[1]DGI Codes Projects Recommendations

[2]Engineered soil depth is measured from the top of the root flare to the bottom of the engineered soil.

Table 3 Engineered Soil Volume Per Tree Size For Suspended Pavement Systems

Deeproot Silva Cell



Citygreen Stratavault

Product	Height	Base	Soil Capacity (cu ft)	Manufacture Location	Material	Stacking Allowed	Interlocking?
Deeproot Silva Cell 1x	16.7 in	2 by 4 feet	15.27	California	Fiberglass, Homopolymer Polypropylene	No	No
Deeproot Silva Cell 2x	30.9 in	2 by 4 feet	28.21	California	Fiberglass, Homopolymer Polypropylene	No	No
Deeproot Silva Cell 3x	43 in	2 by 4 feet	39.28	California	Fiberglass, Homopolymer Polypropylene	No	No
GreenBlue Rootspace 400 Series	19 in	22 by 22 in	4.4	Ohio	Recycled Polypropylene	Yes	Yes
GreenBlue Rootspace 600 Series	27 in	22 by 22 in	6.25	Ohio	Recycled Polypropylene	Yes	Yes
Citygreen Stratavault 30	16 in	24 by 24 in	4.91	Ohio	Recycled Polypropylene	Yes	Yes
Citygreen Stratavault 45	16 in	24 by 24 in	4.91	Ohio	Recycled Acrylonitrile Butadiene Styrene	Yes	Yes

Note: Engineered soil depth should be between 30 to 40 inches. Engineered soil depth is measured from the top of the root flare to the bottom of the engineered soil.

Table 4 Proprietary Suspended Pavement System Comparison

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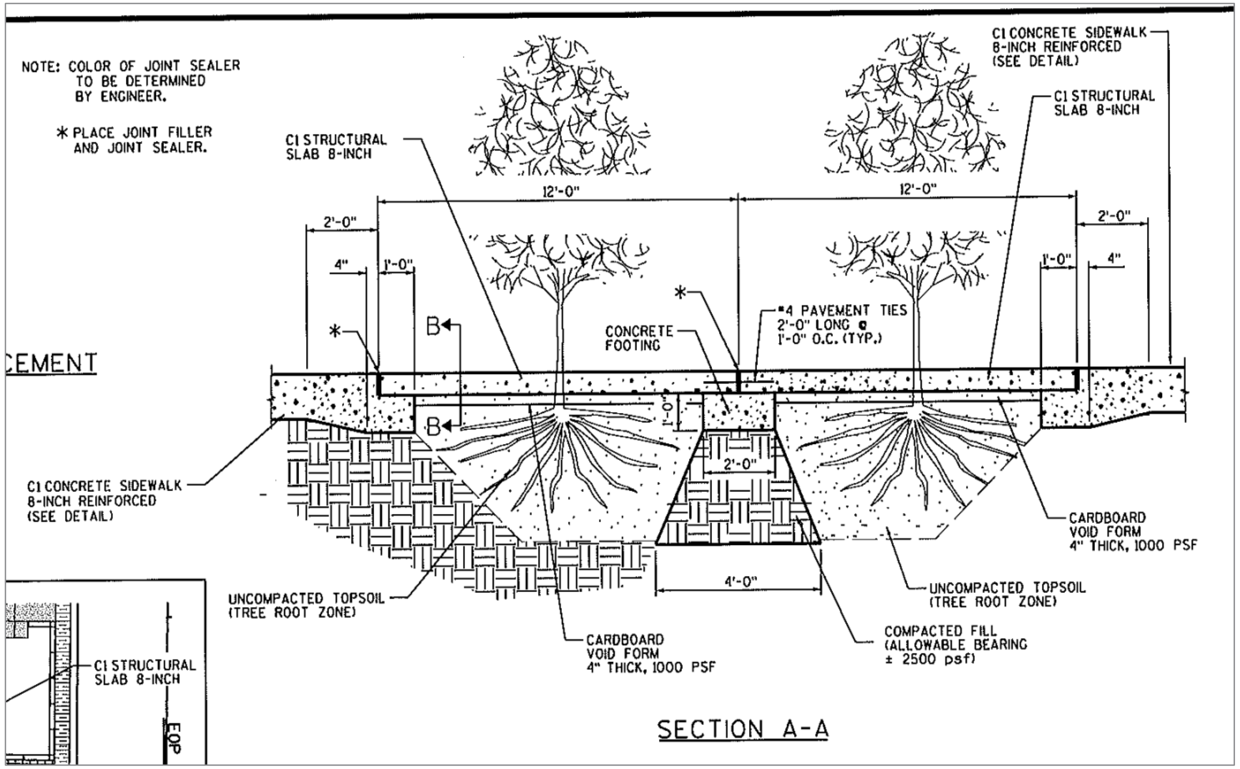
<u>Nonproprietary</u> Suspended Pavement System

- State Street suspended pavement system
  - City of Madison design



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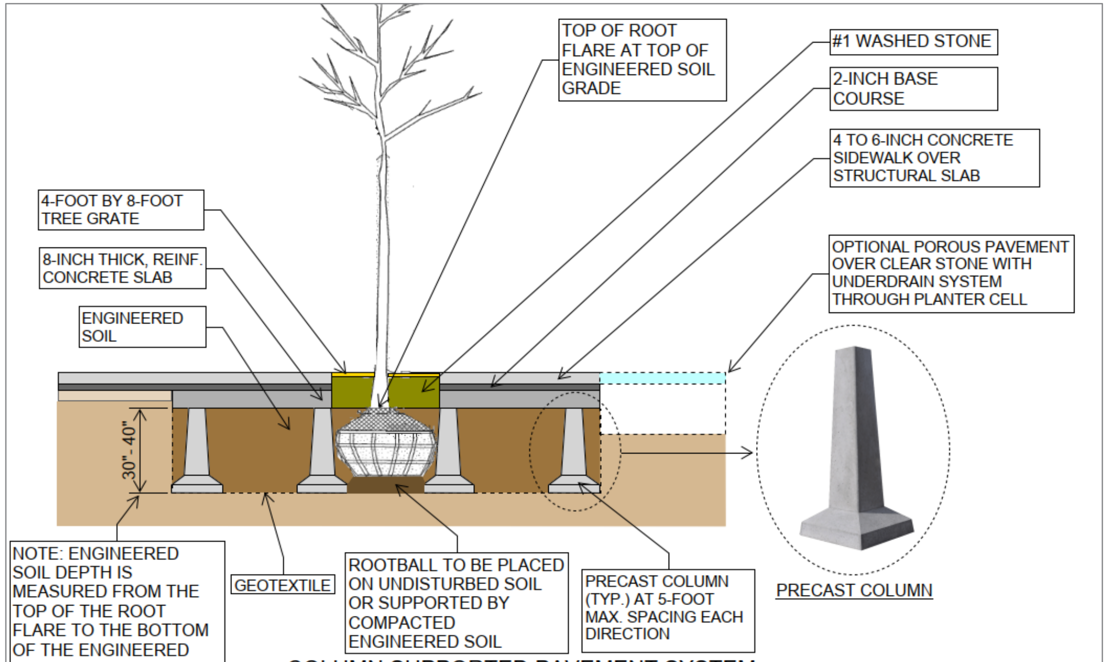
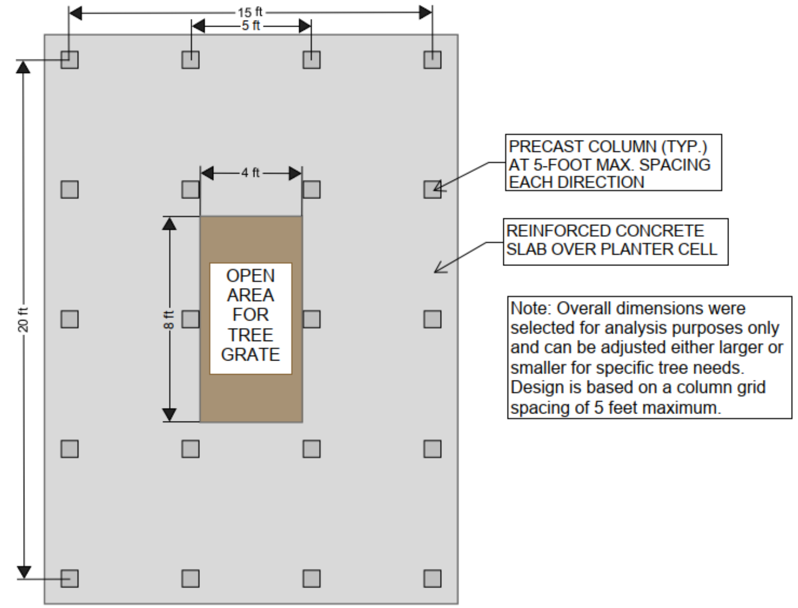
Custom Suspended Pavement System

- Strand's suspended pavement system concept design
  - EX-PIER precast column by EZ-CRETE



COLUMN SUPPORTED PAVEMENT SYSTEM - SECTION VIEW (NOT TO SCALE)



COLUMN SUPPORTED PAVEMENT SYSTEM - PLAN VIEW

Side-by-Side Cost Comparison

	Nonproprietary		Proprietary		
	Strand Concrete Pillar Prototype	**State Street Cardboard Void Form**	**Deeproot's Silva Cells**	**GreenBlue's RootSpace**	**Citygreen's Stratavault**
Delivered Product Cost ($/cu ft) provided by manufacturer	14.55 (Strand-Pillar and Structural Slab Only)	16.10	17.00	12.90	13.21
Installed Cost ($/cu ft). per City bid tabs	28.03 (Strand-Concept Level OPCC)	24.32	66.25	36.99	37.88
Comments	Costs based on 2022 unit costs for system components. No bid tabs currently exist for this prototype system.	Cost based on 2013 State Street project.	Installed cost average of 2013 Fairchild-Mifflin project, 2019 Capitol Café project, and 2017 Bassett Street project.	Installed cost from 2020 project on Martin Luther King Jr. Boulevard.	2022 Delivered Cost inflated using representative GreenBlue Root Space difference between 2022 Delivered Cost and Installed Cost (287% Inflation).

Note: OPCC=Opinion of Probable Construction Cost

Table 5 Typical Costs of Suspended Pavement Systems (2022 Dollars)

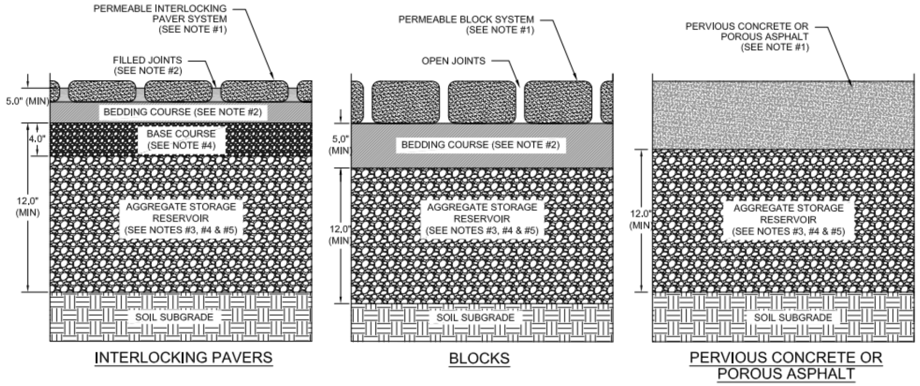
Permeable Pavement Systems

- Permeable pavement – description
- Types:
  - Pervious concrete
  - Porous asphalt
  - Permeable pavers/blocks
  - Permeable interlocking concrete pavers (PICP)
- System comparison
- Design considerations:
  - Siting considerations
  - Structural considerations
  - Usage considerations
  - Stormwater quality considerations
  - Typical sections and standard specifications

Permeable Pavement – Description

- Design components
- WDNR design standards
- Maintenance requirements

FIGURE 1. CRITERIA FOR UNDERDRAIN DISCHARGE AND INFILTRATION PRETREATMENT CREDITS



NOTES:

1. PAVEMENT SURFACE PERCENT VOIDS SHALL BE LESS THAN 25%.
2. JOINT STONE AND BEDDING COURSE SHALL CONSIST OF ASTM C-33, 8, 9, 89, OR 57 AGGREGATE.
3. AGGREGATE STORAGE RESERVOIR DEPTH SHALL BE A MINIMUM OF 12 INCHES.
4. BASE AND / OR SUBBASE COURSES WITH MINIMUM POROSITY OF 30% CAN BE CONSIDERED AGGREGATE STORAGE RESERVOIR. BASE COURSE FOR PERMEABLE INTERLOCKING PAVERS SHALL BE 4.0" DEPTH OF ASTM C-33, 57 AGGREGATE AND CAN BE CONSIDERED PART OF THE AGGREGATE STORAGE DEPTH.
5. UNDERDRAINS CAN BE LOCATED WITHIN OR BELOW THE AGGREGATE STORAGE RESERVOIR. UNDERDRAINS (OR EQUIVALENT) ARE REQUIRED IF THE AGGREGATE STORAGE RESERVOIR DRAIN DOWN TIME WILL EXCEED 72 HOURS.

WISCONSIN DEPT. OF NATURAL RESOURCES
1008
TECHNICAL STANDARD No.
01/2014
REVISION DATE
NOT TO SCALE

Permeable Pavement	Organization	Design Guidance and Standards
Pervious Concrete	▪ ACI ▪ Wisconsin Ready Mixed Concrete Association (WRMCA) ▪ NRMCA	▪ WDNR Technical Standard 1008[1] ▪ Report on Pervious Concrete, ACI[2] ▪ Pervious In Practice Guide, NRMCA[3]
Porous Asphalt	▪ Wisconsin Asphalt Pavement Association (WAPA) ▪ NAPA	▪ WDNR Technical Standard 1008[1] ▪ Porous Asphalt Pavements Technical Bulletin, WAPA[4]
Permeable Pavers/Blocks	▪ Interlocking Concrete Pavement Institute	▪ WDNR Technical Standard 1008[1] ▪ Standard 68-18, American Society of Civil Engineers[5] (ASCE)
PICP	▪ Interlocking Concrete Pavement Institute	▪ WDNR Technical Standard 1008[1] ▪ Standard 68-18, American Society of Civil Engineers[5]

[1]https://dnr.wisconsin.gov/sites/default/files/topic/Stormwater/1008_PermeablePavement_06-2021.pdf
[2]https://www.concrete.org/publications/internationalconcreteabstractsportal/m/details/id/51663557
[3]https://www.nrmca.org/association-resources/research-and-engineering/pervious-in-practice-pip/
[4]http://www.wispave.org/wp-content/uploads/dlm_uploads/WAPA_Tech_Bulletin_Porous_Asphalt_Pavements_2015-09.pdf
[5]https://sp360.asce.org/PersonifyEbusiness/Merchandise/Product-Details/productId/244074874

Table 6 Permeable Pavement Industry Standards

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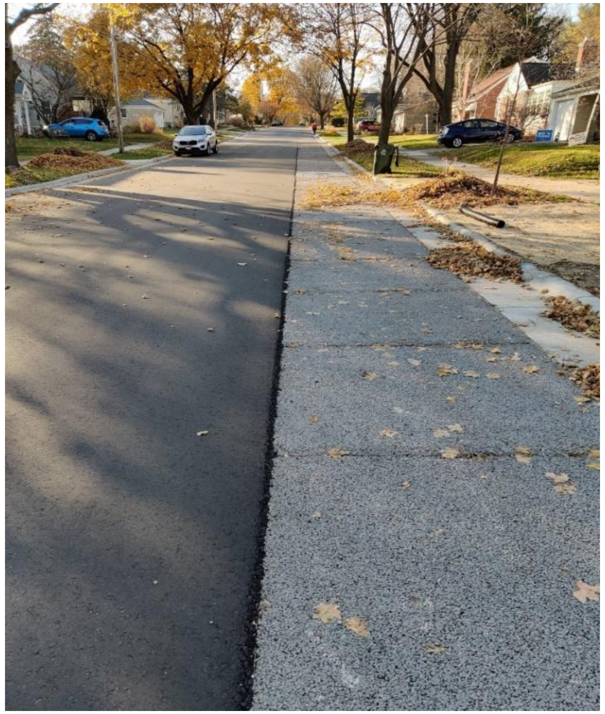
Pervious Concrete and Porous Asphalt

- Pervious concrete
  - Typical thickness of 5” to 8”
  - 15 to 35% voids
  - Precast pervious concrete panels are available (Spancrete)
- Porous asphalt
  - Minimum thickness of 2.5”
  - 16 to 20% voids



Precast Pervious Concrete-Madison
Spancrete

Permeable Pavers/Blocks and Permeable Interlocking Concrete Pavement Systems

- Permeable pavers/blocks
  - Minimum thickness of 3”
  - 5 to 15% open surface area
  - Aggregate replacement after street sweeping
- Permeable interlocking concrete pavers (PICP)
  - Herringbone and other interlocking designs to promote strength
  - Most recommended for higher load environments with caveats

Permeable pavers/blocks-Bayfield, WI

PICP-Madison, WI

System Comparison

		Street Typology	Permeable Pavement Use[1] ○: Yes ●: Maybe ■: No	Potential Permeable Pavement Use
Collector	Arterial	Urban Avenue	●	Bike lane, sidewalk
		Boulevard	●	Bike lane, sidewalk
		Parkway	●	Bike lane, sidewalk
		Mixed-Use Connector	●	Bike lane, sidewalk, parking lane
		Community Main Street	●	Bike lane, sidewalk, parking lane
		Community Connector	●	Bike lane, sidewalk, parking lane, center turn lane
	Local	Mixed-Use Neighborhood Street	○	Bike lane, sidewalk, parking lane, drive lane,
		Neighborhood Street	○	Drive lane, sidewalk, parking lane
		Neighborhood Yield Street	○	Drive lane, sidewalk, parking lane
		Civic Space	○	Drive lane, sidewalk
		Neighborhood Shared Street	○	Drive lane, shared-use areas, pedestrian zone

[1]Consult Tables 8 and 9 for additional decision-making criteria for a specific site.

Table 7 Permeable Pavement Appropriateness Per Street Type

Design Considerations: GIS Overlay Tool for Siting BMPs

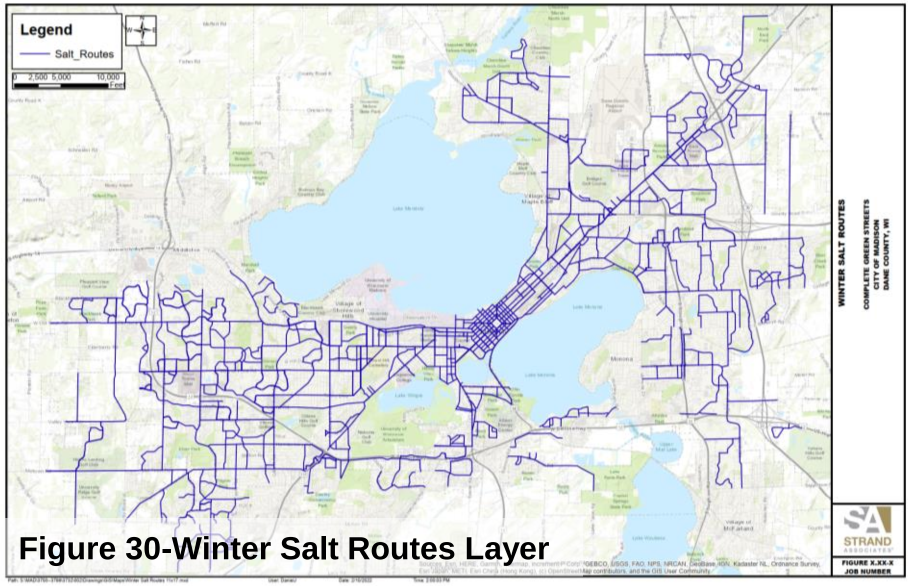


Figure 30-Winter Salt Routes Layer

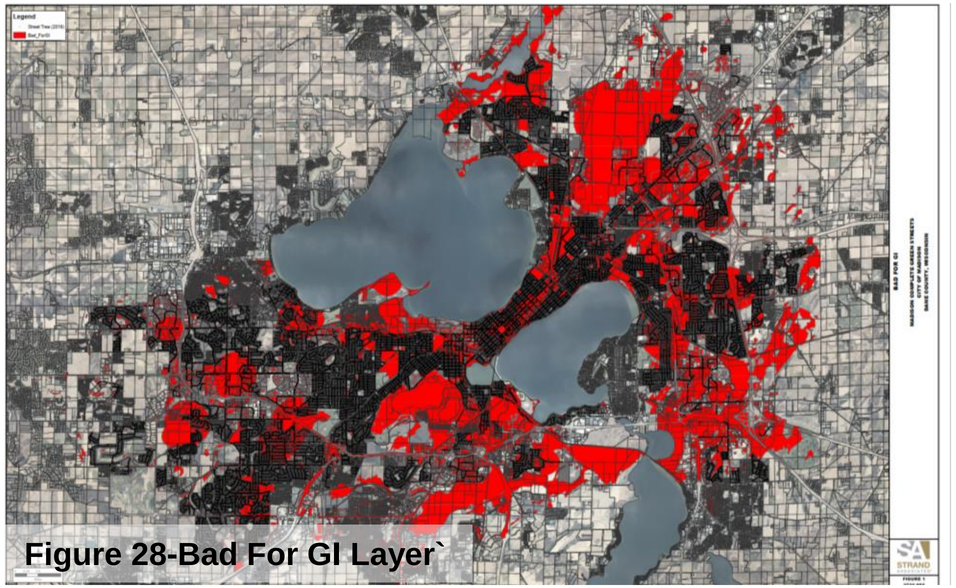


Figure 28-Bad For GI Layer`

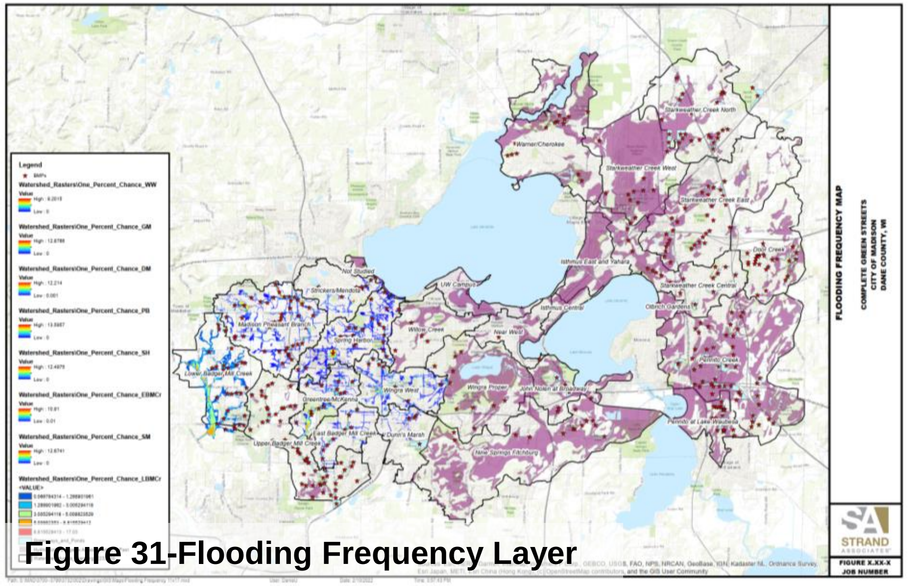


Figure 31-Flooding Frequency Layer

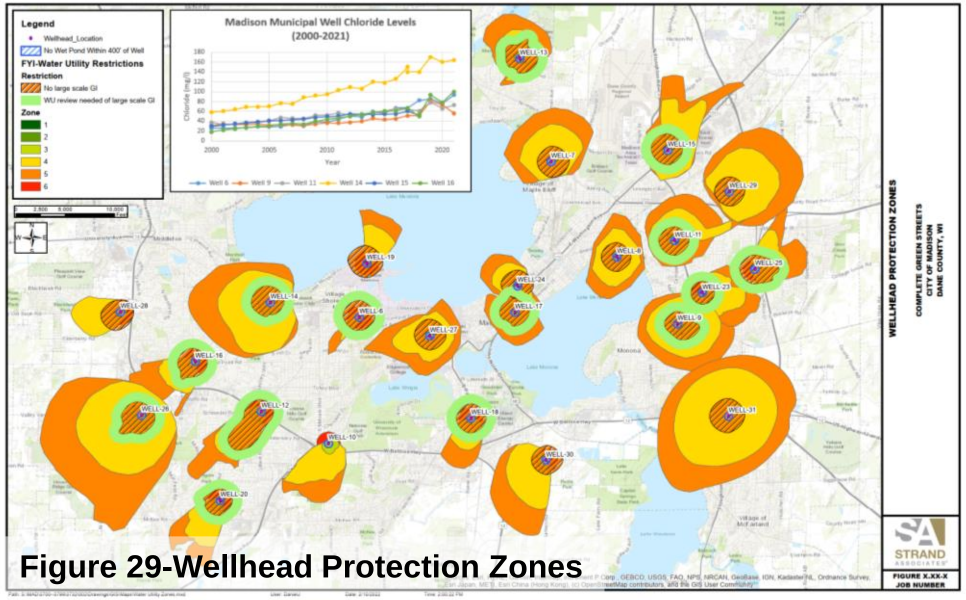


Figure 29-Wellhead Protection Zones

Design Considerations: Structural Considerations

<table>
<tr><th>Permeable Pavement Type[6]</th><th>Compatible with Motor Vehicle Travel Lane</th><th>Compatible with Parking Lane</th><th>Compatible with Bicycle /Pedestrian Paths and Sidewalks</th><th>Compatible with In-Street Shared Bicycle Lane</th><th>Compatible with Grade-Separated Bicycle Lane</th></tr>
<tr><td>Pervious Concrete</td><td><table><tr><th>Surface Type</th><th>Minimum Pervious Concrete Thickness (inches)[3]</th></tr><tr><td>Sidewalks</td><td>5</td></tr><tr><td>Parking Lots & Residential Driveways</td><td>6</td></tr><tr><td>Streets & Commercial Driveways</td><td>8</td></tr></table></td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Porous Asphalt</td><td><table><tr><th>W_{18} (ESALs)</th><th>Minimum Porous Asphalt Thickness (inches)[2]</th></tr><tr><td>50,000</td><td>3.0</td></tr><tr><td>100,000</td><td>3.5</td></tr><tr><td>250,000</td><td>4.0</td></tr><tr><td>500,000</td><td>4.5</td></tr><tr><td>750,000</td><td>5.0</td></tr><tr><td>1,000,000</td><td>5.5</td></tr><tr><td>2,000,000</td><td>6.0</td></tr><tr><td>4,000,000</td><td>6.5</td></tr></table></td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Permeable Pavers/ blocks</td><td><35 miles per hour (mph) and <1 million lifetime Equivalent Single Axle Loads (ESALs)[1]</td><td>Yes</td><td>Not Preferred (short connections only)[4], ADA Considerations[5]</td><td>Not Preferred (short connections only)[4]</td><td>Not Preferred (short connections only)[4]</td></tr>
<tr><td>Permeable Interlocking Concrete Pavers</td><td><35 mph and <1 million lifetime ESALs[1]</td><td>Yes</td><td>Not Preferred (short connections only)[4], ADA Considerations[5]</td><td>Not Preferred (short connections only)[4]</td><td>Not Preferred (short connections only)[4]</td></tr>
</table>

Sources and notes:
[1]*Permeable Interlocking Concrete Pavement*, TechBrief Publication Number FHWA-HIF-15-007, January 2015
[2]*Porous Asphalt Pavements-Not Just for Parking Lots Anymore* presentation at VAA 2017 Fall Asphalt Conference, Charles W. Schwartz, University of Maryland, NAPA, October 3, 2017
[3]*Pervious Concrete Design Presentation, NRMCA*
[4]Consider rider comfort given the potential for permeable pavers/blocks to have a bumpier, less smooth surface compared to pervious concrete or porous asphalt.
[5]In accordance with ADA Section 302.3 and 303.2, verify with manufacturer that the horizontal joint dimension between pavers/blocks is less than 1/2 inch and vertical elevation change between pavers/blocks is less than 1/4 inch.
[6]See section E. Permeable Pavement Siting Considerations for additional decision-making criteria.

Table 9 Permeable Pavement Usage in Various Parts of the ROW

Project Location	Street Type	ADT	ESALs
John Nolen Drive at Blair Street, Madison, Wisconsin	Parkway	42,100	10,000,000
East Johnson Street, Madison, Wisconsin	Urban Avenue	28,500	1,800,000
Buckeye Road, Madison, Wisconsin	Community Connector	5,970	580,000
Clay Street, Whitewater, Wisconsin	Neighborhood Street	420	7,300

Table 10 Local Project with ADTs and ESALs

	Minimum Compressive Strength (psi)	Compressive Strength Range (psi)	AASHTO HS-20 Rated[6]	Average Daily Traffic (ADT) Typical Usage Range Guidance
Conventional Concrete		3,500 to 5,000	Yes	varies
Pervious Concrete	400[1]	400 to 4,000[1]	No information	varies (<500[8])
Conventional Asphalt		3,000 to 5,000	Yes	varies
Porous Asphalt	2,250[2]	2,250 to 5,000[2]	No information	varies (<500[8])
Permeable pavers/blocks	8,000[3]		No information	-
Permeable pavers/blocks: Belgard	7,200[7]	8,000 (average)[7]	No information	-
PICP	12,600[4]		No information	-
PICP–Pavedrain	8,900[5] (laboratory tested)		Yes	-
Fire Department Minimum	75	NA	NA	NA
Fire Truck Wheel Load (maximum)	187.5[7]	NA	NA	NA
Fire Truck Stabilizer Outrigger Load (Maximum)	322[7]	NA	NA	NA

Sources and notes:
[1]*Report on Pervious Concrete,* ACI, March 2010
[2]*Porous Asphalt Pavements-Not Just for Parking Lots Anymore presentation at VAA* 2017 Fall Asphalt Conference, Charles W. Schwartz, University of Maryland, NAPA, October 3, 2017
[3]*Permeable Pavement Combined Section of Minnesota Stormwater Manual*
[4]*ASCE, Standard 68-18*
[5]*Pavedrain Concrete Block Structural Analysis for HS-25 AASHTO Truck Loading, Pennoni Associates, Inc.*, November 19, 2014. Analysis assumes 4,000 psi concrete compressive strength per ASTM D 6684-04.
[6]HS-20 Loading is a semi-truck loading with 8,000 pounds front axle load (4,000 pounds wheel load) and 32,000 rear axles load (16,000-wheel load).
[7]*Structural Design of Roads for Fire Trucks,* Belgard Commercial, December 23, 2013.
[8]*Connecticut Stormwater Quality Manual,* 2004

Table 8 Permeable Pavement Typical Compressive Strength and ADT Usage Range

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Design Considerations: Stormwater Quality Considerations

- Stormwater quality considerations
  - Infiltration rate must exceed 100 in/hr upon installation
  - 100% treatment of stormwater that infiltrates
  - 65% TSS and 35% TP treatment if underdrain is present and used

	USEPA[1]		USGS Study in Madison[2]		Technical Standard 1008	
Permeable Pavement Type	**TSS Reduction (%)**	**TP Reduction (%)**	**TSS Reduction (%)**	**TP Reduction (%)**	**TSS Reduction (%)**	**TP Reduction (%)**
Pervious Concrete	>65	31 to 65	59	23	65	35
Porous Asphalt	>65	31 to 65	62	18	65	35
Permeable Pavers/Blocks	>65	31 to 65			65	35
Permeable Interlocking Concrete Pavers			65	11		

[1]*Green Streets Handbook* (USEPA 841-B-18-001), USEPA, March 2021
[2]Hydraulic, Water-Quality, and Temperature Performance of Three Types of Permeable Pavement Under High Sediment Loading Conditions, Scientific Investigations Report 2018-5037, USGS, 2018
[3] Standard 1008, WDNR for the portion of the average annual runoff volume that passes through the permeable pavement surface and discharges through the underdrain system when certain conditions are met. A 100 percent pollutant (TP and TSS) removal credit is given for the portion of the average annual runoff volume that infiltrates into the subgrade soils.

Table 11 Permeable Pavement Stormwater Quality Treatment Performance

Design Considerations: Standard Specifications & Typical Sections

02839 POROUS PAVEMENT GREEN INFRASTRUCTURE STRATEGY

[NTS: The specification is considered to be a technical guidance document to assist users with the design of green infrastructure strategies. It is the responsibility of the design engineer to make revisions to the specification as needed for specific design projects. It is recommended the documents are reviewed by a licensed professional engineer before releasing for construction. Note that the specification was last updated by the City in 2022.]

A. SCOPE

This Section covers the work necessary to furnish and install porous pavement green infrastructure strategies, including the porous pavement surface, bedding aggregate layer, base course aggregate layer, stormwater storage aggregate layer, underdrain piping, cleanouts, and observation wells.

1. GENERAL

[NTS: Update language of this Section as necessary based on applicable references to front-end specifications.]

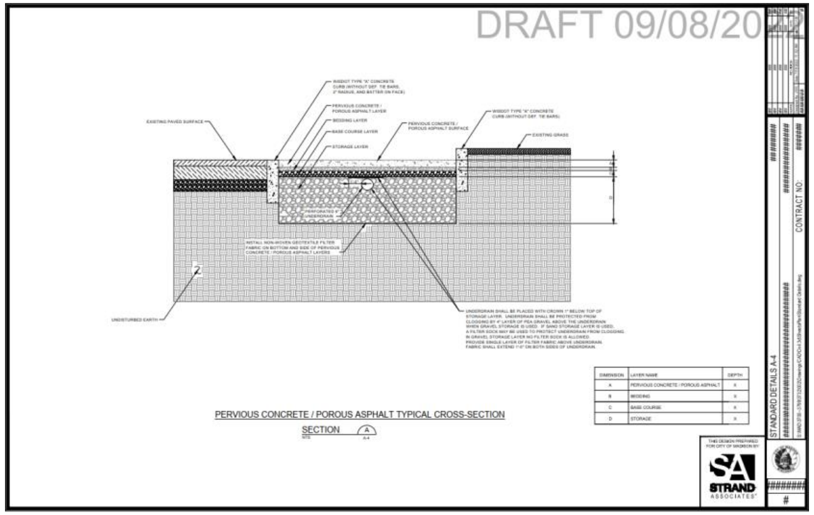
See CONDITIONS OF THE CONTRACT, and Division 1, GENERAL REQUIREMENTS, which contain information and requirements that apply to the work specified herein and are mandatory for this project.

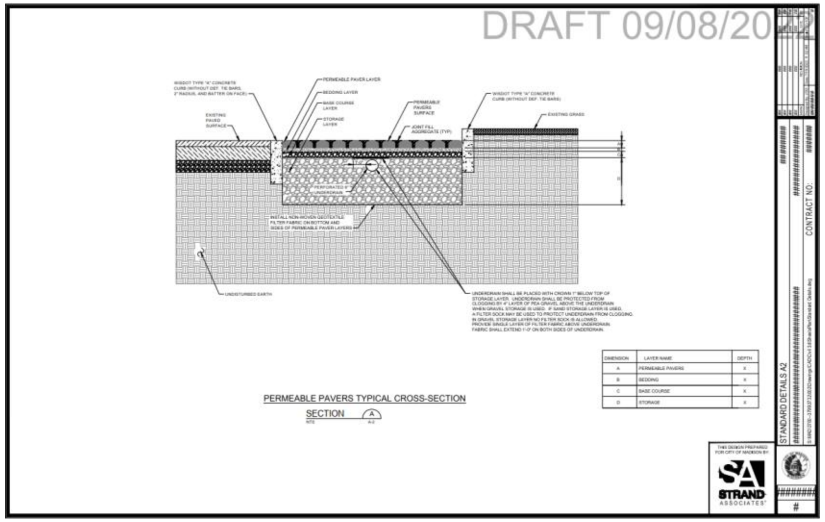
2. RELATED WORK

[NTS: The list below may not be fully inclusive depending upon the specifics of each individual project. Update language of this Section as necessary based on applicable references to other technical specification sections.]

The applicable requirements, materials and workmanship specified in the following Sections are included by reference in this Section. The list below is from the Wisconsin Department of Transportation (WisDOT) Standards and Specifications for Highway and Structure Construction, latest edition.

Standard Specifications





Typical Sections

Design Considerations: Usage Considerations

- Usage considerations
  - Bi-annual vacuuming of pavement after fall and winter
  - No snow piling allowed
  - Pavers should be plowed with caution
  - City concerns with technologies
  - ADTs and ESALs

Non-Permeable Pavement Green Infrastructure Systems

- Non-permeable pavement green infrastructure – description
- DGI priority
- Types:
  - Bioretention basin
  - Bioswale
  - Terrace rain garden
  - Traffic-calming rain garden bump out (stormwater curb extension)
  - Rock vault
  - Vegetated filter strip
  - Stormwater planter
  - Catch basin
  - Stormwater terrace
  - Coanda effect screen
- System Comparison and Madison Design Requirements
- Green infrastructure design guidance documents
- DGI and tree canopy decision-making flowchart

Madison's definition of GI is generally a stormwater BMP having infiltration as a main function

Non-Permeable Pavement Green Infrastructure – Description

- WDNR Technical Standards
  - Bioretention Basins (1004)
  - Rain gardens (1009)
  - Vegetated swales, filter strips, and bioswales (1005)
- City of Madison GI studies and fliers

	TSS Reduction (%)	TP Reduction (%)	Type of BMP
Bioretention Basin	77[3] to 85[4]	-	Filtration and/or infiltration
Bioswale	47[3] to 63[4]	-	Filtration and/or infiltration
Rain Gardens	77[3] to 85[4]	-	Infiltration
Traffic-Calming Rain Garden Bump Out	77[3] to 85[4]	-	Filtration and/or infiltration
Rock Vaults	60[5]	-	Filtration (permeable pavement) and infiltration
Filter Strips	52[3] to 63[4]	-	Filtration and/or infiltration
Stormwater Planters	77[3] to 85[4]	-	Filtration and/or infiltration
Catch Basins	5 to 15	-	Settlement
Coanda Screens	23[2]	16[2]	Filtration
Stormwater Terraces	Varies	-	Infiltration

[1]*Green Streets Handbook* (EPA 841-B-18-001), USEPA, March 2021
[2]*Evaluation of Stormwater Treatment Vault with Coanda-Effect Screen for Removal of Solids and Phosphorus in Urban Runoff*, ASCE, Nicolas H. Buer and William R. Selbig, 2020
[3]International Stormwater BMP Database, The Water Research Foundation (WRF), ASCE-Environmental and Water Resources Institute (EWRI), and Federal Highway Administration (FHWA).
[4]*Minnesota Stormwater Manual*
[5]WinSLAMM modeling by City as permeable pavement with twice yearly cleaning and 4:1 run-on ratio.

Table 15 Nonpermeable Pavement Green Infrastructure Stormwater Quality Treatment Performance

DGI Priority

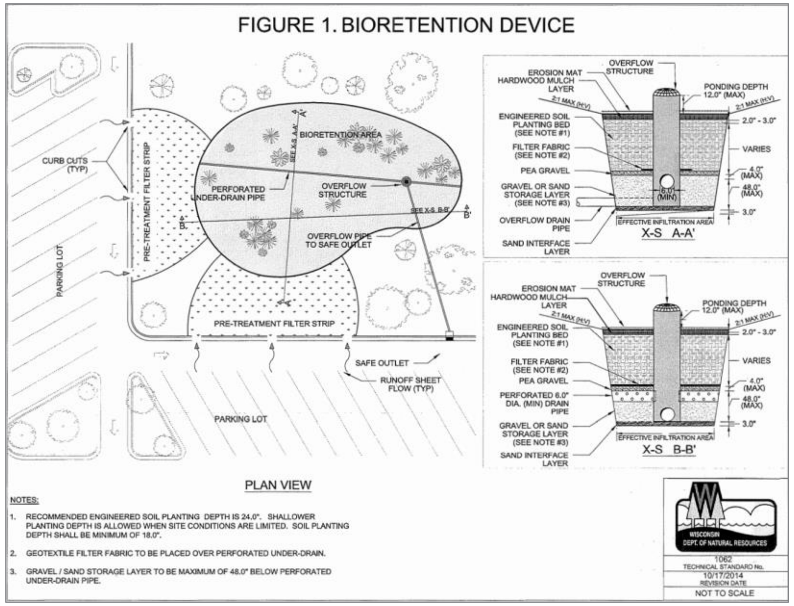
Table 12 DGI Priority

DGI Priority	Underlying Infiltration Potential at Surface or Within 5 feet of Surface (See Figure 28[1])	Location in Relation to Wellhead Protection Zones (See Figure 29)	Location Relative to Winter Salt Routes (See Figure 30)	Location Relative to Existing Flooding During 100-Year Event (See Figure 31)	Terrace Area Available for DGI	Stormwater Quality Need In Terms of TMDL Reachshed TSS and TP Reduction Performance[3]
High (3)	Loamy Sand and Sandy Soils (1.63 in/hr to 3.6 in/hr)	Outside wellhead protection zones for all wells.	Project not located on winter salt route.	Located upstream of a known watershed with existing flooding outside of ROW.	8 to 10 feet	Reachshed / TSS / TP 47 / <40% / <27% 62 / <40% / <27% **64 / <40% / <27%** 65 / <40% / <27% 66 / <40% / <27% Note: 40% TSS and 27% TP are existing conditions baselines to allow purchase of TP credits from Yahara Watershed Improvement Network (WINs).
Moderate (2)	Sandy Loam, Fine Sand, Loamy Sand, Very Vine Sand, and loamy fine sand (0.5 in/hr)	Within wellhead protection zones for Well Nos. 7, 8, 10, 12, 13, 17, 18, 19, 20, 23, 24, 25, 26, 27, 28, 29, 30, 31 but outside the large-scale DGI exclusion zones (orange cross-hatched areas on Figure 29)	Drainage from off-site winter salt route area enters project location.	Located upstream of a known watershed with existing flooding inside of ROW.	6 to 8 feet	Reachshed / TSS / TP 47 / >40% / >27% **62 / 40 to 82% / 27 to 78%** 64 / 40 to 73% / 27 to 61% **65 / 40 to 68% / 27 to 63%** **66 / 40 to 62% / 27 to 54%**
Low (1)	Loam to Clay to Loam Soils (0.07 in/hr to 0.24 in/hr)	Within Well 6, 9, 11, 14, 15, and 16 wellhead protection zones. Within large-scale DGI Water Utility Review zones (light green areas on Figure 29) at remaining wells.	Project located on winter salt route.	No flooding within watershed.	4 to 6 feet	Reachshed / TSS / TP **47 / >40% / >27%** 62 / >82% / >78% 64 / >73% / >61% 65 / >68% / >63% 66 / >62% / >54% Note: Values in this table represent the TSS and TP reduction targets per TMDL Reachshed for the Rock River TMDL.
No Priority (0)		Within large-scale DGI exclusion zones (orange cross-hatched areas on Figure 29) at remaining wells.			<4 feet	City's Existing Conditions Model Results for Information Only[2] Reachshed / TSS / TP 47 / 76.6% / 67.8% 62 / 54.2% / 39.3% 64 / 30.3% / 22.9% 65 / 50.8% / 31.0% 66 / 47.8% / 33.9% Citywide Total / 35.9% / 26.4%

TMDL=Total Maximum Daily Load
[1]WDNR Technical Standard 1002–Site Evaluation for Infiltration, Table 2-Design Static Infiltration Rates for Soil Textures Receiving Storm Water
[2]City TMDL 2020 SLAMM Analysis, February 22, 2021
[3]Bold values are current priority based on existing conditions model results

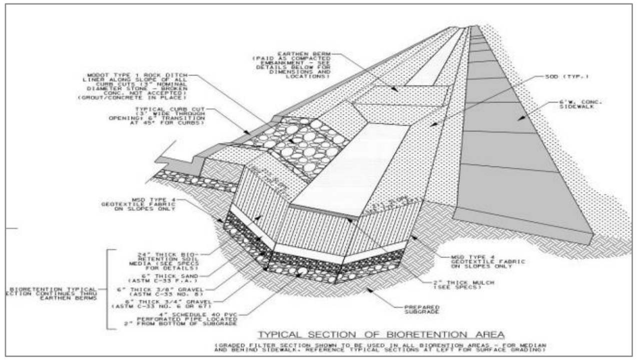
Bioretention Basin

- Typical section
- Large scale storm event bypass
- Limitations



Bioswale

- Typical section
- Pretreatment necessary
- Limitations

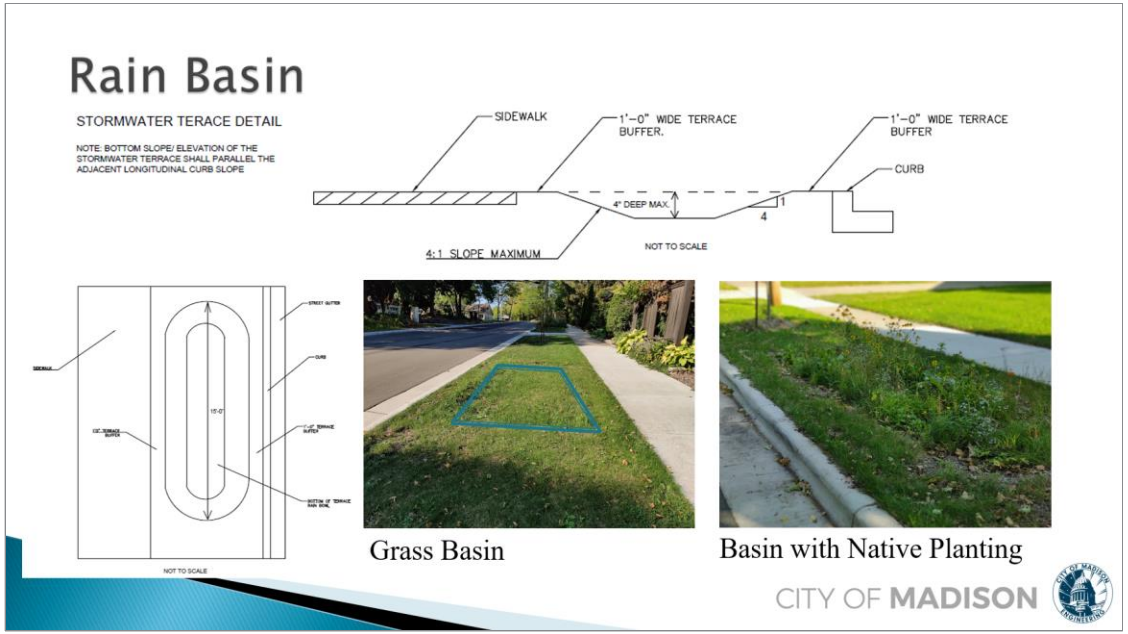


Terrace Rain Garden

- City of Madison program
  (gold, silver, and bronze)
- Owned and operated by residents, but subsidized through City
- Small scale bioretention basin

Stormwater Terrace

- City of Madison program
  (gold, silver, and bronze)
- Similar to terrace rain garden
- Does not collect water from the street



Source: City of Madison

Traffic-Calming Rain Garden Bump Out (Stormwater Curb Extension)

- Similar to terrace rain garden or bioretention basin
- Makes streets more pedestrian-friendly
- Used where crossings are frequent and could be dangerous

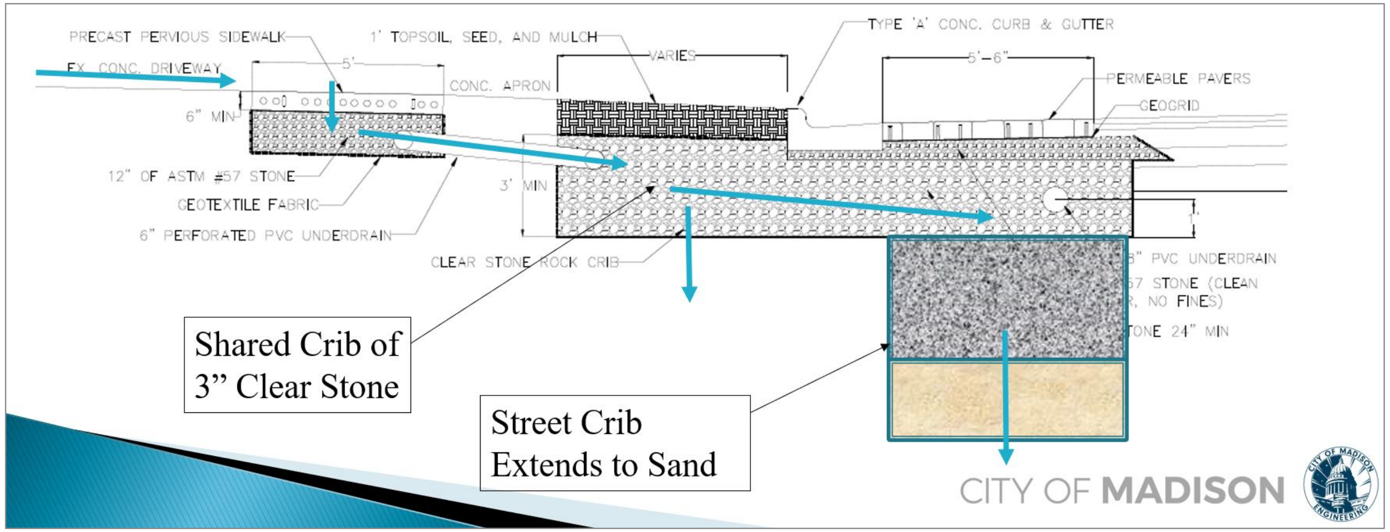
Abby Hall, USEPA

End-of-street stormwater curb extensions in a neighborhood in Portland, OR.

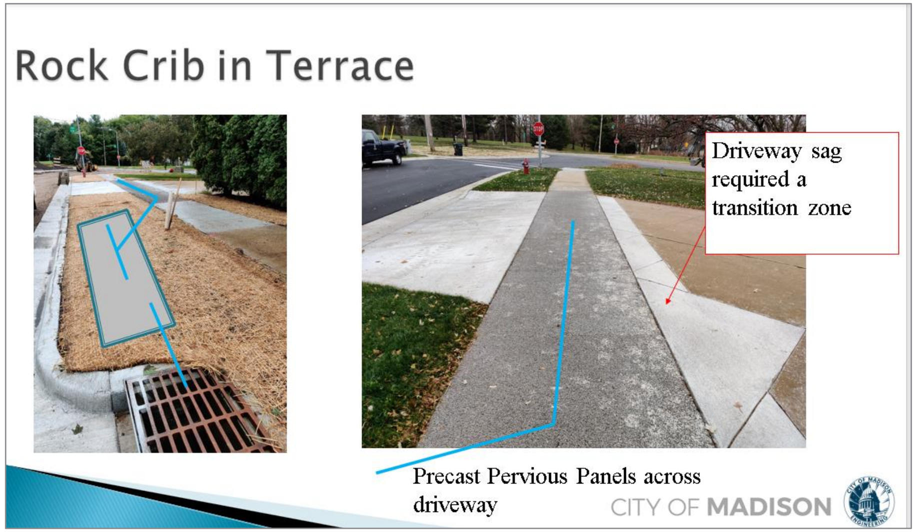
Strand’s Bump Out Design in Aurora, IL

Rock Vault

- Typical section
- Commonly used with porous pavement



Source: City of Madison



Source: City of Madison

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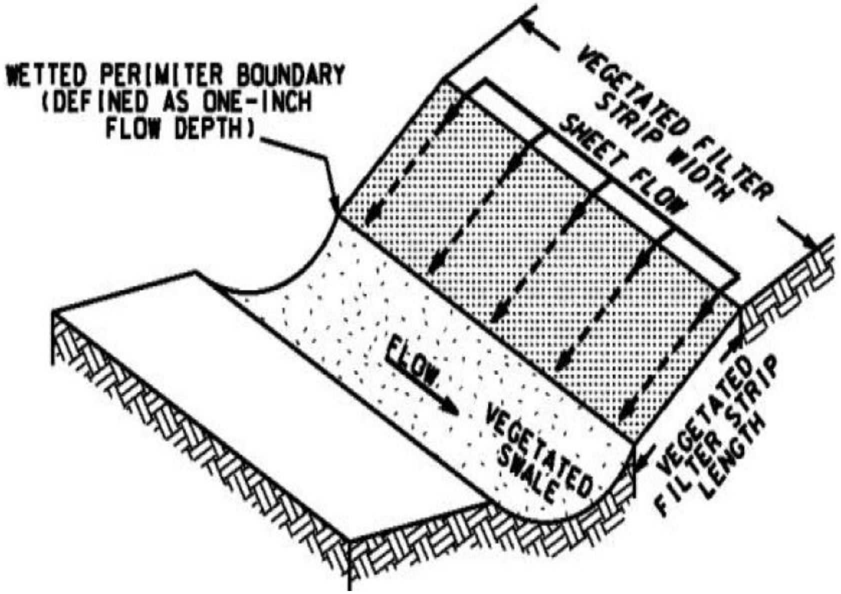
Vegetated Filter Strip

- Pretreatment device for swales and bioretention basins
- Want to maximize flow length and keep slope low
- Limitations

Nancy Arazan

Vegetated filter strip at the edge of a parking lot intercepts and filters stormwater runoff before the water reaches the infiltration bed at the center of the practice.



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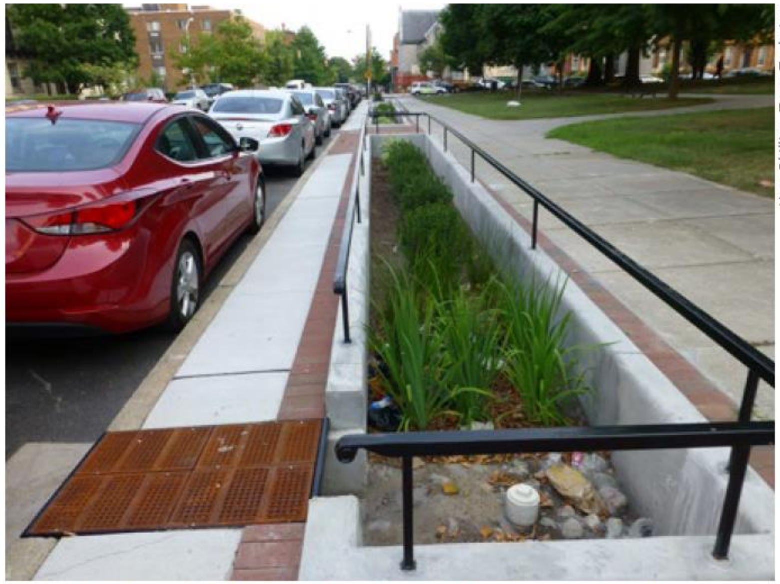
Stormwater Planter

- Used in urban settings with lack of space
- Act as a small bioretention basin
- Can have positive visual benefits for location



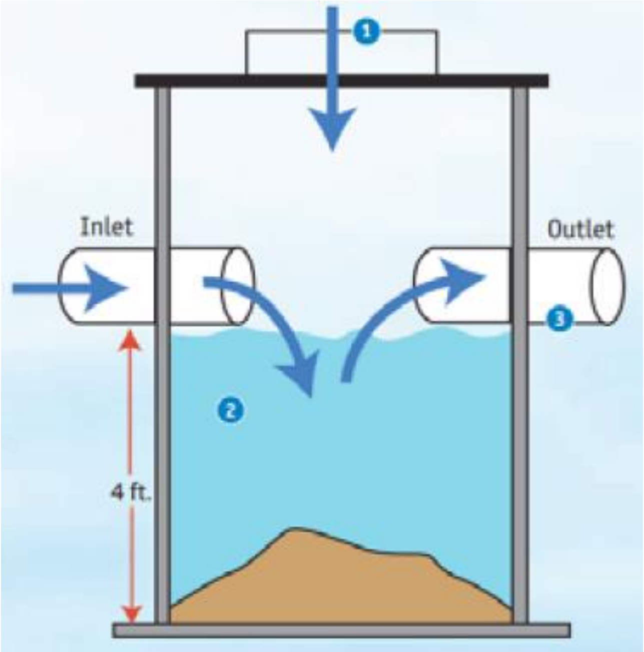
Kary Phillips, Tetra Tech, Inc.

A pedestrian-friendly sidewalk planter includes safety rails and a metal sidewalk bridge in Baltimore, MD.

Strand's Stormwater Planter Design in Cincinnati, OH

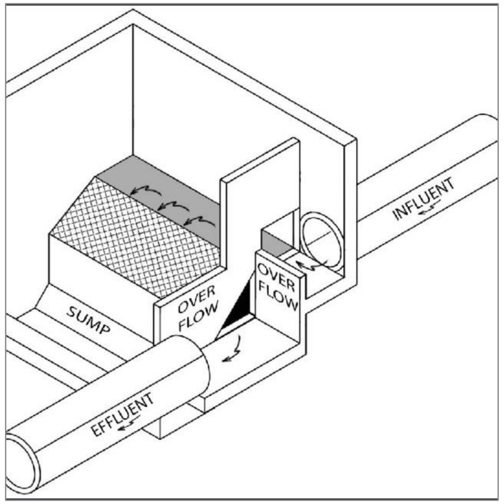
Catch Basin

- Typical catch basin design that can be used when infiltration is not an option
- Easy to install and widely used
- Only truly effective with regular cleaning



Coanda Effect Screen

- Requires 1.5 to 2 feet of drop
- Screens can fail
- Potential floatables bypass
- Regular sump cleaning



System Comparison and Madison Design Requirements

- Infiltration is an option for all besides the Coanda Effect Screen

		Street Type[1] O Yes ● Maybe ■ No	Bioretention Basin	Bioswale	Terrace Rain Garden	Traffic-Calming Rain Garden Bump Out	Rock Vault	Filter Strip	Stormwater Planter	Catch Basin	Coanda Screen	Stormwater Terrace
	Arterial	Urban Avenue	●	●	■	■	■	●	●	O	O	■
		Boulevard	O	O	●	■	■	O	●	O	O	●
		Parkway	O	O	●	■	■	O	●	O	O	●
		Mixed-Use Connector	●	■	■	●	■	■	O	O	O	■
		Community Main Street	●	■	■	●	■	■	O	O	O	■
Collector		Community Connector	●	●	■	●	■	●	●	O	O	■
	Local	Mixed-Use Neighborhood Street	●	●	O	O	●	●	O	O	O	O
		Neighborhood Street	O	●	O	O	O	●	●	O	O	O
		Neighborhood Yield Street	●	●	O	O	O	●	●	O	O	O
		Civic Space	O	●	O	O	●	●	O	O	O	O
		Neighborhood Shared Street	●	●	●	●	●	●	●	O	O	●

DGI Type	Minimum Required Width in ROW (feet)	Typical Use (In ROW or Outside ROW)	Comment	Relative Cost
Bioretention Basin	NA	See comments.	Stormwater planters and traffic-calming rain garden bump out/curb extensions are variations of bioretention basins used within the ROW.	$$
Bioswale	8 feet assuming 1-foot depth with 3:1 side slopes, 1-foot buffer from back of curb, and 1-foot buffer from sidewalk.	Both	Filtration and/or infiltration.	$
Terrace Rain Gardens	10 feet	Both	In accordance with City's Roger Bannerman Rain Garden Initiative.	$
Traffic-Calming Rain Garden Bump Out/Curb Extension	4 feet terrace plus 4 feet	In ROW	Bump out for traffic calming and/or pedestrian refuge expands available terrace area.	$$
Rock Vaults	4 feet	Subsurface, In ROW	Can extend into traveled way.	$
Filter Strips	10 to 20 feet	In ROW if no sidewalk; outside ROW if sidewalk drains to City-owned open area.	Generally used for pretreatment of stormwater BMPs unless distributed flow off of ROW without curb and gutter.	$
Stormwater Planters	4 to 10 feet	In ROW	Walls allow for unlimited width. If a tree is planted in a planter, then minimum width should be 4 feet.	$$$
Catch Basins	NA	In ROW		$
Coanda Screens	NA	Both	Typically installed at outfall. Adequate vertical drop required.	$$$
Stormwater Terraces	10 feet	In ROW	In accordance with City's Roger Bannerman Rain Garden Initiative	$

Green Infrastructure Design Guidance

- Milwaukee Metropolitan Sewerage District sizing calculator
- Decision-making flow chart


Green Infrastructure Sizing Calculator
Milwaukee Metropolitan Sewerage District

Disclaimer

Green infrastructure sizing calculator is specific to MMSD service area, results are not for final design, and not all MMSD green infrastructure strategies are included in the calculator. Refer to MMSD Chapter 13 Rules and Regulations for additional information.

Note: Please provide requested project information in ***blue*** *boxes.*

Project Drainage Area	
4000	Drainage Area (ft^2)
2000	Impervious Drainage Area (ft^2)
R	Land Use (C = Commercial, I =Industrial, R = Residential)

Project Site Dimensions	
200	Available Project Area Length (feet)
20	Available Project Area Width (feet)
10	:1 Length to Width Ratio
4,000	Available Project Area (ft^2)

Project Specific Questions

Yes	No	
☐	☑	Is the project area for the green infrastructure strategy within the right-of-way?
☐	☑	Are the topographic slopes adjacent to the green infrastructure strategy greater than 12%?
☐	☑	Is the depth to bedrock less than 6 feet?
☐	☑	Is the depth to groundwater less than 6 feet?
☐	☑	Is the project area within 10 feet horizontally of building foundations?
☐	☑	Is the project area within 10 feet laterally from underground sanitary sewer infrastructure or other utilities?

Note: After providing requested project information, green infrastructure strategies which are not recommended based on characteristics for the specific project will not be selectable. Please select an appropriate green infrastructure strategy to begin design and develop costs and quantities.

Bioswale / Bioretention | Porous Pavement | Rain Garden

Typical max impervious drainage area is approx 4000 sf

Note: If none of the green infrastructure strategies displayed above can be selected based on the specific site-suitability parameters, other green infrastructure strategies may be viable and should be considered, including stormwater trees, native landscaping, and soil amendments. See below for links to typical details and specifications.

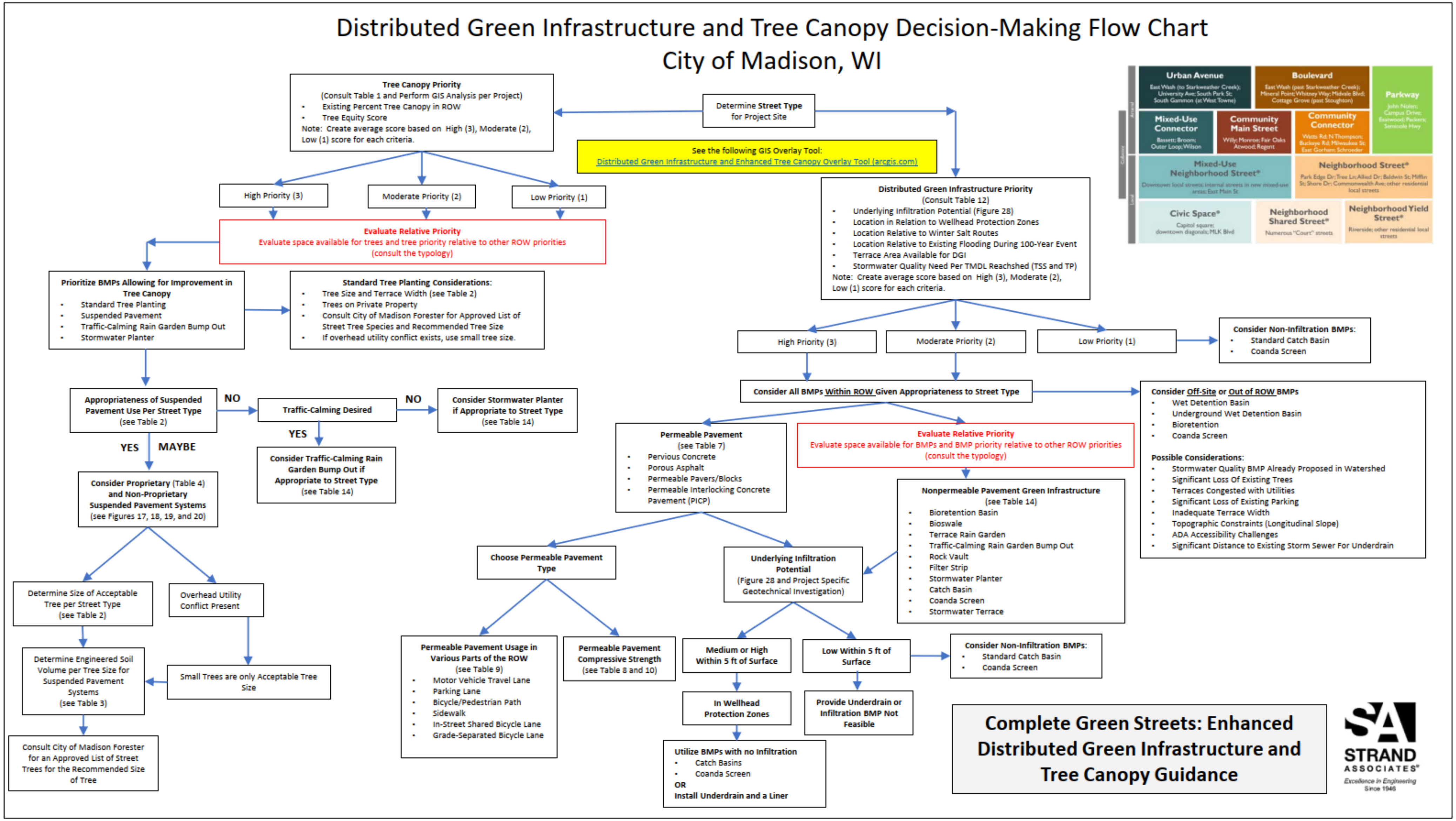
Additional Green Infrastructure Strategies (Not Included in Sizing Calculator)

Stormwater Tree | Native Landscaping | Soil Amendments

Stormwater Runoff Capture Goal

Stormwater Runoff Generated from Impervious Surfaces During a 0.5-Inch Rainfall Event 600 gallons

DGI and Tree Canopy Decision Making Flowchart



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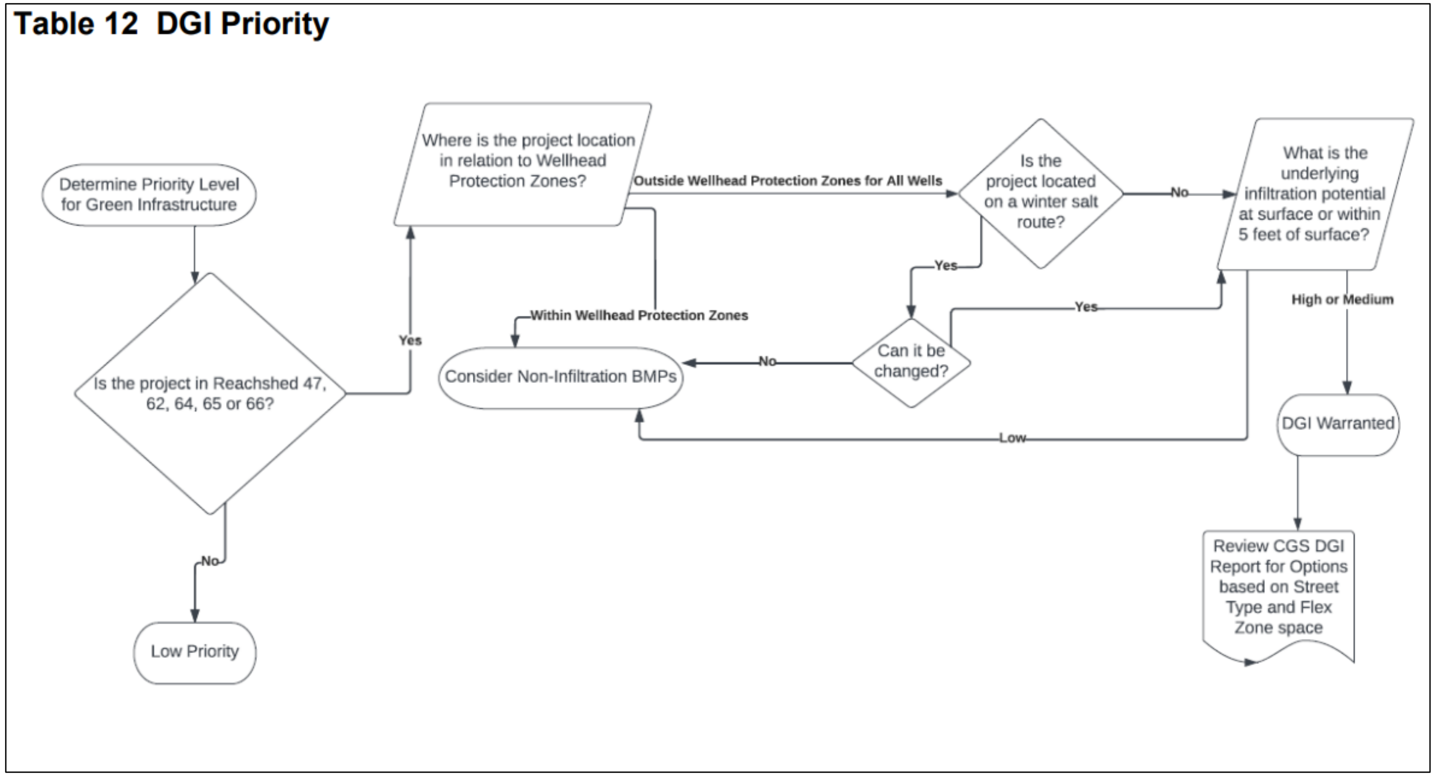
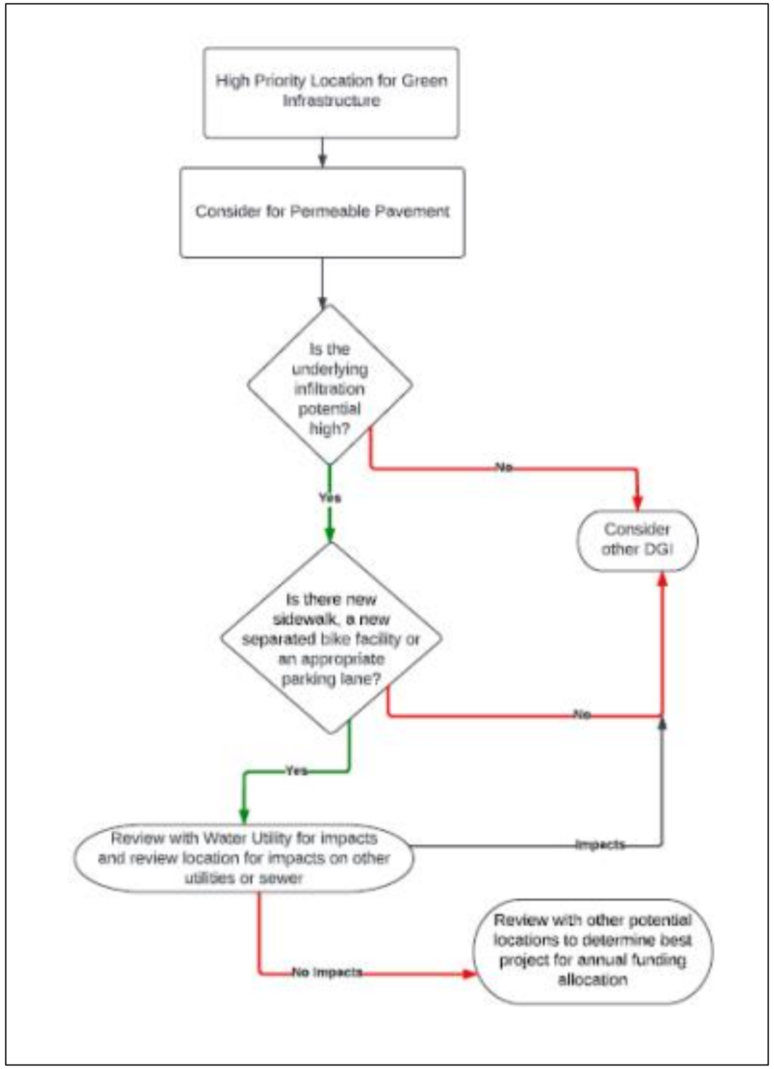
DGI and Tree Canopy Decision Making Flowchart





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Question and Answer

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